RECONSTRUCTION FOR LOW-INCOME COMMUNITIES IN EARTHQUAKE ZONES

An investigation for the implementation of community-managed housing reconstruction programmes in low-income countries located in earthquakes zones

by

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To my dear parents
Dr Sajid and Rashida,
and my dear wife Gauhar
whose love, patience and interest
in my research work proved to be
a great source of encouragement

Abstract

The world's earthquake problem is increasing without a change in the earth's geology. Human suffering during earthquakes is almost entirely caused by man-made structures. This is mainly because the world's population is fast increasing and previously unoccupied areas are now being inhabited without much attention being given to vulnerability of the building sites and construction techniques. Such buildings cannot withstand even moderate earthquakes.

Earthquake fatality records show that most of the losses to life occur in low-income and lower middle-income countries. Economic losses due to earthquakes are usually large in high-income countries. The financial impact of earthquake disasters is greater in poorer countries, who find serious problems in rebuilding their towns and villages after a disaster. Most government-implemented reconstruction programmes in low-income and lower middle-income countries have failed because they did not meet the socio-economic needs of the earthquake-victims. Consequently a majority of such communities were obliged to live in vulnerable houses.

The lack of acceptability of most reconstruction programmes emphasised the need to investigate and analyse the associated problems. This has been performed by studying a recently implemented programme. It was intended to review the earthquake-victims' response to the programme and what should be done to introduce efficient and effective earthquake-resistant construction strategies in the hazard-prone areas. For this purpose, field work was carried out in the Republic of Yemen to study the reconstruction programme undertaken after the 1982 earthquake.

The research findings suggest that reconstruction programmes will be implemented more efficiently and effectively, if the people living in earthquake-affected area are aware of the hazard and they manage the location, design and construction of their houses using safe techniques. The study proposes certain measures for adoption by the governments of such countries to mitigate the risk of disasters in earthquake-prone areas.

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The research work, particularly social surveys and technical work in the mountainous Highlands region of Yemen was not easy to say the least. Many of the target villages were found almost inaccessible due to the extremely poor road conditions which presented further problems during rains. Working late hours in remote areas presented physical risks as car hijacking and highway robbery have become a common feature in northern Yemen. The civil war of 1994 caused a temporary disruption in the field surveys. The research might have remained incomplete if the war had not come to an end in July. The return of peace and tranquillity in Yemen gave me an opportunity to resume and complete my field work.

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INTRODUCTION

"Natural disasters such as earthquakes are part of the environment in which we live. We cannot eliminate them but if we work together we shall be able to limit the losses of life and the destruction they cause."

(Jan Eliasson, 1983)

Mankind is striving, from times unknown, for its basic and essential needs of water, food and shelter. 'Food, water and shelter are primary needs for human survival' (Franceys, 1991). Even in the remotest areas of the world, where advanced technical skills and conventional building materials are not available, the man has made some kind of shelter to serve his purpose. He has found some water and food, no matter how little it might be, to ensure his survival. The design and appearance of shelter may differ from area to area depending upon climate, type and availability of local materials and needs and affordability of the individual. Shelter may vary from snow-made igloos in the North Pole to thatched huts in Africa; from cloth-made tents in Sahara to mud houses in South Asia; or from boat houses in the Far East to mountain caves in the Middle East. In all cases these abodes do provide shelter and a feeling of safety to their occupants. For advancement and development however other infrastructure, such as schools, roads, hospitals, water supply, sanitation, irrigation and industry are also necessary. Like health and environment, infrastructure is an important area in which government policy and finance play an important part because of its impact on economic development and human welfare (The World Bank, 1994).

The people living in high or upper middle-income countries[1] are already privileged to have the benefits of minimum risk and acceptable physical infrastructure. In recent years the low-income and lower middle-income countries have made substantial investments in infrastructure achieving encouraging gains form the householders and producers by providing them shelters and access to services such as safe water,

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[1] The World Bank (1994) classifies world economies into the following groups:

1. Low-income: GNP per capita less than US$ 675 or less;
2. Lower middle-income: GNP per capita US$ 676 to 2,695;
3. Higher middle-income: GNP per capita US$ 2,696 to 8,355; and
4. High-income: GNP per capita US$ 8,356 and above.

sanitation, electric power, telecommunication and transport. These investments amount to US$ 200 billion per year and are about 4% of their total output or about 20% of their total investment. Even more infrastructure investments and expansion of services are needed to extend the reach of services to the people living in rural areas and to the poor (The World Bank, 1994). The countries which cannot afford to finance these development programmes through their own resources depend on foreign assistance. What is usually overlooked in the low-income or lower middle income countries is the safety of the infrastructure against natural hazards such as earthquakes, cyclones, tsunamis, tornadoes and floods. This is because of inadequate awareness and lack of technical and financial resources at the government and peoples' level. The disasters, caused by these hazards, are not uncommon and quite often we learn that a certain part of the world is devastated by one such disaster causing great loss of life and damage to property. Each year, in several areas of the world, natural disasters cause loss of life and a great deal of damage especially to low-cost and self-built houses. The devastation caused by natural hazards in low-income countries is overwhelming.

When natural disasters hit low-income or lower middle-income countries, the effects are far more catastrophic when compared to the upper middle-income and high-income countries. In such countries hazard monitoring systems are efficient, the people are literate and well aware of the consequences of the natural hazards, and building controls for the safety of infrastructure are strictly applied against earthquakes and other natural hazards. Such structures are expensive, because of the high safety standards prescribed in the building codes, but they are affordable in high-income countries. In contrast, literacy levels and natural hazard awareness in the poorer countries is usually low. Hazard monitoring systems and building controls in such countries are either non-existent or not strictly applied. It is estimated that as much as 95% of loss of human life due to natural disasters occurs in low-income countries (Davis, 1978). Among all natural hazards, earthquakes, probably receive the highest priority, because of their unpredictability and the rising amount of losses in recent years. As such the focus of this research is on identifying no-cost or low-cost strategies to mitigate earthquake losses in low-income and lower-middle-income countries.

1.1 Earthquakes

Earthquakes are regarded to be one of the most formidable and widely spread threats to human life and property around the world since ancient times (UNDRO, 1978). The suddenness of their occurrence with the accompanying terrifying noise, the violence of movements which in a few moments turn a living city into a pile of rubble contribute to man's fear and helplessness. Quite often they initiate some other hazards, such as tsunamis, landslides, fires, liquefaction and land subsiding. When earthquakes devastate cities or other populated regions they destroy buildings, disrupt systems of transport and communication and sometimes start fires which further aggravate the catastrophe and increase the ultimate death toll (Raphael, 1986).

It is estimated that since the year 1000 AD more than five million people have expired in earthquakes. These estimates vary because of lack of any reliable record of earthquakes until the beginning of the twentieth century. According to one estimate about 350,000 people perished during the period 1926 through 1950 which gives the average figure of 15,200 victims per year. Some other estimates suggest the average annual death toll in earthquakes is about 24,000 (UNDRO, 1978). This figure seems to have significantly increased in the last quarter of this century. Table 1.1 shows estimated victim figures of some of the most fatal earthquake disasters and how the disaster casualties have increased in recent years.

TABLE 1.1: Significant earthquake disasters in history

Year	Location	Country	Number of Dead
742	Marib	Yemen	--
856	Comith	Greece	45,000
1038	Shensi	China	23,000
1057	Chihli	China	25,000
1268	Silicia	Asia Minor	60,000
1290	Chihli	China	100,000
1293	Kamakura	Japan	30,000
1531	Lisbon	Portugal	30,000
1556	Shan-tee	China	830,000
1693	Sicily	Italy	60,000
1730	Hokkaido	Japan	137,000
1737	Calcutta	India	300,000
1755	Lisbon	Portugal	60,000
1783	Calabria	Italy	50,000
1797	--	Peru/Equador	40,000
1868	--	Peru/Equador	40,000
1908	Messina	Italy	83,000
1920	Kansu	China	200,000
1923	Tokyo	Japan	99,331
1935	Quetta	Pakistan	25,000
1939	--	Chile	28,000
1970	Chimbote	Peru	66,794
1976	Tangshan	China	242,469
1988	--	Armenia	25,000
1990	--	Iran	40,000
1992	Marathawada	India	20,000
1995	Kobe	Japan	5,470
1995	Neftgorsk	Russia	2,000

Sources: UNDRO, 1978; Bolt, 1978; Coburn and Spence, 1992; Newsweek, 6/1995.

The time interval between disasters is often quite irregular which adds to the unpredictability of the earthquakes. The example of Italy is notable where four serious earthquakes occurred between 1905 and 1930 with a total of 120,000 victims. After that no big disaster took place until 1976 in Friuli. In several other countries subject to earthquakes (Yugoslavia, Morocco,) only one serious earthquake has occurred during the current century. In some other countries such as China, Romania, India, Mexico and Japan two or more such disasters have taken place in the same period. This irregularity stresses the need to study earthquake risk over long periods covering several hundred years.

The loss of life and property are far greater in low-income or lower middle-income countries, as compared to the upper middle-income or high-income countries, mainly because of low public awareness of the earthquake hazard and vulnerability of the infrastructure. The sharp rise in population and the tendency of the rural population to move to urban centres in the poorer countries, in the hope of jobs and better living condition, is probably one of the reasons for higher death toll in earthquakes, particularly when the epicentre is near large cities (UNDRO, 1978). This has already happened in China, Guatemala, Turkey, Romania, Algeria, Iran and India. The traditional infrastructure in such countries is usually not capable of resisting even moderate earthquakes. The risk of serious damage from earthquakes has reduced in the richer earthquake-prone countries because of technological advancement, application of building codes for earthquake-resistant designs, and the peoples awareness of the possible disaster.

The seismicity of the earth has not changed but two important phenomena have converged in the recent past. The first is a natural cause as a consequence of which certain seismic foci (or hypocentre) have been close to densely populated areas. The second cause is that population growth in the low-income and lower middle-income countries has resulted in rapid expansion of urban and semi-urban areas, the growth of which is neither planned nor controlled. The combination of these two phenomena is causing and will continue to cause severe human and property losses. It is therefore essential that not only the growth of towns and cites should be planned but it should also be controlled in such a way that risks against earthquakes and other natural hazards are minimised. Taking these considerations in urban and rural development and reconstruction involves several factors, such as establishing building standards, the methods of construction, the location of buildings and other infrastructure, and the use of land. The need of planning for location of new human settlements becomes all the more important in view of the long-term disaster risks. While considering how to minimise earthquakes losses, it is necessary to take into account our knowledge of the natural hazard and the technical means by which human lives and property can be protected against the imminent danger. The appearance and size of the structures are also equally important considerations, which vary according to the socio-economic, socio-cultural and climatic needs of each area.

While earthquakes and other natural hazards cannot be stopped, it is essential to plan and prepare in advance against them in order to minimise the resultant damage.

1.2 Preparedness and planning

Awareness about earthquakes and other natural hazards and the amount of devastation they cause seems to have improved in recent years on a global basis. The last few years have seen growing understanding of disasters and their consequences among the governments and the peoples, around the world (UNDRO, 1982). In the face of increasing social and economic cost of natural disasters in low-income countries, the donors and the disaster-prone countries, have made some efforts to:

a) improve understanding of natural hazards;

b) estimate the hazard risks more precisely;

c) improve the quality of post-disaster relief; and

d) take adequate preparedness measures to mitigate the hazard losses.

Progress in achieving the above goals has however been slow because of some chronic and inherent problems in the low-income countries as mentioned in the foregoing paragraphs. Other problems include degradation of environments, economic recession and poorly coordinated development and reconstruction planning. The magnitude of human suffering in disaster prone low-income and lower middle-income countries suggests that the relief measures and post disaster activities are not sufficient (UNDRO, 1976). According to some estimates more than one hundred countries, which achieved independence in the last four decades, are in the low-income bracket (Khawaja and Malik, 1992). Millions of people in these countries are living in abject poverty without adequate food, shelter, education and health-care facilities. The suffering is further aggravated by their lack of awareness about natural disasters. When disasters strike these areas and cause heavy life and property losses, the majority of the people regard them as "acts of God". Many people in such countries believe that human efforts cannot withstand against an inevitable divine activity.

UNDRO (1982) discourages this resigned attitude by making the following comments:

a) natural disasters, such as earthquakes, are not merely "acts of God" but are aggravated by human error and lack of foresight;

b) disaster relief can be made more effective through systemised planning and management; and

c) pre-disaster planning helps to reduce some of the severest effects of disasters.

While global efforts in providing relief supplies to disaster-affected areas have considerably improved, enough progress has not been made in the development and reconstruction of safe infrastructure in the disaster areas. This is mainly due to the general lack of hazard awareness, lack of resources, and quite often the lack of commitment in the governments of the hazard-prone poorer countries. What is even less valued among all related issues is that infrastructure is the end result of a long chain of social, economic, technological, environmental, political and other interactions. What is further ignored is that the government implemented infrastructure building programmes in such areas, are merely a process rather than the product. DHV Consultants (1989) noted during the post earthquake reconstruction programme in Dhamar, that construction of new houses under self-help programme was not their only target. The programme was also meant to transfer knowledge on earthquake resistant building techniques and to stimulate the local economy.

Review of the information available in some of the disaster-affected areas, suggests that the magnitude of human suffering in these areas is immense and relief measures and post disaster activities are insufficient. The process to educate the people and the leaders for prevention against future disasters and also for overall social and economic development remains a priority. Therefore, whatever the difficulties might be, efforts to prepare for disasters and proper planning for development and reconstruction activities must continue.

1.3 Development and reconstruction

Development or advancement in poorer countries faces many serious problems such as lack of resources, fast increasing population, low literacy, etc. The efforts for development are further frustrated by natural calamities, which frequently take a heavy toll on life and property. Rehabilitation of victims and reconstruction of infrastructure in such disaster-affected areas become immediate needs, whereas re-allocation of the limited resources causes a blow to the national economies and adversely affects the development plans. The reconstruction process presents a multiple-objective approach which aims at not only providing safe and economical infrastructure to the victims, but also in addressing their environmental and social needs (Muhanna, 1989). The effects of disasters are no doubt immense in terms of human life, but their influence on social and economic development of the country are also of great consequence. Losses caused by natural disasters such as earthquakes, off-set the momentum of national economic development process for a number of years, in most of the disaster prone low-income countries.

The Oxford dictionary defines reconstruction as the process of constructing a structure again. However the real purpose of reconstruction in disaster-affected areas is more than simply restoring the status quo. It requires rebuilding the infrastructure in the disaster-affected area in such a way, that the infrastructure is not only safer against any future hazard, but also culturally acceptable and financially affordable to the local people. When the above considerations are ignored the reaction of the victims is indifferent or lukewarm which does not produce the desired results of the efforts and resources involved. The conservative attitude of the disaster-affected people about their shelter needs, has been repeatedly been observed by experts. Davis (1978) commented that when a tidal wave demolished a village, or an earthquake reduced a town to a heap of rubble, it was logical to believe that the victims will prefer move to safer shelters, away from the disaster area. In reality however the local population usually prefers to stay in the same area and build similar houses as before, from the material recovered from the rubble. This is because of socio-economic reasons such as moving the village above flood level could mean giving up fishing rights or loosing fertile lands. Raphael (1986) commented on people's attachment to their traditions and custom by saying that cultural factors often strongly influence the way in which people can accept new shelters. Similarly adopting earthquake-resistant designs could mean expensive structures which may be alien in appearance, uncomfortable for the local climate and economically unaffordable. These factors of everyday importance weigh heavily against a disaster hazard which may be repeated once in ten years or more.

Reconstruction with alien technolcgies may demand skills and materials that are unavailable in the area. It is easy for experts to say when visiting a disaster affected area, that the failure occurred due to heavy roofs, or insufficient bond between walls and the roofs (Davis, 1978). Acting on this advice, making light roofs and providing a good bond between walls and roofs, may not be easy for the poor man in a low-income country who has to depend on his own meagre resources in building a safe house. When we compare a traditional local house, vulnerable to earthquakes, with a safe house designed by experts, the comparison is usually not as straight forward as it would appear to be. While the safe house will have a lightweight roof and somewhat unfamiliar design the structure will usually require expensive insulation to avoid extreme temperatures. On the other hand the traditional house built with thick walls and heavy roofs, though unsafe against earthquakes, provides everyday comfort to the inhabitant at a low price, for which local materials and skills are easily available. When these benefits are compared with the experts prescribed safety measures against earthquake hazards, which might come once in several years and may have become history in the memories of local residents, the choice is not too difficult.

After a disaster, most of the survivors want to return to their area and start reconstruction of the damaged houses as soon as possible (Geipel, 1982). Their reaction to any new technology is that of suspicion in terms of higher cost and unsuitability for their needs. In most of the disaster prone low-income countries people attach less importance to vulnerability of their traditional houses than to relatively higher cost of the earthquake resistant houses which they find economically unaffordable.

In most of the low-income countries, particularly in the rural areas, people live in self-made low-cost houses. The design of these houses is usually not based on sound engineering techniques. The materials used are those which are locally available at minimal prices. This is mainly due to the fact that the common man, with his limited resources, can afford to spend only a small amount on his shelter. Such buildings have some common features, such as low-strength cement-sand blocks or unburnt clay bricks commonly called adobe material, weak mortars, heavy and usually overloaded roof structures and no ties between the roofs and walls. Such buildings or shelters are built by the local unskilled or semi-skilled labour using primitive building techniques. Non-engineered buildings made of earthen materials and low-strength masonry have usually varying and unpredictable properties, detailing and workmanship (Krawlinker, 1986). Other infrastructure such as roads, health centres, water supply and sanitation works also fall short of their respective standards and requirements in the low-income and lower middle-income countries. The Military Governor of Kano State, Nigeria, acknowledged this in the 15th WEDC Conference of 1989, by mentioning that not only shelters but roads, water supply, sanitation, schools and other infrastructure were inadequate to meet the common demand of the people living in the low-income countries. While such countries strive hard to provide even the bare minimum of these facilities to their population, which may take several years, powers of nature such as earthquakes can destroy all efforts within a few moments.

Discussing similar circumstances in other parts of the world, Thompson (1986) observed that the progress in information dissemination and community involvement for preparedness for natural hazards was far less than desired.

Davis (1978) summarised the considerations faced by the governments and donors, involved in rehabilitation and reconstruction after a disaster, as follows:

a) long-term planning needs for preparedness and response in the face of a disaster;
b) difficulties in moving the people to less vulnerable areas;
c) natural resistance of the victims to safe but unfamiliar and probably more expensive building techniques; and
d) to educate the victims that disasters like earthquakes are not simply "acts of God".

The World Bank (1994) estimates show that over 70 per cent, more than 4 billion of the population of the world lives in low-income countries. With increasing life expectancy and little control on growth rate, the total population figure is expected to be double by the turn of century. It is estimated that nearly 80 per cent of this figure will comprise population of low-income or lower middle-income countries. This will create a high demand for the necessities of life such as food, water, shelter, health facilities, transport, etc in these countries. To get these basic facilities the need for infrastructure development cannot be over emphasised. Shah et al (1990) observed that the need for integrated development of the rural areas, including necessary infrastructure eg roads, water supply, electricity, primary education and health-care was overwhelming. It is important that this infrastructure should be able to withstand the effects of earthquakes and other natural hazards. Low-income countries, who struggle to provide even the basic infrastructure to their people, can hardly afford to start rebuilding these facilities once again, after a natural disaster has devastated a certain area.

1.4 Problem statement

Earthquakes, which can be far more devastating than other natural hazards offer an immense challenge to the world and mitigation of this risk should receive priority. The dangers of earthquakes are among the worst of natural disasters (Muhanna, 1989). While other natural hazards such as cyclones, floods, droughts and fire are caused by natural forces above the surface of earth they can be predicted much more precisely than earthquakes. Also these hazards follow a relatively established pattern of probability and their areas of activity are better defined. Disasters caused by natural hazards, other than earthquakes, are mainly because of inability of the concerned low-income governments to take precautionary measures in spite of predictions and warnings by meteorological centres. On the other hand earthquakes originate below the surface of earth and it is almost impossible to predict them accurately. Their duration is only a few seconds but in this short duration even moderate earthquakes can cause heavy losses of life and infrastructure in low-income countries where structures are seldom based on earthquake-resistant designs. The loss of human life and injuries, sometimes causing permanent disability, are the most tragic consequences of earthquakes but the economic consequences are far reaching. Major earthquakes cause a devastating, and sometimes irreparable, blow to the victim countries' economy in which infrastructure is completely or partially damaged (Coburn and Spence, 1992). The most obvious consequence is destruction of the built environment which was developed over a period of several decades or centuries in some cases. Private homes, offices, shops, business centres, schools, hospitals, monuments and places of historical and cultural heritage are destroyed in a matter of seconds. The lifeline infrastructure such as roads, railways, water, sanitation, gas and electricity are damaged causing serious problems of communications and supplies. As a result people are not only rendered homeless but a number of them, specially in the private sector, also lose their jobs. In severe cases of earthquake destruction, rehabilitation and rebuilding of the environment may take several years. The historical and cultural heritage might never be recovered. The economic impact can be far reaching causing a reduction in the gross national product

(GNP), and an increase in unemployment and inflation. It is forecast that a severe earthquake in a major financial centre such as Tokyo, New York or London can destabilise the international monetary system. Table 1.2 shows economic losses suffered during some recent major earthquakes.

Table 1.2: Economic losses suffered in some recent earthquakes

Country	Affected area	Year	Loss ($bn)	GNP that year ($bn)	Loss in GNP (%)
Nicaragua	Managua	1972	2.0	5.0	40.0
Guatemala	Guatemala City	1976	1.1	6.1	18.0
China	Tang-shang	1976	6.0	400.0	1.5
Rumania	Bucharest	1977	0.8	26.7	3.0
Yugoslavia	Montenegro	1979	2.2	22.0	10.0
Italy	Campania	1980	45.0	661.8	6.8
Mexico	Mexico City	1985	5.0	166.7	3.0
Greece	Kalamata	1986	0.8	40.0	2.0
El Salvador	San Salvador	1986	1.5	4.8	31.0
Armenia	Armenia	1988	17.0	566.7	3.0
USA	Loma Prieta	1989	8.0	4,705.8	0.2
Iran	Manjil	1990	7.2	100.0	7.2
Philippines	Luzon	1990	1.5	55.1	2.7
USA	Northridge	1994	30.0	6,259.9	0.5
Japan	Kobe	1995	200.0	4,214.2	4.8

Source: Coburn and Spence, 1992; Newsweek 1/1994 and 6/1995.

There is no doubt that preparedness for earthquakes is extremely important to minimise life and property losses during the catastrophe. The need for preparedness for earthquakes is extremely important in view of the rapidly increasing problems and disasters caused by earthquakes around the world (Spence and Coburn, 1987). About 20 earthquakes of large magnitude occur every year of which 10-20% take place in mid-ocean. A good number of the remaining 80-90% occur in uninhabited areas or deep below the earth crust and therefore do not cause any appreciable harm to human life and property. However, as the world's population is increasing and previously uninhabited areas being settled in at a fast pace, the risk of earthquake disaster is also increasing. Table 1.3 shows the increasing propensity for earthquakes to cause damage.

Table 1.3 Fatal earthquakes by decade

Period	Number of earthquakes	Fatal earthquakes with Magnitude* above 6 (%)	Earthquakes causing above 1,000 deaths (%)
1900-1910	191	34	9.5
1910-1920	146	33	15.5
1920-1930	189	43	13.0
1930-1940	202	49	14.0
1940-1950	188	52	22.0
1950-1960	212	49	9.0
1960-1970	228	62	12.0
1970-1980	223	54	25.0
1980-1990	181	60	22.5

Magnitude*: Earthquake magnitude measured on Richter Scale.
Source: Coburn and Spence, 1992.

The concerned governments, earth scientists and engineers should necessarily draw and implement plans for mitigation of earthquake disasters. At the same time however, earthquakes can devastate an area not prepared for the hazard. This could be due to several reasons such as lack of resources of the concerned governments, long duration since the last such incident which may have faded its consequences in the memories of the people, peoples lack of information about the preparedness measures, peoples' and governments' disregard of such measures thinking that earthquakes are merely "acts of God" which cannot be controlled. In such circumstances, proper planning and management, with community involvement, are essential tools for post earthquake relief and reconstruction work to make best possible use of the available resources.

1.5 General objectives of the study

The major objectives of the study are as follows:

1.5.1 <u>Initial responses</u>: Initial responses of the government and the earthquake-affected people, and the extent of their willingness to undertake the post-disaster relief work.

1.5.2 <u>Planning</u>: To evaluate the efficiency and effectiveness of the government's planning process adapted to examine the compatibility of the reconstruction programme with respect to severity of the situation faced by the victims.

1.5.3 Programme implementation: To analyse as to what extent the objectives of the reconstruction programme were realised, and to identify issues and constraints which inhibited efficient and effective implementation of the programme.

1.5.4 Community management: To ascertain the role of the earthquake-affected community in different phases of the reconstruction programme with the intention to elaborate how community management can significantly enhance effectiveness and acceptability of such programmes.

1.5.5 Recommendations: To propose recommendations for developing and implementing future reconstruction programmes for Yemen in particular, and other countries facing similar problems in general.

1.6 The earthquake disaster and the reconstruction programme

Yemen was hit by a disastrous earthquake in 1982, causing heavy damage to life and property in a vast area. The earthquake and the following reconstruction programme provided an interesting case for technical and social study and research where the focus groups were the earthquake-affected people, beneficiaries of the reconstruction programme and the government engineers who implemented the reconstruction programme (Krueger, 1994).

The Republic of Yemen is a low-income country. The World Bank, United Nations and other international agencies place Yemen among the list of the least developed countries (The World Bank, 1994). This category is assigned to those countries which not only have a low per capita income, but also where the chances of future economic development are not very bright. The socio-economic profile of Yemen and the post-earthquake reconstruction programme are discussed in detail in Chapters 3 and 4. Only a brief introductory paragraph is presented here for initial understanding of the case study.

The Republic of Yemen has a long history of earthquakes. The first recorded information on an earthquake disaster dates back to the seventh century which caused the collapse of the historical Marib dam. Some of the existing centuries-old multi-storeyed buildings contain all round wooden ring beams at different intervals. This shows that due consideration was made by ancient designers for safety against earthquakes. Most of the latter-day earthquakes, however, do not seem to have caused any appreciable damage as almost all of them either occurred in the low population areas, or in the sea near the Yemeni coast (Table 4.1). Secondly, continuous depletion of forest resources caused scarcity of wood and the cost became prohibitive for any major use in house building. Thirdly the people developed a taste for architectural decoration and gradually general appearance of the buildings became more significant in building designs then overall strength and resistance against earthquakes (Figure 1.1). The use of wood was restricted to ornamental purposes only. Under these circumstances when a moderate earthquake, of 5.8 magnitude on Richter scale, struck Dhamar governorate in December 1982, it caused a heavy loss of life and property damage.

Field studies carried out in the earthquake affected areas of Yemen, during 1992-1995, revealed the lack of hazard awareness among the local people. It was also noted that there was hardly any preparedness to mitigate the risk of a similar disaster in the future, at the government's or the people's level. The main emphasis of the government implemented reconstruction programme focused on providing a certain number of earthquake-resistant infrastructure designed by foreign experts. A look at most of this infrastructure suggests that the local resources were not fully utilised. The earthquake victims, whose local knowledge and experience in construction was an important resource, were ignored in the relief and reconstruction processes. This therapeutic or manipulative approach made the programme less acceptable, and therefore less sustainable (Choguill et al, 1995). The reconstruction programme could not be completed as initially announced and a large number of the earthquake victims had to revert back to their vulnerable traditional houses for different reasons. This situation provided an interesting and important topic for detailed study.

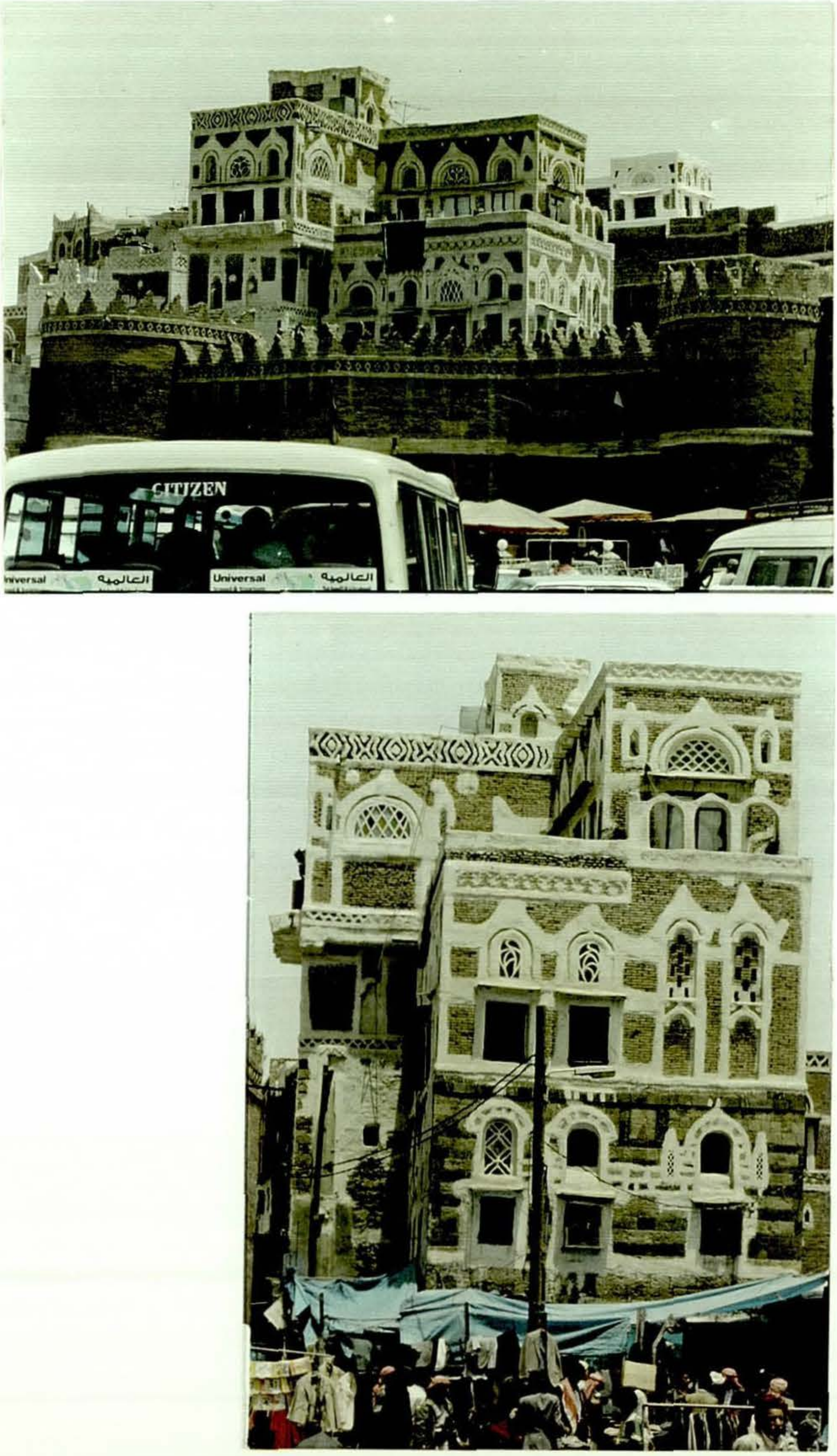


Figure 1.1: Architectural decoration is a salient feature in traditional buildings in Yemen
Source: Field Surveys, 1994

1.7 Study procedure and research methodology

The methodological framework to realise the above study objectives is discussed in detail in Chapter 7. In brief, the study requires collection and analyses of extensive data on different aspects of the reconstruction programme designed and implemented in Dhamar Governorate of Yemen. The required data and information was collected from:

a) various published and unpublished sources mainly available in Yemen and Pakistan, and at the Loughborough University of Technology;

b) interviews with the earthquake victims (or the intended beneficiaries of the reconstruction programme;

c) interviews with the sheikhs of the earthquake-affected communities;

d) interviews with the government officials who participated in the reconstruction programme;

e) technical measurements in the field; and

f) discussions with some expert in the related subjects.

For this purpose a set of detailed questionnaires were prepared for use in the field (Annex 1). The data collected through questionnaires was evaluated and statistically analysed in the light of the pre-defined objective verifiable indexes (OVIs). The OVIs for each study objective are described in Chapter 7.

1.8 The research

The research postulates that relief measures or reconstruction work in the disaster area, is the outcome of a process consisting of the following three steps:

a) assessment of the nature and extent of damages caused by the disaster;

b) preparation of detailed plans to provide necessary assistance to the victims, both in short term and long term, including securing and allocation of resources necessary to implement the plan; and

c) implementation and management of the relief and reconstruction programme.

1.9 The hypothesis

It is vital that there should be full understanding and unanimity among the victims, government and donors on issues related to safety of the infrastructure as well as its acceptability and affordability at the beneficiary level to ensure efficiency and effectiveness of the reconstruction programme. Within this broad framework the present study aims to show that life and infrastructure losses can be mitigated, and the reconstruction work can be implemented efficiently and effectively, in the low-income and lower middle-income countries, located in earthquake zones through:

a) adept management and mobilisation of resources; and
b) motivation of the victims concerning hazard awareness, and their adaptation of earthquake-resistant techniques.

These considerations lead to the following hypothesis to be investigated that:
'*Efficient and effective reconstruction in an earthquake zone cannot be undertaken without community management*'.

The following definitions are used for different terms used in this hypothesis:

Efficient: the infrastructure built with least cost, in minimal time and affordable for the local community;

Effective: the infrastructure which is risk minimising, fully utilised, acceptable to the beneficiaries, and provides full coverage;

Reconstruction:
i) undertaking new construction to replace the collapsed infrastructure which cannot be economically repaired;
ii) repairing and restoring the existing infrastructure which suffered repairable damage during the disaster;
iii) strengthening the existing vulnerable infrastructure, which apparently did not suffer any damage but may present a potential risk in a future earthquake;

Community management: close involvement and participation of the beneficiary community in every stage of the short-term and long-term relief work, such as planning, siting, designing and implementation of the reconstruction programme;

Earthquake zones: The world's earthquake zones are described in detail in Chapter 2. It will be sufficient to say here, that the areas where a moderate to severe earthquakes can be expected anytime in a given interval of time, according to seismicity of a particular area.

This hypothesis is intended to have a universal application, but the earthquake problem is not as serious in the richer countries as it is in the poorer countries. The communities in the former category of countries usually have high literacy, hazard awareness, adequate resources and independence to take decisions. The situation is almost reverse in most of the low-income and lower middle-income countries, where literacy levels are low, hazard awareness is almost non-existent, and the communities do not usually have significant independence in decision taking. The focus of this study is therefore mainly on the communities of the latter category.

1.10 Review of the existing literature

There was not much concern about the seismicity of Yemen before the 1982 Earthquake. According to the seismicity records (chapter 4), there had not been any disastrous earthquakes in the country in the past several hundred years. This led to the people concentrating more on decorating their houses rather than caring for their safety against earthquakes. There was no reliable system of monitoring in the country.

When the earthquake occurred in 1982 it took the government and the people of Yemen, as well as the experts by surprise. This perhaps one of the reasons that there was not much literature available regarding the seismicity of Yemen or vulnerability of the Yemeni buildings. Although the subject of earthquakes is discussed in detail in chapter 2 but seismic studies is not the topic of discussion of this thesis. Some of the experts who conducted seismic studies after the earthquake are Shu'lan (1989), Al-Salim (1993), etc.

After the earthquake, different types of reconstruction strategies were applied in the earthquake affected areas and various studies were made by different agencies.

One of these strategies was introduced by Oxfam, an international NGO, working under the British Overseas Development Administration (ODA) assistance programme. This strategy mainly concentrated on studying the traditional housing in the disaster area, identifying their vulnerability against the hazard, and training of the local builders in earthquake-resistant building techniques. A lot of useful literature was produced during and after the implementation of this programme such as Aysan (1983, 1985), Leslie (1983, 1984 and 1986), and Coburn and Leslie (1985). This material provides a lot of basic information and statistics about the earthquake and the training programme. There is however not much comment on the other building programmes in these studies.

The other strategy of aided self-help housing was implemented under the European assistance programme in which a Dutch consultant, DHV played the lead role. In this programme the earthquake victims were supposed to contribute land, locally available materials, and unskilled labour while the rest of the cost was born by the project. Organisers of this programme also produced useful material about the traditional Yemeni buildings but the focus in these studies remained on the self-help programme. Salient among these studies are Vulto (1986), SCREAA (1986), DHV (1988 and 1989), Dijkgraaf (1989), Jaghman (1989) Van Dijkhuzen (1989), and Kassem (1989).

Another strategy was used by the Arab countries which provided the largest number of housing and other infrastructure in the disaster area (for detail see chapter 4). Under this strategy turnkey houses were provided to the victims. There is hardly any literature available on this programme except for some project reports mainly discussing the cost and structural designs of this infrastructure.

The post-disaster technical assistance provided by the Government of India also resulted in the production of very useful material. This main topic of discussion in these studies was the structural strength of Yemeni buildings and the methods of repairing them. The study material was provided by Arya (1985, 1991 and 1994) and Al-Shamie (1989).

Apart from this some UN agencies such as UNCDF (1989 and 1991) UNICEF (1985), UNCHS (1987), UN/DHA (1985) and some individuals such as Buwalda et al (1992), Barakat (1993), etc also produced useful literature but most of it concentrated on the social aspects, water supply an other issues.

It should be admitted that there was not much progress the study of disaster management and earthquake protection measures. The earthquakes of Turkey (1970), Yemen (1982) and others encouraged the experts to concentrate on vulnerability of the traditional buildings in low-income countries and low-cost protection measures against earthquakes and other natural hazards. Some of the remarkable contributions in this regard have come from Coburn and Hughes (1983), Coburn (1986), Spence and Coburn (1987), Coburn and Spence (1992) and Arya (1994). This literature provides a lot of good information about the increasing risk of earthquake disasters and technical mainly technical solutions for improving the existing building stock in low-income countries. There is however not enough comment in these studies about hazard awareness of the people living in such areas. Some other experts, such as Davis (1978), generally mentioned the need for hazard awareness among the people living in hazard-prone areas.

In Yemen the principal sources of information were the UN offices, various government offices involved in the reconstruction programme and the Oxfam office. Almost all these offices had kept there records very poorly and the researcher sometimes had to look into the waste dumps in these offices to look for any useful material. Only UNICEF was found better organised but there information was more related to the water supply and health aspects.

The review of this literature led to the study of literature on other programmes and strategies related to reconstruction, low-cost housing, community-based infrastructure projects, preparedness, disaster management, risk management, etc. The literature reviewed was written by various authors, such as Office of Foreign Disaster Relief of USAID (1981), Aysan and Oliver (1987), Merriman and Browitt (1993), Aysan (1993), Wassef (1993), Paul et al (1993), Davis (1978, 1981, 1989, 1991, 1993, 1995), Key (1995), and Davis and Lambert (1995).

The study of this literature gave the researcher an opportunity to review a number of reconstruction programmes around the world. It was noted that many of these programmes failed to achieve their main objectives of providing efficient, effective and sustainable infrastructure in the disaster areas. Detailed discussion on some of these programmes exists in chapter 6. Some other programmes are briefly discussed below.

The post-cyclone disaster reconstruction programme in Andhra Pradesh, India was undertaken by the government of Andhra Pradesh and some NGOs. The government provided the financial support and guidelines for safe construction. According to Reddy (1995), an official of the government agency responsible for programme implementation, the programme was successfully implemented. The beneficiaries participated in the construction stage. It is not known whether this project proved to be sustainable because the cost of such construction seems to be beyond the capacity of a common man in India.

The self-help reconstruction programme, after the 1983 Popayan earthquake in Columbia was undertaken by a government-sponsored agency SENA, and achieved mixed results (Wilches-Chaux, 1995). This programme mainly concentrated on training of the local artisans in earthquake-resistant construction. The programme was accepted by only a small percentage of the victims for socio-economic reasons.

The rural housing project, after the 1987 earthquake in Equador, was jointly implemented by the Inter-American Development Bank (IDB), the government of Equador and UNCHS/Habitat (Jordan, 1995). This programme failed in general to meet its objectives. The concerned government implementing agency, the Ministry of Social Welfare, was very centralised and was not in favour of community management. The distribution of houses was carried out under political pressure. The result was that many victims did not receive any shelter while some others, who were not the disaster victims, became the beneficiaries. This project created a negative impact on the victims.

The post-disaster reconstruction programme, after the 1986 earthquake in El Salvador was undertaken by the government, with the assistance of USAID (Clark, 1995). The disaster victims had an active role in this programme. Years later, when the government support was withdrawn, the project proved to be unsustainable.

A similar programme in Jamaica, after the Hurricane Andrew disaster in 1988, also failed to produce any lasting results because of the lack of commitment by the implementing agencies (Oliver-Smith and Parker, 1995).

There are several other examples such as the post-flood rural rehabilitation programme in Jamaica (Hodges, 1995), the Alto-Mayo reconstruction plan in Peru (Maskrey, 1995), the Philippines core shelter housing programme (Cory, 1995), disaster-resistant housing programme in the Solomon Islands and the Pacific (Boyle, 1995), the Dhamar building education project (Cory, 1995), etc, which can be quoted as examples. This literature review suggests that any reconstruction strategies may not create any lasting impact if they do not consider:

a) hazard awareness of the disaster victims;
b) the victims' social, cultural and economic conditions; and
c) the role of the community in decision taking regarding location, design, size and construction of the infrastructure.

Many of these studies concentrated on the technical aspects of the reconstruction programmes, or the low-cost housing programmes, and gave lower priority to the feelings of the disaster victims. It was therefore considered necessary for this thesis to study a reconstruction approach focusing principally on the people living in the hazard area, their socio-economic life, their general beliefs and concepts about safety, and identifying local solutions for safer homes. The main purpose of this study was to supplement the work of other researchers in the management and mitigation of natural disasters. Detailed discussions on this aspect are given in the final chapters.

1.11 Organisation of the study

As this study is mainly concerned with planning and management of resources for development and reconstruction work in low-income and lower middle-income countries prone to earthquakes, it seems appropriate to discuss the causes and probability of earthquakes, common perceptions, losses to life and property during earthquakes and various responses to face the usually enormous challenge of rehabilitation work in the devastated area.

General organisation of the study is shown in Figure 1.2. The following is a brief introduction of the chapters to follow.

Chapter 2 provides detailed discussion on earthquakes, their causes, probability, possible loss of life and damage to property, general responses of the victims, governments and donors, flaws in various approaches usually adopted in the post earthquake development and reconstruction work and the need for efficient and effective designs for reconstruction in earthquake zones.

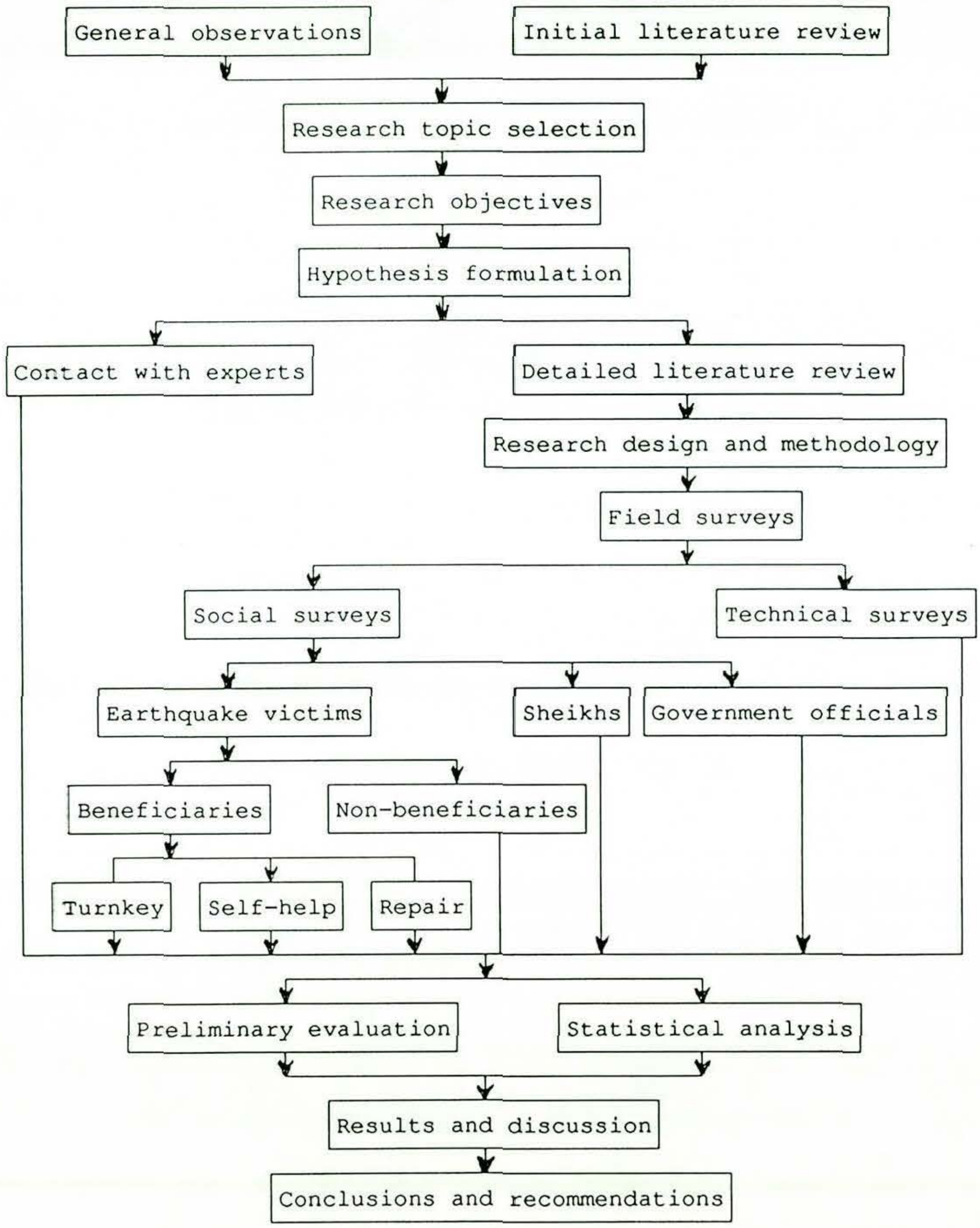


Figure 1.2: Organisation of the study

Chapter 3 gives a profile of the Republic of Yemen which covers general description of the country, physical features, economy, culture and traditions and main concerns of the government and local communities. This detailed look at the country's profile was found necessary to point out that success of any development or reconstruction work in any area heavily depends on due consideration of the local custom, culture, climate and other socio-economic factors.

Chapter 4 is dedicated to the 1982 earthquake in Yemen and the subsequent reconstruction programme. The chapter begins with the historical background of earthquakes in the country and goes on to describe the 1982 earthquake and responses of the surviving community, government and donors. In a case study approach the chapter critically examines the infrastructure existing in Dhamar before the earthquake which proved to be the main cause of heavy human and property losses, and the post-earthquake development and reconstruction programme.

Chapter 5 discusses the major considerations for earthquake resistant designs for different types of materials.

Chapter 6 deals with identification, assessment and management of risk for earthquake resistant design of infrastructure in seismic areas with respect to their acceptability and affordability by the survivors and presents some typical designs for Yemen.

Chapter 7 gives details of the research design. The discussion leads to explaining the problem statement, objectives of the study, formulation of the hypotheses and the methodological framework for data collection, evaluation and analysis.

Chapter 8 presents the data collected from the field and evaluates on the basis of general observation and calculations.

Chapter 9 is entirely based on statistical testing of the field data and the inferences drawn as a result of the analysis.

Chapter 10 summarises the results and discussions derived from the previous chapters.

Chapter 11 starts with drawing conclusions from chapter 10 and finally presents recommendations for future construction and reconstruction work in the earthquake zone in Yemen. These recommendations are intended for other countries as well, faced with the same problems as Yemen.

Summary

Powers of nature are a menace to human life and property. Among natural hazards, earthquakes are considered to be one of the most serious threat to mankind mainly because of their unpredictability and enormity. Most of the damage caused in earthquake disasters is due to the man-made structures. The poorer countries suffer most in such disasters. Government implemented reconstruction programmes in such countries have generally failed to provide adequate and suitable infrastructure in the earthquake-affected areas. These problems provided valid objectives and a hypothesis for research. The Republic of Yemen, where an earthquake occurred in 1982 and where the government implemented a reconstruction programme, provided an opportunity for a case study. The chapter briefly introduces the study process followed in compilation of the thesis.

Chapter Two

Chapter Two

THE EARTHQUAKE HAZARD

"What happens to us is irrelevant to the world geology, but what happens to the world geology is not irrelevant to us". *(Hugh MacDiarmid, 1990)*

Our planet earth is undergoing continuous changes since its creation. Changing the shape of earth through powerful and often hostile forces, such as earthquakes, volcanoes, whirlwinds, tornadoes, floods, etc, is a natural phenomena (National Geographic Society, 1978). Earthquake is reckoned as the most serious among natural hazards since it cannot be correctly predicted and can occur anywhere anytime. The legends regarding ancient cities of Troy in Greece and Taxila in Pakistan suggest that these civilised cities were destroyed by earthquakes (Coburn and Spence, 1992). Most people experience once or more, an earthquake in their lifetime (Gere and Shah, 1984). It is a terrifying experience. Most earthquakes last for only two or three seconds but if the shaking effect continues for a longer duration, the effects can be devastating. The feeling of the floor under our feet giving way, the fear of the buildings and other heavy objects falling on us gives a very uneasy feeling. Those few moments of fear, anxiety and uncertainty give an exaggerated perception about the duration of earthquake. Talking about human perception of the duration of earthquake Darwin (1959) related his experience, during *the Voyage of the Beagle*, that although the tremor on the South American coast lasted for only a few seconds, the time appeared to be much longer.

An earthquake is a natural phenomenon which creates an urge to panic. It is a tremendous force which originates from within earth and can cause violent convulsions on the earth's surface and shakes buildings to the ground in a matter of seconds. The slightest tremor can cause great fear because very few people are knowledgeable about earthquakes (Healy, 1969). Those who have any knowledge or previous experience of earthquakes, take refuge under the tables or door lintels, in the corner of rooms, or in open areas. The inexperienced people get panicky and suffer injuries or the loss of life by trying to take refuge on the top of roofs or trees, or by the side of buildings which are vulnerable and exposed to danger.

2.1 Life and infrastructure losses during earthquakes

Loss of life and infrastructure in earthquakes is usually extensive (Horne, 1983). Earthquakes causing the highest number of fatalities are usually in those places with high population density and vulnerable buildings made of low strength materials with poor workmanship and without any consideration to resist lateral forces produced during an earthquake. This situation is quite familiar in low-income or lower middle-income countries. Some idea of the cost and quality of buildings involved in these fatal incidents can be obtained by comparing the economic losses inflicted by the earthquakes with human life losses (Coburn and Spence 1992). While in China the economic losses are in the vicinity of US$ 1,000 for every life lost, the economic losses in USA are over million for every fatality.

Table 2.1: Major earthquake - affected countries of the world

Earthquake ranking and countries		No of fatal earthquakes 1900-1995	Total estimated deaths	No of earthquakes which killed more than			Return period in years
				1000	10000	100000	
1	China	151	609,550	17	7	2	0.6
2	Japan	79	178,500	8	1	1	1
3	Italy	43	127,902	6	2		2
4	Iran	82	117,764	15	4		1
5	Turkey	110	73,967	14	1		1
6	CIS	46	71,022	5	3		2
7	Peru	53	70,382	2	1		2
8	Pakistan	18	61,773	1	1		5
9	Chile	34	36,020	4	1		3
10	Indonesia	48	25,526	2	1		2
11	Guatemala	14	25,195	2	1		7
12	India	21	22,739	2	1		4
13	Nicaragua	3	13,550	1	1		31
14	Morocco	2	12,013	1	1		46
15	Nepal	4	11,571	1	1		23
16	Philippines	24	10,128	2			4
17	Mexico	44	8,525	2			2
18	Taiwan	49	8,423	3			2
19	Ecuador	26	8,133	3			4
20	Argentina	12	5,589	1			8
21	Algeria	20	5,144	2			5
22	Yemen	3	4,300	2			31

Sources: 1. Coburn & Spence, 1992; 2. Newsweek, 1/1995.

Many factors, such as lack of awareness of the governments and people about earthquakes and the implied devastation, inadequate designs of infrastructure and lack of maintenance are attributed to be the main causes for heavy losses during an earthquake. Earthquake-prone countries want to reduce their life and economic losses. This requires some understanding of the different aspects of earthquake occurrence by all those concerned with earthquake protection. Table 2.1 gives a list of the world's major earthquake countries and the loss of life in this century.

It is estimated on a global basis that one in 8,000 people lose their lives in earthquakes and about one in 800 receive injuries of various degrees. These fatalities are caused by various incidents, such as fires, tsunamis, rock falls, landslides, and other secondary hazards after the earthquakes (Coburn and Spence, 1992). The main cause of loss of life in earthquakes, up to 50% sometimes, is however the collapse of buildings. Masonry buildings made of rubble stone, adobe, rammed earth, non-reinforced clay bricks or concrete block with poor bond, are prone to collapse during earthquakes of even moderate intensity.

In advanced countries, where awareness of the earthquake hazard and the need for safety measures is generally higher than the developing countries, the losses are far less because of the following main reasons:

a) early information dissemination from the agencies responsible for seismological studies and research;
b) awareness and preparedness of the concerned governments and local population in case of disaster; and
c) precautionary and safety measures considered in the design of infrastructure.

Table 2.2 shows some significant earthquakes of the century and the devastation caused by them.

Table 2.2: Significant earthquakes of the century

Year	Country	Richter Magnitude	Loss of life	Other losses
1905	India	8.6	19,000	Long fault in Kashmir Valley; Kangra Town fully destroyed
1906	USA	8.3	500	220,000 homeless; heavy losses to infrastructure
1906	Ecuador	8.9	1,000	Long duration of over three minutes; vast area destroyed
1908	Italy	7.5	58,000	98% buildings in Messina destroyed
1920	China	8.5	200,000	Landslide destroyed many towns and villages in Ningxia
1923	Japan	8.3	99,331	Major destruction in Tokyo and Yokohama including fire
1927	China	8.3	40,912	Heavy property losses
1934	India	8.4	10,700	Land subsidence and foundation settlement in Bihar
1935	Pakistan	7.6	25,000	Quetta city infrastructure completely destroyed
1939	Chile	8.3	28,000	Chillan City destroyed. 100,000 people homeless
1960	Chile	8.5	2,230	61 deaths in Hawaii and 120 in Japan due to Tsunami
1970	Peru	7.8	66,794	800,000 people homeless; 18,000 buried in landslide
1976	China	7.7	242,469	Over 1,000,000 homeless
1980	Algeria	7.3	5,000	Large fault in Al-Asnam. 200,000 people homeless
1982	Yemen	6.0	2,800	Rural infrastructure damaged earthquake and landslides
1983	Turkey	6.9	2,000	Rural infrastructure destroyed
1986	El-Salvador	6.0	1,000	16,000 injured; 150,000 homeless
1988	Armenia	6.9	24,944	500,000 homeless
1990	Iran	7.5	40,000	60,000 injured; 50,000 homeless
1991	Yemen	4.6	Few	11,700 homes destroyed; 200,000 homeless
1992	Indonesia	7.5	2,080	2,000 injured; 100,000 homeless
1992	Egypt	5.9	561	20,000 homeless
1993	India	6.5	20,000	Infrastructure in 50 villages wiped out; 140,000 homeless
1994	USA	6.7	57	Los Angeles infrastructure destroyed; 100,000 homeless. American continent's costliest earthquake with about US$30 billion losses
1995	Japan	6.9	5,470	33,000 injured; 350,000 homeless; world's costliest earthquake with losses estimated at US$150 billion
1995	Russia	7.5	2,000	two-thirds population of Neftegorsk and the entire infrastructure wiped out

Sources: Polyahov, 1974; Gere & Shah, 1984; Coburn and Spence, 1992; UN/DHA, 1993; TIME International 1/1994 and 11/1995; Newsweek 1/1995; The Economist, 4/1995; New Civil Engineer 1/1995.

The frequency of disasters is increasing with the passage of time. Each time the losses, both in terms of life and infrastructure, are also on the increase. This is because of the fact that over 75% of the Latin American population lives in makeshift and vulnerable accommodation (UN Habitat, 1976). Almost the same is true about Asia, where almost three-quarters of the entire world's population lives. It is estimated that during the twelve months between 1970 and 1971, over 51 disasters occurred which claimed 500,000 lives and dislocated some 68 million people. Earthquake disaster projection carried out for two well known seismic areas, for San Francisco and Tokyo, are given in the following Tables 2.3 and 2.4.

Table 2.3: Earthquake disaster projection in San Francisco, USA.

Earthquake features	1906 earthquake	Estimated consequences of earthquake in the near future
Magnitude (Scale)	8.3 (Richter)	8.3 (Richter)
Population	400,000	3,100,000
Deaths	500	8,750 (22,000 injured)
Homeless	220,000	500,000
Damage	Entire commercial and industrial centre destroyed. 55% of houses destroyed	100,000 homes unusable

Source: Davis, 1978

Table 2.4: Earthquake disaster projection in Tokyo, Japan.

Earthquake features	1923 earthquake	Estimated consequences of earthquake in near future
Magnitude (Scale)	8.3 (Richter)	8.3 (Richter)
Population	400,000	12 million
Deaths	500	8,750 (22,000 injured)
Homeless	140,000	500,000 to 1 million
Damage	40% of buildings destroyed. Total loss estimated at US$3 billion	Total destruction in 2 km radius around epicentre. 50% destruction in 5 km radius.

Source: Davis, 1978

The above predictions are in respect of two most advanced and high-income countries where losses can be expected to be minimal because of earthquake resistant design of buildings and the peoples' and governments' awareness, preparedness and resources. The losses in low-income countries can be expected to be manifold in comparison to the above figures.

2.2 What is an earthquake?

Earthquakes, one of the most significant natural hazards, belong to those systematic interactions between man and nature, which cause catastrophic results at times and yet man has no control over them (Geipel, 1991). Mankind has been encountering this catastrophe from times unknown. It is only in the twentieth century that we have begun to understand the earthquakes and their causes (Coburn and Spence, 1992). Earthquakes can now be measured, analysed and mapped.

The following paragraphs discuss in some detail the ancient beliefs, the modern theories and the extent of destruction caused by the earthquakes.

The people in many countries still regard natural hazards, particularly earthquakes, as the 'acts of God' (Gist and Lubin, 1989). These people generally believe, that it is not possible to escape the divine punishment. From man's earliest days his very survival was dependent on the great elemental powers, such as water, wind, sun and earth (Davis, 1978). Each is vital for his survival and yet each can threaten his hold on the planet's surface. Natural disasters such as earthquakes, tornadoes, hurricanes and floods have been commonly referred as 'acts of God' because even today we find ourselves helpless to avert them (Gist and Lubin, 1989). An earthquake, or for that matter, any other natural hazard becomes a disaster only when it hits a populated area (Coburn and Spence, 1992).

Various religious and superstitious beliefs exist in different parts of the world, and different imaginary reasons have been given for earthquakes, such as wrath of the gods and the subsequent divine punishment. A Japanese myth is quite well known for describing the tremors of earthquakes as caused by the capricious flapping of a giant catfish living at the bottom of earth (Figure 2.1). Human mind has however continued to search for logical answers. Healy (1969) observed that various myths and religious explanations could not satisfy the natural scientific curiosity about the causes of earthquakes. The first non-superstitious theory was probably presented by Aristotle (Gere and Shah, 1984). He defined earthquakes as a result of suction of polluted winds of the atmosphere through the caverns and crevices and other holes on the surface of earth. He believed that these winds were ignited by heat below the earth's surface and evicted under great pressure causing earthquake tremors and volcanic eruption. This view continued to hold ground for several centuries until the new theories based on geological investigations gave scientific reasons for the earthquakes.

Darwin (1959) may also have developed some idea about the modern theories of plate tectonics when he commented that a severe earthquake can at once destroy the symbol of our oldest associations with the earth. The very emblem of solidity and strength moves beneath our feet like a thin crust over a fluid. These rational explanations led the scientists to concentrate on the causes of earthquakes from within the earth itself.

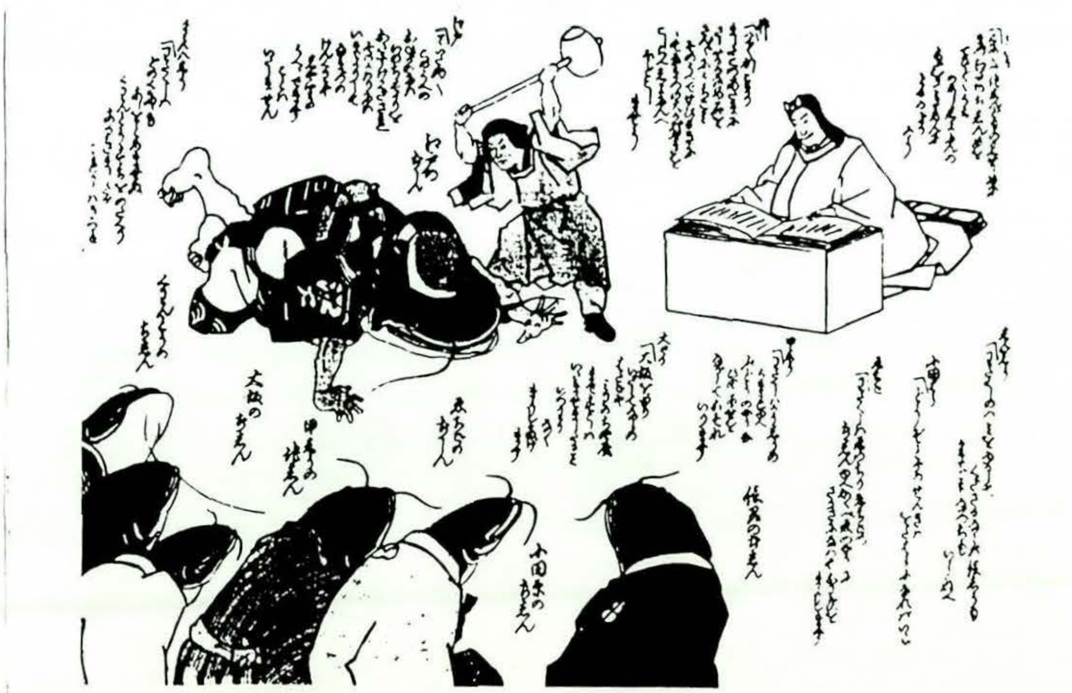


Figure 2.1: One of the early superstitious beliefs regarding causes of earthquakes. The God-Superior from the Kashima shrine, Japan, tells the daimyojin to drive down the pivot stone hard on the Edo (Tokyo) earthquake namazu (catfish) to warn other earthquakes. Each of the onlooking namazu is an historical earthquake. From left, Kwanto, Osaka, Koshu, Echigo, Odawara, and Sado earthquakes.
Source: Bolt, 1978.

2.3 Causes of earthquakes

Experts have been studying earthquakes for years but a convincing theory has still not been developed (Healy, 1969). Many theories are published since the study of earthquakes became an independent science subject called seismology. Seismologists agree that the earth's crust moves almost continuously (Figure 2.2). The reasons for these movements are not agreed upon by all experts but there is a general consensus that most earthquakes occur because of the simple reason that our planet is not the dead slab of rock many people once believed it to be. The metallic core of earth is covered by a layer of slowly churning mantle of rock which remains in plastic condition due to excessive heat and pressure (Grove, 1992). The mantle is topped by the cold, rigid and relatively thin layer of earth crust ranging from about 70 kilometres under the oceans to about 150 kilometres under the continents. This crust or earth cover is not in one piece but a combination of hundreds of thousands of fragments, known as the 'tectonic plates' (Horne, 1979). These plates range in width from a few hundred to several thousand kilometres. The underneath pressures cause constant movement of these plates at the rate of a few centimetres per year. This movement is caused partly by pressures in the molten materials under the crust plates and partly by the rotation of earth. In some areas the new crust material, under pressure from the molten interior, tends to fill the empty spaces by pushing away the adjoining plates. In other areas the plates slide past or push against one another. Such movements release energy in the form of seismic (derived from the Greek word seismos) waves. The difference in movements of tectonic plates, whatever the circumstances leading to this phenomena, causes an earthquake (Melham, 1978). Geologists have found out that edges of the plates are most prone to earthquakes and those countries or towns, which are located along the edges of tectonic plates, are more vulnerable to disasters. Therefore along a fault line deep inside the earth's surface may result in surface faulting. The resulting crack on the surface of the earth gives a viewer visual experience of the earthquake (Arnold and Reitherman, 1982).

The earth's crust is being gradually displaced at the margins of the plates presumably by convection currents in the upper mantle. Bell (1983) describes that differential displacements give rise to elastic strains which eventually surpass the strength of the

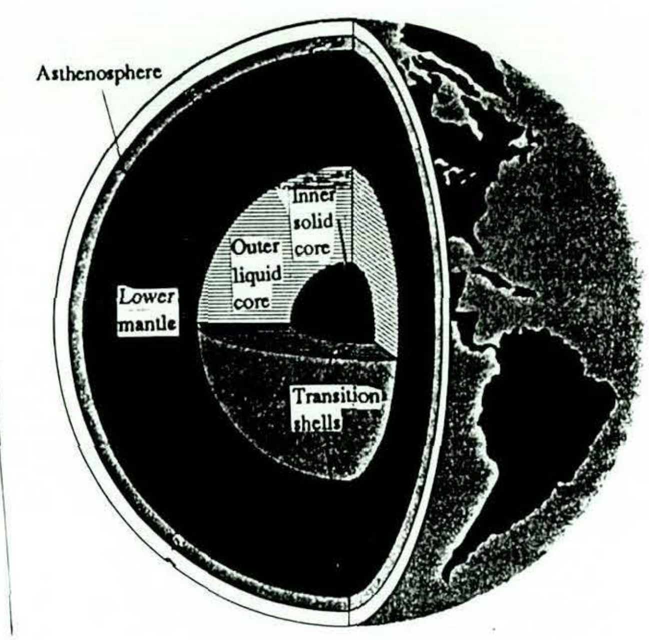


Figure 2.2: A cross-section of earth based on seismological evidence. The outer shell consists of a rocky mantle that has structural discontinuities in its upper part and at its lower boundary that are capable of reflecting or modifying earthquake waves. Below the mantle an outer fluid core surrounds a solid kernel at the Earth's centre; between the two is a transition shell.
Source: Bolt, 1982

rocks above and a fault is created. As a consequence the strain is partly or wholly neutralised and an earthquake occurs. Occasionally minor earthquakes occur in stable parts of the world.

Another simplified explanation of the circumstances causing earthquakes is given by Otsuka (1980). According to him an earthquake is the result of any sudden displacement of the earth's crust either on or beneath its surface. The causes of the displacement may be natural or artificial or both. The term is however restricted to movements of natural origin and to those which take place below the earth's surface. Thus the tremors caused by wind or sea waves, landslides or rockfalls, cannot be regarded as earthquakes.

Not all earthquakes are caused by nature. There are several artificial causes, such as nuclear tests, artificial reservoirs created by construction of dams or pumping water into deep wells, which have triggered small earthquakes in different parts of the world, particularly those areas which are prone to earthquakes (Gere and Shah, 1984). It is widely believed, in the cases of artificial reservoirs and deep wells, that water from these sources lubricates the faults which reduces friction between the underlying crust plates. The result is more earthquakes but usually of low magnitude. Geologists believe that while eliminating earthquakes in seismic zones seems impossible there is, at least in theory, a possibility of controlling major earthquakes by artificially creating several harmless earthquakes of low intensity (Melham, 1978). People living in fault zones will experience frequent tremors strong enough to draw their attention but not strong enough to cause any damage.

2.4 The seismic zones

World geology does not show any changes and major seismic activity occurs in the same regions. Earthquake locations may however change within a region. Sometimes earthquakes may occur where they are least expected such as the Kobe earthquake of 1995 (The Economist, 1995).

The world seismic map prepared after the study of over 700 strongest earthquakes and those with unexpected locations describes the major seismic zones as follows (UNDRO, 1978):

2.4.1 Circum-Pacific seismic belt: 80% of the total seismic energy is released in this zone. The main areas and countries covered in this zone are the eastern coast of Japan, Taiwan, the Philippines, Guam, New Guinea, Solomon Islands, Fiji, Tonga and New Zealand. All types of shallow, intermediate and deep earthquakes occur in this zone.

This classification is based on the depth of focus of an earthquake and is discussed in detail in section 2.7.

On the western coast of the Pacific Ocean Mexico, Alaska, California, Belleny Islands in Antarctica, the Gulf of California, Easter Island, the Galapagos Islands and the Aleutin Islands are covered in this seismic zone.

2.4.2 Trans-Asiatic seismic zone: South European countries such as Spain, Greece, Portugal, Turkey and Cyprus, all North African countries such as Morocco, Algeria and Egypt, some Middle Eastern countries such as Yemen and Iran, South Asian countries such as Pakistan and India, and Far Eastern countries such as Burma and Indonesia are included in this zone. Mostly shallow and intermediate earthquakes occur in this zone.

2.4.3 Mid-ocean rifts zone: This zone is located between the Indo-Atlantic and Indo-Antarctic rifts. Long fracture lines dividing the Atlantic ocean and the Indian Ocean are believed to be the main cause of frequently occurring shallow earthquakes of moderate magnitude in this zone.

Apart from these major zones there are some small and narrow active seismic zones which are responsible for earthquakes in Australia, Philippines, Eurasia, Africa, inner Pacific and the Antarctica.

2.5 Hypocentre or focus

Earthquake is a phenomena produced by sudden changes inside the earth. The origin of an earthquake where faulting and energy release first begins in all directions is called hypocentre or focus (Figure 2.3). Hypocentre is not limited to a point but sometimes may have considerable length or volume (Architectural Institute of Japan, 1970). The depth of hypocentre varies from a few kilometres to several hundred kilometres. Severe earthquakes causing serious damage to life and infrastructure can have their hypocentres shallower than 50 kilometres.

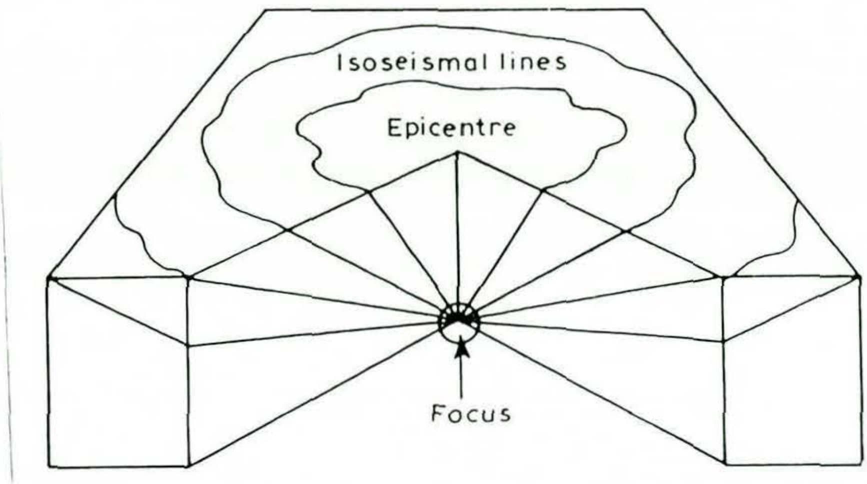


Figure 2.3: Block diagram showing isoseismal lines and their relation to epicentre and hypocentre.
Source: Bell, 1983

2.6 Epicentre

Epicentre is a point on the earth's surface vertically above the hypocentre (Arnold and Reitherman, 1982). Since the faulting plane is not necessarily vertical, and the fault may rupture along a considerable distance, shaking at the epicentre may not be the most intense. Earthquake foci are confined within a limited zone of the earth above and their maximum recorded depth is 700 kilometres.

2.7 Classification of earthquakes

Earthquakes seldom occur at the earth surface. Precise determination of their depth still remains a problem for the seismologists. In fact most earthquakes occur within 25 kilometres from the earth surface. In view of its significance, the depth of foci or hypocentre is used as a basis to classify earthquakes. Bell (1983) categorised the types of earthquakes as follows (Figure 2.4):

a) those occurring within 70 km from the earth surface are called shallow;
b) those occurring between 70 to 300 km depth are classified as intermediate; and
c) those between 300 to 700 km depth are known as deep.

This classification is also accepted by the United Nations (UNDRO, 1978).

Large earthquakes cause powerful shock waves which travel all over the world. The shock near the epicentre is short-lived and does not remain for more than a few seconds, but with the increasing distance, the vibrations last longer. The vibrations of a shallow earthquake are strong but they do not travel far from the epicentre. On the other hand shock waves emitting from a deep earthquake are usually weak but they cover much wider areas.

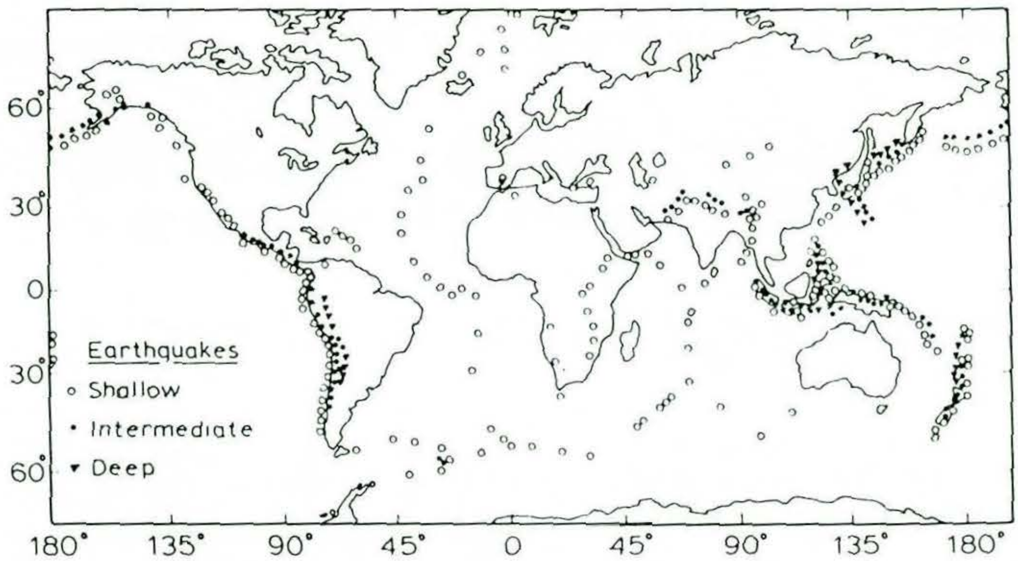


Figure 2.4: Distribution of earthquake epicentres
Source: Bell, 1983

2.8 Earthquake waves

The ground motion transmitted from the hypocentre through the interior of earth and under the base of a building has a random form but also sometimes has an emphatic direction (Arnold and Reitherman, 1982). The motion originates in four well defined types of waves created by a fault rupture as described below (Figure 2.5).

2.8.1 P waves: The primary waves (or longitudinal waves), commonly known as the *P* waves, are the fastest and travel at a speed of about 8 km/sec or 18,000 mph and arrive first to cause the damage. These waves are like sound waves which in the process of their spreading out alternately pull and push at the ground. Most of the damage is caused by these waves.

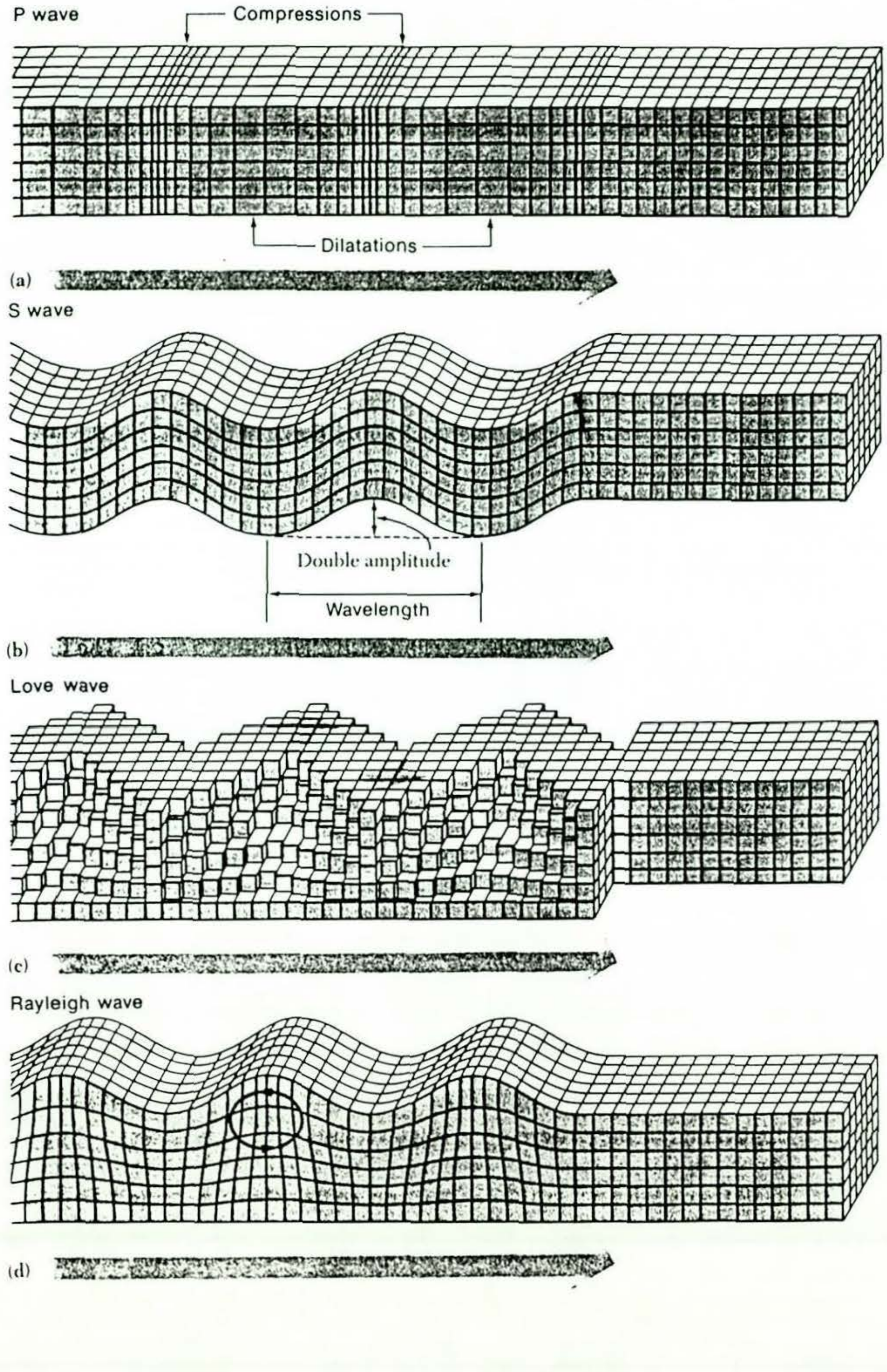


Figure 2.5: The earthquake waves
Source: Bolt, 1988

2.8.2 S waves: The secondary or *S* waves (also known as the transverse waves) shear the earth's surface sideways at right angles to the direction of travel.

2.8.3 Love waves: These waves are similar to the S waves but do not cause any vertical displacement. They move the ground from side to side horizontally parallel to the surface of earth, at right angles to the direction of propagation and produce horizontal shaking.

2.8.4 Raleigh waves: These are also surface waves which cause the disturbed earth material to move both vertically and horizontally in a vertical plane pointing in the direction in which the waves are travelling. Of the two surface waves, the Love waves travel faster than the raleigh waves.

2.9 Seismic risk and earthquake prediction

The study of regional seismicity and with the help of seismic maps its is possible to indicate the regions or areas where next earthquakes will occur. What is however difficult is to specify the exact place, time and magnitude of a future earthquake and whether it will be mild or disastrous (The Economist, 1995).

The records of earthquake intensity show that, every year on average, twenty earthquakes of high magnitude and over one hundred of moderate magnitude occur in different parts of the world (Table 2.5). This showed that one major earthquake can be expected on the surface of earth once in every three days (Al-Shamie, 1989). Although earthquakes are reported from almost all over the world their probable areas of activity are the regions of recent mountain building and the global rift system that is along the edges of tectonic plates which form the earth's crust (Figure 2.6) (Bell, 1983).

Table 2.5: Estimated world-wide earthquakes in a year

Magnitude M	Average number of earthquakes equal to or above M given in the last column
8	2
7	20
6	100
5	3,000
4	15,000
3	above 100,000

Source: Bolt, 1982.

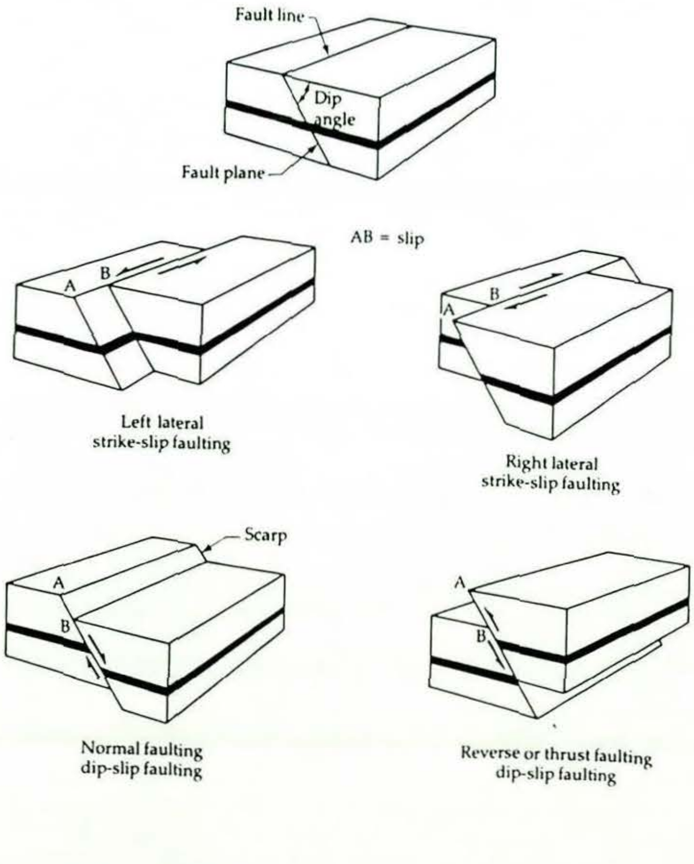


Figure 2.6: Types of earth fault movements
Source: Gere and Shah, 1984

Geologists have well defined the seismic zones of the world (Figure 2.7). In severe earthquake zones the probability of an earthquake is always greater where it may be repeated once in every 50 to 70 years. This does not mean that once an earthquake has occurred the area is safe for the next 50 or 70 years. Probability means that chances of the disaster are one in fifty to one in seventy every year. Gere and Shah (1984) observed that the longer the safe period passing since the last earthquake, the greater the probability of the next one. The probability estimates only inform us that the people and infrastructure in a particular area are at a risk of an earthquake and planning for their safety should be undertaken.

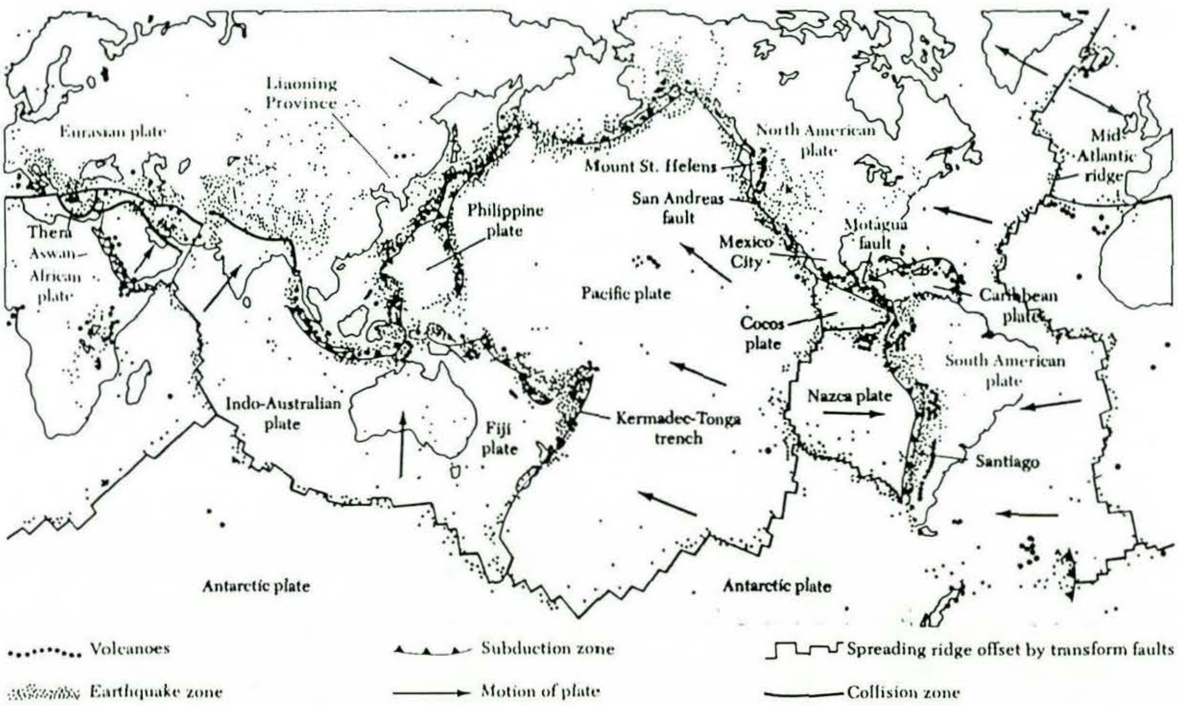


Figure 2.7: World map showing relation between the major tectonic plates and earthquakes and volcanoes
Source: Bolt, 1977

The most important object of seismology and earthquake engineering is to mitigate earthquake disasters and as far as possible, to prevent them from occurring (Hattori, 1980). For these purposes the topics of earthquake prediction, estimation of earthquake motions and the amount of earthquake damage and measures against earthquake disasters have become important research subjects in recent years.

The ideal solution for estimation of earthquake motions is to be able to predict the earthquake with sharp accuracy (Hattori, 1980). Efforts to successfully predict and prevent earthquakes have been made since the 1950s when seismology provided a theoretical framework for the process of earthquake occurrence. It is however realised that the development of conditions which trigger an earthquake is far more complex than expected. Although a few earthquake predictions have been successful in the past, by and large the subject remains as illusive as ever.

In spite of all modern research and laboratory work, it is still not possible to positively predict an earthquake with accuracy (Melham, 1978). While theoretically it is possible to have an earthquake anywhere at any time, the probability in most places is so low that the hazard cannot be considered as a threat for everyday purpose.

Sometimes the signals are strong and obvious to predict an earthquake such as the earthquake of Haicheng in China (1975), with a magnitude of 7.3, was successfully predicted and major life losses were prevented by leading the people out of their homes and into open fields. The traditional type of infrastructure, in Haicheng area, was however completely destroyed in this disaster.

Most of the time earthquakes have taken the engineers and scientists by complete surprise because there were no prior signals. The recent earthquakes of Marathawada in India (1993), Northbridge in the USA (1994) and Kobe in Japan (1995) are among the examples where there were no prior indications of the event (The Economist, 1/1995).

In view of many uncertainties linked with earthquakes, successful predictions are few. Some famous signals, successfully deployed in the past to predict earthquakes, include the following:

a) unusual animal behaviour (Figure 2.8);

b) rising of water level in the wells;

c) tilting of land surface;

d) changes in the electrical resistance of the ground;

e) fluctuation in the magnetic field;

f) changes in the seismic wave velocities;

g) rise in the temperature of hot springs in the area; and

h) increased discharge from hot springs.

Can Animals Predict Earthquakes?

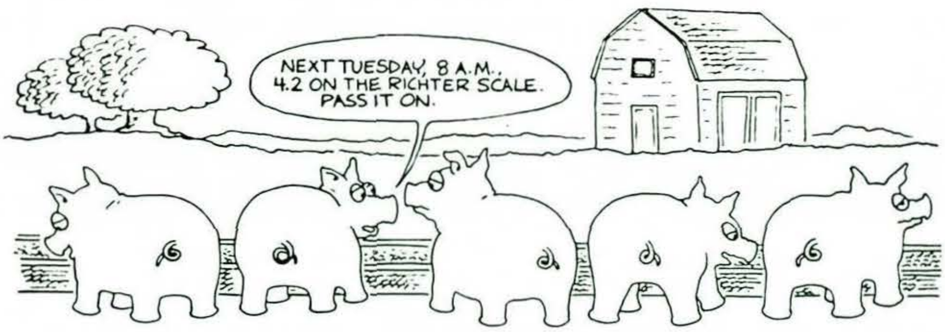


Figure 2.8: Unusual animal behaviour is considered as one of the earthquake prediction signals
Source: Gere and Shah, 1984

Long-term prediction of earthquakes will make it possible to:

a) strengthen the structures of existing buildings;

b) make regulations for land use and earthquake resistant building designs;

c) create public awareness for safety rules and preventive measures; and

d) for planning relief plans.

Short-term prediction will help to:

a) mobilise relief work in the event of a disaster;

b) organise evacuation of endangered buildings and other areas;

c) temporarily close down those industries and factories which may aggravate the disaster; and

d) evacuate low-lying coastal areas which may be susceptible to tsunamis.

2.10 Earthquake measurements

Human efforts have long been focused on estimating and measuring the earthquake forces in order to form an idea about the possible extent of damage they may cause and to take any preparatory measures. The energy released in earthquakes travels through the ground in the form of waves (Section 2.6) which somewhat resembles movement of the sea-waves. In large earthquakes these waves can actually be seen. Various definitions related to the measurement of earthquakes are given in the following paragraphs:

2.10.1 Ground motion: During an earthquake the ground rapidly moves in a complex way in both horizontal and vertical directions. This movement is called ground motion.

2.10.2 Seismograph: The instrument which measures and records ground motions is called a seismograph. The first effective seismograph was built just before the beginning of the twentieth century (Bolt, 1978). The present instruments are more sophisticated and record their readings photographically or electro-magnetically on a tape as compared to the old instruments which used ink-pens for writing their readings on rotating drums (Figure 2.9). These instruments work in such a way that a mass is freely suspended from a frame fixed on the ground. This free suspension of the mass makes it independent of the motion of the frame. When the fixed frame is shaken by earthquake waves, the inertia of the mass forces it to lag behind the motion of the frame. This relative motion is duly recorded. The strong-motion modern seismographs are called *accelerometers* or *accelerographs* (Arnold and Reitherman, 1982). They record the nearby rather than the distant ground motions directly. The graph which they produce is called an *accelerogram*. These instruments are placed so as to record movements along the two horizontal axes and one vertical. Three measures are recorded in each direction and they are of major interest in earthquake study. These measures are called *velocity*, *acceleration*, and *displacement*.

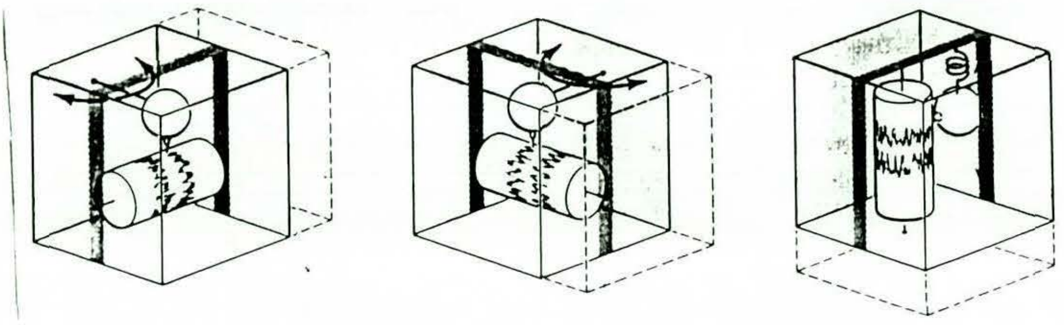


Figure 2.9: Some simple models of pendulum seismographs
Source: Bolt, 1978

2.10.3 Seismogram: The chart or record in any other form carrying readings of a seismograph is called a seismogram. For recording different directions of the earthquake waves a number of instruments are used with different positions of the hanging mass. Very sensitive instruments can record earthquake magnitudes as low as minus two (-2) which is equivalent to the shock created by the dropping of a brick from a table to the ground.

2.10.4 Accelerogram: It is the modern version of a seismogram (Figure 2.10). While the seismogram is a chart prepared by an automatic ink-pen, an accelerogram provides a picture of the ground shaking. The arrival of P wave starts the motion. The S wave is next to arrive. The *time* interval between the arrival of *P* and *S* waves helps to calculate the distance between the instrument and the earthquake focus. The duration of strong earthquake motions can be clearly seen from the accelerogram and the maximum wave *amplitude* can be measured directly in millimetres. The ground acceleration is calculated by relating amplitude to time. Velocity and displacement are mathematically calculated by integrating the acceleration record once and twice, respectively.

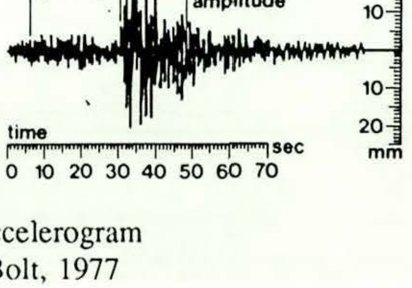


Figure 2.10: Typical accelerogram
Source: Bolt, 1977

2.10.5 Velocity: The rate of ground motion is called velocity (Figure 2.11). It is measured in centimetres per second (cm/sec).

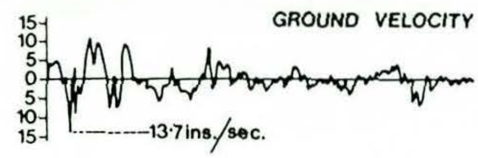


Figure 2.11: Typical earthquake velocity diagram
Source: Bolt, 1977

2.10.6 Acceleration: It is the rate of change of velocity. When acceleration is multiplied with mass, the result is the inertia force which the building must resist in order to remain intact. Acceleration is usually represented by *g* which is the acceleration of a free falling body due to earth's gravity at a rate of 980 centimetres per second per second (cm/sec/sec) or 32 feet/second/second (ft/sec/sec) (Figure 2.12). The *peak ground acceleration* (*PGA*) is the maximum value of acceleration at any instant during the ground motion. The maximum accelerations may range from 0.5 g to 2 g.

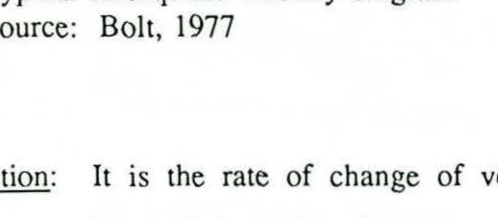


Figure 2.12: Typical earthquake acceleration diagram
Source: Bolt, 1977

The data on intensive earth movements close to the epicentre are of great value foı earthquake engineers and seismologists. Direct measurement of the acceleration of earth motion and the study of its *frequency spectrum* or *response spectrum* are important for an engineer's calculations which assist him in the design of structures (UNDRO, 1978).

2.10.7 Duration: The duration of earthquake shaking is measured in terms of the length of time during which the acceleration peaks exceeded a certain amplitude. The duration varies from a few seconds to a minute or more in strong ground shaking. The longer the duration of earth shaking the more destructive the earthquake will be (Coburn and Spence, 1992).

2.10.8 Frequency: It is the number of times the ground moves backwards and forwards in one second during an earthquake.

2.10.9 Inertia forces: Ground motion created by an earthquake does not act on a building like a force directly hitting the walls such as strong winds (Arnold and Reitherman, 1982). The effect on buildings and other infrastructure is rather internal generated by inertial forces which are the result of vibration of the building mass. Inertial forces are the product of mass and acceleration (Newton's formula: Force = mass x acceleration). Acceleration is already described in para 2.10.6 whereas mass is a function of the weight of the building. This is why earthquake-resistant designs have emphasis on light weight construction.

2.10.10 Period: All buildings vibrate to various degrees when jolted by an earthquake depending upon their flexibility. The swaying backwards and forwards in a given time is called a *cycle*. The duration in which a *cycle* is completed is known as *period*.

2.10.11 Damping: The swaying of a building continues for some time after the disturbance is finished. This swaying also dies away after a while. The rate at which the swaying decreases after the end of the disturbance is called damping and is very important in structural designs.

2.10.12 Resonance: The swaying of ground and the structure above it at a certain point is usually different. While the swaying of ground cannot be altered, the swaying of a building can be controlled through design. If these two movements coincide then the dimensions of the swing become larger and the structure is said to resonate. This phenomena increases loads on the building.

2.10.13 Displacement: It is the distance by which a particle object is removed from its original or at-rest position and is measured in centimetres or inches (Figure 2.13).

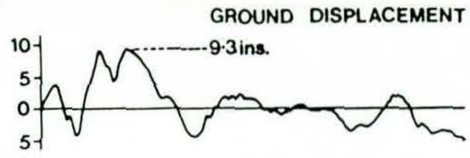


Figure 2.13: Typical displacement diagram
Source: Bolt, 1977

2.10.14 Torsion: Torsion is the result of loads created by inertia forces of an earthquake and the resistance offered by walls and frames of a building. Torsion tries to rotate a building if the loads and resistance are acentric. Detailed explanation of torsion is that earthquake inertia forces tend to horizontally accelerate the particles of a mass. This force can be described as the horizontal equivalent of gravity force. Sometimes the movement of particles is vertical also but it is of lesser significance. If the mass in a floor is uniformly distributed, the resultant force of horizontal acceleration of all its particles is exerted through centre of the floor. If the resultant of resistance provided by walls and frames pushes back through this point and counters the resultant of loads directly, a dynamic balance is maintained. If the direction of the resistance and the loads is not the same, horizontal rotation or torsion will occur which will tend to rotate the building. If the mass is eccentrically disposed the earthquake load will also be acentric. An earthquake generates a load only because of the presence of mass and the amount of load is directly proportional to mass. If the load is acentric, the resistance should also be acentric so that the location of the centre of mass and the centre of resistance are at the same point and torsion is avoided. This is the principle which designers use for countering torsion.

2.10.15 Magnitude: The magnitude of an earthquake is a measure of its total size, the energy generated at its source or focus as estimated from laboratory observations (Coburn and Spence, 1992). This term is used to describe the earthquake as a whole and is different from 'earthquake intensity' which is defined in Section 2.10.16.

The size of an earthquake is related to the amount of elastic energy release in the process of fault rupture. The energy release from an earthquake is like an explosion being detonated below ground with the magnitude being the measure of the energy release.

A number of magnitude scales are in use but the oldest and most commonly used is the Richter scale (M_l) defined by Professor Charles Richter (Figure 2.14). He proved that the magnitude of an earthquake can be measured by instruments (Gere and Shah, 1984). Richter devised a logarithmic scale in 1935 to compare the magnitude of earthquakes in California. His method has since been widely in use, with some modifications, all over the world. Richter related the magnitude of a tectonic earthquake, to the total amount of elastic energy released, when the over-strained rocks under pressure suddenly give way by generating shock waves. The severest recorded earthquake was of magnitude 8.9. Such earthquakes release about 700,000 times the energy of a mild earthquake (Bell, 1983).

Categories of earthquake vis-a-vis their magnitudes are given in Table 2.6.

Table 2.6: Earthquake magnitude and relevant effects

Richter Magnitude	Category	Remarks
2.0 and below	Mild	Not generally felt
3.0	Mild	Felt by some; no losses
4.0	Mild	Felt by most; no major losses
5.0	Moderate	Minor structural damage
6.0	Major	Major damage to earthquake non-resistant structures
7.0	Severe	Major damage to all infrastructure
8.0 and above	Great	Total damage

Source: Gere and Shah; 1984.

This scale is based on the logarithm of amplitude of the largest swing recorded by a standard seismograph (Coburn and Spence, 1992). Different types of seismic waves are emitted in different earthquakes. In general the definition of magnitude which best correlates with the surface effects of earthquakes is the surface wave magnitude Ms because it is the surface waves which are most harmful to buildings.

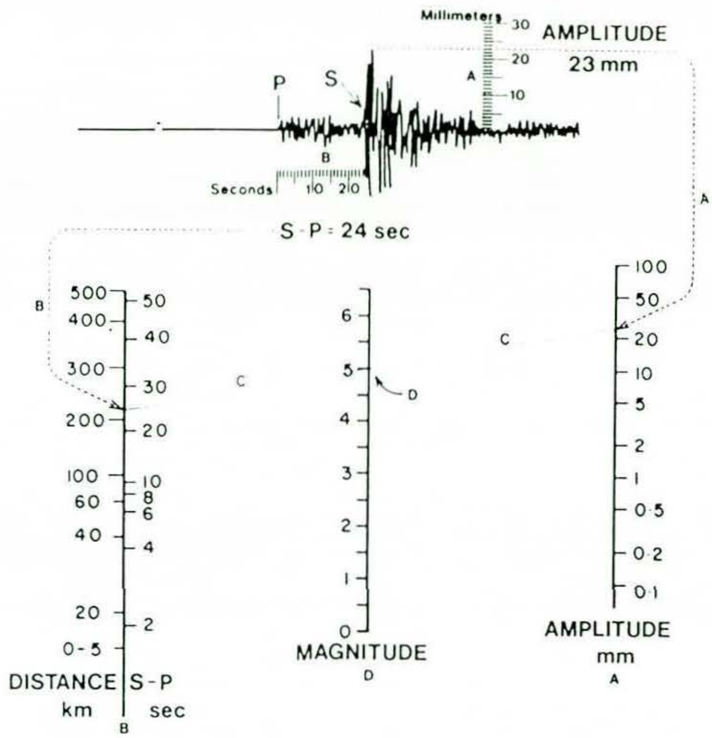


Figure 2.14: The Richter scale.
To determine Richter magnitude at varying distances from the epicentre, connect on the chart: (A) the maximum amplitude recorded by a standard seismometer and (B) the distance of seismometer from the epicentre of the earthquake (or difference in arrival times of P and S waves) by (C) a straight line, and (D) read the magnitude off the centre scale.
Source: Bolt, 1978

A general guide for easier understanding of the earthquake magnitude, the approximate amount of energy release and possible damage is provided by Coburn and Spence (1992) as follows:

- **Magnitude less than 4.5**: An earthquake of this magnitude (Richter scale) represents about 10^8 kilojules of energy release or about 10 tons of TNT exploded underground. It is very rare for an earthquake of less than 4.5 magnitude to cause damage although it might be felt in a large area depending upon the depth of the earthquake. Earthquakes of magnitude 3 or less are difficult to be recorded by seismographs unless they are placed close to the event. A shallow earthquake of 4.5 magnitude can be felt in a radius of about 50 to 100 km from its epicentre.

- **Magnitude 4.5 to 5.5 (local earthquakes)**: An earthquake of 5.5 magnitude is equivalent to energy release of about 10^9 kilojules or 1,000 tons of TNT exploded underground. Earthquakes of 5.0 to 5.5 magnitude may cause damage if they are shallow and if the resultant intensity is high enough to shake fragile buildings in the vicinity. Earthquakes of magnitude up to 5.5 can occur anywhere in the world ie even in areas not known for tectonic activity. An earthquake of 5.5 magnitude may be felt in an area spreading over 100 to 200 km radius.

- **Magnitude 6.0 to 7.0 (large earthquakes)**: The earthquakes of this magnitude represent an energy release ranging from 10^{10} to 10^{12} kilojules or a sub-surface explosion of 6,000 tons of TNT. An atomic bomb explosion also comes under this category. If large earthquakes of magnitude 6.0 and above occur at shallow depths, they may cause intensities of VIII to X causing heavy damage and destruction in the villages and towns near the epicentre. Deep earthquakes of large magnitude are merely part of the earth's tectonic process and do not usually cause any damage above ground. About 200 large earthquakes occur each year. An earthquake of magnitude 7.0 if occurring close to the surface of the earth, can be felt at distances 500 km away from the epicentre.

- **Magnitude 7.0 to 8.9 (great earthquakes)**: Energy release from earthquakes of magnitude 8.0 to 8.9 is in the range of 10^{12} to 10^{14} kilojoules which is equivalent to sub-surface detonation of 400 atomic bombs or one hydrogen bomb. Great earthquakes release large amounts of energy and are the consequence of long linear faults rupturing at one time. Such earthquakes are highly destructive because of the high intensities produced by them. No infrastructure can be expected to withstand great earthquakes. Only one event of magnitude 8.9 is recorded in the history of earthquakes.

2.10.16 Intensity: Intensity can be defined as a measure of the felt effects of an earthquake on humans, infrastructure and other objects. It differs from the earthquake magnitude which is a measure of the earthquake itself although the most severe earthquakes cause devastation of areas over 2,500 sq km or more but most affect only tens of square kilometres. The purpose of introducing intensity scale is to express the severity of earthquake tremor felt through human perception, responses of various objects such as buildings and other infrastructure (Otsuka, 1980).

There are two methods of studying earthquake effects. The first is through observation which is further confirmed through the second method of analysing the earthquake effects on the ground, on buildings and on human beings. Observed effects are those which are noted without using any special instruments (UNDRO, 1978). Earthquake intensity depends on human perception of the damage caused by such event. The earthquakes occurring before the twentieth century, when there were no instruments to measure them, are known as the *historic* earthquakes. Description of the effects of these events is the only evidence which has helped scientists in approximately determining their epicentres and magnitudes and in defining the seismicity of different regions around the world.

Earthquakes perceptible to human beings are called *macroseismic*. The area over which human observation can be made largely varies and depends on the seismic energy developed at the epicentre and depth of the epicentre. It is difficult to exactly define the limits of perception of an earthquake. Individual perception and description of an event varies from one observer to another. It is, therefore, necessary to take an average of the information received from different observers. Progressive efforts have been made to develop scales of intensity which are universally applicable.

2.10.16.1 *Intensity scales*: Scientists have presented various scales such as the Rossi-Forel (1883), Mercalli (1902) and Cancami (1903) for measurement of the intensity of earthquakes. The most widely used intensity scale is the Modified Mercalli (MM) scale which was first introduced by Wood and Neumann in 1931 and later modified by Charles Richter in 1956 (Otsuka, 1980). The Medvedev-Sponheuer-Karnic (MSK) scale was introduced in 1976. It is a further modification of the MM scale and is frequently used in Europe. The Japanese Meteorological Agency (JMA) use a smaller (seven-point) scale.

All scales describe lower degrees of intensity almost in the same way as follows:

I: Shock not felt;

II: Shock felt by a few people living in upper floors;

III: Shock felt by some people indoors, vibration of windows and doors, and swaying of objects;

IV: Shock felt by many people indoors, vibration of windows and doors, clinking of crockery, and creaking of wooden floors and walls;

V: Shock felt by the whole population in a locality, many sleepers awakened, spilling of liquids, and wide swinging of hanging objects.

In the higher degrees of VI to X intensity, the MSK scale is more precise than other intensity scales and takes account of the type of construction, the percentage of buildings damaged and the nature of damage as described in the following paragraphs (UNDRO, 1978):

a) *Type of construction*

Type A: cobweb, adobe, rural and ordinary stone buildings;

Type B: brick, concrete block, combined masonry and wood, bonded stonework;

Type C: steel frame, reinforced concrete and strong wooded buildings.

b) *Percentage of building damage*

Q (few): about 5%;

N (many): about 30%;

P (most): 75% or more.

c) *Nature of damage*

i: cracking, falling of debris and plaster;

ii: cracking of walls, falling of roof tiles, cracking and falling of parts of chimneys;

iii: deep and wide cracks in walls, falling of complete chimneys;

iv: breaches in walls, partial collapse of buildings, destruction of internal walls;

v: total collapse of buildings.

Consequently Table 2.7 can help in determining the intensity of an earthquake at a certain location to a reasonable degree of accuracy.

Table 2.7: Determination of earthquake intensity

MSK Intensity	Type A			Type B			Type C		
	Q	N	P	Q	N	P	Q	N	P
VI	2	1		1					
VII	4	3		2				1	
VIII	5	4		4	3		3	2	
IX		5		5	4		4	3	
X			5		5		5	4	

Source: UNDRO, 1978.

Earthquake intensity also influences the effects of an earthquake on ground. For example at intensity VI small fissures appear if the ground is wet. At intensity VII and VIII the flow of springs changes, cracks develop in roads and water in reservoirs gets turbid due to stirring up of silt. At Intensity IX water and mud get thrown out of lakes and canals, and rockfalls and landslides may occur at many places. Intensity X causes damage to even stronger structures such as bridges, dams, dykes and other embankments, underground pipelines, and railway lines which may get twisted. Fissures as wide as 1 metre may appear in the ground. At intensity XI major destruction occurs and even strong buildings collapse or get severely damaged. Intensity XII completely changes the landscape in which valleys blocked by landslides may form new lakes and existing lakes may dry up due to the creation of large fissures. All physical infrastructure collapses or gets severely damaged.

A comparison of the two most widely used MM (1956) and MSK (1981 revision) scales is given in Table 2.8.

Table 2.8: Seismic intensity scales MM (1956) and MSK (1981)

Intensity	MM Scale	MSK Scale
I.	**Not felt** Marginal and long-period effects of large earthquakes.	**Not noticeable** Below the limit of sensibility. Tremor is detected by seismograph only.
II.	***Felt by persons at rest*** Felt by persons at rest, on upper floors or favourably placed.	**Scarcely noticeable/slight** Vibration felt by people resting in houses, specially upper floors.
III.	**Felt Indoors** Hanging objects swing. Vibrations are like passing of light trucks.	**Weak** Felt mostly indoors. Vibrations are weak. Hanging objects swing.
IV.	**Hanging objects swing** Vibrations are like passing of heavy trucks. Standing cars rock. Windows and doors rattle. Glassware clinks.	**Largely observed** Felt by most people indoors. Vibrations are moderate. Doors and windows rattle. Wooden floors and walls creak.
V.	**Felt indoor** Direction estimated. Sleepers awakened. Liquid disturbed/spilled. Unstable objects displaced. Pendulum clocks upset and change rates. Doors and windows open and shut by themselves.	**Strong** Felt indoors by most; outside by many. Sleeping people awakened. Some run outside. Animals disturbed. Doors and windows open and shut. Grade 1 damage to A type buildings. Sometimes change in the flow of springs.
VI.	**Felt by all** Many frightened and run outside. Persons walk unsteadily. Windows, dishes and glassware break. Damage to week plaster. Cracks in plaster and D type masonry. Heavy Furniture overturned and damaged. Small bells ring.	**Slight damage** Felt indoors and outdoors. Animals run out of stalls. Dishes and glassware break. Grade 1 damage to some single A type and many B type buildings. Grade 2 damage to A type buildings. Sometimes *change in spring flows. Small bells ring.*
VII.	**Difficult to stand** Felt by car drivers. Hanging objects quiver. Furniture broken. Damage to D type masonry. Weak chimneys broken at roof line. Fall of plaster, bricks and stones. Some cracks in C type masonry. Water turbid. Concrete irrigation ditches damaged.	**Damage to buildings** Most people frightened and run quiver. Furniture broken. Damage to outdoors. Large bells ring. Many find it difficult to stand. Many C type buildings suffer grade 1 loss. Many building of A class suffer grade 3 and some grade 4 losses. Cracks in road and stone walls. Landslides. Waves formed on water and water turned turbid. Water levels in wells and spring flows change. In some cases dry springs start flowing and flowing springs become dry. Some sandy banks slip off.

Intensity	MM Scale	MSK Scale
VIII.	**Car steering affected** Damage to masonry C; partial collapse. Some damage to masonry none to masonry A. Fall of stucco and some masonry walls. Twisting and fall of chimneys, monuments, towers and water tanks. Frame house moved if not bolted to the ground. Loose panel wall thrown out. Tree branches broken off. Changes in flow and temperatures of springs and wells. Cracks on wet ground and on steep slopes.	**Destruction of buildings** General fright. Motor drivers are disturbed. Some tree branches broken. Hanging lamps damaged. Many C type buildings suffer grade 2 damage and few of grade 3. Many B type buildings suffer grade 3 losses and few of grade 4. Many buildings of A type suffer losses of grade 4 and some of grade 5. Stone walls collapse. Memorials and monuments twisted. cracks in ground. Damage to roads. Water levels change in wells and reservoirs. Dome dry wells, springs and reservoirs recharge while some existing reservoirs become dry.
IX.	**General panic** Masonry D destroyed; masonry C heavily damaged; masonry B seriously damaged. Damage to foundations. Frame structures shifted off if not bolted down.	**General damage to buildings** General panic. Considerable damage to furniture. Animals run around in confusion and cry. Many building of type C suffer grade 3 damage and few of grade 4. Many buildings of type B suffer damage of grade 3 and few of grade 4. Many buildings of type A suffer grade 5 losses. Monuments and columns fall. reservoirs may show heavy damage. In many cases railway lines are bent and roadways damaged. Overflow of turbid water is seen. Cracks as big as 10 cm appear in slopes and river banks. Landslides, earth flows and high waves in water are common.
X.	**Structure foundations destroyed** Most masonry and framed structures destroyed with their foundations. Some strong wooden structures and bridges destroyed. Serious damage to dams and embankments. Landslides. Water thrown out of river and canal banks. Sand and mud splashed on beaches. Rails bent slightly.	**Building general destruction** Many C type buildings suffer losses of grade 4 losses and some of grade 5. Many B type buildings suffer grade 5 losses. Most of the A type construction collapses. Dam, dykes and other embankments may suffer severe to critical damage. Railway lines are slightly bent. Road pavements and asphalt show waves of Wide cracks in the ground, sometimes as much as 1 metre wide. Broad fissures along water courses. Loose earth slides from steep slopes. Displacement of sand and mud in coastal areas. New lakes formed.

Intensity	MM Scale	MSK Scale
XI.	<u>**Rails greatly bent**</u> Rails bent. Underground pipelines completely out of service.	<u>**Catastrophe**</u> Destruction of most and collapse of many C type buildings. Even strongly built bridges and dams may be destroyed. Railway lines are twisted and buckled. Highways become unusable. Underground pipelines destroyed. Ground fractured by broad fissures and cracks. Numerous landslides and rock falls.
XII.	<u>**Total Damage**</u> Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown into air.	<u>**Landscape changes**</u> Practically all structures above or below ground are heavily damaged or destroyed. Ground surface is radically changed. Large ground cracks with extensive vertical and horizontal movements are seen. Fall of rocks, creation of new lakes, sliding of river banks deflection of rivers and appearance of water falls are the probable events.

<u>**Notes (Type of buildings not earthquake-resistant)**</u>

Masonry A: Good workmanship, mortar and design, use of reinforcing steel to resist lateral forces.

Masonry B: Good workmanship and mortar. Reinforced, but not designed to resist lateral forces.

Masonry C: Ordinary workmanship and mortar. No extreme weaknesses such as lack of corner ties but no reinforcement nor designed to resist horizontal forces.

Masonry D: Weak materials such as adobe, poor mortar, low workmanship standards and horizontally weak.

Type A: Undressed stones, rural structures, adobe or clay houses.

Type B: Ordinary brick buildings, large block construction, partly timbered construction with semi-dressed stoned.

Type C: Precast concrete skeleton construction, precast concrete skeleton construction, precast large panel construction, well-built wooden structures.

<u>**Classification of damage:**</u>

Grade 1: Slight damage: fine cracks in plater, falling of plaster.

Grade 2: Moderate damage: fine cracks in walls, large pieces of plaster fall off, part of chimneys fall down.

Grade 3: Heavy damage: large and deep cracks in walls, chimneys fall down.

Grade 4: Destruction: gaps in walls, collapse of part of buildings, partition walls and filled in walls in frame structures collapse.

Grade 5: Total damage: total collapse of infrastructure.

Sources: Otsuka, 1980; Coburn and Spence, 1992

2.10.16.2 *Single intensity scale*: There are several intensity scales to describe earthquakes and which sometimes creates confusion. Medvedev, Sponheuer and Karnic who developed the famous MSK intensity scale also compiled a table for converting the intensity recorded from one scale to another. Table 2.9 presents this conversion table.

Table 2.9: Conversion table for different seismic intensity scales

MSK seismic scale 1964	Russian Scale 1952	Modified Mercalli scale (MM) 1931	Japanese scale 1950	Rossi-Forrel scale 1873	Mercalli-Cancani-Seiberg scale 1917
1	1	1	0	1	1
2	2	2	1	2	2
3	3	3	2	3	3
4	4	4	2-3	4	4
5	5	5	3	5-6	5
6	6	6	4	7	6
7	7	7	4-5	8	7
8	8	8	5	9	8
9	9	9	5-6	10	9
10	10	10	6	10	10
11	11	11	7	10	11
12	12	12	7	10	12

Source: UNDRO, 1978.

2.10.16.3 *Isoseismals*: The intensity is strongest close to the epicentre. This is why deep earthquakes with high magnitude or those occurring in deserted areas cause less or no human suffering than the shallow earthquakes of even moderate magnitude particularly if their epicentres are located close to populated areas. The maps showing intensity of earthquakes are called isoseismal maps in which lines of equal intensity are separately shown. These maps are prepared by geologists after each significant earthquake (Coburn and Spence, 1992). Isoseismal maps of the past events are very important for predicting the timing, magnitude, intensity and location of the next earthquakes.

2.11 Other hazards accompanied by earthquakes

Even in the short duration in which an earthquake occurs, other major hazards may be triggered off due to the presence of certain geological materials or loose formation of soil slopes in the localities where the seismic shocks are taking place (UNDRO, 1979). Study of the past earthquakes reveals that death and damage toll after an earthquake can rise sharply as a result of follow-on disasters initiated by the earthquake and escalating the crisis further. The most important among these secondary disasters are fires, tsunamis, landslides, liquefaction, ground subsidence and industrial failures. These hazards can be controlled and losses much reduced if the secondary disasters are foreseen and necessary precautionary measures taken in advance (Coburn and Spence, 1992).

2.11.1 Landslides: Landslide in the context of a follow-on hazard to earthquake means downward and outward movement of the slope-forming materials such as natural rock, soil or artificial fill (UNDRO, 1979). Earthquakes cause landslides in areas where the mountains have loose rocks and soil on the slopes. The shake-up sets these materials free resulting in land slides which cause heavy losses to life and property in the lower regions. There are many examples around the world (Peru 1970, Guatemala 1976 and Yemen 1982) in which disintegrating mountainsides sent down tons of debris on the populations residing at their bases and caused havoc. Individual slope failures are generally not so significant and costly as some other natural catastrophes but they are so widespread that the total human and property losses in landslides place them among major natural hazards.

These hazards may not be easily preventable during emergencies due to the time, cost and effort involved in he exercise. Long term preventative measures require identification of the potential threat, informing dissemination among the population at risk and assisting them in making land use planning accordingly, and carrying out geo-technical engineering work which may help stabilise the slopes as far as possible.

2.11.2 Tsunamis: Tsunami is a Japanese word which means bay waves. This is perhaps why these waves are some times called tidal waves. Japan tookalead in identifying and naming this hazard because the country has experienced tsunamis more frequently than others. A tsunami sometimes follows an earthquake and causes devastation in wide spread coastal areas (Coburn and Spence, 1992). Earthquakes of large magnitude, shallow depths and their epicentres located in mid-ocean usually cause the tsunamis. These waves are markedly different from the common wind-waves because of their long wavelength, extremely high speed and low attenuation. Their amplitude at the source is about one metre with a travelling speed of about 1,000 km per hour depending upon the depth of the epicentre and the depth of water at that point. These waves can travel thousand of miles from one end of the ocean to the other slowing down very gradually. When they reach a coastal area the reducing depth of water causes increase in their amplitude by several metres. Their height and abrupt reduction in speed causes them to hit the shores violently thus resulting in serious damage to the coastal life and installations.

Tsunamis are known to have occurred in all oceans and the Mediterranean sea but a majority of them have been observed in the coastal areas of the Pacific Ocean (UNDRO, 1978). They travel in all directions from their point of origin. Approximately 200 tsunamis have been recorded in the current century. While most of them created only local effects about 20 of them caused destruction throughout the Pacific Ocean.

Protection from tsunamis can be achieved by constructing sea walls and beach defences, planting shore-line trees and building other physical obstructions in front of the coastal areas. Population movement from the hazardous areas is also an important prevention measure.

2.11.3 Fires: Fire is also a serious secondary hazard in an earthquake disaster. Severe shaking causes overturning of stoves, heating equipment and electrical appliances and other items which can produce fire. On the other hand seismic vibrations also damage fuel and gas lines and other inflammable materials causing leakage and spill of such materials. The resultant fire becomes a serious threat if there is sufficient combustible material in the vicinity such as wood, plastic, clothes or other similar material, which spread the fire rapidly. Fire can be even more devastating if buildings in the affected area are grouped together. The smoke and fumes released during a fire entirely consume the buildings on fire. Dry weather and winds further aggravate the situation. Some of the post earthquake fires (Japan, 1923) are known to have continued for several days after the earthquake covering vast areas in the process and blocking all escape routes.

Protection against conflagration requires regulations against spread of fire such as the use of incombustible building materials, spacing between building, keeping of fire extinguishers, etc. Public awareness about precautionary measures against fires and what to do in case of a fire plays an important role in minimising losses in such events (Coburn and Spence, 1992).

2.11.4 Differential ground settlement: Sometimes a structure is located on two soils of different compositions. Earthquake shaking causes more settlement of one of these soils than the other which results in foundation settlement and development of cracks in the structure. This phenomena frequently occurs where part of the site is prepared by cutting in the existing ground and the remaining by filling depressions with fresh soil.

2.11.5 Liquefaction: Some deposits in flat alluvial valleys have a very compressible structure which is disturbed by earthquake vibrations (UNDRO, 1979). These vibrations liquefy certain types of sandy soils. A soil in this condition has effectively zero shear strength and therefore the sediments above it are free to move under gravity forces in any direction. The whole material above the liquefied layer may then spread laterally and break up into smaller units. The buildings founded upon such layers can no longer stand on liquified soils and subside, break up or fall on one side causing further damage to other nearby buildings (Gere and Shah, 1984).

2.11.6 Ground subsidence: Ground subsidence is among major natural hazards and frequently appears as the secondary hazard following an earthquake. Soil compaction occurs during an earthquake which results in the filling of voids and settlement of ground. This settlement causes cracks in the buildings, pipelines, roads, etc. Ground subsidence is usually not given serious consideration as compared to other natural hazards such as earthquakes, landslides, volcanoes and floods. This is perhaps because the effect of ground subsidence is not as dramatic as in the case of above hazards (Waltham, 1989). The loss of life is rare in this case. Yet ground subsidence is among the most widespread as compared to other surface hazards. Ground subsidence presents serious threats to the structure above and needs careful assessment.

2.11.7 Dam failures: Severe shaking during earthquakes can result in dam failures which can cause havoc in the downstream areas by flooding and destroying life, agriculture and other property. A routine procedure after an appreciable earthquake should be to inspect all dam structures in the vicinity. Quick reduction of water levels in the reservoir should be undertaken if any damage is suspected. This should be followed by a repair of the affected areas.

2.11.8 Industrial hazards: Earthquakes damage machinery, structures and industrial units (Coburn and Spence, 1992). There are usually many industrial facilities in seismic areas. Some of these facilities are close to population centres and provide jobs for many. While the problems of industries using combustible materials and fuels are discussed in para 2.9.3, these industries also provide employment and industrial products and their failure can create an additional hazard for the local population. Leakage of dangerous fumes and gases due to breach in pipelines or storage tanks during earthquakes can be yet another hazard. The industries, particularly the hazardous industries using or producing dangerous materials, should be located at safe distances from population centres. Their pipelines and storage systems should also be built with safety considerations in the event of a disaster emergency.

2.12 General responses after an earthquake

Table 2.2 shows that earthquakes of moderate or even mild magnitude, in low-income or lower middle-income countries, have caused relatively more damage than severe earthquakes in the developed countries. The study of disasters is in fact the study of poverty since it is the poor countries where most of the disasters occur (Davis, 1978). Some recent studies on earthquake disasters suggest that frequency of disasters has significantly increased during the last fifty years with no major change in the geology or climate of earth. The reasons given for this increase are attributed to over population, rapid urbanisation due to lack of facilities and lack of job opportunities in rural areas, and make-shift shelters used by the poor with unsafe techniques and in dangerous locations, such as mountain slopes and river beds, etc. The people living in such circumstances cannot afford any better abode and resign their fate to the will of God. When an inevitable disaster hits these people their faith in nature and the environments, in which they always felt safe, is suddenly shaken. Their attitudes, however, change after the first shock of the disaster is over. The victims regain initiative to rebuild their shelters and start a normal life. Reconstruction is started by the community with an intention and determination to remove all signs of the tragedy and to restore the system as it was before the catastrophe (Geipel, 1991).

UNDRO (1991) is of the opinion that no disaster is entirely natural. Man unintentionally aggravates the effects of disaster by uncontrolled increase in population, urbanisation and other similar social problems commonly seen in low-income countries. The same agency observed in 1982, that human activity increases the risks of disasters by ignoring essential safety measures in the location and building of settlements. Still the primary response to disaster is provided by the affected community itself. Communities do not leave their future to chance. They try to participate in future planning, with increasing frequency, which provides guidelines for the disaster affected areas (Foster, 1980). The peoples of low-income countries are more self-reliant in the basic skills of rebuilding infrastructure than those in the middle or high income countries (Davis, 1978). This is more true in the rural areas where people are used to building their own houses. The financial and technical resources of these poor communities are however limited. Apart from some immediate but temporary measures, not much can be expected in terms of long term planning and infrastructural inputs.

Leslie (1986) refers to the 1982 earthquake of Yemen, in which the survivors showed a remarkable ability to provide shelters for themselves by using corrugated iron sheets, wood and other materials recovered from the rubble of their old houses, as a good example of community work. Government announcements to reconstruct or repair 42,000 houses to cover all earthquake victims discouraged many of them to start their own relief and rehabilitation works.

Home governments and local NGOs are the next to respond, after the affected communities, in assessing the problems and needs of the disaster area. The magnitude of the disaster, such as an earthquake, and post disaster rehabilitation and reconstruction work, is usually vast and requires diversion of all available resources to provide earliest relief to the victims. Appeals for external humanitarian assistance are made and substantial commitments are received. This assistance, from donor countries, however comes last mainly because of several formalities involved before its delivery, such as the assistance cannot be provided, no matter how urgent it is, without a formal request from the recipient country. Approval of the aid package and its mobilisation also takes time because of the distance and logistic problems in most of the developing countries. UNDRO (1982) is of the opinion, in light of the agency's long experience of relief and reconstruction work in disaster affected areas all over the world, that relief provided by foreign agencies never exceeds 20% of the total work even in the most favourable circumstances.

A good example of response is Guatemala where in 1976 an earthquake destroyed nearly 90% of the structures (Cuny, 1983). In this country some NGOs such as *Oxfam*, *World Neighbours* and *Save the Children* were already working on some development projects. When the disaster hit Guatemala, these NGOs immediately paid their attention to relief and reconstruction works. They assisted the government in mobilising resources at local and international level. The NGOs also participated in providing building materials and training in building techniques to the survivors. The community-based efforts of these NGOs saved the country from a possible economic crisis which seemed inevitable if the reconstruction work had not been carried out efficiently.

Davis (1986) quotes another case study of the 1970 earthquake in Gediz in western Turkey (7.3 on Richter scale), which destroyed most of the infrastructure. The victims and the government responded well to carry out reconstruction work speedily. Aysan (1986) however asserts that the government programmes concentrated more on technical solutions rather than socio-cultural and environmental conditions of the victims. Over the years, which followed since the earthquake in Gediz, people still continue to repair, rebuild or extend their homes according to their needs. It is very important in a development or reconstruction work that local socio-cultural and environmental needs must be respected.

development or reconstruction work that local socio-cultural and environmental needs must be respected.

2.13 Different approaches in development and reconstruction

Yemen was assisted by foreign donors after the earthquake but the ultimate results of the reconstruction programme were not very encouraging. It was observed during the field surveys of this study that although substantial technical and financial assistance was provided by foreign donors to the country, it was not utilised very effectively. The community did not have many resources and experience to cope with the rehabilitation and reconstruction work. The economic situation of the country itself was also better than what it is now. Lack of involvement of local communities in planning and most of the reconstruction programme was probably the main reason for the unsatisfactory results. Institutional deficiencies seem to be an important cause for the lack of impact of the reconstruction programme.

Different strategies were used in implementing reconstruction programmes by the concerned agencies. Some of the donors preferred to deliver turnkey projects. They built good looking structures through contractors with modern facilities. A lot of publicity was given to these projects. Field surveys revealed that the community did not have any say in such programmes. Even the location of houses was not discussed with the victims in most cases. A number of school buildings are short of staff or students. An appreciable number of primary health care units are without staff or supplies although there is an overwhelming demand for health facilities in the area. The local communities find the design and location of such infrastructure alien to their traditions and culture.

On the other hand those donors who helped in building the infrastructure through community involvement, generally implemented their projects with more success although it usually took more time than actually envisaged. The workmanship of these buildings was not as good as those built by the contractors but the people were using these houses with some modifications according their individual needs.

2.14 Need for efficient designs in earthquake zones

Earthquakes are among the oldest enemies of the mankind but the awareness to protect ourselves against them is a relatively recent development (Coburn and Spence, 1992). The reconstruction programme implemented by the government of Yemen, after the 1982 earthquake, has highlighted the view that if there is some preparedness against disasters among communities living in earthquake zones and their governments, and careful planning is made in the use of available human and financial resources, the relief efforts can be much more efficient and effective as compared to those where the relief and reconstruction programmes are undertaken haphazardly and without proper planning.

The Republic of Yemen lies in an earthquake zone and is experiencing earthquakes from times unknown (SCREAA[2], 1986). Earthquake-resistant building techniques are not new to the Yemenis. Leslie (1986) points out that in the earlier structures wooden ring beams were provided at different levels to ensure safety against earthquakes. As time passed, and wood became scarce and expensive, people started using it only for decoration purposes. There was more emphasis on ornamental beauty of the houses rather than their earthquake-resistance. The earthquake of 1982 brought to light all defects in the present day traditional structure. The disaster provided an opportunity to the local engineers and architects to introduce earthquake-resistant designs with full consideration of the socio-cultural and environmental needs of the people. It seems that while there was emphasis on earthquake-resistant designs there was not enough concern about community participation in the relief and reconstruction programme. The general lack of acceptability of the reconstruction programme in Yemen, and what should be done to introduce efficient and effective construction and reconstruction in earthquake zones in not only Yemen, but also of other poorer countries, forms the basis of this study.

SCREAA: Supreme Council for Reconstruction in Earthquake Affected Areas, Republic of Yemen.

The next chapter discusses the country profile of Yemen, to give an idea of the socio-economic and socio-cultural life in the country. This knowledge about the country and its people is considered necessary before discussing the post-earthquake reconstruction programme in detail which had an importance relevance to their everyday life.

Summary:

The earthquake hazard is serious not only because it is unpredictable, but also because it initiates a number of destructive secondary hazards. Another major concern is that many people, particularly those living in low-income and lower middle-income countries, believe that earthquakes are 'acts of God'. It is therefore important, that there should be a general awareness about the earthquake hazard, among the people living in earthquake zones. Literature review shows that the initiative and responses of the victims are important tools in rebuilding a disaster-affected area. Governments' and donors' assistance for the earthquake victims is useful but its mobilisation usually takes some time. The affected community's initiative can, therefore, be utilised by the governments and NGOs to provide timely and safe infrastructure in the disaster area.

Chapter Three

Chapter Three

THE REPUBLIC OF YEMEN - COUNTRY PROFILE

"Tradition was deeply rooted in their culture, and the products of this tradition were never alienated from their environment and cultural roots".

(Jakayo Ocitti, 1993)

3.1 Historical background

Yemen is an old and historical country rich with ancient civilisation. It has always played an important political, economic and strategic role in the region of the Arabian Peninsula. The geographical location of Yemen, on the south-west of the Arabian peninsula, means that it stood both on the periphery of the ancient centres of civilization in the Fertile Crescent and at the entrance to the Red Sea, where the sea routes met between Egypt, the Red Sea ports, East Africa and South Asia (Varanda, 1982). Throughout history Yemen has been influenced by and contributed to developments in the northern lands of the Middle East, but by virtue of its relative isolation has retained a distinctive individuality, particularly in the mountainous areas, known as the Central Highlands.

One of the five principal kingdoms of southern Arabia (Yemen) was the kingdom of Saba (called Sheba in Bible), with its capital in Marib. It was the oldest, the most civilised and the most powerful kingdom in the region (Daum, 1988). Other kingdoms were Ma'in on the slopes of Wadi Jawf, Qataban, Awsan and Hadramawt. In the first century these kingdoms began to decline and the centre of southern Arabian culture and power moved to the Highlands.

The Ottomans ruled Yemen for about a hundred years, during 16th and 17th centuries, until a Yemeni religious leader, Imam Al-Qasim, regained power in 1639. Although the Ottomans never controlled the whole of Yemen, they made an important contribution towards the development of a central government, the central administration system, a network of communications and a series of fortresses along the strategic points throughout the country.

The British occupied the southern part of Yemen in 1839 and declared it as a British Protectorate, with headquarters in Aden. The northern tribes also united themselves under Imam Yahya Hamid Al-Din, after withdrawal of the Ottomans at the end of World War One, and formed a government in the northern areas in 1918.

In 1962 a group of young army officers overthrew the Imamate. This led to a long civil war which continued until 1969. The Yemen Arab Republic was established in 1969-70.

The British left in 1967 and the Aden Protectorate emerged as an independent socialist state, to be known as the Peoples Democratic Republic of Yemen. By mid 1970, the conservatism of northern Yemen's society had prevailed in spite of all foreign influences (Page, 1985). Although the Yemen Arab Republic (YAR) still existed, its potential as a radical force in the peninsula had diminished due to renewed tribal warfare and poor economic situation in the country. Feuds continued between the two Yemeni states till a peace accord was signed, in May 1989, which resulted in unification of the country. The unified country, second largest on the peninsula after Saudi Arabia, is now called the Republic of Yemen, with its capital in Sana'a.

North Yemen remained inaccessible, until early seventies, due to the isolationist policies of its previous rulers, the Imams (Muller, 1991). Aden, on the other hand, flourished under British rule from 1839 to 1967.

Although one of the low-income countries, Yemen has undergone tremendous change and development in the past 20 years (Leslie, 1986). Old traditions and backwardness still inhibit progress but there is a deep desire, throughout the country, to catch up with rest of the world. Muller (1991) estimated that after peace and unification the number of foreign tourists visiting the country was about 40,000 annually.

3.2 Physiography and climate

Yemen is located among arid and semi-desert countries of the region (Al-Fusail et al, 1991). The landscape undergoes rapid changes as one moves from the 2,000 km long coastline of the Red Sea, and northward of the Gulf of Aden, to the great Arabian desert. The country can be divided into five natural regions on the basis of physiography (Figure 3.1). These regions are Tihama, the Midlands, the Highlands, the Eastern and Southern Plateaus and a portion of the Arabian Desert, called Al-Ruba'a Al-Khali (Varanda, 1982).

The maritime semi desert coastal plain, Tihama or 'hot land', has a tropical climate (Table 3.1). It extends 440 km along the Red Sea and is between 25 to 40 km wide. The land in Tihama is quite fertile when irrigated and produces palm dates and cotton (UNCDF[1], 1991).

The Midlands have altitudes up to 1,000 metres split by deep gorges with streams running down to Tihama and to the Gulf of Aden. It is a fertile zone with a subtropical climate.

The mountainous area from the north to the south constitute the Highlands, with altitudes ranging between 1,600 to 3,000 metres. The climate in this region is characterised by warm, temperate and rainy summers and cool and moderately dry winters with frequent fog. The highest mountain in the peninsula, called Nabi Shuaib, is also located in this region.

The Eastern Plateau is a semi desert area with mountains sloping towards the Arabian desert, Al-Ruba'a Al-Khali or 'Empty Quarter'.

As much as 600-1,200 mm rainfall annually has been recorded in the high altitudes of the interior such as Ibb and Ta'izz but the plateau area receives only about 400-500 mm per annum (Al-Fusail et al, 1991). Most of this rainfall occurs in the Midland and Highland regions during the two rainy seasons from March to May and from July to September. The rainfall pattern in Yemen is quite irregular and droughts are not uncommon. Scarcity of rain affects the water resources. Since agriculture is a major component of Yemen's economy, and most of the agriculture is rain fed, the dry years

[1] UNCDF: United Nations Capital Development Fund.

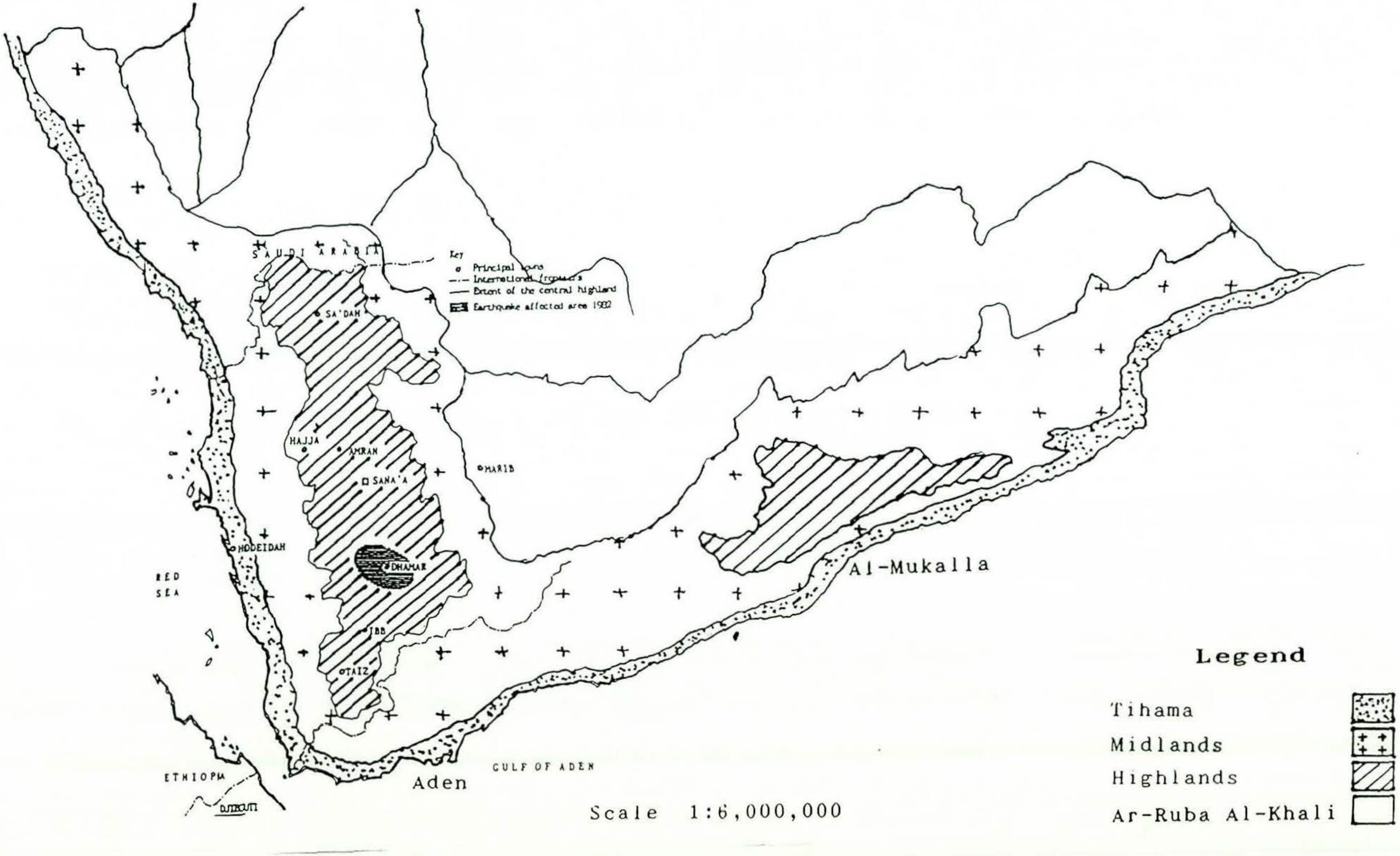


Figure 3.1: The physiographic regions of Yemen Republic
Source: Ministry of Survey, Sana'a, 1992

cause food shortages and further poverty, particularly in the rural areas whose livelihood mostly depends on agriculture.

Table 3.1: Physiographic zones and climate of Yemen

Physiographic zones	Approximate altitude (m)	Climate	Average annual rainfall (mm)
Coastal area 'Tihama'	0-200	Hot, tropical	100-200
Midlands	200-1000	Semi-tropical	400-800
Highlands	1600-2400	Dry, moderate to cold	600-1200
Eastern/Southern Plateaus	1000-1600	Dry, warm to moderate	300-500
Eastern Desert Al-Ruba'a Al-Khali	200-400	Dry, hot to cold	0-100

Source: UNCDF Project Agreement YEM/90/CO1,1991

The five distinctly different types of physiographies, in the country, influence not only the climate but also the culture and custom in these areas.

3.3 Geology

The foundation for the geology of Yemen is the Arabia-Nubian shield which is composed of meta-volcanic and plutonic rocks (MEB[2], 1991). Geologists believe that this shield was formed by a process of microplate or terrain build-up, during the Proterozoic era, about 660 to 900 million years ago. The various terrains lie side by side along linear zones representing edges of the microplates. The youngest and most prominent zone is called the Nabitah Structure which was probably formed by the collision of two crustal plates during the late Proterozoic era. The resultant mountain building ceased around 640 million years followed by wrench faulting which produced the Najd fault system. Between 640 and 540 million years, the whole Arabian-Nubian Shield underwent extensive magmatism resulting in acidic volcanism, caldera formation and the emplacement of numerous granitic complexes. The geologic map of Yemen shows overall geography and stratigraphic relationships of the area (Figure 3.2). The

[2] Mineral Exploration Board, Ministry of Oil and Mineral Resources, Yemen.

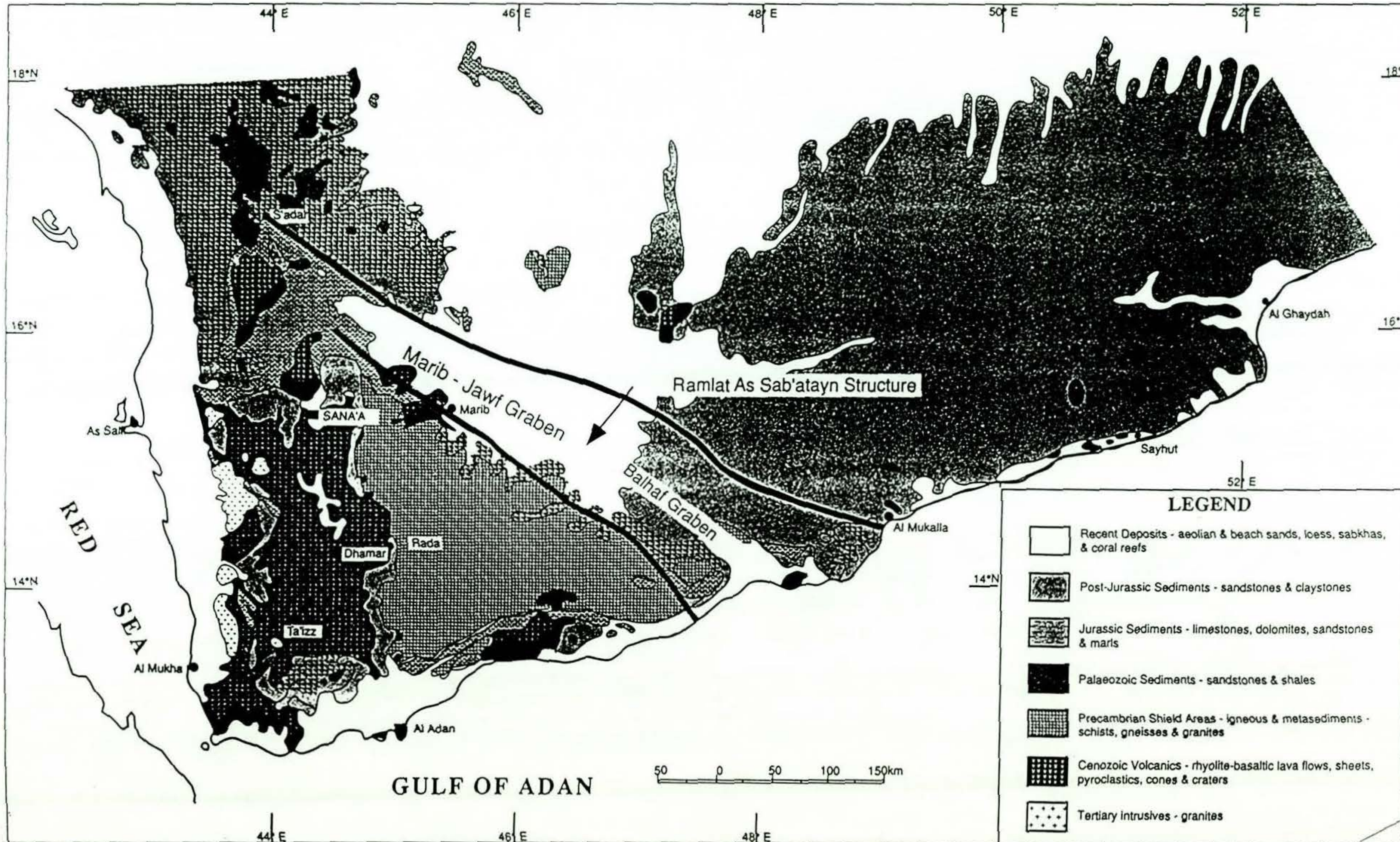


Figure 3.2: Simplified geological map of Yemen
Source: Ministry of Oil and Mineral Resources, 1992

oldest sedimentary rocks are the Cambro-Ordovician sandstone known as Wajid Sandstone which exists only in north-western Yemen.

Large parts of Yemen are overlain by extrusive stratified rocks of Tertiary and Quaternary age which are collectively referred to as the 'Yemen volcanics' or the 'Trap series'. These rocks range in composition from basalt to rhyolite and often contain inter-bedded fresh water sediments. Volcanic activity in the region is believed to be on going from prehistoric times. This volcanism is considered to be related to uplift of the African-Arabian dome and subsequent rifting and separation of the Arabian, Nubian and Somali plates. It has formed most of the highland areas in the country. Continuing occurrence of severe earthquakes, hot springs and sulphurous waters in the area show that the region is not fully dormant. Recent sedimentary deposits include aeolian, beach sands, coral reef along the Red Sea coast, loess, sebkhas and alluvials.

Geologists consider Yemen as structurally simple. The range of geologic formations in Yemen suggests high potential for mineral exploration. Already many industries are commercially exploiting gypsum, salt and limestone deposits which play an important role in the country's economy.

3.4 Natural resources

Yemen is gifted with a variety of natural resources, such as minerals and fisheries but there is an overall shortage of water resources in the country. The following is the present situation with regards to various natural resources:

3.4.1 Land: Yemen has a total estimated land area of 555,000 sq km excluding the Al-Ruba'a Al-Khali desert (MPD[3], 1992). Nearly 70% of this area is covered by the mountainous highlands. Most of the land is used for agricultural purposes but fast rising population, economic difficulties of the recent years and shortage of water resources has adversely affected the use of land. Mineral resources, particularly oil, have some potential but to date no significant change has occurred to bring prosperity to the country.

[3] Ministry of Planning and Development, Yemen.

3.4.2 Oil: Major oil deposits, with an estimated output of 300,000 barrels per day, were found by an American oil exploration firm, in 1984 (Unwin, 1986). Most of the oil and gas have been discovered along the desert 'Al-Ruba'a Al-Khali'. A number of foreign firms are presently engaged in oil exploration in the country. While there are good prospects for further increase in oil production, to date there is no significant upsurge in the national economy because of several factors to be discussed later. It can be argued that if oil had not been discovered, in exportable quantities, the county would have been facing even worse economic difficulties.

3.4.3 Other minerals: Apart from oil, there are several other minerals deposits in the country, as described below:

. *Rock salt*: The rock salt quarry at As-Salif, on the coast to north of Hodeidah, is one of the major mineral projects in Yemen. At this quarry 140,000 tonnes of salt is produced annually of which 120,000 tonnes is exported (MEB, 1992). Salt from evaporation of sea water was also widely produced in the past, but now there is only one major factory left at Khormaskar. This factory, located near Aden, produces about 150,000 tonnes of salt per annum.

. *Gypsum*: Gypsum is extracted, from a quarry near the Al-Salif salt quarry, at the annual rate of 70,000 tonnes of which almost a quarter is used in cement manufacture while the remaining is exported.

. *Industrial clays*: Industrial clays, such as bentonite, are extracted in the eastern part of the country. Other minerals available in the country include silica, limestone, feldspar, barite, celestite, phosphate, graphite and volcanic sinter.

3.4.4 Fisheries: Yemen is gifted with long coastal areas along Red Sea and the Gulf of Aden. There is a big potential for development of the fisheries industry. The average annual catch of marine fish, including prawns, lobsters and shrimps, is estimated at over 80,000 tones per annum which contributes about 1,700 million riyals to the national GDP. Efforts are under way to improve this prospective industry (MPD, 1991).

3.4.5 Water resources: Although some of the Middle Eastern countries, particularly in the north such as Syria, Lebanon and Jordan are blessed with sufficient surface water in the form of perennial rivers on which dams and water reservoirs have been built, Yemen lacks this feature because of its location in the arid and semi desert zone. This leaves the country totally dependent on rainfall and ground water.

Different studies carried out in Yemen reveal that there exists a water crisis of national consequence (YEM/88/001[4], 1992). There is insufficient water to meet the continuously rising demand. About twenty years ago there was no such problem when rain and spring water was mostly used for irrigation which consumes about 90% of the total water (Durrant, 1991). With the introduction of boreholes in Yemen the use of ground water is increasing at a fast rate (Table 3.2).

Table 3.2: Past and present use of springs vs boreholes

Year	Springs	Boreholes	Total
1975	73,000 ha	45,000 ha	118,000 ha
1988	25,000 ha	105,000 ha	130,000 ha
1991	NA	NA	142,000 ha

Source: Durrant, 1991

It should be noted from the above table that the area of spring fed irrigation has considerably decreased in the past few years.

The ground water situation of the basins, especially those nearer to the main cities, suggests that the rate of ground water utilisation exceeds annual recharge (2,600 mcm[5] abstraction against 1,300 mcm recharge), a phenomenon which is commonly known as water mining. The government has been pursuing a growth oriented strategy which requires larger quantities of water to support the overall development process. Although

[4] A United Nations Development Programme (UNDP) and UNCDF funded project agreement for Republic of Yemen.

[5] MCM: Million Cubic Metres.

excessive ground water mining has been the main source of economic growth during the last two decades, it has also caused a dropping of the water table(s) at an alarming rate. It is becoming uneconomical to grow food locally due to high water pumping costs. This implies that the country will have to continue importing food in the years to come (Taqieddin, 1991). Lack of legislation and regulation on ground water extraction, and the use of traditional methods of irrigation, is causing enormous waste of water through seepage and evaporation. The government is considering measures to reduce the renewable imbalance by the protection of water resources, particularly ground water.

In order to achieve a balance, between abstraction and recharge, a annual reduction of 1,300 mcm would be indicated for irrigation use. Durrant (1991) points out that if by the year 2010 municipal and industrial use of water grows to the estimated annual 650 mcm a balance of 650 mcm would be left for irrigation purpose viz only 30% of the total extraction. Table 3.3 shows water present (1990) and future (2010) demands of water in the country.

Table 3.3: Present and future water demands in Yemen (Quantities is million cubic metres)

Province	Present demand (1990)				Future demand (2010)			
	Urban	Rural	Other	Total	Urban	Rural	Other	Total
Abyan	1.66	2.72	0.16	4.54	2.77	4.54	0.27	7.58
Aden	8.48	0.37	0.14	8.99	14.17	0.62	0.23	15.02
Al-Beidah	1.50	2.90	0.20	4.60	5.20	9.10	0.70	15.00
Al-Jawf	0.10	0.70	0.00	0.80	0.20	1.60	0.10	1.90
Al-Mahwit	0.30	2.60	0.10	3.00	1.30	6.20	0.40	7.90
Dhamar	2.60	6.00	0.40	9.00	11.80	12.70	1.20	25.70
Hadramawt	6.12	2.87	0.44	9.43	10.23	4.80	0.73	15.76
Hajjah	0.80	8.00	0.40	9.20	4.40	29.90	1.70	36.00
Hodeidah	7.10	9.10	0.80	17.00	28.40	24.50	2.60	55.00
Ibb	6.70	10.80	0.90	18.40	27.00	24.40	2.60	54.00
Lahej	0.88	2.69	0.07	3.64	1.46	4.50	0.12	6.08
Mahran	0.73	0.23	0.13	1.10	1.22	0.39	0.22	1.84
Marib	0.20	1.00	0.10	1.30	0.50	2.10	0.10	2.70
Sa'adah	0.90	2.50	0.20	3.60	4.10	4.20	0.40	8.70
Sana'a	18.10	11.10	1.50	30.70	127.40	19.50	7.30	154.20
Shabwah	0.96	1.33	0.12	2.40	1.60	2.22	0.20	4.02
Ta'izz	9.70	10.90	1.00	21.60	39.40	22.40	3.10	64.90
Total:	66.82	75.82	6.76	149.40	281.15	173.67	22.07	476.89

Source: Al-Fusail et al, 1991.

In view of not very encouraging prospects for ground water, government efforts are under way to increase efficiency of the surface water sources.

Some consolation could however be derived from the discovery that while the tectonic activity in Yemen, especially in the agricultural areas of the highlands and midlands, has caused natural hazards, such as earthquakes and landslides, it has fractured and faulted the southern escarpment and created dikes in some areas, thus forming a good media for surface water infiltration to enrich the ground water source (Al-Fusail et al, 1989). Additionally, the sedimentary formations provide good aquifers. Natural and mineralised springs prevail along this region and agriculture is highly dependent on such water sources in the mountain regions. Such areas are however few and with erratic rains and persisting drought years, the concern for ground water resources remains a national priority.

3.5 Population

The Ministry of Planning and Development (1991)'s estimates show that Yemen is the highest populated Arab country with a present estimated population of over 13 million, spread over a total area of 555,000 square kilometres which gives a population density of 22 per square kilometre (Table 3.4). About 80% of this population lives in rural areas. Annual population growth rate is estimated to be 3.1 percent while the average household size is 6.7. Life expectancy is 46.3 years. The percentage of male and female population is almost equal. At this growth rate the population will double in the next 20 years (MPD, 1991). Capital Sana'a, Aden, Ta'izz and Hodeidah are the main town centres where most of the 20 percent urban population lives.

High population growth, coupled with inadequate social and physical infrastructure, has its adverse effects on family health, particularly mother and child; general quality of life, such as social services, health and education (YEM/90/001[6], 1992).

[6] A UNCDF funded project for infrastructure development in Dhamar, Republic of Yemen.

A large number of Somali, Ethiopian and Sudani refugees, some of whom have acquired immigrant status, also live in these towns. The total number of refugees in Yemen is estimated at about 100,000 (UNHCR[7], 1993). About 850,000 to one million Yemenis, representing over 10 percent of the country's work force, previously working in Saudi Arabia and Gulf States, returned after the Gulf War and most of them settled in various urban centres such as Sana'a, Ta'izz, Hodeidah and Aden (UNCDF, 1992).

Table 3.4: Estimated population in Yemen (1989-1993)

Year	Estimated population in Republic of Yemen			Total
	Urban	Rural	Refugees*	
1989	2,329,800	9,919,200	NA	11,649,000
1990	2,437,200	9,748,800	5,000	12,191,000
1991	2,512,800	10,051,200	8,032	12,572,032
1992	2,590,700	10,362,800	52,146	13,005,646
1993	2,671,000	10,684,000	59,476	13,414,476

* Almost 95% of the refugees, since 1992, are of Somali origin. Others include Ethiopians, Eriterians, Sudanese, Iraqis, Syrians and Russians.

Sources: Ministry of Planning and Development, 1991.
UN High Commissioner for Refugees, 1993.

The influx of refugees and returning Yemenis has significantly increased the population in cities in recent years causing further pressure on the already overburdened urban infrastructure and creating serious problems for the government (Sulieman, 1991). Lack of adequate housing and job opportunities are beginning to show their effects through increased crime rates and intolerance. Unstable political and economic situation in the neighbouring countries may lead to an increased influx of migrant Yemenis and non-Yemenis, potentially exacerbating these detrimental social effects.

The Government of Yemen is seriously viewing the population growth and related problems for which a national strategy is in the making under the guidelines provided by the Bucharest (1974) and Amman (1988) Conferences on Population Planning (MPD, 1991).

[7] United Nations High Commissioner for Refugees.

3.6 Economy

Yemen is the poorest country among its oil rich neighbours. The country has traditionally been able to support itself because of relatively high rainfall and fertile soil allowing subsistence agriculture in suitable areas. The departure of nearly one million of this labour force, to work in Saudi Arabia and other Gulf States in the early eighties, adversely affected agriculture production. The country's efforts to develop its industry are also not very successful. Average per capita income, according to the World Bank estimates is about US$ 390 per annum (The World Bank, 1994). This figure is not truly representative because a major part of the country's wealth is in the hands of a small high-income minority. The percentage of low-income population is estimated at over 90%. Muller (1991) estimates the average per capita income in Yemen at US$ 650 while the Central Statistical Organisation of the Ministry of Planning and Development (CSO/MPD) in Yemen claims per capita GNP to be YR 7,807 (MPD, 1991). Per capita income in Yemen, calculated by most individuals and agencies on the basis of official currency exchange rate of 12 riyals to a US dollar, is misleading because the market exchange rate is now about 150 Yemeni Riyals to a US Dollar. The real exchange rate, which dictates the prices of consumer goods, places Yemen in the lower bracket of the low-income countries.

The country was receiving an assistance of about US$ 600 million per annum from donors such as, Saudi Arabia, Kuwait, United Arab Emirates, USAID, ODA, Dutch Aid, the United Nations and others, for its development and construction programmes. After the Gulf War, much of the foreign aid was curtailed. The economic situation in Yemen is presently going through a transitional phase and this period can be termed as difficult because of the following main reasons (UNCDF, 1992):

a) unification of two separate countries ie Yemen Arab Republic (YAR) and Peoples Democratic Republic of Yemen (PDRY) with different political ideologies and socio-economic systems to form one integrated system,

b) the Gulf War which resulted in mass exodus of nearly one million Yemenis, from Saudi Arabia and the Gulf states, whose return has not only deprived the country of over 1,300 million dollars revenue in home remittance but also created the problem of providing employment to these returnees;

c) continuous influx of refugees from the Horn of Africa and some Arab countries. The number of these refugees is estimated at 100,000 including the illegal refugees;

d) cancellation or curtailment of economic cooperation by most of the donor countries; and

e) the prevailing and prolonged world recession.

MW&E/UNDTCD (1991) summarise the economic performance of Yemen as follows:

a) GDP increased from YR 22 billion in 1983 to YR 55 billion in 1988;

b) agriculture remains the most important sector of economy by contributing 25%;

c) merchandise exports increased to 4.6 billion in 1988 mainly due to export of crude oil which constitutes 84% of the total exports;

d) merchandise increased twofold between 1983 and 1988 with food items accounting for 30%;

e) private consumption accounts for nearly 86% of the total GDP;

f) private investment is increasing gradually at an average rate of 15%;

g) national savings have been continuously declining and from 1988 they are negative;

h) total government accounts registered a deficit of YR 2 billion in 1989;

i) the rate of unemployment is estimated to be over 30% which is further aggravated by Yemeni nationals returning after the Gulf War and the refugees from neighbouring countries; and

j) the rate of inflation is soaring and the general cost of living index was over 20% during 1991.

Like most low-income countries, Yemen also has a substantial imbalance of trade, amounting to US$ 1,520 million. The total estimated imports in 1991 stood at US$ 2,026 million as compared to the total exports amounting about US$ 506 million (MPD, 1992). This ever increasing trade deficit is placing further pressure on an economy already over burdened by factors mentioned above. The amount of national debt is estimated at over US$ 5,000 million.

An important prospect is the country's potential oil resources which to-date has not brought any significant upsurge in the national economy mainly because of the several negative factors outlined above.

Economic development plays a vital role in the development of other fields, including education which in turn helps improve awareness at the government and community levels. High trade deficits and low industrial development are among the main causes for low socio-economic development in the country.

3.7 Agriculture

Yemen is predominantly an agrarian country. Most agriculture is based on subsistence farming using traditional methods. The country is gifted with some of the most fertile land in the Arabian peninsula, both in the highlands and the dry coastal plain of Tihama (SCREAA, 1986). The total cultivated area is estimated to be over 1.5 million hectares out of which only 15% is irrigated by perennial water supply. Agricultural growth in recent years has not been encouraging mainly due to the use of primitive methods and lack of pest control. The agriculture sector presently employs some 70% of the labour force and contributes about 36% to the GDP (MPD, 1991).

Unwin (1986) estimates that before migration of a large Yemeni labour force to the oil rich Arab countries, in early 1980's, as much as 85% of the country's work force was engaged in agricultural activity. Their mass exodus badly affected local agriculture but this problem was ignored in view of the large sums of foreign earnings remitted by the migrant Yemenis. The local economy sustained itself reasonably well, because of the country's excellent relation with its neighbours, until the Gulf War of 1990. Loss of home remittance and return of migrant Yemenis, coupled with an influx of refugees, created serious problems for the country. The prolonged drought from 1990 to 1992, which had a serious impact on agricultural production, added more to the above problems resulting in increased food imports which caused a further setback to the national economy. The country is in need of some continuous good rainy seasons to harvest good crops to boost the economy.

Yemen is said to be the pioneer in coffee growing which is planted on the mountain slopes near Tihama. Export of coffee has been the biggest foreign exchange earner in the past. World wide recession in the demand for coffee encouraged the Yemenis to replace coffee growing with qat, a narcotic, which is a cash crop and far more profitable. Annual production of qat is estimated at over US$ 1,200 million. Detailed discussion on qat is given in Section 3.14.

Yemen is known for producing a large variety of crops, predominantly cereals, from the advent of Islam in the region (Schmidt, 1988). Important cereals of Yemen are sorghum, millet, wheat, barley and maize. In 1981 the grain production was over 800,000 tons and the country used to export grain to the neighbouring countries. The production however started to decline after departure of a large number of agricultural labour force, to the neighbouring countries, for better employment opportunities. The situation was worsened by continued droughts and other natural calamities.

A number of fruits eg citrus fruits, apricots, peaches, grapes, pomegranates, mangoes and almost all types of vegetables are produced in the Highlands. The hot Tihama plains are known for producing dates, cotton and tobacco. FAO[8] estimates for 1992 showed that cotton production was falling in recent years due to low prices maintained by the government.

Yemen has received assistance in agriculture from a number of foreign countries including Japan, the Netherlands, China and the oil rich Arab states but the overall poor economic activity in the country and the overwhelming influence of qat does not provide any incentive for the local farmer to increase production of his other crops. Table 3.5 and 3.6 show the trends of agriculture production and gradual increase in imports during the last few years. There is continuous decrease in the production of most of the salient crops while the population is increasing at an alarming rate of 3.1%. As a consequence the import bill is also rapidly increasing adding to the economic difficulties of the country.

[8] United Nations Food and Agriculture Organisation.

Table 3.5: Agricultural produce in Yemen (1987-91)

Crop	Yearly figures in thousands of tonnes				
	1987	1988	1989	1990	1991
Wheat	112,527	142,452	162,571	153,346	99,913
Maize	53,876	57,500	68,471	65,639	45,936
Sorgum/Millet	508,780	594,109	574,409	491,294	272,886
Barley	40,568	48,617	58,599	55,003	28,912
Pulses	39,497	46,233	72,459	75,847	42,979
Tomatoes	147,077	145,168	163,034	167,732	171,511
Onions	4,612	45,522	77,473	70,270	58,777
Potatoes	119,253	127,566	140,151	159,849	157,125
Other Vegetables	78,418	79,714	87,111	80,426	93,696
Cotton	6,622	7,810	13,036	7,839	7,291
Tobacco	5,312	6,449	4,394	6,779	6,975
Coffee	5,111	6,473	6,807	7,411	5,430
Palm Dates	30,702	32,927	24,898	20,697	20,906

Source: Ministry of Planning and Development, 1991.

3.8 Trade and industry

The future of Yemen's industry is largely dependent on the outcome of oil exploration which the government is actively pursuing in collaboration with some foreign firms. According to some estimates, the local industry accounted for about 16% of GDP and it employed about 5% of the country's labour force during the mid-eighties (Unwin, 1986). Most of the industry is based on traditional skills, such as textiles, leather work, jewellery, glass making, food processing, utensils making and manufacturing of building materials. Industrialisation in Yemen did not make any substantial impact even when the country was receiving large foreign remittance, from immigrant Yemenis, before the Gulf War. Now the situation is even worse.

Two cement factories, which fall short of meeting the domestic demand, are among the successful projects in the country. The combined capacity of the these factories is over 1 million tonnes per year.

High quality salt deposits in Yemen are estimated at a minimum of 25 million tonnes. Many local agencies and foreign firms are involved in this major mining industry in the country much of which is exported to Russia, Bangladesh and North Korea. Other minerals known to be existing in the country are coal, iron, sulphur, silver, gold and uranium.

Major oil deposits, with an estimated return of 300,000 barrels per day, were found in 1984. Since then many foreign firms have engaged in oil exploration in the country.

The industrial development in Yemen is in its preliminary stages. Most of the domestic demands are fulfilled through imports consisting of vehicles, machinery, electrical appliances, spare parts, food items, electrical goods, furniture, textile, toys, footwear, building materials such as cement, reinforcement steel, water pipes, sanitary fittings, timber and electrical goods, etc, etc. The small local industry is mainly involved in canning and packaging food and some domestic use items. Table 3.6 shows the ever rising deficit between imports and exports in the country. The increasing trade imbalance does not seem to be a matter of serious concern to the government.

Table 3.6: Balance of trade in Yemen (thousands of Riyals)

Year	Imports	Exports	Trade balance
1988	19,840,962	5,394,425	-14,446,537
1989	19,332,894	7,451,441	-11,881,453
1990	18,867,090	8,315,504	-10,551,586
1991	24,314,326	6,075,948	-18,238,378

Source: Ministry of Planing and Development, 1991.

3.9 Education

The World Bank (1994) estimates place adult female literacy rate in Yemen at 26% while the figure for male literacy is estimated to be 38%. Ministry of Planning (1992)'s figures assumes female literacy rate to be about 22% and the male literacy rate as 62% with a national average of 45% (MPD, 1992). These figures however seem to be inflated because of inclusion of those who can read only the Qur'an as a religious obligation. Adult literacy rate in Yemen, particularly among women, is one of the lowest in the world. Unwin (1986) believes that adult literacy in Yemen was only 13.7% by 1985 (males 26.1% and females 3.1%).

Less than 60% of the school age children are enrolled in primary schools. The number of students seeking high school or university education is far less. The percentage of population knowing any other language, besides native Arabic, is reported to be about 15%.

Literacy rate in rural areas, representing over 80% of the national population, is far less than the national average. Knowledge of Arabic is therefore very important for any foreigner working in Yemen, particularly in the rural areas. Lack of education is also one of the major causes for low awareness of various socio-economic problems at the government level as well as at the community level.

3.10 Religion

Yemen has almost 100% Muslim population, with the exception of a small Jewish community, comprising about 5,000 members, which can be seen in northern areas (Klein-Franke, 1988). Islam is the state religion and judiciary and constitution are based on Islamic law (Muller, 1991). Islam came to the region in its early days in the sixth century.

Christianity ceased to exist in Yemen even before the tenth century but there was a sizable population of Jews, who were known for their craftsmanship and settled in various parts of the country. The Jews started facing problems in selling their products after the opening of the Suez Canal by the British in 1849 and declaring Aden as a free port. The consequence was that demand for locally produced handicraft fell sharply in front of the better quality imported goods from Europe. The Jewish community, comprising some 100,000 members, faced many economic problems and most of them left Yemen in 1949 to settle in the newly created State of Israel (Varanda, 1982).

There are two major Islamic sects in Yemen. The people living in the northern part of the country follow Zaidi'ism, one of the oldest form of Shia'ism in Islam. There are no clear geographic boundaries between the two sects but those living south of Dhamar are mostly Sunni Muslims while the Zaidis are found north of Dhamar, including the capital Sana'a. There is a small population of about 2% Ismailis who are mostly settled in the Harraz mountains, east of Manakha.

There is sectarian tolerance and liberalism among the Sunnis and the Zaidis and both worship in the same mosques. The Zaidis, known as fierce fighters, have preserved their culture and traditions well by challenging and fighting against all foreign powers intending to occupy the country. Tribal structure in the Sunnis is less strong. They are relatively more educated and are mostly involved in business.

The strong religious influence in the day to day life, compounded by high illiteracy rate and the tribal system, is linked to awareness at all levels and affects development or reconstruction work in the country.

3.11 Culture and traditions

The Yemeni culture is conservative and all Yemenis are proud of their country and traditions. Yemeni society, like other Arab countries, is male dominated (Myntti, 1979). Males enjoy ultimate power and are fully responsible for the needs of the family. The near total dependence of the women on men, forms the basis of family laws including marriage, divorce and inheritance.

From the time of introduction of Islam, men of religious positions were held in high esteem (Varanda, 1982). Formal religious rule started from 1919 when Imam Yahya Hamid Al-Din established the Imamate regime. Military rule has been in existence since the sixties and has considerably reduced the status differences cultivated under the old regime. The long religious rule and agrarian based tribal culture has influenced the local architecture and other infrastructure designs including houses, water supply and sanitation schemes and clinics in the country (UNICEF[9], 1985).

[9] UNICEF: United Nations Children Fund.

Early marriages are customary. Most of the couples get married between the ages of 15 to 20 years which has many negative effects on health, population growth, employment and education, etc.

3.12 Woman's status in society

A Yemeni woman is a very industrious person and plays important roles in production and reproduction (Myntti, 1979). Her responsibilities in rural areas include, besides child bearing and the normal household duties, fetching water for the family, working in the family agricultural farm, looking after livestock, arranging fuel wood, etc. Women's tasks dominate in producing subsistence crops. Irrigating the farms is however man's responsibility.

The Yemeni society is divided between sexes. Males have the ultimate power and men have the responsibility to bear all expenses for the women and children. The Islamic practices and Yemeni traditions require all Yemeni women to be veiled and no one except the immediate family should see her face (Muller, 1991). Mixing, or sometimes even talking to a stranger, is considered sinful. When a woman works outside the boundaries of her home she covers herself well so that no stranger may have even a glimpse of her body. Woman's status is derived from Qur'an which demands veiling and seclusion from male strangers. The new Yemeni constitution is more liberal with regards to women in comparison of other Arab countries of the peninsula (Myntti, 1979). In Tihama region, and particularly in Aden, women move and work more freely without veiling themselves and sometimes even without covering their heads.

Education, even at primary level, is not considered important for girls in which time they help the family in domestic duties. Very few girls are allowed to continue education beyond primary level. At that age of thirteen or fourteen years, they are considered suitable for marriage. As receiving large sums of cash from the bridegroom is customary in Yemen, many parents wait for their daughters to grow up so that the family could improve the house, or install a water supply system or build a *prestigious* pour-flush latrine in the house, or establish an irrigation pump for the farm.

All projects in which involvement of local women is considered necessary, such as health education, sanitation and primary education for girls, face difficulties in implementation in Yemen. There is relatively more freedom for women in the southern parts of Yemen because of the earlier British, and later socialist influences.

3.13 Local skills

The Jews of Yemen have remained an integral part of the history of the country (Klein-Franke, 1988). Yemeni Jews took keen interest in the intellectual life and economic development of Yemen. They were famous for their craftsmanship and trading skills as silver smiths, smiths, tin cutters, tailors, weavers, potters and as makers of leather goods and gunpowder, etc. Their sudden and mass exodus to Israel, in 1949, created a vacuum in the country as far as local skills were concerned. After the departure of most of the Jews, the Muslims have tried to fill up the gap partly by learning some of the skills themselves and partly by employing expatriate labour.

Yemeni architecture is centuries old and renowned all over the world. When Islamic buildings began to be erected, from the start of the Islamic era, Yemen provided the basic and essential ingredients which the experts believe gave birth to the Islamic art (Lewcock, 1988).

Yemenis are considered to be the first to have introduced multi-storied buildings to the world. These historical structures can still be seen all over the country while some of the oldest are located in the capital Sana'a and in the south-eastern town of Shibam (Figure 3.3).

Yemenis are skilful agriculturists and even before the departure of Jews to Israel, agricultural farming remained with the Muslims. Their generations old agricultural terraces, in the Midlands and the Highlands, are well known for growing qat, vegetables, fruits and other crops. Although ground water is the main source of water supply to agricultural farms, hand-dug and usually stone-lined water ponds called 'majil', which retain surface water for three or four months after the rain, are also used to irrigate farms in the dry season.

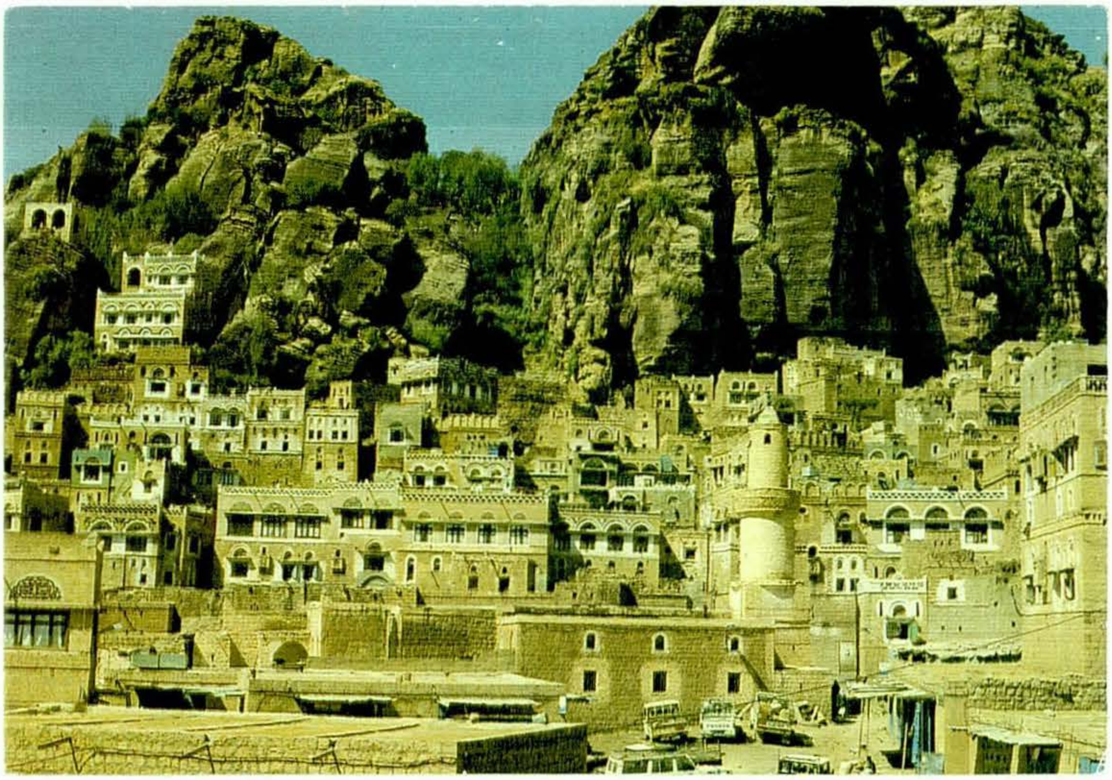


Figure 3.3: The centuries old Yemeni architecture
Source: Ministry of Tourism, 1994

Yemenis' skill in architecture, stone masonry work, and community work exhibited while making agricultural terraces and building mosques, provides a good basis for improvement of safety of their buildings by encouraging them to use simple earthquake-resistance techniques.

3.14 Influence of qat

Chewing or nibbling the green leaves of *qat* is an essential part of Yemeni culture (Muller, 1991). Everyday, after lunch, male relatives and friends gather at each other's place to join the chewing session. Everyone brings his own *qat*. Water pipe (hubble-bubble) and soft drinks and/or bottled water is normally provided by the host but in informal gatherings cigarettes and drinks are also supplied individually. Guests are also welcome to these sessions and if they appear without their bag of *qat*, the host and other visitors willingly share their supply with him. The chewing session usually continues until Maghrib (sunset) prayers.

Women also chew *qat* but to a much lesser degree. It is estimated that almost 90% of Yemeni male adults chew *qat* in *qat* growing regions. Although *qat* chewing is a daily feature, weekends, family ceremonies and national festivals are special occasions when the consumption increases even further.

The *qat* plant 'Catha Edulis' is grown in many countries besides Yemen, such as Ethiopia, Kenya, Somalia, Madagascar and Tanzania. Some forty kinds of *qat* is found in Yemen which is mainly cultivated in the mountain terraces and valleys of the Highlands. *Qat* has many psychological and physical effects on its consumers, such as anxiety, intestinal disorder and psychic behaviour (WHO[10], 1983).

Qat is expensive and an average person spends about 100 Riyals (about 2 US Dollars) daily in buying *qat*. It is a cash crop and the Yemeni farmer gives it preference over all other crops. He irrigates his *qat* farms with expensive water supplied through tankers, if cheaper means are not available. The expansion of *qat* fields in Yemen,

[10] WHO: World Health Organisation, One of the UN agencies.

across the agricultural lands, along mountain slopes and river beds, is slowly replacing other crops. The southern part of the country which did not have much *qat* farming is also catching up fast after unification (Al-Fusail et al, 1991). *Qat* grows all year round but prices fluctuate from season to season. Off season prices are relatively higher when water is scarce.

Access to ground water through bore holes is another incentive for *qat* growers and random drilling will further endanger the already depleted ground water resources of the country.

Qat is said to be a stimulant and almost all Yemenis, and an appreciable number of expatriates living in Yemen for some time, are addicted to it. Yemenis believe that qat is good for mental and physical health and that it improves virility. Medical research conducted out by experts however does not support this belief (WHO, 1983). On the contrary, since *qat* is not washed before consumption, it creates other health hazards as briefly mentioned above.

Qat has significantly affected Yemeni culture and character. Monthly wages of a low-income or lower-middle income Yemeni individual, is in the range of YR 3,000 to YR 6,000. On the average, he spends about 30% to 50% of this amount on buying *qat*. The remaining balance is insufficient for his other personal and family needs such as food, clothing, children's education and health-care. The persisting and ever increasing gap between income and expenditure contributes towards lack of education, lethargy, corruption, receiving bribe money and avoiding hard work, on an individual level. The problems generated by qat at an individual level also has its consequences at the country level.

There are also some positive effects of *qat*, such as providing employment to an appreciable number of the labour force which otherwise would have faced serious problems after the Gulf War. Resource mobilisation and income generation can also be attributed to the cultivation of *qat*. On the national level, however, *qat* is creating a more negative than positive effect on the economy and development of this one of the poorest and least developed countries is seriously hampered by the influence of *qat*.

3.15 Dependence on foreign skills

In spite of being a low-income country, Yemen's dependence on foreign skills is extensive. Expatriate professionals, such as medical doctors, engineers and teachers are mostly recruited from the neighbouring Arab and African countries. These countries include Syria, Jordan, Egypt, Ethiopia, Iraq and Sudan. The skilled and unskilled workers, such as mechanics, technicians and domestic servants come from Somalia, India and the Philippines. Low literacy rate and conservatism are some of the causes for high expatriate employment. The negative impact of this practice on the national economy is a constant drain on the foreign exchange resources of the country, inflation of Yemeni Riyal and large scale unemployment among Yemenis.

3.16 Rural economy

Eighty percent of the Yemeni population lives in rural areas, whose main source of earnings is rain-fed agriculture (MPD, 1991). This can be disappointing in drought years.

Rural infrastructure to support the rural economy is inadequate. The only way to reach the majority of villages is by a four wheel drive vehicle. Some villages are not accessible in the rainy season even by a four wheel drive vehicle.

The village head, called 'Sheikh' or 'Aaqil', is usually a wealthy person with large agricultural farms, private bore holes and more than one prestigious vehicle. He is also a member of the Local Council for Cooperation and Development (LCCD), a village based government agency, responsible for rural development. The influence of the local sheikhs and LCCD can be useful in rural development works but presently their roles are not much appreciated by the community because of the lack of commitment in these two important institutions and the community's lack of trust in them.

3.17 Government's concerns

The government's commitment to improve rural infrastructure does not seem to be enough and there seems to be over-dependence on foreign assistance for national development and reconstruction programmes. Agriculture has always played an important part in Yemeni economy. However, large remittances from immigrant Yemenis and substantial aid packages from rich Arab neighbours and other donors reduced the importance of local agriculture. Rural development was not considered a matter of priority. The foreign aid was also seriously curtailed partly because of Yemen's sympathies with Iraq and partly because of economic difficulties of the donor Arab countries. This abrupt and unexpected situation affected Yemen's economy adversely. Now although the need for agriculture development has revitalised and the government claims to provide better facilities to the local farmer, but, apart from a lack of resources, a lack of sufficient commitment seems to be the major stumbling block.

LCCD, responsible for rural development, is not very effective due to lack of motivation, shortage of funds and lack of skilled manpower. Some village tracks are improved by LCCD in a few areas but in the absence of any technical considerations these roads survive only for one or two rainy seasons.

3.18 Community's concerns

The rural communities generally seem to be aware of their needs and problems with the exception of the safety needs against earthquakes. The main needs indicated by the rural communities during the field surveys were schools, health centres, water supply and farm-to-market roads. They were usually not aware of the solutions to their problems. LCCD is the government agency responsible for attending to these problems about which the people are aware, and some other problems about which the people are not well aware. The latter category of problems include the earthquake hazard, economic and health problems due to excessive qat chewing, and the depletion of water resources because of excessive ground water extraction. LCCD, under the chairmanship of the provincial governor, can be very instrumental in solving the communities' known and unknown problems, but instead it has become a tool of the government for mobilising political support in the rural areas.

At present most rural children have to walk several kilometres to attend schools. Many parents do not find it worthwhile because they can use their young sons on family agriculture farms or for shepherding the livestock. There is no possibility for the girls to go to distant schools in the conservative society. The girls from their childhood start helping their mothers in collecting fuel wood or water for domestic use. If the schools are in the vicinity of one kilometre, a number of young boys and girls might start going to them.

An acute shortage of rural health centres is another problem about which the rural people are very concerned. Even if a health centre exists nearby, in most cases it is without staff or supplies or both. There are no private clinics in the rural areas because the few qualified doctors prefer to work and practice in the urban areas. The nearest hospitals are located at two to three hours drive on rough mountainous roads and only the affluent farmers can afford to have a private vehicle. Under these circumstances getting medical care for even serious patients becomes a problem.

The demand for farm-to-market roads is also high. Most of the hilly tracks suffer from lack of drainage and lack of maintenance problems. During rains these roads become impassable due to too much water or land slides and a number of villages remain isolated from the rest of the area for a number of weeks. This problem adversely affects the local economy because the farm produce cannot be transported to the market during most of the rainy season. The market prices also rapidly rise in this period due to the shortage in supplies. LCCD cannot cope with this large amount of work due to a lack of equipment coupled with a lack of financial and technical resources. The people doubt the competence of LCCD to undertake any major rural development work.

Water supply and sanitation is also a major issue in a majority of the villages but the people do not consider it as important as the need for schools, roads and health services. Because of the difficulty in getting water from distant bore holes or mountain springs the people consume very little water in a day. Urban per capita water needs of a country reflect its economic, social and health development. WHO guidelines suggest an average daily per capita consumption for domestic use in the range of 120 to 150 litres. The known Yemeni figure for urban areas is 64 litres per capita per day.

Similarly average daily per capita consumption of water in rural areas is about 21 litres against WHO guidelines of 60 to 80 litres per capita per day (Al-Fusail et al, 1991). Bathing may be once in several weeks and clothes are also not washed on a regular basis. A lack of knowledge about personal hygiene and the importance of clean water for health is another reason for the people's lack of concern for water supply and sanitation.

There is little concept of building schools, roads, clinics, water schemes through community efforts in the northern parts of Yemen, although the same people build their houses, mosques and agricultural terraces through community work. The government is considered responsible for providing all the above facilities. The people in south Yemen are relatively more accustomed to community work to meet most of their needs. There are several reasons for the above attitudes, such as lack of education, poverty, lack of trust of the village leadership (sheikhs) and LCCD, and tribal rivalries.

Summary

The Republic of Yemen is a low-income country. The country has an old history and the people are generally conservative in all matters, including the design of their houses. The government and the people are aware and concerned about many of their problems. There are certain real problems about which sufficient awareness seems to be lacking. One such problem is the earthquake hazard. The country had better economic conditions in 1982 than now, when the last earthquake occurred. It may be a more serious problem than before, if an earthquake occurs in future. There is an urgent need for awareness of the persisting earthquake hazard and the necessary measures.

Chapter Four

Chapter Four

EARTHQUAKES IN YEMEN AND RECONSTRUCTION AFTER THE 1982 DISASTER

"Housing has a long tradition in Yemen. Excavation work carried out by some French archaeologists suggests that houses of eight or nine stories were built even two thousand years ago". *(Cor Dijkgraaf, 1989)*

4.1 Historical overview

Legendary evidence of earthquakes in Yemen dates back to the seventh century BC (Shu'lan, 1989). Most of the earthquakes are reported to have occurred along the coastal areas of the Gulf of Aden and the Red Sea. Systematic historical records of these events is not available. The famous Sabean Dam in Sa'adah-Marib is known to have been destroyed in the year 742 AD (SCREAA, 1986). Table 4.1 presents some historic earthquakes in Yemen.

Table 4.1: Historic earthquakes of Yemen

Year	Approximate location	No of documented earthquakes
742	Marib	1
872	Districts of Aden and Sana'a	1
1072	Sana'a, Zabid and Mukha	1
1154	Between Sana'a and Aden	1
1259	West of Sana'a	2
1265	Sana'a	Sequence of shocks
1349	Zabid	1
1359	Zabid, Sana'a and Aden	1 + many after-shocks
1387	Hajar in Aden District	1 + many after-shocks
1394	Mazwa	Sequence of shocks
1427	Zabid	1 + many after-shocks
1463	Zabid	Many shocks for three days
1502	Zabid	Sequence of shocks
1613	Aden	1
1644	East of Sa'adah	1 with landslides
1647	Sana'a	1
1667	Sana'a and rest of Yemen	1
1675	Dawran	30 shocks in sequence
1788	Hodeidah	1 + many after-shocks
1789	Between Mukha and Abu Arish	Sequence of shocks
1859	Aden and Mukha	Sequence of shocks
1873	West of Sana'a	1 with landslides
1878	Dhamar and Yarim	Shocks for three months
1895	Mukha and Ta'izz	3
1909	North of Ma'abar	1

Source: Supreme Council for Reconstruction of Earthquake Affected Areas, 1986.

It can be seen from Table 4.1 that not only have earthquakes been occurring frequently in Yemen, but even in the Dhamar governorate and other surrounding areas, which experienced a disastrous earthquake in 1982 have also suffered from earthquakes in the past (Figure 4.1).

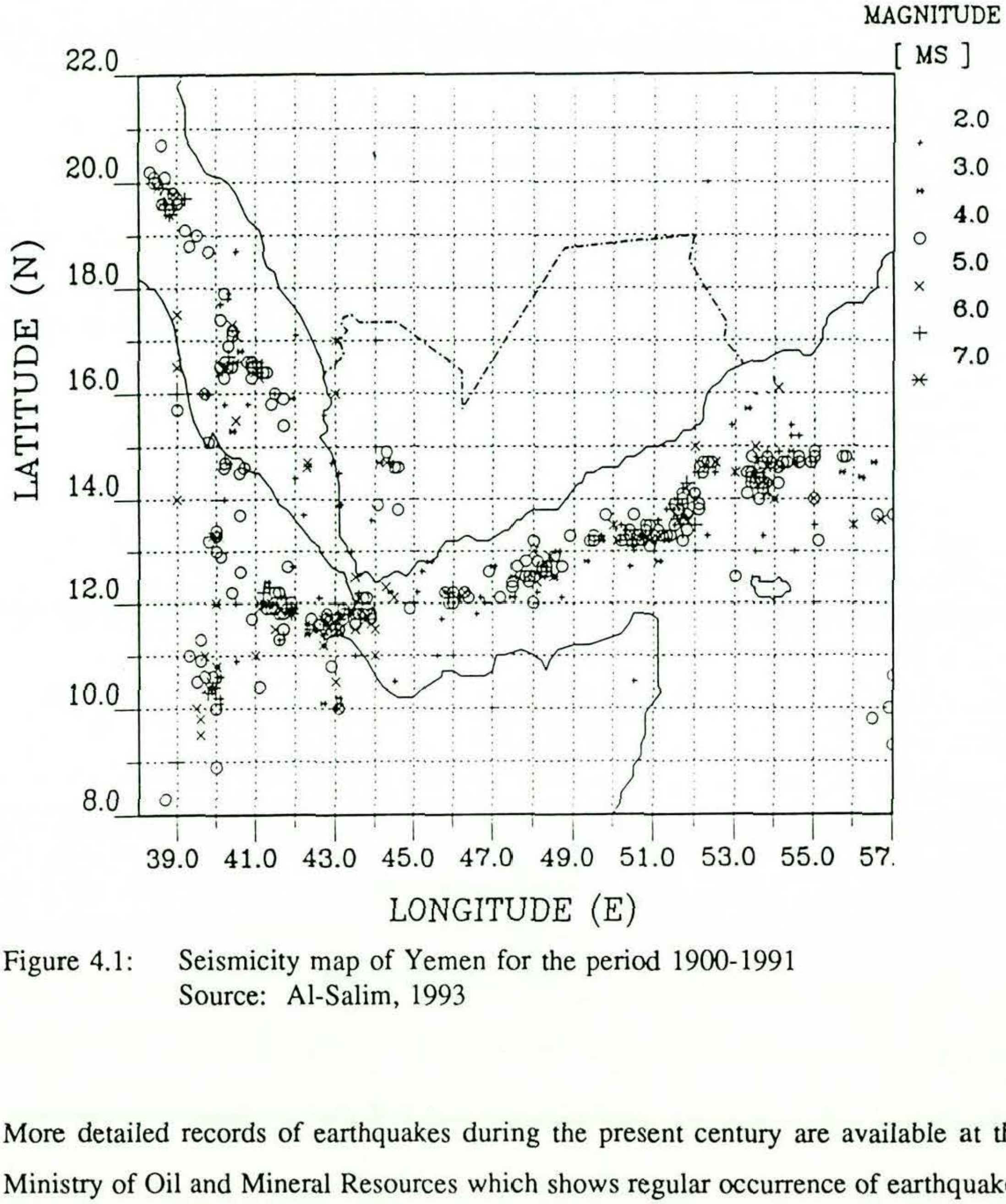


Figure 4.1: Seismicity map of Yemen for the period 1900-1991
Source: Al-Salim, 1993

More detailed records of earthquakes during the present century are available at the Ministry of Oil and Mineral Resources which shows regular occurrence of earthquakes in the country (SOC[1], 1992). Table 4.2 presents some of the recent earthquakes.

1. Seismological Observatory Centre, Ministry of Oil and Mineral Resources, Republic of Yemen.

Table 4.2: Some recent earthquakes in Yemen

Year	Location	Richter Magnitude	Depth in metres	Estimated losses
1930	Near Aden	5.6	Shallow	Minor losses@
1941	Near S'adah	6.3	Shallow	Minor losses
1950	Southern Coast	5.9	NA	Minor losses
1958	Southern Coast	5.5	NA	Minor losses
1961	Aden Coast	6.1	NA	Minor losses
1973	Aden Coast	4.5	38	Minor losses
1975	Hodeidah Coast	5.2	41	Minor losses
1982*	Dhamar	6.0	18	2800 dead, 40,000 homeless and
1982*	Dhamar	6.3	NA	miscellaneous infrastructure
1982*	Dhamar	6.4	33	destroyed
1985	Southern Coast	5.2	3	Minor losses
1987	Near Hadramawt	3.8	33	Minor losses
1991	Al-Udeyn	4.6	Shallow	200,000 homeless

Source: 1. Seismological Observation Centre, Dhamar, 1992.
2. DHA-UNDRO News, 1993.

@ Minor losses due to earthquakes occurring in the sea.

* All these earthquakes occurred on 13 December 1982.

Most of the historical earthquakes seem to be undocumented due to their occurrence in the sparsely populated areas. Minor shocks in the recent past, before the 1982 earthquake could not be recorded because of the absence of seismic stations in the country. Geologists mention about three moderate earthquakes having occurred in Ta'izz, Sa'adah and Ibb regions in the years 1955, 1959 and 1965 (Arya et al, 1985).

In view of high earthquake risk in Yemen, and lessons learnt from the 1982 earthquake in Dhamar the government has now established twenty seismic stations in different parts of the country. These observatory centres will help in monitoring seismic movements and ground acceleration in different areas. The information can be helpful in microzoning these areas and initiating building controls (Shu'lan, 1989). The frequency and magnitude of earthquakes in Yemen explicitly requires the designs of infrastructure, particularly the buildings, to be earthquake-resistant. While a number of new buildings in towns and cities are now being designed on earthquake-resistant principles the rural buildings still continue to be built in the traditional way with no consideration for safety in the case of an earthquake. The engineers, architects and geologists in the country are concerned with the continued use of unsafe building technologies by the rural population. Their concern about the government's persistent lack of introduction of a building code is even greater.

4.2 The earthquake of 1982

Almost the entire governorate of Dhamar was rocked by a moderate earthquake in December 1982 (Figure 4.2). This earthquake was reported to be of magnitude 5.8 to 6.0 on the Richter Scale (Arya et al, 1985). The shock was felt over a large area including Sana'a, the country's capital, 100 kilometres north of Dhamar town. Rumbling sounds of a fore-shock preceding the main shock were reported from a number of villages. About 5,000 sq km area around the epicentre was heavily damaged while the total damage affected area measured some 20,000 sq km. The earthquake claimed about 2,800 human lives and some 4,000 people received serious injuries (Gere and Shah, 1984). The loss of livestock and property was also extensive. It is estimated that some 70,000 dwellings built of stone-masonry laid in mud-mortar were completely destroyed or were damaged to various degrees thus rendering over 265,300 people homeless. The depth of the epicentre was determined at 10 kilometres (Jaghman, 1989). In the following days a series of after-shocks were received and a number of buildings which had earlier developed cracks in the first main shock collapsed or severely damaged thus further increasing the losses above the initial estimates (SCREAA, 1986).

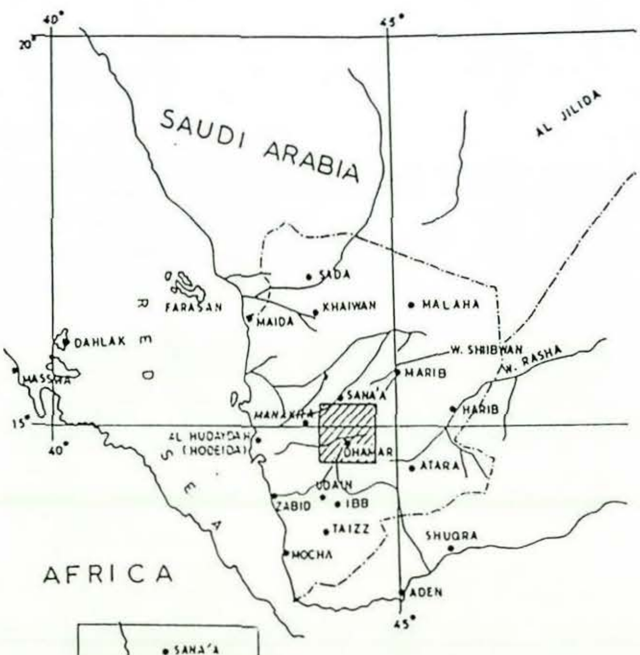


Figure 4.2: The 1982 earthquake-affected area in Yemen
Source: Arya et al, 1985

4.3 Description of the study area

Dhamar governorate is located in the middle of the Republic of Yemen and its headquarters Dhamar is about 100 kilometres south of the capital Sana'a. It is considered to be among the under served areas in the country (MPD, 1991). Most of the population lives in the form of scattered mountain communities with little social infrastructure. The governorate consists of nine districts or 'nahiyas' (DGHO, 1990). The governorate suffered from an earthquake disaster in 1982. The government took up short-term relief and long-term development measures to rebuild infrastructure in the devastated areas with the assistance of foreign donors. It seems relevant to briefly describe the salient socio-economic features of Dhamar governorate, before discussing the earthquake and the reconstruction programme.

4.3.1 Economic features: As much as 70 percent of the economically active population of Dhamar governorate is engaged in agriculture and affiliated activities (MPD, 1991) which accounts for about 60 to 70 percent of the regional gross domestic product (GDP). Most of the remaining work force comprises of skilled and unskilled workers. There is a high unemployment rate of over 15 percent. The per capita GNP in Dhamar governorate is reported to be YR 7,500 (MPD, 1991). This amounts to only US$ 90 per capita per annum according to the current exchange rate in the open market. Inflation is also high in Dhamar like most of the country. Economic progress of the governorate is hampered by the following major factors:

a) isolation of villages and farms from markets due to extremely poor road conditions in the mountainous areas;
b) absence of population centres with the basic social and economic infrastructure needed to retain skilled and educated people (UNCDF, 1991); and
c) lack of secondary road system and other essential infrastructure, which happens to be a country wide problem but it is more serious in the Dhamar governorate.

Consequently the scattered rural population has been unable to fully participate in development activities in the governorate (Consulting Engineering Services, 1986). The government's development plans attempt to address these problems on national level through provision of better roads and social infrastructure. The government is, however, experiencing difficulties as an aftermath of the Gulf crisis which immensely reduced foreign remittances, the return of over one million migrant Yemenis, an influx of refugees from neighbouring African countries, long droughts and more recently the civil war in the country.

4.3.2 Population structure: Dhamar governorate is located in the Central Highlands. Dhamar's estimated population, based on the 1986 census, is over 900,000 (MPD, 1991). The average household size is 7 persons. The governorate has a high rural population which is nearly 90% of the total. The ratio between male and female population is almost equal. The study of census reports suggests that while there is a high population growth of over 9% in Dhamar town, the growth rate in rural areas is less than 1%. This suggests a large scale migration of the rural population to Dhamar and other urban centres in the country (Consulting Engineering Services, 1986). These figures give the average annual growth rate in the governorate as 3.26 % which is above the national average of 3.1%. This high growth rate is due to a crude birth rate of 55 per thousand against a crude death rate of 30 per thousand (Dhamar Governorate Health Office, 1988). Table 4.3 below, based on 1986 census, shows the population trends of Dhamar governorate.

Table 4.3: Projected population estimates of Dhamar governorate

Location	Year		
	1991	1995	2001
Dhamar Town	71,482	101,087	169,068
Rural Areas	759,220	863,045	1,046,227

Source: Dhamar Governorate Health Office (DGHO), 1990.

4.3.3 Topography and climate: Dhamar covers an area of 7,885 sq km with a mountainous topography which rises abruptly from the flat Tihama coastal plain in the west to altitudes ranging between 1,200 to 2,700 metres. The area of Dhamar town is approximately 20 sq km (ACE et al, 1993). On the eastern side, towards Ruba'a Al-Khali desert the fall in altitude is gentle. The western highlands of Dhamar are carved by deep gorges, valleys and plateaus (DGHO, 1990). These valleys and plateaus are gifted with good quality soil for agriculture (UNCDF, 1991). The climate is usually dry and temperate which becomes quite cold during winters with occasional frost and snow on the mountains. Rainfall is erratic and droughts are not uncommon. The average annual rainfall is 525 mm. The bulk of the rainfall occurs during the summer season between April to June. A shorter rainy season occurs from August to September.

4.3.4 Literacy rate: Literacy in Dhamar is below the national level of about 18%. There is one graduate college in Dhamar which is affiliated with Sana'a University. Apart from this college, there are a limited number of secondary schools confined to towns and a few large villages. Primary schools are also inadequate, and a number of children do not attend schools simply because they are not available in the vicinity. Low literacy rate can also be attributed to the rural population's attitude towards education who do not consider it very important. They prefer to utilise the services of their children for assisting them in the family farming, shepherding livestock, fetching water for domestic use, collecting fuel wood and miscellaneous other duties for the family. The average literacy rate in the rural areas is not more than 5%. More recently, however, the people of Dhamar are showing more interest in educating their children.

4.3.5 Agriculture: Flat land is limited in the governorate because of the mountainous topography. People usually have small land holdings mostly as a result of the centuries old tradition of making terraces between mountains introduced in the reign of the legendary queen Arwa (Edge, 1992). Agriculture is generally rain-fed and is the main occupation in the region. Agriculture is still labour intensive. The basic unit in agricultural production is the extended family household. Repeated and prolonged droughts have encouraged farmers to use ground water which is expensive but more reliable than the erratic rains. Dhamar is among the major food producing regions of the country. The principal crops in Dhamar governorate are cereals such as wheat, maize, sorghum and millet which are for domestic consumption only. Other major crops are tomatoes, potatoes and melons which complement the traditional cash crops of coffee, *qat* and fruits. Various fruits such as citrus fruit, peaches, apples and apricots are also produced in appreciable quantities (MPD, 1992). As a consequence of high pumping costs, less profitable crops are slowly going out of production, thus making more cultivated area available for the much more profitable cash crop, *qat*. Like the rest of the country, food production in Dhamar also tends to show a declining trend, thus making the regional economy more dependent on food imports.

4.3.6 Industry: The local economic scene of Dhamar is not different from rest of the country and the average per capita income places Dhamarites in the low-income bracket, close to the national average. The Gulf War has had its effects on Dhamar's economy as well. There is no major industrial unit in Dhamar except for two small dairy plants, one at Ar-Rusabah and the other near Dhamar town. Both of these plants belong to the government. There also exist some privately owned poultry farms which cater for poultry needs in the governorate. There is, however, good potential for the development of agriculture based industries in Dhamar for which land, cheap labour, Dhamar's central location in the country, with reliable telecommunication system and some other infrastructure, is an incentive. The capital Sana'a is almost reaching its limits and cannot continue to accommodate the ever-increasing population. The existing infrastructure in Sana'a is also inadequate and its water resources are depleting fast. Under these circumstances, Dhamar, because of its close vicinity to Sana'a and good climate, provides a genuine opportunity for future development.

4.3.7 Social patterns: Dhamar, as is generally the case in northern Yemen, has a conservative society with a strong tribal system. Most villages are basically tribal settlements built on rocky outcrops for the reason of security against rival tribes (Leslie, 1986). The traditional home in Dhamar, like most other areas in the highlands, is a defensive structure made of thick walls from stone masonry. The houses comprise several floors with different floors for different purposes, for example, the ground floor is usually used as a stable for domestic animals, the first floor is mainly at the disposal of women while the top floor is used by men to receive guests and chew qat. Higher location of the men's floor gives them an opportunity to keep a close eye on strangers and their enemies, considered necessary because of the continuing tribal feuds. These houses and their location proved to be highly vulnerable during the earthquake of 1982. In spite of suffering heavy death toll and property losses the people called it an *act of God* and did not consider the type and location of their homes as a contributing factor to the scale of destruction.

4.4 Seismo-tectonic set-up of the region

The study of satellite imageries of Yemen indicates the presence of an active N20'W-S20'E trending belt with recent faults and volcanism within several thousand years. This belt, extending from the Dhamar-Rada'a quaternary volcanic massif in the south continues towards Sa'adah in the north and is intercepted by a major northeast-southwest trending active belt with recent faults extending from the Marib-Sirwah volcanic massif in the northeast and extending toward the southeast in the central mountainous region. The 1982 Dhamar earthquake occurred in the zone of intersection of these two belts. Ground fractures from N10'W to N20'W were noted in the region. These fractures followed the recent faults along the Dhamar-Sa'adah belt and were noted to occur at some places along a length of 15 kilometres with the western side moving up a few millimetres with respect to the eastern side. This phenomena indicated the thrust fault mechanism in which the western region was probably over-thrusting the eastern region. The openings caused by the fractures ranged from a few millimetres to 10 centimetres and extended over 50 to 100 metres distance. No strike-slip movements or offsets were observed along the ground fractures. Figure 4.3 shows the seismo-tectonic map of Yemen.

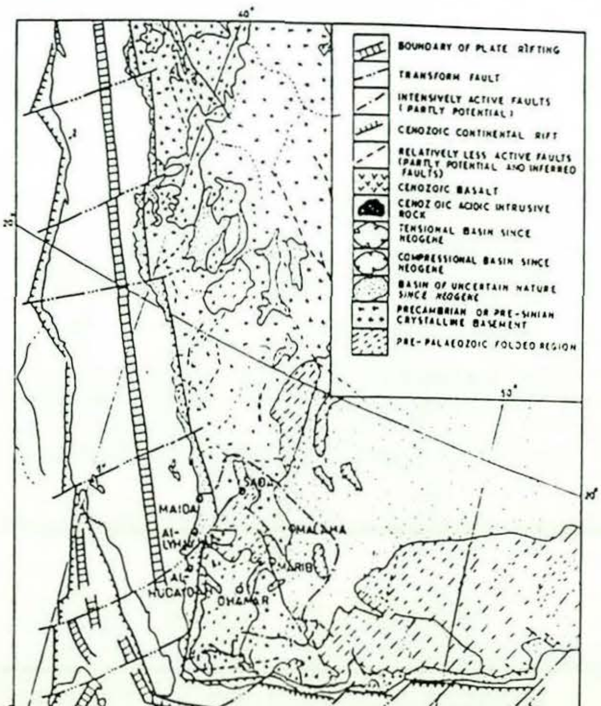


Figure 4.3: Seismo-tectonic map of Yemen
Source: Arya et al, 1985

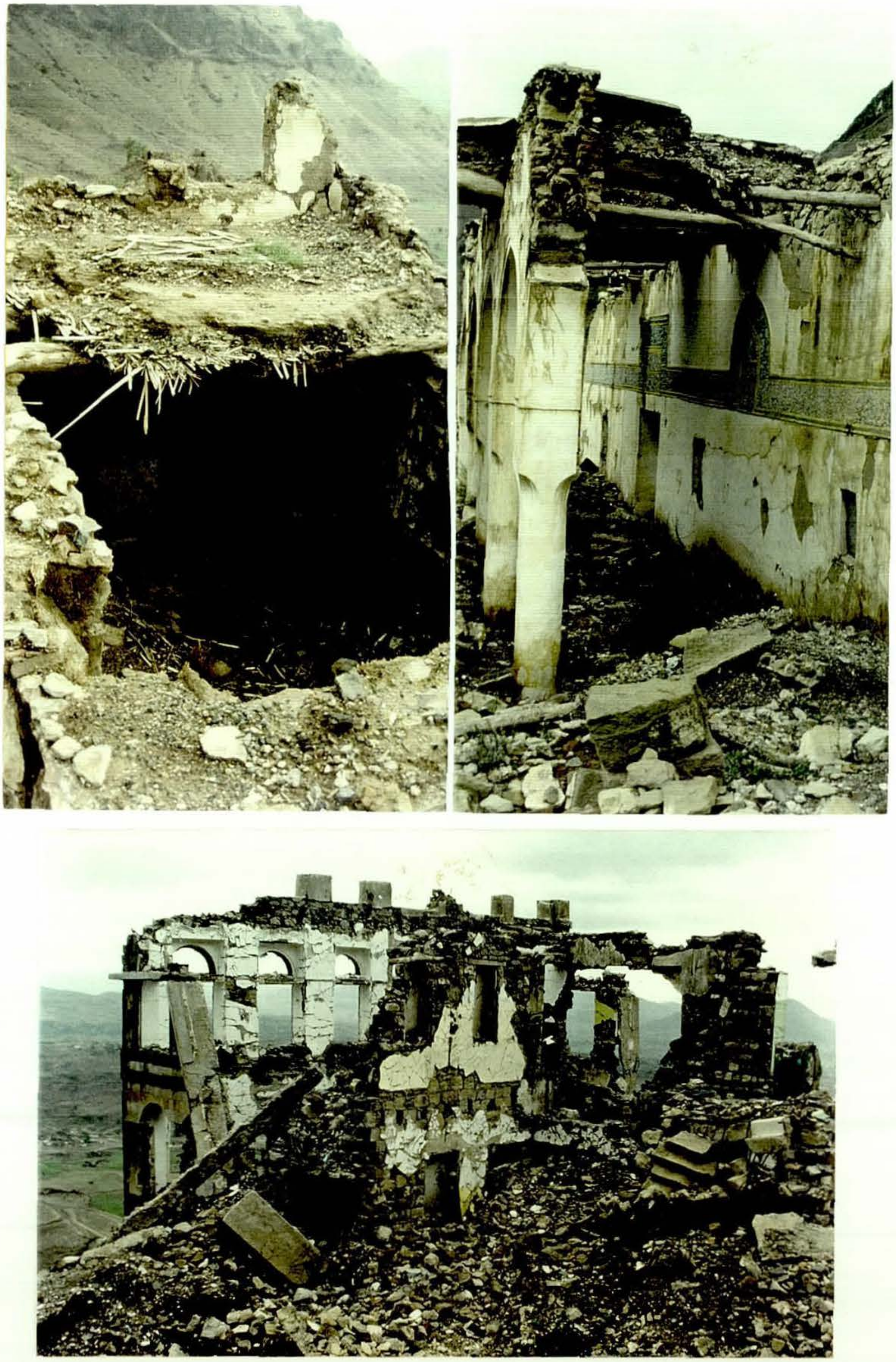


Figure 4.4: Some of the buildings damaged during the 1982 earthquake
Source: Field Surveys, 1994

4.5 Intensity of earthquake and ground motion

The Dhamar earthquake caused panic among the local residents. Most of the random rubble and adobe construction in Dhamar and Ma'abar areas suffered large and deep cracks in the walls, collapse of outer and inner surfaces of the masonry walls causing partial or complete collapse of buildings (Figure 4.4). Many single storey buildings made of dressed stones or concrete blocks, laid in gypsum or cement : mortar suffered moderate damage and showed cracks only along the mortar joints without endangering the safety of the buildings. This heavy damage corresponds to Modified Mercalli (MM) scale intensity VIII and is reported to have covered a 45 x 35 sq km area in the Dhamar governorate. Over 70% of houses located in this area suffered irreparable damage. Figure 4.5 shows the isoseismal map of the earthquake-affected area describing various damage zones ranging from MM intensity VI to VIII based on the degree of damage observed in these areas and the integrated effect of the main shock and the after-shocks. It was observed that ground motion intensity decreased faster in the areas of ground fractures than the hilly terrain which suffered heavy damage over a large area. Slumping of the dry-packed masonry retaining walls supporting agricultural farms in the intensity VIII zone was reported. Sliding and overturning of loose objects such as utensils and furniture was also reported in the region. The damage area under intensity VII was measured to be 65 km north-south and 75 km east-west of Dhamar.

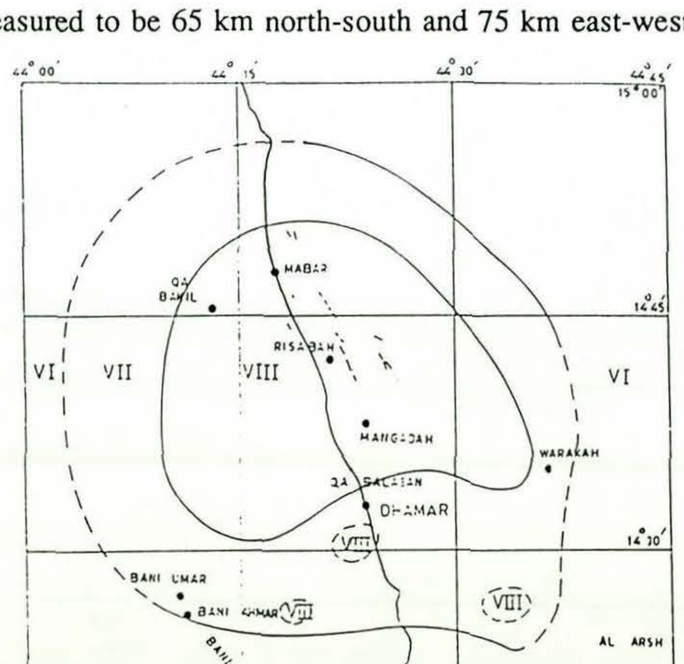


Figure 4.5: Isoseismal map of the 1982 earthquake in Yemen
Source: Arya et al, 1985

4.6 Traditional construction

Most of the settlements in the highlands of Yemen take the form of scattered villages of stone masonry houses, built on rocky outcrops or slopes for reasons of defence (Leslie, 1986). The country is well known for its ancient mud and masonry architectural work, which is to date part of the Yemeni culture (Figure 4.6). In the past Yemeni architectural designs kept a good balance of beauty and stability which made the buildings strong enough to withstand the earthquakes. The ancient houses used traditional strengthening practices, such as timber ties and ring beams (SCREAA 1986). Excavations carried out by French archaeologists reveal that even 2,000 years ago, the Yemenis used to build as high as eight to nine storey buildings (Dijkgraaf, 1989). It was found that several earthquake resistant techniques were known in Yemen in past. These tested techniques for strengthening and stabilising buildings were ignored by the later day builders and emphasis remained only on beautification (Vulto, 1989). This happened to be the main cause for heavy losses in the 1982 earthquake in the country which proved the vulnerability of the traditional houses.

The existing rural houses in northern Yemen are usually built from stone masonry while block masonry is more common in the south. In most of the traditional construction, the walls tend to separate vertically in the absence of a binding force. This type of construction was frequently destroyed in the earthquake of 1982.

Most of the new traditional construction in the area consists of random rubble or half-cut stone masonry or adobe (Figure 4.7). The stone-masonry walls are usually 60 to 90 cm thick. Heavy stones are provided on the outside and inside and the remaining gap in between is filled with stone scrap and mud. This practice does not allow any connection between the outer and inner sides of the walls. There is also no inter-locking of the walls at the corners or between perpendicular walls (Arya et al, 1985).

The traditional buildings are usually located on cliffs or steep hill sides directly resting on the exposed rocks. Where these buildings rest on soil, foundations are dug to shallow depths of about 50 centimetres which are packed with dry stones or stones and mud. The height of the building can go up to three to four storeys or 12 to 15 metres.

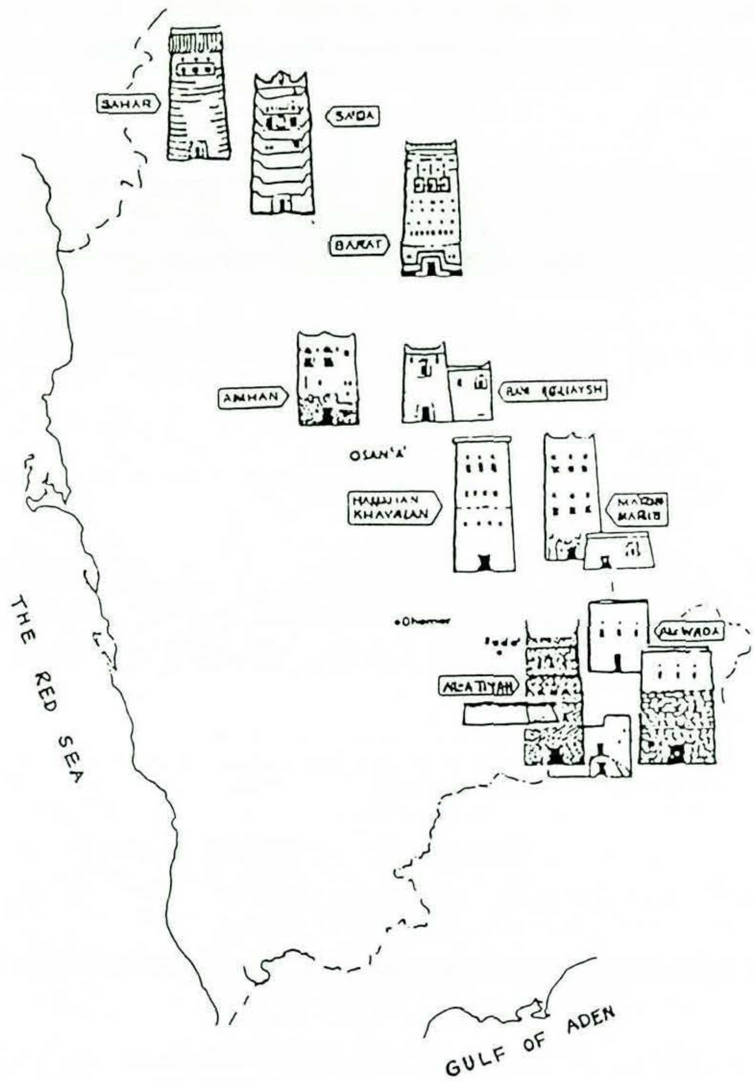


Figure 4.6: Typical mud architectural designs of traditional buildings in Yemen
Source: Executive Office for Reconstruction, Yemen, 1985

The door and window openings are usually few and small due to the extreme weather conditions.

The roofs are almost always flat, made of roughly dressed round or half-round timber joists or tree branches, covering spans of 3 to 3.5 metres with about 50 cm centre-to-centre spacing in between. This limits the width of the room but the length can be as much as 12 to 15 metres. The timber joists are sometimes covered with wooden planks but in most cases bush or weed is used to form the deck for receiving clay topping. The clay topping in a new traditional house is about 20 to 25 thick but quite often a 10 cm or so thick layer of clay is added just before the rainy season for protection against leakage which continues to add to the thickness and weight of the roof with the passage

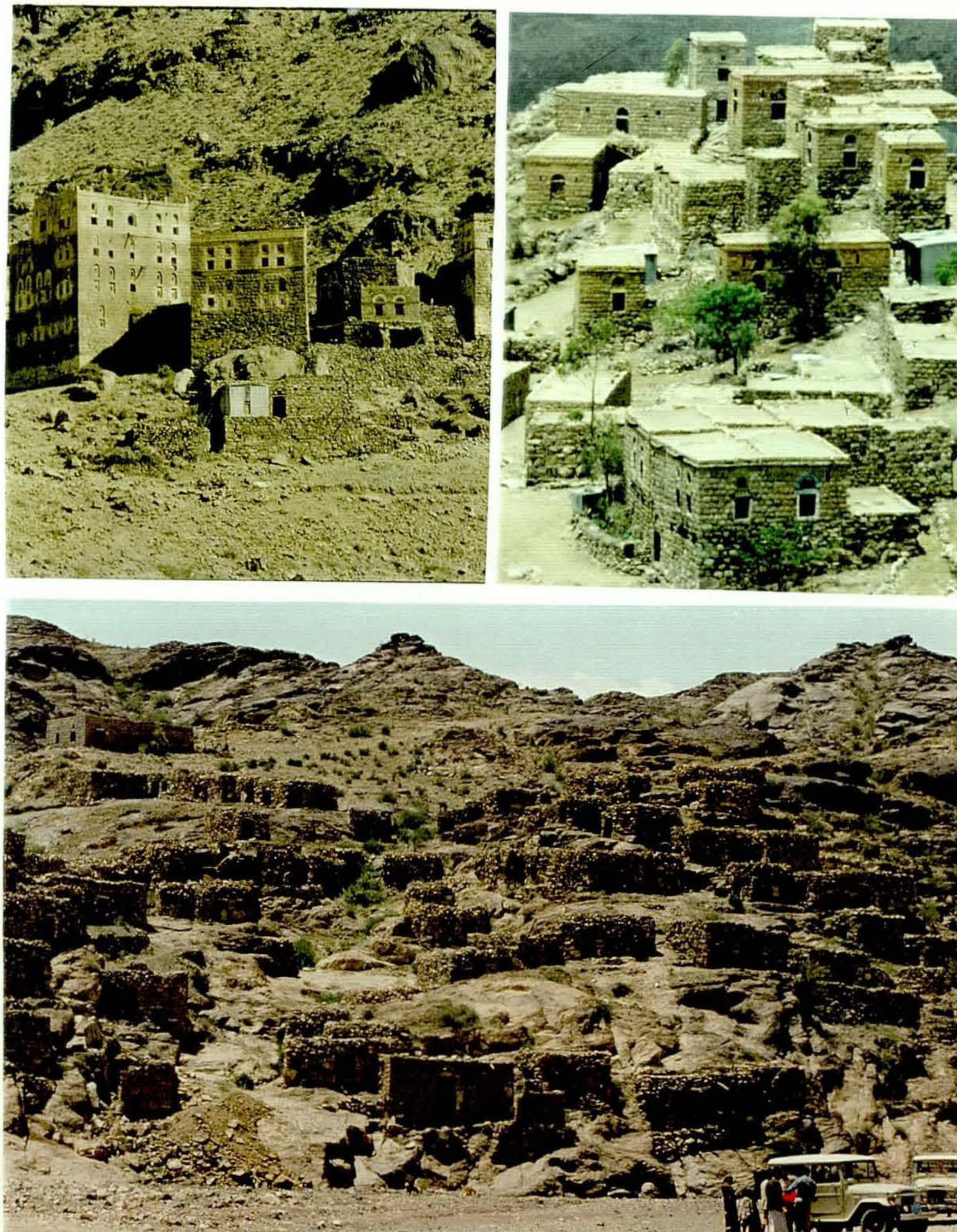


Figure 4.7: Traditional stone-masonry work in Yemen
Source: Field Surveys, 1994

of years. Sometimes an old roof can be as thick as 90 cm thus adding to the vulnerability of the building. When roof tops are used as floors, concrete screed with cement plaster is sometimes applied to get a smooth surface. Parapet walls on roofs are of low height, made from rubble stone covered with clay plaster mixed with straw.

The few public buildings such as dispensaries and schools in the pre-earthquake era were built and maintained by the government. These buildings were usually single storeyed built on proper foundations. The walls were made of half-cut stones with a proper bond between the walls and between the wall and roof. The roofs of these buildings were made from reinforced concrete. These public buildings suffered only minor to moderate damage during the earthquake.

4.7 Community's response

Estimated property losses in the 1982 earthquake run well over 2 billion US dollars. The local population was caught completely unaware by the disaster and most of them suffered heavy losses to life and property. The surviving community's response to the catastrophe, immediately after recovering from the shock, was that of self-help (Leslie, 1986). They erected temporary shelters by tying bed sheets and blankets over wooden posts and whatever else was readily available from the ruins of their collapsed houses. Those who could get hold of some corrugated iron sheets made better shelters. They helped each other in fixing the emergency shelters and by sharing food and other essential items. These shelters were later supplemented by tents provided by the government. Fears about further tremors prevented most people from returning to their damaged homes. The government's repeated announcements through media regarding the supply of emergency shelter on an immediate basis, and the permanent shelter in the nearest possible future to all survivors discouraged many of them from starting even the simplest type of reconstruction by exploiting their own resources such as the materials from their ruined homes.

The Turnkey free housing built in the reconstruction programme was available to only a few, relatively influential, percentage of the earthquake victims (Figure 4.8). A majority of the people were not satisfied by the reconstruction programme for various reasons. Detailed discussion on this issue is given in Chapters 8 and 9.

The donor assisted self-help housing programme required the beneficiaries to contribute 30% of the total cost by providing unskilled labour and local materials (Figure 4.9). The beneficiaries response to this programme was better than the turnkey housing programme.

The government also assisted some of those people whose houses were not seriously damaged by repairing and strengthening their existing houses (Figure 4.10). The beneficiaries had to contribute a major part of the repair cost in this programme and most of them were not happy.

There were still a large number of earthquake-affected people who could not benefit from the government's reconstruction programme. These people felt bitter because the government took away their initiative by promising them free housing and then did not produce. The construction cost also substantially rose in the meantime thus making house building even more problematic. Many of these people or non-beneficiaries went back to live in their damaged houses which could prove lethal in a future earthquake.

4.8 Government's response

The government announced relief measures immediately after the disaster (SCREAA, 1986). The relief programme included tents, food and medicines for the victims. The government appointed a high level body under the Prime Minister and named the Supreme Council for Reconstruction in Earthquake Affected Areas (SCREAA) to monitor the relief work at the national level and to coordinate international assistance (Wijenberg, 1989). SCREAA represented all those ministries who were involved in the relief and reconstruction work one way or the other. These ministries included the Ministry of Works, the Ministry of Municipalities and Housing, the Ministry of Water Supply and Electricity, the Ministry of Oil and Mineral Resources, the Central Planning Organisation, and the General Union of the Local Councils and Cooperatives for Development. The government announced its plans to reconstruct 25,000 houses and to repair 17,000 through local resources and foreign assistance apart from the development of the infrastructure (SCREAA, 1986).

Figure 4.8:
A turnkey house

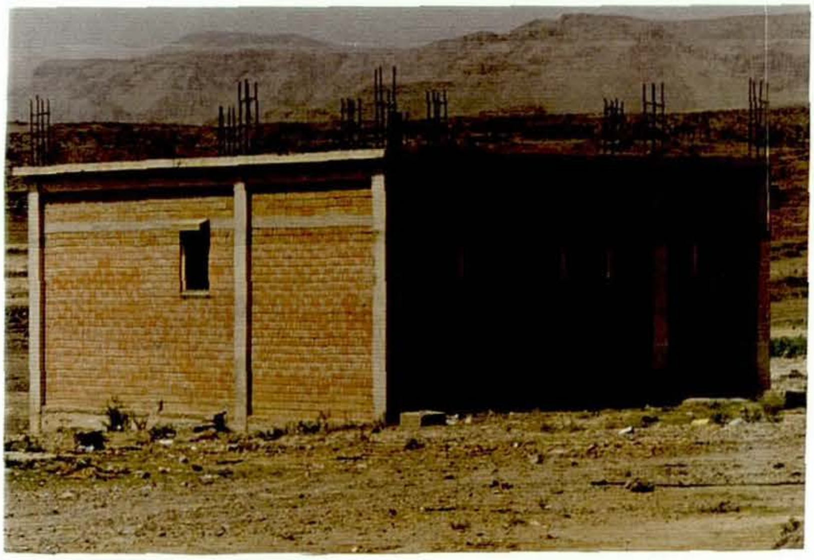
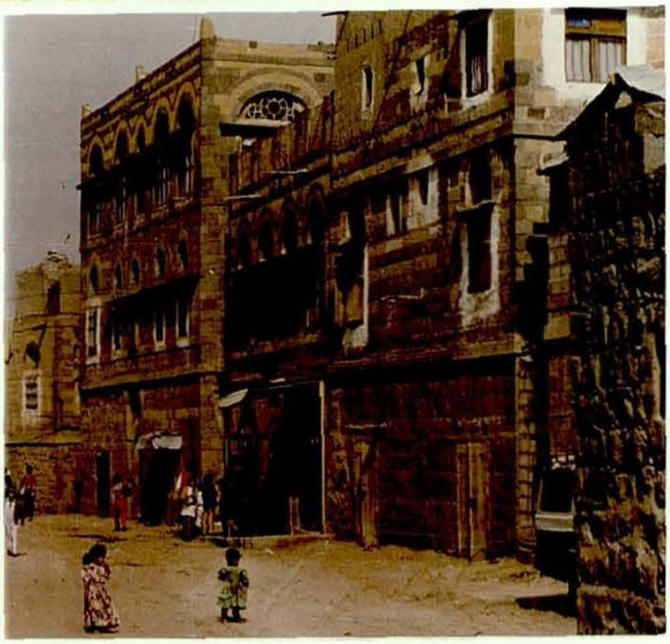


Figure 4.9:
An aided self-help house

Figure 4.10:
An aided repaired house



Source: Field Surveys, 1994

At the local level, an Executive Office for Reconstruction in Dhamar (EOR) was established, under SCREAA, with the responsibility to supervise and implement the reconstruction and resettlement activities in the Dhamar Governorate (DHV Consultants, 1988). A world wide appeal to help combat this disaster was launched by the Government of Yemen. At the local level, teams of engineers and other experts from all provinces were despatched to the disaster area to participate in the relief efforts. Technical and statistical survey teams also toured the area to collect technical data for use in future planning.

EOR divided the entire governorate into twenty zones in order to avoid duplication of efforts and to facilitate better coordination and monitoring (Kassem, 1989). Seventeen of these zones where a majority of the buildings had been destroyed were earmarked for the turnkey housing programme to be constructed through contractors (Figure 4.11). The remaining three zones covered those villages where repairable damage had occurred to most of the houses and only a few houses were destroyed in each village. These three zones were to be covered under the self-help programme. These zones were assigned to different donors in accordance with the aid package committed by them.

Under the reconstruction programme, 10,300 turnkey housing units were actually built through open bidding while another 1,300 houses were completed under the Self-help programme. About the same number of houses, in repairable condition, were repaired. As such only about 50-55% of the original target was achieved.

Many factors are said to be responsible for this shortfall, such as deficiencies in planning and mobilisation of resources. The government claims that some of the donors did not provide their committed assistance which was an important element in hampering the reconstruction programme, and left the government in a difficult situation. The one hundred-bed hospital in Ma'abar, the second largest town in Dhamar governorate, is quoted as an example. This hospital is badly needed but the government has so far not been able to complete it.

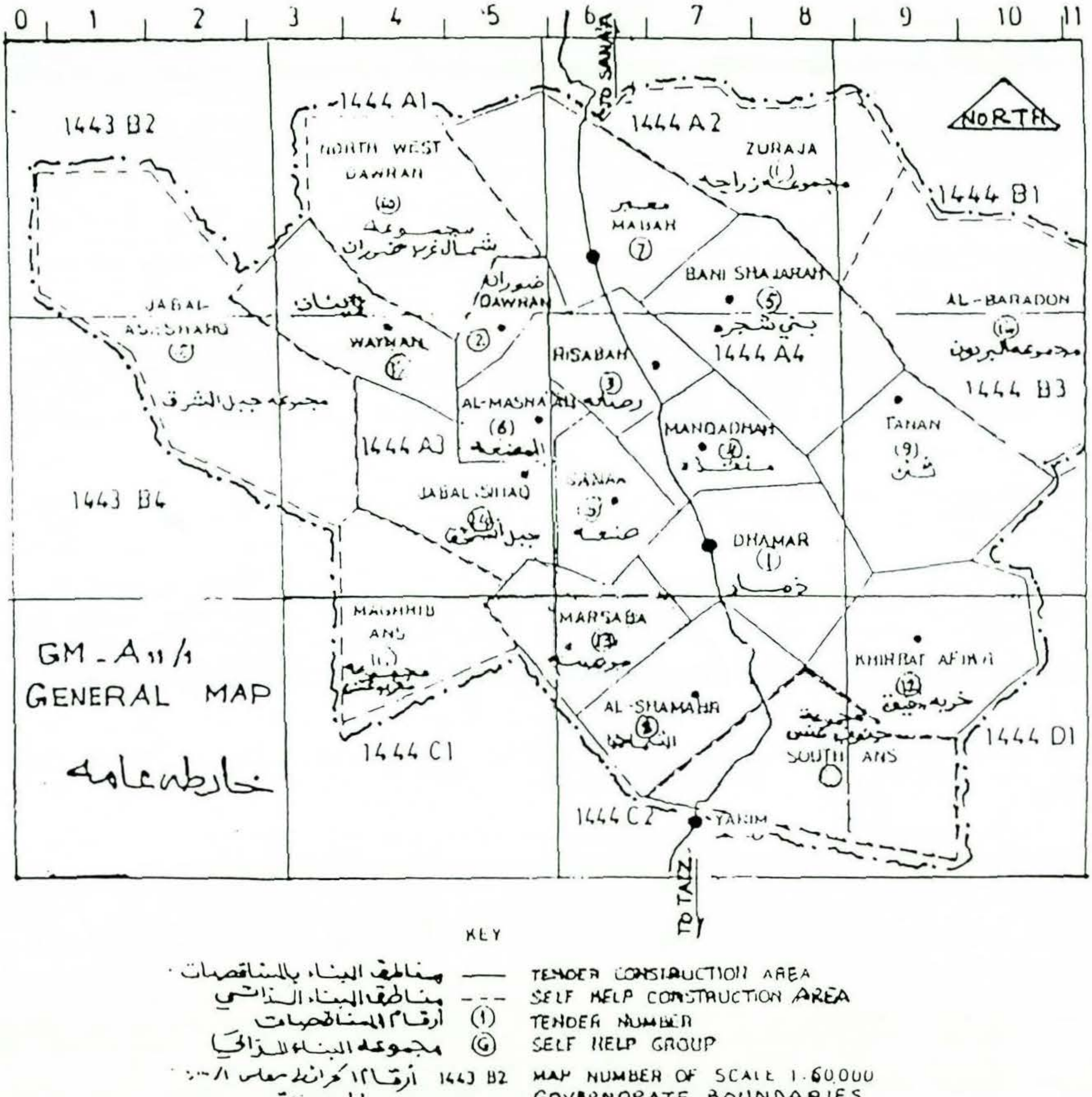


Figure 4.11: Map of Dhamar showing the governorate distributed in 20 zones. 17 of these zones were rebuilt through a contractor, while the remaining 3 were assisted by aided self-help projects.
Source: Executive Office for Reconstrution, Dhamar, 1992

4.9 Donors' response

Donors' response to the country's appeal for help in rebuilding the earthquake-affected areas was overwhelming. Several multilateral and bilateral agencies, such as Saudi Arab Fund, UAE Fund, Kuwait Fund, USAID, Dutch Aid, UNDP, UNCDF and UNICEF agreed to provide technical and financial assistance in the relief and reconstruction work (UNCDF, 1990). Apart from financial assistance in the reconstruction work, some donors such as ODA sponsored programmes for training the local artisans in simple earthquake-resistant techniques, and mostly by using local materials.

Most of the reconstruction activities continued until 1989. It can be seen from Table 4.3 that the reconstruction activity generally involved the building of housing units, primary schools (PS), hospitals, health centres (HC), primary health care units (PHCUs), mosques and water supply and sanitation schemes (WSS). The first project was to build some 74 kilometres of feeder roads in the North West Dawran region of the Dhamar governorate, has just started after identifying the urgency of this project and in response to the demand from the local communities. The idea behind building feeder roads and to provide perennial access between agriculture farms and potential markets in the region is to help improve the socio-economic condition of the local population. Table 4.3 also provides brief details of the amount and type of assistance provided by various donors in rebuilding the physical infrastructure in the earthquake-affected areas of Dhamar governorate.

Table 4.4: Post-earthquake donor assistance for reconstruction in Yemen

Donor	Nature of assistance for infrastructure	Cost in millions of US$
Saudi Arabia	3413 low-cost houses, health centres and schools	68
Kuwait	1514 low-cost houses and one 102 bed hospital	27
Kuwait Fund	Health facilities and miscellaneous rural infrastructure	33
UAE	665 houses and other rural infrastructure	17
Oman	326 houses	5
Qatar	Miscellaneous social services eg PHCUs, mosques, schools	5
Dutch Aid	184 low-cost houses	5
USAID	369 low-cost houses and medical facilities	10
EEC	46 low-cost houses	1
Germany	Water supply systems	3
UK	Technical assistance for design and repair of infrastructure	
India	Technical assistance for design and repair of infrastructure	
USSR	Building materials for reconstruction work	3
UNCDF	279 houses	3
Japan	Building materials for rural infrastructure	
North Korea	Cement for reconstruction work	
IDB	Schools	2
USA	Technical assistance through Peace Corps Volunteers	
Sweden	Social guidance community development	
UNICEF	Health centres and PHCUs	2

Source: UNCDF Project Agreement YEM/90/CO1; 1990

4.10 Pre-earthquake infrastructure

There was hardly any modern physical infrastructure in the northern parts of Yemen until the end of the Imamate regime in the middle of 1960s. Centuries old traditional water collection and irrigation systems still exist which are famous for land-use planning and economical use of run-off in a country where rainfall is low and erratic. Most of the modern development started in the early 1970's. The infrastructure existing in the rural areas of Yemen before the 1982 earthquake is briefly discussed in the following paragraphs.

4.10.1 Housing: The traditional houses in north Yemen are defensive buildings sufficient for all the domestic activities within its compound (Leslie, 1986). The rural houses in the highlands are multi-storeyed comprising of three or four floors (Figure 4.12). The ground floor is used as a stable for domestic animals and storing fodder and crop. The middle floors are for the use of women and children. The rooms in these floors are built around a central staircase. The top floor is meant for men which

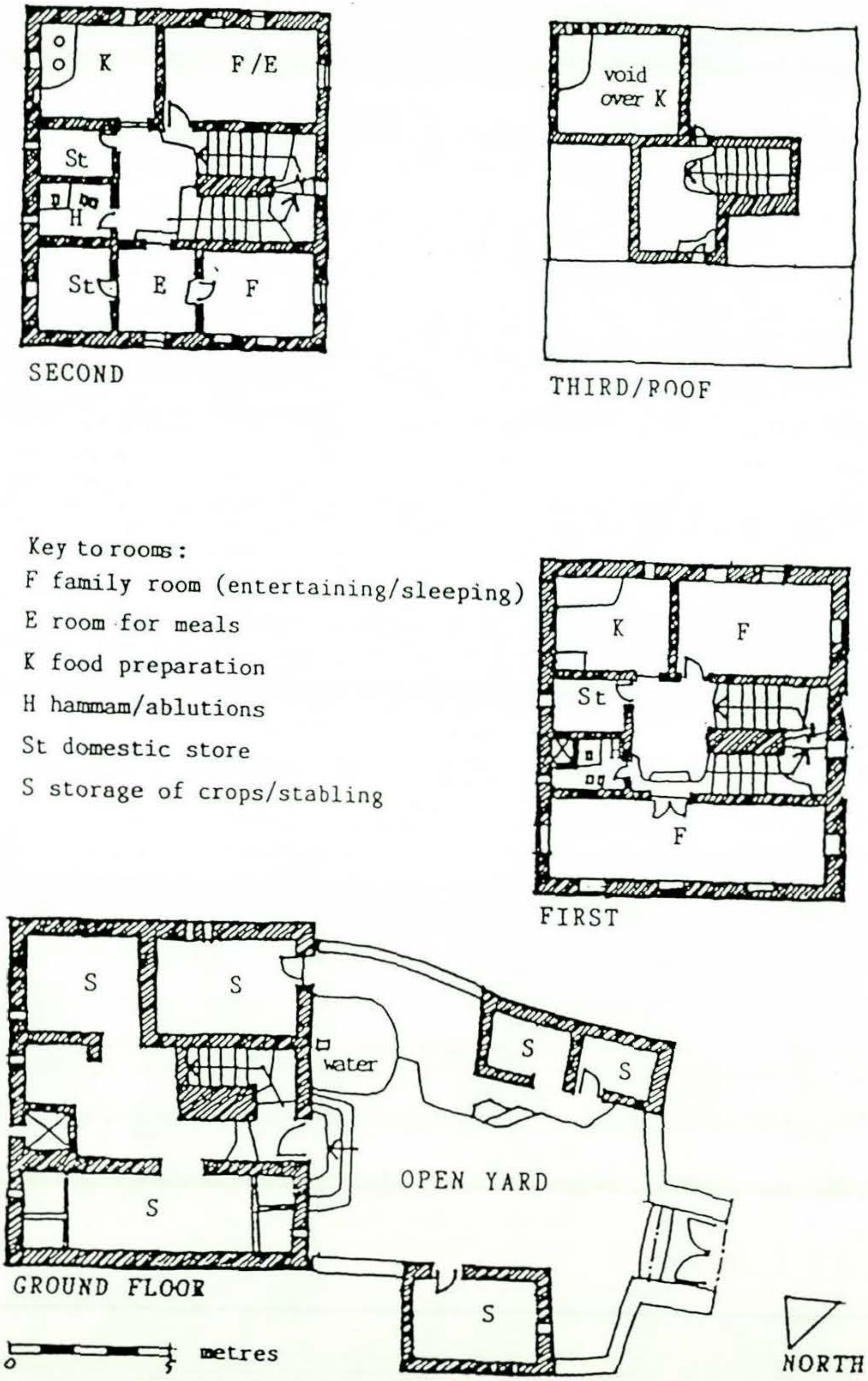


Figure 4.12: Layout plan for a traditional rural house in north Yemen
Source: Leslie, 1986

includes one or more 'divans'. The divan is used for receiving guests, holding feasts and chewing qat for long hours. These buildings are not safe against earthquakes as experienced during the last earthquake in Dhamar (1982) and Al-Udeyn (1991) in which moderate earthquakes caused severe loss of life and property. Traditional roofs were also found to be vulnerable to damage because the timber joists often do not penetrate far into the walls and are easily separated from their support walls. The heavy mud roof proved to be yet another dangerous component of the structure during the earthquake of 1982. DHV Consultants (1989) determined the following weak points in traditional Yemeni houses:

a) the composition of a wall has two tiers (internal and external) without any functional connection in between;

b) the conical shape of the inner side of the stone which allows very little bond in the masonry work;

c) the excessive weight of thick roof with little connection to the walls; and

d) the lack of a tie beam connecting outer walls.

These factors make the structure very weak and dangerous in the face of an earthquake.

4.10.2 Water supply: Myntti (1979) observed that water supply was one of the most serious problems in Yemen. Surface water is rare while ground water is usually deep. There are very few water supply schemes in rural areas. Outside larger towns and cities piped water supply systems are virtually unknown (SCREAA, 1986). Water supply for domestic use is provided by women and children who fetch it by hand or on donkey-backs (Figure 4.13). The entire water fetching operation may take several hours, in some cases, depending upon distance of the water source and high location of the house. The pre-earthquake water collecting systems, which are still widely used in rural areas, are primitive and generally unsafe. In these systems water is collected from open ponds filled by rain water called 'majils', open streams, irrigation boreholes or mountain springs.

Only boreholes, which were much fewer in the early eighties than now, and to some extent mountain springs, could be considered as a safe water source. It is not only the water source but also the methods of transporting and carrying water which affect water

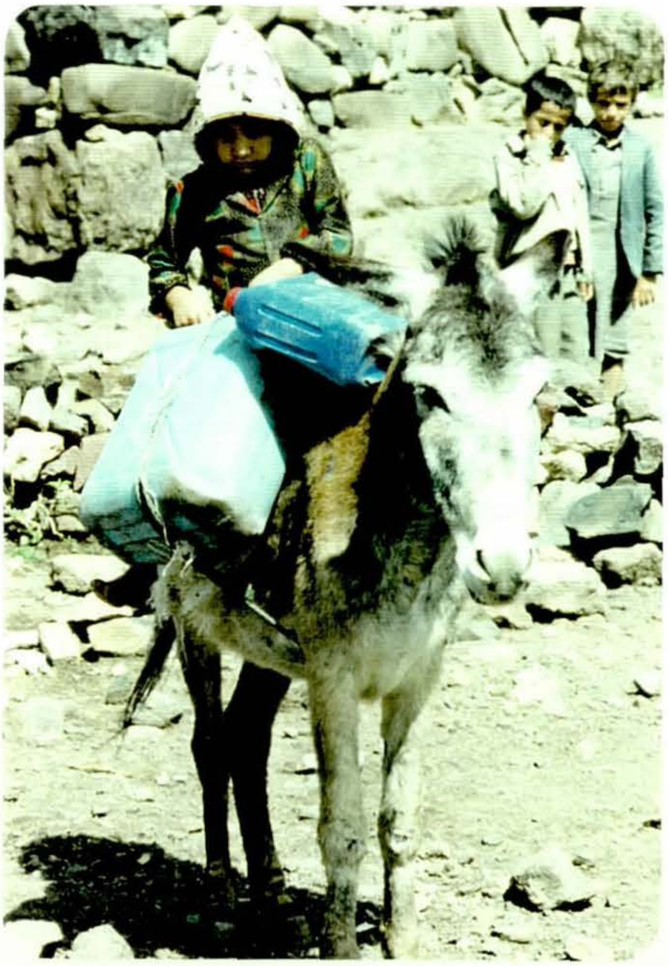


Figure 4.13: A small Yemeni girl fetching water for the family
Source: Field Surveys, 1994

quality. Majils and open streams are extremely unsafe for human consumption because of their exposed surface. Further, human beings and domestic animals take water from these sources, by directly entering inside the pond or stream, which makes them undisputed health hazards.

4.10.3 Sanitation: Public sanitation and hygiene are poor in Yemen (Myntti, 1979). Most of the diseases in Yemen are caused by unsafe water supply and poor sanitation, for example diarrhoea, tuberculosis, malaria, dysentery, worms, intestinal diseases and bilharzia. Traditionally rural Yemenis use open fields for defecation. Dry or pour-flush latrines were rare in rural areas before the earthquake of 1982.

4.10.4 Health services: Before the earthquake a few hospitals and clinics existed only in the main towns which usually suffered from lack of skilled staff and supplies. These hospitals and clinics were insufficient to meet even the local demand of towns. Health related infrastructure was almost non-existent in rural areas and even primary health-care units were not seen in these areas because of isolationist and anti-development policies of the Imamate regimes (Muller, 1991). People mostly depended on traditional treatment. Only serious patients were brought to the hospitals. Local culture and conservatism, which discourages women's contact with strangers, also played a major role in non-availability of such facilities. Poor living conditions and an acute shortage of professional and paramedical facilities were other reasons for the lack of health-care in rural areas.

4.10.5 Roads: Only a few primary roads, such as Sana'a-Ta'izz and Ta'izz-Aden existed as single lane asphalt roads before the earthquake. Most of the towns were approachable by gravel surfaced roads which suffered from a lack of maintenance. Secondary roads were also very few and connected only some main areas. The so called feeder or tertiary roads were no more than animal tracks on which only four-wheel drive vehicles could travel. There were only a few people who could afford four-wheel drive vehicles. Donkeys were mostly used for short journeys. A number of villages in the mountain regions used to become inaccessible during the rains due to erosion and land slides. Such villages remained isolated for several weeks from the rest of the country.

Lack of all-weather roads adversely affected local economy. Inability to transport agricultural produce to the markets, in the rainy seasons, added to the economic difficulties of the rural population.

4.10.6 Telecommunication: Primitive telecommunication system existed only in urban areas. There was no such system in rural areas. Rural people had to travel long distances on foot or by occasional transport to reach the nearest telephone or post office, a facility which they rarely used.

4.10.7 Electric supply: Public sector electric supply was restricted to cities and towns. Only a handful of privately-owned generators could be found in the rural areas. A very small number of affluent farmers or traders could afford this luxury for their farms, houses and shops.

4.10.8 Fuel energy: Oil or gas were not discovered in commercial quantities in Yemen before the earthquake of 1982. Most of the country's population depended on wood or charcoal for fuel. This became the main cause of the shortage of forest area over the years. Evidence from ancient buildings in Yemen shows that the use of wooden tie beams in the walls was common which made such buildings safer against earthquakes. However, the indiscriminate cutting of trees, for wood fuel use, depleted the forest resource. Use of wood in buildings became rare and only for ornamental purposes due to its rising cost. As a consequence the buildings became unsafe with the passage of time and when a moderate earthquake hit Dhamar in 1982 it caused serious damage to life and property.

4.11 Post earthquake reconstruction programme

Kassem (1989) says that the Government of Yemen after the earthquake of 1982, started a vast and comprehensive reconstruction programme in the disaster affected area, under donor assistance, at an estimated cost of 2.68 billion Yemeni Riyals. The purpose was to remove all physical signs of the catastrophe by providing shelter to the homeless and by compensating survivors for their losses. As a consequence the following construction programme was envisaged:

- 10,000 low-cost houses through a contractor;
- 3,000 low-cost houses through self-help;
- 95 primary and secondary schools;
- 57 mosques;
- 24 rural health centres;
- one 200 bed hospital in Dhamar and one 102-bed hospital in Ma'abar;
- electrification of 80 villages;
- levelling of Dhamar-Dhabah road; and
- 259 water supply schemes.

4.11.1 <u>Housing</u>: The government financed, on its own, the repair of 17,000 houses which were not completely destroyed and could be used after some repairs. 10,000 earthquake resistant housing units were built through contractors on a turnkey basis. The self-help reconstruction programme, under which nearly 3,000 houses were built in remote rural areas, was the first of its kind in the history of Yemen (Wijenberg, 1989).

The primary aim of Dhamar Aided Self Help (DASH) Reconstruction Project was to introduce earthquake-resistant building techniques using local building materials and simple building techniques. The new houses were intended to be attractive and affordable to the average household, keeping in view the local culture and traditions. With all construction elements strongly connected to each other, the tight box like structure should be able to withstand shock waves from any direction (DHV Consultant, 1989). The emphasis in the self-help programme was to maintain, as much as possible, local architecture and to improve on the available building knowledge in the area (Vulto, 1989).

The DASH project was implemented with the following objectives (Sutmuller, 1989):

a) short-term: to provide shelter to the homeless; and

b) long-term: introduction and transfer of knowledge concerning earthquake resistant techniques.

The main emphasis was on the following points:

a) to maximise the use of local building materials;

b) to safeguard the Yemeni architecture;

c) to build on existing building techniques;

d) to build a house affordable to most of the population; and

e) to introduce a self-help concept with maximum participation of the beneficiaries.

4.11.2 Primary and secondary schools: 95 primary and secondary schools were built on turn-key basis in the entire governorate (Figure 4.14). A group of five to ten villages or more with about a hundred students and no school in the vicinity of 3 to 4 kilometres were provided with primary schools. Other larger villages with existing primary schools, but no facility for further education, were considered for secondary schools.

4.11.3 Mosques: 57 mosques of various sizes, depending upon local population, were built in different areas through contractors (Figure 4.15). The mosques are also used for imparting religious education to the local children.

4.11.4 Hospitals and rural health centres: Health facilities were poor in Dhamar and Ma'abar towns and almost non-existent in the rural areas. A 200 bed hospital was built in Dhamar under donor assistance. Another hospital at Ma'abar has not been completed to date.

24 rural health centres were built through contractor at different locations in the Dhamar Governorate (Figure 4.16). Building of primary health care units is still continuing. Most of the rural health centre or units, however, suffer from a lack of staff and supplies.

4.11.5 Rural electrification: 80 villages were electrified by installing diesel generators and by providing a limited distribution system. The beneficiaries in these villages receive electricity supply for four to five hours daily in the evening. Fuel supply is not a problem in Yemen, even in remote areas, but maintenance facilities for mechanical and electrical equipment is a problem.

Figure 4.14:
A primary school in Al-Marwan

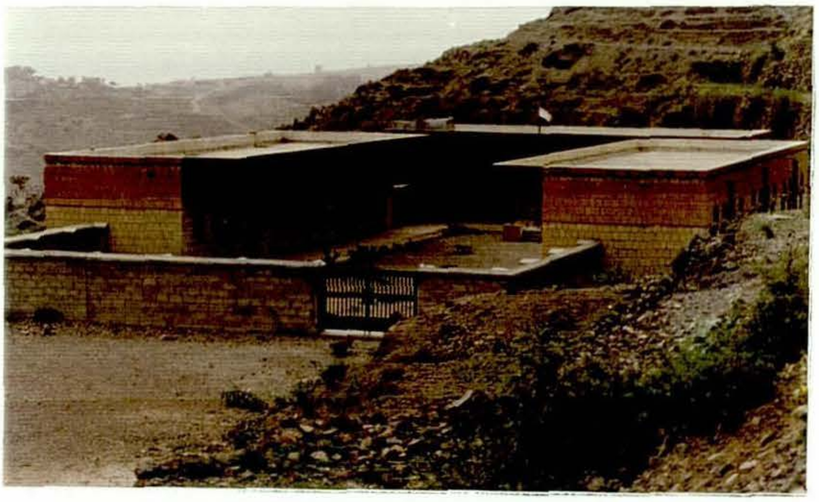
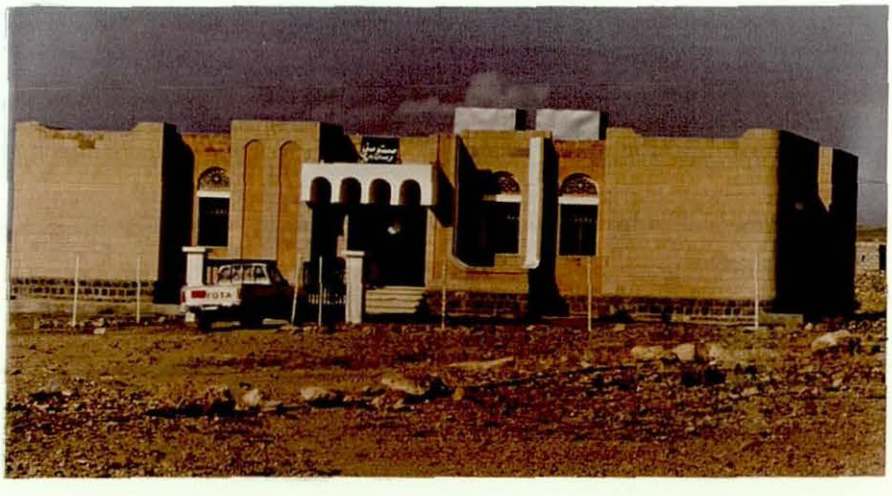


Figure 4.15:
A mosque in Dhamar

Figure 4.16:
A health centre in Dawran



Infrastructure built during the reconstruction programme

Source: Field Surveys, 1994

4.11.6 Roads: Road building programme, comprising of widening the Sana'a-Dhamar-Ta'izz road and the building of the Dhamar-Albaidah road, was confined to urban areas only. This programme was, however, part of the national development plan and not specifically related to post earthquake reconstruction. Dhamar is well known for agriculture production and most of the existing approach roads in rural areas are nothing but animal tracks which are not accessible in the rainy season. The need to improve these tracks is well established but apart from the levelling and grading of the Dhamar-Dhabah road no significant road work was carried out in the rural areas of Dhamar in the reconstruction programme.

4.11.7 Water supply and sanitation schemes: 259 water supply schemes were originally planned for the earthquake-affected areas, but less than 50% could actually be built. Only two urban water supply schemes for the only two towns of the governorate, Dhamar and Ma'abar were built. The rural schemes are based on pumping ground water to a storage tank on an elevated point, and distribution by gravity (Figure 4.17). Because of conservatism and tribal rivalries community water supply is not popular in Yemen and people prefer domestic connections. For this purpose the beneficiaries, who could afford it, preferred to pay for private connections.

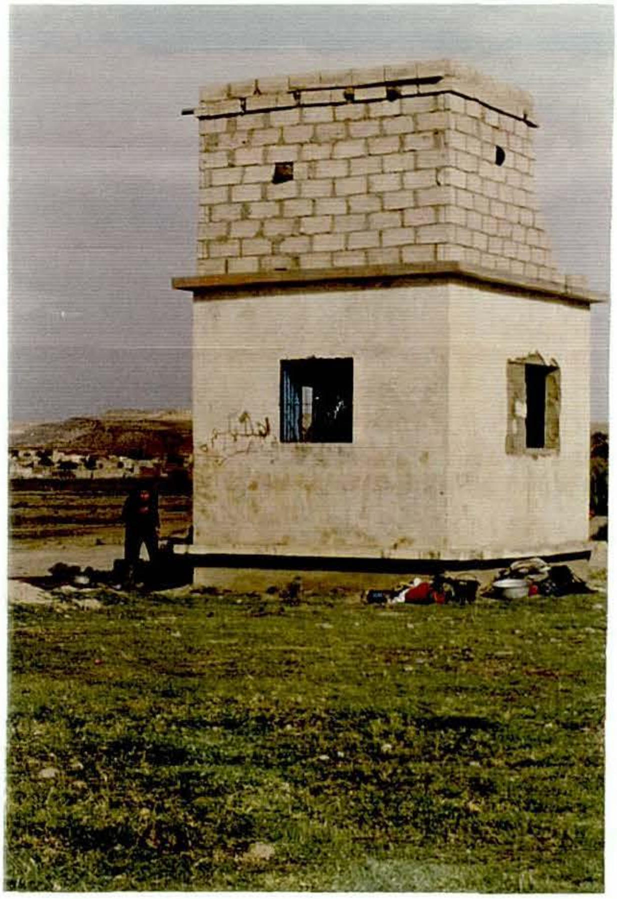
The sanitation programme included building pour-flush latrines in the new houses, schools, hospitals, health centres and mosques. Local artisans were trained on building soak pits and related sewerage systems.

The water supply, sanitation and hygiene programme still continues in the rural areas of Dhamar under Dutch assistance.

4.12 Reconstruction programme details

The entire work was divided into four categories as follows (SCREAA, 1986):

a) repair of nearly 17,000 houses, in repairable condition, through government resources;
b) reconstruction of vastly destructed areas by contractors through open bidding;
c) reconstruction of partly damaged areas through self-help projects; and
d) development and reconstruction of the infrastructure through contractors.



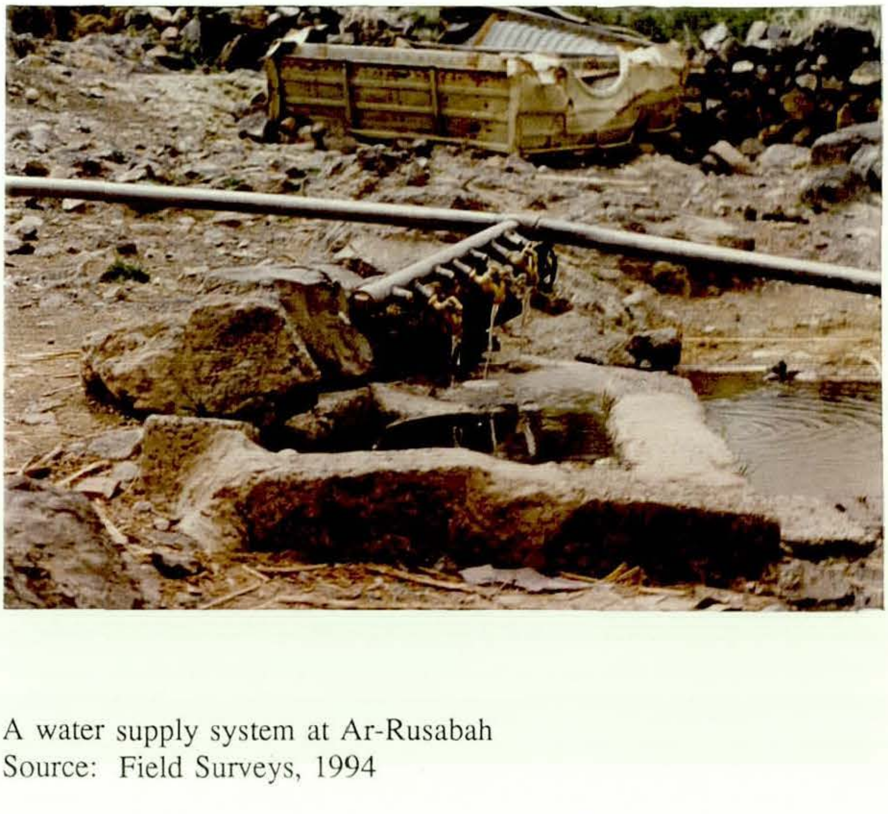


Figure 4.17: A water supply system at Ar-Rusabah
Source: Field Surveys, 1994

The houses with minor damages were repaired through local contractors. The contracts were directly signed between the Executive Office for Reconstruction (EOR), Dhamar and the contractors after assessment of damage to each house and the amount of repair involved. Other houses requiring minor repairs were repaired through release of cash funds to the owners. The cash was issued in four instalments. The first instalment was paid immediately after signing an agreement between EOR and the victims. The next payments were released after certification by EOR Engineers regarding satisfactory completion of the previous phases.

Major repair works included adding reinforced concrete tie-beams under roofs with deep anchorage in the support walls, replacement of delaminated walls, filling of cracks, replacement of occasional broken wooden beams. In cases where more wooden beams of the same roof were found broken or cracked the entire roof was replaced with a reinforced concrete roof.

In the Turnkey approach master and survey plans for location of houses and other infrastructure were prepared by the government engineers. The design of buildings was prepared by foreign experts and was based on earthquake resistant techniques. This design was standardised for all victims (EOR, 1989). Tenders for building these structures in each area were issued through advertisement and works awarded to successful bidders. A total of 10,301 houses (Table 4.4) were completed under the reconstruction programme. Construction of 95 schools, 57 mosques, 24 health centres and over 250 water supply schemes and electrification of more than 80 villages was also part of the reconstruction and development programme. The victims were not consulted about the location, design or construction of any of these works.

Table 4.5: Reconstruction of houses through contractors

Location	Beneficiary villages	No of houses	Origin of contractor	Total Contract Price (YR)	Cost per house (YR)	Donor
Dhamar	10	679	Turkey	51,601,000	75,996	Saudi Arabia
Dawran	12	774	India	59,365,800	76,700	Saudi Arabia
Rusaban	13	1001	Yemen	76,261,185	76,185	Saudi Arabia
Manqadah	10	713	Yemen	56,396,161	79,097	Yemen
B.Shajarah	23	1076	Yugoslavia	76,536,867	71,131	Yemen
L.Asshawis	15	812	Yemen	46,539,172	57,314	Yemen
Ma'abar	16	1006	Italy	62,720,076	62,346	Saudi Arabia
Ashshamahi	16	388	China	34,434,224	88,748	Kuwait/Oman
Tinen	15	620	Yemen	48,464,160	78,168	UAE/ZWA*
Wynan	38	443	Bangladesh	53,160,000	120,000	Yemen
Sunaa	13	711	South korea	57,740,310	81,210	Kuwait PC**
Khirb Afiq	11	394	Yemen	29,572,401	75,057	Yemen
Marsabah	12	462	China	33,882,618	73,339	Kuwait/Oman
Jabal Ishaq	30	553	Bangladesh	58,065,000	105,000	Yemen
Zurajah	33	391	China/Yemen	37,825,235	96,740	Yemen
Dawran	35	195	China/Yemen	19,370,314	99,335	Yemen
Ar-Rusabah	26	183	China/Yemen	8,244,800	45,054	Yemen

* United Arab Emirates and Zubiani Women's Association, a UAE NGO.
** Kuwait Peoples' Committee, A Kuwaiti NGO.
Source: Executive Office for Reconstruction, Dhamar, Yemen.

The average cost of a Turnkey house, built during the period 1983 through to 1987, comes out at about YR 80,084 or about US$ 14,000.

Sparsely scattered remote villages, with a lesser number of damaged houses and approachable by narrow and dangerous mountainous roads, were regarded by the government as too expensive to be built by contractors. Some donor agencies, who offered to assist with self-help programmes, were invited to work in these areas. The cost of reconstructing houses under this approach was shared between government and the beneficiaries. The government provided all imported materials which were not available in rural areas together with skilled labour. Technical supervision and training of the local craftsmen in earthquake-resistant building techniques was also provided by the government. The beneficiaries contributed with land for the house, local materials, such as stones, gravel, sand, clay, water for construction and unskilled labour. Beneficiaries' contribution accounted for a maximum of 30% of the total cost and the house was built in four phases (Table 4.5). Van Dijkhuizen (1989) reported that the criterion for selection of beneficiaries was that the old (pre-earthquake) house must be totally destroyed.

Table 4.6: Self-help reconstruction project material check list

Phase	Total material input			
	Description of material	Quantity	Description of material	Quantity
1	Sand	4 m^3	Cement	30 bags
	Gravel	2 m^3	Reinforcement steel 8 mm	74m
	Stones 30 cm height	400 pieces	Wood planks 2x10 cm	120m
	Soil	25 m^3	Nails 2.5 inch	1 kg
	Water for construction	2 m^3	-	-
2	Sand	56 m^3	Cement	80 bags
	Gravel	7 m^3	Wire mesh	75m
	Stones 30 cm height	1120 pieces	Reinforcement steel 6 mm	23m
	Water	3 m^3	Reinforcement steel 8 mm	148m
	-	-	Door frames	6 pieces
	-	-	Window frames	9 pieces
3	Sand	2 m^3	Cement	35 bags
	Gravel	4 m^3	Wire mesh	12m
	Stones 30 cm height	400 pieces	Reinforcement steel 6 mm	23m
	Water	2 m^3	Reinforcement steel 8 mm	148m
	-	-	Galvanised wire 3 mm	50m
	-	-	Timber joists 7x12 cm	130m
4	Sand	1 m^3	Cement	35 bags
	Gravel	3 m^3	Plywood 12 mm	18 sheets
	Stones 30 cm height	225 pieces	Nails 1.5 inch	1 kg
	Water	2 m^3	Nails 2.5 inch	1 kg
	Soil	6 m^3	Roof protection foil	60 m^2
	Yemeni arches	10 pieces	Doors	6 pieces
	-	-	Windows	9 pieces

Source: Self-help Project Reconstruction Report, 1989.

The procedure for building houses under the self-help programme required signing a contract between EOR and the victim after which building materials for various stages of work, such as cement, reinforcing steel, wood, doors and windows were delivered at site. The beneficiary also contributed his part for the relevant stage of work. The next instalment of materials was issued only after the previous stage of work was completed. Different phases of work mentioned in Table 4.5 describe each phase of work in detail together with the contributions of the government and the beneficiaries.

The following rules were applied for reconstruction under the self-help programme:

a) design and sizes of houses were the same as those built through a contractor;

b) beneficiary contribution was fixed and the same for everyone;

c) planning to start the building was done centrally at EOR office in Dhamar. The beneficiaries could not decide on their own to start the construction activities;

d) the building programme was directly supervised by EOR; and

e) the time for completion of all activities at one site was four months.

Table 4.7 shows details of the number of houses built under self-help approach, beneficiary areas and the sources of funds:

Table 4.7: Reconstruction of houses under Self-help programme

Location	Number of houses	Source of foreign funds	Source of local funds
Maghrib Ans	600	Dutch Aid/EEC	GOY/Loan from USAID
N W Dawran	280	UNDP/UNCDF	Government of Yemen
Jabal Ashsharq	400	Dutch Aid	GOY/Loan from USAID

Source: Executive Office for Reconstruction, Dhamar, Yemen.

EOR (1986) reported that this approach was found to be useful for those areas where reconstruction through a contractor was not economically feasible. A partial contribution of the cost by the victims reduced construction cost for the government. The use of local labour helped train them for future development works. The use of local materials not only saved cost but also helped the local economy and created more local jobs. The programme helped the beneficiaries as they became house owners by contributing only a small amount (less than one third) of the total cost. The feeling of ownership from the very beginning of the reconstruction work encouraged owners to put their maximum efforts to finish the houses to a high standard.

4.13 General observations

The Turnkey approach was favoured by some bilateral donors, especially the rich Arab countries. Housing units, hospitals, health centres, health centres, schools, water and power supply systems, mosques, and a few kilometres of roads were built under this approach in selected areas. Field surveys showed, that the houses delivered under the turnkey approach remained unoccupied for a long time, despite the fact they were provided free of cost. Even today an appreciable number of these houses can be seen unoccupied. The door, windows, electrical and sanitary fittings had been scavenged by the earthquake-affected people for use in their traditional houses. Some houses were seen to be used as stables for domestic animals, or barns to stock fodder. In some places the turnkey houses were found being rented out to expatriate teachers who taught at the local primary schools. The contractor built structures based on earthquake-resistant design. The victims had mixed reactions about these structures. Most of them preferred to stay in their area and they repaired or rebuilt their damaged houses even though they were not earthquake-resistant. When they received contractor built houses they either used them as second houses for guests or invariably added more rooms to suit their needs, such as kitchens, toilets, stables for domestic animals, barns and stores. They did not like the location of the new houses which, although safer, were usually away from the old houses where the victims had their agricultural lands and other belongings. They also found these houses different in appearance from the traditional houses, in which stone masonry work was a dominant part of construction whereas the new houses were made from block masonry. A number of houses remained unoccupied for a long time after completion.

Under the turnkey approach the victims appreciated the building of the other infrastructure, which came more as new development work, and was better than the housing programme. This infrastructure comprised of schools, mosques, water supply, electric supply and health centres. The victims were also not involved in their location, design or construction. Most of this infrastructure deteriorated over a short period of time due to lack of maintenance.

The self-help approach was introduced by some United Nations agencies, such as UNCDF, UNDP and UNICEF, and some western bilateral donors such as Dutch-Aid, USAID and ODA. The Self-help programme was a new experience in the country (Dijkgraaf, 1989). This approach was confined to construction of houses only. Under this approach the beneficiaries were responsible for providing the land for the house. According to the government sources, the beneficiaries had to contribute up to 30% of the total cost in the form of local materials, water and unskilled labour. Most of the beneficiaries, however, claimed that they had to provide food and qat also for labourers and government supervisors on a regular basis, in addition to their agreed contribution. They estimated their actual cost sharing in the aided Self-help programme at 50% of the total cost. Although the houses provided under this approach were occupied soon after completion, they were subjected to a number of alterations afterwards.

The self-help programme faced some difficulties in the beginning as the victims were reluctant to pay their contribution. But once this programme overcame its initial problems the beneficiaries took more interest in this programme than the Turnkey programme. Earthquake-resistant designs of these houses were also alien to the victims but they were found to be more acceptable than the Turnkey houses, mainly because of some participation by the beneficiaries in this programme. Like the contractor built houses, the beneficiaries had to add additional rooms to these houses as well in order to meet their needs.

The victims seemed to be somewhat satisfied with the repair programme. This programme involved restoration of those houses which had received repairable damage during the earthquake. This programme was originally intended for the entire earthquake-affected area but later the government limited it to Dhamar town only. There were no serious complaints about this programme, except that there was no proper criteria for fixing priority for the houses to be repaired first. Another complaint was that only a few houses were actually repaired out the figure originally announced by the government. One reason for the fewer complaints of this programme could be the relative smallness of the programme, where prolonged and excessive involvement of the government was not possible.

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A literature review shows that almost no effort was made by the government to inform the people about the earthquake risk in the area, and that the disaster could be repeated again within a few years. At the end, the earthquake-affected people had more complaints about the programme than appreciation.

Summary

The 1982 earthquake caused heavy losses in Dhamar governorate. The earthquake-affected people showed their initiative in immediately making temporary shelter and food arrangements for themselves. The government made its arrangements but it took some time before the emergency relief reached the victims. They announced long-term arrangements consisting of: providing shelter to all victims together with some other infrastructure, such as roads, schools, health centres, water supply schemes and mosques. The government implemented reconstruction programme could not be completed as planned. The beneficiaries of the programme had several complaints and many of them preferred to live in their traditional houses. Most of the other infrastructure also did not last long and went into disuse because of the lack of maintenance. Apparently no steps were taken by the government in creating hazard awareness among the earthquake victims.

Chapter Five

Chapter Five

GENERAL CONSIDERATIONS FOR SAFE DESIGNS

"The value of any earthquake prediction programme will be greatly reduced if the collapse of structures and the resulting life hazard could be avoided through effective application of earthquake engineering knowledge". *(Ray Clough, 1978)*

It is an interesting fact that most of the regions of low seismicity around the world are almost uninhabited such as Siberia, Greenland, Canada, most of Australia, the Amazon, the Sahara and Antarctica (Arnold and Reitherman, 1982). On the other hand most of the historic architectural designs emerged from seismic areas such as Greece, Egypt, India, Italy, China and Japan. It seems that ancient architects did not consider earthquakes as a natural hazard and concentrated their efforts on providing comfort against climatic problems. The reason given for this approach is that the climatic issue is an everyday problem whereas earthquakes occur once in several years and therefore do not remain fresh in the memories of the local people after some time.

Another reason is that earthquakes did not receive any serious attention from scientists and engineers until beginning of the twentieth century when population growth and building congestion, particularly in the urban areas, led to some serious disasters and heavy casualties in different parts of the world located in seismic zones. It was after the San Francisco (1906) and Tokyo (1923) earthquakes that earthquake-resistance was first given any serious consideration in building designs. It is now well established that human suffering caused by earthquakes is almost entirely because of man-made structures (Smith, 1994). Life and property losses due to earthquakes have increased in the later part of this century as discussed in Chapter 2. In spite of modern research it is still not possible to predict or prevent earthquakes and as such scientists, engineers and architects are concentrating more on limiting the damage they cause (UNDRO, 1978). In addition to the protection of housing, which is directly concerned with saving human life and shelter, attempts are also being made to protect other infrastructure such as industrial buildings, chemical factories, fuel storage tanks, thermal plants and nuclear power stations which can further aggravate a disaster through the leakage of chemical, inflammable materials and nuclear radiation.

The design of buildings and other infrastructure to protect them against earthquakes is a skilled job and requires a good understanding of the destructive nature of earthquakes and the mechanism under which they are triggered off (Coburn and Spence, 1992). Specialists in the fields of civil, structural and geotechnical engineering have very important roles in the design of earthquake resistant structures and the related protection measures. However in view of the increasing danger of earthquakes and international concern for mitigating earthquake losses, it is necessary that earthquake-resistant design should become an easy-to-understand and non-specialist skill within the guidelines provided by the specialists in order to have a safer environment. The application of these standards is becoming an essential practice in order to guarantee the safety of urban and rural population centres. One of the major steps in widening the scope of earthquake-resistant design is to bring into fold other professionals directly involved in the planning and design of infrastructure such as architects, surveyors and interior designers, etc.

The subject of earthquake-resistant design is so extensive and still immature that it is difficult to present any ready-made solutions for any particular project. (Dorwick, 1978). The general principles apply to the whole range of building construction and civil engineering, while the detailed design is more related to structural and architectural aspects. Earthquakes require engineers and architects to make a number of important considerations which are not necessary in the normal design process. A simplified flow chart indicating the design process requirements for earthquake-resistant structures is given in Figure 5.1.

Earthquakes produce both horizontal and vertical forces. The horizontal forces are of far greater importance as they create vibrations over long distances, depending upon magnitude and depth of the earthquake. The effect of vertical forces is only significant close to the epicentre of an earthquake. Most of the earthquake-resistant structures are therefore braced to resist horizontal forces only (Smith, 1994). This concept is however under intense review after the Northridge and Kobe earthquakes of 1994 and 1995. Many experts are now of the opinion that the vertical forces should also be given due consideration in earthquake design (New Civil Engineer, 11/1995).

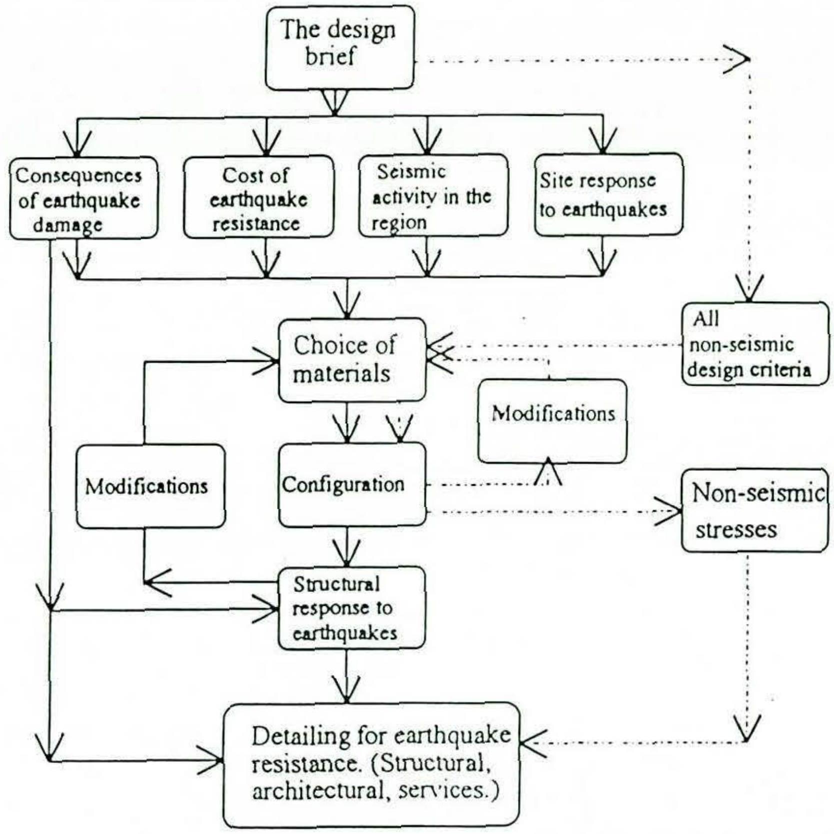


Figure 5.1: Simplified flow chart for earthquake-resistant design
Source: Smith, 1994

5.1 Objectives of earthquake-resistant design and construction

It is not possible to make completely earthquake-proof structures which will not suffer damage in any destructive earthquake (Architectural Institute of Japan, 1970). The concept behind earthquake-resistant structures is that of 'acceptable risk' (Coburn and Spence, 1992). The objectives for earthquake-resistant design and construction of structures are as follows:

a) to resist minor earthquakes without damage;

b) to resist moderate earthquakes without significant structural damage, but with some non-structural damage; and

c) to resist major or severe earthquake without major failure of the structural framework of the structure or its elements and equipment, and to maintain life safety;

Great earthquakes are rare. The criteria for earthquake-resistant designs do not cover great earthquakes because such designs will make the construction costs exorbitant and therefore uneconomical.

A brief review of the considerations for earthquake-resistant design is given in the following paragraphs.

5.2 Site selection

The selection of site is a very important first step in the design of a structure in a seismic area (Coburn and Spence, 1992). The site selection process not only requires consideration of the earthquake hazard but also other secondary hazards which usually accompany earthquakes. An assessment of the earthquake hazard in terms of duration and severity is very important in assessing the needs for site selection and the structure to be built in a particular area. No site can be expected to be ideal in every respect. Selection of a safe site is therefore based on judgement about the risks and cost involved to avoid those risks. Some sites are, however, so hazardous that they make the cost of a safe building prohibitive. A brief discussion on such sites is given below. Engineers try to avoid such sites as far as possible. Site assessment should provide enough information to determine loading and other inputs for structural design. This process becomes easier if zoning maps giving geotechnical details of the area and a building design code are available. The task, however, becomes difficult if seismic hazard assessment of the site is to be carried out first.

The following are among the important considerations for site selection:

a) what is the earthquake-pattern in the region in terms of size, nature of the event and recurrence period?

b) whether an active fault can be identified which passes through or near the site and may create a potential risk to any structure in the area?

c) what are other potential hazards at the site such as tsunamis, landslides, subsidence and liquefaction? and,

d) what are the soil conditions in the area?

5.2.1 Local geology and soil conditions: The effect of an earthquake on a site greatly depends on the local geology and soil conditions (Dorwick, 1978). In this regard the topography and nature of the bed-rock and the nature and geometry of the deposited soils are of significant importance. Rocks provide less damping to shock waves than the softer compressible soils which aggravate earthquake damage on structures.

Horizontal variation in soils at a site can also be a potential danger during an earthquake particularly if a building is founded on different types of adjoining soils. Different types of soils behave differently during an earthquake. In such a case their compressibility is also different and thus affect the safety of a building. In brief terms the geology and topography of a region can have the following influences in site selection (Smith, 1994):

a) the amount of movement created in the underlying rocks and soils and damage caused by an earthquake;
b) the amount of damping effects provided by the soils; and
c) any possible refraction and reflection of the shock waves.

5.2.1.1 *Landslides and rockfalls*: Slopes made of sedimentary rocks fail during earthquakes and slide downwards in the form of avalanches. Sedimentary rocks are formed by the action of water, wind or glacier (Singh, 1992). These huge heaps of mud and debris may bury alive the population and property at the foot of the slopes or cause serious damage through rockfalls (Figure 5.2). Similarly building on in-fill soils or partly on in-fill and partly on hard soils is also dangerous because of the different behaviours of the two types of soils (Figure 5.3). Building on sloping rock foundation is also not safe (Figure 5.4). There are solutions for such situations as well, and they are discussed later in this chapter. Such solutions are however expensive.

5.2.1.2 *Liquefaction*: In some other cases such as where sandy pockets occur in mostly clay soils, slope failures may result in liquefaction which is another hazard for building foundations. Liquefaction can also occur in flat areas containing cohesionless soils.

Site and soil investigations, such as drilling bore holes and soil analysis are very important for any physical infrastructure development or a construction project. The

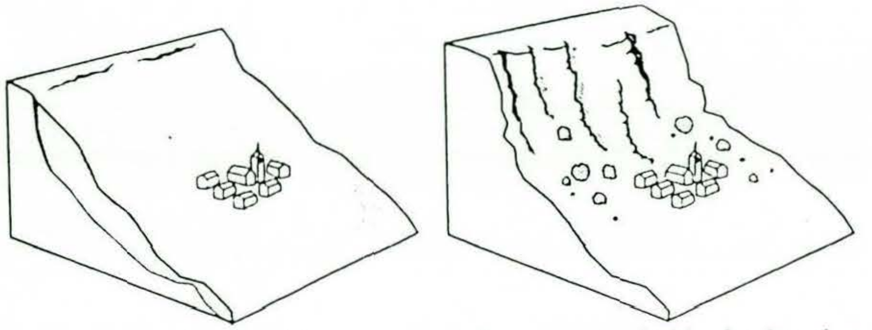
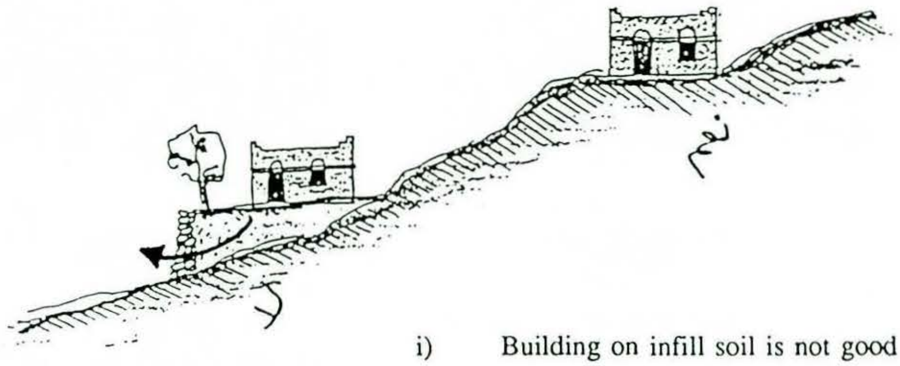
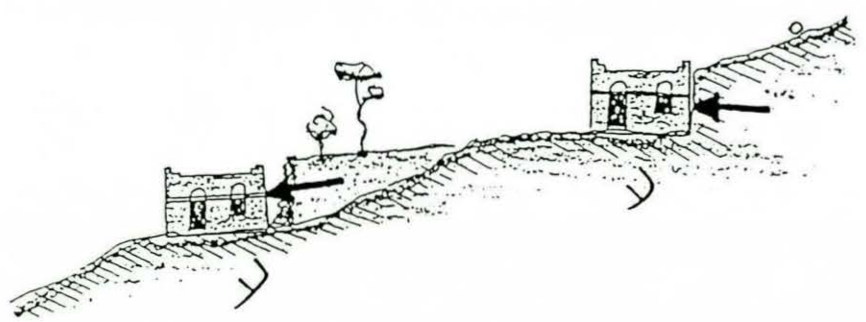


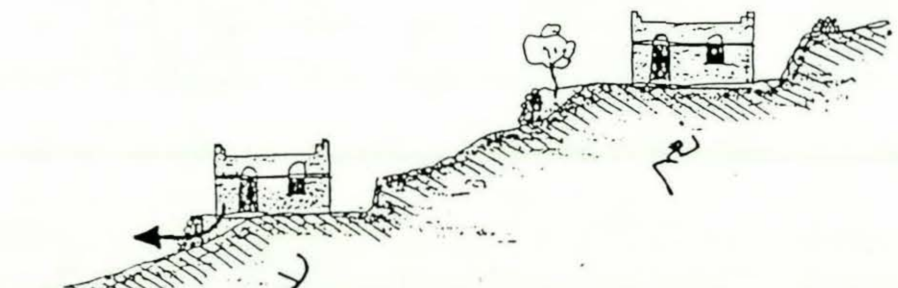
Figure 5.2: Sites exposed to landslides or rockfalls are not suitable for locating buildings



i) Building on infill soil is not good



ii) Building very close to a retaining wall is not good



iii) Building half on infill soil and half on hard soil is not good

Figure 5.3: Some safe and unsafe building sites
Sources: Coburn and Spence, 1992
Dhamar Aided Self-Help Project (DASH), Dhamar, 1988

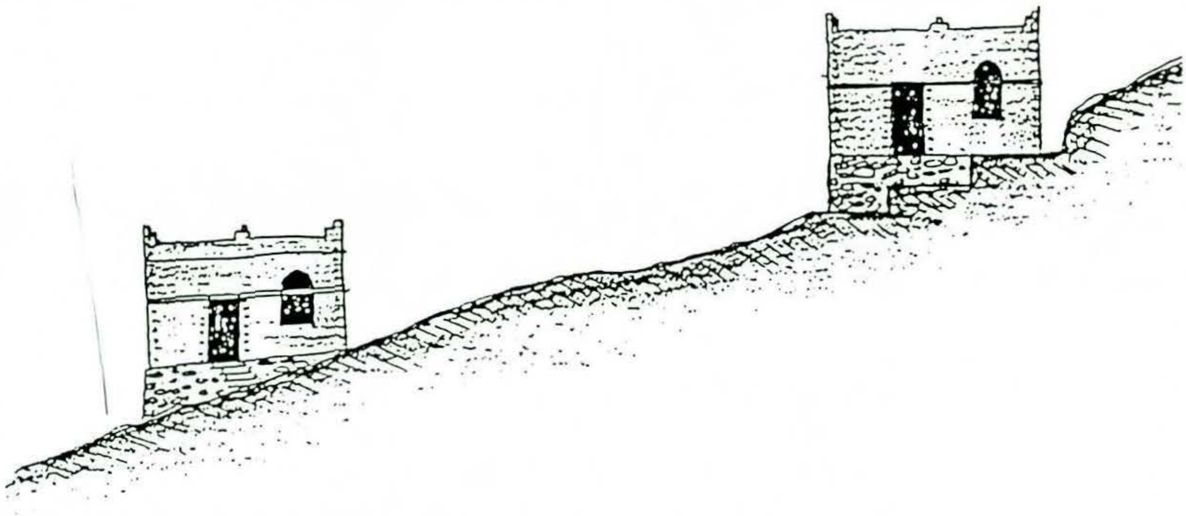


Figure 5.4: Sloping rock is an unsafe building location. Never build on a sloping rock. Make horizontal and flat steps for foundation.

scope of site investigation depends on the importance of the project and the amount of the budget available. It is also very important to know the depth of bedrock or strong rock-like material which is preferable for building foundations.

5.2.2 Distance between houses: New buildings, no matter how safely designed have a potential danger of damage in an earthquake if they are located very close to old buildings (DHV, 1988). Old buildings are usually not designed to resist earthquakes. Previous seismic shocks weaken such buildings and make them more vulnerable even if they do not have any apparent sign of damage. The old buildings become a serious threat in any future earthquakes and their close vicinity to new buildings creates an additional safety hazard (Figure 5.5).

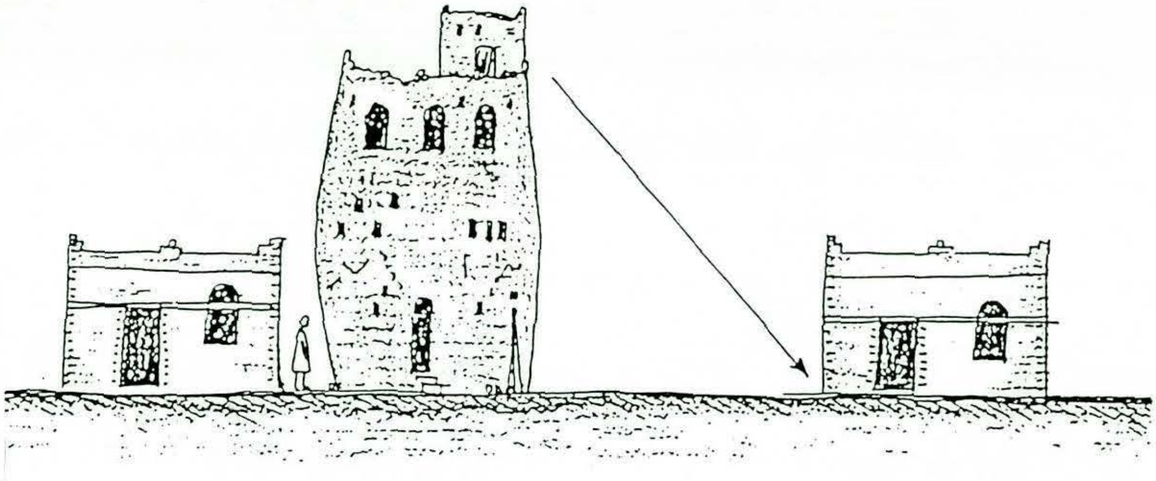


Figure 5.5: Close vicinity to an old vulnerable building is a hazard.
Source: Dhamar Aided Self-Help Project, 1986

5.3 Construction materials

The choice of construction materials is an important factor for earthquake-resistant structures (Dorwick, 1978). It is not always possible to get the desired materials. Their local availability, political and economic factors influence the selection criteria.

The following qualities desired in earthquake-resistant structures are closely related to the choice of construction materials:

5.3.1 Ductility: This is the ability of a structure to repeatedly distort or deform without collapsing. Ductility is also defined as the ability of the structural elements of a building to undergo considerable amounts of plastic deformation before failing;

5.3.2 *Stiffness*: It is the ability of a structure to resist any attempts by the earthquake forces to deform it. This quality is needed in a structure so that the displacements are within acceptable limits so that interaction between the structural and non-structural elements can be controlled. A very stiff building, however, tends to be brittle and may cause problems in avoiding resonance. *Stiff structures are suitable for long period sites.* Stiffness of a structure should therefore be related to the sub-soil properties of the site. Stiff structures (structures in which non-structural elements are integrated with the structural elements for unified resistance against earthquake forces) are mostly recommended to be built on long period sites because of their high response on such sites.

5.3.3 Flexibility: This property is related to the ductility of a structure. Fully flexible structures are those in which all non-structural elements such as doors, windows, in-fill panels, partitions, claddings, staircases and lift shafts are separated from the structural elements such as beams, columns and floors. The purpose of designing flexible structures is to make them as ductile as possible. Flexible structures are considered more suitable for short period sites where they have high response.

Infrastructure built with materials consisting of the following properties has better chances of withstanding an earthquake (Smith, 1994):

a) *high ductility* (ability of a material to deform after its maximum strength has been achieved without loosing its ability to carry load);
b) *high strength* (mild steel is one of the most well known materials known for its qualities of ductility and strength and is considered suitable for construction in seismic areas);
c) *low weight* (timber has the highest strength versus weight ratio);
d) *uniformity* in composition and strength;
e) *similar mechanical qualities* in all directions;
f) *orthotropy* (ability to resist earthquake forces in all directions)
g) *simple* in application or use; and
f) producing *good bond* when used with other materials.

The importance of these properties is related to the size and importance of a structure (Dorwick, 1978). For larger structures and important buildings like hospitals, airports, offices and market centres the above described material properties are certainly of greater significance than some other structures of less importance.

The choice of materials for construction in seismic areas largely depends on their availability and cost (Coburn and Spence, 1992). Rubble, stone, rammed earth, adobe, bricks or cement concrete blocks are low strength, low ductility and high weight building materials. These materials do not perform well against earthquakes when used without reinforcing steel or wood (Chin, 1980).

Table 5.1 shows the performance of various structural materials in different types of buildings. The order of suitability is only a guideline as the type of construction and the choice of material varies from area to area.

Table 5.1: Performance of structural materials in buildings

Structural materials in approximate order of suitability	Type of building		
	High-rise	Medium-rise	Low-rise
Best (1)	steel	steel	timber
(2)	in-situ reinforced Concrete	in-situ reinforced concrete	in-situ reinforced concrete
(3)		good precast concrete	steel
(4)		prestressed concrete	prestressed concrete
(5)		good reinforced masonry	good reinforced masonry
(6)			precast concrete
(7)			primitive reinforced masonry
Worst (8)			un-reinforced masonry (adobe, rammed earth, bricks, stones or blocks)

where: Low-rise = 1 to 3 storeys; Medium-rise = 4 to 7 storeys; and High-rise = 8 storeys or above.

Sources:
1. Dorwick, 1978.
2. Loyidos, 1993.

5.4 Configuration

The configuration of a building can be defined as the nature, size and location of the structural and non-structural elements which may affect the structural performance of a building (Smith, 1994). These elements consist of the following:

a) walls, columns, floors, staircases and service cores;
b) the number and type of internal partitions; and
c) how the external walls are built to allow air and light in the building.

It is now fully acknowledged that configuration, simplicity and directness of seismic resistance of a structure is as important as structural design for the lateral forces. Past experience has shown that structures with irregular configuration suffer more losses than those having regular configuration (Green, 1987). Plan irregularities are having L, H, U, T or similar shapes. Vertical irregularities are created by set-backs, unplanned and unsymmetrical openings such as doors, windows, etc. Most desirable configurations are square, rectangular or circular shapes.

Earthquake-resistant designs without emphasis on seismic detailing sharply increase the cost of a building because of the high content of steel reinforcement (in reinforced concrete designs) or steel members (in steel frame designs) required to achieve the desired level of strength (Arnold and Reitherman, 1982).

5.4.1 Safety requirements in a structure: As partly discussed before, a structure will have the maximum chances of survival in an earthquake, when:

a) the load bearing membersare uniformly distributed;
b) the columns and walls are without offsets;
c) all beams are free from offsets;
d) columns and beams are co-axial;
e) reinforced concrete columns and beams are of the same width;
f) the dimensions of principal members are not changed suddenly;
g) the structure is as continuous (redundant) and monolithic as possible;
h) there should be no soft storeys. Multi-storey buildings are usually provided with cross-walls or frame-infilling in the upper storeys which are mostly used for

residential or office purposes. The ground floors are however composed of columns only to allow space for car parking or commercial letting. Such open storeys are called soft storeys and they become a serious weakness for the entire structure because of the discontinuity in the structural form of the building.

i) there should be limitations in the plan-size and slenderness of a structure. The problems of plan-size and their possible solutions are discussed in Table 5.2. The slenderness (height-width ratio) of a building should not normally exceed 3 or 4. Special design considerations are required for higher slenderness ratios.

Figure 5.6 shows some of the desirable configurations.

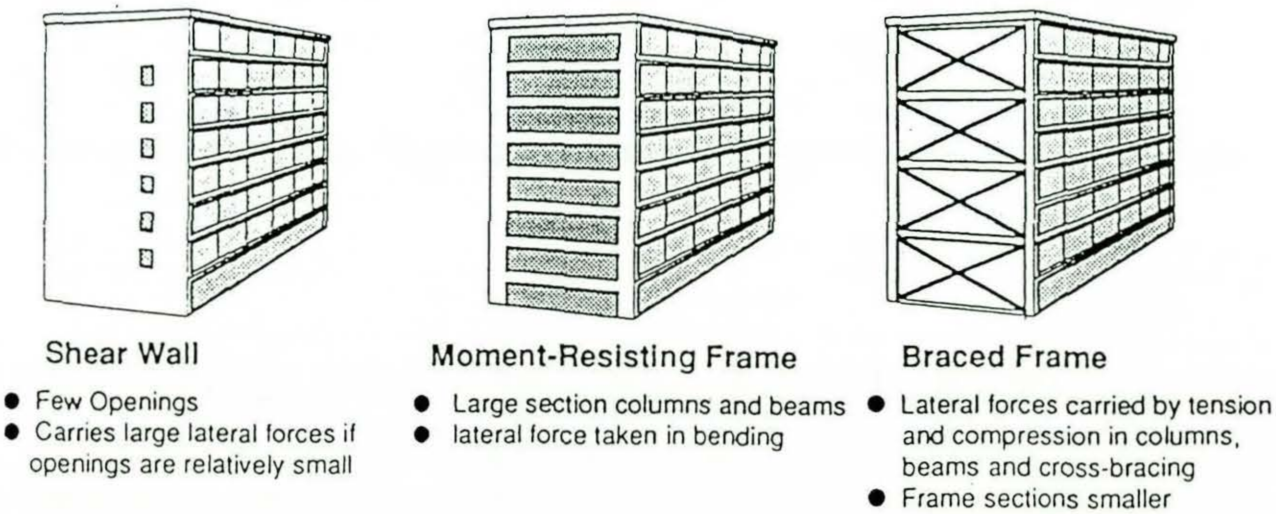


Figure 5.6: Some desirable building congfigurations
Source: Coburn and Spence, 1992

5.4.2 <u>Problematic configuration</u>: Configuration, directness and simplicity are extremely important for the safety of a structure during earthquakes. It is, however, not always possible to have an ideal configuration for various reasons. The problems of configuration and their possible solutions are discussed in Table 5.2.

Table 5.2: Configuration problems and possible solutions

Configuration problems		Architectural statement	Structural problem statement	Solution
Extreme dimensions				
a)	Extreme height-depth ratio	Planning or space problem	High over-turning forces, large drift	Revise dimensions or structural system
b)	Extreme plan area; large area-small height	Mostly ware-houses, shopping centres, offices	Large diaphragm forces	Sub-divide building by seismic joints
c)	Extreme elevation; large length-small depth	Mostly ware-houses, workshops and offices	Large lateral forces in perimeter to big difference in resistance of the two axes	Sub-divide building by seismic joints
Horizontal layout				
a)	Variation in perimeter strength-stiffness	Mostly in structures where some walls/ corners are blank and some with big openings	Torsion due extreme variation in strength and stiffness	Add frames; disconnect walls or use fames and light weight walls
b)	False symmetry	Mostly in offices and commercial building in cities to use open spaces	Torsion due to unsymmetrical core	Disconnect core or use frame with non-structural core walls
c)	Re-entrant corners	Mostly in old residential, hospitals and offices in urban areas	Torsion and stress concentration at the corner notches	Separate the joining walls or provide architectural relief at the inner notch
d)	Mass eccentricities	Book stacks in libraries, equipment or elevated swimming pools	Torsion and stress concentration	Add resistance around mass to balance resistance and mass
Vertical layout				
a)	Vertical and reverse set-backs	Mostly due to programme or site limitations	Stress concentration at the notch, disorderly periods	Special structural system and dynamic analysis
b)	Soft storey frames	Mostly for ground-floor car parking or shopping or fashion	Abrupt change of stiffness at point of discontinuity	Add bracing or columns or both as per requirement
c)	Variations in column stiffness within a storey	Due to need for variety in spaces or for fashion	Abrupt change in stiffness, higher forces in stiffer column	Re-design structure to balance system
d)	Discontinuous shear wall	Planning restricts use of shear wall on entrance floor or for fashion	Discontinuity in load path; stress concentration for heavily loaded elements	No solution except redesigning the whole structure
e)	Weal column-strong beam	Common where large window-area exists like schools, hospitals and offices	Columns fail before beams	No solution except add full walls to reduce spade
f)	Modifications in primary structure	Major/minor changes in structure to accommodate additional needs	Serious when modifications make changes in-fill panel arrangement	Remove in-fill panels or use light weight material for in-fill columns
Adjacency				
a)	Building separation	Structure with set-backs	Pounding may occur depending on building period, drift height and distance	Ensure adequate separation considering opposite building vibrations
Shear walls				
a)	Coupled	Mostly in building corridors for architectural purposes only	Deformation between walls and links not same	Links should be redesigned to ensure compatible deformation with walls
b)	Random openings	Windows, doors, ducts and other openings according to actual needs	Transfer of earthquake forces is restricted	All openings should be pre-conceived in design and duly reinforced for non-linear behaviour

Continued ...

Table 5.2: Configuration problems and possible solutions

Configuration problems		Architectural statement	Structural problem statement	Solution
Diaphragm				
a)	Openings	For vertical circulation of air or light arrangements	Seriously reduces diaphragm resistance capacity	Should be pre-conceived during design & reinforced for non-linear behaviour
b)	Shape	Mostly for circulation of air and light	Seriously reduces diaphragm capacity at critical position	Should be pre-conceived during design & reinforced for non-linear behaviour
c)	Tower	A set-back, mostly for architectural decoration	Diaphragm at set-back must be able to transfer full tower loads	Design should pre-conceive this problem and reinforce diaphragm accordingly

Source: Arnold and Reitherman, 1982.

It will be seen from Table 5.2 that it is extremely important to design the configuration of a structure before embarking on structural design. Irrational configuration can seriously handicap the capacities of diaphragms and shear walls in resisting earthquake forces, no matter how well the structural design is prepared. While some of these problems can be solved through modifications the others cannot be rectified after a structure is built. Such buildings always remain at far more risk than those which are designed with the consideration of configuration.

5.5 Earthquake-resistant design considerations

The occurrence and behaviour of earthquakes is mostly unpredictable. The only reliable knowledge about seismic loads is that they are predominantly horizontal and dynamic in character (Loyidos, 1993). Vertical dynamic loads can be of significance only near the epicentre. No clear knowledge about the amount of energy released, the direction of movement, and the frequency and duration of an earthquake is available. The response of a structure to seismic forces depends on a number of factors, such as the period of vibration, damping, ductility, and the type of soil on which the structure is built. A combination of these factors and some more, make earthquake-resistant design a difficult task.

5.5.1 Basic principles in earthquake-resistant designs: Earthquake-resistant designs are based on the following essential features (Dorwick, 1978):

a) In framed structures columns should be designed stiffer than the beams so that the beams will absorb the earthquake energy and fail before the columns. In this way damage to the structure and the resultant losses is much reduced;

b) failure should be in flexure instead of shear;

c) premature failure of joints between the structural elements should be prevented as early failure of joints will mean early collapse of the structure, no matter how well the elements are designed; and

d) ductile rather than brittle failure should be obtained as ductile structures are better absorbants of earthquake energy. Should a failure occur, ductile structures are likely to suffer less damage than brittle structures.

Earthquake motion has both vertical and horizontal components. Normally only the dominant horizontal motion is considered for design purposes. For earthquake-resistant design of large structures however, vertical motions should also be taken into consideration (Architectural Institute of Japan, 1970).

5.5.2 What the seismic design codes say about structural design: The present design codes used in most countries of the world can be summarised as follows:

a) seismic forces acting on a structure shall be determined as equivalent static loads using the statistically evaluated seismic coefficient or the shear force coefficients. Sectional dimensions of the elements shall be determined from the stresses and strains caused by these equivalent loads;

b) seismic forces acting on a structure shall be determined from the response spectrum considering various factors such as the ground characteristics, natural periods and damping coefficients of buildings (Figure 5.7). Deflection and the storey shear force can then be calculated and stresses and sections of each element determined; and

c) considering subsoil conditions, earthquake motions shall be selected from past strong earthquake records and by means of structural response analysis from them, the sections shall be revised after considering the amount of deflection and stresses.

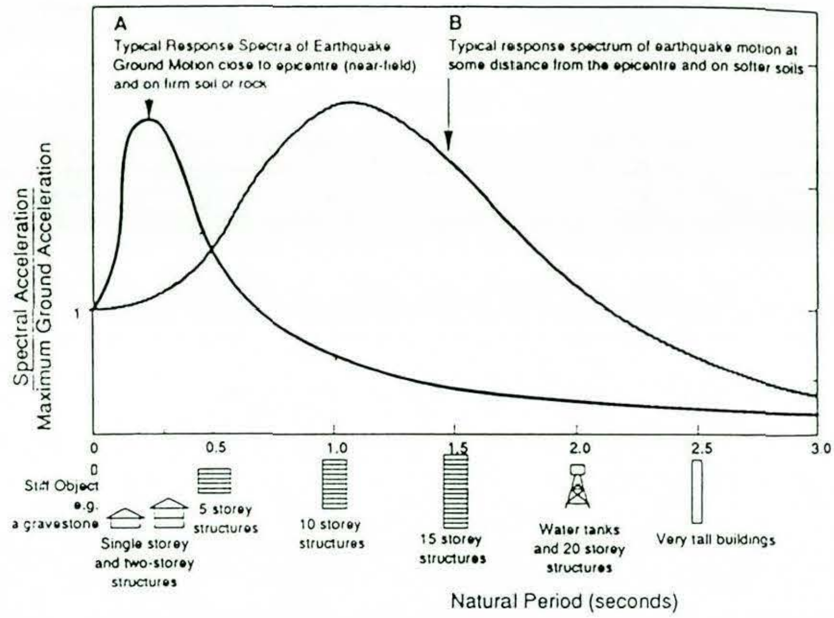


Figure 5.7: Typical diagram showing response spectra of earthquake ground motion

Certain problems such as energy dissipation between the ground and foundation, implication factor of the ground, and the relationship between previously recorded ground motions and those statistically expected in future are still unresolved. These problems make the determination of the earthquake motions, which act at the bottom of buildings, difficult (Figure 5.8).

5.5.3 Structural and non-structural elements: **It** is important to know the functions and importance of structural and non-structural elements of a building to understand their roles in resisting seismic forces. The following is a brief description of these elements.

5.5.3.1 *Structural elements*: The structural elements considered to be of great significance in the safety of a structure, are described below:

a) **Diaphragms**: The elements of a structure which offer horizontal resistance (floors and roofs) to lateral forces and transfer them to the vertical members are called diaphragms. A diaphragm acts as the web of a beam and its edges as the flanges. Diaphragms are interrupted by several other members such as staircases, elevators, skylights, ducts, etc. Detailing of all these members is necessary for safe design of buildings.

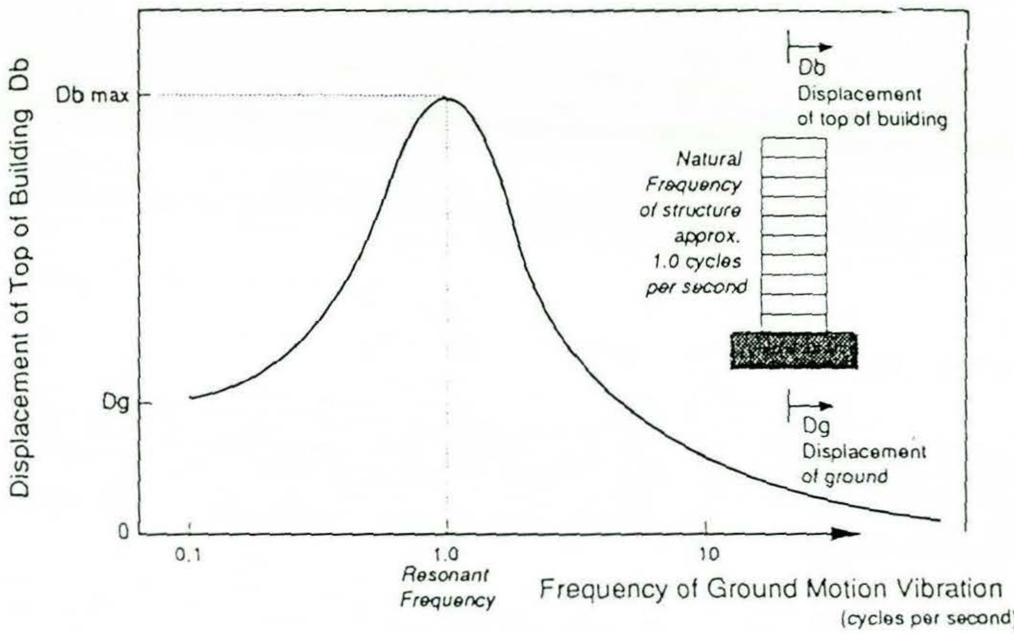


Figure 5.8: Frequency of ground motion vibration directly affects its displacement
Source: Coburn and Spence, 1992

b) **Shear walls**: Vertical cantilever walls designed to receive lateral forces from diaphragms and transmit them to the ground are known as shear walls. The forces in these walls are predominantly shear forces. Slender shear walls may also be subjected to bending apart from shear forces. The safety of a structure requires that its shear walls should be able to resist torsional forces which try to rotate the structure during an earthquake. The size and location of shear walls is crucial for the safety of buildings.

c) **Braced frames**: The function of braced frames is similar to that of shear walls. In braced frames, the bracing members transmit the horizontal forces in tension and compression. Such frames can be very stiff. They are considered useful only for the external walls of a structure. Braced frames usually provide less resistance than shear walls. Braces are generally made from steel rolled sections, circular bars or pipes. Earthquake forces cause the bracings in a structure to expand or to contract. When resistance in the braces is not enough to check the earthquake forces the expansion or contraction in the braces is so much that they loose their effectiveness. This failure results in deformation or collapse of the vertical structure.

d) **Moment-resisting frames**: In this type of frame the horizontal forces are transmitted by bending moments in their columns and framing beams. A moment-resisting frame can be designed by using reinforced concrete to be as strong as required. Moment-resisting frame structures tend to be more flexible than braced or shear walled structures.

5.5.3.2 *Non-structural elements*: An appreciable amount of damage caused to structures during earthquakes is due to its non-structural members (Dorwick, 1978).

An understanding of non-structural elements and their performance in earthquakes is necessary because a great deal of a building's inherent resistance to lateral forces is determined by its layout. It is important to note that some non-structural elements become very responsive to the lateral forces during earthquakes. This means that any member or element of a structure which resists the forces generated by an earthquake deserves full consideration in its design and placement. Non-structural elements, such as in-fill and partitions walls are insignificant in their seismic performance if they are made of flexible materials. But if these elements are made of rigid materials, such as brick masonry or concrete, they may have a significant effect on the performance and safety of a structure during an earthquake. The effects which the non-structural elements create during earthquakes can be summarised as follows:

a) influence on the natural vibration period of the structure by changing seismic energy and seismic stresses for which the structure is originally designed;
b) change in lateral stiffness of the structure and stress distribution;
c) premature failure of the structure by pounding; and
d) serious damage to the non-structural elements themselves from pounding causing life and property losses within the building.

The following principles are usually applied in the seismic detailing of non-structural elements:

a) **Infill panels and partitions**: Earthquakes produce differential movements in every floor which is in relation to the adjacent floors of a multi-storey structure. This phenomena is called storey drift. Vertical deformations in the height of each storey, between floors and beams occur in this period. Infill panels are designed to counter these movements and their overall response on structural frames is as follows:

i) to increase stiffness and hence the base shear response during earthquakes;

ii) to increase the overall energy absorption capacity of the structure; and

iii) to alter shear distribution in the entire structure.

There are two approaches as follows:

i) **Integrating infill panels with the structure**: The influence of non-structural members increases with the flexibility of the main structure. Negative influence of non-structural elements in stiff structures can be controlled by including them in the structural design. In this way the non-structural members no longer remain non-structural and perform together with the structural members during an earthquake.

ii) **Separating infill panels from the structure**: This method of restraining the influence of shear stiffness of non-structural members is applicable to flexible structures. In this method gaps are left between non-structural and the structural members above them and the two are linked together using dowels (hooks made of reinforcing steel, partly embedded in the non-structural member and partly in the structural member immediately above). The remaining gaps are filled with flexible materials such as putty. In this way the non-structural elements are allowed minimal influence on the seismic performance of the structure.

The above solutions are more effective when applied together with the considerations for seismic detailing or configuration.

c) **Cladding, curtain walls, doors and windows**: Like infill panels, cladding or any other non-structural item such curtain walls, doors and windows should also be installed with the same principles of either integrating them with or separating them from the structure.

5.5.4 <u>Design considerations</u>: Most building codes require that a structure should be designed to be safe against dead loads (self-load of the building together with the load of any other immovable item such as equipment), live load (human beings and animals, if any), snow load, soil pressure, water pressure and seismic load (Architectural Institute of Japan, 1970).

5.5.4.1 *Orthogonal effects*: Earthquake forces act in both principal directions of a structure but do not attain their maximum value at the same time (Green, 1987). This phenomenon is called orthogonal effects. The American based Applied Technology Council (ATC) code 3-06 on earthquakes suggests that structural elements should be designed for 100% of the effects of the seismic forces in one principal direction and 30% in the other principal direction.

5.5.4.2 *General requirements for static analysis*: There are certain essential requirement for an earthquake-resistant structure. These requirements make it necessary to have adequate vertical bracing elements, in the form of either frames or shear walls which provide stability to the structure by transmitting all earthquake forces to the ground (Green, 1987). There must also be the diaphragms to tie the structure together and transfer all lateral forces to the vertical bracing elements. A continuous path is necessary for transmitting each lateral force from its origin to the ground. The point of origin of a seismic force is the centre of gravity of the mass which is being accelerated. The vertical bracing elements must be supported on a foundation capable of resisting all downward loads, possible uplifts and horizontal shear forces. The footings should be tied together to prevent any relative horizontal movements.

a) **Distribution of earthquake forces without torsion**: Structures with reinforced concrete floors and roofs are usually considered to be diaphragms which are rigid under the action of the distributing forces acting in the same plane as the diaphragm. It is assumed that deformation of a diaphragm within its plane is insignificant to alter the load distribution. This means that there is no horizontal rotation of the diaphragm due to torsion. If the bracing elements in a structure are all of the same type, either shear walls or frames, the total lateral load will be distributed to these elements in proportion of their rigidities or stiffness factors (the stiffness factor of a structural element is the force required to produce a unit deflection). If a bracing system includes both shear walls and frames a different method of load distribution shall be used.

b) **Beam and column frames**: A commonly known vertical bracing system is the frame with moment resisting beam to column connections sometimes known as the rigid frame (for more detail refer to sub-section 5.5.3).

If there is no torsion and there are no shear walls the earthquake load may be distributed to the frames in proportion to their stiffness factors. The stiffness factor is equal to the triangular load which produces a unit deflection at the top of the frame. The triangular load varies from maximum at the top to zero at the ground. This load is used as the equivalent static force for the seismic design method.

c) **Shear walls without openings**: Shear walls (also see sub-section 5.5.3) are built either alone or together with frames to give more stiffness to a building. A shear wall acts as a vertical cantilever beam which goes through a lateral deflection due to bending and shear. If the walls have no openings or the openings are small the bending deflection will predominate. If the relatively small shear deflection is ignored the stiffness factor of the shear wall is proportional to the moment of inertia of a horizontal section of the wall.

The walls of elevator shafts, stairwells and central cores are frequently designed as shear walls and they seldom have any openings. The walls between adjacent properties are also usually without openings. If shear walls are to be used as bracings, it is important that they do not have openings. Shear walls with openings create serious problems in structural design.
Deflection of a wall is primarily due to bending but may be influenced by rotation of a foundation which on compressible soils. This effect can be countered by using foundations under the shear walls which will reduce the rotation to a minimum. A combined footing with a large moment of inertia is mostly preferred for compressible soils (Green, 1987).

d) **Combination of shear walls and frames**: If a bracing system without torsion consists of both shear walls and frames, the load cannot be distributed proportionately to their stiffness factors because their modes of deflection are not the same. Shear walls prominently deflect in bending and this deflection is more in the case of a frame. For a combined system the beams connecting shear walls to frames in the same plane should have hinged type connections. The interaction between the two types of structures is thus reduced to a system of horizontal forces.

e) **Distribution of forces with torsion**: Horizontal torsion exists at any floor of a building if the direction of the total resultant seismic force above the floor does not intersect the vertical line through the centre of rigidity of the vertical bracing elements at that floor. An earthquake-resistant design usually considers the resultant seismic force acting in the direction of each major axis and either or both forces may produce torsion.

d) **Dynamic analysis**: Static analysis methods are not considered very accurate for large structures and quite often dynamic analysis becomes a necessity (Dorwick, 1978). Dynamic analysis for the design of earthquake-resistant structures is done by using an accelerogram. Various complex methods have been developed for dynamic analysis of structures. The solution of the equations of motion and the usual statistical relationships of equilibrium and stiffness are common in them. Computer analyses is done by the matrix methods for structures with more than three degrees of freedom.

Three main techniques used in dynamic analysis are named as follows:

- direct integration of the equation of motions through step-by-step procedures;
- normal mode analysis; and
- response spectrum techniques.

It is difficult to provide clear advice on the use of a certain method for seismic analysis and design of structures as there may be several limitations in practice, such as the shortage of technical staff, lack of finance and statutory regulations. In general, however, it can be said that the sophistication of dynamic analysis required increases with the size and complexity of a structure. Table 5.3 is a simple guideline for the applicability of analytical methods for preparing earthquake-resistant designs.

Table 5.3: Guidelines for analysing different structural designs

Type of structure	Method of analysis
Small simple structures	(1) Equivalent static forces (use appropriate code)
	(2) Response spectra (use appropriate spectra)
Moderately large and demanding structures	(3) Modal analysis (use appropriate dynamic input)
	(4) Non-linear plane frame (use appropriate dynamic input)
Large complex structures	(5) Non-linear 3-D frame (use appropriate dynamic input)

Source: Dorwick, 1978.

5.6 Construction controls

A strong physical infrastructure is probably the best protection against earthquakes (Coburn and Spence, 1992). The quality of construction of structures is of immense importance for resistance against earthquakes. Minimum design and construction standards approved through legislation can be regarded as the first step in minimising future earthquake risks. These codes should remain under constant review for inclusion of any new techniques for earthquake-resistant structures. These codes should be made part of the syllabi at the polytechnics, and universities teaching civil engineering.

Apart from academic application of building codes, the supervision and monitoring of construction works, to ensure the desired levels of quantity and quality of materials and workmanship at site are equally important.

Summary

It is ironical that the first serious considerations to the earthquake hazard were given after the 1906 and 1923 earthquakes in the USA and Japan, and once again the earthquake experts are busy in reviewing the established theories after the 1994 and

1995 earthquakes in the same countries. It is difficult to prescribe any exact guidelines for the safety of buildings, because of the unpredictable (or still unknown) behaviour of the earthquake forces. There are, however, some important considerations which can be helpful in the safety of a building. These considerations are location, construction materials, configuration, structural design and construction controls of a building. What is more important for the people living in earthquake zones, is to have an awareness about the earthquake hazard and to apply the safety measures while constructing their houses and other buildings.

Chapter Six

Chapter Six

GENERAL CONSIDERATIONS FOR RISK MANAGEMENT IN SEISMIC DESIGNS

"It is widely accepted that sufficient resources are never available to remove every possible risk no matter how trivial it is. Depending upon availability of resources, we have to set our priorities as to which risk should be removed first".

(Trevor Kletz, 1988)

The rising number of earthquake disasters around the world has made the study of earthquake-resistant design a major concern for planners, engineers and architects. Seismic designing is becoming more sophisticated and thought provoking as further research continues in this field. This positive change has revised the concept of professional liability and responsibility (Arnold and Reitherman, 1982). According to this new concept seismic designs should not only be earthquake-resistant but should also be acceptable and affordable for their users.

Earthquakes occurring in urban areas of high-income or higher middle-income countries are excessively costly (The Economist, 1995). The Northridge earthquake of 1994 with 57 human casualties and over US$ 20 billion losses is considered to be the costliest earthquake in American history. Financial losses suffered in the recent (January 1995) earthquake in Kobe are initially estimated at US$ 110 billion and may go further up in the range of US$ 150 to 200 billion which is about 4% of Japan's annual gross domestic product (GDP). The number of dead in this earthquake is 5,470 while the number of homeless is 310,000. Similar disasters in low-income or lower middle income countries however cause even more severe blows to their economies, and form a larger part their GDP and usually cancel out any real economic growth. The effects of earthquakes must therefore be viewed, not only in humanitarian terms, but also in social and economic terms (UNDRO, 1978).

The people living in high-income or higher middle-income countries may be able to financially afford, and may be willing to pay for the high cost of earthquake-resistant steel framed or reinforced concrete structures because of their awareness of earthquake risk. Their awareness is probably due to the high literacy in such countries. But most of the people in low-income or lower middle-income countries are poor. They represent about 80% of the world's population (The World Bank, 1995). Most of them cannot afford the high cost of earthquake-resistant houses capable of withstanding severe earthquakes.

Field surveys in Yemen and study of other low-income countries, having suffered from earthquakes in recent years, suggest that even those who may afford such high costs are not willing to pay due to their conservatism, and lack of awareness of the usefulness of earthquake-resistant designs. What is needed in a situation like this is to introduce designs which are safer against earthquakes and not too alien from the traditional designs. The degree to which an engineer or an architect should go in preparing earthquake-resistant as well as affordable and socially acceptable structural designs, requires understanding of some essential terms given in the following section.

6.1 Definitions

UNDRO (1980) has classified various concepts and terms related to the earthquake hazard as follows (Figure 6.1):

6.1.1 Hazard: The probability of occurrence of an earthquake of a certain severity, within a specific period of time, in a given area is known as earthquake hazard. An earthquake may be specified in terms of its source characteristics such as *magnitude* or its effects observed in a particular area such as *intensity*, *peak ground acceleration (PGA)* or similar characteristics based on ground motion.

6.1.2 Risk: The expected number of elements at risk such as lives lost, persons injured, property damaged, social and economic activities disrupted in a specified future time is termed as earthquake risk. Jones-Lee (1989) defines risk more or less in the same way by saying that, it is the extent of an individual's exposure to the possibility of death or injury in a specified time.

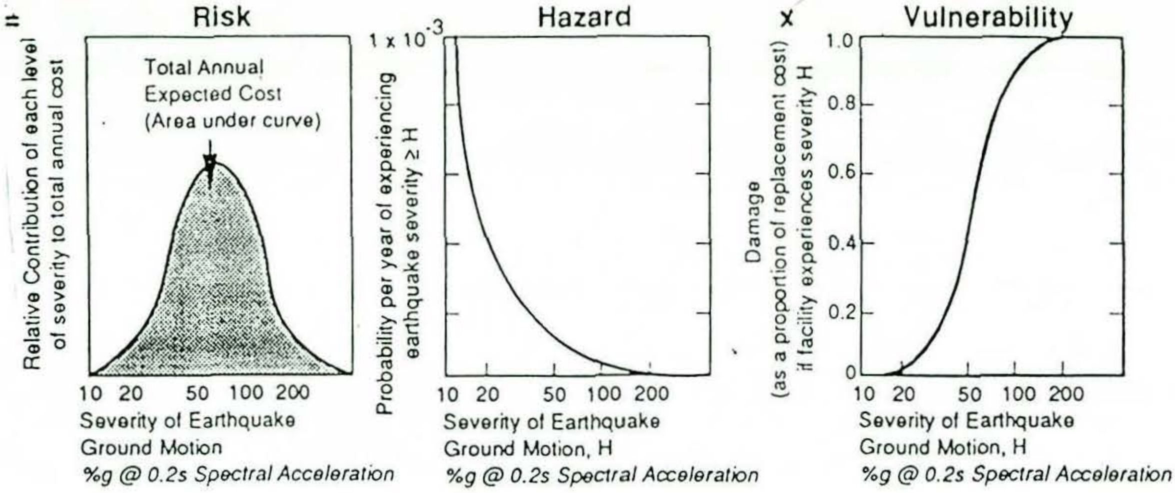


Figure 6.1: Risk, hazard and vulnerability
Source: Coburn and Spence, 1992

6.1.3 Vulnerability: The degree of loss to a given element at risk or a set of such elements resulting from the occurrence of a hazard, such as occurrence of an earthquake of a given severity is called vulnerability. Vulnerability of an element can also be defined as the ratio between expected loss and maximum possible loss.

6.1.4 Probability: It is a number between zero and one, indicated in percentage which represents a judgement about the perceived likelihood of the occurrence of an event such as an earthquake. Zero implies that the event is impossible, while the figure one indicates that the event is certain. Probability can therefore be defined as the degree of possibility of an event between the extreme limits between impossibility and certainty.

Mathematically risk can be expressed by the following formula:

$$R_{ij} = H_j \times V_{ij}$$

in which R_{ij} is the risk to an element, such as building *i* due to the earthquake ground motion of severity *j*. H_j is the hazard or probability of experiencing earthquake ground motion. V_{ij} is the vulnerability or the level of loss which will be caused to the element at risk *i*, as a result of experiencing ground motion severity.

6.1.5 Safety: Safety can be defined as the degree of protection, from attenuation of physical risk (Jones-Lee, 1991). While talking about safety, it usually means the safety of human life.

6.2 Vulnerability assessment

It can be seen from the above formula that risk to any structure, or the occupants of that structure is a direct function of vulnerability. This means that greater the vulnerability of a structure, higher the risk for the structure and its occupants in the case of an earthquake.

Two well known methods of assessing vulnerability are *predicted* vulnerability and *observed* vulnerability (Coburn and Spence, 1992).

Predicted vulnerability deals with expected performance of building's design specifications and judgement of the assessor. This method is preferred in case of engineered structures build with proper designs and engineering calculations.

Observed vulnerability is based on statistical data available from the damage caused by past earthquakes. This method is more suitable for determining the vulnerability of non-engineered structures, made of low-strength material such as adobe, unreinforced masonry, timber whose earthquake-resistance is difficult to find out.

Apart from design there are other equally important factors which influence the performance of a structure during earthquakes. Knowledge of these secondary factors is also very important in assessing vulnerability of a structure. Table 6.1 shows the secondary vulnerability factors.

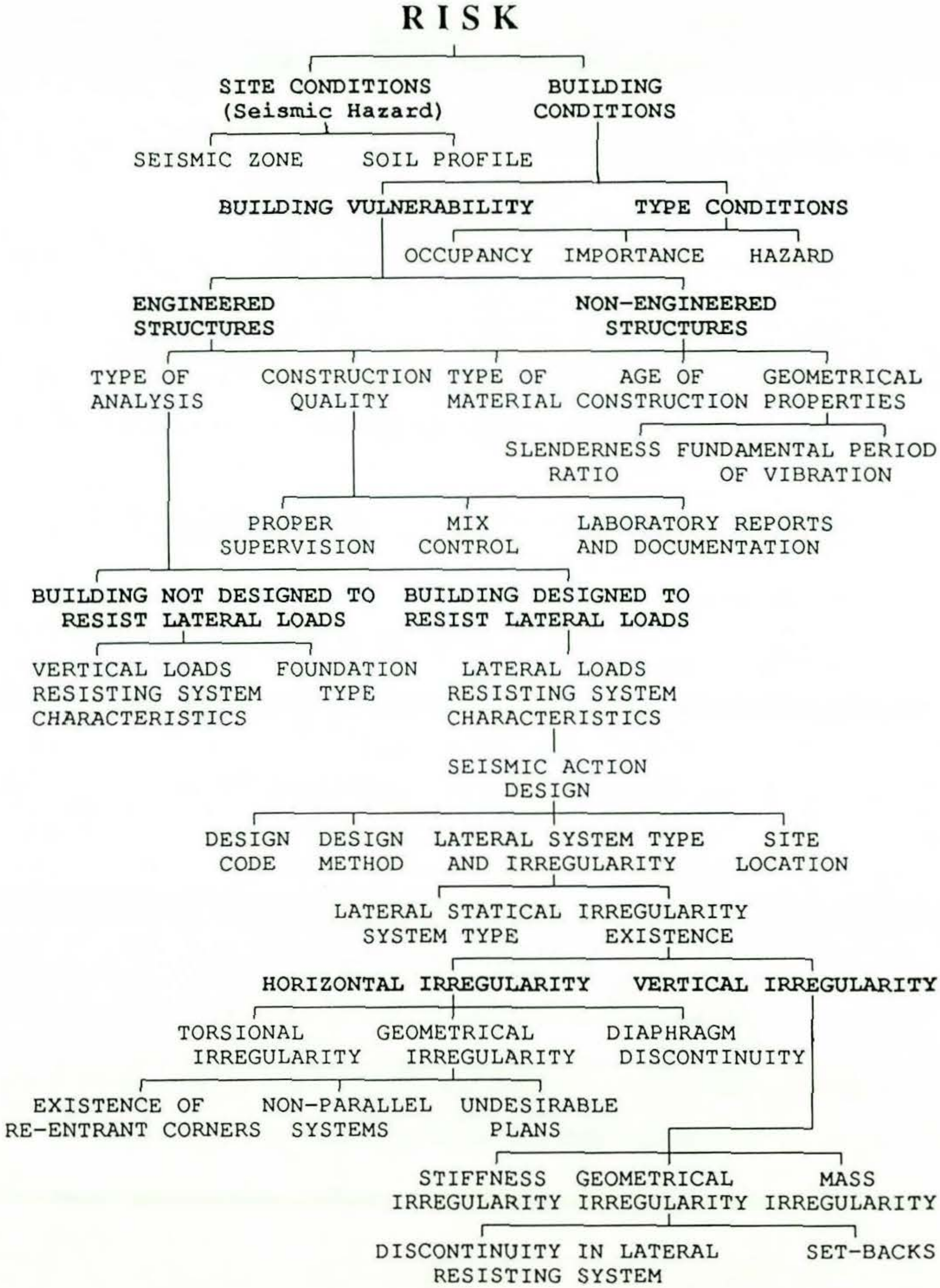
Table 6.1: Secondary vulnerability factors of structures

No	Secondary factors
	Structural form
1	Non-symmetrical or irregular plans.
2	Differences in architectural plans and stiffness of various storeys particularly in the case of framed
3	structures. Number of storeys and stiffness of structure and its effect on natural period and dynamic characteristics of structure.
4	Single directions of strength such as all load bearing walls in one direction and building orientation with respect to direction of the seismic forces.
5	Excessive wall openings leaving insufficient wall area to resist shear. This is more common in masonry structures.
6	Heavy roofs and disposition of loads with height.
7	Depth, adequacy and frost protection of the foundations.
8	Design faults. Good practices such as alignment of vertical load bearing members not followed.
	Site planning
1	Stiffening effects of adjacent buildings.
2	Pounding effects due to collision of adjoining buildings.
3	Subsoil quality causing liquefaction.
4	Slope effects causing subsidence and weakening buildings.
5	Local ground failures causing landslides or rockfalls further exacerbated during earthquakes.
	Construction quality
1	
2	Use of low quality building materials not conforming with specifications in emergencies.
3	Poor workmanship. Ignorance of good practice and details.
4	Deliberate neglect of specifications due to corruption.
	Mixing building materials of different seismic performance.
	History
1	
2	Decay and weakening of materials such as wood and steel due to old age.
3	Structures weakened by previous earthquakes or other shocks.
4	Quality of repair, maintenance and strengthening measures.
	Modifications, additions and alterations affecting building configuration and overall behaviour of the structure during earthquakes.

Source: Coburn and Spence, 1992

6.3 Seismic risk domain tree

The seismic risk to different structures depends upon a number of factors, such as site conditions, building conditions, whether the buildings are engineered or non-engineered structures, whether the configuration is aseismic or not, what is the quality of construction, etc. All these considerations are extremely important in the design of earthquake-resistant structures. The degree to which all or any of these factors are considered also indicate the degree of risk to which a structure is vulnerable in the case of an earthquake. The factors responsible for seismic risk to structure are shown in the seismic risk domain tree given in Figure 6.2.



Source: Sadek et al, 1994.

Figure 6.2: Seismic risk domain tree

6.4 Damage evaluation

Assessment of structural damage to a building is not an easy task because of their different mechanisms and different materials. The construction materials can range from adobe, stones or bricks to wood, reinforced concrete and steel frames. Structural damages such as the cracking of the masonry, sapping or joints deterioration in wood, and the failure of reinforced concrete or steel frames present damage of different natures which can be hard to compare.

6.4.1 Repair cost ratio method: One way of assessing structural damage is in financial terms and the method is known as the repair vs cost ratio. According to this method structural damage is quantified by comparing the cost of the structure with respect to the cost of repair. This method is however not considered very satisfactory because of the following problems:

a) dependence on prevailing economic situation;
b) artificially high or low prices of certain materials due to short or excess supply of those materials at a given time;
c) variation of material costs from place to place;
d) variation of labour costs from place to place;
e) different ways of repairing and strengthening;
f) price variations from one period to another; and
g) nature of repair being different for different type of structures.

The other method is based on direct assessment of structural damage.

6.4.2 Structural damage assessment method: This method categorises different states of structural damage for different types of materials which can be used for working costs at any time, and at any place. Other factors contributing to economic losses such human life casualties, homelessness, unemployment etc. can also be linked up by this method. Table 6.2 briefly shows damage descriptions.

Table 6.2: Description of structural damage

Category (C) and damage degree (D)		Nature of damage to different structures	
C	D	Load-bearing masonry	RC framed structures
0	Undamaged	No obvious damage	No obvious damage
1	Slight damage	Hairline cracks	Infill panel damaged
2	Moderate damage	Cracks 5 to 20 mm	Cracks < 10 mm in structure
3	Heavy damage	Cracks > 20 mm or wall material removed	Heavy damage to structural members, falling of concrete
4	Partial destruction	Total collapse of individual walls or a support below roof	Total collapse of individual structural member of major deflection of frame
5	Collapse	More than one wall or more than half or roof collapsed	Failure of structural members causing fall of complete roof or slab

Source: Coburn and Spence, 1992.

6.5 Damage distribution

In most of the moderate to severe earthquakes, the structures suffer a variety of damage. Table 6.3 shows probable damage distribution in structures. Besides giving the probability of damage in different earthquake intensity, the table provides a relatively simple method for estimating cost of damage to the structure. In this method, the total estimated cost of structure is multiplied by the central damage factor (CDF), expressed in percentage of the total cost to arrive at the probable repair or reconstruction cost.

Table 6.3: General form of damage probability matrix

Damage state	Central damage factor (%)	Probability of damage (%) by intensity						
		VI	VII	VIII	IX	X	XI	XII
1	0	95	49	30	14	3	1	0.4
2	0.5	3	38	40	30	10	3	0.6
3	5	1.5	8	16	24	30	10	1
4	20	0.4	2	8	16	26	30	3
5	45	0.1	1.5	3	10	18	30	18
6	80	--	1	2	4	10	18	39
7	100	--	0.5	1	2	3	8	38

Key to the extent of damage:

1:	**None**:	
2:	**Slight**:	Limited damage not necessary to be repaired;
3:	**Light**:	Appreciable localised damage but usually not serious enough to warrant repair;
4:	**Moderate**:	Significant localised damage requiring repair;
5:	**Heavy**:	Extensive damage requiring major repairs;
6:	**Major**:	Widespread serious damage requiring complete rehabilitation;and
7:	**Collapse**:	Total destruction of most the structure necessitating reconstruction.

Source: Coburn and Spence, 1992.

Other methods of assessing damage distribution are through expert opinion survey and by using PSI scales of intensity.

6.5.1 Expert opinion survey method: This method is based on asking a number of experts about the extent of damage to a structure considering different class of buildings and different levels of earthquake intensities. The consensus of the opinions of these experts is taken as the probable damage.

6.5.2 Parameterless scale of intensity (PSI) method: The PSI method involves aggregating damage data relevant to the structures under consideration at the given levels of earthquake intensity. The probabilistic application of these data can then be applied to predict future damage to similar buildings, having the same age and similar ground conditions, for a recurrence of that intensity. Such detailed data for all types of buildings are however scarce. Most of the information collected in this regard is an aggregate of data gathered from different countries and from a number of earthquakes. This method is considered to be reasonably reliable because all seismic intensity scales assume that the performance of similar type of buildings under similar conditions of foundation soil, configuration, etc., is similar irrespective of their location. There can however be differences in recording observations and classifying intensities by different survey teams visiting different earthquake affected areas at different times. This difficulty can be overcome by using a large number of damage surveys and eliminating any unreliable data. Damage distribution diagrams for various type of construction are prepared from these data to assess the damage distribution.

6.6 Human casualty estimates in economic terms

The foremost purpose of earthquake protection is saving human life, although huge infrastructure losses accompanying large earthquakes cannot be ignored (Valery, 1995). Casualty estimation is more difficult than property loss estimation, because of extreme variations from one disaster to another. Death tolls in earthquakes of same intensities, in low-income countries are usually far more than high-income countries, mainly because of non-engineered structures built in unsafe locations and on poor foundation soils. Casualties can be due to building collapse, automobile and other machinery accidents, heart attacks, and secondary disasters such landslides, liquefaction, subsidence, rockfall and fires. Earthquake records show that building collapse alone accounts for 75 to 90% of the total human casualty (Coburn and Spence, 1992).

The following equation is derived to express casualties in a given earthquake disaster:

$$K = K_s + K' + K_2$$

in which K_s is the number of persons dead due to structural damage, K' represents the deaths caused by non-structural damage and K_2 represents the figure for secondary disasters. In severe earthquakes K_s is the dominant factor in the overall value of K but in moderate earthquakes the other components K' and K_2 are quite variable.

6.7 Lethality ratio

Lethality ratio is defined as the number of people killed with respect to the number of buildings collapsed. If this relationship is reasonably established, it is easy to determine the number of people killed in an earthquake by counting the number of buildings collapsed. Ks can therefore be further elaborated by the following formula:

$$K_s = D_5 \times [M_1 \times M_2 \times M_3 \times \{M_4 + M_5(1 - M_4)\}]$$

where D_5 is the total number of collapsed structures in a damage of level 5. The value of K_s will be different for different types of structures. This formula should therefore be used for a set of similar types of structures.

M_1 to M_5 represent different modifiers to a potential mortality rate. These modifiers vary from country to country and from urban areas to rural areas.

The factor M_1 represents population size of the building and is dependent on household size in the particular area under consideration.

The factor M_2 depends on the time of the day when the disaster has taken place. The number of life losses vary at different times of the day. Fatalities during night time, when people are in bed are usually far more than the day time when most people are outside at work.

M_3 depicts the people trapped inside buildings at the time of the earthquake. The number of survivors in single storey buildings are usually more than those in multi-storey buildings because of the former's better chances of rescuing themselves.

The factor M_4 is related to injuries caused during earthquakes some of which can be fatal, while the rest can be moderate to light injuries requiring little or no treatment.

M_5 is related to the efficiency of the rescue operations which can affect the number of casualties among the victims trapped in a collapsed structure.

6.8 Other losses

Other losses in earthquakes are caused by destruction of the finishing works, material, furniture, machinery during collapse of a structure, secondary hazards, unemployment, etc.

6.9 Prevailing concepts of risk management

It is obvious from the brief discussion in the above paragraphs, that overall earthquake losses are getting more and more unbearable in modern times. Construction of larger and more complex commercial and public buildings, increased use of elevated roads and motor ways, sprawling housing systems, fast developing utility services, such as water supply, sewerage, telephone system, electric supply, and multiplying industries have raised the cost of disasters. It is estimated that even a modest earthquake striking an urban area in a high-income or higher middle-income country will cost in the vicinity of US$ 30 to 50 billions or about 1% of the GDP of a rich country such as Japan (The Economist, April 1995). An equivalent of the 1906 earthquake in San Francisco will today cost around US$ 115 billion. Similarly if the 1923 earthquake in Tokyo is repeated, it will cost in the range of US$ 900 million to 1.4 trillion. Even the richest countries cannot afford such huge deficits.

Death tolls in the high-income and higher-middle income countries are much reduced mainly because of the application of building codes which have made structures far safer. Moreover the economic costs of earthquake are not limited to repairing and reconstructing buildings alone. The interruption in business and unemployment adds up to the financial problems (Valery 1995). Earthquake engineers' primary concern is to save people and not structures, but the sky rocketing financial losses caused by earthquakes and secondary disasters also cannot be ignored.

The low-income and lower middle-income earthquake-prone countries are in a worse dilemma. A number of them, such as Yemen do not have any building codes (Field surveys, 1994). Even those who have such a code, do not follow it strictly, such as Pakistan where a building code was introduced after the 1935 earthquake. Tables 1.1 and 1.2 show that lack of any serious attempt to save life and infrastructure in the low-income and lower middle-income countries, has resulted in a high death toll and large financial losses in recent years. Their economies which are suffering with the chronic problems of inadequate financial resources, high population, illiteracy, lack of adequate infrastructure, etc. cannot afford the tremendous losses caused by earthquakes. They seek help from the high-income and higher middle-income countries and other donors such as the United Nations whose financial constraints are also increasing. This persisting problem has increased the world's interest in saving structures along with human life. The idea emerging from this situation is a new philosophy called the risk management.

Earthquakes remain as unpredictable as ever but many people around the world continue to insist that seismology should be able to correctly predict earthquakes (The Economist, April 1995). This trend is dangerous as it creates a tendency of lack of preparedness leading to unnecessary life and property losses. Even if reliable predictions are possible, only human lives can be saved and not the infrastructure and facilities (Gere and Shah, 1984). Evacuation of cities and villages, and providing shelter to the homeless populations will be another major problem. The best protection against earthquakes is therefore to prepare for them.

Earthquake-resistant design considerations necessary for earthquake protection are discussed in Chapter 5. There are other important measures, both at macro and micro level which form part of the strategies for risk management against earthquakes. These measures are discussed in following sections.

6.10 Macroseismic studies

The earthquakes which can be felt by human beings are called macroseismic earthquakes (UNDRO, 1978). The method of studying earthquake effects without the use of any instruments involves making observations on the ground, on buildings and on the people affected. Earthquakes occurring before the twentieth century are called *historic* earthquakes because description of these earthquakes is the only source of information to estimate the magnitudes and the depth of these earthquakes. Various intensity scales to describe earthquake effects are discussed in chapter 2. Keeping a record of historical earthquakes is a useful measure for earthquake protection.

6.11 Isoseismal maps

In the preparation of isoseismal maps, seismic intensities observed in different parts of an earthquake-affected area are marked on a map and locations with similar observations are joined by lines. These lines are called isoseismal lines which indicate the areas in which similar intensities have been observed. The epicentre is located in the isoseismal of the highest intensity. The shape of isoseismal also gives information about the subsoil conditions and depth of the focus.

6.12 Microzoning

Microzoning is an important and promising technique in earthquake protection (Coburn and Spence, 1992). The purpose of this record is to identify and record on a map the variations in earthquake hazard in a limited area such as a town or a city. Microzoning maps are very helpful in land-use planning particularly when development and reconstruction is to be undertaken in an area. Important information for earthquake protection includes the following:

a) soil conditions and topographic variations which can amplify ground motion;

b) susceptibility of the area to landslides, rockfall, ground subsidence and other forms of ground failure; and

c) low-lying coastal areas subject to Tsunamis.

Earthquake protection measures at micro level, in an earthquake-affected area, deal with the following aspects:

a) repair and maintenance of the repairable structures which can be rehabilitated to sufficient degree of earthquake-resistance without raising the repair cost beyond affordability limits of the beneficiaries;

b) strengthening and retrofitting existing structures, which have experienced one or more earthquakes but apparently look in-tact;

c) reconstruction of new structures in place of collapsed structures or additional to meet local needs.

As this research mainly focuses on issues related to masonry structures, a common type of construction in low-income and lower middle-income countries, including Yemen where the case study was undertaken, the discussion in the following sections has its emphasis on strengthening and construction of masonry works.

6.13 Causes of damage and collapse of masonry structures

The main causes of damage and collapse of masonry structures, observed in Yemen and other earthquake affected areas, and reported by engineers and consultants, such as Davis (1978), Jolyon (1984), DHV (1989), Arya (1991), Coburn and Spence (1992) and Abid (1993) are as follows:

a) high rigidity causing high response to earthquake ground motion. The amplification of earthquake acceleration could be as much as three or four times. Large masses of walls and thick heavy roofs create large inertia forces;

b) tensile and shear strengths in the common masonry works are small, almost zero in rubble stone masonry laid in mud mortar, thus incapable of resisting such stresses imposed during earthquakes;

c) lack of bond due to no through stones which are necessary to connect the outer and inner wythes of the walls. In Yemen the wythes were quickly separated or delaminated from each other as the shaking started (Figure 6.3), because not only there was no bond between the outer and inner wythes due to absence of through stones, but also between masonry courses due to the use of mud mortar. The pyramid-shaped facing stones became loose in the shaking and the vertical load forced the outer wythe to bulge outside and the inner wythe to bulge inside;

d) poor bond between perpendicular walls allows them to separate at the junctions causing loss of box-like action and leaving each wall to resist inertia forces on its own mass. This problem can be physically seen from the almost vertical cracks which appear at the junction of the perpendicular walls. These cracks are widest at the top. The roof acts as a separate bending wall perpendicular to the supporting walls unaided by their shear-wall action;

e) the roofs have no diaphragm action to be able to transfer inertia forces to all four walls or two wall acting as shear walls; and

f) random cracks at the corners of the openings indicate the seismic detailing problems which restrict free movement of the earthquake forces.

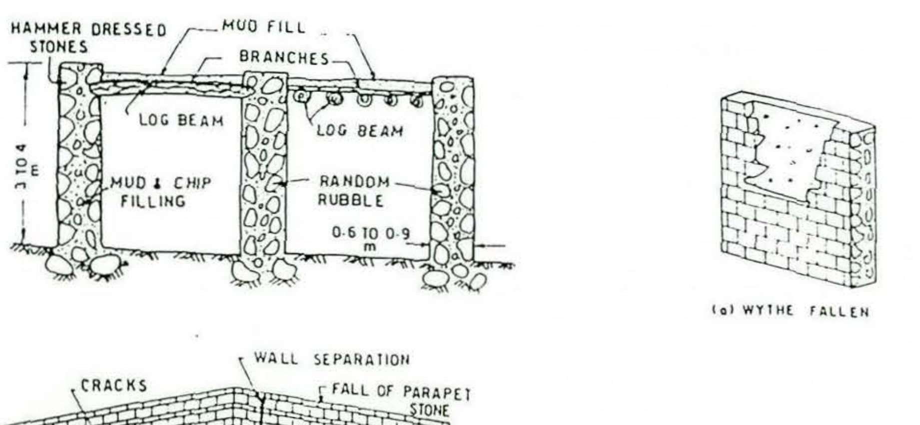


Figure 6.3: Section of a typical Yemeni house and the various defects observed after the 1982 earthquake
Source: Arya, 1991

6.14 Low-cost repair of damaged masonry structures

Improving the resistance of existing masonry structures in earthquake zones is an important task. Some recent earthquakes have clearly shown the weakness and vulnerability of the old stock particularly where rubble stone masonry work or adobe is the dominant construction material (Coburn and Spence, 1992). Better construction methods and technologies are necessary to minimise future disasters but such methods can be implemented only if they are affordable for the people having low incomes. The new and improved methods should also be easy for adaptation by the local artisans and should be culturally acceptable to the users.

Many reconstruction programmes, involving new construction and improvement of the existing structures in earthquake-affected countries such as Mexico, Guatemala, Nicaragua and Turkey have proved to be not very successful because the above limitations were ignored (Davis, 1978). The survivors or intended beneficiaries in such cases, unimpressed by the improvements went back to their traditional abodes.

The risk management concept requires a realistic approach of low-cost upgrading of the traditional structures, affordable and culturally acceptable to the people. The main objective of this approach is to keep the damage minimal from a moderate earthquake, expected in a 10 year (or more) cycle and to give their occupants a good chance to escape in the case of a rare severe earthquake. Many of the common defects in traditional structures observed in Yemen and reported from other countries can be removed at a nominal cost by using simple technologies easily adaptable by the local builder (Arya, 1991).

It should be noted that *restoration* of a traditional building means that the repaired structure should be able to regain at least its original strength. The process involves close examination of the entire structure to identify even the smallest cracks and other weak spots in the masonry works. In the case of Yemen the restoration process also necessitated strengthening, because the traditional structures were found incapable of withstanding even a moderate earthquake of MSK intensity not higher than VIII in any place. One of the safety measures suggested by Arya (1991) for Yemen, was to get rid of all storeys above the second storey. Arya claim that this measure is applicable to all earthquake-prone countries with similar type of construction. Low to moderate strength structures stand better chances of remaining in^tact if they are low rise.

6.14.1 Grouting in cracks: Finer cracks should be filled with 1:1 cement-water or gypsum-water grout while wider cracks should be repaired with 1:1 or 1:2 cement-sand mortar. This method becomes too expensive if used in dry masonry hence not advisable. Imported materials with high tensile strength, such as epoxies are very expensive and not affordable for the low-income people. Also the availability of such materials is not always guaranteed.

6.14.2 Stitching of stone-wythes: Installation of bonding elements which connect the outer and inner wythes of masonry walls, is essential in all load-bearing walls (Figure 6.4). If some portions of the wall has fallen, it will have to rebuilt by using cement-sand mortar and by placing steel reinforcement to join it with the existing wall.

Providing R.C.'through' elements for 'stitching' stone wythes

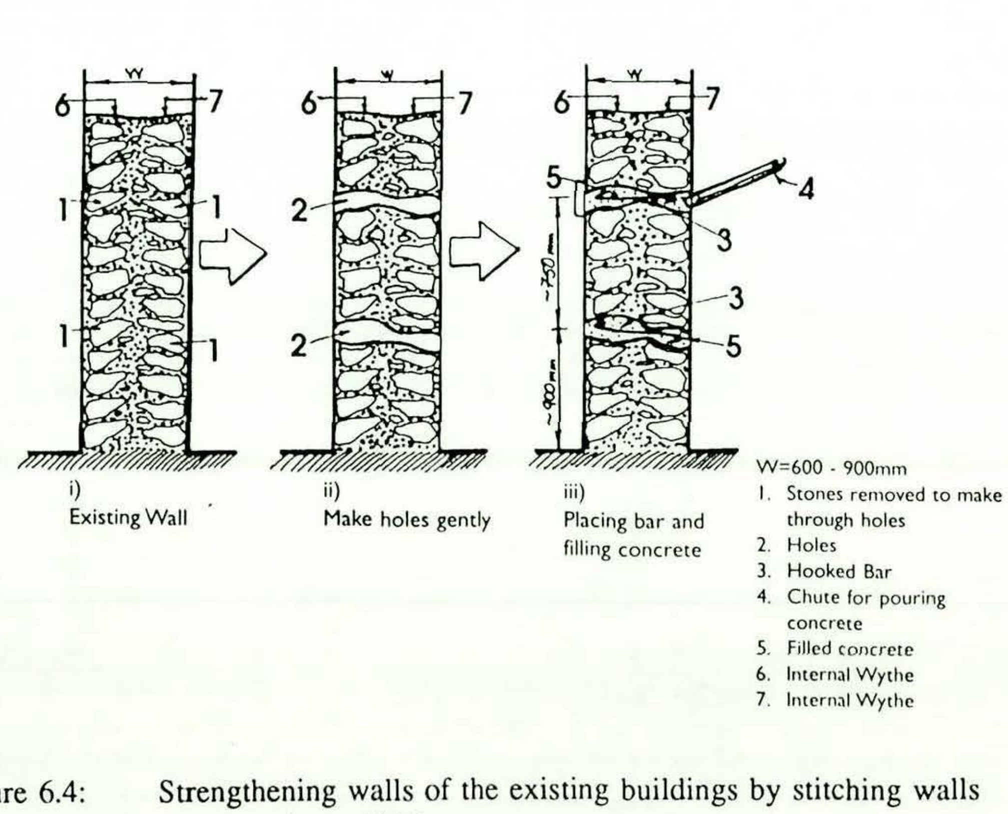


Figure 6.4: Strengthening walls of the existing buildings by stitching walls
Source: Arya, 1994

6.14.3 Treating bulged walls: Mild bulging indicates hollowness between the inner and outer wythes of walls. This problem can be treated by filling cement-sand mortar in the gap after stitching the wall, otherwise hydrostatic pressures develop inside which may cause bursting of the wall. This treatment is not applicable to seriously bulging walls. Such walls need to be dismantled and rebuilt in cement-sand mortar with proper bonding with the remaining portions of the existing walls. Such repair works need extreme care as sometimes soaring of the adjoining walls or roof may be required.

6.14.4 Wooden ring beams: Some of the old buildings have wood beams horizontally usually placed at the lintel levels. These beams are usually weak at the joints. They held the masonry walls intact as far as possible, but cracks started to appear in the walls wherever the joints separated. These wood beams can be fortified by nailing steel strips at the joints, in order to restore their tensile strength and resistance to earthquake forces.

6.15 Low-cost strengthening of existing masonry structures

The study of traditional masonry structures and building practices in some of the low-income earthquake-prone countries shows that a number of building practices were being followed without any consideration of their effect on earthquake-resistance of the structure. These practices can be reviewed and low-cost measures can be applied to improve earthquake resistance of the existing structures.

According to the nature of weakness noticed in a structure, strengthening may require any or all of the following measures (Coburn and Spence, 1992):

a) modifying the plan to reduce asymmetry;
b) improving connections between perpendicular walls;
c) strengthening or replacing floors and roofs and improving their bond with the load bearing walls;
d) strengthening the walls;
e) strengthening the foundations; and
f) improving drainage at the roofs and ground levels.

Some the measures for strengthening existing structures are discussed below (Arya, 1991):

6.15.1 Installing reinforced concrete bands: This reinforced band (Figure 6.5) is also known as the *bond beam, parameter beam* or *chaining*. The band can be installed internally or externally at various levels of the structure such as plinth level, lintel level and

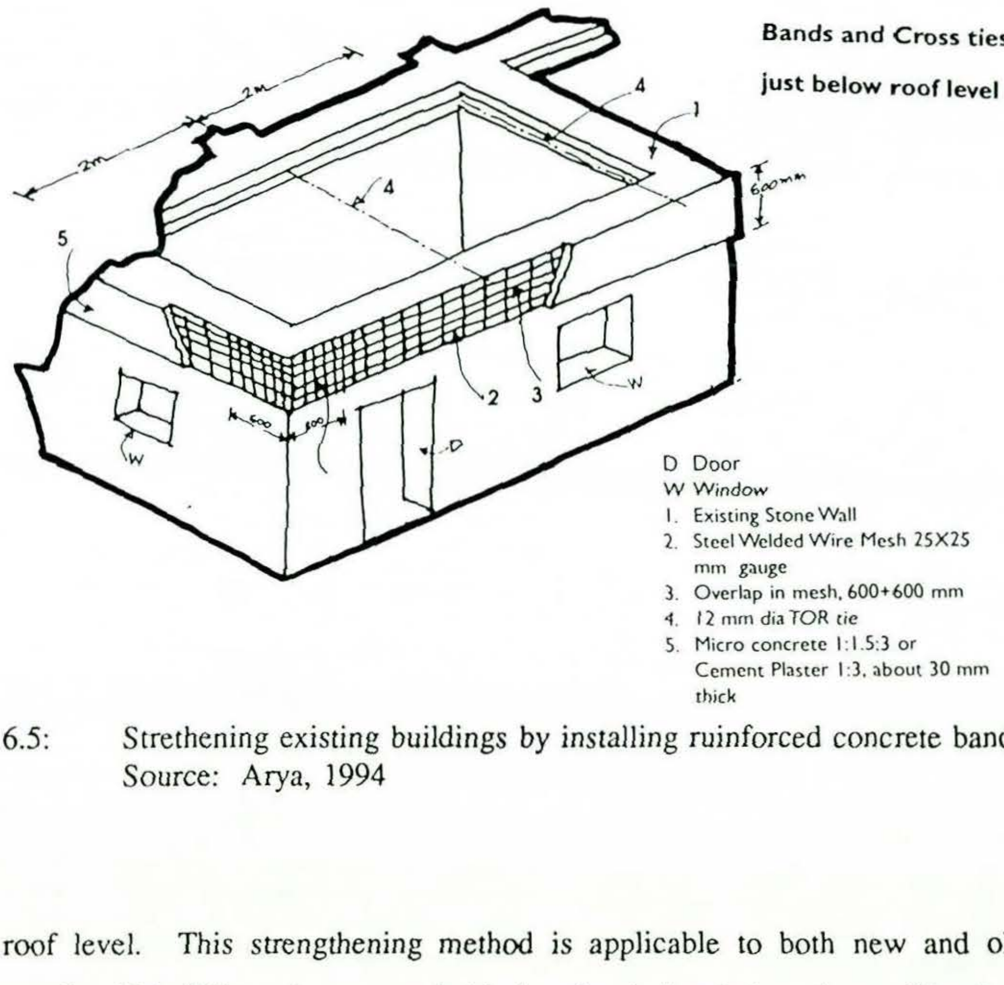


Figure 6.5: Strethening existing buildings by installing ruinforced concrete bands
Source: Arya, 1994

below roof level. This strengthening method is applicable to both new and old structures. In old buildings the most suitable location is just below the roof level of each storey, where it will have to be installed over the existing wall. The band has two important functions as follows:

a) to bind all walls together and prevent their separation at the corners. Tying perpendicular walls at the corners is necessary to prevent kinematic instability of walls which means their overturning out of plane after separation at the corners.

b) to act as horizontal bending beam to resist the horizontal inertia force of floor or roof together with that of the mass of the external walls. This action is of particular significance as the traditional floors do not act as diaphragms.

6.15.2 Strapping: Extensive strapping of the walls, roofs and floors by using both vertical and horizontal steel ties improves bond between these members.

6.15.3 Reducing earth-load from roof: Most traditional houses in low-income and lower middle-income countries have large layers of earth on roof of thickness ranging from 60 cm to 90 cm. The purpose of this earth is to provide climatic comfort but it also becomes deadly during earthquakes, because the earthquake forces are directly proportional to mass of the structure. If this layer is reduced to 20 cm the climatic effect on the building remains more or less the same but it drastically reduces the weight of the roof with a better chance for survival of the structure (Figure 6.6). A polythene layer can also be placed horizontally at the middle of this layer for water sealing of the roof.

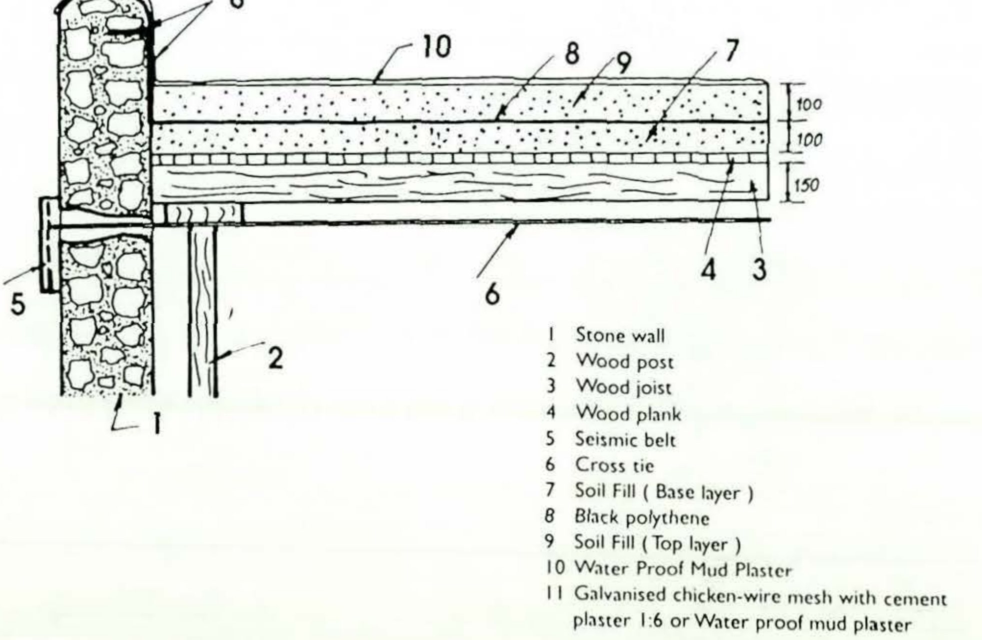


Figure 6.6: Roof treatment to reduce weight of soil and to provide protection against water penetration
Source: Arya, 1994

Sometimes complete coverage of the external walls of structures with nominal steel and covering it with rich cement plaster, is also recommended but it considerably raises the cost of strengthening. This method is used when damaged walls need extensive repairs.

6.15.4 Retrofitting wooden frames: If the structure has wooden columns to support large roofs, the use of knee braces (Figure 6.7) helps in strengthening the columns and improved distribution of the roof load.

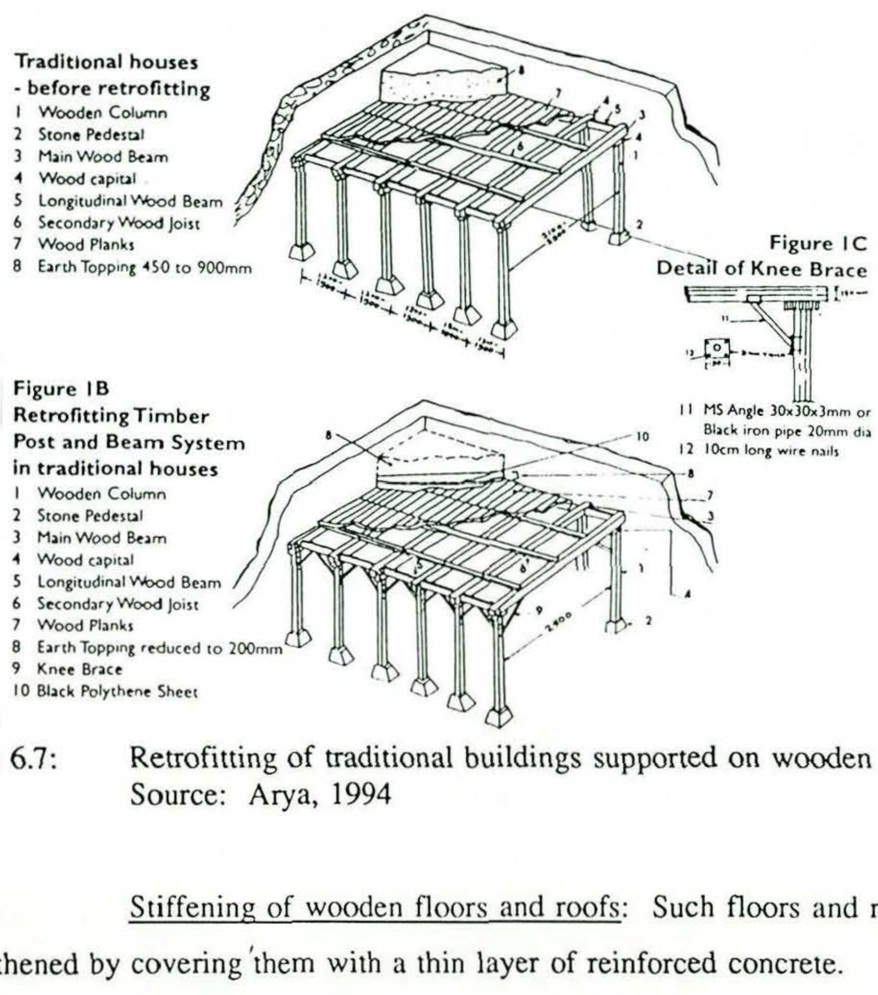


Figure 6.7: Retrofitting of traditional buildings supported on wooden frames
Source: Arya, 1994

6.15.5 Stiffening of wooden floors and roofs: Such floors and roofs can be strengthened by covering them with a thin layer of reinforced concrete.

6.15.6 Water penetration: One of the most common defects in low-strength traditional buildings is that allows water penetration into the walls. This causes ends of the timber roof joists to rot, or steel joists to rust and the mud mortar to soften resulting in deformation and instability of the walls. Such structures become further susceptible to earthquake damage. Installation of improved drainage system, with overhanging eaves at the roof level and improved surface water run off are inexpensive measures to restore such structures.

6.16 Strengthening of reinforced concrete structures

The main problems of weakness in reinforced concrete structures are the following:

a) insufficient lateral load resistance because of design fault;

b) inadequate ductility because of insufficient longitudinal reinforcement at beam-column or slab-column junctions;

c) concentration of local stresses due to complex and irregular geometry of the structure in plan and elevation;

d) interaction between structural and non-structural elements due to eccentricity causing unintended torsion and stress concentration;

e) weak ground floor (soft storeys) due to lack of shear walls;

f) high flexibility combined with insufficient spacing between buildings resulting in pounding by neighbouring buildings during earthquakes; and

g) unrepaired damage from previous earthquakes also makes such structures more vulnerable during the next earthquakes.

6.16.1 General measures: The following general measures are taken for strengthening of reinforced structures:

a) to increase lateral load resistance and to increase ductility of the structure where such deficiencies are noted;

b) to remove or redesign non-structural walls in order to improve shear strength. This measure is taken where flexible infill walls have caused or are feared to caused pounding inside the structure; and

c) stiffening of tall structures located on softer soils is also sometimes carried out to reduce natural period of the structure below that of the subsoil. Strengthening of foundations may also be required in such cases.

6.16.2 Specific measures: Specific measures for strengthening reinforced concrete structures are described below:

a) *shear walls*: adding more shear walls in a reinforced concrete frame structure is a common method for increasing its shear resistance. These additional walls are also usually made of reinforced concrete.

The walls are designed and built to have a good bond and composite action with the existing structure. Addition of shear walls changes the load distribution pattern of the structure and may also require strengthening of the foundations.

b) *jacketing*: another method of increasing dimensions and strength of the existing principal frame members is to encase them with new reinforced concrete covers. This method, commonly known as *jacketing*, also improves ductility of the building. Any concrete damaged in a previous earthquake can also be replaced by this method. This work also requires careful handling in order to achieve the desired bond between the existing structure and the new work.

After going through the above methods of restoring and strengthening the existing infrastructure in earthquake areas, it seems appropriate to review some reconstruction works undertaken in different parts of the world.

6.17 Study of reconstruction programmes in some earthquake-affected Areas

Reconstruction in earthquake affected areas is one of the most challenging tasks (Davis, 1978). Construction costs of hundreds or thousands of new houses and other infrastructure such as hospitals, health centres, water supply systems and roads reach several million dollars which the low-income or lower middle-income countries can ill afford from their own resources. Most of the reconstruction work is carried out with foreign assistance.

The main objectives of the reconstruction programmes are usually the following (DHV, 1989):

a) to introduce low-cost earthquake-resistant building techniques using local materials and local building methods; and

b) to introduce houses which are affordable and culturally acceptable to the intended beneficiaries in particular and common people in general.

In spite of seemingly good intentions of the concerned government agencies, responsible for programme implementation, most of the post-earthquake reconstruction programmes in low-income and lower middle-income countries has failed to meet the desired level of success and impact on affected people. Some of these reconstruction programmes are discussed in the following paragraphs.

6.17.1 Reconstruction of Quetta City: Quetta city of Pakistan was hit, by a severe earthquake measuring 7.6 magnitude, in 1935, which destroyed almost every building in the city and surrounding villages (Coburn and Spence, 1992). The earthquake claimed 25,000 lives. It was not possible to relocate the city to another place. Earth scientists declared the city safe from another similar earthquake for a long period. The government ordered all new construction to be built by using earthquake-resistant techniques. This prompted drawing up of a building code which is considered to be the pioneer of all modern codes of practice.

General regulations were issued specifying shape, size and spacing of the buildings and the construction methods were also reviewed. The code required all residential masonry buildings to have reinforced beams and vertical reinforcement at all corners and at the junctions of perpendicular walls. This practice came to be known as Quetta bond. For important buildings such as hospitals, airports and government offices, a system of steel frames with brick infill panels was introduced.

The Quetta bond remained in practice for some years, when the building controls were strictly monitored by the government. As the city population grew in the following years with the influx of refugees from Afghanistan and India, it became impossible to keep a tight control in building construction.

Another problem was that the building code did not offer any cheaper alternatives. In recent years the use of prescribed quantities of steel reinforcement and wood was found to be beyond the reach of a common person. Today most of the low-income population of Quetta (total estimated population 800,000) lives in unauthorised masonry structures of low strength.

The Quetta bond provided a good solution for building earthquake-resistant structures. The proposed buildings were culturally acceptable for which local materials and workmanship were available. What the code however lacked was the economic aspect and only a small percentage of the local population could afford to build such houses from their own resources. If an earthquake similar to the one of 1935 were to be repeated today, the life and property losses will be far greater.

6.17.2 Reconstruction in Skopje: This Yugoslavian town suffered a moderate earthquake of 6.0 magnitude in 1963. Many buildings collapsed or were seriously damaged causing over 1,000 deaths and leaving tens of thousands homeless. Massive funds were received through international assistance and local resources. The government embarked on a large reconstruction and repair programme designed mainly for rehabilitation of the earthquake victims. Reconstruction and strengthening of the public buildings and other facilities was also part of the programme (Davis, 1978).

This programme dragged on for over fifteen years, despite availability of sufficient finances and no technical problems. The government was finally forced to leave the programme incomplete and shelve it mainly because of legal intervention, political interference and financial corruption problems.

The incomplete reconstruction programme failed to create any positive impact on the intended beneficiaries. Most of them did not receive any housing and the majority of them went back to live in their damage-prone houses to show their mistrust and disapproval of the government's reconstruction programme.

6.17.3 Reconstruction in Gediz: A major earthquake of 7.3 Richter magnitude hit Gediz area in western Turkey in 1970. Over 1,100 people were killed in this earthquake and a large number of structures collapsed causing extensive economic losses (Gere and Shah, 1984).

The main objective of the Turkish government in the following reconstruction programme was to reduce vulnerability of the people and structures. A large number of the earthquake survivors benefitted from the programme. In the long run however, the reconstruction programme achieved very little success in its goal. This happened mainly because the technical and scientific techniques employed in improving the safety of local housing system were indifferent to the socio-cultural, economic and environmental conditions of the local communities (Aysan, 1986). Over the passing years the affected communities have continued to modify, extend or even rebuild their government provided post-disaster houses according to their needs by using traditional construction techniques. Consequently the vulnerability of the present housing stock is even more than before, because of increase in population and extensive building activity going on without any consideration for safe location or safe construction.

The reconstruction programme in Gediz is one of the many to highlight that such programmes should not only pay attention to the technical issues, but should also consider the socio-cultural values and economic conditions of the affected communities. These considerations are vital to increase the acceptability of such programmes.

6.17.4 Reconstruction in Managua: Managua, the capital of Nicaragua, experienced a deadly earthquake in 1972 recording 6.2 magnitude on Richter scale. 5,000 people perished in this disaster while extensive building damage left tens of thousand homeless (Gere and Shah, 1984). The economic losses ran into millions of dollars.

The government assured the earthquake victims about its intentions to provide houses to everyone whose house had been destroyed by the earthquake. The government also promised to repair and strengthen all those houses which were only partly damaged.

The government appealed for international help. The neighbouring countries were quick to respond. Columbia provided 100 houses and 12 class-rooms. On completion, the entire lot of 100 houses was distributed among the President's family members and friends and some high-ranking military officers (Davis, 1978). Most of the earthquake victims could not benefit from the reconstruction programme. The programme failed to create any positive impact. The government's instructions for building safe houses were ignored and the earthquake victims preferred to build new houses or repair their existing houses through own resources and using the old vulnerable building techniques.

6.17.5 Reconstruction in Guatemala: A severe earthquake measuring 7.5 magnitude on Richter scale 7.6 hit Guatemala in 1976, killing 23,000 people and causing extensive damage to adobe construction. Numerous landslides, occurring as secondary disaster caused further damage leaving one-fifth of the country's population homeless.

It is interesting to note that historically the Guatemalans were accustomed to safe building technologies and used to live in simple timber frame houses, covered with corn stalk walling. When the Spanish invaders came they brought with them the lethal technology of adobe walls and heavily tiled roofs. This is perhaps one of the few examples in the world where the new technology rendered the traditional technology unsafe (Davis, 1978).

As happens in most cases, the reconstruction programme following the 1976 earthquake failed to consider the basic issues of affordability and acceptability of the local communities. The programme managed to provide shelter to only a small percentage of the earthquake victims. The remaining poverty-stricken people had themselves to cater for their shelter needs. In the process, many of them reverted to even more vulnerable shelters. A future severe earthquake in the same area, which can be repeated once in 25 years, is liable to cause real havoc.

6.17.6 Reconstruction of Mexico City: Mexico city has suffered three earthquakes of damaging effects since 1957 of magnitude ranging from 7.6 to 8.0 (DHA News, 4/1993). The second severe earthquake occurred in 1978, while the last one occurred in 1985 thus taking the total death toll to about 7,000. Huge property losses accompanied these repeated disasters and several hundred thousand people were rendered homeless. The high level of damage was due to rapid expansion of the city and the types of structures built during the 1960s and 1970s. This adverse situation was compounded by high intensity of the last earthquake which is said to be the highest in Mexico city in the current century. The local subsoil conditions are also unfavourable as the city is built on the bed of an ancient dried lake, making it more vulnerable to strong ground motions more than most other places elsewhere. The saturated soils resonate even from moderate earthquakes occurring 400 km away. The return period of 15 years for moderate to severe earthquakes in Mexico city is relatively high.

The Mexican government has adopted several measures to avoid future disasters as follows:

a) large-scale strengthening of important structures such as schools, hospitals, government offices, airports, nuclear facilities, power houses, water works and historical buildings;

b) a major reconstruction programme to rehabilitate the disaster victims; and

c) revision of the urban master plan including microzoning of the city; and

d) revision of the existing building codes.

This programme is successful to the extent of strengthening of government built important structure and houses. The slum areas, where majority of the city population lives still generally continue to live in shelters devoid of any safety considerations.

6.17.7 Reconstruction in Maharashtra: Marathawada area of Maharashtra, India received an earthquake of 6.5 magnitude in 1993 in which 50 villages were wiped out. The death toll is estimated to be over 20,000 while the number of homeless is in the vicinity of 150,000 (DHA News, 1993).

Most of the houses in Marathawada area are made of stone rubble masonry with poor bond between perpendicular walls, and between walls and roofs. The roofs are heavy with 60 to 90 cm depth of earth to provide climatic comfort. The heavy roofs and the lack of bond between walls and roofs became the main cause of heavy destruction in Marathawada. The government of India took up the repair and reconstruction of Marathawada mainly through its own resources. The government made unrealistic promises to the victims that they will be provided new shelters before the next rainy season. But except for a handful of different looking new houses, most of the people are still living in temporary shelters (Sharma, 1995). The process is slow and may take several years in completion because the Indian government is finding difficulties in mobilising resources for the enormous job of providing safe shelters and other infrastructure to a very large number of the homeless people in the earthquake affected area. The lack of a well-formulated rehabilitation policy has led to confusion. If they are hit by another earthquake while they are still living in their vulnerable make-shift shelters, it could be a greater misfortune for the Marathawada people, than the last one.

As the traditional construction in Marathawada is similar to that in Yemen, discussed in detail in chapter 4, the technology recommended for repair and strengthening of existing houses in Marathawada is also the same as in Yemen (Arya, 1994).

6.17.8 Reconstruction in Northridge: The Northridge earthquake which caused serious damage to infrastructure in Los Angles and other nearby areas, was of 6.7 Richter magnitude. The death toll was only 54 mainly because the earthquake occurred in the middle of night of a public holiday when most of the local residents had travelled out. The earthquake smashed overhead freeway bridges and multi-storey car parks to the ground, mainly because of the soft-storey factor. A few high-rise structures also toppled probably because of torsional forces created by eccentric loading. The economic losses caused by this earthquake are estimated at US$ 30 billion making it the costliest earthquake in the history of the American Continent (The Economist, 1994).

A building code covering earthquake-resistance of all buildings is strictly followed in California state and other seismic areas of the United States. The low-rise, mostly residential structures are made of timber. The medium-rise and high-rise buildings are made of reinforced concrete and steel frame. Experts believe that the Northridge earthquake losses would have been far more if the above protection measures were not applied.

The USA is a high-income country with ample technical and financial resources. Small wonder that the repair and reconstruction work, entirely funded by the government, has been completed two months ahead of schedule.

This is in contrast to the low-income or lower middle-income countries, where post-earthquake reconstruction works drag on for years as discussed in the case of Marathawada and some other cases. Earthquakes not only cause heavy losses to life and infrastructure only, but also sometimes they completely change the socio-economic patterns of the affected communities. Many households suddenly find themselves shelterless and jobless after the disaster. A number of such households become destitutes as the concerned governments continue to follow indifferent relief and reconstruction programmes. The promised assistance to the affected people either never comes or comes only partly and so late that most of the effect is lost.

Yemen's case, where this research was conducted is no different. The reconstruction programme is still incomplete after thirteen years of the disaster. A large amount of the financial assistance has been spent and wasted to a great extent as nearly half of the affected people have not benefitted from the programme. Even the beneficiaries are not satisfied with the houses built for them. A majority of the government engineers and other officials involved in the reconstruction programme believe that the programme could have been implemented in a better way (refer to chapter 6 for details).

6.17.9 The Kobe disaster: Kobe is one of the major industrialised cities of Japan. It is ironical that only a few year ago the government of Japan had placed this city on the list of low-risk seismic areas (The Economist, 4/1995). Earthquake hazard awareness and technological advancement in Japan is one of the highest in the world. The country is also among the richest. In spite of all these positive factors, the earthquake of January 1995 (Richter Magnitude 6.9) caused extensive damage to the housing and other infrastructure. In the wake of the disaster 5,470 people lost their lives and some 33,000 became homeless. The economic loss is estimated to be about 200 billion US dollars. The main cause of the heavy losses is that the pre-conceived low seismicity of the area, and non-occurrence of an earthquake in or around Kobe, for hundreds of years had led the seismologists to believe that the chances of severe earthquake in the area were almost nil. The heavy roofed buildings and insufficient bond between roofs and wall is said to be responsible for the colossal damage.

The Northridge and the Kobe earthquakes have exhibited that the established knowledge about the hazard is still incomplete (El-Nashai, 1995). The increasing incidence of the earthquakes to occur almost anywhere, has led the European scientists to develop a Eurocode for earthquake-resistant considerations in all construction works.

Like USA, Japan is a high-income country. The government is working fast to rebuild Kobe with safer construction techniques.

6.18 Acceptable risk, affordability and acceptability

The terms acceptable risk, affordability and acceptability are crucial in earthquake-resistant design of structures. It is worthwhile to establish simple definitions of these terms in this context.

6.18.1 Acceptable risk: Earthquake intensity level XII on Modified Mercalli and MSK scales means total collapse. As such no infrastructure can be expected to escape destruction in great earthquakes of Richter magnitude 8.0 and above, corresponding to intensity levels XI and XII. It is therefore not possible to have earthquake-proof structures. This is why structures designed to resist earthquakes are called earthquake-resistant and not earthquake-proof structures. The level of acceptable risk for different type of buildings also varies because an increase in safety measures also increases the cost. The main categories of buildings are classified as (i) *occupancy*; (ii) *importance*; and (iii) *hazard*.

Acceptable risk in the case of an *occupancy* building, such as a house or an apartment means that it should suffer no damage in minor earthquakes and resist structural damage in moderate earthquakes. In severe earthquakes such buildings may suffer major damage but not collapse and the occupants should be able to escape safely.

The level of acceptable risk for *important* buildings such as offices, hospitals, airports, railway stations and schools is higher than the *occupancy* buildings. Acceptable risk for an important building requires that the building should suffer no or only superficial damage in a moderate earthquake and no structural failure in severe earthquakes.

Acceptable risk for *hazard* buildings such as nuclear plants, fuel dumps and dams requires that they should be able to withstand even severe earthquakes without any structural failure damage. Serious damage to such structures can trigger off serious secondary disasters causing further fatalities and other losses and disruption in rescue and relief operations.

The above definitions could be called as the technical definitions. But while dealing with shelters the people's perception of risk is very important. Risk has been defined earlier in this chapter. Further discussion is given in Chapter 11.

6.18.2 Affordability: In development and reconstruction programmes the question of affordability and acceptability is more related to housing. In house building the people have to mainly depend on their own financial resources. Considerations of their individual, cultural and climatic needs are of paramount importance to make the housing designs acceptable to the community.

Affordability is a relative phenomenon which varies from place to place depending upon socio-economic condition of the concerned people.

The people in Yemen are generally poor but a strong joint-family system exists among them, under which all earning members of a household pool their resources to meet their needs jointly. Wealthy relatives, not part of the same household also sometimes assist if an important financial undertaking is beyond the means of their kin. House building and marriages are considered among important undertakings. However affordability levels for house building in Yemen should be based on the economic means of the concerned households only. Affordability of the earthquake-affected people in Yemen is further
discussed in Chapter 9.

6.18.3 Acceptability: Housing systems designed for the disaster victims should be critically examined by them as to how similar it is to their traditional housing and whether its location, design and size can take care of their essential needs. Any housing system not considering these basic requirements should be rejected by the beneficiaries.

It was observed in Yemen that even in the case of beneficiaries of the post-earthquake reconstruction programme, who had to pay nothing or only a part of the total cost, the issue of acceptability played a vital role in the fate of the programme.

Yemeni people are conservative muslims and attach great value to their old Islamic traditions including Yemeni architecture. Detailed discussion on the socio-economic profile of Yemen and traditional housing exists in chapters 3 and 7. Salient features of traditional Yemeni housing in the context of acceptability are given below.

Traditional housing in Yemen is based on their cultural and climatic needs. The traditional houses have large rooms and are three to four storey high. There are several rooms in the house because of joint-family system in practice in which each family has a large number of children. The walls and roofs are thick to provide climatic comfort. The women's quarters are kept separate for religious reasons. The men's retiring rooms are on the top floor for vigilance in case of an enemy attack. Livestock keeping for dairy purposes and for use in agriculture farms is an integral part of Yemeni culture. Stables for the livestock are therefore also considered necessary in rural houses. Large kitchens because of joint-family system is yet another essential need. Any housing design which does not correspond to these basic needs of the Yemeni people is not acceptable to them.

Acceptability of the reconstruction programme in Yemen is further discussed in detail, in Chapter 9.

6.19 Acceptable risk for earthquake-resistant designs in Yemen

According to the seismic studies of Yemen, the probability of an earthquake of magnitude 6 is about 4 to 5 times in 25 years. The probability of an earthquake of magnitude 7 is once in 25 years,while the probability of an earthquake of magnitude 8 is less than once even in 100 years (Al-Salim, 1993). Table 6.4 shows the probable return period of earthquakes of different magnitudes in Yemen.

Table 6.4: Probable return period of earthquakes in Yemen

Magnitude M (Richter scale)	1 year	10 years	20 years	25 years	75 years	100 years	200 years
3.0	33.9	338.6	677.2	846.5	1692.9	3385.8	6771.7
4.0	6.3	63.2	126.4	158.0	315.9	631.8	1263.7
5.0	1.7	11.8	23.6	29.5	59.0	117.9	235.8
6.0	0.2	2.2	4.4	5.5	11.0	22.0	44.0
7.0	0.0	0.4	0.8	1.0	2.1	4.1	8.2
8.0	0.0	0.1	0.2	0.2	0.4	0.8	1.5
9.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3

Source: Al-Salim, 1993.

The record available from the Seismic Observatory Centre of the Ministry of Oil and Mineralogy in Yemen does not show any earthquake of magnitude 7 or above having occurred in the country. As such it seems reasonable to assume that acceptable risk in Yemen will allow a building to be considered as safe if it does not collapse in an earthquake of magnitude 7 with an intensity of about 8 to 9.

Technical measures for risk management by engineers, based on literature review, are described in the following section.

6.20 Measures for engineers

Engineers visiting the earthquake affected areas in Yemen and elsewhere with masonry structures, find the existing buildings in the following four conditions (Arya, 1991):

a) collapsed buildings beyond economic repairs, requiring reconstruction;

b) damaged buildings requiring major or minor repairs;

c) buildings showing little or no apparent damage but weakened by the last earthquake and thus in need of strengthening to resist future earthquakes; and

d) buildings with only superficial or no damage, not requiring any repair or strengthening measures.

The buildings planned, designed and supervised by engineers are known as *engineered buildings* and they usually fall in the last category. Such buildings may also however suffer repairable damage in a severe earthquake, if they are not based on earthquake-resistant design principles. Almost all public buildings are engineered buildings and usually suffer only moderate damage even in severe earthquakes. Expert engineers recommend that repair of such damage should be carried out as soon as possible, after the earthquake in order to keep them functioning with full efficiency at a time when they are most needed.

Serious problems are however encountered in the *non-engineered* buildings, usually built by local artisans in consultation with the house-owners whose main considerations are social and cultural needs, climatic comfort and cost saving. An engineer will have to examine all buildings in the earthquake-affected area systematically to determine the nature and extent of damage to each structure.

Most of the low-income communities around the world live in non-engineered buildings. Experts agree that the engineers should provide such earthquake-resistant guidelines to the people which are affordable and acceptable to them. The most common and well known problems in such building, and their possible solutions are summarised in the self-explanatory Tables 6.5 and 6.6.

Table 6.5: Common design problems in non-engineered buildings and possible technical solutions.

Building component	Type of construction	Type of problem	Type of damage 1	2	3	4	Possible low-cost solution	Is affordability an issue?	Is acceptability an issue?
Roof	Three trunks or branches placed on opposite walls with insufficient bearing providing little bond with walls and heavy load of clay (30 cm or more) on top	Separate vibration in each direction causing lack of diaphragm action with four walls in resisting lateral loads. Old roofs are more vulnerable due to insect action or rotting thus further reducing bond with walls		*	*	*	Roof collapse can be lethal. Changing week rafters or those with small wall bearings will be needed. Typing with walls will be done by steel straps	Yes	No
Roof	As above	As above			*	*	Reduce depth of earth on roof to 20 cm which will provide the same climatic comfort but make the roof safer	No	No
Roof	Large roofs built as above but given extra support by wooden columns	As above			*	*	Retrofit columns with roof by using knee-braces.	Yes	No
Roofs and floors	Roof and floors made of timber	Flexibility may cause pounding and major damage to the whole structure			*	*	Wooden floors and roofs can be stiffened by covering them with a thin layer of RC	Yes	Yes
Roofs	As above and several other types of roofs	Water penetration from roofs to walls due to poor drainage poor sealing of roofs causes damage to timber or steel joists, softening of mud mortar and weakening of walls	*	*	*	*	Improved roof drainage and placing eaves at roof level is a low-cost measure to restore safety of the structure	Yes	No
Masonry walls	Rubble stone masonry with outer and inner wythes laid in mud or week cement-sand mortar. In between hearting filled with stone chipping and mud mortar	Cracks in the walls without major structural damage		*			Minor cracks to be repaired with 1:1 cement or gypsum grout. Wider cracks to be repaired with 1:1 or 1:2 cement sand mortar	No	No
Masonry walls	As above	No bond between outer and inner wythes of walls causing falling of some portions of the wall		*	*		Fallen portions can be rebuilt by using cement sand mortar. Repaired portion can be joined with the existing wall by placing steel bars in between	No	No
Masonry walls	As above	As above			*		Further strength can be provided by placing through bonding elements in the wall. This is called stitching	Yes	No

Table 6.5: Common design problems in non-engineered buildings and possible technical solutions.

Building component	Type of construction	Type of problem	Type of damage				Possible low-cost solution	Is affordability an issue?	Is acceptability an issue?
			1	2	3	4			
Masonry	As above	As above				*	Steel straps at joints and all corners will be needed. Wooden ring beams at lintel, cill and roof levels will provide further strength	Yes	No
Masonry walls	As above	Bulging of walls indicates hollowness which creates hydrostatic pressure in the mortar and bursting or wall					This work is done after stitching the wall by filling the bulged portions with cement-sand mortar. Seriously bulged walls need dismantling and rebuilding	No	No
Masonry walls	As above	Lack of bond or poor bond between walls and roofs			*	*	Reinforced concrete (RC) bands can be installed in new works at the plinth, lintel and just below roof and floor levels within wall thickness. In old work RC bands can be placed below roof and floor levels outside the wall	Yes	No
Masonry walls	As above	Lack of bond between walls and floor			*	*	Heavy strapping by using steel bars between walls and floors improves bond and gives more rigidity to the structure	Yes	No

Key
1: none or superficial damage;
2: damage requiring repair and restoration;
3: no apparent damage but weakened structure requiring strengthening;
4: major damage or collapse requiring reconstruction.

Source:
1: Arya et al, 1985;
2: Arya, 1991;

Table 6.6: Secondary factors for improving earthquake-resistance of buildings

Problem	Possible solution	Is community's affordability an issue?	Is community's acceptability an issue?
Site conditions Existing site may have a geological fault increasing the probability of a future earthquake or the subsoil conditions may cause liquefaction, subsidence, landslides or rockfall	Change of site may be required.	Yes	Yes
Distance between houses Closeness of old and unrepaired houses may make new construction vulnerable	Examine the repair and strengthening measures for the adjoining buildings as well and made suggestions if so required. New houses should be located at safe distances from old houses.	Yes	Yes
Construction materials People prefer to use familiar materials easily available in the market	Emphasis should remain on the use of local materials but unsafe methods of their use should be changed	Yes	Yes
Configuration Extreme dimensions, problematic horizontal and vertical layouts, excessive openings in shear walls and diaphragms, and adjacency of another building with configuration problems	Revision of dimensions or structural design	Yes	Yes
Structural design Difference in stiffness of various storeys and their effect on the natural period and dynamic characteristic of the structures, insufficient wall area to resist shear, heavy roofs and design faults	Revision of structural design to ensure safety	Yes	Yes
Construction quality Use of low quality building materials, poor workmanship, mixing materials of different seismic performance and	Review of design to strengthen the existing works	Yes	Yes
History Decay and rotting of materials due to age, weakening effects by previous shocks, low quality of repair and maintenance, modifications affecting seismic behaviour of the structure	Strengthening measures may be required	Yes	Yes

Source: Coburn and Spence, 1992;

Summary

The rising number of earthquake disasters is now a matter of major concern for the governments and engineers all over the world. The recent earthquakes in USA and Japan have shaken the established concepts of safety. The problem however is not so serious for the high-income or higher middle-income. The real problem is for the poorer people who form over 70% of the world population. Most of these people live in non-engineered houses. Post-earthquake reconstruction programmes in low-income and lower middle-income countries have generally failed to satisfy the needs of the victims, because of indifferent approaches of those responsible for implementation of such programmes. Risk management requires that the reconstruction programmes should not only provide safe infrastructure, but that it should also be affordable and acceptable to the people, and they should use the same techniques in the future construction as well.

Chapter Seven

Chapter Seven

THE RESEARCH DESIGN

"In the early twentieth century, anthropologists developed a method of investigation called 'field work', which was one of observation of the culture in its natural habitat. This involved learning the language of the people, observing the rituals and everyday life of the people, and talking at length to a variety of informants in a natural conversation. This was a major step towards organised social research".

(The Open University, 1979)

7.1 Research Methods

Most research scientists agree that scientific research follows a sequential methodology, in which the following steps act as gears to the assurance of quality research (Buckley, 1976):

a) gathering information from observations, which take place through a definable searching process;

b) defining the research problem, thereby explaining why the research is being conducted, and what is intended to be achieved at the end;

c) formulating a research plan by selecting the appropriate strategies, domains and techniques for the research;

d) initiating inquiry according to the plan, in the light of the need to obtain relevant and sufficient evidence;

e) stating the outcome of the inquiry in explicit terms, which may result in support or refutation of an existing hypothesis; and

f) documenting the conclusions with sufficient support and clarity, so that these conclusions establish what was done, what was found and what significance the findings may have.

The methodology followed in this research is based on the above prescribed steps. Accordingly, the research problems were identified through preliminary literature review and field observations which led to describing the study objectives. The objective are presented in Section 7.2.

7.2 Specific objectives of the study

Different approaches used for the implementation of the reconstruction programme in Dhamar has provided the basis for studying and investigating these approaches in detail in order to derive policy implications for efficient and effective implementation of future reconstruction programmes, not only in Yemen, but also in other countries facing similar problems. Major objectives of the research are presented below:

Objective 1: to examine initial responses of the government and the earthquake-affected communities, and the extent of their willingness to undertake the post-disaster relief work;

Objective 2: to evaluate the efficiency and effectiveness of the government's planning process, and to examine the compatibility of the reconstruction programme with respect to the severity of the situation faced by the victims;

Objective 3: to analyse to what extent the objectives of the reconstruction programme were realised, and to identify the issues and constraints which inhibited or contributed to the efficient and effective implementation of the programme;

Objective 4: to ascertain the role of the earthquake-affected community in different phases of the reconstruction programme, with the intention to elaborate how community management can enhance the efficiency and effectiveness of such programmes; and

Objective 5: to propose recommendations to serve as guidelines for the development and implementation of future reconstruction programmes for Yemen in particular, and other countries facing similar problems in general.

7.3 Common research strategies

The purpose of choosing a research strategy, is to find a way for generating and testing a theory which could help in achieving the research objectives (Jawahar, 1995). Four common strategies described by experts, such as Buckley (1976), are given in the following paragraphs.

7.3.1 Opinion research: When a researcher seeks the views, judgement and appraisals of other persons with regards to the research problem, he/she engages himself/herself in an opinion research. This approach is one of the most well known methods to study people's behaviour and responses about a certain problem. This approach requires learning the concerned people's views and observations through questionnaires and personal interviews (Fink and Kosekoff, 1985).

7.3.2 Empirical research: This strategy requires that the researcher should observe and/or experience the things for himself, rather than mediation through others. Case-studies, field observations and laboratory testing come under this category.

A case-study can be defined as the in-depth study of a particular case under consideration, which will ultimately help in making assessments and drawing conclusions for other similar cases (Hamel et al, 1993). Intensive methods of field research, based on case-study, are of great value and importance in making certain conclusions. A case-study requires personal involvement of the researcher in finding out the real information from reliable sources and then presenting them in the light of his research. The data collected by the case-study method is considered to be superior than the information gathered through bureaucratic and administrative sources (Blumer and Warwick, 1983). Many experts, such as Yin (1993), are convinced that case-study research is an essential form of social investigation.

7.3.3 Archival research: This approach involves examination of the recorded facts, such as original documents, files and recorded facts investigated and published by some other researchers;

7.3.4 Analytical research: This research methodology relies on the use of internal logic on the part of the researcher. In this approach, the researcher has all the resources required for solving the problem at his/her disposal. No explicit reference or external data is necessary in this method. This strategy is not very commonly used because not many researchers can find all the resources needed for their research within themselves.

The present study has used two of the above described techniques, i.e. the opinion research and the empirical research techniques.

The opinion strategy was used because the responses of the people, for whom the reconstruction programme was implemented, and on which the research focused, was vital for the study. The opinion of those who implemented the programme, was also of significant importance.

The empirical technique was used as an additional tool of research, because the researcher stayed and worked on a United Nations project in the disaster-affected area, for three years (1992-1995). His long presence in the study area gave him an opportunity to conduct the field studies and laboratory tests in support of the research.

7.4 Methodological framework

The methodological framework provides a clear idea about what information is to be collected, how it will be analysed, and in what way it will be interpreted. Formulation of OVIs becomes the step-by-step guideline for the individual research work. The clearer the OVIs are the more comprehensive the research work is. The research study reported in this dissertation is based on insights into the issues under consideration, which are further examined through statistical analysis.

The study objectives are already described in Section 7.2. The methodological framework to achieve these objectives comprises the following steps:

a) formulating objective verifiable indicators (OVIs);
b) identifying data needs and sources;
c) reviewing relevant literature;
d) determining survey methodology and collecting field data;
e) processing field data and analysing it;
f) interpreting results from analysis with reference to OVIs; and
g) drawing conclusions and making recommendations.

7.5 Objective verifiable indicators (OVIs)

OVIs are very important to clearly identify the problem under investigation, why it is being investigated, how it will be investigated, and what will be achieved as a result of the investigation.

7.5.1 OVIs for objective 1: The 1982 earthquake came suddenly. Literature review, and later field studies indicated that neither the government nor the people had much idea about hazard. After the earthquake, both the government and the victims reacted on their own. The responses are studied under the following OVIs:

a) nature of the government's temporary arrangements (emergency help);
b) time taken in providing the emergency help;
c) coverage of victims by the emergency help;
d) impact of the emergency help on victims;
e) earthquake-affected community's immediate response;
f) time taken in victims' immediate response; and
g) coverage of victims by their immediate response.

7.5.2 OVIs for objective 2: The review of efficiency and effectiveness of the reconstruction programme required evaluation and analysis of the following OVIs:

a) cost of the infrastructure built during the reconstruction programme;
b) delivery time of the infrastructure;
c) affordability of housing for the victims;
d) earthquake-resistance of the infrastructure;
e) extent of utilisation of the infrastructure;
f) acceptability of the infrastructure; and
g) extent of coverage of the victims by the reconstruction programme.

7.5.3 OVIs for objective 3 The main objectives of the reconstruction programme, as seen during literature review and discussed with the Yemeni colleague engineers, were to provide earthquake-resistant housing and other infrastructure to cover the entire earthquake-affected population. It was intended that the reconstructed infrastructure should be available to the people in the shortest possible time, it should be fully acceptable and affordable for future construction and that it should be fully utilised.

In order to confirm how far these objectives were achieved, it was considered necessary to conduct a social, as well as a technical evaluation of the reconstruction programme. The OVIs for the two types of investigation are given below under separate titles:

7.5.3.1 *Social evaluation:*

a) coverage of the earthquake victims;

b) full utilisation of the infrastructure built in the reconstruction programme;

c) satisfaction with the reconstruction programme;

d) constraint in implementing the programme;

e) institutional deficiencies;

f) working conditions for the field staff;

g) political interference;

h) donor preferences;

i) local contractors, lack of experience; and

f) lack of the community's appreciation of the reconstruction programme.

7.5.3.2 *Technical evaluation:*

a) dimensions of various rooms in the house;

b) location of different rooms;

c) general condition of the house;

d) materials used in construction;

e) ground (safety) conditions against earthquakes;

f) load bearing capacity;

g) materials used in foundation;

h) location of tie beams;

i) materials used in super structure;

j) materials used in roof structure;

k) protection measures against roof leakages;

l) protection measures for foundation; and

m) laboratory test results.

7.5.4 OVIs for objective 4: In order to review the earthquake-affected community's role in the short-term measures (immediate relief) and long-term measures (reconstruction programme), it was considered necessary to test the following OVIs:

a) initial responses of the government;

b) initial responses of the community;

c) level of community involvement in location of the infrastructure;

d) level of community involvement in design of the infrastructure; and

e) level of community involvement in construction.

Figure 9.1 presents the study objectives and the OVIs in a diagrammatic form.

7.5.5 Basis for conclusions and recommendations: The inferences derived from the evaluation and analysis under the above OVIs, led to draw certain conclusions. The recommendations based on these conclusions are presented in Chapter 11.

7.6 Identification of data needs and sources

The study of development and reconstruction problems, in earthquake zones, emphasised the need for gathering information from various sources. The required data included information about earthquakes, recorded events of significant importance in various parts of the world, their probability and preparatory measures considered against them. This information was gathered through the following sources.

7.6.1 Literature review: The following sources were used for the literature review:

a) study of relevant technical books through personal purchase or on loan from the Pilkington Library and WEDC Resource Centre, both at the Loughborough University of Technology. Some essential material, not available at these sources, was arranged by them from other libraries in the UK;

b) visit to well known sources of information, such as the Oxford Centre for Disaster Studies (OCDS), the Martin Centre for Architecture and Urban Studies (MCAUS), the Imperial College, University of London, the Overseas Development Institute, London (IDA), the Development Planning Unit, London (DPU), and different United Nations offices and the World Bank office in Yemen. These visits were made in order to hold discussions with experts on various topics covered in this research and to collect study material;

c) study of various technical conference papers, journals and periodicals on the subject available at the above sources, Sana'a University, UN and the World Bank offices in Yemen and Pakistan, and the Geological Survey of Pakistan;

d) study of news bulletins published by various specialised agencies, such as UN/DHA; WHO, UNICEF, UN/HABITAT-DHS, UN/AEC, UNICEF, UNIDO, etc;

e) review of the record available at the government ministries and other offices in Yemen, such as the Ministry of Construction, the Ministry of Urban Planning, the Ministry of Oil and Mineral Resources, the Ministry of Planning and Development, the Executive Office of SCREAA Dhamar, and the Seismological Observatory Centre Dhamar;

f) study of the literature published by various international and bilateral agencies and NGOs, who were involved in the reconstruction programme, such as UNDP, UNCDF, UNICEF and Dutch-Aid, and NGOs such as OXFAM;

g) carrying out computer searches via the Pilkington Library at Loughborough University, OCDS, MCAUS, IDA, DPU, and the Imperial College, London to locate any relevant material for the research; and

h) undertaking discussions or correspondence with different experts in the related fields. The names of some of these experts and their fields of expertise are given below:

i)	Disaster management	Dr Ian Davis (OCDS), Dr Andrew Coburn (MCAUS), Mr Robin Spence (MCAUS), and Dr Anand Arya of the Building Material and Technology Promotion Council (BMTPC), India;
ii)	Earthquakes and seismic studies	Mr Mazin Salim (UNDP) and Mr Jamal Shu'lan of the Seismological Observatory Centre (SOC), Yemen;
iii)	Geology	Mr Osman Thabit (SOC) and Mr Najeeb Husain (SOC);
iv)	Reconstruction	Dr Ian Davis (OCDS), Dr Anand Arya (BMTPC), Dr Andrew

		Coburn (MCAUS), and Mr Robin Spence (MCAUS);
v)	Statistics	Mr L Jawahar Nesan of the Wolverhampton University (WT) and Dr J R Calvert of the Loughborough University of Technology (LUT);
vi)	Architecture	Dr Ian Davis (OCDS), Dr Anand Arya (BMTPC), Dr Andrew Coburn (MCAUS), Mr Robin Spence (MCAUS), and Mr Kamal Turki of the Ministry of Construction (MOC), Yemen;
vii)	Structural engineering	Mr Mike Smith (LUT), Dr Simon Austin (LUT) and Dr John Dickens (LUT);
viii)	Low-cost housing	Mr Richard Neale (LUT), and Mr Paul Sutmuller and Mr Cor Dijkgraaf (DHV Consultants, Amersfoort, Holland);
ix)	Sociology	Dr Jo Beall of the Imperial College, London (ICL), Dr Muhammad Aslam (UNDP) and Ms Maliha Husain (EDC Consultants, Islamabad, Pakistan);
x)	Economics	Dr Tariq Husain (EDC) and Dr M A Farooqi (UNHCR);
xi)	Demography	Mr Mohammad Afzal of the Pakistan Institute of Development Economics (PIDE) and Dr Mohammad Rafiq (UNDTCD);
xii)	Community management	Dr Richard Franceys (LUT), Dr Andrew Cotton (LUT), Ms Joy

		Morgan (WEDC consultant) and Dr Jo Beall (ICL);
xiii)	Low-cost infrastructure	Dr Richard Franceys (LUT), Dr Andrew Cotton (LUT) and Dr Andrew Coburn (MCAUS);
xiv)	Social and technical surveys	Dr Richard Franceys (LUT), Dr Muhammad Aslam (UNDP), Mr Mohammed Omar (MOC) and Mr Max Hunt (LUT);
xv)	Earthquake-resistant designs	Mr Robin Spence (MCAUS), Mr Khalid Hazza'a (MOC) and Mr Abdul Ghafoor (MOC);
xvi)	Soil mechanics	Mr Abdulhabib Alwan (MOC) and Mr Geza Vastagh (UN/FAO); and
xvii)	Computer software	Mr L Jawahar Nesan (WU), Mr Max Hunt (LUT) and Mr Yahaya Al-Ansi (SOC).

7.6.2 Social surveys: Much of the data and information required to satisfy the research objectives are *qualitative* in nature as they are required to determine the *behaviourial responses* of the affected communities as well as of the government functionaries towards the reconstruction programme. To this effect, a detailed social survey was carried out in the disaster affected areas to collect information through personal interviews with the following sources:

a) different sections of the earthquake-affected community; the survey covered all categories of the survivors since many of them benefitted from the emergency relief works and the reconstruction programme but quite an appreciable number did not benefit from either programme; and

b) government engineers and other supervisory staff who worked with SCREAA and participated in the reconstruction programme.

7.6.3 Technical evaluation: Another source of information, regarding safety of the buildings, was to make technical measurements of various houses and other infrastructure in the disaster affected area. This was done on selected samples representing all categories of houses and other infrastructure available in the project area.

7.6.4 Personal observations: Personal observations of the researcher, who lived among the affected communities in the disaster-affected area for three years, and the respondents' observations helped in screening and verifying the data collected through the above sources. This approach required the researcher to learn the Arabic language, because this is the only language spoken and understood in rural Yemen.

7.6.5 Survey methodology and data collection: As discussed earlier, the Dhamar governorate has a very conservative society with a low literacy rate. In the rural areas of the governorate only a few men can read and write. The female literacy rate is less than 5%. Collection of unbiased data was not easy under these circumstances. It was therefore not possible to collect most of the information in numbers, which could have been used for *quantitative* research. As a consequence of this limitation, the survey questionnaires had to be simple enough so the respondents could answer easily and with little risk of providing any incorrect information. As most of the data was to be based on the participant observation and unstructured in-depth interviews, emphasis was laid on such information which could later be used for *qualitative research.*

7.6.5.1 *Preliminaries*: Qualitative research is mainly identified with participant observation which entails sustained and in-depth study by the researcher of the subject communities, organisations or whatever. Qualitative research can also be defined as an approach to the study of social world which seeks to describe and analyse the culture and behaviour of human beings individually or collectively from the point of view of those being studied (Bryman, 1988). Participant observation, however, is not the only method of data collection in this approach. Unstructured interviews, in which the interviewer gives minimal guidance to the respondents, is a more popular technique. Qualitative research refers to peoples' behaviour, their beliefs, social attitudes and organisational functions, etc (Strauss and Corbin, 1990).

Social surveys are an important means to collect information from people about their ideas, feelings, beliefs, social, cultural, financial and educational background (Fink and Kosecoff, 1985). These surveys, however, require different sampling techniques according to different circumstances and needs for which the surveys are being conducted such as:

a) how wide a coverage is required?
b) what type of respondents will be available? and
c) will the selected group of respondents be representative of the community?

The answers to such questions provide a clue to the researcher to decide about a sampling design (Twumasi, 1986).

There are two types of sampling techniques as follows:

a) probability sampling; and
b) non-probability sampling.

In probability sampling each and every unit within the population to be surveyed is given an equal chance to be selected. The area under study is marked and a map is prepared. The number of houses in this mapped area are counted which is followed by determining the selection criteria for sampling. The larger the sample the better the chances for accuracy of information, but important factors, such as time, energy, number of surveyors available and cost help determine the sample size. Some commonly used probability sampling techniques are as mentioned below:

a) simple random sampling;
b) stratified sampling;
c) systematic sampling; and
d) cluster sampling (Fink and Kosecoff, 1985).

In non-probability sampling the researcher has a freer hand and he decides to take what he considers as the representative unit of the population. There are three major types of non-probability sampling techniques as follows (Twumasi, 1986):

a) accidental sampling;
b) purposive sampling; and
c) quota sampling.

Surveys can be in the form of questionnaires to be directly filled in by the respondents. This method is applicable in societies having a high literacy rate. In contrast, Yemen has a low literacy rate (18%), thus suggesting the need for personal interviews using a simple questionnaire. Lack of time and resources, problems in finding technically qualified and experienced surveyors, remoteness of the project area, and difficult working conditions forced the researcher to adopt a purposive sampling technique. However an effort was made to represent the broader characteristics of the respondents by selecting them from all walks of life and sexes.

In view of the fact that local language is Arabic and only about 1% of the population understood English, questions were kept simple and straight-forward in order to ensure legitimacy of respondents' answers.

7.6.5.2 _Sample selection_: Respondents of the social and technical surveys represented the four categories. A total of seven questionnaires were designed to cover all categories of respondents (Annex 1). The general categories of these respondents are described below:

a) the earthquake victims, some of whom benefitted from the government implemented reconstruction programme;
b) the sheikhs (tribal leaders) representing the affected communities;
c) government officials who participated in the reconstruction programme; and
d) observations of surveyors who conducted the surveys.

a) **The earthquake victims**: The victims of the 1982 earthquake in Dhamar can be classified into the following four major groups:

i) those whose houses were fully damaged and they were the beneficiaries of the turnkey housing programme. For convenience, these respondents are referred to as the *Turnkey category* in the following chapters;
ii) those whose houses were fully damaged and they were the beneficiaries of the self-help housing programme. These respondents are referred to as the *Self-help category* in the next chapters;
iii) those whose houses were partly damaged and they benefitted from the repair programme. The repair programme was implemented for the traditional houses which were originally located, designed and constructed by their owners. Besides asking their views about the repair programme, these respondents were also interviewed in detail about their traditional houses. For convenience this category of respondents is referred to as the *Traditional category* in the following chapters; and
iv) Those whose houses suffered collapse, or repairable damage, but they did not benefit from any of the above programmes and had to rely on themselves for shelter.

All these four categories had different experiences and views about the reconstruction programme. Their problems were also different. Therefore, separate questionnaires were designed for each category to determine their response to the reconstruction programme. Complete questionnaires for each group of the respondents are placed in Annex 1 of this thesis and marked 1-A, 1-B, 1-C and 1-D. Personal views of the respondents about preparatory measures for protection against earthquakes, immediate relief measures after the earthquake, the reconstruction programme, their confidence in the safety of the new or repaired infrastructure, their trust in traditional leadership and government agencies, etc. were important elements of the interviews and social survey. Special provisions were made in the questionnaires to cross-check participants' observations.

For categories (i) and (ii), ten well-dispersed settlements each were selected. From each village, four respondents representing different walks of life and different sexes were selected for detailed interviews. In total, 160 respondents were interviewed with equal distribution among all categories. An effort was made to select sample units well-dispersed in the Dhamar governorate to give a reasonable representation of the entire governorate. Since the repair programme was confined to only Dhamar town, all respondents under this category were selected from different parts of the town. The respondents from the non-beneficiary category were selected from the different areas representing the above three categories of respondents. A map showing the villages, where the surveys were conducted, is placed at Annex 2.

b) Sheikhs of the affected communities: Village heads, known as *sheikhs*, are the traditional leaders of villages. The sheikhs have traditional, and in some cases official responsibilities, to take up local problems and demands with the government. They are well informed about the problems in their respective areas and about their solutions, because they serve as an important link between the people and the government. It is also considered unconventional and unethical to collect information from the people in a village, without the knowledge of the sheikh. A surveyor may be regarded with as an intruder, if he or she tries to conduct social surveys and interviews without the knowledge and blessings of the sheikh. The sheikhs of the affected communities were interviewed to obtain an overview of the disaster effects and reconstruction programme in their respective villages. This was acheived by using a separate questionnaire. In total, 20 sheikhs were interviewed. This questionnaire is marked 2 (Annex 1). The list of the interviewed community sheikhs is given in Annex 3.

c) Government officials: Government engineers and other officials who participated in the reconstruction programme had their own views about the implementation of the reconstruction programme. These views were considered very important to know the institutional problems linked with the reconstruction programme. Their impressions about the reconstruction programme were recorded using a detailed questionnaire, marked 3 (Annex 1). About 50 Engineers and some other technical staff, such as geologists, architects and various technicians, worked under the SCREAA office in Dhamar during the reconstruction programme. SCREAA was dissolved in 1992 and the engineers and other staff were transferred to different government ministries. Fortunately most of the engineers who held responsible positions during the reconstruction phase, particularly those involved in the implementation of the Turnkey, Self-help and Repair programmes were still present and available for interviews. The results reported in this study are based on interviews with 20 officials comprising of 12 engineers, 3 geologists, 2 architects and 3 technical supervisors (Annex 4).

The social survey data compiled as a result of these interviews, (the victims, sheikhs and government officials) is given in Annex 5.

d) **Surveyors' observations**: The researcher, who lived in the study area for three years and his three surveyors, who had lived and worked in the disaster affected area since 1982, and all of them participated in the reconstruction programme, also made their own observations. These observations were considered important. A separate questionnaire was prepared for the surveyors to record their views of the infrastructure they visited. This questionnaire is marked 4 and also part of Annex 1. The surveyors' technical observations were based on field measurements carried out at 40 different sites selected for the study, including the town of Dhamar. This information is presented in Annex 6.

7.6.5.3 _Interview procedure_: Before starting the actual data collection effort, all questionnaires were extensively pretested in the field, and necessary adjustments were made to enhance the clarity of the questionnaires. Actual field surveys were started in April 1994, but were interrupted by the civil war in Yemen from May to July. The researcher and his surveyors continued to work at the beginning of the war, but a stage came in the month of April 1994 when there was risk to life and the researcher was evacuated from the country by his employer, the United Nations. The researcher returned to Yemen in July 1994. It took three months' extensive field work to complete the remaining field work.

Figure 7.1: The researcher and the field surveyors with some of the respondents
Source: Field Surveys, 1994

The researcher selected and trained three surveyors to carry out the social and technical surveys. All these surveyors were Yemenis and of rural origin with technical background and some past experience in social surveys. Their simple life style and homogeneity with the local population was very convenient in gaining the confidence of the respondents. These surveyors were trained together and each questionnaire was discussed in detail during the training sessions. The surveyors were specially trained to remain *objective* during the interview sessions, in order to allow the respondents to express their opinions without bias.

The roads in the study area are very rough. Most of the target villages were found to be almost inaccessible without a four-wheel drive vehicle. Driving in these areas became more hazardous after sunset. The researcher accompanied the surveyors in most of their field visits and closely supervised and monitored the interviews (Figure 7.1). The researcher's personal knowledge of the Arabic language, with the local accent proved to be very useful in the interviewing sessions. This helped him in not only conducting a number of interviews of the victims by himself, but also in monitoring other interviews conducted by the surveyors, to ensure that unbiased information was being recorded.

The government engineers and other concerned officials were entirely interviewed by the researcher himself.

7.6.5.4 *Timing of interviews*: The best time to hold individual interviews is morning, that is, before midday when the people are in their farms or shops or doing some other business. After midday, the afternoon prayer is immediately followed by luncheon. A long qat chewing session starts soon after luncheon and lasts until sunset or sometimes even later. It is almost impossible to speak to someone individually during the qat chewing period. During the qat session, most Yemenis, particularly those in the rural areas, are in a very light mood and do not give full attention to questions. They also try to exaggerate the answers. Afternoon time for field surveys is also not the best for surveyors if they are Yemenis. In view of the above limitations, all interviews were conducted in the morning hours.

7.6.5.5 *General considerations*: Yemeni society, particularly in the northern part of the country, is very conservative. The rural population is even more tradition oriented. For this reason special care was taken not to ask any question which could have slightest conflict with their local customs, traditions or religious beliefs.

The questionnaires were prepared keeping in mind all members of the society and representing different walks of life and sexes.

Yemeni people are generally good natured but at the same time very curious. All male members of the village including small children, present at the time of the visits of the surveyors, always tried to answer the questions unanimously. Selecting the respondents and interviewing them separately was therefore was another challenge.

7.6.5.6 *Interviews of women respondents*: Interviewing women, who are seldom exposed to any other environment besides their homes and family farms, was yet another challenge. It was most difficult to keep the male members from feeding answers to the female respondents. The researcher and his surveyors found some elderly women, some working women and some girl students from the beneficiary villages to participate in the interviews with the consent of their male relatives. This was possible only because of the confidence and good social contact established with the local community.

7.6.6 Difficulties in data collection: Poverty, frequent droughts, high unemployment, low literacy and the prolonged tussle between the northern and southern parts of Yemen had badly affected the socio-economic structure of the Yemeni society during the time of this study. The law and order situation was going from bad to worse. Highway robberies, car snatching and abduction of foreigners at gun-point for ransom had become common features. Many people in Yemen believed that the military were behind such crimes. The researcher also faced some of these problems in the pursuit of his research and lost a new 4x4 vehicle at gun-point. The vehicle could never be recovered. The civil war of 1994 proved to be another deterrent which has already been discussed earlier in this chapter.

7.6.7 Data processing and analysis: There is no standard analytical procedure to formulate and evaluate options for the development and reconstruction work in low-income countries. The procedure has to be adjusted according to local conditions, depending upon the nature of the problem to be addressed and the type of data available. Analysing data from the surveys involves tallying and averaging responses, looking at their relationships and comparing them (Fink and Kosecoff, 1985).

Data analysis was performed by comparing the information collected through interviews, participant observation, inspection of records and field testing. In this context, the first step, the data collected through field surveys was examined for its consistency and validity. This involved a thorough checking and editing of all questionnaires. The next step involved tabulating the collected information in order to separate the research data into its constituent parts. Finally, OVIs were derived and analysed in terms of percentages and absolute numbers. The results obtained were compared with the existing available information. These results are discussed in detail in the next two chapters.

Summary

Research design is key to a research study. Experts have described different and useful guidelines for the collection of information. But it is the researcher who prepares the research design to suit his study. Care is taken that while no relevant information is left out, at the same time, no irrelevant information is included. The choice of qualitative or quantitative research depends on the type of research rather than the researcher's preference. The hypothesis, objectives and OVIs need to be constantly considered while preparing the questionnaires. The quality of questionnaires influences the analysis of data. Social and technical surveys in low-income countries offer several difficulties and challenges. Personal involvement, dedication and foresight of the researcher are important tools in collecting the information which ultimately provides the basis for testing the hypothesis, drawing conclusions and making recommendations.

Chapter Eight

Chapter Eight

PRELIMINARY EVALUATION OF THE FIELD DATA

"Interactual communication is fairly easy when it is cognitive or based on what we know, but experimental communication is nearly impossible because it is based on what we feel ... " *(Porter Samoven, 1976)*

The 1982 earthquake disaster in Yemen and the following short-term and long-term measures to rehabilitate the surviving communities after the disaster, presented an interesting case for detailed study. The objectives and the methodological framework of the study have already been described in detail in Chapter 7. These objectives called for comprehensive field surveys in the disaster-affected areas and evaluation and analysis of the data collected.

In pursuance of the need for field data for the study objectives, sufficient information from different categories of respondents was collected through interviews, by using detailed questionnaires. The discussions in this chapter are no more than preliminary evaluation of the field data, in the order of the field survey questionnaires and do not necessarily follow the sequential order of the study objectives. Data processing, statistical analysis and discussions with respect to the OVIs, is presented in Chapter 9 in the order of the objectives given in Chapter 7.

8.1 Socio-economic features of the earthquake victims

All respondents from the earthquake victims were those who had themselves experienced the 1982 earthquake disaster, and the following short-term relief and long-term reconstruction programmes. These respondents represented different age groups, sexes, professions, education levels and financial status. Their socio-economic features are provided in Table 8.1.

Table 8.1: Socio-economic features of the respondents

Type of benefi-ciaries	Total no of respon	Avg age in yrs	Literacy level (%)					Occupation (%)			Average annual income (Yemeni Riyals)				H/h size no.
			0	1	2	3	4	GS	PS	HW	Average per h/hold	Percentage			
												HI	MI	LI	
TK	40	46	38	30	22	10	0	22	75	3	117,875	17%	40%	43%	9
SH	40	42	29	24	26	19	2	38	55	7	97,643	7%	28%	65%	8
RP	40	41	24	24	27	17	8	41	56	3	111,000	10%	29%	61%	6
NB	40	40	44	15	21	15	5	24	71	5	99,634	7%	32%	61%	8
	160	42	34	23	24	15	4	31	64	5	106,538	105	325	58%	8

Source: Field surveys, 1994.

Key

Respondents' categories: TK: Turnkey; SH: Self-help; RP: Repair programme; NB: Non-beneficiaries

Education levels: O: Illiterate; 1: Primary; 2: Middle; 3: Secondary; and 4: Above secondary.

Occupation: GS: Government sector; PS: Private sector (mostly farming); and HW: Housewife.

Income groups: LI: Low income (up to YR 100,000 per annum)
MI: Middle income (YR 100,001-200,000 per annum)
HI: High income (YR 200,001 and above per annum)

Note:

The above income levels are based on the prevalent market rates in 1994, and the individuals' capacities to meet their basic needs.

According to the information available from field and presented in the Table 8.1, the average age of the respondents was estimated to be about 42 years. There was not much variation in the age groups of the respondents from different categories. The field survey results are quite consistent with those of the last census, in which the average age in Dhamar Governorate was reported to be about 46 years (MPD, 1991).

Literacy among the respondents was found to be higher than the overall literacy level in the governorate, probably due to the fact that 25% of the respondents were from Dhamar town where the literacy rate is more than in the villages. Secondly, many respondents, who could only read and recite the Muslim holy book the *Qur'an,* claimed to have attended primary school. Thirdly, the low literacy among women which drastically affects overall literacy figures in the governorate, were not many among the respondents for reasons of conservatism. Fourthly, most of the socio-economic data in the existing literature available from the government was projected from the 1986 census figures, but development in certain sectors, such as education, is generally believed to be more than the projections. The survey figures showed that 57% of the respondents were illiterate or had little education. Another 39% of the respondents had an education level of middle to secondary school. The remaining 4% had studied further beyond secondary school. The literacy rate was particulary low for the respondents representing the turnkey and the non-beneficiary categories. The general tendency observed in the governorate was that most people preferred to use their children in helping the family in farming, fetching water for domestic use, collecting fuel wood or shepherding domestic animals, instead of sending them to schools.

The survey data indicated that about 64% of the respondents were working for the private sector (mainly agriculture farming), followed by 31% in the government sector and 5% as housewives. Some women respondents were also found in the government and private sectors, and a few were students. The government statistics indicated that about 70 % of the people of Dhamar were engaged in agricultural farming or affiliated activities. The main reason for the low survey figures was perhaps that the surveys of beneficiaries of the traditional housing repair programme were conducted within the Dhamar municipal limits, the only place where this programme was implemented. Dhamar town has a higher number of people working in the public sector. This was probably the reason why a slightly higher number of the respondents turned out to be government servants. It was not easy to interview women in a conservative Yemeni society and to get their independent views. Male relatives stayed around and tended to feed information to the women. The percentage of female respondents might have been more if at least one of the surveyors was also a woman.

The average annual income of the respondents was estimated to range between a minimum of YR 99,634 per household (or YR 12,454 per capita) for the respondents from the Non-beneficiary category, to a maximum of YR 117,875 per household (or YR 13,097 per capita) for the respondents representing the turnkey category. These figures were slightly above the government statistics quoted in the literature review, probably due to the reason that income figures had lately shown an upward trend in the recent past and particularly after the civil war of 1994. The average annual income for the entire sample was YR 106,538. This is slightly higher than the GNP and was possibly due to the high inflation in the country and did not necessarily mean a better economic situation. In actual fact the purchasing capacity of a common consumer was much reduced. Given the current economic conditions and continuously rising price levels, the following classification could tentatively be used to represent different income groups among the victims:

a) low-income < YR 100,000;

b) middle-income YR 100,001 to YR 200,000; and

c) high-income > YR 200,001.

Based on this classification, 58% of the respondents represented the low-income category, 32% the middle-income category, and 10% high-income category. Several factors, as discussed in detail in Chapter 3, had driven the people to below the poverty line. The people in low-income bracket were found to be suffering more, since 30% to 50 % of their income was consumed by chewing *qat* and smoking. The 1994 civil war in the country had caused a further blow to the country's economy causing spiralling inflation and unemployment.

The average household size in the study area was found to be 8 persons, which was close to the official figure of 7 persons. There was no systematic trend or pattern showing relationship between household size and income level.

8.2 Initial responses

The initial responses of the government and the earthquake victims, and the materials used in providing temporary shelter, etc are summarised in Tables 8.2 and 8.3.

Table 8.2: Extent of damage to existing houses and survivors's response

Survivors category	House condition after earthquake		Survivors' initial responses			
	Total damage	Part damage	Helped by self/ community	Awaited government help	Spent money	Used labour
Turnkey	90%	10%	98%	2%	-	-
Self-help	98%	2%	95%	5%	-	-
Repair	7%	93%	95%	5%	-	-
Non-beneficiary	80%	20%	100%	0%	-	-

Source: Field surveys, 1994.

8.2.1 Earthquake victims' response: About 80% of the total respondents in the study area reported that their houses were totally damaged as a result of the earthquake. Almost all of them moved out of their houses after the first shock, to save their lives and a few items of value. Even in cases where the houses were not totally damaged, they moved to open fields and made temporary shelters in the wake of the government's emergency help.

8.2.2 Materials used for temporary shelters: The survivors mostly used blankets, wooden poles and materials recovered from the debris of their damaged houses in making their temporary shelters. The government's emergency help consisted of tents and blankets. The earthquake-affected people did not hire any skilled or unskilled labour in making the temporary shelters.

8.2.3 Source and nature of emergency help: About 97.5% of the victims had already made their temporary shelter arrangements of some kind, before the arrival of the government's emergency help. Only a small percentage, 2.5%, waited for the government's help after the disaster. Relatives and friends of the victims living outside the disaster area, also temporarily sheltered some of the victims, or helped them in making their temporary shelters.

The emergency help from the government invariably consisted of tents and blankets. These items were initially supplied by the armed forces, but later many neighbouring countries also sent in their help. The food comprised of dry milk, cereals, cooking oil and sugar. The government also supplied first-aid facilities to a few villages. Water was supplied by water tankers provided the local UN offices. No arrangements were made for sanitation. Food and medicines were also provided by donors.

Table 8.3: Initial responses

Objectives verifiable indicators	Victim's responses					
	TK	SH	RP	NB	Sheikhs	Govt
a) Nature of temporary arrangement	Shelter, food	Shelter, food	Shelter, food	Shelter, food	Liaison community/ government	Shelter, food, first-aid
b) Materials used for temporary arrangements	Blankets/ debris wood, zinc	Blankets, debris	Blankets, debris	Blankets, debris, wood, zinc	Used own means to disseminate information	Tents, blankets
c) Source and nature of emergency assistance	Self/ community	Self/ community	Self/ community	Self/ community	Government/ community	Mostly donors
d) Time taken in providing emergency help	Immediate	Immediate	Immediate	Immediate	Immediate	7 to 30 days or more
e) Coverage of relief operations	98%	95%	95%	100%	-	65%
f) Criterion for providing relief operations	1) 70% 2) 20% 3) 10%	1) 85% 2) 15% 3) 0%	1) 80% 2) 20% 3) 20%	-	-	-

Source: Field surveys, 1994.

Key

1. Nature of damage to the infrastructure;
2. Social and political influence; and
3. Donors' preference.

8.2.4 Time taken in providing emergency help: The response from all the victims' categories agreed that the government's emergency help started reaching some of them after a week. The emergency help took more time in the case of remote areas, which was 4 weeks or more in some cases. Emergency help to the victims located in remote villages was also inadequate in many cases, because by the time the government teams reached there, the available relief materials were nearly finished because of mismanagement.

The sheikhs provided liaison between their victims and the government and helped the surveyors in preparing lists of the victims and the extent of damage in their respective areas. The government respondents however considered these lists and the damage estimates to be inaccurate and said it was one of the main reasons for the low coverage of the victims with the emergency help and the long-term reconstruction programme.

8.2.5 Coverage of emergency help: The victims' coverage by the government in providing relief measures, including temporary shelters was 65%. The remaining 35% did not receive any assistance from the government or any other source. They had to rely on their own temporary arrangements. Quite a large number of such victims, who could neither benefit from the emergency help nor the reconstruction programme, can still be seen living in their vulnerable make-shift shelters in some of the villages.

8.2.6 Criterion for providing emergency help: The criterion for providing emergency help in most cases (60% to 85%) was based on the extent of damage caused to houses. There was, however, one problem with this criterion which was more seriously felt during the reconstruction phase. As discussed before, traditional Yemeni buildings are multi-storeyed in which many families live together under the extended family system. These families usually consist of the older parents, their children and the grand children. In the emergency help however only one small tent was considered enough for all people living in the entire building. This created difficulties and while only a few members of the family could benefit from the emergency shelters, the rest had to cater for their shelter needs on their own.

According to the victims, political and social influences also played their part to an appreciable extent (15% to 20%) in the provision of the emergency help. The villages with stronger political connections had a better say in obtaining emergency relief for their people. In contrast, the survivors having less political influence received inadequate and belated emergency help. Some donors, mostly oil-rich Arab neighbours, were said to have dictated their terms in choosing the areas for emergency help. They preferred the areas alongside the main roads, which were easily accessible and where the visitors and passers by could admire the assistance provided by such concerned countries. The percentage of such cases is between 10% and 20%.

In general, the survivors of the earthquake disaster in Yemen responded faster, better and much more economically to meet their emergency shelter needs. The government also mobilised available resources to provide the emergency assistance but it was late and inadequate. The socio-political factors played an important role in prioritising assistance to favourable segments of the surviving community.

8.3 Preparedness

Discussions with the government respondents and field observations revealed that there was none or little preparedness against the hazard, at the government's level or the community's level, before or after the earthquake. The Table 8.4 and the following paragraphs take a look at this aspect.

Table 8.4: Preparedness against a future disaster

Preparedness	Existence of earthquake warning system	Safety codes in bylaws to minimise losses	Resources allocated for relief operations	Resources available in future disaster	
				Government	Average household
Before 1982 earthquake	No	No	No	None	Small
After 1982 earthquake	No	No	No	None	Small

Source: Field surveys, 1994.

8.3.1 Existence of earthquake warning system: All government respondents confirmed that there was no hazard monitoring system in the country prior to the earthquake of 1982. Although some seismic observatories had been established after the earthquake, but there were no building controls in existence. A small percentage (5%) of these respondent revealed that concerns about the vulnerability of traditional buildings were expressed by some engineers before the earthquake, but no serious attention was paid by the relevant authorities.

There was no code of safety in the country's building by-laws for resistance against earthquakes prior to the 1982 disaster. There was still no building code, after the earthquake, although the Sana'a University has raised its voice on the matter.

About 35% of government engineers believed that the Yemeni people were conservative and tradition-oriented, and they would probably not give up their traditional style of building construction even if a safety code was introduced. A large number of respondents (40%) were of the opinion that the frequency of even moderate earthquakes was low in Yemen and the need for earthquake designs was not serious. About 25% of the respondents were of the opinion that the introduction of earthquake resistant designs would raise the construction cost significantly, implying serious concerns about the economic affordability of this technology.

8.3.2 <u>General steps taken to minimise losses during earthquakes</u>: Most of the government respondents agreed that the government had not made any arrangements to minimise suffering and losses in the case of a future disaster. Should such a catastrophe occur, the country will have to rely heavily on foreign assistance. The community itself was also not prepared. The majority of the people in the study area were poor. Their meagre resources hardly allowed them to prepare for an earthquake emergency in advance. More seriously, they did not believe in preparedness against the earthquakes. A number of earthquake victims, when questioned about the safety of their houses, said that earthquakes come under Allah's will and only the next earthquake could determine whether their houses were safe or vulnerable.

8.3.3 <u>Resources allocated for emergency relief operations</u>: Nearly all government respondents said that the government had not earmarked or allocated any special resources in the current development plan to meet emergency assistance needs arising from a future disaster. This was partly due to the fact that the country was facing formidable economic constraints from several of the reasons described in Chapter 3.

A lack of awareness at the government, as well as the community level, was probably the main factor for the lack of preparedness. If the surviving communities had any concern about the hazard, they might have insisted on the government for resource allocation for this purpose. The attitude of Allah's will prevails not only at the people's level but also at the government level.

8.4 Reconstruction programme

The reconstruction programme had two main components. These components were, the housing programme and the other infrastructure programme. The housing programme constituted a large part of the programme. The other infrastructure comprised of schools, mosques, water supply, roads, health centres, etc. These two components are discussed below.

8.4.1 The housing programme: The survey results describing the responses of the beneficiaries to the housing reconstruction programme are summarised in Tables 8.5 through 8.8.

Table 8.5: Coverage in the housing programme

Objectives verifiable indicators	Survivors			
	Turnkey	Self-help	Repair	Non-beneficiary
a) Extent of coverage provided to disaster affected communities	52%	50%	13%	0%

Source: Executive Office for Reconstruction, Dhamar, 1989.

8.4.1.1 *Extent of housing coverage provided to affected community*: The literature review shows that the government, after assessing the losses, announced its commitment to rebuilding or repairing all 42,000 houses damaged by the earthquake. 25,000 of these houses were seriously damaged and had to be rebuilt, while the remaining 17,000 were to be repaired. In reality, only 10,931 houses were built under the turnkey programme out of a target of 25,000. Another 3,000 houses were built under the Self-help programme from a target of 5,000. Thus the coverage was 48 and 40% short of the planned targets under turnkey and self-help reconstruction programmes, respectively. The government officials attributed this shortfall mainly to the initial estimates of the damages which were said to be highly inflated. The government engineers indicated that resource availability was not a serious constraint at the time when the reconstruction programme was planned. Yemen was economically much better off and was having good relations with its rich neighbours and other donors at the time of the disaster.

The performance in the repair programme (traditional category) was even less than the turnkey or self-help programmes, in which only 13% (2,200 houses) of the planned target (17,000 houses) was realised. The major reason for the shortfall was reported to be a lack of understanding between the government and the affected communities. For instance, according to the government respondents, the government's plan was to provide reinforced tie-beams in the load bearing sections of the buildings which the victims did not consider to be necessary. Instead, they insisted on a complete renovation of the buildings including repainting them. In contrast, the survivors claim that the government had allocated only YR 20,000 per house, which was not sufficient for most of the houses. They also questioned the universal application of the figure YR 20,000 to all houses which were damaged to different extents and therefore needed different repairs. This programme was intended to be implemented in all disaster-affected areas of the Dhamar governorate but difficulties were faced from the very start and the government had to abandon it after only partially finishing the works in Dhamar town.

A large number of survivors in the disaster affected area did not benefit at all from the reconstruction programme. The survivors attributed incorrect estimates and the wrong distribution criterion as the major reasons for insufficient coverage. As discussed earlier, the traditional house usually accommodate several families living together under the joint family system. While counting the damaged houses the government surveyors counted one large building, which provided shelter for three or four families, as one house which was replaced by one small house built under the reconstruction programme. Consequently, only one out of three or four families could be accommodated while the remaining families had to cater for their shelter needs by themselves. Poverty in the study area has forced a large number of the rural population to continue living in their temporary shelters to date (Figure 8.1).

Table 8.6: Criterion for location, design and construction

Beneficiaries' category	Community participation				Reason*	
	Location	Design	Size	Construction	Not invited	Sheikh represented
Turnkey	0%	0%	0%	0%	76%	24%
Self-help	100%	0%	0%	100%	93%	7%
Repair	100%	0% (repair)	0%	100%	100%	0%

Source: Executive Office for Reconstruction, Dhamar, 1989.

* Reason for lack of participation in various stages of work.

8.4.1.2 Criterion for site selection, design and size of houses: The surveys revealed that none of the respondents in the Turnkey category were individually consulted about location, design, size or construction of these houses (Table 8.6). The reason given by 76% of the respondents was that they were not asked to give their opinion while the remaining 24% claimed that they were represented by their sheikh in the decision making process.

In the self-help category all respondents were consulted about the location of the house mainly because according to the agreement, between the government and the beneficiaries, the latter were responsible to provide land for the houses. All of these beneficiaries reported that they were not consulted about the design or size of their houses. About 93% of respondents under this category reported that they were not invited to give their views on the design and size of houses while the remaining 7% indicated that they were represented by their sheikhs. The survey results suggest that all beneficiaries of the self-help scheme invariably participated in the construction programme and contributed with unskilled labour, water, local materials, and food for the labourers. The beneficiaries indicated their contribution was about 50% of the total

Figure 8.1: The non-beneficiaires still live in disaster prone houses
Source: Field Surveys, 1994

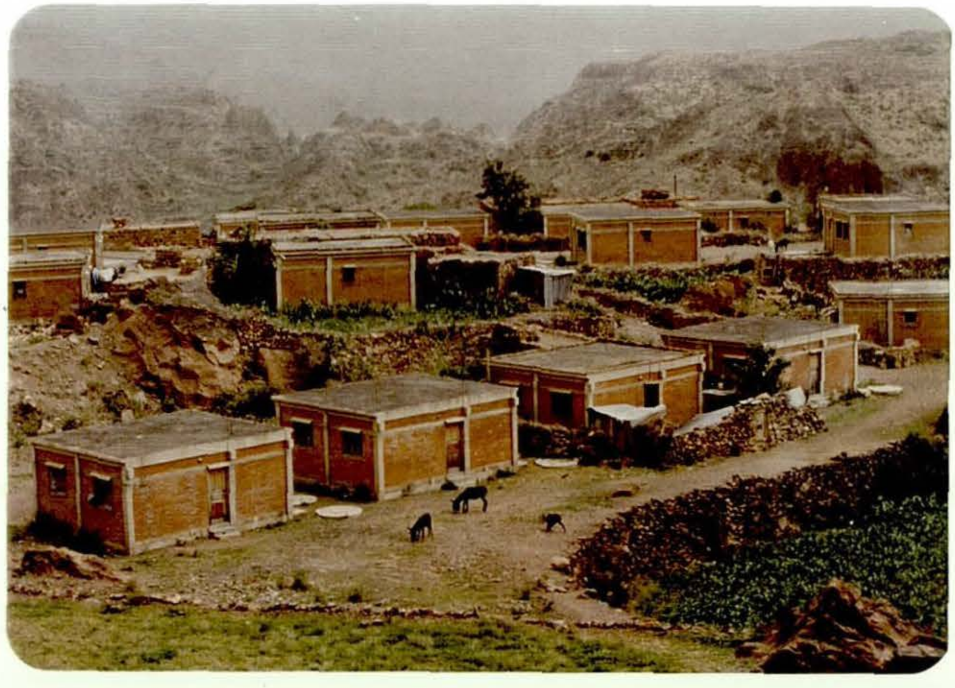


Figure 8.2: Box-like earthquake resistant houses are different from the traditional houses in most respects
Source: Field Surveys, 1994

cost, while the government estimates showed that the beneficiaries' contribution was only 30%.

The beneficiaries of the repair programme revealed that they were not consulted about the repair of their houses. According to them the government chalked out a fixed programme which was indicated to all concerned beneficiaries. The programme was reported to be very rigid in nature since no deviations or adjustments were possible. Many beneficiaries of this scheme had to use their own financial resources, often by taking loans or by selling valuables such as personal jewellery, to make the necessary adjustments to suit their family needs.

8.4.1.3 Acceptability problems in the new houses: Table 8.7 shows the problems in acceptability of the houses built during the reconstruction programme.

Table 8.7: Survivors' acceptability problems in the new houses

Category	Problems in Acceptability (%)																
	Rooms			Kitchen		Latrn		Lack of					Other Acceptability Features				
	Sz	No	Ln	Ln	Sz	Ln	Sz	St	Bn	Sb	Se	Fn	Ga	C	Wk	Fv	Bw
Turn-key	80	90	37	95	100	62.5	60	95	87.5	85	70	85	20	35	15	10	28
Self-help	62.5	82.5	17	85	93	65	57	85	67.5	77.5	65	69	33	15	3	2	13

Source: Field Surveys, 1994.

Key

Sz:	size;	No:	number;
Ln:	location;	St:	storage;
Bn:	barn;	Sb:	stable;
Se:	separate entrance for women;	Cl:	climatic suitability;
Fn:	insufficiency for family needs;	Ga:	general appearance;
Wk:	work (distance from);	Bw:	boundary wall; and
Fv:	family village (distance from).		

The new houses were completely different from the traditional houses (Figure 8.2). As discussed earlier, the design and size of these houses were not discussed with the beneficiaries, which became the main source of discontent among the beneficiaries. The survey results suggest that 62.5% to 80% of beneficiaries did not like the small size of the rooms. About 90% of the turnkey respondents considered the number of rooms to be too few for their needs. These problems were confirmed by 85% of respondents from the government officials category who agree. About 37% of them were not satisfied with the location of the rooms, while only 17% of the respondents from the self-help category expressed similar concerns.

The majority of the respondents (93 to 100%) from the turnkey and self-help schemes expressed their dissatisfaction about the size of the kitchen, while 85 to 95% disliked its location inside the house. The kitchen in a traditional house is about the size of a room (4.0 x 3.5 m^2) to accommodate an earthen oven and accessories and is usually built on top of the roof to avoid the smoke from the fuel-wood entering the house. The new kitchen is not only small (1.8 x 1.8 m^2) but is also located inside the house with smoke filling the house as soon as the oven is lighted. A large proportion of the government engineers sample (80%) also considered this as a serious problem.

About 60 to 74% of the respondents expressed serious reservations about the location of the latrine inside the house and next to the kitchen, while 62.5 to 75% did not approve of its size. Yemenis are used to large sized latrines (4.0 x 3.5 m^2 or so) where half the portion is reserved for washing clothes. Although traditional latrines are also located inside the house they are usually away from the kitchen and other main rooms.

Most people in rural Dhamar are farmers. They keep livestock for their dairy needs and for farming practices. It is very important for these farmers to have storage for keeping grain and stables and barns to take care of the livestock. About 85 to 95% of the respondents showed their dissatisfaction of the new houses because they did not have adequate facilities for storage and livestock.

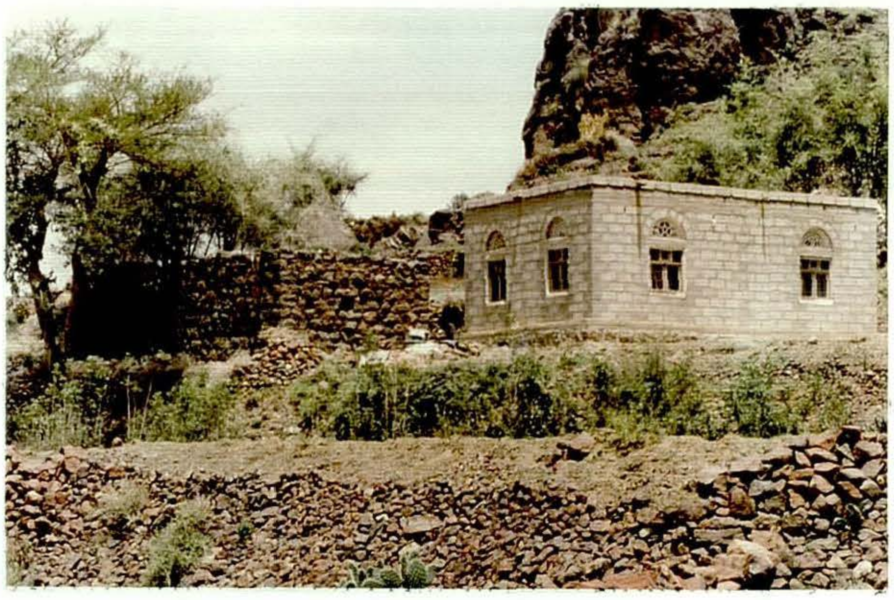
The new houses had only one entrance. This was not acceptable to a majority of the beneficiaries who felt a lack of privacy for women when a male guest visited them. A majority of the sampled respondents expressed their reservations on this issue.

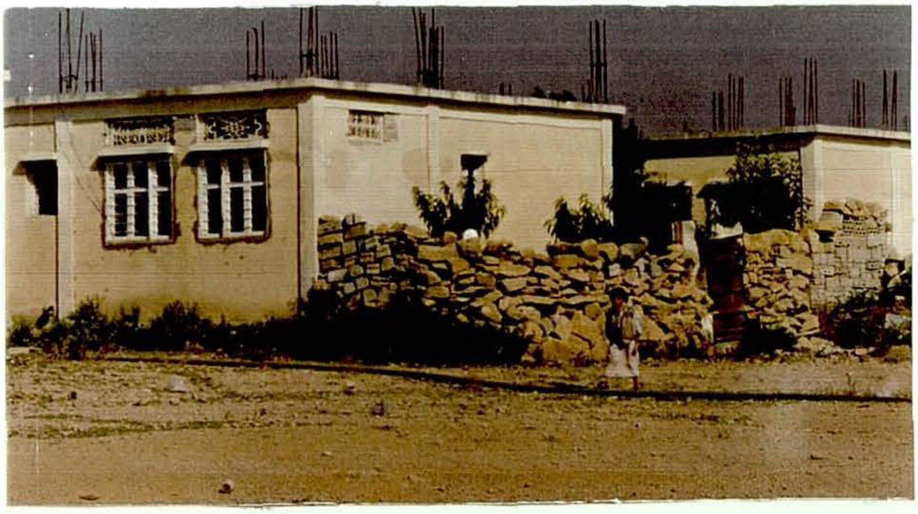
A large number of the respondents (69 to 85%) considered the houses to be small or insufficient for their family needs. Although the average household size in Dhamar governorate is 7 to 8 persons, the number of people living in a house is usually quite large because of the extended family system. The new houses were insufficient for such large families.

The earthquake survivors received the new houses because they were living in temporary shelters and the new houses were either being distributed free of cost (turnkey programme) or with only part contribution (self-help programme). Field surveys showed that some beneficiaries never occupied the Turnkey houses for their own habitation. They built (or repaired their damaged houses) from their own resources, and started using the houses transferred to them under the reconstruction programme for other purposes, such as stable, storage, barn or as guest houses. In certain other cases, electrical and sanitary fittings, doors and windows, etc. were removed from the government built houses, and subsequently installed in self built houses. Tribal rivalries and armed encounters in the northern Yemen, including the Dhamar governorate, are quite common. According to the government respondents, the beneficiaries sometimes used to test the strength and safety of the walls by shooting at them. If the bullets penetrated through the walls the houses were considered as unsafe. As such the clay bricks, which were mostly used in the turnkey houses, did not resist bullets and proved to be another reason of dissatisfaction among the beneficiaries. The self-help housing programme did not face such problems.

8.4.1.4 *Type of changes made in the new houses:* In spite of the problems mentioned in the preceding section, a majority of the houses built under the turnkey programme, and almost all houses built under the self-help programme were now occupied. The beneficiaries reluctantly reconciled with the situation because they were generally poor and had no other alternative. However, they did make a number of changes in these houses to suit their needs and affordability (Figure 8.3). Table 8.8 shows the percentage of beneficiaries who made alterations and amendments in their turnkey and self-help houses.

A kitchen and a toilet added to an aided self-help house





A boundary wall added to a turnkey house

A kitchen, a toilet and a stable added to an aided self-help house

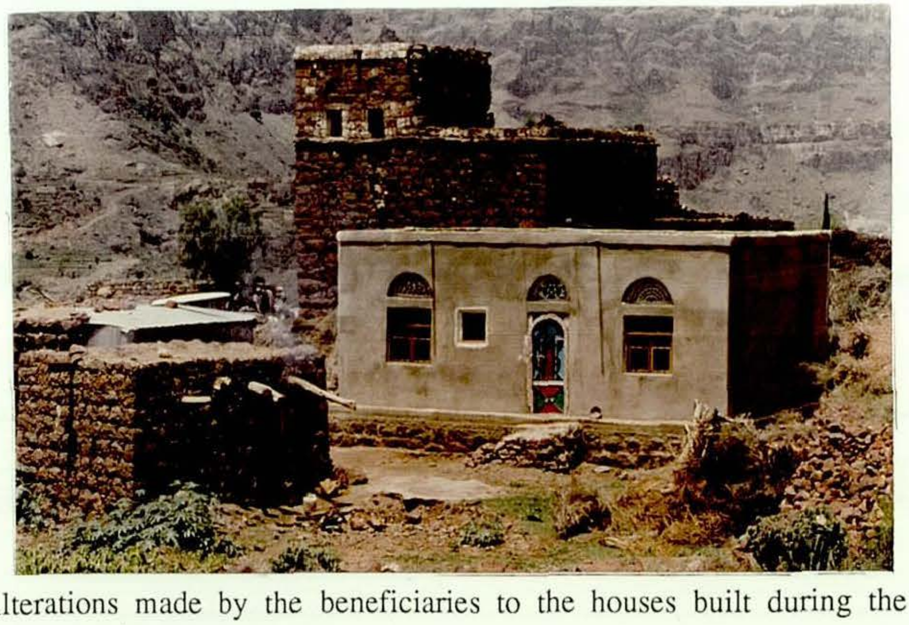


Figure 8.3: Alterations made by the beneficiaries to the houses built during the reconstruction programme
Source: Field Surveys, 1994

Table 8.8: Types of changes made in the new houses

Type of House	Changes made (% age)								
	Rooms		New addition outside the house					Second Entrance	Boundary Wall
	Size	No	Kitchen	latrn	Store	Barn	Stable		
Turn-key	0	18	60	30	38	28	33	4	4
Self-help	0	21	64	33	36	24	29	12	12

Source: Field surveys, 1994.

Although the respondents complained about the size of the rooms, none of the respondents made any alteration in the size. It was a difficult proposition, both technically and financially. About 18 to 21% of the respondents, who were rich and could afford, added some rooms outside the house. Most of these people added a divan (living room) and a kitchen outside the house. The percentage of beneficiaries who built new latrines, stores, barns and stables outside their houses ranged between 24 to 38%. Those who built a second entrance or a boundary wall were relatively small in number (4 to 12% and 4 to 10%, respectively). Those who were not able to make much needed alterations in their new houses attributed it to lack of resources.

8.4.2 Other infrastructure: Construction and rehabilitation of other infrastructure, such as schools, mosques, health centres, hospitals, electrification schemes, roads and water supply schemes) were also part of the government's commitment to carry out development in the disaster-affected areas.

8.4.2.1 *Extent of coverage*: A list of the committed infrastructure, other then housing, included:

a) 95 primary and secondary schools;

b) 57 mosques;

c) 24 rural health centres;

d) one 200-bed hospital in Dhamar and one 102-bed hospital in Ma'abar;

e) electrification of 80 villages;

f) rehabilitation of Dhamar-Dhabah road;

g) 100 km of new feeder secondary and tertiary roads; and

h) 259 water supply schemes.

Like the housing schemes, this part of the reconstruction programme also fell short of the planned targets. The government respondents attribute this shortfall also to wrong estimates of the disaster. However informal discussions with some contractors, who participated in the reconstruction programme, such as the Bangladesh Construction Company, Arabian Construction Company and the China Construction Company revealed that ever-increasing demands for commission and kickbacks by the government

Supervisory staff and repeated stoppage of work by the militant beneficiary tribes in Haddah and Ans districts, were the main causes of this shortfall. The militant tribes in the earthquake area also frequently interfered with the work and caused delays and increasing losses. Many of these contractors were forced to abandon their contracts uncompleted.

Table 8.9 shows percentage completion of the infrastructure.

Table 8.9: Other infrastructure committed by government

Survivors Category	Percentage completion of the committed infrastructure							Comm-unity partic-ipation
	School	Mosque	Clinics	Hospital	E/Supp	Roads	W/supp	
Turnkey	65	63	13	50	13	20	40	6
Self-help	24	12	29	0	0	20	21	0
Repair	15	15	0	0	2	2	2	0

Source: Field surveys, 1994.

In areas where the turnkey housing programme was implemented, construction and rehabilitation of other infrastructure was also part of the overall contract. Therefore, relatively better results were achieved in realising the planned targets. More specifically, targets realised were: 65% for schools, 63% for mosques, 13% for clinics or rural health centres, 50% for hospitals (one of the two hospitals was built in Dhamar town while the Ma'abar hospital is still pending), 13% for electrification schemes, 20% for roads and 40% for water supply schemes.

The self-help houses and repair programme (traditional houses) agreements were executed between the EOR on behalf of the government, and the beneficiaries individually. However, construction of other infrastructure in these areas was the responsibility of the government. The survey results for areas where self-help schemes were implemented suggest that very little progress was made to achieve the planned targets. The following is the progress achieved in building other infrastructure, in the self-help housing area:

a) 24% schools;
b) 12% mosques;
c) 29% health centres;
d) 20% roads; and
e) 21% water supply schemes.

In areas where the repair programme (traditional housing) was implemented, the progress was even lower as a very small fraction of the committed infrastructure was built. The targets realised were:

a) 15% schools;
b) 15% for mosques;
c) 2% for electrification schemes;
d) 2% for roads; and
e) 2% for water supply schemes.

8.4.2.2 *Community participation in site selection, design and size*: All respondents (beneficiaries, sheikhs and the government engineers) confirmed the fact that the beneficiaries of the reconstruction programme were not involved in the site selection, design or construction of any of this infrastructure.

8.4.2.3 *Acceptability problems in the new infrastructure*: The victims did not have any major problems in accepting this infrastructure since it was always considered to be the government's property. During the field surveys most of this infrastructure was found to be in poor condition because of the lack of maintenance. The schools and mosques were in relatively better shape.

The mosques are traditionally looked after by the community using them. As the mosques built during the reconstruction programme were also maintained by the earthquake victims they were in a reasonable condition of maintenance at the time of field visits.

The people's increasing interest in education was helping to maintain the school buildings as well. Teachers for the schools were provided by the government, under the national service scheme, which required every secondary school graduate to teach in a primary school for at least two years, before applying for under-graduation at the university.

Lack of health services was a national problem due to an acute shortage of staff, medical equipment and drugs. Even major cities like Sana'a, Aden, Ta'izz and Hodeidah do not have sufficient medical facilities. The situation in rural areas is worse. Most of the health centres visited during the field surveys were found to be deserted due to a lack of staff, supplies, or both.

The fate of the water supply and electric schemes was also not different. Most of them were not functioning due to a breakdown of equipment and no maintenance.

The roads serving the villages, were in poor shape due to continuous erosion and no maintenance. These roads were frequently breached during rainy seasons and consequently many villages were occasionally cut off for several days from markets and other important areas until the government repaired the damaged roads. These repairs were usually of a temporary nature and the same situation was repeated after almost every major rainfall.

The local communities did not consider themselves responsible for maintaining the roads or most of the above infrastructure. Instead they frequently excavated drains across the new roads, to divert upstream storm water, or water pumped from boreholes, to their agriculture farms. This activity further reduced the life of the earth roads. There was no concern at the government's level to educate the beneficiaries to maintain the infrastructure for their own benefit.

8.5 Evaluation of the reconstruction programme

The survey results with respect to the degree of social acceptability of the reconstruction programme among the beneficiaries are shown in Table 8.10.

8.6 Social evaluation

Table 8.10: Social evaluation of the housing programme

OVIs	Beneficiaries acceptability (%)								
	Turnkey			Self-help			Traditional (Repair)		
	A	MA	NA	A	MA	NA	A	MA	NA
Timely delivery	15	2.5	82.5	32.5	17.5	50	51	37	12
Climatic suitability	30	55	15	27	70	2	97.5	2.5	0
Suitability for family need	3	32	65	5	24	71	100	0	0
Socio-cultural acceptability	42.5	55	2.5	32.5	62.5	5	100	0	0
General appearance	50	40	10	17.5	72.5	10	100	0	0
Affordability	50	40	10	17.5	72.5	10	100	0	0
Acceptability of location	55	35	10	90	5	5	100	0	0
Acceptability of size	0	30	70	7	48	45	100	0	0
Safety against earthquakes	20	42.5	37.5	15	52.5	32.5	0	10	0
Quality of work	42.5	55	2.5	32.5	62.5	5	51	44	5

Source: Field surveys, 1994.

Key
A: Acceptable;
MA: Marginally acceptable; and
NA: Not acceptable

8.6.1 Delivery schedule: The beneficiaries of the Turnkey houses were very sceptical about the delay in the delivery of the houses which was sometimes as late as 3 to 4 years. During all this period the beneficiaries had to stay in temporary shelters or with relatives and friends. Only 15% of the respondents considered the delivery as timely and acceptable. Most of these beneficiaries were those who were socially influential enough to receive their houses without much delay. The majority of the beneficiaries (82.5%) felt that the delay was unacceptable. Only 2.5% of the respondents considered the delivery schedule as marginally acceptable.

Delivery of the houses constructed under the Self-help programme was also late. The government respondents attributed the delays to political interference and institutional deficiencies. The remoteness and lack of vehicle access to some villages was given as another important cause of delay, and sometimes even the abandoning of the proposed house by the government. The construction work also got delayed frequently because a number of beneficiaries could not find sufficient resources to make their contribution. Construction for some of these houses was prolonged until 1993. However, the beneficiaries of this programme were relatively less dissatisfied as compared to the beneficiaries of the turnkey programme. In terms of figures, 32.5% of the respondents considered the delay as acceptable, 17.5% as marginally acceptable, while 50% thought it unacceptable.

The programme covering repair of traditional houses was short in nature and completed relatively earlier because of the small nature of the repair work involved, easier communication, availability of building materials, and close vicinity of the SCREAA office. No major complaints regarding timely delivery of the repair programme were reported by the beneficiaries. More than half of the sample respondents (51%) considered the repair programme as acceptable, 37% as marginally acceptable and 12% as unacceptable.

8.6.2 Climatic suitability: The traditional houses, although vulnerable to earthquakes, are extremely suitable for the local temperate climate which can go to either extremes between day and night. Even in a normal day the temperature difference between early morning and noon hours can be as much as 20°C. The thick walls and roofs of traditional houses made with stones and clay make them very comfortable in all seasons. The multi-storey construction makes them even more temperature resistant. In contrast, the walls and roofs of the new single-storeyed earthquake resistant houses are comparatively much thinner. These house were reported to be not temperature resistant.

The Turnkey houses were built with clay bricks which provided thin walls (10 cm), thus making them very cold in the winters and unbearably hot during summers specially during the noon hours. This turned out to be a major complaint of the respondents. Only 30% of the beneficiaries considered their house as acceptable for the local climate. About 55% of the respondents viewed climatic suitability of these houses as marginally acceptable, while the remaining 15% ranked these houses as unacceptable.

Although the self-help houses had thicker walls made of 20 cm thick concrete blocks, which were more temperature-resistant as compared to the brick walls but the roofs of self-help houses were made of plywood resting on wooden beams. The plywood was covered with a thin layer of soil. As roofs are more vulnerable to the transmitting heat of the sun inside a building, the self-help houses were also not very temperature-resistant. Only 27% of the recipients of the self-help houses found their houses acceptable for the local climate. A large proportion of the respondents (70%) considered their new houses as marginally acceptable for local climatic conditions, while the remaining 2% viewed them to be unacceptable for local climate.

8.6.3 Suitability for family needs: The turnkey and self-help houses have almost the same covered areas (48 m^2). The beneficiaries of both categories considered the new houses as too small for their family needs. Social surveys revealed that 65% to 71% of the respondents indicated their non-acceptability for the new houses from the point of view of their family needs. About 24% to 32% of the respondents found the new houses as marginally acceptable, while only 3% to 5% of the beneficiaries were satisfied with the size of the new houses. As discussed earlier, a majority of the respondents made additional changes in the houses to suit their family needs which essentially confirmed the fact that beneficiaries were dissatisfied with the size of the new houses.

8.6.4 Socio-cultural acceptability: Only 32.5% to 42.5% of total beneficiaries indicated their acceptance for new houses from socio-cultural perspective. About 55% to 62.5% of the respondents considered the new houses as only marginally acceptable for their socio-cultural needs, whereas 2.5% to 5% of the respondents under both categories found them unacceptable.6

8.6.5 General appearance: The turnkey houses, built by foreign contractors, have relatively better finishing. The houses under the self-help programme were built by local artisans with block masonry and no plaster or paint on walls which gives them a modest look. In the turnkey category 50% of the beneficiaries reported that the new houses had an acceptable appearance, while the remaining 50% considered it marginally acceptable or not acceptable. In the self-help category only 17.5% accepted the appearance, while the rest, 82.5%, thought it was marginally acceptable or not acceptable.

8.6.6 Affordability: The turnkey houses were distributed free of cost whereas the beneficiaries of Self-help houses had to contribute 30% to 50% of the construction costs. The average construction cost was about YR 80,000 for a Turnkey house and about YR 70,000 for a house built under the self help programme. Both types of beneficiaries, however, reported that they would have built better and bigger houses, according to their respective needs, if they had more say in the design and construction of their houses.

About 50% of the respondents from the turnkey category found their new houses affordable; 40% indicated that new houses were marginally affordable; and the remaining 10% felt that these houses were unaffordable. On the other hand, no one in the self-help category thought that their houses were affordable for an average beneficiary. Only 17.5% of them considered their house was affordable. The remaining 72.5% of respondents indicated that they could only marginally afford these houses, while 10% of respondents reported that these houses were unaffordable.

8.6.7 Acceptability of location: The beneficiaries of turnkey houses were not consulted about location of their houses. The traditional houses were usually built on hill tops or steep slopes with no technical consideration for resistance against earthquakes. When the reconstruction programme was undertaken the emphasis was on both these issues.

The government did not consult the recipients of the houses built under the turnkey programme about the location of houses in most cases. Consequently, despite the fact that the new houses are designed to be earthquake resistant, 10% of the beneficiaries did not find the location acceptable, 55% indicated their satisfaction with the location of new houses, while 35% considered the location of their houses as marginally acceptable. The reason for relatively better acceptability of location of the Turnkey houses is that most of these houses were built not too far from the traditional villages of the owners. There were some complaints of inconvenience in some cases, but they were not too many.

Since land for houses built under the self-help category was provided by the beneficiaries themselves, they were far more satisfied about the location of their houses than the beneficiaries of the turnkey houses. About 90% of the beneficiaries indicated that they were fully satisfied with the location of their houses. Only 10% considered the location as marginally acceptable or not acceptable.

8.6.8 Design acceptability: The architectural design of the new houses, although completely different from the design of a typical traditional house, was acceptable to 30% to 40% of the beneficiaries. About 40% to 45% of the respondents did not appreciate the *box* like design but marginally accepted it in the absence of an alternative design. The design of the new houses was unacceptable to 20% to 25% of the beneficiaries.

8.6.9 Acceptability of size: None of the turnkey beneficiaries were happy about the size of the new houses. A large majority, 70% of respondents reported that the small size was unacceptable, while 30% considered the size as marginally acceptable for them.

In the self-help category only 7% among the beneficiaries were of the opinion that the size of their houses was acceptable. About 48% considered the size as marginally acceptable, and it was unacceptable to the remaining 45% of the respondents.

8.6.10 Safety against earthquakes: The government respondents revealed that the new houses were designed to resist an earthquake of magnitude 7.0 on the Richter Scale. During the field survey, most of the beneficiaries were found not to have much knowledge about the safety aspects because of the lack of awareness about the earthquake hazard. They repeatedly said that only Allah knew whether the new houses were safe or not, and that only another earthquake could prove the safety of these houses.

Only 20% of the respondents under the turnkey category agreed that earthquake-resistance was an important factor in their accepting new houses. The remaining 80% considered the safety factor as marginally acceptable or not acceptable.

Safety considerations were acceptable for only 15% of the respondents in the self-help category, while 32.5% of the respondents found the safety considerations as unacceptable. The rest 52.5% respondents indicated that the safety factor played a marginal role in convincing them to accept the new houses.

Only 10% of respondents in the repair programme (traditional houses) category indicated their marginal acceptability of the repair programme because of a consideration of the safety against earthquakes. About 90% of these respondents believed that safety against earthquakes could not be guaranteed by anyone except Allah and therefore they were not convinced of accepting the new houses based on the safety aspect.

8.6.11 Quality of Work: The quality of work was acceptable to 42.5% of the respondents from the turnkey category, 32.5% of the respondents from the self-help category, and 51% of the respondents from the repair programme (traditional housing) category.

About 55% of the people, both under the turnkey and the self-help categories, and 62.5% of the respondents from the repair programme category considered the quality of work as marginally acceptable. The quality of work was reported to be unacceptable by 2.5%, 5% and 5% of the respondents under the turnkey, self-help and repair categories, respectively.

8.7 Technical evaluation of the housing programme

A total of 40 houses of different categories, built by private owners and the governments, and other infrastructure were visited by the technical surveyors. With the exception of traditional houses and a few mosques, all other infrastructure, was built by the government during the post earthquake reconstruction programme. All this infrastructure was built with earthquake resistant techniques and no community participation.

Different categories of houses were visited by the surveyors in different areas all over the governorate. The ratio various categories of house visited was as follows:

a) Turnkey houses 34%;

b) Self-help houses 19%;

c) Repaired (traditional) houses 13%; and

d) Unrepaired traditional houses 34%.

The ratio of government built and owner-built houses, inspected during field surveys, was 53% and 47% respectively.

The survey results with respect to the salient technical features of the traditional houses and different categories of houses built under the reconstruction programme are given in Table 8.11.

Table 8.11: Technical evaluation of the housing programme

OVIs		Type of house			
		Turnkey	Self-help	Repaired (Traditional)	Unrepaired (Traditional)
Usual dimensions of rooms (in square metres) boundary wall (in linear metres)	Divan	3.9x3.0	4.1x2.7	6.0x3.0	6.0x3.0
	Bedroom	3.0x2.8	2.9x2.6	4.0x3.0	4.0x3.0
	Kitchen	1.8x1.8	1.7x1.7	4.0x3.0	4.0x3.0
	Latrine	1.8x1.8	1.7x1.5	4.0x3.0	4.0x3.0
	Store	-	-	2.5x1.5	2.5x1.5
	Barn	-	-	2.0x1.5	2.0x1.5
	Stable	-	-	4.0x3.0	4.0x3.0
	Boundary wall	-	-	10.0	20.0
Usual location of rooms	Divan	G/floor	G/floor	Floor 3	Floor 3
	Bedroom	G/floor	G/floor	floor 3	Floor 3
	Kitchen	G/floor	G/floor	Roof top	Roof top
	Latrine	G/floor	G/floor	Floor 1	Floor 1
	Store	-	Floor 1	Floor 1	Floor 1
	Barn	-	Outside	Outside	Outside
	Stable	-	G/floor	G/floor	G/floor
Number of main rooms		3	3 or more	6 or more	6 or more
Number of storeys		1	1	3 to 4	3 to 4
General condition of house		Fair, good	Fair to good	Fair to good	Fair to good
Construction materials	Foundation Superstructure Roof	RCC material Clay, bricks RCC material	RCC PCC blocks wood, clay	Stone, clay Stone, clay wood, clay	Stone, clay Stone, clay wood, clay
Location of house		Safe	Safe	Safe	unsafe
Soil bearing capacity (kq/cm^2		2.5 - 3.0	2.7 - 3.3	2.2 to 2.8	2.5 to 3.5
Location of tie beams		Roof, lintel and foundation level	Lintel level	Lintel level	None
Roof leakage protection		Slope 1 in 30	Slope 1 in 30	Slope 1 in 40	Slope 1 in 50
Foundation protection	Foundation above natural drainage				
Laboratory test results		satisfactory	satisfactory	satisfactory	satisfactory

Source: Field surveys, 1994.

8.7.1 *Dimensions, location and size of rooms*: Technical surveys showed that there was a vast difference in the number, location and size of rooms in the houses built during the reconstruction programme and the privately built traditional house. The overall sizes of the two types were also different. The turnkey and self-help houses were more or less of the same size and internal design.

The dimensions of the divan (living room), mainly used for receiving male guests and chewing *qat* are merely 3.90 x 3.05 m^2 in the turnkey houses and 4.1 x 2.7 m^2 in the self help houses whereas the dimensions of the same room in a traditional house ranged from 7.0 x 3.5 m^2 to 5.0 x 3.0 m^2. Sometimes even two divans were seen in the traditional houses.

The dimensions of the other main rooms such as bedrooms were recorded as 3.05 x 2.8 m^2 in the turnkey house and 2.9 x 2.6 m^2 in the self-house. There were only two such rooms in each of these categories. The dimensions of these main rooms in a traditional house ranged from 4.0 x 3.0 m^2 to 2.5 x 1.5 m^2 and there number was six or above.

The sizes of kitchen and latrine in the turnkey houses were measured to be the same i.e. 1.8 x 1.8 m^2. In the Self-help houses, the kitchen dimensions were noted as 1.7 x 1.7 m^2, whereas the latrine dimensions were noted as 1.7 x 1.5 m^2. The sizes of kitchen and latrine in the traditional houses were also found to be almost equal but they were much larger than the government built houses. The traditional kitchen and latrine sizes were measured to be in the range of 4.0 x 3.0 m^2.

The beneficiaries had to add a number of rooms in the houses built under the reconstruction programme in order to meet their requirements. On the other hand the traditional houses had a number of accessory rooms such as stores, barns and stables for domestic animals. The stores and barns were of a relatively small size, such as 2.5 x 1.5 m^2 but the ground floors in most of the traditional houses were found to be used as stables for the safety of the animals during the night time. Family members were observed to be living between the second and fourth floors.

8.7.2 Number of storeys: The government built houses, both turnkey and self-help, were only single storeyed whereas the traditional houses had several storeys with the external walls slightly tapering inwards as the height increased. Consequently the ground floor had the largest covered area in the entire house, followed by the first floor and then second floor and so on.

8.7.3 General condition of the houses: The general condition of the privately owned traditional houses was seen to be ranging from fair to good, in spite of their relatively longer life, simpler construction and little finishing work than the houses built under the reconstruction programme. In the government built self-help houses were observed to be in generally better condition with respect to the turnkey houses. Most of the self-help houses were found to be occupied by the owners, whereas a number of the turnkey houses were seen being used as stables or stores by their wealthier owners, who lived next door in their self built houses.

8.7.4 Construction materials: Construction materials used in traditional houses were usually wood, clay and stone. Field surveys showed that cement, sand, stone aggregate and reinforcing steel had predominantly been used in the government built houses.

In foundations and up to the plinth level, the local black basalt stone had been used in the traditional houses. In the government built houses reinforced concrete had been used in foundations.

The material used in the superstructure of the turnkey houses was mostly clay bricks laid in cement mortar. In a very few cases concrete blocks were also used. Superstructure work in the self-help houses was all in block masonry.

Technical surveyors observed that the traditional houses used dressed conical stones laid in clay mortar on the external faces of the thick superstructure walls while the internal faces were built from irregular undressed stones. Stone scrap and mud was used to fill in between the wall faces. This made the house climatically suitable, but at the same time vulnerable to the earthquakes. This was one of the main reasons for the collapsing of the traditional houses in the last earthquake.

The available evidence suggests that the traditional houses used tree branches and clay to build their houses roofs. These branches were usually not straight so the distribution of roof load on these branches (or beams) and walls was not uniform. It was noticed that there was very little bond between the wooden beams and walls as the beam ends did not fully cover the width of the walls. This problem was probably the main cause for roof collapse during the last earthquake. The turnkey houses used reinforced concrete in roof structures. The self-help houses used several wooden beams, galvanised steel wire mesh covered with plywood and clay in the roofs.

8.7.5 Location of the house: The survey data suggests that most traditional houses were built on top of hills, steep mountain slopes or close to other tall buildings. This is a traditional practice because of tribal rivalries and is done so that the enemies could be seen from a long distance. This practice also rendered the traditional houses more vulnerable to earthquakes. On the other hand safe location was an important consideration in the government built houses. According to the surveys only 40% of the existing traditional houses were located on safe ground whereas 100% of the government built houses are on safe locations.

8.7.6 Sub-soil conditions: The Dhamar governorate is located in the Central Highlands where ground conditions for building foundations are generally good. The data on soil bearing capacity shows it ranging from 2.5 to 3.5 kg/cm^2. It was noted that all buildings, i.e. the government built houses and other infrastructure, and the traditional houses were built on safe ground conditions.

8.7.7 Location of tie-beams: It was observed that reinforced concrete tie beams were provided at the foundation, lintel and roof levels in all government built houses and other infrastructure. A large number of traditional houses were destroyed by the earthquake perhaps due to a lack of tie beams. 74% of the houses inspected during the technical surveys had wooden tie beams only at the lintel level. The remaining 26% had no tie beams.

8.7.8 Protection against roof leakage: Roof leakage protection in the traditional as well as government built houses was observed to be achieved by providing roof slopes ranging from 1 in 30 to 1 in 50.

8.7.9 Foundation protection: Foundation protection in all government houses and most traditional houses was observed to be carried out by building the houses above natural drainage level. Only a few traditional houses' ground floors were found below the natural drainage level in which cases side drains had been built by their owners around the house to divert any drainage water.

8.7.10 Laboratory tests: Laboratory tests in respect of a number of houses and other infrastructure inspected during the technical surveys in Dhamar governorate were carried out as shown in Table 8.12.

Table 8.12: Laboratory tests performed during surveys

Category of infrastructure	Site visited		Laboratory tests			
	Number	%	RCC/PCC strength	Block strength	Water Test on Stones	Sieve Analysis
Turnkey house	11	41	Yes	Yes	Yes	Yes
Self-help house	6	22	Yes	Yes		Yes
Repaired house	5	19	Yes	Yes		
Mosques	2	7	Yes	Yes	Yes	
Schools	2	7	Yes		Yes	
Health centres	1	4	Yes			
Total:	27	100				

Source: Field surveys, 1994.

The tests were performed on concrete cubes and concrete blocks, measuring 15x15x15 cm^3 and 20x10x10 cm^3 respectively, to determine their crushing strength in kg/cm^2 on the samples available at the SCREAA (now MOC) laboratory. Tests were also performed on the available stone samples for water penetration which is described in terms of percentage of water retained by weight of the sample. Soil samples were collected, where possible, from the reconstruction sites. Sieve analysis tests were performed on these samples at the MOC laboratory. All these test results are attached with the technical surveys.

Table 8.13 presents salient features of various test results in more detail.

Table 8.13: Salient features of laboratory test results

Infrastructure location and Type	Concrete cubes for RCC and PCC works 15x15x15 cu cm			Concrete blocks 20x10x10 cu cm for masonry walls		
	Crushing load kg	Crushing stress kg/sq cm	Remarks	Crushing load kg	Crushing strength kg/sq cm	Remarks
Manqadah						
Turnkey	450-480	204-218	Good	240-370	53	Okay
Al-Marwan						
Turnkey	500-550	227-229	Good	310-370	57	Good
Mosque	450-470	213-220	Okay			
School	300-320	136-145	NA			
Turnkey	580-680	263-308	V/good	345-352	61	Good
Beihan						
Self-help	400-550	181-249	Okay	350-350	60	Good
Self-help	1050-112	476-544	V/good	429-546	63	Good
Self-help	800-900	302-408	V/good			
Al-Jami'a						
Repaired	300-300	136-136	NA			
Repaired	640-680	290-308	Good			
Jarf At-Tahir						
Self-help	450-480	213-218	Good			
Self-help	300-460	136-209	Okay			
Bir Khabud						
Repaired	590-700	267-317	Good			
Repaired	470-650	213-295	Good	310-310	53	Okay
Bab Al-Falak						
Turnkey	900-1000	408-453	V/good			
Turnkey	340-360	154-162	Okay			
Al-Salah						
Repaired	460-450	162-227	Okay			
Ar-Rusabah						
Mosque	750-880	340-399	V/good	210-210	36	NA
Turnkey	650-780	295-354	V/good			
Al-Kola						
Turnkey	460-490	209-222	Good			
Turnkey	600-720	272-326	V/good	429-507	60	Good
Turnkey	690-870	313-394	V/good			
M/Ash-Sharq						
Self-house	680-730	308-331	V/good			
Hammam Ali						
Turnkey	520-540	236-245	V/good	351-356	65	Good
Dawran						
Turnkey	700-700	317-317	V/good	430-509	60	Good
Health Centre	560-600	254-272	Good			
School	640-800	290-363	V/good			

Note: Okay: Acceptable result; NA: Not acceptable result.

Source: Field surveys, 1994.

Table 8.13 shows that out of 27 concrete cube samples collected from various sites of the reconstruction programme, 93% were of the quality ranging from acceptable to very good. Only 7% samples showed the quality of concrete work as of unacceptable quality. These results confirm response of the beneficiaries regarding quality of work of the new and repaired infrastructure which they appreciated in general.

Out of 10 samples of the concrete blocks 90% results showed that the quality of blocks prepared and used in masonry works of the reconstruction programme were of acceptable to good quality. Only 10% results showed the quality as unacceptable.

Apart from the concrete and block tests, water penetration tests on stones used in masonry work in the reconstruction programme, and sieve analysis tests on soils at various sites were also performed. These results showed that the quality of stones used in the reconstruction programme was of strong enough for safety purpose.

The sub-soil conditions in the Highlands of Yemen are claimed to be good. Sieve analysis of the soil samples collected from different housing areas confirmed that the soil was composed of well graded materials. The results showed that 68% to 83% of the soils ware retained between sieves number 150 to 600. The quantity of coarser materials, retained between sieves 10 to 1.18 mm, ranged from 10 to 30%. The finer materials left in the pan were from 2% to 7%. Although the quality of soils in the reconstruction programme area slightly varied from site to site but in general, it could be described as well graded sandy clay mixed with some gravel.

8.8 Earthquake-victims' role in implementation of reconstruction programme

The post-earthquake reconstruction programme was implemented for the earthquake victims and their appreciation of the governments's programme was of immense significance. The following Table 8.14 shows the extent of community participation in the programme.

Table 8.14: Role of local communities in programme implementation

OVIs	Reconstruction programme category			
	Turnkey houses	Self-help houses	Repair programme	Other infrastructure
Planning and decision making	Government	Government	Government	Government
Programme implementation	Government	Government	Government	Government
Level of community involvement	Community not involved	Involved in location and construction	Involved in repair only	Community not involved
Acceptance of programme by community	Low	Low	Moderate	Moderate

Source: Social surveys, 1994.

8.8.1 Criteria for planning and decision making: According to the government respondents, one of the government's priorities was to reconstruct the infrastructure in the disaster-affected areas of Dhamar as quickly as possible with minimal involvement of the community. The initial surveys to assess the damage caused by the earthquake, which were to form the basis of the entire reconstruction programme, were also unilaterally conducted by the government. Although some of the village sheikhs participated in preparing these, but for most of them, being illiterate, their participation was of ceremonial nature. Even in the later stages prior to implementation of the reconstruction programme, the community had no role to play in planning and deciding about the number, type, size and design of the houses and other infrastructure to be built in the disaster-affected areas. The survivors clearly mentioned during interviews that no one invited them to discuss these important issues. The sheikhs on the other hand complained that when they raised their concerns with the government about these problems, there was no positive response. Surveys carried out in the government organisations confirmed that the beneficiaries were not consulted in planning and design of the infrastructure for various reasons, because:

a) the programme was implemented on emergency basis and there was no time to consult the beneficiaries;

b) most of the beneficiaries were illiterate and they would not have understood the details of planning and decision making; and

c) tribal rivalries were common in the disaster affected area and it would have been extremely difficult to bring all beneficiaries to agreement.

8.8.2 Programme implementation: Surveys of the beneficiaries and government engineers indicated that implementation of the reconstruction programme was entirely carried out by the government. Most of the government respondents complained during interviews that the Executive Office of SCREAA had a very centralised administrative policy. All instructions regarding programme implementation came from the top hierarchy which they had to abide by as the final orders. In these circumstances there was little opportunity for the community to have any say in the programme implementation. This is perhaps the reason that over 90% of the respondents expressed their dissatisfaction of the Turnkey programme.

8.8.3 Level of community involvement in the reconstruction programme: In the Turnkey programme there was no community involvement because the entire house, including the land, was provided to the beneficiaries completely free. Most of the beneficiaries did not like these houses. Their reaction and reservations to this free offer is discussed in detail in the foregoing paragraphs.

In the Self-help programme the beneficiaries were involved in location and construction of the houses only because the beneficiaries had to provide land and participate in the construction cost. They were not consulted about design, size and general appearance of their houses. Only 14% of the respondents expressed their satisfaction of this programme.

The beneficiaries' involvement in the repair programme was limited to the construction part only because they were required to contribute a major part of the total cost of the repair works (often more than 50%). Field surveys showed that the beneficiaries were not much satisfied with this programme. Serious disputes arose between the government and the beneficiaries from the very beginning about the programme about the extent and nature of the repair work. This led to abandonment of the programme after repairing houses in Dhamar town only. Originally the repair programme was supposed to cover all disaster affected areas. According to surveys 51% of the respondents were satisfied with the timely delivery of the repair programme while the same percentage was found satisfied with the quality of work.

8.8.4 *Acceptability of the reconstruction programme among the beneficiaries*: The field survey data revealed that only 1.5% of the beneficiaries were consulted about implementation of other infrastructure building programme. Again this involvement was only about location of the infrastructure in those places where the land had to be taken from the community. The community was not consulted about the type, design, size and general appearance of the infrastructure. A survey of the government organisations confirmed that community participation in public use infrastructure was almost 0%. The approval rating of the infrastructure is however moderate (50%) because there was almost no such infrastructure in Dhamar, prior to earthquake. Although the respondents were aware and weary of the fact that they were not consulted at any stage of this programme but 50% of them felt satisfied because there existed at least a few facilities existed for health, education, water supply and electricity, etc which were non-existent in the past.

8.9 Why some of the earthquake affected people could not receive assistance under any category of the housing programme

8.9.1 Socio-economic factors: It was difficult to assess the exact number of those earthquake survivors who did not benefit from the housing programme but it was felt during field surveys that the percentage was significant. The beneficiaries in each village tended to inflate the number of non-beneficiaries who were either related to them or from the same tribes. On the other hand the respondents from government organisations tended to deflate the percentage of the non-beneficiaries. They could not give any fixed number or percentage of the non-beneficiaries but just said that the benefits were available to most of the survivors. No records were available to confirm the figure. The main reasons seemed to be the following:

a) the initial estimates, on the basis of which the government announced its reconstruction programme and appealed for foreign assistance, were that 25,000 houses were completely destroyed while another 17,000 were partly damaged. The government committed itself to rebuild and repair the same number of houses. In actual practice however only 13,351 houses were built and 2,200 houses were repaired. Thus the total number of houses built or repaired was only 37% of the original commitment. No definite reason was given in the available literature, nor it could it be confirmed from survey of the government officials that why the above figure of 13,351 was chosen for building new houses against an estimated demand of 25,000 new houses. Financial resources did not a seem to be a serious problem for the government. The country was at that time enjoying excellent relations with its rich neighbours and the western donors. Technical and financial assistance was readily available. The main reason given for abandoning the repair programme, after repairing only 2,200 houses in Dhamar town against an overall demand of 17,000 houses for the entire governorate, was that the beneficiaries were more concerned about the government to renovating their houses rather than strengthening them is not convincing. These figures indicate, even if the initial estimates of losses were not 100% correct, that the number of non-beneficiaries was large;

b) one of the major complaints of the earthquake victims was that their family houses before the earthquake were multi-storeyed traditional buildings in which four to five families were staying. When the earthquake demolished their homes, only one small house for each large building was allotted to them as replacement which could hardly suffice for the needs of only one small family. So only one of the four or five families, previously living in the traditional houses could use the new houses. The remaining members of the family were not given any consideration. This policy left a large number of victims without any shelter;

c) some of the sites for self-help houses were extremely remote in the mountain areas with almost no road conditions. Carrying building materials to these sites was almost impossible. The government was supposed to improve accessibility of these villages before starting the houses. The roads to such villages were never built due to the institutional deficiencies and similar problems at the Executive Office of SCREAA, as such the housing programme could not be extended to these villages;

d) although foreign assistance for the reconstruction programme was in hard currency, the agreements between the government and the contractors were partly in hard currency and partly in local currency. The Yemeni Riyal, which was strong in early eighties and its market price was about 1 US$: YR 3.5 sharply fell in the later years. In 1988 the exchange rate reached 1 US$: YR 11 or more. As the reconstruction programme lingered on for different reasons, such as, institutional deficiencies, political interference, etc, the contractors found themselves facing losses due to inflation of the local currency. The works were stopped by many contractors and prolonged disputes started with the government. Some of the foreign contractors got so frustrated that they abandoned their projects and left the country for good to avoid further losses. Institutional deficiencies were among the major causes for the government not reviewing the payment procedure in an attempt to save the contractors from suffering losses. Discussions with some contractors involved in the reconstruction programme revealed that the government engineers and other supervisory staff, always expected favours for any services provided to the contractors no matter how genuine they were. All this caused curtailment of the programme which deprived a number of beneficiaries from receiving shelter; and

e) as briefly mentioned above lack of organisation among the beneficiary tribes and their mutual rivalries was also an important cause of delay and abandonment of the reconstruction programme in certain areas (government surveys, 1994). Quite frequently they used to stop the contractors' works by force to change location of the works or for some other reasons. The government did not have any firm policy to deal with such situations and did not intervene quickly to solve site problems with the result that in most cases the contractors suffered losses due to prolonged stoppage of works. Many of them could not afford to work in these conditions and left the country.

It was observed during surveys that the non-beneficiaries were those poor people who were deprived in every respect. They were not related to the sheikhs or other important people in the village and therefore did not have any social or political influence to press their demands. The sheikhs' surveys estimated the non-beneficiaries to be 43% which seemed reasonable according to the actual situation observed by the surveyors.

8.9.2 Nature and source of alternate arrangements for the non-beneficiaries: A survey of the non-beneficiaries showed, that the survivors who could not benefit from any category of the reconstruction programme had to depend on themselves. Some of them stayed with their relatives for some time, or moved to centuries-old mountain caves where their ancestors used to live, or moved to the government provided temporary shelters (tents) immediately after the disaster.

A small percentage of wealthy non-beneficiary survivors built new houses for themselves but most of the non-beneficiaries were poor and the disaster had further aggravated their financial difficulties. Some of them moved back to their disaster affected and earlier abandoned houses. Some made extremely vulnerable shelters by using debris from their old damaged houses. Such shelters were made by piling stones one above another in irregular shape of walls, without using any mortar, and then covering them by corrugated iron sheets or tree branches. A very few non-beneficiaries purchased corrugated iron sheets and wood at subsidised prices from the government and made shelters themselves. These 'metal houses' become extremely cold in the night time and extremely hot in the day time.

Summary

A preliminary look at the social and technical survey data gives a reasonably good concept of the research problem and the results to be drawn. Evaluation and detailed discussions on this data before statistical analysis, gives further legitimacy to the process of statistical testing and drawing of inferences. The combined exercise of preliminary data evaluation and detailed statistical analysis help in drawing truly objective conclusions, which ultimately form the basis of recommending guidelines for the future. The preliminary evaluation in this chapter gives an idea that the earthquake-affected community responded quickly and adequately to provide immediate shelter and needs to the victims. The government's emergency help was neither timely nor sufficient for all victims. This evaluation also indicates that, the delivery the reconstruction programme was also late and could not cover all victims. Even the beneficiaries found many problems with the new houses and most of them did not find it acceptable. There was very little community participation in the reconstruction programme.

Chapter Nine

Chapter Nine

STATISTICAL ANALYSIS

"Statistical methodology allows the effective collection, analysis and presentation of numerical information, on the basis of which optimal decisions can be made".

(Paul Marston, 1982)

The science concerned with collecting facts and analysing them is given the name of *statistics* (Walker et al, 1993). Walpole (1983) describes that in statistical studies we are mainly concerned with the presentation and interpretation of the chance outcomes which occur during an investigation. In common use the term statistics is frequently used in a quantitative way such as a person's body dimensions, or a government's budget, etc. Chase (1967) explains that these numbers or figures however only become useful when a certain order is given to the masses of numbers collected in scientific and social data collecting exercises. The ordering of information is done by using certain statistical methods. Some of these methods which describe the characteristics of a group are called *descriptive methods*. Other techniques in which inferences are drawn about a large group of individuals, when only a small group or sample of them can be observed, are known as *inferential procedures*. As this research also examined only some samples of individuals, from different categories of the earthquake-affected people in Yemen, inferential procedures have been used in the statistical analysis.

Research in the social sciences differs from the physical sciences or the so-called natural sciences in what is being studied and not in terms of the methods (Weiss, 1968). As such this research, based on both social and technical evaluation of the post-earthquake reconstruction programme in Yemen, has not deployed any special methods for the analytical work.

A *variable* in statistical terminology means a quantity which assumes different values which may be measured in some appropriate unit (Chambers, 1948). Height, weight, age, education level, etc are the examples of variables. The number of times a particular value of a variable occurs in a set of observations is called *frequency*. The table showing the frequency of occurrence of all values of a variable in a set of observations is named as a *frequency of distribution table*. The distribution of total population is expressed in a mathematical form by using a small number of constants or *parameters*. One of the purposes of using statistical analysis is to test a theory, an assumption or a hypothesis (Noether, 1990).

9.1 Hypothesis testing techniques

There are two methods or techniques for testing a hypothesis. These are known as the *parametric* and the *nonparametric* techniques. The analytical tests related to parametric techniques are applicable when the following conditions exist (Siegel, 1956):

a) the observations are independent ie the score of one sample does not influence or bias the score of the other;
b) the observations are drawn from a normally distributed population;
c) the scores are real numerical numbers and not just representations;
d) the populations under study have the same variance;
e) the variables involved are measured in at least an *interval scale* to facilitate the arithmetical calculations involving addition, division and finding means of the data under analysis; and
f) The sample size is large (not less than 30).

These conditions are not usually met when behaviourial responses of individuals are being studied, particularly when the data is in a *ranking order*. The nonparametric techniques are uniquely suited in such cases. Some of their advantages are listed below:

a) the nonparametric tests do not place any precondition that how the population under study should is distributed. This is why these techniques are sometimes referred to as the *distribution free* tests;
b) many nonparametric tests can be applied when the scores are not numerical but simply ranks. Because of this quality such tests are often called as the *ranking* tests;
c) the nonparametric tests are comparatively simpler than the parametric tests.
d) the nonparametric tests can be applied to even small sample sizes such as 6.

As most of the data collected during field surveys are of ranking order and in an ordinal scale, the nonparametric technique was considered to be most appropriate for statistical analysis in this study.

Further, since the responses of the three types of house owners were considered to be of significant importance, the analysis was carried out by using relevant tests available for *k independent samples* (Jawahar, 1995).

9.2 Steps to be followed in hypothesis testing

The hypothesis testing procedure involves the following six steps (Siegel, 1956):

a) state the null hypothesis (H_0);

b) choose an appropriate statistical test suitable for testing H_0;

c) specify the significance level (usually 0.05 in studies such as this) and a sample size N (40 for each category of respondents in this case);

d) find the sampling distribution of the statistical test under H_0;

e) define the region of rejection on the basis of steps (b) to (d); and

f) compute the value of the statistical test by using the information collected from the samples. If the value of the result is in the region of rejection, the decision will be to reject H_0 and accept the alternate hypothesis (H_1). If the level of significance is such (less than 0.05 in this case) the decision will be to retain H_0 and reject H_1.

9.3 Frequency analysis and mean score

The responses analysed through the frequency test are presented in the form of graphs for easier comparison between the three groups of respondents (Annex 7). The answers regarding acceptability of the reconstruction programme are in the ranking of i) acceptable; ii) marginally acceptable; and iii) not acceptable. In a society where literacy level is very low, further ranking was not possible with the risk of affecting the quality of data. The frequency was calculated in percentage and tabulated. In order to determine the tendency of rating of the programme acceptability, mean score for each variable was calculated by using SPSS-X (Release 3.0) software.

9.4 Analysis of variance (ANOVA) test

Kuruskal-Wallis one-way analysis by ranks is considered to be extremely useful for determine the independent samples when the data is in *skewed* form (Siegel, 1956). The test examines the null hypothesis by determining whether the k samples come from the same or different populations with respect to the averages. The purpose of using this test was to confirm whether the three types of samples represented the same or identical groups of populations of the earthquake-affected people. This test is crucial to justify if the research findings will apply to all population sections under study.

9.5 Kendalls' rank correlation coefficient

This test is suitable as a measure of correlation between two or more sets of data. The sampling distribution of the coefficient is known and it is tested for significance (Siegel, 1956). It is a measure of association or correlation requiring both variables to be measured in at least an ordinal scale so that the individuals under study may be ranked in two orders. The test's power efficiency is up to 91%. Spearman's correlation test is also equally efficient. However, according to Dr J.R. Calvert of the Business School at Loughborough University the Spearman's test is considered to be more suitable for two samples.

9.6 Rationale for the statistical tests used in this analysis

Before rationalising the tests used in this analysis it seems appropriate to mention some of the basic insights involved in selecting different statistical tests to examine the data from different aspects.

In statistics the operations and relations used in obtaining the scores, define and limit the manipulation and operations which are permissible in handling scores. In general there are four types of scales in which scores can be collected to conduct any type of research (Siegel, 1956). These scales are known as *nominal*, *ordinal*, *interval* and *ratio*.

The nominal scale is simply a classificatory scale in which numbers are used only to classify objects. This type of data measure is considered to be the of the weakest type of information.

In ordinal scale the objects of one category of are not just different from the other categories but have some kind of relationship between them such as 'acceptable', 'marginally acceptable' and 'not acceptable'. The ordinal scale differs from the nominal scale in the sense that it not only records the relation of equivalence (=) but also the relation of greater than (>) or smaller than (<).

The interval scale has all the characteristics of an ordinal scale and in addition the distances between two numbers on the scale are also known. This quality makes the measurements strong for which usually parametric tests are applied. Such data is however difficult to find when peoples attitudes and preferences are being studied.

When a scale has all the qualities of an interval scale and in addition has a true zero point as its origin it is known as the ratio scale. Information of this type is rarely available.

The scale used in the field surveys of this research was ordinal for which only non-parametric techniques are applicable.

The frequency analysis was used to examine the percentage of ratings on different categories of agreement among the three samples. Based on the maximum percentage of rating in a particular category, the hypothetical conclusions were drawn. For cross-checking, whether the results obtained from the frequency analysis represent the whole sample, a test of goodness-of-fit type was required. One such test is the one-sample chi square test which requires at least five expected frequencies for each category. This test was therefore considered unsuitable for this analysis. This study made use of the Kuruskal-Wallis one-way ANOVA test, known for its usefulness to examine if the samples from different categories of house owners under study signified any genuine population differences. All these three tests, including the Kendall's Correlation of Coefficient test, were performed by using SPSS-X (Release 3.0) software package. The graphical charts were prepared through another software package, Excell (5.0) available at Loughborough University of Technology.

The following sections briefly describe the statistical analysis undertaken and the inferences drawn in each case with reference to the objectives of the thesis (Figure 9.1). For the sake of clarity and not to be repetitive, all the tests carried out for one objective are discussed within the same section. All graphical charts resulting from the Frequency tests and the Kendall's Correlation of Coefficients test are presented in Annex 7. The tables for the Kuruskal-Wallis ANOVA and Kendall's tests are included in the main text.

9.7 Objective 1: initial responses of the government and the earthquake-victims and the extent of their willingness to undertake the post-disaster relief work

The main response to provide relief to the earthquake-victims, after the earthquakes, came from the government and the people themselves. The respondents categories, used in this chapter, are described in Section 7.6. The responses received from the various respondents are discussed below in the light of the statistical analysis.

9.7.1 Government's response: The literature review and the evaluation of the reconstruction programme have shown us that the government's response immediately after the earthquake mainly consisted of the following steps:

a) declaring a state of emergency throughout the country;
b) creating a special and high powered body, called the Supreme Council for Reconstruction of Earthquake Affected Areas (SCREAA). The SCREAA was headed by the prime minister himself and had representatives from the key ministries whose cooperation was considered necessary to deal with the emergency. This body had a direct liaison with the aid giving agencies;
c) appealing to the international community for assistance; and
d) making arrangements for emergency relief for the survivors.

The literature review and the evaluation of the field data shows us that the government's emergency help mainly comprising tents and blankets started reaching the disaster area after a week by which time the people had already gone through the phase

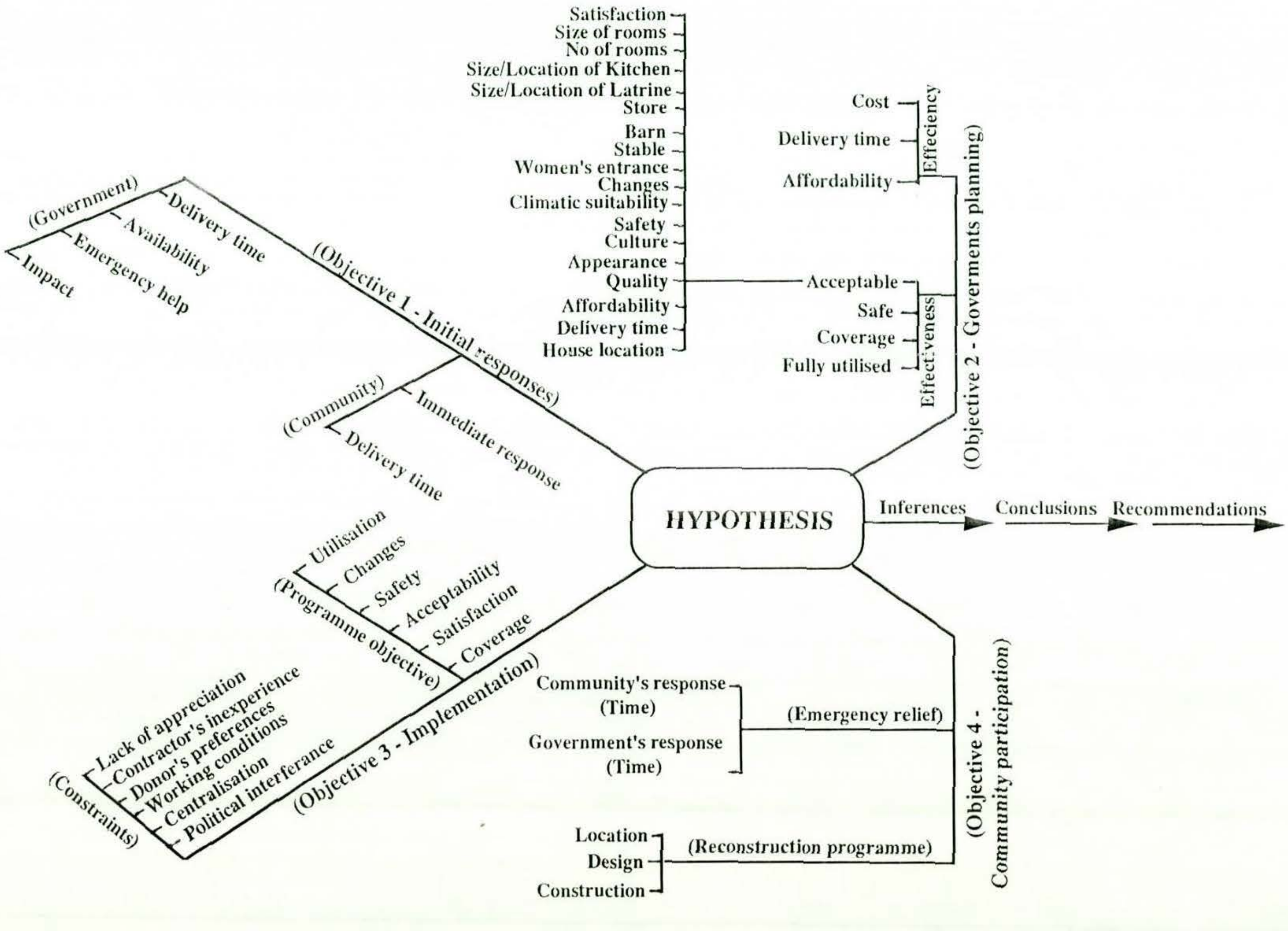


Figure 9.1: Data analysis - critical factors for hypothesis testing

of immediate response. The relevant variables to statistically test the government's response are discussed below:

9.7.1.1 *Emergency help*: The Frequency test (Annex 7, Chart 1) shows that 100% of the respondents are of the opinion that the emergency help came from the government.

It can be inferred from the above analysis that the government provided the emergency help to the earthquake victims.

9.7.1.2 *Delivery time*: The Frequency test (Annex 7, Chart 2) shows that the respondents from the government officials differed in their in their opinion about the timing of the emergency help. Ten percent of them thought that the government's help was available to the earthquake victims within one week of the disaster. A larger group of 40% respondents felt that it took up to 15 days before the emergency help reached all victims. Only 5% held the view that the emergency help was provided in about three weeks time. Another 40% were of the opinion that it took as much as one month to despatch the emergency help to all people in the earthquake affected area. A small group of 5% thought that the help reached all victims in about two months' time. It is obvious from the above responses that the government's help was not *immediate*.

It can be inferred from the above analysis, that the government's emergency help was not delivered to the earthquake victims at the proper time.

9.7.1.3 *Availability*: The Frequency test (Annex 7, Chart 3) to determine whether the government's emergency help covered all victims shows, that none of the government respondents were of the opinion that the emergency help was available to all victims. The test results show that 85% of the respondents thought that the help was available to most victims. The rest 15% felt that the emergency help was available to only some victims. No one says that the help was not available to any of the victims.

On the basis of the above analysis, it can be inferred that the government's emergency help was available to most of the victims.

9.7.1.4 *Impact*: The Frequency test (Annex 7, Chart 4) to determine what impact did the emergency help created on the victims suggest's that 100% government respondents agreed that the victims were not satisfied with the emergency help.

It can be inferred from the above analysis that the earthquake victims were not satisfied with the government's emergency help which created negative, rather than positive impact on the people.

9.7.2 Community's response: Literature review shows that the 1982 earthquake disaster in Dhamar governorate, killed several thousand people and caused extensive damage to the property. As a result, several hundred thousand people were left homeless in the disaster-stricken area. In order to meet the challenge, the earthquake-affected community responded to meet its immediate needs of shelter and food. The data collected in this respect, from the field surveys, was also statistically analysed.

9.7.2.1 *Immediate responses*: The Frequency test (Annex 7, Chart 5) shows us that only 2.5% people (just one person) in the Turnkey category waited for the government's emergency help while the remaining 97.5% helped themselves. In case of the other two categories, 100% of the immediate response came from the earthquake-affected people. The response was in terms of temporary shelter, food, first-aid and medical care.

The Kuruskal-Wallis ANOVA test, applied to all three categories of house owners, gave the significance level as 0.3679 (Table 9.1). This result shows that the probability associated with the occurrence of a value under null hypothesis (H_0), as large as the H value (Kuruskal-Wallis Coefficient), is greater than 0.05 (previously set value of significance) which enables us to accept the null hypothesis that the three categories of house owners represented the same population.

Table 9.1: Analysis of Variance of immediate responses of the three categories of house owners

Variable (Similarity by group)	Significance Alpha = 0.05	Inference
Immediate response	0.3679	There is no significant difference between the three samples of population with respect to their responses after the earthquake

The inference to be drawn from the above analysis is that the earthquake-affected community also responded to meet its immediate needs after the disaster, such as temporary shelter, food and first-aid.

9.7.1.2 *Delivery time*: The literature review shows us that the earthquake-victims responded immediately to their shelter and food needs. Some of them took care of their needs by themselves, while the rest were helped by family and friends. The community provided itself with very simple temporary shelter and other needs from the very first day after the disaster.

9.7.1.3 *Coverage*: The literature review also shows us that the people living in the earthquake-affected area provided temporary shelter, food and first-aid to all victims.

9.7.3 Summary of inferences: The inferences drawn in this section can be summarised as follows that:

a) the government's initial responses to the earthquake-disaster included emergency (but not immediate) help of the victims;

b) the government's emergency help was not delivered at the time expected by the earthquake victims;

c) the emergency help was made available to *most* of the victims but not to *all* of them;

d) the inadequate emergency help (not covering all victims) and its belated delivery created a negative impact on the victims;

e) the earthquake-affected community's also responded to meet its basic needs after the disaster;

f) the community's response was immediate; and

g) the community's response covered all victims.

9.8 Objective 2: to evaluate the efficiency and effectiveness of the government's planning process in order to examine the compatibility of the reconstruction programme with respect to severity of the situation faced by the victims

This aspect was studied mainly in the context of the government's planning to provide an efficient and effective reconstruction programme.

9.8.1 Efficiency: An *efficient* infrastructure has been defined in chapter 1, as the one which is *least costing*, is *affordable* and is *delivered on time* to the people.

9.8.1.1: Cost: A comparison of the estimated costs and some other salient features of the different types of housing in the study area is shown in Table 9.2. This comparison shows that the government built houses were not least-cost.

Table 9.2: Comparison of government built houses with the traditional houses

Housing category	Type	Main building materials	Expected damage in an earthquake		Approximate unit costs US$/$m^2$	Estimated cost of a house US$		
			Moderate	Severe		Small 56.33 m^2	Medium 81.12 m^2	Large 145.60 m^2
Government	Turnkey	Blocks, cement, aggregate, reinforcing steel	0	1	250	14,082	20,280	36,400
	Self-help	Blocks, cement, aggregate, wood, reinforcing steel	1	2	209	11,765	16,942	30,409
Private	Traditional	Stone, clay, tree branches	4	5	120 (economic) 24 (financial)	6,760 1,352	9,734 1,947	3,494 24,752

Notes: 0: undamaged; 1: slight; 2: moderate; 3: heavy; 4: partial destruction; 5: total collapse

Economic cost: the cost based on market rates
Financial cost: the cost actually paid by individual

In order to test the efficiency of the reconstruction programme, statistical tests were applied to the other two main variables i.e. delivery and affordability.

9.8.1.2 *Delivery time*: It was noted during the literature review and the evaluation of the reconstruction programme that the government built houses were not delivered at the promised time. The Frequency test (Annex 7, Chart 6) conducted on the house owners shows that in the Turnkey category only 15% people considered the delivery time of houses as acceptable to them, 2.5% felt that it was only marginally acceptable to them while the remaining 82.5% considered the delay as unacceptable. In the Self-help category 32.5% people thought that the delivery time, in spite of delay, was acceptable to them, 17.5% consider the delay as marginally acceptable and for the 50% people the delay was unacceptable. 100% of the third category of respondents, i.e. the traditional house owners, who finance and build their houses by themselves, considered the delivery time of their houses was acceptable to them.

The low acceptability of the time taken in delivering the houses to the beneficiaries is reflected in the Frequency test (Annex 7, Chart 7) conducted on the data collected from the government's surveys. Only 10% of these respondents felt that the houses were delivered in reasonable time while 90% were of the opinion that government built houses were delivered late.

The ANOVA test to examine the people's views about the time taken in the delivery of their houses shows a significance level of 0.0000 (Table 9.3). This result indicates that the three categories of house owners had different views about the delivery time of their houses. It is apparent that majority of the beneficiaries of the government houses found the delay in the handing over of their houses only as marginally acceptable. On the other hand the Traditional category considered the delivery time, managed by themselves, as fully acceptable. This result shows that these three categories had the same perceptions about the time of delivery of their respective houses and differed only when some of them did not receive their houses on the promised time.

Table 9.3: Analysis of Variance of the time of delivery of houses to the three categories of house owners

Variable (Similarity by group)	Significance Alpha = 0.05	Inference
Delivery time	0.0000	There three sample of population significantly differ in their acceptability of the time of delivery of their respective houses

The Kendall's Correlation test (Table 9.4) applied on the Turnkey category shows that these people's satisfaction has a significant (0.0010) correlation with the time of delivery. Only 2 of the 40 respondents were the satisfied people and both of them considered the delivery time as acceptable (Annex 7, Chart 8). The other 38 respondent were generally unsatisfied with the programme (Annex 7, Chart 9). Four of them found the delivery as acceptable, 1 considered it as marginally acceptable while the remaining 33 respondents thought the delivery time as unacceptable. In the Self-help and the Traditional categories, no significant correlation could be found between the people's satisfaction and delivery which shows that delivery was not a significant issue for these respondents. The analysis shows that satisfaction of all the people living in the study area was linked with the time of delivery of their houses and it become a significant issue when the delivery was later than expected.

Table 9.4: Correlation of the people's satisfaction (Turnkey category) with time of delivery of houses

Variable 1	Variable 2	Significance
Satisfaction	Delivery	0.001

It can be inferred that the delivery time of the government built houses was acceptable to only some of the beneficiaries. The majority of them considered it as marginally acceptable or not acceptable. In contrast, the traditional houses owners were found to be fully satisfied with the delivery time of their houses.

9.8.1.3 *Affordability*: Although the turnkey houses were provided free of cost to their beneficiaries, the respondents were asked to what extent they could afford if they were to build these houses by using their own funds.

The frequency test (Annex 7, Chart 10) shows that in the turnkey category 50% people found these houses as affordable, 40% as marginally affordable and the remaining 10% as unaffordable. Among the Self-help people 17.5% find their houses as affordable, 72.5% as marginally affordable and 10% as unaffordable. In the traditional category, 100% of the house owners considered their houses as affordable. The reason for a higher degree of perception of affordability among the recipients of Turnkey houses, with respect to their counterparts in the self-help category, seems to be due to the fact that they received their houses without spending any money and their views on affordability were based only on assumptions. On the other hand the literature review shows us, that the self-help people had to contribute about 30% to 50% of the total cost of their houses. This contribution was paid at a time when these people had gone through a major disaster which not only claimed many lives, but also economically crippled them and these people were left with hardly any resources. This hardship was probably the cause of their stronger views on affordability although their houses were relatively cheaper than the turnkey houses. Also the literature review shows that most of the self-house owners were bitter about the fact that while some of them were lucky enough to receive the turnkey houses completely free of cost, they had to pay an appreciable percentage of the cost for their house. The traditional houses were truly inexpensive houses as seen in Figure 9.2 and the views of their owners reflect the same.

The ANOVA test conducted on all three categories of respondents shows the significance level as 0.0000 (Table 9.5). This result shows that the three categories of house owners had different opinions about affordability of the houses in which they are living. This result shows that all three categories of respondents had very clear ideas about affordability. They considered those houses as unaffordable which they found to be beyond the limits of their affordability, and reckoned those houses as affordable which they could afford to build from their own resources.

Table 9.5: Analysis of variance of affordability of houses to the three categories of house owners

Variable (Similarity by group)	Significance Alpha = 0.05	Inference
Affordability	0.0000	The three samples of population significantly differ in their opinions about the affordability of their respective houses

It can be inferred that a smaller percentage of the recipients of government houses (turnkey and self-help) considered there houses as affordable. The majority of the beneficiaries however considered them as unaffordable.

9.8.2 Effectiveness: According to the definitions given in chapter 1 of this thesis, an *effective* infrastructure is the one which is *risk minimising*, *fully utilised*, *acceptable* and provides *full coverage* to the victims. The extent and the way in which the government built houses were utilised, is discussed in the previous chapters on literature review and evaluation. For testing the efficiency of the housing programme, statistical tests were applied to three main variables i.e. safety (earthquake-resistance), acceptability and coverage. The acceptability of the reconstruction programme found to be closely linked with the people's satisfaction with respect to their houses. In order to examine the people's acceptability of the reconstruction programme, all related variables were statistically analysed. The detail of these tests is described in the following paragraphs.

9.8.2.1 *Safety*: The safety of infrastructure in an earthquake zone means its earthquake-resistance. Figure 9.2 shows the estimated earthquake-resistance of different category of houses on the basis of literature review.

The frequency test (Annex 7, Chart 11) applied with respect to the safety indicated that in the turnkey category 20% of the respondents found their house acceptable for safety considerations. Another 42.5% found the safety considerations as only marginally acceptable. The rest 37.5 said that only the next earthquake could tell whether their houses were safe enough, and that they did not find any safety considerations of their houses as acceptable because no one except Allah could give such a guarantee. In the Self-help category, 15% of the respondents find the houses acceptable because they were safer. The majority, 52.5% thought the house only marginally acceptable for the reason of safety. The remaining 32.5% said the any assurances of safety were not acceptable to them. In the traditional houses no one thought that safety considerations were acceptable. Only 10% of these people said that safety considerations were marginally acceptable to them. The remaining 90% thought that safety considerations were not acceptable to them because only Allah knew when and how severe earthquake will take place.

The ANOVA test shows the significance level as 0.0000 (Table 9.6) which indicates that the three categories of house owners did not agree about the concept of safety against earthquakes probably because of the lack of awareness and the lack of a clear concept about the earthquake hazard in their area.

Table 9.6: Analysis of variance of safety of houses to the three categories of house owners

Variable (Similarity by group)	*Significance* Alpha = 0.05	Inference
Safety (Earthquake-resistance)	0.0000	The three samples of population significantly differ in their opinions about safety probably because of their lack of awareness of the earthquake hazard

The Kendall's Correlation test (Table 9.7) separately applied on all three categories gives a significance of 0.033 between the peoples' satisfaction and safety. There were 2 satisfied (Annex 7, Chart 8) and 38 unsatisfied respondents (Annex 7, Chart 9) in this sample. Both of these overall satisfied respondents were satisfied with the earthquake-resistance of their house. Six of the 38 unsatisfied respondents were satisfied with the safety considerations in their houses. Seventeen of them considered this aspect as marginally acceptable and 15 respondents considered the concept of safety as unacceptable. There was no significant correlation between the people's satisfaction with respect to safety in the other two categories.

Table 9.7: Correlation of the people's satisfaction (turnkey category) with safety of houses

Variable 1	Variable 2	Significance
Satisfaction	Safety (Earthquake-resistance)	0.033

It can be inferred that although the government built houses were based on earthquake-resistant techniques, but the victims could not appreciate this because of their lack of awareness of the hazard.

9.8.2.2 *Acceptability*: The houses built during the reconstruction programme were quite different from the traditional houses in almost every respect which became a crucial reason with regards to their beneficiaries' acceptability, although these houses were stronger and more modern than the traditional houses. The government distributed the turnkey houses free of cost and contributed up to 50% to 70% of the cost in the aided self-help house programmes.

Frequency tests were applied to all variables related to the acceptability the people. These variables were delivery, climatic suitability, location of house, availability, location and sizes of various rooms, safety (earthquake-resistance), cultural needs, general appearance, quality of work and affordability. Delivery, safety and affordability are already discussed above. The other variables will be discussed in the following paragraphs.

. *Climatic suitability*: The frequency test (Annex 7, Chart 12) applied to know the people's views on climatic suitability shows that in the turnkey category 30% people found their houses as acceptable, 55% as marginally acceptable and 15% as unacceptable. In the self-help category 27% people felt the climatic suitability of their houses as acceptable, 70% as marginally acceptable and 3% as not acceptable. In the traditional category, 97.5% people considered the climatic suitability of their houses as acceptable and 2.5% as marginally acceptable.

The ANOVA test (Table 9.8) found the significance level as 0.0000 which shows different opinions of the people about their different type of houses. Their opinions would probably would probably have been alike if asked about the same type of houses.

Table 9.8: Analysis of variance of climatic acceptability of houses for the three categories of house owners

Variable (Similarity by group)	Significance Alpha = 0.05	Inference
Climatic suitability	0.0000	The three samples of population significantly differ in their opinions about climatic suitability of their different type of houses

It can be inferred that majority of the respondents from the government built turnkey and self-help categories considered their houses as only marginally acceptable or not acceptable whereas almost all respondents from the traditional category considered their houses as acceptable for climatic suitability.

. *Location of the house*: Literature review shows that the people of Yemen are very sensitive about the location of their houses for the reasons of culture, supervision of agricultural farms and tribal rivalries.

Frequency test (Annex 7, Chart 13) applied to learn their views about the location of their respective houses revealed that 55% from the turnkey category found the location as acceptable, 35% thought it as marginally unacceptable, and 10% as unacceptable. In the self-help category 90% found the location of the houses as acceptable, 5% as marginally acceptable, and 5% as not acceptable. Among the traditional house owners 100% said that the location their houses was fully acceptable to them.

The ANOVA test found the significance as 0.0000 (Table 9.9). This shows that the people of the three categories differed in their opinions on location about the different houses they were occupying. They would probably have given the same opinion if asked about the same type of houses.

Table 9.9: Analysis of Variance of acceptability of the location of houses for the three categories of house owners

Variable (Similarity by group)	Significance Alpha = 0.05	Inference
Location	0.0000	The three samples of population significantly differ in their opinions about location of their different type of houses

The inference to be drawn is that the people of the earthquake-affected areas attached significant importance to the location of their houses. Majority of the people living in the government houses (turnkey and self-help) considered the location of their houses as marginally acceptable or not acceptable. In contrast, all respondents from the traditional category found the location of their houses as acceptable to them.

. *Culture*: Literature review shows us that the Yemeni people are conservative in almost every respect and they have high regards for their cultural values. Because of the extended family system prevalent in the society, they prefer to have large houses with a number of rooms and facilities. Qat chewing is also a very salient feature of the culture which has influenced the design of traditional houses. All these cultural aspects are related the people's satisfaction and are discussed in detail in the next section 9.9. In this paragraph the discussion will be confined to the overall cultural acceptability of the reconstruction programme. In order to examine their views on acceptability of different categories of houses with respect to culture statistical analysis was carried out.

The Frequency test (Annex 7, Chart 14) revealed that 42.5% of the turnkey houses owners considered their new houses as culturally acceptable, 55% as marginally acceptable and 2.5% as not acceptable. In the self-help category 32.5% respondents think that the new houses are culturally acceptable, 62.5% as marginally acceptable and 5% as not acceptable. In the traditional category 100% people think that their houses are culturally acceptable.

The ANOVA test showed recorded the significance as 0.0000. This result indicates that the samples understudy differed in their opinions about the cultural acceptability of the government built houses and the turnkey houses. Their views would probably be the same if asked about the same houses.

Table 9.10: Analysis of variance of acceptability of the cultural acceptability of houses for the three categories of house owners

Variable (Similarity by group)	Significance Alpha = 0.05	Inference
Culture	0.0000	The three samples of population significantly differ in their opinions about cultural acceptability of their different type of houses

The correlation test shows the people's satisfaction and acceptability has a significance of 0.011 in relation to culture. In turnkey category both of the 2 satisfied people found their houses as suitable in all related factors (Annex 7, Chart 8). Out of the 38 people unsatisfied with the reconstruction programme (Annex 7, Chart 9), 4 thought that the houses were acceptable to them for cultural considerations. A large majority of 27 people felt that their cultural acceptability the houses was only marginal. The remaining 7 said that the turnkey houses were culturally unacceptable.

Table 9.11: Correlation of the people's satisfaction (turnkey category) with culture acceptability of houses

Variable 1	Variable 2	Significance
Satisfaction	Culture	0.011

No significance could be found in the other two categories.

It can be inferred that majority of the respondents from the government built houses (turnkey and self-help) considered cultural acceptability of their houses as marginally acceptable or not acceptable. All respondents from the traditional category considered their houses as culturally acceptable.

. *General appearance*: The frequency test (Annex 7, Chart 15) to examine general appearance showed that 50% people in the turnkey category found the general appearance of their houses as acceptable, 40% as marginally acceptable and 10% as unacceptable. In the self-help category 17.5% of respondents found the appearance of their houses as acceptable, 72.5% as marginally acceptable and 10% as unacceptable. In the traditional category, 100% respondents found the appearance of their houses as acceptable.

The ANOVA test (Table 9.12) gives a significance of 0.0000. The result understandably showed that different samples, selected from the same population, gave different comments on general appearance of different categories of houses.

Table 9.12: Analysis of variance of acceptability of the general appearance of houses for the three categories of house owners

Variable (Similarity by group)	Significance Alpha = 0.05	Inference
General appearance	0.0000	The three samples of population significantly differ in their opinions about physical appearance of their different type of houses

The inference to be drawn is that the majority of people living in the turnkey and self-help houses considered the general appearance of their houses as only marginally acceptable or not acceptable. All people from the traditional houses considered the physical appearance of their houses as acceptable.

. *Quality of work*: The Frequency test was applied (Annex 7, Chart 16) to examine the people's views about the acceptability of the quality of work in their house. The results indicated that 42.5% of the turnkey house owners found the quality of work in their houses of acceptable nature, 55% as marginally acceptable and 2.5% as not acceptable. In the self-help category 32.5% found it as acceptable, 62.5% as marginally acceptable and 5% as not acceptable. In the traditional housing category 75% of the respondents felt the quality their houses as acceptable, 20% as marginally acceptable, while 5% thought they were unacceptable.

The ANOVA test gives a significance of 0.0011 (Table 9.13). This result shows that different samples selected from the same population differed when asked to give their views about different types of houses. Their views probably would have been the same if asked about the same houses. This indicates that three categories of respondents actually represent the same population.

Table 9.13: Analysis of variance of acceptability of the quality of work of houses for the three categories of house owners

Variable (Similarity by group)	Significance Alpha = 0.05	Inference
Quality of work	0.0000	The three samples of population significantly differ in their opinions about the quality of work in their different type of houses

An inference can be drawn that the people in the earthquake-affected area had different opinions about the quality of work in their respective houses. The majority of respondents from the turnkey and self-help categories considered the quality of work of their houses as marginally acceptable or not acceptable. The traditional category respondents generally approved the quality of work in their houses.

9.8.2.3 *Coverage*: The literature review and evaluation of the reconstruction programme show that only about 50% to 55% of the earthquake victims could be covered. This is indicated in the survey of the government officials.

The frequency test (Annex 7, Chart 17) results also confirm that 100% respondents of the government respondents agreed that the reconstruction programme failed to provide benefits to all victims.

9.8.3 <u>Summary of inferences</u>: The inferences drawn from the analysis in this section, can be concluded as follows:

a) the government built houses were not least-cost;

b) most of these houses were not delivered on time; and

c) the new houses were not affordable or only marginally affordable to majority of the people living in the earthquake-affected area;

It can therefore be concluded that the that the government implemented reconstruction programme, comprising mostly reconstruction of houses for the earthquake victims, was *not efficient*.

d) although the new houses were earthquake-resistant, but most of the people in the earthquake area did not consider any guarantee of safety acceptable to them. They thought that only the next earthquake would confirm how safe the new houses were. The people in the study area generally did not have a clear concept about the earthquake hazard and the need for safety against this hazard. One of the probable reasons could be that the government did not make any serious attempts to create this awareness during the reconstruction programme although it was a good opportunity;

e) majority of the people regarded these government built houses as unacceptable for different reasons discussed above and in the evaluation;

f) the government built Turnkey and Self-help houses were not fully utilised as discussed in evaluation; and

g) they did not provide full coverage to the earthquake victims as discussed above and in the last chapter.

It can be concluded from the inferences that the reconstruction programme was *not very effective.*

9.9 Objective 3: to analyse as to what extent the objectives of the reconstruction programme were realised and to identify the issues and constraints which inhibited the efficient and effective implementation of the programme

This section will discuss the main objectives of the reconstruction programme and what major constraints were faced in its efficient and effective implementation. The programme objectives are presented in the sub-section 9.9.1 while the constraints are discussed in the next sub-section 9.9.2. The inferences are presented at the end under sub-section 9.9.3.

9.9.1 Programme objectives: The government's objectives of the reconstruction programme are listed in the literature review. The following paragraphs will discuss these objectives together with the statistical analysis and inferences drawn from the analysis:

9.9.1.1 *Coverage*: One of the major objectives of the reconstruction programme was to cover all earthquake victims according to their respective shelter needs and the available resources. The literature review shows us that at the time of the earthquake the government of Yemen was enjoying excellent relations with its oil-rich neighbours and the international donors, who responded with huge amounts of assistance soon after the government's appeal. The government also had its own resources mainly because of the large amount of about US$ 1.5 billion annually remitted to its coffers by migrant Yemenis in Saudi Arabia and the Gulf States. As such resources were not a major problem at the time of the disaster. In spite of these favourable circumstances, the evaluation of the programme shows us that only about 50% to 55% of the earthquake victims were covered by the reconstruction programme. The survey of the government officials (section 9.8) also confirms that all victims could not be covered by the programme (Annex 7, Chart 17). As such the reconstruction programme failed to meet one of its major objectives i.e., to provide coverage to all victims. The statistical tests conducted to examine coverage of the victims are discussed in Section 9.8.

The inference is therefore that the reconstruction programme failed in meeting one of its objectives to provide coverage to all earthquake victims.

9.9.1.2 *Utilisation*: Another important objective of the reconstruction programme was, that the new houses allotted to the beneficiaries should be fully utilised. It has been discussed during in the earlier chapters on literature review and evaluation, and in Section 9.8 that the reconstructed houses, particularly the turnkey houses were not fully utilised. This result shows that the government's objective of getting full utilisation of the reconstruction programme could not be achieved.

The inference to be drawn from the above discussion is, that the infrastructure built during the reconstruction programme was not fully utilised.

9.9.1.3 *Satisfaction*: It has been discussed in Section 9.8 that the earthquake-affected people's satisfaction and acceptability of the reconstruction programme was closely linked with a number of factors. Apart from expressing their views on overall satisfaction with the reconstruction programme, they gave their comments about these factors as well. The statistical tests applied to the overall satisfaction of the people and various other factors are discussed in the following paragraphs:

. *Overall satisfaction*: The frequency test (Annex 7, Chart 18) conducted to examine the people's satisfaction with the programme revealed that only 5% people were satisfied with the turnkey programme. The remaining 95% people were unsatisfied. In the self-help category, 40% people expressed their overall satisfaction with the programme, while the rest 60% considered the programme as unsatisfactory. In the traditional housing category 100% respondent said they were satisfied with their self-built houses. The above analysis gives an idea of the people's degree of satisfaction with the different types of housing systems under study.

The ANOVA test (Table 9.14) applied to the three samples, to examine their satisfaction with their respective housing systems, gave a significance level of 0.0000.

Table 9.14: Analysis of variance of satisfaction for the three categories of house owners

Variable (Similarity by group)	Significance Alpha = 0.05	Inference
Satisfaction	0.0000	The three samples of population significantly differ in their opinions about their satisfaction with their different type of houses

This result confirms that the three categories of house owners had different opinions concerning their overall satisfaction with their different type of houses. This shows that the three categories of respondents differ in their level of satisfaction with respective houses. However it can be seen from the frequency analysis that 100 respondents from the traditional category, who managed the location, design, construction and funding of their houses, were satisfied with their houses. On the other, majority of the beneficiaries of the government implemented turnkey and self-help programmes were unsatisfied with their houses. This shows that their was some similarity between these two categories of respondents and they represented the same population with respect to the variable *'satisfaction'*.

The correlation test (Table 9.15) (Annex 7, Charts 8 and 9) shows us that the turnkey category's satisfaction with the reconstruction programme, was correlated to a number of critical factors, such as culture (significance 0.11), barn (significance 0.000), delivery (significance 0.001), entrance (significance 0.029), kitchen (significance 0.000), latrine (significance 0.020), number of rooms (significance 0.000), size of rooms (significance 0.004), safety (significance 0.033), stable (significance 0.001) and store (significance 0.000). No correlation of satisfaction with these variables was found in the other two categories of house owners (self-help and traditional). The above results show that the above mentioned factors (variables) have some influence on the satisfaction of the turnkey category beneficiaries.

Table 9.15: Correlation of the people's satisfaction (turnkey category) with other critical factors for acceptability of the houses

Variable 1	Variable 2	Significance
Satisfaction	Culture	0.011
	Availability of barn	0.000
	Delivery time	0.001
	Women's entrance	0.029
	Location/size of kitchen	0.000
	Location/size of latrine	0.020
	Number of rooms	0.000
	Size of rooms	0.004
	Safety	0.033
	Availability of stable	0.001
	Availability of store	0.000

The Kuruskal-Wallis test (Table 9.16) performed on the above variables also confirmed the same results, that the three samples of population significantly differ in their opinions on satisfaction with their respective and different type of houses.

Table 9.16: Analysis of variance of satisfaction for the three categories of house owners

Variable (Similarity by group)	Significance Alpha = 0.05	Inference
Satisfaction	0.0000	The three samples of population significantly differ in their opinions about their satisfaction and the related factors in their different type of houses
Culture	0.0000	
Availability of barn	0.0000	
Delivery time	0.0000	
Women's entrance	0.0000	
Location/size of kitchen	0.0000	
Location/size of latrine	0.0000	
Number of rooms	0.0000	
Size of rooms	0.0000	
Safety	0.0000	
Stable	0.0000	
Store	0.0000	

Out of 40 people in this category, only two were the satisfied people. Both of them were satisfied with all the above mentioned critical factors (Annex 7, Chart 8). In the unsatisfied group (Annex 7, Chart 9), comprising 38 people, expressed their marginal satisfaction or dissatisfaction over most of the correlated factors. To elaborate further, 25 of the 38 unsatisfied people only marginally accepted their dissatisfaction some of the correlate factors, such as culture, barn, entrance, kitchen, latrine, number of rooms, size of rooms, stable and store. However some other correlated factors, such delivery and safety indicated a high proportion of unsatisfied people among these beneficiaries.

. *Culture*: It has already been discussed at length in the literature review and evaluation of the reconstruction programme that Yemen is a conservative country with centuries old culture. The researcher observed in his long stay in Yemen, that the Yemeni people are generally proud of their being one of the first countries to have accepted Islam as the state religion. They greatly value their ancient culture, religion and traditions. These attitudes are reflected in their everyday life, particularly their homes. The traditional houses present a complete picture of their culture, traditions, religion and techniques to minimise climatic discomfort in a temperate climate. It was no chance that the nearly 100% people from the traditional category were found to be satisfied with their houses in every respect. On the other hand, the hand the government built turnkey and self-help are almost a contrast to the traditional houses. This is probably why the earthquake-affected people's dissatisfaction, with regards to culture is expressed not only in the literature review and evaluation of reconstruction programme earlier discussed in this study, but also in the statistical analysis presented in Section 9.8.

The inference, as presented in Section 9.8, is that most of the beneficiaries in both turnkey and self-help categories either marginally accepted the cultural aspects of their houses or did not accept it at all. All respondents from the traditional category found their houses as culturally acceptable.

. *Delivery*: The delay in delivery of first the emergency relief after the earthquake disaster, and later the reconstruction programme was another major cause of the earthquake affected people's dissatisfaction. Literature review shows that most of the disaster-affected waited for months to receive their promised houses. Many of them did not get them even after a long and patient wait as discussed under coverage. For those who were lucky enough to receive the houses at long last, did not find them sufficient for their needs as discussed in the following paragraphs. The reasons of delay, uncertainty in receiving shelter, and later insufficiency of the house added up to the recipients dissatisfaction of the time taken by the government in delivering the houses. Statistical analysis discussed in Section 9.8 shows that majority of the dissatisfied beneficiaries found the delivery of the reconstruction programme unacceptable.

The inference is that most of the beneficiaries of the government built houses found the delivery time as unacceptable. The traditional category people considered the delivery of their houses as acceptable.

. *Size of rooms*: The frequency test (Annex 7, Chart 19) carried out examine the people's satisfaction with the size of rooms, showed that in the turnkey category 20% people were satisfied and the remaining 80% were not satisfied. In the self-help category 37.5% people were satisfied with the size of their rooms but 62.5% were unsatisfied. Among the traditional house owners 100% people were satisfied with the size of rooms in their houses.

The inference to be drawn is, that size of rooms in the government built houses were not acceptable to majority of the beneficiaries. The traditional house owners felt that the size of rooms in their houses were fully acceptable to them.

. *Number of rooms*: The frequency test (Annex 7, Chart 20) applied on the three samples showed that 10% people in the turnkey category were satisfied with number of rooms in their houses. The remaining 90% were unsatisfied with the number of rooms. In the self-help category 17.5% of the respondents were satisfied with the number of rooms in their houses while 82.5% were not satisfied. In the traditional category 100% were satisfied with the number of rooms in their houses.

The inference is that most of the beneficiaries of the reconstruction programme did not think the few number of rooms in their houses as acceptable. The traditional house owners considered the number of rooms in their houses as acceptable.

. *Location and size of kitchen*: The literature review presented earlier in this study shows us that the location and size of kitchen in a house is very important for the people of Yemen. The frequency test (Annex 7, Chart 21) conducted to examine this aspect indicated that 5% of the turnkey category of respondents were satisfied with the location and size of the kitchens in their houses while 95% were unsatisfied. In the Self-help category 15% were satisfied with the location and size of kitchen and 85% were unsatisfied. In the traditional category all 100% respondents expressed their satisfaction with the location and size of kitchen in their houses.

The inference to be drawn from the above analysis is that majority of the beneficiaries of the reconstruction programme considered the location and size of kitchens in their houses as not acceptable. On the other hand the traditional house owners thought the location and size of kitchens in their houses as fully acceptable.

. *Location and size of latrine*: The frequency test (Annex 7, Chart 22) undertaken to determine the satisfaction of the three samples of population regarding their views about the location and size of latrine showed that 27.5% of the turnkey category people were satisfied while 62.5% were unsatisfied. Among the self-help respondents 35% recorded their views as satisfied 65% were the unsatisfied people. In the traditional category all 100% respondents expressed their satisfaction with the location and size of latrines in their houses.

The inference to be drawn from the above analysis is, that the location and size of latrine was only marginally or not acceptable to most of the beneficiaries of the reconstruction programme. On the other hand the traditional house owners thought the location and size of latrines in their houses as fully acceptable to them.

. *Availability of a store*: The frequency test (Annex 7, Chart 23) conducted to examine the satisfaction of the three categories of respondents with respect to availability of a store in the house indicated that only 5% of the turnkey people were satisfied while 95% were not satisfied. In the self-help category 15% of the respondents said that they were satisfied. The remaining 85% said that they were not satisfied with the house because of non-availability of the a store. In the traditional category all 100% respondents expressed their satisfaction with their houses because of the availability of store.

The inference is that the lack of a store in the government built houses was a major source of only marginal acceptability or non-acceptability for most of the beneficiaries of the reconstruction programme. On the other hand availability of a store in the traditional was one of the important causes for acceptability by their owners.

. *Availability of barn*: The frequency test (Annex 7, Chart 24) carried out to find out the satisfaction of the three samples of the earthquake-affected community regarding the availability of a barn in the house showed that 12.5% of respondents from the turnkey category were satisfied while 87.5% were not satisfied for this reason. Among the self-help people 32.5% respondents said that they were satisfied in spite of the absence of a barn in their houses. The remaining 67.5% said that they were not satisfied in the absence of a barn. In the traditional category 100% respondents expressed their satisfaction with their houses because all of them had barns in their houses.

The inference is that the lack of barn in the government built houses was a major source of only marginal acceptability or non-acceptability for most of the beneficiaries of the reconstruction programme. On the other hand availability of a barn in the traditional was one of the important causes for acceptability by their owners.

. *Availability of stable*: Literature review shows that almost all rural Yemenis keep livestock and other domestic animals to have as much self-sufficiency in their agricultural and domestic activities as possible.

The frequency test (Annex 7, Chart 25) conducted to determine the satisfaction of the three samples of the earthquake-affected community regarding the availability of a stable in the house showed that 15% of respondents from the turnkey category were satisfied while 85% were not satisfied. In the self-help category 22.5% people responded that they were satisfied although there was no stable in their houses. The remaining 77.5% said that they were not satisfied in the absence of a stable. In the traditional category 97.5% respondents expressed their satisfaction with their houses because all of them had stables in their houses. Only 2.5% mentioned about dissatisfaction on this account.

The inference is that the non-availability of a stable in the government built houses was a major source of only marginal acceptability or non-acceptability for most of the beneficiaries of the reconstruction programme. The availability of a stable in the traditional house was one of the important causes for acceptability by their owners.

. *Availability of a separate entrance for women*: It is discussed in detail in the literature review that Yemen has a very conservative Islamic culture. The rural people forming almost 80% of the population are even more conservative. For them segregation of sexes is very important. All women are kept away from strangers or visitors from other tribes. The rooms and entrances to receive outsiders are therefore separate from rest of the family house.

The Frequency test (Annex 7, Chart 26) conducted to determine the satisfaction of the three categories of respondents regarding the availability of a separate entrance for women in the house indicated that 30% of respondents from the turnkey category were satisfied while 70% were not satisfied. In the self-help category 35% people responded that they were satisfied although there was no separate for privacy of the women in their houses. The remaining 65% said that they were not satisfied in the absence of a separate entrance. In the traditional category 100% respondents expressed their satisfaction with their houses because their houses had separate entrances for women.

The inference is that the absence of a separate entrance for women in the government built houses was a major source of only marginal acceptability or non-acceptability for most of the beneficiaries of the reconstruction programme. The availability of a separate entrance for women in the traditional house was one of the important causes for acceptability by their owners.

. *Safety*: The aspect of safety or earthquake-resistance of the houses in the study area has also been discussed in Section 9.8. Although the houses built during the reconstruction programme are designed under earthquake-resistant techniques but the people had no clear concept about safety or vulnerability of their houses. Only small percentages of respondents from the turnkey and self-help categories acknowledged their satisfaction and acceptability of the houses because of safety consideration. Most of the respondents from all categories thought safety considerations of only marginally acceptable to them because no could say definitely how their houses will perform in the next earthquakes. It confirms that all three samples of respondents represent the same population because of their similar views about safety.

The inference is, that the people of the earthquake-affected area in Yemen have low perception of the earthquake hazard and the vulnerability of traditional houses. It is because of this lack of awareness that they did not appreciate the earthquake-resistance of the government built houses.

. *Changes*: We have seen in the literature review that the beneficiaries of both turnkey and self-help houses carried out major changes in their houses to suit their needs. The few people who did not make any modifications or alterations were mostly those who could not afford them.

The frequency test (Annex 7, Chart 27) to examine the changes carried out in the different categories of houses was also one way to determine the people's satisfaction with reconstruction programme. The results indicated that 62.5% people in the turnkey category carried out major changes in their houses. In the self-help category 52.5% of the people carried out changes, while no one in the traditional category undertook any changes.

The inference which can be drawn from then above analysis that the earthquake-affected people's low acceptability of the reconstruction programme is evident from the amount of changes carried out in their houses on a large scale. The traditional house owners did not undertake any changes in their houses which confirms their acceptability of their houses.

9.9.2 Constraints: It has been discussed in section 9.8 that the post-earthquake reconstruction programme was neither efficient nor effective. The government officials, when asked in their interviews about the reconstruction programme and to give their candid opinion, gave different perceptions. These respondents mentioned several constraints in programme implementation such as centralisation in decision taking, political interference, difficult working conditions, etc. The information based on these interviews was statistically analysed and is presented in this section.

In response to the question, whether they were satisfied with the implementation of the reconstruction programme, the frequency test (Annex 7, Chart 28) showed that 20% of the government officials were satisfied with the implementation of the programme while 80% were not satisfied.

The correlation test (Table 9.16) indicated that there was a significant correlation of 0.001 between constraints and programme implementation. The test determined that there were 4 satisfied (Annex 7 Chart 29) and 16 unsatisfied respondents (Annex 7, Chart 30). None of the 4 satisfied respondents thought that there were any constraints in programme implementation. Among the unsatisfied respondents, 14 thought that several constraints hampered the programme implementation in meeting its objectives.

Table 9.17: Correlation of the programme implementation with other critical factors (government respondents)

Variable 1	Variable 2	Significance
Implementation	Centralisation Constraints Working conditions	0.008 0.001 0.003

The inference is that majority of the government respondents were not satisfied with the implementation of the post-disaster reconstruction programme in Yemen. It is also inferred that there were several constraints which influenced the programme in not meeting its objectives. These constraints, as pointed out by the respondents, are discussed in the following paragraphs.

9.9.2.1 *Centralisation in the government's decision taking*: A Frequency test (Annex 7, Chart 31) was conducted to examine what percentage of the government officials considered centralisation as a constraint. The test determined that 60% of the respondents agreed that centralisation in decision taking was one of the causes of the reconstruction programme not meeting its objectives. The rest 40% did not think that centralisation hampered the reconstruction programme.

The Correlation test (Table 9.17) showed that there was a significant correlation between centralisation and programme implementation. Only 1 of the 4 satisfied respondents (Annex 7, Chart 29) did not agree that centralisation caused any problems in programme implementation, but the other 3 satisfied respondents said that centralisation was a major constraint. In the unsatisfied group (Annex 7, Chart 30) of the government respondents 13 agreed that centralisation was a constraint in programme implementation. The rest 3 thought that it was not a constraint.

The inference is that centralisation in decision taking did have its implications in the implementation of the reconstruction programme according to its objectives.

9.9.2.2 *Difficult working conditions*: The government respondents mentioned in their interviews about the difficult working conditions with which they had to cope during implementation of the reconstruction programme. These difficulties included long working hours without adequate compensation, poor camping arrangements for the site staff, inadequate transport facilities and difficult accessibility of most of the villages in the mountainous terrain of the earthquake-affected area.

The frequency test (Annex 7, Chart 32) conducted to examine the government respondents' views about difficult working conditions showed that 65% of them agreed that the working conditions for the engineers and other field staff was a constraint in the implementation of the reconstruction programme. The other 35% respondents did not think that the working conditions hampered the programme in any way.

The correlation test (Table 9.17) showed that there was a significant correlation of 0.003 between working conditions and implementation. None of the 4 satisfied respondents

(Annex 7, Chart 29) thought that working conditions influenced the in programme implementation. In the unsatisfied group (Annex 7, Chart 30) of the government respondents 12 agreed that centralisation was a constraint in programme implementation, while the remaining 4 said working conditions were not a constraint to the programme.

The inference is that an appreciable majority of the government respondents believe that working conditions was a constraint for the reconstruction to meet its objectives.

9.9.2.3 *Political interference*: Another constraint in implementation of the programme, which came to surface during interviews of the government respondents, was the political interference of senior government functionaries, members of the parliament and tribal sheikhs.

The frequency test (Annex 7, Chart 33) conducted to examine the government respondents' views about political interference revealed that 60% of them thought it was a constraint in the implementation of the reconstruction programme. The other 40% respondents did not think that there was any political interference in the implementation of the programme.

The correlation test (Table 9.18) showed that political interference was a significant constraint (significance level 0.003) in programme implementation. The test found 8 satisfied respondents (Annex 7, Chart 34) and 12 unsatisfied respondents (Annex 7, Chart 34). Among the satisfied respondents 4 thought political interference as a constraint in programme implementation. The other 4 thought that political interference was not a constraint. In the unsatisfied group of 12 officials, 10 considered political interference as a constraint in implementation of the reconstruction programme. The remaining 2 thought that there was no political interference.

Table 9.18: Correlation of constraints with political interference (government respondents)

Variable 1	Variable 2	Significance
Constraints	Political interference	0.012

The inference is that political interference was a significant constraint in deterring the implementation of the reconstruction according to its objectives.

9.9.2.4 *Donor's preferences*: Literature review and interviews of the government officials identified another constraint, which some of the respondents considered to have influenced the reconstruction programme. This constraint was the preferences of certain donor's for certain type of projects and there implementation in a certain way. According to the government respondents, sometimes these preferences were contrary to the government's implementation plans but the government had no choice because the foreign assistance was usually conditional.

The frequency test (Annex 7, Chart 36) conducted to examine the impact of donors' preferences on the implementation of the programme revealed that 20% of the government respondents thought it was a constraint. The rest 80% respondents did not think that donors' preference was a major constraint.

The inference is that the donors' preference was not a significant constraint in deterring the implementation of the reconstruction according to its objectives.

9.9.2.5 *Lack of experience of local contractors*: Some of the government officials also mentioned in their interviews, the lack of experience of local contractors as a constraint in programme implementation.

The frequency test (Annex 7, Chart 37) conducted to examine the impact of lack of experience of the local contractors as a constraint, indicated that 45% of the government respondents thought it was a constraint. The remaining 55% respondents did not think that local contractors' lack of experience in handling major reconstruction jobs was a constraint.

The inference is that the lack of experience of the local contractors was not a significant constraint.

9.9.2.6 *Lack of the communities appreciation of the programme*: Some of the government respondents talked about the affected community's lack of appreciation and the consequent lack of cooperation, being a constraint in the implementation of the reconstruction programme.

A frequency test (Annex 7, Chart 38) conducted to examine whether the earthquake-affected community's lack of appreciation of the reconstruction programme was a constraint in programme implementation. The result indicated that 50% of the government respondents thought it was a constraint while the remaining 50% respondents did not think there was such a constraint.

The inference is that the government respondents are equally divided in their views about the community's lack of appreciation of the reconstruction programme as a significant constraint.

9.9.3 Summary of inferences: The post-earthquake reconstruction programme in Yemen failed to meet its objectives as confirmed by the analysis and discussions contained in this section. The reasons, based on the inferences drawn in the foregoing paragraphs in this section, can be summarised as follows:

a) the reconstruction programme failed in providing coverage to all earthquake victims;
b) the housing system, which formed major part of the reconstruction programme, was not fully utilised;
c) the programme failed to create a positive impact on the earthquake victims because of inadequate coverage of the victims, belated delivery and several other factors;
d) majority of the recipients of the government built houses (Turnkey and Self-help) were not satisfied with the new houses. The low acceptability of these houses was mainly because they did not meet many of the needs of the local community. The main causes of dissatisfaction of the beneficiaries were in respect of the size and number of rooms, location and size of kitchen and latrine. The other complaints were about the non-availability of store, barn, stable and separate entrance for women.

d) most people in the earthquake area under study have low perception about the earthquake hazard in their area and the vulnerability of traditional houses. The reconstruction programme also failed in creating the hazard awareness in the local people. The government built new houses, because of the beneficiaries' general dissatisfaction and lack of acceptability, created a negative impact. As a consequence quite a few of the recipients of government houses preferred to live in the traditional houses; and

e) implementation of the reconstruction programme was impeded by several constraints such as centralisation in decision taking, political interference and difficult working conditions for the staff. These problems could probably be avoided if the government had not involved itself so heavily in programme implementation.

9.10 Objective 4: to ascertain the role of the earthquake-victims in different phases of the reconstruction programme with the intention to elaborate how community management can enhance efficiency and effectiveness of such programmes

This section will examine the role of the earthquake-victims in the reconstruction programme and how a community can contribute in the efficient and effective implementation of a development/reconstruction programme in their area. There were two phases of activities after the 1982 earthquake i.e. the short-term measures (initial responses) and the long-term measures (reconstruction programme). The earthquake-affected community's role in the short-term measures is discussed in sub-section 9.10.1 and its role in the long-term measures is discussed in section 9.10.2. The subsequent inferences are presented in Section 9.10.3

9.10.1 Short-term measures: The short-term measures after the earthquake were the initial responses of the government and the earthquake-affected community. These responses have been discussed in section 9.7 and are only summarised in the following paragraphs.

9.10.1.1 *Initial responses of the earthquake-victims*: The earthquake victims quickly responded to the post-disaster situation by meeting their immediate needs of temporary shelter and food. In Addition, as discussed in detail in Section 9.7, the community's response covered all victims.

The inference is that the analysis of the earthquake-affected community's response after the disaster shows that the community were well aware of not only their immediate needs but also their responsibilities. This shows the earthquake-affected community's management skills in dealing with its problems.

9.10.1.2 *Initial responses of the government*: The government's response was late to reach the victims by which time the phase of immediate relief was nearly over. Besides, the government's emergency help could not cover all victims therefore created resentment and bitterness among the victims as discussed in the literature review and in Sections 9.8 and 9.9.

The inference to be drawn is that the government was not well prepared to address the post-disaster situation despite the fact that the country is well known for earthquakes. It could not adequately meet one of its objectives of providing immediate relief to the earthquake victims. The government's inadequate response immediately after the earthquake, created a negative rather than a positive impact among the victims.

9.10.2 Long-term measures: The long-term measures consist of the implementation of the reconstruction programme in which residential houses and some other infrastructure such as schools, health centres, water supply schemes, etc. were built for the earthquake victims. Literature review shows that the government had promised to rebuild 25,000 houses and to repair 17,000 house. In actual practice the government could provide only about 13,000 new houses and 3,000 repaired houses. The low coverage of the victims and their low acceptability of the reconstruction programme is already discussed in the foregoing paragraphs.

The inference to be drawn from the above discussion is that the government could not sufficiently fulfil its objective of providing shelter to all earthquake victims.

9.10.3 Community's role in the reconstruction programme: The literature review and evaluation of the reconstruction programme have shown that the earthquake-affected community had very limited role in its implementation. This community's involvement in the reconstruction programme was also reviewed by collecting relevant field data and then statistically analysing it. The process of this analysis and the inferences drawn are presented in the following paragraphs.

9.10.3.1 *Location*: The frequency analysis (Annex 7, Chart 13) shows that 100% respondents from the turnkey category agreed that the location of their houses was entirely decided by the government for which they consulted their sheikhs in a few cases. In the self-help category all 40 respondents agreed that the location of their houses was jointly decided by the government and the beneficiaries, mainly because the latter had to contribute the land for house building although sometimes they were represented by their sheikhs. In the traditional category all 40 respondents replied that the government was not involved in the location of their houses, and they themselves decided about it.

The Kuruskal-Wallis test (Table 9.19) conducted to examine the people's views about the variable 'location', gave a significance level of 0.0000 which showed the difference between the three samples. This difference is probably due to the different ways the site selection is done in each case.

Table 9.19: Analysis of variance of location of house for the three categories of house owners

Variable (Similarity by group)	Significance Alpha = 0.05	Inference
Location	0.0000	The three samples of population significantly differ in their opinions about the procedure for location of the site for their houses

The inference is that in the turnkey houses, which form the bulk of the reconstruction programme, there was absolutely no community involvement. In the self-help category the beneficiaries were involved because they had to contribute the land for their houses. This type of involvement cannot be considered as community management. The location of traditional houses was fully managed by the community and the government had absolutely no role them.

9.10.3.2 *Design:* The frequency analysis (Annex 7, Chart 39) shows that 100% respondents from the turnkey and the self-help categories agreed that the designs of their houses were decided by the government and they were absolutely not consulted about it. In the traditional category all 40 respondents replied that the government was absolutely not involved the design of their houses, and that these designs were entirely managed by the individual houses owners.

The Kuruskal-Wallis test (Table 9.20) conducted to examine the people's views on the variable 'design', gave a significance level of 0.0000 which showed the difference between the three samples. This difference is probably due to the different ways of the management of design in each case.

Table 9.20: Analysis of variance of design of house for the three categories of house owners

Variable (Similarity by group)	Significance Alpha = 0.05	Inference
Design	0.0000	The three samples of population significantly differ in their opinions about the procedure for design of their houses

The inference is that both in the turnkey and self-help houses, there was absolutely no community involvement. The location of traditional houses was fully managed by the community and the government had absolutely no role in them.

9.10.3.3 *Construction*: The frequency analysis (Annex 7, Chart 40) shows that 100% respondents from the turnkey category agreed that the construction of their houses entirely carried by the government through contractors in which they were not involved. In the self-help category 100% respondents agreed that they had participated in the construction of their houses. The literature review shows us that this involvement consisted of providing unskilled labour and local materials by the house owner. The supervision was however completely carried out by the government which suggests a relatively weaker role for the house owner in this category. In the Traditional category all 40 respondents replied that the construction of their houses was fully managed by them.

The Kuruskal-Wallis test (Table 9.21) conducted to examine the people's views on the variable 'construction', gave a significance level of 0.0000 which shows the difference between the three samples. This difference is probably due to the different ways in of the management of construction in each case.

Table 9.21: Analysis of variance of construction of house for the three categories of house owners

Variable (Similarity by group)	Significance Alpha = 0.05	Inference
Design	0.0000	The three samples of population significantly differ in their opinions about the procedure for design of their houses

The inference to be drawn in this case that is the community had either no role or a weak role in the construction of the government implemented reconstruction programme. On the other hand the traditional house construction was fully managed by the community.

9.10.4 <u>Summary of inferences</u>: The overall inference drawn at the conclusion of this section can be summarised follows:

a) as discussed before in Section 9.7, the earthquake-affected community showed its management skills in its initial responses after the earthquake by providing itself with its temporary shelter, food and first-aid needs;

b) the communities post-disaster response was not only immediate but it also provided coverage to the entire earthquake victims;

c) the government's emergency help, fully managed by the government was late and could not reach the victims immediately when they needed it most;

d) the government managed emergency help did not cover all victims;

e) All decision taking in most of the reconstruction programme, including infrastructure other than housing, such as schools, mosques, health centre, water supply and roads, was done by the government.

f) There was no community participation in the turnkey programme, which was the major activity of the reconstruction programme. Community participation in the self-help houses was followed under a very didactic approach in which the beneficiaries were just told what they were supposed to do.

g) All phases of implementation of the traditional houses, such as site selection, design and construction was fully managed by the community.

9.11 Objective 5: to propose recommendations to serve as guidelines for the development and implementation of future reconstruction programmes for Yemen in particular and other countries facing similar problems in general

This chapter was devoted to statistically analysing the field data and presenting the inferences in an objective manner. Chapter 10 discusses the results based on the evaluation of the reconstruction programme carried out in Chapter 8 and the inferences drawn from the analysis in this chapter. The last Chapter 11, presents the conclusions and recommendations in an objective way, for Yemen in particular, and other countries facing similar problems in particular.

Summary

The government's emergency help immediately after the earthquake did not reach the victims on time and it did not cover all victims. The earthquake-affected community acted immediately to provide for the needs of the victims and covered all victims. The government implemented reconstruction programme was *neither efficient nor effective*; The reconstruction programme also failed to create earthquake hazard awareness among the victims. The earthquake victims had no involvement in the management of the government's emergency help, and very little involvement in most of the reconstruction programme. It can therefore be concluded that there was *no community management* in the government's emergency help or the reconstruction programme. The reconstruction programme suffered from several constraints within the organisation which could probably have been avoided if the government was less involved in management of the programme. The community fully managed the implementation of the traditional houses and it was fully satisfied with these houses.

Chapter Ten

Chapter Ten

RESULTS AND DISCUSSION

"Who should draw the picture? The community should - not in the sense of actually drawing or reproducing it. There are photographic and reproduction methods available today, which are inexpensive and efficient - but in the sense of deciding the picture motif or theme". *(Andreas Fuglasang, 1982)*

The 1982 earthquake in Yemen and the following immediate and long term measures to rehabilitate the surviving communities after the disaster presented an interesting case for detailed study. The nature and objectives of the study called for comprehensive field surveys in the disaster affected areas. Evaluation of the data collected from field surveys, and the bulk of discussion about the earthquake-victims and the following reconstruction programme is given in Chapter 8. Statistical analysis to test the hypothesis and the subsequent inferences are presented in Chapter 9. This chapter will summarise the findings of the previous two chapters and make an objective attempt to present the outcome. The conclusions drawn from the outcome will be discussed in the next chapter which will lead to the recommendations.

10.1 The earthquake-victims

The social evaluation and statistical analysis results show that the three categories of house-owners i.e. those living in the turnkey, self-help and traditional type of houses were not much different from each other in socio-economic and socio-cultural terms. The majority of them were poor people, with little education and major dependence on rain-fed agriculture earnings which is not very promising because of erratic rains. Their concepts of acceptability of the housing systems were also alike. They attached great importance to the location, design and sizes of their homes. They were equally keen about different components of a house such as the location and size of the kitchen, the location and size of the latrine, the availability of a store, a barn, a stable, a separate entrance for women, and a boundary wall to give some privacy to the inhabitants. Climatic comfort, appearance and affordability were the other major factors of their acceptability.

10.2 Housing in the study area

The turnkey housing programme, fully funded by the government and distributed free of cost, came under strong criticism from the beneficiaries. These houses were not fully utilised and the beneficiaries still prefer to live in their traditional houses. Many of the beneficiaries were using the turnkey houses for other purposes than personal living such stable, barn, guest house, or for renting them out to tenants who are mostly outsiders. Others carried out major changes to suit their needs. The remaining few who did not carry out any changes, were mostly those poor people who could not afford any changes. Many turnkey house owners considered their houses as unaffordable and claimed that they would have made better and bigger houses if they were built by them.

The self-help house owners, who contributed 30% to 50% of the total cost, were relatively more satisfied. Most of these houses were occupied by their original beneficiaries although quite a few of them had to make some additions and alterations to suit their individual needs. The self-help house owners were however more vocal about affordability because of the following reasons:

a) they had to contribute an appreciable amount of money for their houses while the turnkey programme, being implemented simultaneously, was handing out the houses free of cost;

b) they had to pay their contribution at a time when they were going through an economic crisis after the disaster; and

c) they were paying a relatively higher price for a house in which they had little say in the design and size.

The third category i.e. the traditional house owners were found to be the most satisfied people. They found their houses suitable and acceptable in almost every respect. These houses were also affordable to them because of their extremely low cost. Estimated costs of different types of houses under study are already presented in chapter 9. One common aspect observed among all categories of the respondents, and should be a matter of great concern to the government, was the people's lack of awareness about the safety of their houses against earthquakes.

Those living in the government-built turnkey and self-help house, were not too confident about the earthquake-resistances of their new homes. The majority of them simply said that only the next earthquake would tell whether their homes are safe. This attitude, at least for some respondents, could also be a corollary because of their overall disapproval of the reconstruction programme. In the traditional housing category only a few people were concerned about the safety of their homes, despite the fact that many of them saw several similar buildings raised to the ground or seriously damaged in the last earthquake. Most of them said that only Allah knew when the next earthquake will come and whether their homes will survive it.

It can therefore be concluded from these discussions, and the previous chapters 8 and 9, that the entire earthquake-victims had clear and similar perceptions about their shelter needs. Most of them were however not aware, and not concerned, that an earthquake is a geological event rather than simply an *act of God* against which preparedness is necessary.

Considering the people's preferences for acceptability of their housing and affordability, on the basis of field observations where the researcher spent three years, some designs of different earthquake-resistance, costs and sizes were prepared. The purpose of this exercise was to examine what an earthquake-resistant house will cost if it were to be built in the light of the people's considerations for acceptability. The following sections discuss these designs in some detail.

10.3 Some earthquake-resistant designs based on considerations of acceptability and affordability of the people living in the study area

Table 10.1 presents three different type of houses of sizes 56.33 m^2, 81.12 m^2 and 145.60 m^2 keeping in view the above considerations. These houses were designed in the light of discussions held with the survivors of 1982 earthquake during field surveys, and by considering the use of different materials available in Yemen, and different strengthening methods in practice in the country to resist earthquakes of different magnitudes and intensities. These designs were based on traditional Yemeni designs. All these houses were initially single-storeyed houses on which further storeys could be added according to individual needs and resources. The heights of these buildings should however not be increased beyond the low-rise limits (not more than three storeys).

Table 10.1: Some proposed earthquake-resistant designs for Yemen

Type of House	Foundations	Columns	Plinth beam	Lintel beam	Outer walls	Inner walls	Roofs
A	Black basalt stone wall	Without	Without	Only above openings	Solid cement concrete blocks	Solid cement concrete blocks	All wood
B	As above	As above	Reinforced concrete	Continuous	As above	As above	As above
C	As above	As above	Without	Only above openings	Dressed stone	Semi-dressed stone	As above
D	As above	As above	Reinforced concrete	Continuous	As above	As above	Reinforced concrete
E	Reinforced concrete	Reinforced concrete	As above	As above	Solid cement concrete blocks	Solid cement concrete blocks	Reinforced concrete
F	As above	As above	As above	As above	Dressed stone	As above	As above

Source: Field Surveys, 1994.

The cost estimates of these houses, prepared on the basis of market rates prevailing in December 1994 are given in Table 10.1. Three different sizes of houses, made of different type of material have different costs.

The small house of size 56.33 m^2 consists of one bedroom, one *divan* or male visitors' room, one large kitchen, a toilet and a temporary shed for the domestic animals.

The medium-sized house with a covered area of 81.12 m^2 has two bedrooms, one divan, a large kitchen, á toilet, a stable for livestock and a courtyard for privacy of the women.

The large house meant for an extended family system, a common practice in Yemen, with a covered area of 145.60 m^2 comprises three bedrooms, one divan, one living room, two toilets, one store, one large stable and two courtyards.

Table 10.2: Cost estimates of proposed earthquake-resistant houses in Yemen

Covered area (sq m)	A-type house (US$)	B-type house (US$)	C-type house (US$)	D-type house (US$)	E-type house (US$)	F-type house (US$)
56.33	4,675	5,238	6,083	6,816	10,590	11,548
81.12	6,732	7,544	8,761	9,816	15,250	16,630
145.60	12,085	13,541	15,725	17,618	27,372	29,848

Source: Field Surveys, 1994.

10.3.1 A-type house: The least expensive of these houses has a covered area of 56.33 m^2 (Figure 10.1). This house comprises one bedroom with a divan, kitchen, toilet and temporary shed for use as a stable. The foundation walls are made of black basalt, a commonly used material in Yemen, covered with 10 cm thick plain cement concrete at plinth level. There are no ring beams or columns in this type of house. The lintels are provided only above the door and the window openings. All inside and outside construction is in solid block masonry, the size of blocks being 40x20x20 cm^3. The roof is made of plywood resting on wooden rafters. The wooden roof is covered with 20 cm thick layer of clay. Polythene sheeting is placed in the middle of the soil, 10 cm from the top, to seal off water leakage and provide roof drainage. The estimated cost of this small house is about US$ 4,675 according to 1994 rates. The size of this house can be increased by adding another bedroom and a boundary wall.

The cost of a medium sized house of covered area 81.12 m^2, made of the same materials and by using the same construction method is estimated at US$ 6,732 (Figure 10.2). This house also has the provision to be further extended whenever required.

The cost of a large house of this category having a covered area of 145.60 m^2 is about US 12,085 (Figure 10.3). This house can also be increased in size by adding another storey and a boundary wall and another stable for domestic animals.

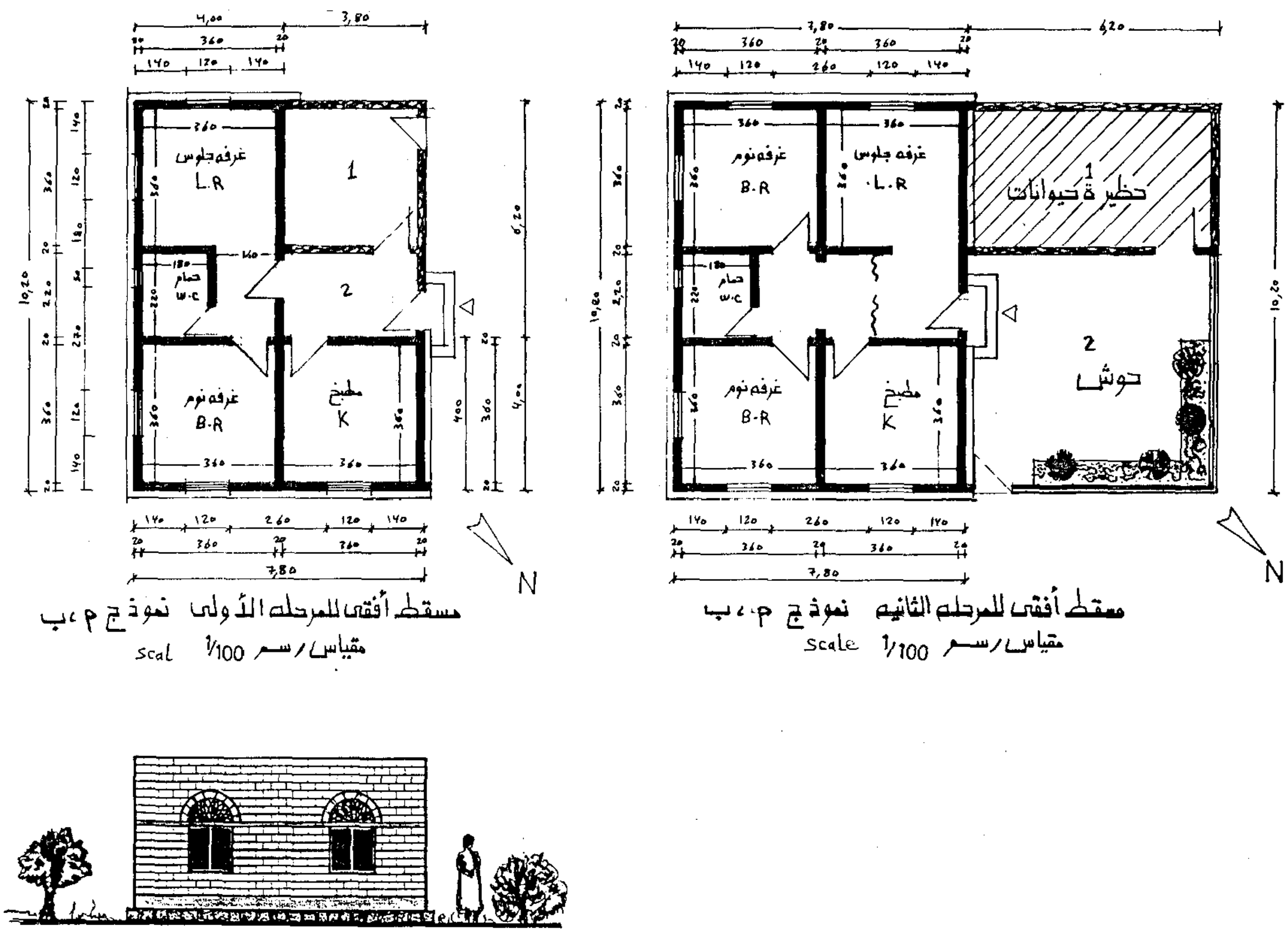


Figure 10.1: Proposed design of a small earthquake-resistant house for Yemen
Source: Field Surveys, 1994

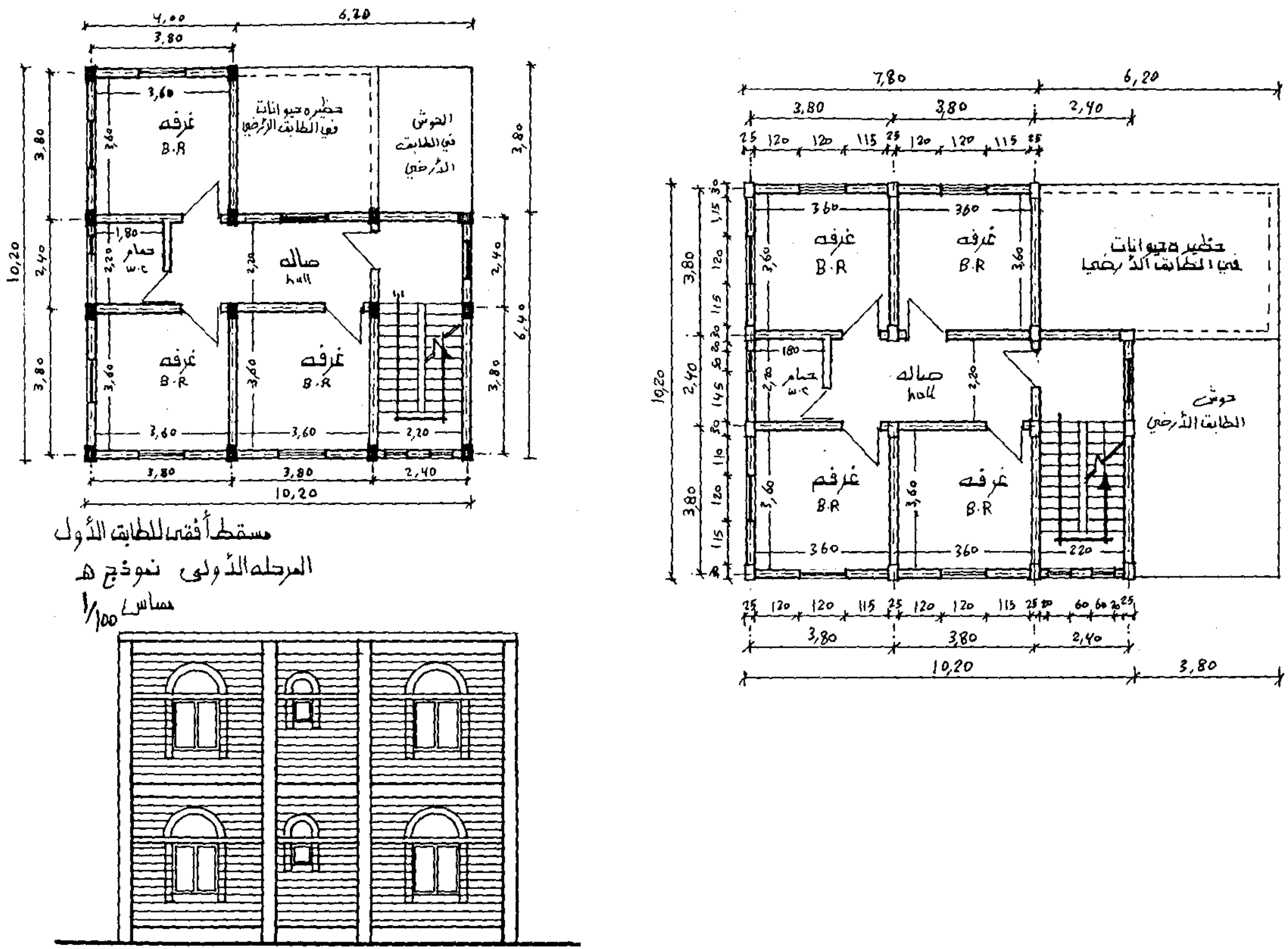
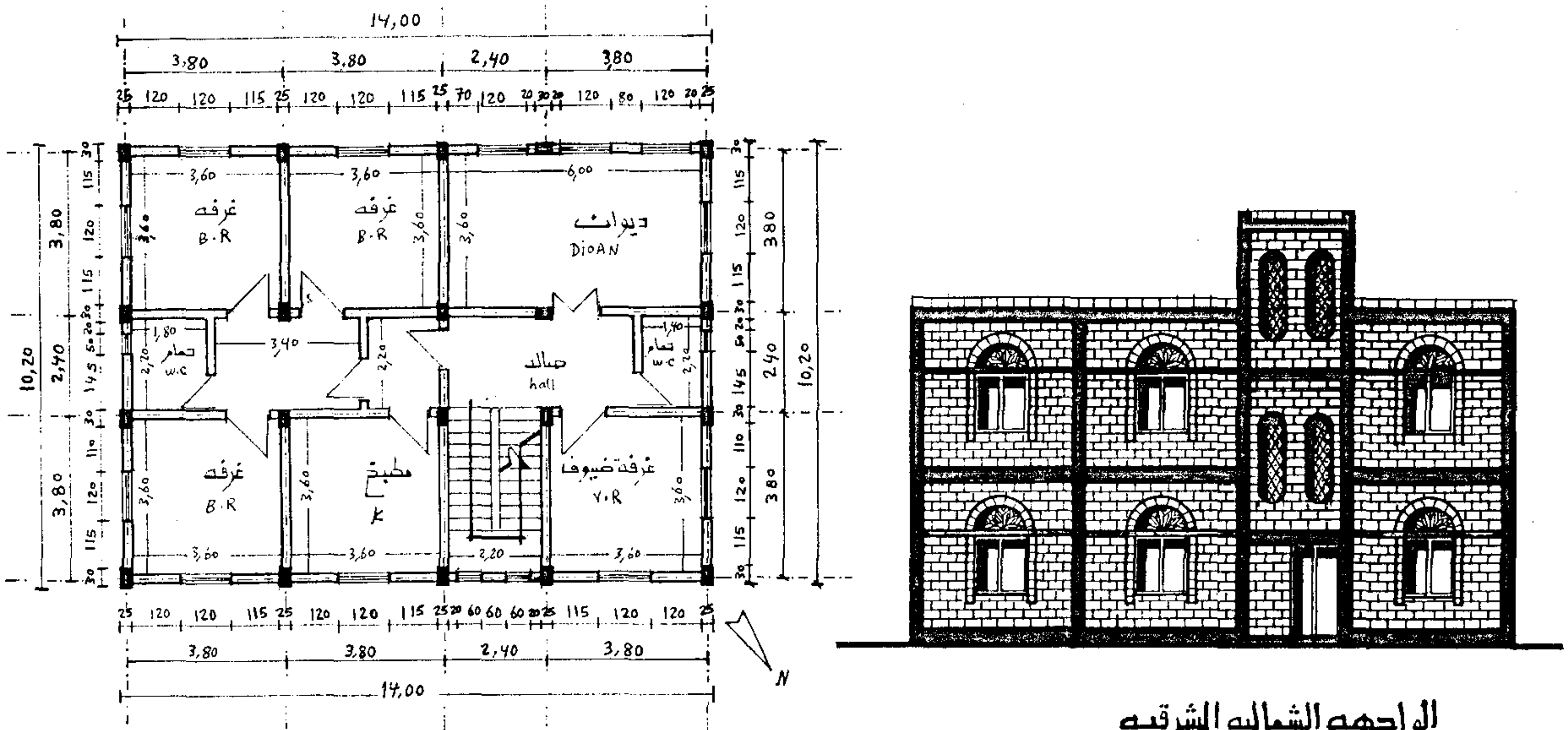


Figure 10.2: Proposed design of a medium earthquake-resistant house for Yemen
Source: Field Surveys, 1994



مسقط أفقي للطابق الثاني (مقياس رسم) 1/100

التوسع الراسي للمرحله الثالثه

النموذج (هـ)

الواجهه الشماليه الشرقيه

مقياس رسم 1/100

Figure 10.3: Proposed design of a large earthquake-resistant house for Yemen
Source: Field Surveys, 1994

10.3.2 B-type house: This house also has black basalt stone masonry foundation. There is a reinforced concrete continuous beam at the plinth level and another at the lintel level. There are no concrete columns. Both inside and outside walls are made of solid cement concrete blocks of size 40x20x20 cm^3. The roof is the same as for A-Type house.

The costs of small, medium and large houses in this category are estimated to be US$ 5,238, 7,544 and 13,541 respectively.

10.3.3 C-type house: The foundation wall is made of black basalt stone masonry. There are no columns or plinth beam. Reinforced concrete lintels are provided only above the doors and the windows. All outside walls are made of dressed stone and inside walls are made of semi-dressed stone. The roof is the same as for A-Type and B-Type houses.

Estimated costs of small, medium and large houses are US$ 6,083, 8,761 and 15,725 respectively.

10.3.4 D-type house: The foundation wall is made of black basalt stone masonry. There are no columns. Reinforced concrete continuous beams are provided at plinth and lintel levels. All outside walls are made of dressed stone and inside walls are made of semi-dressed stone. The roof is made of reinforced concrete placed on reinforced concrete beams.

The cost of small, medium and large houses are US$ 6,816, 9,816 and 17,618 respectively.

10.3.5 E-type house: The foundation is made of reinforced concrete in this type of house. Reinforced concrete continuous beams are provided at plinth and lintel levels together with reinforced columns for vertical support. All outside walls are made of solid block while the inside walls are made of hollow blocks, each of size 40x20x20 cm^3. The roof consists of reinforced concrete slab placed on reinforced concrete beams.

The small house in this case will cost US$ 10,590, the medium size US$ 15,250 and the large size 27,372.

10.3.6 F-type house: The foundation, the continuous beams at plinth and lintel levels and the columns all are made of reinforced concrete. All outside walls are made of dressed stones while the inside walls are composed of hollow blocks. The roof slab and beams are made of reinforced concrete.

The small, medium and large houses of this category are estimated to cost about US$ 11,548, 16,630 and 29,848.

Figure 10.4 presents the estimated costs of these houses with respect their earthquake-resistance based on literature survey.

Table 10.3: Comparison of government built houses with traditional houses and experimental designs

Housing Category	Type	Main building materials	Expected damage in an earthquake		Approximate unit costs US$/sqm	Estimated cost of a house US$		
			Moderate	Severe		Small 56.33 sqm	Medium 81.12 sqm	Large 145.60 sqm
Government	Turnkey	Blocks, cement, aggregate, reinforcing steel	0	1	250	14,082	20,280	36,400
	Self-help	Blocks, cement aggregate, reinforcing steel, wood	1	2	209	11,765	16,942	30,409
Private	Old, mostly in rural areas	Stone, clay, tree branches	4	5	120 (economic) 24 (financial)	6,760 1,352	9,734 1,947	17,472 3,494
	New, mostly in suburban areas	Stone, cement, aggregate, reinforcing steel, clay	3	4	150	9,576	13,790	24,752
Proposed	A	Blocks, cement, wood, stone	2	3	83	4,675	6,732	12,085
	B	Stone, cement, wood	2	3	93	5,238	7,544	13,541
	C	Blocks, cement, wood, reinforced steel, aggregate, stone	1	2	108	6,083	8,761	15,725
	D	Stone, cement, wood, reinforced steel, aggregate,	1	2	121	6,816	9,816	17,618
	E	Blocks, cement, reinforced steel, aggregate, stone	0	1	188	10,590	15,250	27,372
	F	Stone, cement, aggregate, reinforced steel	0	1	205	11,548	16,630	29,848

Notes: 0: undamaged; 1: slight; 2: moderate; 3: heavy; 4: partial destruction; 5: total collapse. Economic cost: cost based on market rates. Financial cost: the cost actually borne by the owner.

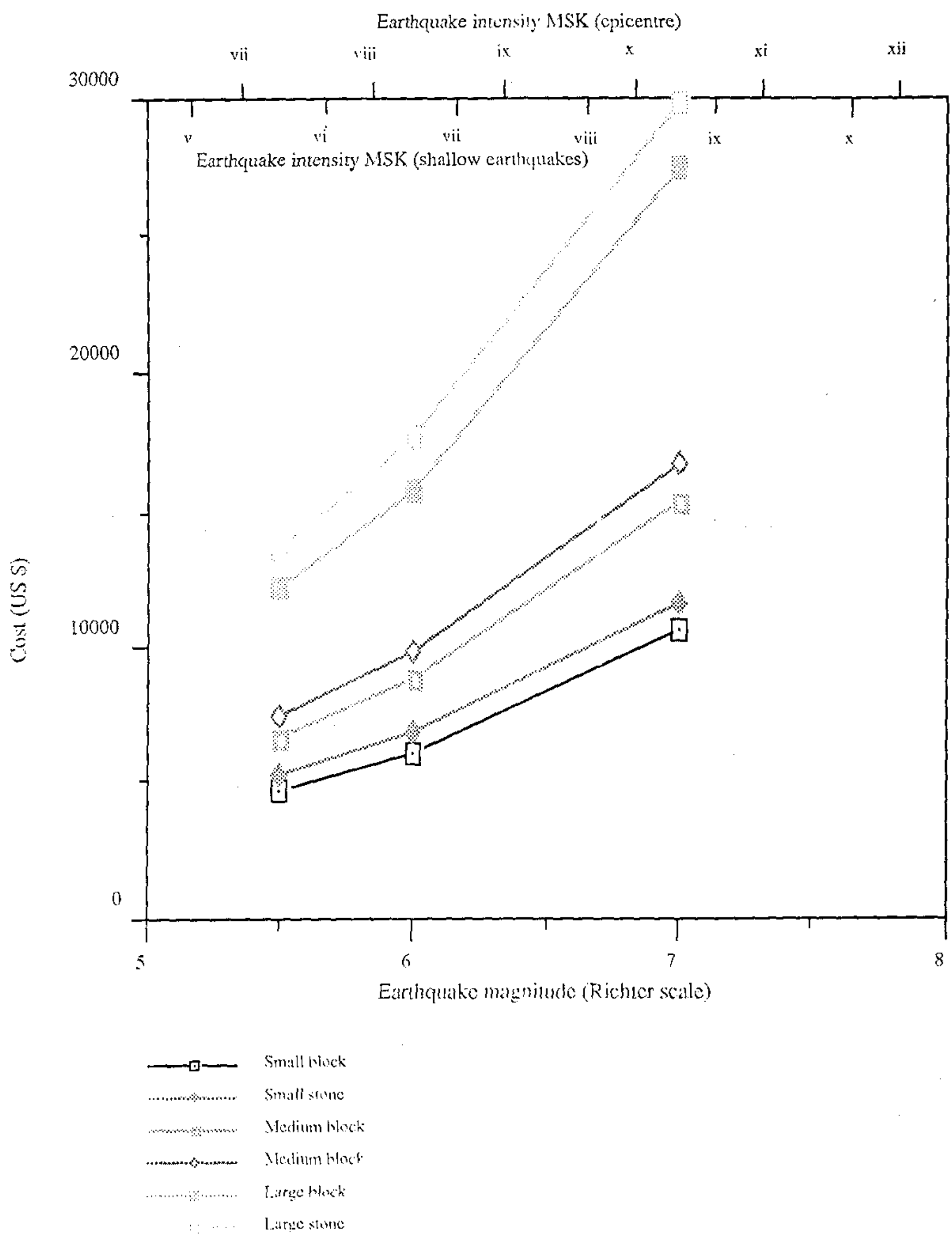


Figure 10.4: Earthquake-resistance of structures vs cost

Table 10.3 presents a comparison of houses built during the reconstruction programme (turnkey and self-help) with the private traditional houses and the experimental designs prepared by the researcher. The assessment of earthquake-resistance of these houses is based on literature review of the information available from several sources such as Spence and Coburn (1987), Arya (1991) and Coburn and Spence (1992).

According to the figures available from EOR records, the turnkey houses on the average cost US$ 250 per m^2 while the Self-help houses cost about US$ 209 per m^2 based on the prevalent market prices in 1994. The market price of a traditional house, built of much cheaper and locally available materials, comes out to be about US$ 120 per m^2. This cost is drastically curtailed in actual practice because of the local and almost free availability the required construction materials. The labour cost is also practically insignificant because the rural people build their houses by themselves. The only real money is spent on transporting the material to the building site and in buying doors, windows, Yemeni arches (qamariyyahs) and fixtures and fittings for the kitchen and latrine. Discussions with the traditional house owners and local engineers revealed that the actual or financial cost of these houses for the owners was not more than 20% of the economic cost. This is one of the major factors for the Yemeni people to prefer the traditional houses. Further discussion on the traditional houses and their vulnerability to earthquakes is given in Section 10.4.3.

The above comparison induces us to look at our hypothesis in the light of evaluation and analysis of the field data.

The hypothesis has earlier been stated as:
'Efficient and effective reconstruction in an earthquake zone cannot be undertaken without community management'.

For the convenience of interpretation, the definitions of some of the key words used in the hypothesis, and relevant to the following Table 10.4, can be summarised in the following terms:

Efficient: The infrastructure:

i) built with the least cost;

ii) in minimal time; and

iii) affordable to the users.

Effective: The infrastructure should be:

i) risk minimising (earthquake-resistant);

ii) fully utilised;

iii) acceptable to the users; and

iv) providing full coverage.

Community management: The affected community's close involvement in decision taking and participation in every stage of the reconstruction work such as planning, siting, designing and construction.

The following Table 10.4 is based on the information given in Table 10.3. It attempts to examine the government built housing, during the reconstruction programme, with the traditional housing.

Table 10.4: Comparison of government housing with traditional housing in Yemen with respect to hypothesis

Housing category	Type	Effective			Efficient			Community management			
		Cost	Timely delivery	Afford-ability	Earth-quake Resis-tance	Fully utilised	Accep-table	Plan-ning	Design	Location (siting)	Construc-tion
Government	Turnkey	High	No	No	High	No (major modifica-tion)	No	No	No	No	No
	Aided self-help	Moderate	No	No	Moderate	Yes (with modifica-tion)	Not fully	No	No	Partly	Partly
Private	Traditional	Low	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes

10.4.1 <u>Turnkey houses</u>: The above Table 10.4 shows that although the government built turnkey houses were probably resistant against some severe earthquakes, but they could understandably not leave any positive impact on the their beneficiaries in particular, and the other people in particular. This is because of their high cost (which made them unaffordable), belated delivery, and lack of acceptability for cultural and several other reasons discussed in detail in the previous chapters. One of the reasons for high cost of these houses was the use of mostly imported material as shown in Table 10.3. A very didactic approach was applied while building these houses and the users were not involved at any stage of implementation of these this housing programme. No wonder that these houses remained unoccupied for a long time after completion and the beneficiaries started using them only after major modifications.

10.4.2 Self-help houses: The aided self-help houses were probably strong enough to survive moderate earthquakes. These houses were also delivered much later than the scheduled delivery time. Though relatively cheaper when compared with the Turnkey houses, the beneficiaries still found their cost prohibitive for private building. This housing category was also considerably dependent on the use of imported materials but to a lesser degree than the Turnkey houses. The users were involved in the implementation of these house to some extent. These houses were relatively more acceptable to their beneficiaries and they were almost fully utilised on completion and handing over, although most of the users had to carry out some additions and alterations to suit their individual needs.

10.4.3 Traditional houses: The traditional houses were found to be vulnerable to even moderate earthquakes which made them a serious hazard for their occupants. The people living in the earthquake-affected areas in Yemen have already suffered bitterly because of such construction. Another similar experience may cause even more serious damage because a number of the existing traditional houses must already have been shaken by the last earthquake. Even a light tremor can be fatal for the residents for these houses which has a probability of once in 25 years. These houses truly represent the Yemeni culture, traditions and needs. The owners take all decisions in their location, design and building. Such houses are usually built in different stages according to the immediate needs and availability of funds with the individuals. The economic cost of such houses (the cost based on prevalent market rates) is not very low. However, since most of the rural Yemenis are familiar with simple construction techniques required in a traditional house, and all materials are locally available at almost no cost, their financial cost (the cost actually paid by the owner) is affordable even for a poor person. The main materials used in these houses are stone, clay and wood.

Most of the rural Yemen has mountainous topography which makes availability of building stones easier. Clay is also easily available almost everywhere at no cost. Timber could be a costly item if purchased from market. However in the absence of any laws against cutting trees, the people go out and cut any tree not owned by an individual. Some trees are also grown on farmlands for shade and for use in house construction. The trunks and larger branches are used as beams while the smaller branches are used as rafters or purlins. The people carry out house construction, or the construction of a mosque or a Qur'anic school at such a time, when they are they not very busy in their agricultural farms. The most suitable times are usually the rainy season, when crops have been cultivated and the time for harvesting is still a long way off. The extended family system is very helpful in such activities when all male and female members of the family, including children, join in with the construction work.

The traditional houses are very popular among their owners. They are very comfortable in the local temperate climate where there is a vast difference between the day and night temperatures. These houses have abundant space not only for the family needs but also for the domestic animals, storage of farm produce and fodder for the livestock, etc. Most of these people however do not have a clear concept about the vulnerability of their houses. The real need therefore seems to be an awareness and appreciation of the seriousness of the earthquake hazard for their lives and property. This awareness is needed as a preparedness measure not only for the welfare of the people living in the earthquake zone, but also for the government of Yemen, in order to minimise the chances of yet another inevitable disaster after the 1982 earthquake and the two other disasters of a different kind, the 1990 Gulf War and the 1994 civil war.

As a consequence of the above discussion, and the evaluation and analysis contained in the foregoing Chapters 8 and 9, the review of the post 1982-earthquake government implemented reconstruction programme can be concluded and summarised in the following words that:

i) it was not efficient;

ii) it was not effective; and

iii) the affected community was not given an opportunity to manage the programme despite the fact that it had well demonstrated its initiative and management skills in the form of initial responses immediately after the earthquake.

These conclusions lead us to delve into the concept of the value of safety and how individuals perceive it. The discussion on this topic is briefly presented in Section 10.5.

10.5 The value of life and safety

According to Jones-Lee (1989) the words *safety* and *risk* are so widely used and in so many different ways that it becomes necessary to define them.

Safety is frequently related to human life. In this study however this word is intended to cover not only the safety of human life but also the property and economic resources of individuals and countries. *Risk* is a variable against safety. The greater the risk, the less the safety in terms of human life or property or both. Most people consider life exceedingly precious. Still quite often we see that everyone accepts small risks to his own life and to the life of his dear ones in return for some benefits such as saving of money or effort or some other gains (Bergstrom, 1982). Not only individuals but even societies continually make decisions demonstrating that the people are willing to make exchanges for safety and their other needs (Blomquist, 1982).

Economics plays a vital part in a discussion about life and safety. An improved safety standards can be achieved only at a cost which requires the curtailment of certain other needs. The more a society or an individual spends on safety the less will be available for other needs such education, health and recreation, etc. Considering all these factors, most people prefer lower rather than higher levels of exposure to the risk of death or injury (Jones-Lee, 1989). It follows that the individual or social choice of an optimal level of safety in any context has a significant economic dimension.

Even the most humane and affluent societies cannot afford to pay for apparently beneficial improvement in standards if they are too expensive in comparison to the benefits to be drawn out of them. The necessity of such decisions suggests that even in the matters of life and death their must be a logic of choice sometimes described as pricing the priceless (*Bergstrom, 1982*). The economic considerations require a decision concerning the appropriate *trade-off* or *balance* between various needs and the scarce resources. The underlying principle is how much an individual is willing to pay to have better safety standards against a risk such as the earthquake hazard. The fundamental input to cost benefit analysis, is in all cases in an individuals *willingness to pay.*

Bergstrom (1982) and Lee-Jones (1989) define *willingness to pay* as an individual's decision closely related to his marginal rates of substitution of wealth for physical risk. The most commonly employed principle of allocative decision-making is the *cost-benefit analysis* in which an individual's life is valued in terms of *human capital* defined as the expected present value of his future earnings (Jones-Lee, 1976). However when we are dealing with human lives, it is very important to consider their common perceptions. These perceptions can be collective when infrastructure other than housing such water supply systems, sanitation, hospitals, roads and schools are under consideration. But for housing individual perceptions and their preferences are of great significance as seen from the data evaluation and analysis presented in the last two chapters.

The inferences drawn in the last chapter clearly indicate that the people living in the earthquake-affected area place significant importance to the cultural and physical aspects of the their houses but they are not very clear about the persisting earthquake hazard in their area and most of them are not too concerned. The need is therefore to let them acknowledge the risk they unknowingly face in their everyday life but tend to be ignorant about it.

Experts on the subject of value of life, such as Jones-Lee (1989), are of the opinion that individuals usually like to spend a small amount to achieve improved standards of safety. This is perhaps because of the reason that the money they spend is something physical which they can feel, whereas any assurance of improved safety is only imaginary. It therefore takes an effort to convince the people to spend more for better safety. These efforts can be really arduous when dealing with a conservative and primitive society, such as the rural Yemenis. This issue however does not seem to be as difficult as one would expect it to be for the following reasons:

a) the Yemeni people are generally familiar with simple building construction techniques. This has earlier been acknowledged by Davis (1978) in a generalised way by saying that the rural people are usually skilled in fundamental building skills;

b) the building materials of their choice are also locally available at almost no cost; and

c) as the literature review has revealed, they have been making earthquake-resistant buildings in the past. They turned to decorating their houses and ignored safety only in the later years, when they did not experience an earthquake disaster for a very long time. The way a humane government can help these people is by information dissemination through media, education, workshops and technical assistance programme with emphasis on the following two points:

    i) creating awareness about the earthquake hazard and the vulnerability of their houses; and

    ii) introducing simple techniques of improving the earthquake-resistance of their homes at no cost or very little cost.

The real job for the government seems to be to motivate these people to use the simple and almost no-cost earthquake-resistant building techniques which are not alien to them and some of which have been used by their forefathers. According to Bergstrom (1982), such a motivation requires a humane government and its willingness to use its resources funds on creating awareness and motivation in the community to improve their safety conditions.

Final conclusions and recommendations are presented in the next and final chapter.

<u>*Summary*</u>

It is not possible to mitigate the risk of disaster in a hazard-prone area, without the local community's active participation. This involves the individual's perception of the hazard risk and how much they are willing to trade off against the relative safety. In Yemen the problem of the people's willingness to pay seems to be less serious because of their ancient traditions of making earthquake-resistant houses. They only gave up the safer techniques when disastrous earthquakes did not occur for a long time. The need is therefore to revive these people's earlier awareness and the re-use of safer techniques.

Chapter Eleven

Chapter Eleven

CONCLUSIONS AND RECOMMENDATIONS

"If genuine change is desired, it will occur only through the social mechanisms for change which the community has established and to which it is accustomed".

(Andreas Fuglasang, 1982)

The literature review, field survey and observations, evaluation and analysis, and results and discussions, contained in Chapters 2 through 10 lead us to draw certain conclusions about the post-earthquake reconstruction programme in Yemen. These conclusions will be used to make some recommendations. The conclusions are given in the following paragraphs. The recommendations will be presented towards the end of this chapter.

11.1 Conclusions

The following conclusions can be drawn from the earlier discussions:

11.1.1 Earthquakes and secondary hazards

a) Earthquakes are one of the most serious natural hazards.

b) Earthquakes trigger off a series of secondary hazards such as landslides, rockfalls, liquefaction, subsidence, industrial fires and dam failures which add to the severity of this hazard.

11.1.2 Causes of earthquakes

a) The causes of earthquakes are not simply *acts of God.*

b) Subsurface geological events are mainly responsible for earthquakes.

c) Some artificial causes can also sometimes be responsible for earthquakes but such earthquakes are usually insignificant and localised.

11.1.3 Earthquake prediction

a) Earthquakes are unpredictable in most cases.

b) Scientists' efforts in predicting earthquakes have not met much success to date.

c) Even if it were possible to predict earthquakes accurately in terms of magnitude, intensity, location and time, only life losses could be saved but not the economic losses which can be staggering in some cases. This reason makes it essential to concentrate on protection from earthquakes rather than their prediction.

11.1.4 Causes of earthquake disasters

a) Earthquakes are natural events which cannot be averted.

b) There is no change in the world geology. It is the man-made structures which are responsible for earthquake losses. This rising earthquake losses (Figure 11.1) and other natural disasters have prompted the United Nations to declare the period 1991-2000 as the decade for disaster reduction.

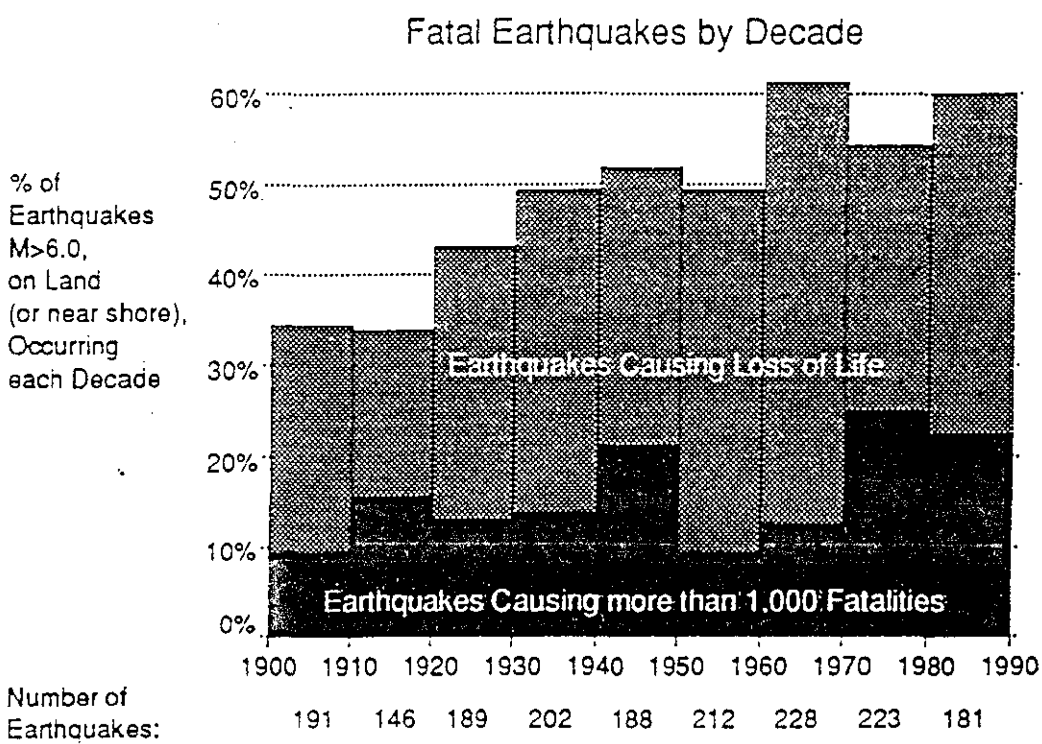


Figure 11.1: The world's earthquake problem is increasing mainly because of man-made structures
Source: Coburn and Spence, 1992

11.1.5 Earthquakes disasters and low-income countries

a) Most of the life losses due to earthquakes occur in low-income and lower middle-income countries.

b) The causes of life and property losses in such countries are usually the peoples' lack of awareness about the earthquake hazard, lack of concern about vulnerability of their homes, and continued use of unsafe building practices.

c) The main causes attributable to the governments of such countries include their lack of concern for creating awareness about the hazard in their people living in earthquake zones, and the lack of application of any building controls;

11.1.6 Earthquake-resistant designs

a) It is not possible to make earthquake-proof structural designs because great earthquakes of magnitude 8 and above cause total collapse of infrastructure. This leads to the need for earthquake-resistant designs.

b) The standards of earthquake-resistance of structures vary from one geographic region to another depending upon the probability and intensity of severe earthquake in each region. Safety standards of structures also vary according to the type of buildings such as *occupancy*, *important* and *hazard.*

11.1.7 Infrastructure of greater concern

a) The *important* and *hazard* buildings are much fewer in number than the *occupancy* buildings and are usually public owned. Such buildings are almost always state controlled and application of the required safety codes can be more strictly applied.

a) The main source of concern are the privately owned *occupancy* buildings, particularly those located in the low-income and lower middle-income countries, in which cultural and climatic needs usually take priority over safety considerations.

11.1.8 Impact of the reconstruction programme in Yemen

The post-earthquake reconstruction programme failed to create any positive impact on the earthquake-victims because of the following reasons:

a) It was not *efficient* in the sense that:

- it was not cost effective (Figure 11.2);
- it was not completed in minimal time; and
- it was not affordable.

b) Although it was risk minimising but it was not *effective* in the sense that:

- buildings were not fully utilised;
- it was not acceptable to the users; and
- it did not provide coverage to all earthquake victims.

c) It was not *managed* by the community in the sense that:

- the community had no part in decision taking in the location of Turnkey programme, which included houses and some other infrastructure, forming the bulk of the reconstruction programme (about 80%);
- the community had absolutely no say in the design of housing (both Turnkey and Self-help) or any other infrastructure; and
- the community had no say in the construction of the Turnkey programme.

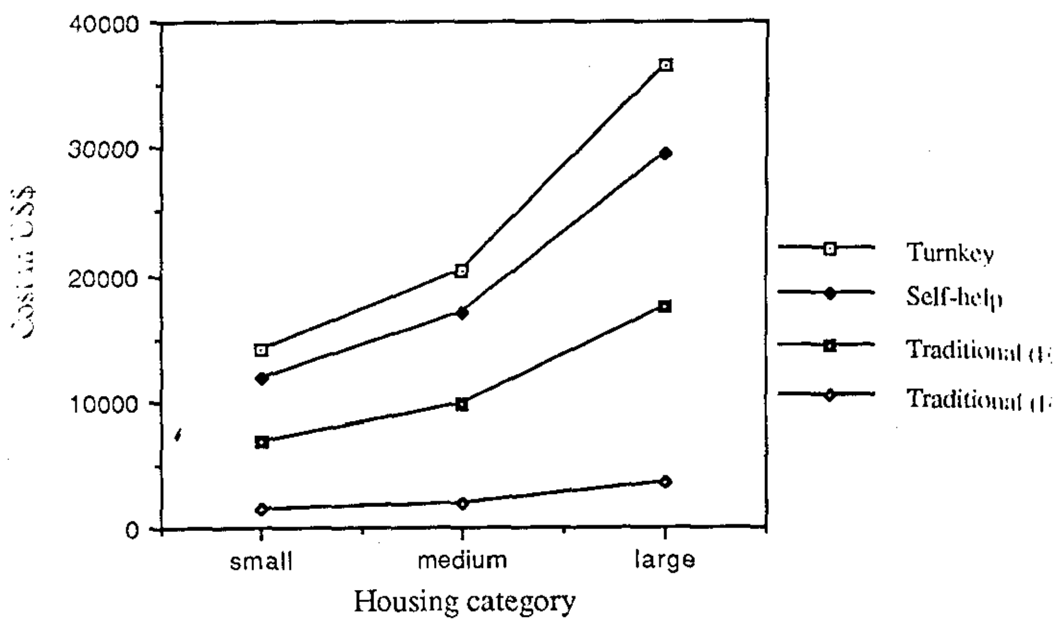


Figure 11.2: Cost comparison of government-built houses with traditional houses

The impact of the reconstruction programme in Yemen is not different from similar programmes in some other low-income and lower middle-income countries. Literature review shows that most of these programmes have generally failed to achieve their main objectives of:

a) informing the affected communities about the risk of earthquakes which could be repeated in their respective areas anytime based on the seismicity of the area;

b) convincing the majority of the earthquake victims of the importance of using earthquake-resistant techniques in building their houses and other infrastructure which would minimise life and property losses; and

c) convincing the concerned governments in not only creating hazard awareness among the people but also in the application of certain building controls to minimise losses in future earthquakes.

11.2 Suggested measures

Most experts agree on the following general measures which the governments of earthquake-prone countries can take to minimise the risk of earthquake disasters (Coburn and Spence, 1992):

11.2.1 Earthquake prediction: There is no need for wasting resources, particularly in the case of poorer countries, on earthquake prediction.

11.2.2 Safety culture: Creation of a safety culture through legislation and by encouraging individual groups, private organisations and other social and cultural groups to help in informing the people about the consequences of earthquakes, and about the availability of some simple techniques for improving the strength of buildings against earthquakes.

National disaster preparedness plans can be made to reduce future earthquake losses by taking several measures such as identifying the role of engineers, architects, geologists, economists and other experts for the integrated safety plans.

11.2.3 Construction controls: Minimum standards for building design and construction can be specified through legislation to ensure a safe environment. Codes of practice for buildings should regulate all buildings to be based on seismic design. These codes should be under constant review for further improvement. The application of building codes in design and construction should be carefully monitored and there should be penalties for not following these codes. Engineers, architects, building owners and others involved in building design and construction should be aware of the consequences of not applying seismic design codes. The concerned authorities should be capable of checking building designs and other safety measures during construction and should be able to regulate and enforce the specified building codes. Life spans of buildings should also be specified during which inspection at regular intervals to assess the condition of building should be carried out. If the building under inspection is found to be deteriorating in maintenance standards which may affect its safety against an earthquake, mandatory repair measures should be suggested which should be monitored by the concerned municipal authorities.

11.2.4 Management of existing building stock: The existing buildings can be surveyed by engineers to categorise them according to their degree of vulnerability to earthquakes. The categorisation should be on the basis of improvement measures required to make these building safe. Those buildings which cannot be strengthened economically should be recommended for demolition. The landlords can be made responsible to improve the existing building stock through legislation and encouraged through the provision of soft loans. Poorer people can be given grants to improve the safety of their buildings. Insurance of buildings is another measure which can be applied to achieve a safer building environment.

11.2.5 Education and training: Earthquake-prone countries can introduce the study of earthquakes and their consequences at different levels of education. Earthquake engineering and earthquake-resistant designs can be made part of the university syllabi. Vocational training and refresher courses for engineers in practice is also useful to improve their knowledge of earthquake issues and solutions.

11.2.6 Community awareness: Community awareness of earthquake risks and the need for protection measures against possible losses is essential to get public support for all government activities in this regard. This can be achieved through community information campaigns, exposure of earthquake issues on mass media, speeches on earthquakes and protection measures at different other forums including educational institutions.

11.2.7 Engineering research: Continued engineering research to increase knowledge about earthquakes and to improve the methods to protect against earthquakes losses should be a continuous process. Seismological records can be improved by establishing seismological observatories which record information about even minor earthquakes.

11.2.8 Financial allocations: The unpredictable nature of earthquakes requires that earthquake-prone countries should keep special budgets to provide for relief and emergency needs in the case of a disaster. Earthquake risk analyses indicate the probable amount of earthquake damage to be expected in the next 10, 25, 50 or 100 years. This data can be used to keep provisions for earthquake losses and protection measures.

11.2.9 Isoseismal maps and microzoning: Preparation of isoseismal maps and microzoning is discussed in Chapter 8. These information recording techniques can be well utilised in development planning for buildings and other infrastructure.

The measures for engineers are discussed in detail in Chapter 6.

11.3 Recommendations

Figure 11.3 shows the measures prescribed by UNDRO (1979) for reducing the catastrophic effects of earthquake. Arya (1991), Coburn and Spence (1992) and Arya (1994) have described such measures in more detail which governments and engineers can take in mitigating the hazard. Some of these measures are discussed above while the rest have earlier been discussed in the literature review.

All these measures seem to be of immense importance. Yet none of them seems always to succeed, as has been seen in the case of Yemen and learnt during literature review, if the people living in earthquake zones are not aware or concerned about the hazard.

In view of earlier discussions and above it follows that the main task for the government of Yemen lies in creating an awareness about the lingering hazard among the people living in the earthquake zone. This awareness should be linked with their feeling of concern about the vulnerability of their homes which can be lethal in the next earthquake and which can come any time. This awareness will in effect be only a revival process because they have used the earthquake-resistant techniques in the past.

Several measures can be used to achieve these goals. Some of these measures are described below:

11.3.1 Preparedness measures

a) The researcher observed during his field surveys that the Yemeni people are very fond of watching television programmes. They are even more engrossed in TV programmes during their qat chewing sessions in the afternoons. The TV

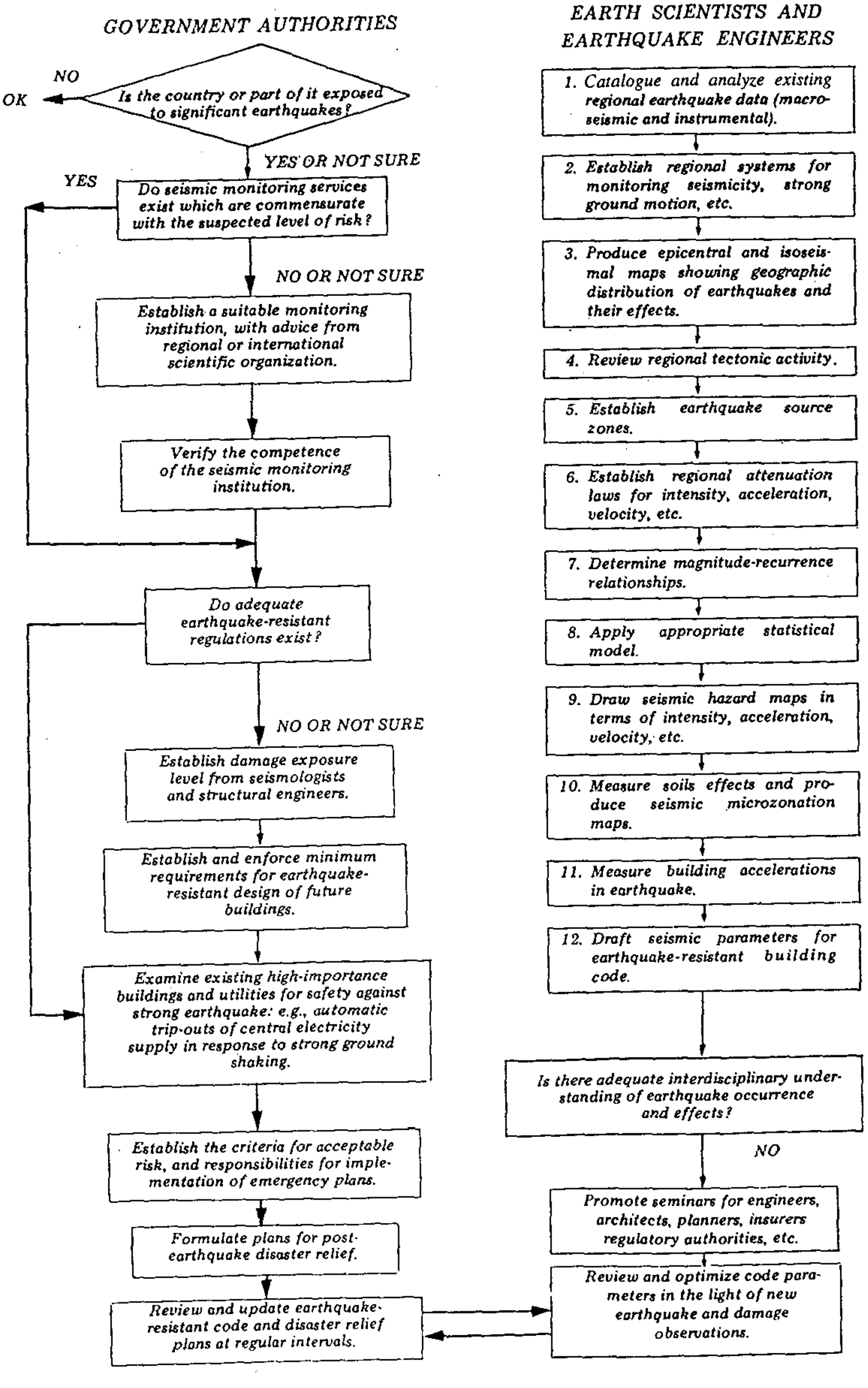


Figure 11.3: UNDRO's proposed planning for the mitigation of earthquake disasters

programmes in Yemen are mostly based on political activities in and around the country or some entertainment programmes. This hobby or habit can be very usefully exploited by showing some documentary films or plays which inform the people about the earthquake hazard in their area and the fragility of their traditional homes.

b) Many Yemenis are now realising the importance of education and more children are going to schools than in the past. The subject of earthquakes, with particular reference to Yemen, can be introduced in the school curriculum to create the awareness from an early age.

c) Traditional earthquake-resistant building techniques used by the Yemenis in the past can be revived by holding village level workshops.

d) Training programmes can be organised for the local masons for using earthquake-resistant techniques in the traditional construction by using local materials and local tools.

11.3.2 Post-disaster measures

In the case of a future disaster the affected community should be allowed a much stronger role in the reconstruction works. The poor people can be helped with building loans to be repaid in easy instalments. Grants can be given to extremely needy people in special cases, provided the facility is not misused.

Community involvement is mistaken by many as merely informing the concerned community that a certain programme will be implemented by the government in their area. In such cases the people's role is no more than therapeutic. The previous discussion shows us that a similar role was given to the beneficiaries of the so-called self-help house in the last reconstruction programme. This type of weak role is not very productive to achieve positive results, as seen in this study.

The following strengths of the earthquake-affected community have already been discussed in the previous chapters:

a) management skills while providing for its temporary shelter needs immediately after the earthquake;

b) mutual cooperation shown in the last earthquake when the people, whose houses were badly damaged, were provided shelter by their friends or neighbours;

c) building skills in constructing traditional houses and other similar buildings;

d) the knowledge and use of locally available construction materials; and

e) the knowledge and skills of cost saving on procuring materials and labour house building.

These are all very vital strengths for the community to manage its house building programmes. The only weakness this community has is its lack of awareness and concern about the earthquake hazard in the area. This awareness can be revived, because it already existed in the past, by employing several low-cost measures some of which are discussed above.

It can be said with conviction that as a consequence of this awareness and empowerment in the future reconstruction programmes, this community is capable of making earthquake-resistant houses and other infrastructure which will provide:

a) a safe building environment to ensure safer life for them;

b) positive affects on the local economy because the reconstructed houses will have longer lives; and

c) better chances for survival and improvement of the country's economy as the scarce resources could be used for other public services such as health, education, etc.

d) an example for other low-income and lower middle-income countries, located in earthquake zones, and facing similar problems.

This thesis refers to the post-earthquake reconstruction in Yemen, a low-income country with mostly non-engineered traditional buildings. Societies and economic conditions vary from country to country. The findings and recommendations contained in this chapter are therefore valid for Yemen and other countries with similar structures and similar socio-economic conditions.

11.4 Further research

The interview of the government engineers surfaced several problems faced by them in the implementation of the reconstruction programme. These problems are discussed in detail in the literature review and the following chapters on evaluation and analysis. These difficulties include a wide range of problems such as:

a) centralisation in the government's decision making;

b) political interference in the works and house allotment procedures;

c) donor's preferences about projects, their location and the construction techniques;

d) lack of experience of the local contractors;

e) lack of the community's appreciation of the programme;

f) tribal rivalries among the earthquake affected community; and

g) harsh working conditions.

Further research in these areas, which could prove helpful in the Yemeni government's implementation of similar work in future and other countries facing similar problems, will be interesting.

Summary

Sometimes the solutions to our problems are relatively more simple than we presume. In reconstruction and development of earthquake-prone or earthquake-affected areas, the local people's awareness of the hazard is the primary factor to mitigate the risk of future disasters. The government's efforts in information dissemination concerning the hazard can be vital in creating awareness among people. The development and reconstruction in such areas can meet its objectives of having a safer environment through:

a) the local communities' awareness of the hazard; and

b) the local communities' empowerment (Meethan&Kevin, 1995) and management to build their own houses by using earthquake-resistant techniques.

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Annex 1

QUESTIONNAIRE FORMS

1982 Earthquake Disaster in Dhamar Governorate of Yemen and the Subsequent Reconstruction and Development Programme

QUESTIONNAIRE NUMBER 1-A: BENEFICIARIES OF TURN KEY HOUSES

Card number:__________ Date:__________

Location:____________ (village/town) District:_____________

Respondent:______________________ Age:______________years

Education Level:

0	1	2	3	4	5

(0: illiterate; 1: primary; 2: middle; 3: secondary; 4: above)

Occupation:________________ Average Annual Income YR___________

Number of Dependents_________ Surveyor_______________________

= =

1. **Was your home fully or partly damaged in the earthquake?**
   a: fully damaged;
   b: partly damaged.

2. **What did you do immediately after the disaster?**
   a: made temporary shelter yourself;
   b: repaired your old house;
   c: moved with friends or relatives;
   d: waited for government help;
   e: other (specify) ______________________.

3. **What material did you use in making your temporary shelter?**
   a: tents;
   b: blankets;
   c: zinc sheets;
   d: wood;
   e: material recovered from debris of the old house;
   f: other.

4. **If your answer to question 2 above is 'a' or 'b' what was the cost of providing temporary shelter?**
   YR __________________.

5. Did you use any skilled or unskilled labour in making your temporary shelter?
   a: yes;
   b: no.

6. Who provided the emergency help?
   a: self;
   b: government;
   c: other (specify)______________.

7. What kind of help was provided by the above source/s?

Type of help	Source*		
	1	2	3
a: building materials			
b: tents, blankets			
c: labour			
d: technical supervision			
e: cash			
f: other (specify)____________________________			

* 1: self; 2: government; 3: other (specify) ____________.

8. Who was mainly involved in various stages of the housing reconstruction programme?

Reconstruction features	Government	Community	Yourself
a: site selection			
b: design			
c: construction			
d: other			

9. **If you were not involved at any stage of the housing reconstruction programme, what was the reason?**
   a: no one invited you;
   b: your sheikh represented you;
   c: you are not an influential person and no one would have cared about your views;
   d: Any other reason (describe)____________________________.

10. **Are you satisfied with the government provided house?**
   a: yes;
   b: to some extent;
   c: no.

11. **If 'yes' what are the main reasons?**
   a: it is free of cost including land;
   b: it was delivered in short time;
   c: it is an earthquake resistant structure;
   d: it meets family needs;
   e: it is culturally acceptable;
   f: any other factor (describe) ____________________________.

12. **If 'no' then what problems did you find in your new house?**

Features of acceptability	Acceptable	Unacceptable
a: room sizes		
b: number of rooms		
c: location of rooms		
d: general appearance		
e: size of latrine		
f: location of latrine		
g: size of kitchen		
h: location of kitchen		
i: boundary wall		
j: other problems		

13. **If the answer is 'unacceptable' then why?**
   - a: rooms too are small;
   - b: number of rooms are too few;
   - c: location of kitchen is inside the house;
   - d: location of latrine is inside the house;
   - e: non existence of a store;
   - f: non existence of a barn;
   - g: non existence of a stable for domestic animals;
   - h: no separate entrance for women;
   - i: general appearance is different from traditional houses;
   - j: it is insufficient for family needs;
   - k: it is not suitable for local climate;
   - l: it is away from work place;
   - m: it is away from the family village;
   - n: any other reason (explain) ____________________________
     ____.

14. **Did you use the house as it was delivered?**
   - a: yes;
   - b: no.

15. **If 'yes', why?**
   - a: the government did not allow any changes;
   - b: you did not have any money to make any changes;
   - c: you reconciled with the new designs although different from traditional designs;
   - d: any other reason ___________________________________.

16. **If 'no', what changes did you carry out to make the new house more acceptable for your needs?**
   - a: changed the sizes of rooms;
   - b: increased the number of rooms;
   - c: built a kitchen outside the house;
   - d: built a latrine outside the house;
   - e: built a store;
   - f: built a barn;
   - g: built a stable for domestic animals;
   - h: built a separate entrance for women;
   - i: made changes to give traditional touch to the general appearance of the house;
   - j: made changes to meet family needs;
   - k: made changes to improve suitable for local climate;
   - l: built a boundary wall around the house;

m: any other changes ______________________________
____.

17. **Was any other infrastructure also built in your village?**
    a: yes;
    b: no.

18. **If 'yes', what was this other infrastructure?**
    a: school;
    b: road;
    c: clinic;
    d: water supply scheme;
    e: sanitation scheme;
    f: electric supply scheme;
    g: mosque;
    h: other (specify) ________________.

19. **Were you involved in planning, design and/or construction of other infrastructure?**
    a: yes;
    b: no.

20. **If 'no', what were the reasons?**
    a: no one invited you to give your views;
    b: your sheikh represented you;
    c: your are not an influential person and nobody would have listened to your views;
    d: any other reason (describe)__________________________
    ____.

21. **Are you satisfied with the sheikh's representation?**
    a: yes;
    b: no;
    c: not always.

22. To summarise your overall impression of the reconstruction programme please give your comments on the following aspects:

Reasons	1*	2	3
a: timely delivery			
b: climatic suitability			
c: design			
d: location			
e: size			
f: safety against earthquakes & other hazards			
g: suitability of houses for family needs			
h: socio-cultural acceptability			
i: physical appearance			
j: quality of work (strong building/finishing)			
k: social equity			
l: affordability			
m: meets other traditional needs			
n: social costs			

* 1: acceptable; 2: minimally acceptable; 3: not acceptable.

1982 Earthquake Disaster in Dhamar Governorate of Yemen and the Subsequent Reconstruction and Development Programme

QUESTIONNAIRE NUMBER 1-B: BENEFICIARIES OF SELF HELP HOUSES

Card number:__________ Date:__________

Location:__________ (village/town) District:__________

Respondent:__________ Age:__________years

Education Level:	0	1	2	3	4	5

(0: illiterate; 1: primary; 2: middle; 3: secondary; 4: above)

Occupation:__________ Average Annual Income YR__________

Number of Dependents__________ Surveyor__________

==================================

1. **Was your home fully or partly damaged in the earthquake?**
   a: fully damaged;
   b: partly damaged.

2. **What did you do immediately after the disaster?**
   a: made temporary shelter yourself;
   b: repaired your old house;
   c: moved with friends or relatives;
   d: waited for government help;
   e: *other (specify)* __________.

3. **What material did you use in making your temporary shelter?**
   a: tents;
   b: blankets;
   c: zinc sheets;
   d: wood;
   e: material recovered from debris of the old house;
   f: other.

4. **If your answer to question 2 above is 'a' or 'b' what was the cost of providing temporary shelter?**
   YR __________.

5. **Did you use any skilled or unskilled labour in making your temporary shelter?**
a: yes;
b: no.

6. **Who provided the emergency help?**
a: self;
b: government;
c: other

7. **What kind of help was provided by the above source/s?**

Type of help	Source*		
	1	2	3
a: building materials			
b: tents, blankets			
c: labour			
d: technical supervision			
e: cash			
f: other (specify) ____________			

* 1: self; 2: government; 3: other (specify) __________.

8. **Who was mainly responsible for the house reconstruction programme?**

Reconstruction features	Government	Community	Yourself
a: site selection			
b: design			
c: construction			
d: other			

9. **Were you involved in the planning your house?**
a: yes;
b: no.

10. **Were you involved in designing your house?**
   - a: yes;
   - b: to some extent;
   - c: no.

11. **If the answer is 'a' or 'b', what was the nature of your involvement?**
   - a: decision on size of rooms;
   - b: decision on number of rooms;
   - c: decision on location of rooms;
   - d: decision on size, number and location of other facilities eg latrine, store, barn, stable, other (explain) ________________________________

     ____
   - e: given a limited choice of standard designs from which to choose one.

12. **If you were not involved in planning or designing your house, what was the reason?**
   - a: no one invited you;
   - b: your sheikh represented you;
   - c: you are not an influential person;
   - d: Any other reason (describe)__________________________

     ____.

13. **Who provided land for the house?**
   - a: yourself;
   - b: government;
   - c: your community;
   - d: sheikh.

14. **Did you participate in reconstruction of your house?**
   - a: yes;
   - b: no.

15. **If 'yes', what was the nature of your participation?**

Nature of Contribution	%age of Total Cost
a: local materials (sand, stone, etc)	
b: water for construction	
c: skilled labour	
d: unskilled labour	
e: cash	
f: food for labourers	
g: transport for materials/labourers	
h: other (specify) ______________	

16. ***Did you face any problems in making your contribution?***
    a: yes;
    b: no.

17. **If 'yes', what were these problems?**
    a: shortage of funds;
    b: non availability of materials in the vicinity;
    c: difficulties in finding labour;
    d: other (specify) ______________________.

18. **Are you satisfied with your self-help house?**
    a: yes;
    b: to some extent;
    c: no.

19 **If 'yes' what are the main reasons?**
    a: completed and delivered in short time;
    b: earthquake resistant structure;
    c: met family needs;
    d: culturally acceptable;
    e: any other factor (describe) ____________________.

20. **If 'no' or 'to some extent', what problems did you find in your new house?**

Features of acceptability	Acceptable	Unacceptable
a: room sizes		
b: number of rooms		
c: location of rooms		
d: general appearance		
e: size of latrine		
f: location of latrine		
g: size of kitchen		
h: location of kitchen		
i: boundary wall		
j: other problems		

21. **If the answer is 'unacceptable' then why?**
a: rooms are too small;
b: number of rooms are too few;
c: location of kitchen is inside the house;
d: location of latrine is inside the house;
e: non existence of a store;
f: non existence of a barn;
g: non existence of a stable for domestic animals;
h: no separate entrance for women;
i: general appearance is different from traditional houses;
j: insufficient for family needs;
k: not suitable for local climate;
l: away from work place;
m: away from family village;
n: any other reason (explain) ______________________
____.

22. **Did you use the house as it was delivered?**
a: yes;
b: no.

23. **If 'yes', why?**
    a: the government did not allow any changes;
    b: you did not have any money to make any changes;
    c: you reconciled with the new designs although different from traditional designs;
    d: any other reason ______________________________.

24. **If 'no', what changes did you carry out to make the new house more acceptable for your needs?**
    a: changed the sizes of rooms;
    b: increased the number of rooms;
    c: built a kitchen outside the house;
    d: built a latrine outside the house;
    e: built a store;
    f: built a barn;
    g: built a stable for domestic animals;
    h: built a separate entrance for women;
    i: made changes to give traditional touch to the general appearance of the house;
    j: made changes to meet family needs;
    k: made changes to improve suitable for local climate;
    l: built a boundary wall around the house;
    m: any other changes__________________________________
    ____.

25. **Was any other infrastructure built in your village?**
    a: yes;
    b: no.

26. **If 'yes', what did the other infrastructure comprise of?**
    a: school;
    b: road;
    c: clinic;
    d: water supply scheme;
    e: sanitation scheme;
    f: electric supply scheme;
    g: mosque;
    h: other (specify) _________________.

27. **Were you involved in planning, design and/or construction of other infrastructure?**
    a: yes;
    b: no.

28. **If 'no', what were the reasons?**
   - a: no one invited you to give your views;
   - b: your sheikh represented you;
   - c: your are not an influential person and nobody would have listened;
   - d: any other reason (describe)______________________________
   ____.

29. **Are you satisfied with the sheikh's representation?**
   - a: yes;
   - b: no;
   - c: not always.

30. **To summarise your overall impression of the reconstruction programme please give your comments on the following aspects:**

Reasons	1*	2	3
a: timely delivery			
b: climatic suitability			
c: design			
d: size			
e: safety against earthquakes & other hazards			
f: suitability of the house for family needs			
g: socio-cultural acceptability			
h: physical appearance			
i: quality of work (strong building/finishing)			
j: social equity			
k: affordability			
l: meets other traditional needs			
m: social costs			

* 1: acceptable; 2: minimally acceptable; 3: not acceptable

1982 Earthquake Disaster in Dhamar Governorate of Yemen and the Subsequent Reconstruction and Development Programme

<u>QUESTIONNAIRE NUMBER 1-C: BENEFICIARIES OF REPAIR PROGRAMME</u>

Card number:__________ Date:___________

Location:_____________ (village/town) District:______________

Respondent:________________________ Age:______________years

Education Level: | 0 | 1 | 2 | 3 | 4 | 5 |

(0: illiterate; 1: primary; 2: middle; 3: secondary; 4: above)

Occupation:_______________ Average Annual Income YR___________

Number of Dependents_________ Surveyor_______________________

= =

1. **Was your home or fully or partly damaged in earthquake?**
   a: fully damaged;
   b: partly damaged.

2. **What did you do immediately after the disaster?**
   a: made temporary shelter yourself;
   b: repaired your old house;
   c: moved with friends or relatives;
   d: waited for government help;
   e: other (specify) ______________________.

3. **What material did you use in making your temporary shelter?**
   a: tents;
   b: blankets;
   c: zinc sheets;
   d: wood;
   e: material recovered from debris of the old house;
   f: other.

4. **If your answer to question 2 above is *'a' or 'b' what was the cost of providing* temporary shelter?**
   YR __________________.

5. **Did you use any skilled or unskilled labour in making your temporary shelter?**
   a: yes;

b: no.

6. **Who provided the emergency help?**
   a: self;
   b: government;
   c: other

7. **What kind of help was provided by the above source/s?**

Type of help	Source*		
	1	2	3
a: building materials			
b: tents			
c: labour			
d: technical supervision			
e: cash			
f: other (specify)________________			

* 1: self; 2: government; 3: other (specify) ____________.

8. **Who decided for repair of your house?**
   a: Yourself;
   b: government;
   c: community;
   d: other (specify) ________________.

9. **Were you involved in designing the repair or rehabilitation of your house?**
   a: yes;
   b: to some extent;
   c: no.

10. **If 'yes' or 'to some extent', what was the nature of your involvement?**
   a: decision on strengthening the roofs;
   b: decision on strengthening the walls;
   c: decision on strengthening the foundations;
   d: decision on any other alteration or repair (explain)
   ____.

11. **If you were not involved in planning and designing the repair of your house, what was the reason?**
a: no one asked you;
b: your sheikh represented you;
c: you are not an influential person and no one would have listened to your views;
d: *Any other reason (describe)*________________________________
____.

12. **Did you contribute in repair/rehabilitation of your existing house?**
a: yes;
b: no.

13. **If 'yes' then what was the nature of your contribution?**

Nature of Contribution	%age of Total Cost
a: local materials (sand, stone, etc)	
b: water for repair work	
c: skilled labour	
d: unskilled labour	
e: cash	
f: food for labourers	
g: transport for materials/labourers	
h: other (specify) ____________	

14. **Did you face any problems in making your contribution?**
a: yes
b: no.

15. **If 'yes', what were these problems?**
a: shortage of funds;
b: non availability of materials;
c: difficulties in finding labour;
d: other (specify)____.

16. **Are you satisfied with the repair works?**
    a: yes;
    b: to some extent;
    c: no.

17. **If 'no' or 'to some extent', what problems did you find in your repaired house?**
    a: repair work spoiled the appearance of the house;
    b: repair works took a long time and caused inconvenience;
    c: repair was not carried out as planned;
    d: repair was not undertaken according to the actual needs;
    e: repair work was of sub-standard quality (below specifications);
    c: any other problem specify.

18 **Did you use the repaired house as it was delivered?**
    a: yes;
    b: no.

19. **If 'yes', why?**
    a: the government did not allow any changes;
    b: you did not have any money to make any changes;
    c: you reconciled with the repair work, to avoid further expenses, although it was not satisfactory;
    d: you accepted the repaired house to avoid any further waste of time because you did not have any other shelter;
    e: any other reason ______________________.

20. **If the answer is 'no', what changes did you carry out to make the repair work more acceptable for your needs?**

    a: completed the remaining repair work left incomplete in the repair/reconstruction programme;
    b: improved the finishing work to cover defects in cement plaster work, tile work, etc;
    b: repainted the house to conceal patch work done by govt;
    d: any other changes ______________________
    ______________________.

21. **Was any other infrastructure built in your village besides housing?**
    a: yes;
    b: no.

22. **If 'yes', what did the other infrastructure comprise of?**
    a: school;

b: road;
c: clinic;
d: water supply scheme;
e: sanitation scheme;
f: electric supply scheme;
g: mosque;
h: other (specify) ________________.

23. **Were you involved in planning, design and/or construction of other infrastructure?**
a: yes;
b: no.

24. **If 'no', what were the reasons?**
a: no one asked for your views;
b: your sheikh represented you;
c: your are not an influential person and nobody would have listened to your views;
d: any other reason (describe)__________________________.

25. **Are you satisfied with the sheikh's representation?**
a: yes;
b: no;
c: not always.

26. **To summarise your overall impression of the reconstruction programme please give your final comments on the following:**

Reasons	1*	2	3
a: timely delivery			
b: design			
c: safety against earthquakes & other hazards			
d: physical appearance			
e: quality of work (strong building/finishing)			
f: affordability			
g: social costs			

* 1: acceptable; 2: minimally acceptable; 3: not acceptable

1982 Earthquake Disaster in Dhamar Governorate of Yemen and the Subsequent Reconstruction and Development Programme

QUESTIONNAIRE NUMBER 1-D: NON-RECIPIENTS OF ASSISTANCE

Card number:__________ Date:__________

Location:____________ (village/town) District:____________

Respondent:______________________ Age:____________years

Education Level:

0	1	2	3	4	5

(0: illiterate; 1: primary; 2: middle; 3: secondary; 4: above)

Occupation:__________________ Age Ann Income YR__________

Number of Dependents_________ Surveyor____________________

= =

1. **Was your home fully or partly damaged in the earthquake?**
   a: fully damaged;
   b: partly damaged.

2. **What did you do immediately after the disaster?**
   a: made temporary shelter yourself;
   b: repaired your old house;
   c: moved with friends or relatives;
   d: waited for government help;
   e: other (specify) ____________________.

3. **What material did you use in making your temporary shelter?**
   a: tents;
   b: blankets;
   c: zinc sheets;
   d: wood;
   e: material recovered from debris of the old house;
   f: other.

4. **If your answer to question 2 above is 'a' or 'b' what was the cost of providing temporary shelter?**
   YR ________________.

5. **Did you use any skilled or unskilled labour in making your temporary shelter?**
   a: yes;
   b: no.

6. **Who provided the emergency help?**
   a: self;
   b: government;
   c: other

7. **What kind of help was provided by the above source/s?**

Type of help	Source*		
	1	2	3
a: building materials			
b: tents			
c: labour			
d: technical supervision			
e: cash			
f: other (specify)__________________			

1: self; 2: government; 3: other (specify) ____________.
If the answer is 'd' (for non recipients of any assistance) then:

8. **Why did you not receive a new house or get at least the old house repaired?**
   a: new house or repair facilities not offered by the government;
   b: not influential enough to push your case through normal channels;
   c: could not afford the social costs;
   d: unable to give contribution for self help scheme;
   e: any other reason (specify): ____________________.

9. **What did you do when you did not receive government assistance in any form?**
   a: accepted it as a matter of luck or Allah's will;
   b: directly protested to the concerned government agency;
   c: complained to the village sheikh;
   d: took any other action (specify)____________________
   ______________________________________.

10. **What did you do to provide yourself with a shelter?**
   a: continued to live in the damaged house;
   b: repaired the old house through your own means;
   c: built a new house;
   d: other means (specify)_________________________

11. **If the answer is 'b' or 'c' above, did you follow the new design techniques introduced in the reconstruction programme?**
   a: yes;
   b: to some extent;
   c: no.

12. **If 'yes', why?**
   a: *to ensure safety against earthquakes;*
   b: to ensure economy because the new designs are cost effective;
   c: to ensure climatic suitability because the new designs have given due consideration to this necessity;
   d: to have traditional appearance which is an important aspect of the new designs;
   e: to have sufficient accommodation to meet family needs which is a salient feature of the new designs;
   f: to benefit from other socio-cultural considerations made in the new designs;
   g: to have modern and more attractive design than the existing old and obsolete designs;
   h: any other reason ________________________________
   ____.

13. **If no, why?**
   a: earthquakes come under Allah's will and no one can stop them. What is the use of earthquake resistant designs when the destruction occurs anyway;
   b: the earthquake resistant designs introduced in the reconstruction programme are uneconomical and non-affordable for a common man in Yemen?
   c: the new designs are not suitable climatically whereas the traditional houses comfortable in all climates;
   d: the new designs are completely different from the traditional designs;
   e: the new designs provide very small accommodation not sufficient to meet a Yemeni family needs;
   f: the new designs have little consideration of Yemeni socio-cultural needs and cannot be used without major changes;
   g: the new designs are hardly attractive as compared to the traditional designs in Yemen;
   h: any other reason ________________________________
   ____.

14. **If your answer is 'to some extent', why?**
   a: to ensure safety against earthquakes;
   b: to ensure economy because the new designs are cost effective;

c: to ensure climatic suitability because the new designs have given due consideration to this necessity;

d: to have modern and more attractive design than the existing old and obsolete designs;

e: any other reason ______________________________
______________________________________.

15. **Was any other infrastructure built in your village besides housing?**

a: yes;
b: no.

16. **If 'yes' what did the other infrastructure comprise of it?**

a: school;
b: road;
c: clinic;
d: water supply scheme;
e: sanitation scheme;
f: electric supply scheme;
g: mosque;
h: other (specify) _______________.

17. **Were you involved in planning, design and/or construction of other infrastructure?**

a: yes;
b: no.

18. **If the answer is 'no', what were the reasons?**

a: no one invited you to give your views;
b: your sheikh represented you;
c: your are not an influential person and nobody would have listened;
d: any other reason (describe)_________________________
______________________________________.

19. **Are you satisfied with the sheikh's representation?**

a: yes;
b: no;
c: not always.

20. **What is your overall impression of the reconstruction programme as a whole?**

a: successful;
b: moderately successful; or
c: unsuccessful.

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QUESTIONNAIRE NUMBER 2: FOR SHEIKHS OF THE SURVIVING COMMUNITIES

Card number:__________ Date:___________

Location:_____________ (village/town) District:_____________

Respondent:__________________ Surveyor:__________________

Respondent's Education Level:

0	1	2	3	4	5

(0: illiterate; 1: primary; 2: middle; 3: secondary; 4: above)

==

1. Since when are you sheikh of this village?
   19___.

2. What was the approximate number of houses in the village at the time of the disaster?
   _____.

3. About how many houses were destroyed?
   _____.

4. What was the population of your village at that time?
   _____.

5. Was their any skilled labour available in the village?
   a: yes;
   b: no.

6. Did the government announce any immediate relief measure?
   a: yes;
   b: no.

7. If yes, what were these measures?
   a: supply of tents;
   b: supply corrugated iron sheet huts;
   c: supply of building materials;
   d: technical advice;
   e: financial assistance;
   f: other (specify)______________________________.

8. **How much time did the government take in providing immediate relief to your village?**
_____days.

9. **About what percentage of victims in your village occupied the temporary shelters provided by the government?**
________%.

10. **How did the survivors in your area respond to provide for their relief needs?**
a: by making temporary shelters on their own;
b: by doing minor repairs to their damaged houses;
c: by moving to the houses of their relatives or friends;
c: through local community cooperation;
d: any other (specify) ______________________________.

11. **Did you have any other infrastructure in your village, besides houses?**
a: yes;
b: no.

12. **If yes, what type of infrastructure was it?**
a: mosque;
b: school;
c: health centre;
d: water supply system;
f: electric supply system;
g: other (specify) ______________________________.

13. **Did any of this infrastructure suffer any losses?**
a: yes;
b: no.

14. **If yes, what was the extent of damage?**

Nature of loss	School	Water supply	Sanit-tion	Mosqu	Elec supp	Roads	Health infras	Other _____
repair-able								
total damage								

15. **Did the government announce a programme to reconstruct houses and build other infrastructure in your area?**

a: yes;
b: no.

16. **What was the government announced commitment for your area?**
a: houses ____________________no.
b: roads ____________________km.
c: clinics____________________no.
d: mosques____________________no.
e: water supply scheme__________no.
f: sanitation scheme __________no.
g: electric supply scheme_______no.

17. **Were you involved in assessing the infrastructure reconstruction needs of your area?**
a: yes;
b: no.

18. **Were you asked to give your opinion in determining location of the infrastructure to be reconstructed in your area?**
a: yes;
b: no.

19. **Were you consulted in the design of the infrastructure to be rebuilt?**
a: yes
b: no.

20. **If your answer to questions 17 to 19 is 'no', what do you think was the reason?**
a: the government did not consider necessary to consult anyone;
b: the reconstruction programme was carried out in a emergency and there was no time for consulting every sheikh or community about their views;
c: tribal rivalries would have created lot of difficulties and waste of time;
d: literacy level in the disaster area is low and most of the sheikhs would not have understood the technical details particularly with respect to earthquake resistance;
e: any other reason (describe)____________________________
____.

21. **Did the government meet its commitment?**
a: yes;
b: to some extent;
c: no.

22. **If 'yes' or 'to some extent', approximately how many houses and other infrastructure was built in your area?**

Houses	School	Water supply	Sanit-tion	Mosqu	Elec supp	Roads	Health infras	Other ____
____	____	____	____	____	____	____	____	____

23. **If 'no' give reasons to the best of your knowledge:**
    a: government could not mobilise enough resources;
    b: government assisted politically stronger areas more than others;
    c: concerned government agency helped those areas and individuals more who gave them favours;

    d: local tribal rivalries caused abandonment of the infrastructure building programme in your area;
    e: any other reason (specify)____________________.

24. **About what percentage of people in your area did not house under any of the schemes (turn key/self help/repair)?**
    __________ %.

25. **What did you do to assist the people in you village who did not receive houses or repair facilities?**
    a: raised concern with the government;
    b: raised funds at community level to repair the damaged houses;
    c: contacted NGOs for their assistance;
    d: could not do anything;
    e: other________________________________
    ____.

26. **If no, it was because:**
    a: *there is no use complaining to the government because it listen's to only* politically stronger areas;
    b: LCCD is only a tool of the government and does not much care about peoples problems;
    c: tribal rivalries have made the local communities weaker and there is little chance to get their support on such issues;
    d; any other reason (specify) ____________________
    ____.

27. **Did the government provide any further assistance after your protest?**
    a: yes;
    b: no.

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QUESTIONNAIRE NUMBER 3: FOR GOVERNMENT ENGINEERS AND OTHER OFFICIALS INVOLVED IN THE RECONSTRUCTION PROGRAMME

Card number:__________ Date:__________

Respondent:________________ Occupation____________________

Ministry:__________Present position_______ Surveyor___________

= =

Part A: Before the Earthquake

1. **What was your position/occupation in Supreme Council for Reconstruction of Earthquake Affected Areas (SCREAA) at the time of its creation ______________________________?**

2. **Do you know of the existence of any earthquake warning system in the country prior to the disaster?**
   a: yes, there was such a system;
   b: no, I don't such a system existed in the country.

3. **Are you aware if any foreign or local agency predict or warn against the earthquake?**
   a: yes, we did receive a prior warning through external agencies;
   b: no, I don't think any such warning was received.

4. **If 'yes', do you know if the government took any preparatory steps to minimise losses as a result of the warning?**
   a: yes, the government did take some preparatory measures;
   b: no, the government could not take any advance measures.

5. **Do you know if any individual or agency expressed concern about vulnerability *of infrastructure in the country, particularly in rural areas, prior to the* earthquake?**
   a: yes, local engineers had expressed their concerns at times;
   b: no, I don't think anybody expressed any concern.

6. **Are you aware if any safety measures were considered for resistance against earthquakes, in location of infrastructure?**
   a: yes, safety measures with regards to location of infrastructure were generally considered;
   b: no, I don't think much attention was paid in this regard.

7. **Are you aware if any safety measures were considered for resistance against earthquakes in design of infrastructure?**
   a: yes, safety measures were generally considered;
   b: no, I don't think any serious attention was paid.

8. **If 'yes', what were these measures?**
   a: reducing roof load;
   b: providing tie beams in walls;
   c: increasing bond between roofs and walls;
   d: strengthening of foundations;
   e: other ________________________________.

9. **Do you know if any safety code was introduced in the country's building by-laws to make earthquake resistant structures?**
   a: yes, there was such a code of practice;
   b: no, I don't think such a code was introduced.

Part B: Emergency Relief Work Immediately after the Earthquake

10. **What immediate relief measures were provided to the victims?**
   a: temporary shelters;
   b: water supply;
   c: sanitation;
   d: electric supply;
   e: clinics;
   f: schools;
   g: other__________.

11. **How much time these emergency measures take from the date of the disaster?**
   __________.

12. **Were the relief measure available to all victims?**
   a: yes;
   b: most of them;
   c: some of them;
   d: no.

13. **If 'no' or 'to some of them', what were the reasons?**
   a: lack of resources;
   b: lack of information of about the victims;
   c: lack of organisation within SCREAA;
   d: lack of desire on part of the victims to use alien relief materials;
   e: other constraints (specify) ________________________.

14. **What was the criteria for providing relief to the victims?**
   a: nature of damage to the existing house;

b: number of members in the household;
c: *social status of the household;*
d: first come first served;
e: *other (specify)* ______________________________.

15. **Do you think that the victims were satisfied with the government's emergency relief operations?**
    a: yes;
    b; no.

16. **If 'no' what to your knowledge were the main causes of victims' dissatisfaction?**
    a: inadequate shelter for minimal needs;
    b: culturally unacceptable shelter;
    c: *lack of essential services eg water supply, sanitation, electricity;*
    d: unsuitable location from victims' considerations;
    e: *lengthy and cumbersome official procedures;*
    f: unequal treatment of victims;
    g: other ______________________.

<u>Part C:</u> <u>Reconstruction Programme with Development Objectives</u>

<u>HOUSING PROGRAMME</u>

17. **Do you think the reconstruction programme implemented as initially planned by the government?**
    a: yes;
    b: no.

18. **If *no*, what was the main cause of the government not meeting its envisaged reconstruction programme?**
    a: lack of local resources;
    b: lack of committed support by donors;
    c: lack of planning and management;
    d: institutional deficiencies;
    e: lack of community support;
    f: other constraints ______________________________.

19. **Were the beneficiaries satisfied *with* the *houses* they *received under the* reconstruction programme?**
    a: yes;
    b: to great extent;
    c: to some extent;
    b: no.

20. **If the answer is 'a' or 'b', what were the main reasons of their satisfaction?**

a: finished houses were delivered in a reasonable time;

b: the houses were provided free of cost (turn key) project or with a small contribution (self help);

c: the new houses (in case of total damage) or repaired houses (in case of repairable damage) covered almost all victim households and there were no serious complaints;

d: the new house designs met the usual accommodation needs of the victims;

e: although the new houses had a different appearance from the traditional north Yemeni houses but cultural acceptability did not pose any problems;

f: the new houses are earthquake resistant with minimal danger to life and property should such a catastrophe occur in future;

g: the new houses were located in safe locations with little chances of earth failure, sliding or overturning;

h: repair to less damaged houses was carried out by strengthening the existing structures by adding reinforced beams and columns. This did not affect the former shape so acceptability was not a problem in this case as well;

i: any other positive factor (specify)__________________
____.

21. If the answer is 'c' or 'd' what were the main reasons for the beneficiaries' dissatisfaction?

Reasons	Turn Key	Self Help
a: delays in delivery due cumbersome procedures		
b: unsuitable location		
c: one design without family size consideration		
d: size of house too small for normal household		
e: rooms size too small		
f: number of rooms too few		
g: location of kitchen not suitable		
h: location of latrine not suitable		
i: only one entrance not suitable culturally		
j: unfamiliar design		
k: climatic unsuitability		
l: victims' contribution beyond their capacity		
m: social costs		
n: other (specify) ____________________		

22. Were the beneficiaries consulted about the location of new houses?
a: yes;
b: no.

23. Were the beneficiaries consulted about the design of new houses?
a: yes;
b: no.

24. Do you know if any code of safety, for resistance against earthquakes, was introduced in building designs after the 1982 disaster?
a; yes, a safety code was introduced;
b: no code was introduced but most engineers started following

international design codes;

c: no, I don't think such a code was introduced.

25. **If 'no' why?**

a: earthquakes do not occur in Yemen very often;

b: cost of construction in earthquake resistant designs sharply rises which the common people cannot afford;

c: literacy in Yemen is low and most people do not follow any building codes;

d: Yemeni people, particularly in rural areas, are conservative in every respect and do not accept any changes in their traditional building practices;

e: any other reason ____.

OTHER INFRASTRUCTURE

26. **Who identified the need of the infrastructure, other than housing, in the disaster affected area?**

a: government;

b: donor;

c; community;

d: other __________.

27. **Were the victims consulted about location, design or construction of this 'other infrastructure'?**

a: yes;

b: no.

28. **If 'no', why?**

a: the reconstruction programme was carried out in an emergency and there was no time to consult the beneficiaries;

b: most of the beneficiaries were illiterate and they could not understand technical details;

c: tribal system is strong in the project area. Mutual rivalries among beneficiaries would not have allowed any common decision;

d: the donors provided help under certain conditions which included design and site selection by them;

e: any other reason ____.

29. **What was the main criteria for determining the size of infrastructure?**

a: extent of damage;

b: political importance of the area;

c: population size;
d: donors' preferences;
e: socioeconomic factors;
f: resource availability;
g: other ______________________________.

30. **Did you face any constraints during *implementation* of the *reconstruction* programme?**
   a: yes;
   b: no.

31. **If 'yes', what were these constraints?**
   a: governmental:
   - institutional deficiencies;
   - delays in approval procedures;
   - lack of technical capability of implementing agency;
   - lack of resource availability;
   - donors' interventions;
   - management problems;
   - social interventions;
   - other ______________.

   b: contractor level:
   - lack of technical and management know how;
   - lack of resource mobilisation capability;
   - lack of experience in emergency works;
   - lack of skilled labour for reconstruction works;
   - other ______________.

   c: community level:
   - lack of organisation;
   - lack of trust on government functionaries;
   - lack of social set up for decision making;
   - lack of appreciation of the reconstruction programme;
   - other ______________.

32. **Are you satisfied with the way SCREAA implemented the reconstruction programme?**
   a: yes;
   b: no.

33. **If 'no', why?**

a: centralisation in decision making;
b: lack of economic incentives;
c: difficult working conditions;
d: Inability of top management in making rational decisions;
e: deficient working environment;
f: lack of flow of information among concerned organisations;
g: undue influence of some donors;
h: other ________________________________.

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QUESTIONNAIRE NUMBER 4: TECHNICAL EVALUATION OF INFRASTRUCTURE

Card number:__________ Date:__________________

Location:____________________ District:__________________

Surveyor:____________________ Occupation:____________________

Type of Infrastructure: 1. House; 2. other ____________________

Built in: 19___ (before/after earthquake) Owner:________________

= =

PART A: For Houses Only

1. **What is the type of house?**
   - a: turn key;
   - b: self help;
   - c: repair programme;
   - d: owner financed.

2. **What are the dimensions of various rooms in the house?**

   size

   - a: divan (drawing room)____________________;
   - b: room no 1 ____________________________;
   - c: room no 2 ____________________________;
   - d: room no 3 ____________________________;
   - e: room no 4 ____________________________;
   - f: room no 5 ____________________________;
   - g: kitchen ____________________________;
   - h: latrine ____________________________;
   - i: stable for domestic animals______________;
   - j: barn ________________________________;
   - k: store ________________________________;
   - l: boundary wall __________________________;
   - m: other ________________________________.

3. **Who built this house?**
   - a: government;
   - b: owner;
   - c: other.

4. **Has any additional construction been done to this house?**
   a: yes;
   b: no.

5. **Who financed this additional construction?**
   a: government;
   b: owner.

6. **What does this additional construction comprise of?**
   size

   a: room ______________________________;
   b: kitchen ___________________________;
   c: latrine ___________________________;
   d: stable for domestic animals ______________;
   e: barn ______________________________;
   f: store _____________________________;
   g: boundary wall _______________________;
   h: other _____________________________.

7. **What is the location of the following with respect to the main house?**
   a: kitchen outside/inside/roof top;
   b: latrine outside/inside;
   c: stable for domestic animals outside/inside;
   d: barn outside/inside;
   e: store outside/inside;
   f: other _____________________________.

8. **How is the house being used?**
   a: as residence;
   b: as guest house;
   c: as stable for domestic animals;
   d: as barn (store for animal feed);
   e: as teachers hostel for local school;
   f: deserted/abandoned;
   g: other ___________________________.

PART B: For Houses and Other Infrastructure

9. **What is the general condition of Maintenance of the Building?**
   a: good;
   b: fair;
   c: poor;
   d: in fair condition but in disuse;
   e: deserted and scavenged;
   f: other ______________________.

9. **What materials are used in the building?**
   - a: stone;
   - b: clay;
   - c: wood;
   - d: cement;
   - e: reinforcing steel;
   - f: other____________________.

10. **Who designed the building?**
    - a: engineer/architect;
    - b: local artisan.

11. **How can you describe the ground conditions regarding location of the building with respect to safety against earthquakes?**
    - a: flat ground away from tall buildings or mountain sides;
    - b: flat ground but lose back fill;
    - c: safe ground but close to another vulnerable structure;
    - d: steep gradient and vulnerable ground;
    - e: other (specify)__________________________________.

12. **What is the load bearing capacity of the natural ground in this area?**
    __________ kg/cm sq.

13. **What material is used in the building foundation?**
    - a: plain concrete;
    - b: reinforced concrete;
    - c: stone masonry;
    - d: block masonry;
    - e: other__________________________.

14. **Have any tie beams been provided throughout the walls?**
    - a: yes;
    - b: no.

15. **What is the location of the tie beams?**
    - a: foundation level;
    - b: floor level;
    - c: lintel level;
    - d: roof level.

16. **What are the cross sectional dimensions of the tie beams?**
    ______cm x _______cm.

17. **What material is used in the super structure?**
   a: stone masonry;
   b: block masonry;
   c: adobe (unburnt mud bricks);
   d: other ______________________________.

18. **How the roof load is transferred to foundation?**
   a: load transmitted through thick bearing walls;
   b: load transmitted to foundation through reinforced framed structure;
   c: other ____.

19. **What material is used in the roof structure?**
   a: reinforced concrete;
   b: wood;
   c: corrugated galvanised iron (GI) sheets;
   d: thatch material
   e: other ___________________________________.

20. **What are the protection measures against roof leakage?**
   a: roof slope 1 in _________
   b: bitumen coat ____________
   c: other___________________

21. **What are the measures for foundation protection?**
   a: plinth above natural drainage level;
   b: provision of a drainage system around the house;
   c: plain cement concrete apron all around;
   d: other ____________________________________.

22. **What was the overall cost of the building at the time of construction?**
   YR_________________________.

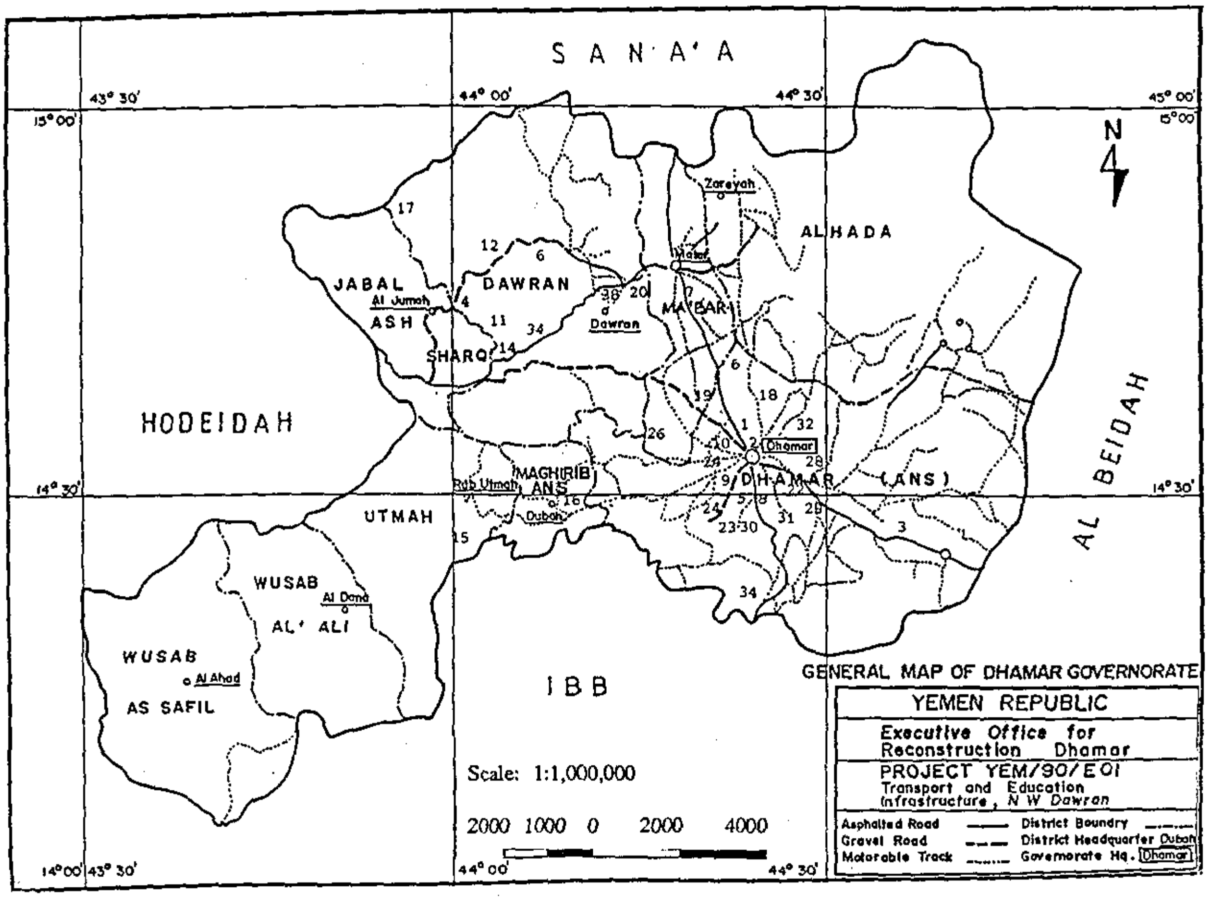
23. **Are any laboratory test results available for the this infrastructure?**
   a: yes;
   b: no.

24. **If 'yes', what are these tests?**
   a: load bearing capacity of the natural ground;
   b: concrete cube tests for RCC and PCC works;
   c: concrete blocks tests;
   d: water penetration tests for stones;
   c: sieve analyses tests;
   d: other ___________________.

(Note: Attach the available test results with the questionnaire).

Annex 2

MAP OF SURVEYED VILLAGES



List of villages where social surveys were conducted

1.	Bab Al-Falak	21.	Al-Jamia'ah
2.	Hammam Ali	22.	Haya Nasir
3.	Al-Kola	23.	Al-Jarjish
4.	Al-Marwan	24.	Al-Mahal
5.	Al-Mahillah	25.	Bir Khabud
6.	Hijrat Manqadah	26.	Al-Jumiah
7.	Ar-Rusabah	27.	Al-Khadhar
8.	Qarn Dhamar	28.	Al-Nasr
9.	Al-Husain	29.	Al-Salah
10.	Al-Sheikh	30.	Al-Guhayfah
11.	Beihan	31.	Jab Jab
12.	Mowghar	32.	Al-Huda
13.	Jarf Al-Tahir	33.	Al-Nasir
14.	Ar-Rizwah	34.	Al-Komaini
15.	Wathan	35.	Madinah Sakaniyyah
16.	Dubah	36.	Ma'abar
17.	Madinat Ash-Sharq	37.	Dhamar
18.	Mawshak	38.	Dawran
19.	Juma'ah	39.	Bani Haysan
20.	Al-Harf	40.	Bani Sabr

Source: Executive Office for Reconstruction, Yemen, 1992

Annex 3

LIST OF RESPONDENT SHEIKHS

Annex 3: **List of the community sheikhs interviewed**

	Name	Village	District
1.	Ahmad Ali Al-Koli	Al-Kola	Ans
2.	Ali Mohammed	Al-Marwan	Dawran
3.	Saleh Ali Al-Sisi	Mowghar	Ans
4.	Ahmad Al-Jahrani	Al-Rusabah	Jahran
5.	Hamud Husain Abdallah	Al-Husain	Ans
6.	Izzi Ghalib Sanad	Wathan	Uthma
7.	Mohammed Abdur-Razzaq	Dubah	Maghrib Ans
8.	Mohammed Haji Ali	Al-Mahal	Dhamar
9.	Ahmad Badr Hatim	Al-Harf	Dawran
10.	Abdurrahman Ali Ahmad	Ar-Rizwah	Dawran
11.	Abdallah Husain Izzi	Al-Mahal	Dhamar
12.	Ali Mabkhut Al-Mujari	Al-Salah	Dhamar
13.	Saleh bin Saleh	Al-Huda	Dhamar
14.	Ali Husein Al-Mowshaki	Al-Mowshak	Maghrib Ans
15.	Ali Ahmad Saleh	Al-Huda	Dhamar
16.	Husein Yahya Gheylan	Al-Nasir	Dhamar
17.	Mohammed Al-Reymi	Al-Khadar	Dhamar
18.	Abdulkarim Al-Hajj	Al-Guhaifah	Dhamar
19.	Abdallah bin Ahmad	Jab-Jab	Dhamar
20.	Saleh Al-Tulabi	Madinah Sakaniyyah	Dhamar

Source: Field surveys, 1994.

Annex 4

LIST OF GOVERNMENT RESPONDENTS

Annex 4: **List of the government officials interviewed**

No	Name	Occupation	Employing ministry	Position during reconstruction programme	Present position
1	Mohammed Hamud Sharaabi	Architect	Construction	Architect Self-help Programme	Deputy Manager Dhamar
2	Abdur Rahman Samawi	Civil Engineer	Urban Planning	Civil Engineer Turnkey Housing Programme	Senior Civil Engineer
3	Waheed Hasan Musa	Civil Engineer	Urban Planning	Civil Engineer Turnkey Housing Programme	Director Civil Works
4	Munir Yusuf Hashim	Civil Engineer	Construction	General Manager Self-help Programme	Director General O&M
5	Alawy Awad Al-Ziadi	Civil Engineer	Construction	Deputy Manager Self-help Programme	Deputy Manager O&M
6	Khalid Hazza'a Nuo'man	Civil Engineer	Construction	Civil Engineer Aided Self-help Programme	Project Engineer Schools
7	Abdul Salam Kassem	Civil Engineer	Construction	Manager Construction Supervision	Director General Dhamar
8	Abdul Habib Alwan	Structural Engineer	Construction	Civil Engineer Soil Testing Laboratory	Manager Soil Testing
9	Abdul Saeed Farah	Civil Works Supervisor	Construction	Supervisor Self-help Programme	Foreman Civil Works
10	Mohammed Umar Salim	Civil Works Supervisor	Construction	Foreman Self-help Programme	Foreman Civil Works
11	Mohammed Ahmad Mansoor	Civil Works Supervisor	Construction	Supervisor Self-help Programme	Foreman Civil Works
12	Mohamed Thabit Hassan	Civil Engineer	Construction	Director Repair Programme	Director General (civil works)
13	Kamal Ahmad Turki	Architect	Construction	Civil Engineer Turnkey Programme	Deputy Manager Hodeidah
14	Nasir Ali Dirham	Civil Engineer	Construction	Civil Engineer Turnkey Programme	Senior Engineer Sana'a
15	Abdi Ilah Mansoor	Civil Engineer	Construction	Civil Engineer Repair Programme	Senior Engineer Sana'a
16	Abdul Ghafoor Ta'izzi	Civil Engineer	Construction	Deputy Manager Self-help Programme	Senior Engineer Dhamar
17	Nasir Ali Al-Mukhadiri	Civil Engineer	Oil and Mineral Resources	Civil Engineer, civil works (geology)	Senior Engineer Dhamar
18	Najeeb Husein Ali	Geologist	Oil and Mineral Resources	Senior Geologist	Senior Geologist Dhamar
19	Othman Abdallah Thabit	Geologist	Oil and Mineral Resources	Senior Geologist	Deputy General Manager Dhamar
120	Jamal Mohamed Shu'lan	Geologist	Oil and Mineral Resources	Senior Geologist	General Manager Dhamar

Annex 5

SOCIAL SURVEY DATA

QUESTIONNAIRE 1-A: BENEFICIARIES OF TURN KEY HOUSING PROGRAMME

Respondent's Particulars												Victims Immediate Response									Government's Response/Immediate Relief								
Resp No	Age Yrs	Education					Occupation			Average Annual Income (YR)	Min Size	1		2				3	4		5		6						
																							a		b		c		
		0	1	2	3	4	GS	PS	HW			a	b	a	b	c	d	Yr	a	b	a	b	i	ii	i	ii	i	ii	
1	45				x			x		200,000	6	x		x				-		x		x							
2	40		x					x		150,000	3	x		x				-		x		x							
3	45				x		x			80,000	8	x		x				-		x		x							
4	35			x				x		500,000	15	x				x		-		x		x							
5	40	x						x		100,000	8	x				x		-		x		x							
6	46		x					x		50,000	11	x		x				-		x		x							
7	36		x					x		80,000	2	x		x				-		x		x							
8	35				x					100,000	10	x		x				-		x		x							
9	45		x				x			70,000	7	x				x		-		x		x							
10	45	x						x		100,000	6	x		x				-		x		x							
11	46			x				x		200,000	10	x		x				-		x		x							
12	37			x				x		100,000	11	x		x		x		-		x		x							
13	46	x					x	x		80,000	10	x				x		-		x		x							
14	56	x								100,000	16	x		x			x	-		x		x							
15	26				x					50,000	4	x		x				10,000		x		x							
16	60	x					x	x		100,000	15	x		x				-		x		x							
17	50		x							100,000	12	x		x				-		x		x							
18	50	x					x		x	100,000	10	x						-		x		x							
19	46		x					x		80,000	10	x		x				-		x		x							
20	66			x				x		100,000	14	x		x				-		x		x							
21	60	x						x		100,000	11	x				x		-		x		x							
22	80	x						x		60,000	7	x		x				-		x		x							
23	70		x					x		200,000	21	x				x		-		x		x							
24	46		x					x		150,000	10	x		x				-		x		x							
25	60			x						80,000	5	x		x				-		x		x							
26	50		x							100,000	10	x		x				-		x		x							
27	40	x								150,000	15	x		x				-		x		x							
28	60		x				x			100,000	12	x		x				-		x									
29	46	x					x	x		60,000	5		x		x			5,000		x	x								
30	36		x					x		30,000	8	x	x		x			1,000		x	x								
31	50	x						x		40,000	3							-		x	x								
32	28	x						x		30,000	8	x	x	x				-		x	x	x							
33	65			x				x		60,000	14	x		x				-		x		x							
34	40	x						x		200,000	14	x		x				-		x									
35	36	x						x		40,000	9	x		x				-		x	x	x							
36	32	x	x					x		150,000	4	x		x				1,200		x		x							
37	26			x			x	x		300,000	6	x		x				-		x		x							
38	50			x				x		75,000	4	x						-		x		x							
39	60	x								300,000	7			x				-		x									
40	32			x			x	x		60,000	4		x	x				-			x								
40		16	12	9	4		9	30	1	4,715,000	368	36	4	30	2	7	1			40	6	34	0	0	0	0	0	0	0
Ave	45.p	38	30	22	10		22	75	3	117,875	9.2	90	10	75	5	18	2			100	15	85	0	0	0	0	0	0	0

QUESTIONNAIRE 1-A: BENEFICIARIES OF TURN KEY HOUSING PROGRAMME

6				7									8		9		10				
d		e		a			b			c											
i	ii	i	ii	i	ii	iii	i	ii	iii	i	ii	iii	a	b	a	b	a	b	c	d	e
			x	x			x			x			x			x					
			x	x		x	x			x			x			x					
			x	x		x	x			x			x			x					
			x	x		x	x			x						x					
			x	x			x			x			x			x					
			x	x			x			x			x			x					
			x	x			x			x			x			x					
			x	x			x			x			x	x		x					
			x	x			x			x			x			x					
			x	x			x			x			x			x					
			x	x	x		x			x			x			x					
			x	x			x			x			x			x					
			x	x			x			x			x			x					
			x	x			x			x			x	x		x					
			x	x			x			x			x			x					
			x	x			x			x			x			x					
			x	x			x			x			x								
			x	x	x		x			x				x							
			x	x			x			x			x								
			x	x			x			x			x								
			x	x			x			x			x								
			x	x	x		x			x			x	x							
			x	x			x			x			x								
			x	x			x			x											
			x	x			x			x											
			x	x			x			x											
			x	x	x		x			x				x							
			x	x			x			x											
			x	x	x		x			x											
				x	x					x											
			x	x	x					x				x							
			x	x						x											
			x	x						x											
			x	x	x					x				x							
			x	x			x			x											
			x	x	x		x			x											
			x	x	x		x			x											
			x	x	x		x			x											
			x	x	x		x			x											
				x	x					x											
0	0	5	35	40	12	3	40	0	0	40	0	0	22	7	1	39	0	0	0	0	0
0	0	13	87	100	30	8	100	0	0	100	0	0	53	17	2	98	0	0	0	0	0

QUESTIONNAIRE 1-A: BENEFICIARIES OF TURN KEY HOUSING PROGRAMME

11																	
a		b		c		d		e		f		g		h		i	
i	ii	i	ii	i	ii	i	ii	i	ii	i	ii	i	ii	i	ii	i	ii
	x		x		x	x			x		x		x		x		
	x		x	x	x	x	x	x									
	x		x	x		x	x										
x		x	x	x	x	x	x										
	x	x	x	x	x	x	x										
x		x	x	x	x	x	x										
	x		x	x	x	x	x	x									
x			x	x	x	x	x										
	x		x	x	x	x	x										
x			x	x	x	x											
	x		x	x	x	x											
			x	x	x	x											
x	x		x	x	x	x		x									
	x		x	x	x	x		x									
	x		x	x	x	x											
	x		x	x	x	x		x									
	x		x	x	x	x											
	x		x	x		x											
	x		x	x		x											
	x		x	x		x											
	x		x	x		x											
	x		x	x		x											
	x		x	x		x											
	x		x	x		x											
	x		x	x		x											
x	x		x			x											
	x		x			x											
	x		x			x											
	x		x			x											
	x		x			x											
	x		x			x											
x	x		x			x		x									
	x		x			x		x									
	x		x					x									
x								x									
8	32	6	35	26	16	32	8	10	30	16	24	0	40	1	39	0	1
20	80	13	87	63	37	80	20	25	75	40	60	0	100	3	87	0	28

12							
a	b	c	d	e	f	g	h
x	x	x	x	x	x	x	x
	x	x	x	x	x	x	x
	x	x	x	x	x	x	x
	x	x	x	x	x	x	x
	x	x	x	x	x	x	x
	x	x	x	x		x	x
	x	x	x	x	x	x	x
	x	x	x	x	x	x	x
	x	x	x	x	x	x	x
	x	x	x	x	x	x	x
	x	x	x	x	x	x	x
	x	x	x	x	x	x	x
	x	x	x	x	x	x	x
	x	x	x	x	x	x	x
	x	x	x	x	x	x	x
	x	x	x	x	x	x	x
	x	x	x	x	x	x	x
	x	x	x	x	x	x	x
	x	x	x	x	x	x	
	x	x	x	x	x	x	x
	x	x	x	x	x	x	x
	x	x	x	x	x	x	x
	x	x	x	x	x	x	x
	x	x	x	x	x	x	x
	x	x	x	x	x	x	x
	x	x		x	x	x	x
	x	x	x	x	x	x	x
	x	x	x	x	x	x	x
	x	x	x	x	x	x	x
	x	x		x	x	x	x
	x	x		x	x	x	x
	x	x		x	x	x	
	x	x		x	x	x	
	x	x		x	x		
	x	x		x	x		
	x	x		x			
	x	x					
32	36	37	29	38	35	34	27
80	90	93	73	95	87	85	68

QUESTIONNAIRE 1-A: BENEFICIARIES OF TURN KEY HOUSING PROGRAMME

12						13		14			15												16		17	
i	j	k	l	m	n	a	b	a	b	c	a	b	c	d	e	f	g	h	i	j	k	l	a	b	a	b
13	34	14	5	4	5	15	25	0	11	2	0	7	24	12	15	11	13	4		3		4	32	8	26	8
33	85	36	15	10	13	38	62	0	28	5	0	18	60	30	38	28	33	10		8		10	80	20	65	20

QUESTIONNAIRE 1-A: BENEFICIARIES OF TURN KEY HOUSING PROGRAMME

17						18		19			20			21														
														a			b			c			d			e		
c	d	e	f	g	h	a	b	a	b	c	a	b	c	i	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
	x			x			x			x	x					x		x			x							x
	x			x			x					x		x				x		x								x
	x			x			x	x		x						x			x					x			x	
				x			x						x			x		x		x			x					x
				x			x				x		x			x		x							x			x
	x			x			x		x							x		x			x							x
	x						x		x				x			x		x		x	x							x
	x						x		x				x			x		x										x
							x									x		x					x	x			x	x
	x			x			x									x		x	x				x	x				x
							x							x			x			x								
				x			x									x			x		x						x	x
				x			x									x			x				x	x	x			x
				x			x									x	x						x	x				
				x			x									x		x									x	x
							x									x		x										x
																x		x			x						x	x
	x						x									x		x			x				x			
	x															x		x			x		x	x	x		x	x
	x			x			x											x			x				x			
	x			x			x								x	x		x							x			x
x	x		x	x			x									x		x			x		x	x	x		x	x
x	x		x	x			x			x	x					x		x			x							
x	x		x	x												x		x						x	x		x	x
x	x		x	x			x									x			x	x	x		x		x			x
	x		x	x		x	x									x		x		x	x							
				x			x				x					x		x	x	x			x	x				x
				x												x		x			x		x	x	x		x	
							x									x	x			x								x
						x	x									x	x			x							x	x
							x									x	x			x	x				x			x
							x									x	x										x	x
																x	x											
																	x	x							x		x	x
				x												x					x							
				x							x			x		x	x								x			x
				x			x													x					x			
				x			x							x			x											
							x						x	x			x	x		x								
							x			x		x		x				x			x							x
										x		x		x							x							x
																												x
																					x							x
5	16		5	26		2	31	24		5	5	3	5	6	1	33	11	23	6	12	18	10	21	15	4		12	28
13	40		13	63		5	78	60		13	13	8	13	15	3	82	28	58	14	30	45	26	52	38	10		30	70

QUESTIONNAIRE 1-A: BENEFICIARIES OF TURN KEY HOUSING PROGRAMME

21																										
f			g			h			i			j			k			l			m			n		
i	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
	x				x			x	x				x			x		x	x			x		-N	1	L-
	x			x		x			x				x			x		x	x			x			"	
					x	x				x				x					x			x			"	
	x	x			x					x					x		x	x	x			x	x		"	
	x				x		x			x		x			x										"	
x					x		x			x		x			x			x	x			x			"	
	x			x			x	x	x			x	x			x				x		x			"	
don't know				x						x			x		x			x				x			"	
	x				x		x	x	x				x				x					x	x		"	
	x				x					x			x			x			x						"	
x					x		x	x		x			x			x						x			"	
x					x			x			x		x		x			x				x			"	
don't know				x				x		x			x			x			x	x			x		"	
			x						x			x				x			x	x			x		"	
	x				x		x			x			x					x					x		"	
	x			x		x	x			x			x			x		x					x		"	
	x				x					x		x				x							x		"	
x					x		x			x			x			x			x				x		"	
don't know				x			x						x			x						x			"	
don't know					x	x	x		x	x			x			x		x				x			"	
					x					x			x		x				x			x			"	
don't know	x			x			x						x		x				x			x			"	
don't know					x		x	x		x		x	x			x		x				x			"	
don't know					x					x	x		x		x			x	x				x		"	
don't know				x			x			x			x			x							x		"	
don't know					x		x			x			x			x		x				x			"	
don't know				x			x			x			x			x						x			"	
don't know					x		x						x			x						x			"	
don't know					x		x		x			x			x							x			"	
					x	x	x		x			x			x							x			"	
x				x			x		x	x		x			x										"	
	x				x							x			x							x			"	
x				x			x		x			x				x						x			"	
x					x		x		x			x			x							x			"	
x				x			x		x			x				x						x			"	
	x				x	x	x		x			x			x				x			x			"	
don't know				x			x		x			x				x			x			x			"	
x					x				x			x				x		x	x						"	
	x				x		x		x			x					x	x	x			x	x		"	
									x			x				x		x							"	
																									"	
9	17		1	13	26	6	27	7	17	21	2	17	22	1	16	22	3	20	16	4		29	11	N	I	L
23	43		3	32	66	16	67	18	43	52	5	43	66	2	38	66	7	50	40	10		73	27			

QUESTIONNAIRE 1-B: BENEFICIARIES OF TURN KEY HOUSING PROGRAMME

Respondent's Particulars												Victims Immediate Response									Government's Response/Immediate Relief								
Resp No	Age Yrs	Education					Occupation			Average Annual Income (YR)	Min Size	1		2				3	4		5		6						
																							a		b		c		
		0	1	2	3	4	GS	PS	HW			a	b	a	b	c	d	YR	a	b	a	b	i	ii	i	ii	i	ii	
1	25		x					x		80,000	12	x				x		-		x		x							
2	35	x							x	69,000	7	x				x		-		x		x							
3	50		x					x		70,000	4	x				x		-		x		x							
4	26				x		x			80,000	14	x			x			-		x		x							
5	35		x					x		100,000	5	x		x				-		x		x							
6	26			x	x		x			200,000	12	x				x		-		x		x							
7	30									250,000	20	x				x		-		x		x							
8	25				x		x			150,000	12	x				x		-		x		x							
9	30		x				x	x		100,000	5	x				x		-		x		x							
10	40		x				x			150,000	7	x		x				-		x		x	x						
11	40				x				x	60,000	7	x				x		-		x		x							
12	27			x			x	x		100,000	18	x						-		x		x		x					
13	32				x					60,000	8	x				x	x	-		x		x		x					
14	44			x						60,000	5	x		x				-		x		x			x				
15	39		x				x	x		70,000	7	x				x		-		x		x	x	x					
16	50	x				x	x			100,000	14	x						-		x		x			x				
17	31						x	x		70,000	5	x		x		x		-		x		x	x						
18	65	x						x		30,000	2	x		x		x		-		x		x							
19	70	x					x	x		80,000	5	x		x				-		x		x	x						
20	60	x						x		100,000	4	x						-		x		x	x						
21	55	x						x		100,000	9	x						-		x		x	x						
22	55	x								90,000	9	x				x		-		x		x							
23	45		x					x		80,000	11	x		x		x		-		x		x							
24	65							x		70,000	3	x					x	-		x		x							
25	35		x	x				x		150,000	9	x						-		x		x							
26	26	x					x	x		80,000	6	x		x				-		x		x	x						
27	40	x								100,000	12	x		x		x		-		x		x							
28	45			x				x		90,000	5		x					-		x									
29	25	x		x	x			x		100,000	3	x						-		x	x								
30	32	x								60,000	3	x				x		-		x	x								
31	56	x	x				x			80,000	9	x		x		x		-		x	x		x						
32	38	x					x			36,000	6	x		x		x		-		x	x	x				x	x		
33	28								x	75,000	5	x						-		x		x	x						
34	40			x			x	x		85,000	7	x						-		x									
35	45	x	x		x					400,000	16	x				x		-		x	x	x							
36	35			x			x	x		50,000	4	x				x		-		x		x							
37	40							x		50,000	12	x		x		x		-		x		x							
38	42			x	x		x			150,000	15	x				x		-		x		x							
39	40			x				x		90,000	8	x		x				-		x									
40	28	x		x			x	x		70,000	4	x		x		x		-			x								
41	30		x	x			x			90,000	9	x		x		x		-											
42	48									45,000	1	x		x				-											
Total	1652	12	10	11	8	1	16	23	3	4,101,000	338	41	1	16	1	21	2	-	0	42	10	32	2	4	2	1	1	0	0
%	42	29	24	26	19	2	38	55	7	97643	8	98	2	38	2	57	5	-	0	100	24	76	5	10	5	2	2	0	0

QUESTIONNAIRE 1-B: BENEFICIARIES OF TURN KEY HOUSING PROGRAMME

6				7									8		9			10		11		
d		e		a			b			c												
i	ii	i	ii	i	ii	iii	i	ii	iii	i	ii	iii	a	b	a	b	c	a	b	a	b	c
			x	x			x		x	x		x		x				x		x		
			x	x		x	x		x	x		x		x				x		x		
			x	x		x	x		x	x		x		x				x		x		
			x	x		x	x		x	x		x		x				x		x		
			x	x		x	x		x	x		x		x				x		x		
			x	x		x	x		x	x		x		x				x		x		
			x	x		x	x		x	x				x				x		x		
			x	x		x	x	x	x	x		x		x				x		x		
			x	x			x		x	x				x				x		x		
		x	x	x			x		x	x		x		x				x		x		
			x	x	x		x		x	x				x				x		x		
			x	x			x		x	x		x		x				x		x		
			x	x			x		x	x		x		x				x				
			x	x			x		x	x				x				x		x		x
		x	x	x			x		x	x	x			x				x		x		
			x	x			x	x	x	x				x				x		x		
			x	x			x		x	x				x				x		x		
			x	x	x		x		x	x		x		x					x	x		
			x	x			x		x	x		x		x				x		x		
		x	x	x			x		x	x				x				x		x		
			x	x			x		x	x				x				x		x		
			x	x	x		x	x	x	x				x					x	x		
			x	x			x		x	x		x		x				x	x	x		
			x	x			x		x	x		x		x				x		x		
			x	x			x		x	x		x		x				x		x		
		x	x	x			x		x	x		x		x				x		x		
		x	x	x	x		x		x	x		x		x				x		x		
			x	x			x		x	x		x		x				x		x		
			x	x	x		x		x	x		x		x				x		x		
				x	x				x	x		x		x				x		x		
			x	x	x				x	x		x		x				x		x		
			x	x					x	x		x		x				x		x		
			x	x					x	x		x		x				x		x		
			x	x	x				x	x		x		x				x		x		
			x	x			x		x	x		x		x				x		x		
			x	x	x		x		x	x		x		x				x		x		
			x	x	x		x		x	x		x		x				x		x		
			x	x	x		x		x	x		x		x				x		x		
			x	x	x		x		x	x		x		x				x		x		
		x		x	x				x	x		x		x				x		x		
0	0	6	31	42	3	39	42	0	0	42	0	32	0	42	0	0	0	39	3	41	0	1
0	0	14	74	100	7	93	100	0	0	100	0	76	0	100	0	0	0	93	7	98	0	2

QUESTIONNAIRE 1-B: BENEFICIARIES OF TURN KEY HOUSING PROGRAMME

12		13							14		15			16		17				18											
																				a		b		c		d		e		f	
a	b	a	b	c	d	e	f	g	a	b	a	b	c	a	c	a	b	c	d	i	ii	i	ii	i	ii	i	ii	i	ii	i	ii
x		x	x		x	x	x		x		x	x		x		x			x	x			x	x		x			x		x
x		x	x		x		x		x		x	x			x					x			x	x		x			x	x	
x		x	x		x		x		x		x			x									x	x		x			x		x
x		x	x		x		x		x		x	x			x						x		x	x		x			x		x
x		x	x	x	x		x		x		x	x			x						x		x	x			x		x		x
x		x	x		x		x		x		x	x			x						x	x		x		x			x		x
x		x	x	x	x		x		x		x	x			x						x		x	x			x		x		x
x		x	x		x		x		x		x	x			x					x	x		x	x		x			x		x
x		x	x		x	x	x		x		x	x		x	x					x	x		x	x					x	x	x
x		x	x		x	x	x		x		x					x				x			x	x			x			x	
x		x	x		x	x	x		x		x	x		x	x								x	x			x		x	x	
x		x	x		x	x	x		x		x				x	x							x	x		x		x			
x		x	x		x		x		x		x	x			x						x		x	x			x		x	x	x
x		x	x		x	x	x		x		x	x			x					x	x		x	x		x		x	x	x	
x		x	x		x	x	x		x		x	x			x						x		x	x		x				x	
x									x		x				x						x		x			x				x	
x						x	x		x		x				x								x	x		x		x	x		
x		x	x		x		x		x		x	x			x						x		x	x	x	x		x			x
x		x	x		x		x		x		x	x			x						x		x			x		x			x
x		x	x		x		x		x						x						x		x			x			x		x
x		x	x		x		x		x		x				x	x					x		x	x		x		x			x
x		x	x		x		x		x		x				x						x		x			x		x			x
x		x	x		x		x		x		x				x	x					x		x			x		x	x		x
x		x	x		x		x		x			x			x						x		x	x	x	x					x
x		x	x		x		x		x			x			x						x		x	x		x		x	x	x	x
x		x	x		x		x		x		x			x	x						x	x	x	x		x		x	x		x
x		x	x		x		x		x			x			x	x					x		x	x	x						x
x		x	x		x		x		x		x				x						x			x		x	x	x	x	x	x
x		x	x		x		x		x		x				x	x					x		x	x			x	x	x		
x		x	x		x		x		x		x				x					x	x		x	x	x		x			x	x
x		x	x		x		x		x		x				x					x	x		x	x		x					
x		x	x		x		x		x		x				x						x		x		x	x		x	x		
x		x	x		x		x		x		x				x								x	x		x		x	x	x	
x		x	x		x		x		x		x	x			x								x	x		x				x	x
x		x	x	x	x		x		x		x				x						x		x			x		x	x		x
x		x	x		x		x		x		x	x			x						x		x	x			x			x	
x		x	x		x		x		x		x				x								x	x	x	x		x			
x		x	x		x		x		x		x	x			x						x		x	x		x		x	x	x	x
x		x	x		x		x		x			x			x						x		x	x					x		x
x		x	x		x		x		x		x	x		x	x	x					x			x							x
x		x	x		x		x		x		x	x			x						x			x	x						x
x		x	x		x		x		x		x				x						x		x	x		x					
																					x		x	x		x		x		x	
42	0	40	39	3	40	8	42	0	42	0	33	23	0	6	36	8	0	0	1	8	34	0	38	33	7	30	9	18	24	17	25
100	0	95	93	7	95	19	100	0	100	0	79	55	0	14	86	19	0	0	2	19	71	0	90	79	17	71	21	43	57	40	60

QUESTIONNAIRE 1-B: BENEFICIARIES OF TURN KEY HOUSING PROGRAMME

18						19														20		21			22						
g		h		i																											
i	ii	i	ii	i	ii	a	b	c	d	e	f	g	h	i	j	k	l	m	n	a	b	a	b	c	a	b	c	d	e	f	g
	x		x			x	x	x		x	x	x	x							x			x			x					
	x		x		x		x	x		x	x	x	x		x				x		x								x	x	
	x		x		x			x		x	x	x	x		x						x							x	x		x
	x		x		x	x	x	x	x	x	x	x	x		x						x						x	x	x	x	x
	x		x			x	x	x	x	x	x	x	x	x	x						x					x	x	x	x	x	x
	x		x		x	x		x	x	x	x	x	x	x	x	x					x					x	x	x			x
	x		x		x	x	x	x	x	x	x	x	x	x							x						x		x	x	x
	x		x			x	x	x	x	x	x	x	x	x	x				x		x						x	x	x	x	x
	x		x		x	x	x	x	x	x	x	x	x								x						x	x	x	x	x
	x		x				x	x	x	x	x	x	x		x				x	x							x	x			
	x		x		x		x	x	x	x	x	x	x		x						x			x			x		x		
	x		x				x	x		x	x	x	x		x				x		x		x			\	x	x			x
	x		x		x	x	x	x		x	x	x	x						x	x							x				
	x		x		x	x	x	x		x	x	x	x		x				x		x					x			x		x
	x		x		x	x	x	x		x	x	x	x						x		x						x		x	x	x
	x		x		x	x	x	x		x	x	x	x								x					x				x	
	x		x		x	x	x	x	x	x	x	x	x		x						x					x	x	x	x		
	x		x			x	x	x	x	x	x	x	x		x						x						x				
	x		x			x	x	x	x	x	x	x	x		x						x						x	x			
	x		x			x	x	x	x	x	x	x	x		x						x					x	x				
	x		x			x	x	x	x	x	x	x	x		x						x						x	x	x		
	x		x			x	x	x	x	x	x	x	x		x						x						x				
	x		x			x	x	x	x	x	x	x	x		x				x	x			x				x	x			
	x		x			x	x	x	x	x	x	x	x			x		x	x	x	x		x				x	x			
	x		x			x	x	x	x	x	x	x	x																		
x	x	x	x			x	x	x		x	x	x	x		x				x	x	x		x			x					
	x		x			x	x	x	x	x	x	x	x		x						x							x			
	x		x					x	x	x	x	x	x		x	x	x										x		x	x	
	x		x			x	x	x	x	x	x	x	x		x				x	x	x			x							
	x				x	x	x	x	x	x	x	x	x																x		
	x	x	x		x	x	x	x	x	x	x	x	x		x				x	x	x		x				x	x	x		
	x		x			x	x	x	x	x	x	x	x		x						x						x			x	x
	x				x		x	x	x	x	x	x	x		x						x									x	
	x		x		x		x	x	x	x	x	x	x														x				
	x		x			x	x	x	x	x	x	x	x		x				x	x											
	x		x			x		x	x	x	x	x	x		x				x	x	x					x	x				
	x		x			x	x	x	x	x	x	x	x		x	x							x				x				x
	x		x			x	x	x	x	x	x	x	x		x	x			x	x	x		x				x				
	x		x			x	x	x	x	x	x	x	x		x				x	x											
	x					x	x	x	x	x	x				x						x						x				
	x		x																												
	x	x				x	x	x	x	x	x	x	x		x																
			x			x	x	x	x	x	x	x	x		x				x	x			x				x				
1	39	4	36	0	16	33	38	40	28	39	37	37	32	4	29	5	3	1	10	13	29	0	9	2	0	9	27	14	16	10	12
2	93	10	86	0	38	79	90	95	67	93	88	88	76	10	69	12	7	2	21	31	69	0	21	5	0	21	64	33	36	21	2

QUESTIONNAIRE 1-B: BENEFICIARIES OF TURN KEY HOUSING PROGRAMME

22					23		24								25		26			27			28								
																							a			b			c		
h	i	j	k	l	a	b	a	b	c	d	e	f	g	h	a	b	a	b	c	a	b	c	i	ii	iii	i	ii	iii	i	ii	iii
						x																	x							x	
x						x																			x		x			x	
						x																			x		x			x	
						x																			x		x			x	
						x																			x		x				x
	x	x	x			x																			x		x			x	
						x																			x		x			x	
						x																			x		x		x		
						x																			x		x				x
						x																		x		x				x	
	x					x																			x		x			x	
						x																		x			x			x	
						x																		x		x			x		
x	x					x										x	x					x			x		x		x		
x						x										x	x							x			x			x	
	x	x				x										x	x								x	x			x		
					x											x	x						x		x	x			x		
					x		x		x	x			x			x	x								x		x			x	
					x		x		x	x			x			x	x										x		x		
					x		x		x	x			x			x	x				x						x			x	
					x		x		x	x			x			x			x					x	x	x			x		
						x	x	x	x							x			x				x			x			x		
					x											x			x								x				
					x		x	x								x	x			x				x			x		x		
					x		x	x	x	x						x		x						x			x				x
					x		x	x	x	x						x			x		x		x				x		x		
						x	x	x	x	x						x			x					x			x			x	x
						x										x		x								x			x		
					x											x			x				x		x			x			x
					x		x	x								x			x				x		x		x				
x	x					x	x	x								x	x								x		x			x	x
						x																					x				x
						x																				x			x		
x		x			x	x																		x			x				
					x																		x			x			x	x	
					x		x	x								x	x						x				x		x		
					x		x	x								x			x	x			x				x		x		
						x	x	x								x			x	x		x	x				x				
					x											x	x			x			x				x				x
					x											x	x						x			x			x		
					x		x	x	x	x						x			x				x			x			x		
							x	x	x	x						x	x										x				
							x						x			x			x					x						x	
5	5	3	1	4	18	24	17	12	12	9	0	0	5	0	0	26	13	2	11	4	2	4	13	11	18	12	29	1	17	17	8
12	12	7	2	10	43	57	40	29	29	21	0	0	12	0	0	62	31	5	26	10	5	10	31	26	43	29	69	2	40	40	20

QUESTIONNAIRE 1-B: BENEFICIARIES OF TURN KEY HOUSING PROGRAMME

28																														
d			e			f			g			h			i			j			k			l			m			n
i	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii	
x				x			x				x		x		x				x			x			x			x		None
x				x		x					x		x		x			x			x				x			x		
x				x		D/N	D/N	D/N		x			x			x			x			x				x			x	
x					x	-do-	-do-	-do-		x				x		x			x			x				x			x	
x				x		-do-	-do-	-do-		x			x			x			x			x				x		x		
x				x		-do-	-do-	-do-			x		x			x			x		x				x			x		
x					x	-do-	-do-	-do-			x		x			x			x			x				x		x		
	x			x		-do-	-do-	-do-		x			x			x			x			x				x		x		
x					x	-do-	-do-	-do-		x			x			x			x			x				x			x	
x					x			x			x		x		x				x			x			x			x		
x					x	-do-	-do-	D/N					x			x			x			x			x				x	
x				x			x				x	x				x			x			x			x			x		
x			x			x			x				x			x		x				x				x			x	
x				x			x				x			x		x		x				x				x			x	
x					x		x				x					x			x			x				x			x	
x					x		x				x		x			x		x				x				x			x	
x					x	x					x		x		x			x			x					x		x		
x				x			x				x		x			x			x			x				x		x		
x				x			x			x			x			x			x			x				x			x	
x				x			x			x	x		x			x			x			x				x		x		
x					x		x				x		x		x			x				x				x		x		
x					x		x				x		x			x			x				x			x			x	
x				x				x			x			x		x				x		x			x				x	
x					x			x			x	x			x				x		x				x			x		
x					x			x			x		x			x				x					x			x		
x					x			x			x	x					x		x		x				x			x		
		x			x	x			x		x			x	x					x		x			x				x	
x				x		x				x			x		x			x			x				x				x	
x					x		x				x		x		x			x							x				x	
x				x			x			x			x			x				x		x			x			x		
x					x		x				x			x	x			x				x				x			x	
x				x			x				x		x			x			x			x				x			x	
x				x			x				x		x			x			x			x			x				x	
	x				x		x				x		x			x		x								x			x	
x			x				x				x		x			x		x			x	x			x			x		
x			x			x					x			x	x					x		x			x			x		
x					x		x				x		x			x			x				x		x			x		
x					x		x			x				x			x			x		x			x				x	
		x		x				x			x		x		x				x			x				x		x		
x				x			x				x		x		x					x		x				x		x		
x				x			x				x		x		x					x			x		x			x		
x				x			x				x		x		x				x				x		x			x		
38	2	2	3	20	19	6	22	6	2	10	30	3	32	7	15	25	2	11	23	8	7	31	4	0	21	21	0	23	19	None
90	5	5	7	48	45	19	52	14	5	24	71	7	76	17	35	60	5	26	55	19	17	74	9	0	50	50	0	55	45	

QUESTIONNAIRE 1-C: BENEFICIARIES OF REPAIR PROGRAMME

Respondent's Particulars												Victims Immediate Response									Government's Response/Immediate Relief									
Resp No	Age	Education					Occupation			Av Ann Inc YR	House-hold Size	1		2				3	4		5		6					
																							a		b		c	
		0	1	2	3	4	GS	PS	HW			a	b	a	b	c	d	Yr	a	b	a	b	i	ii	i	ii	i	ii
1	45		x					x		150,000	9		x	x				-		x	x							
2	35			x			x			100,000	7		x			x		-		x		x						
3	26					x	x			150,000	8		x				x	-		x		x						
4	22		x					x		400,000	7		x	x				-		x	x							
5	40		x				x			80,000	6		x			x		-		x		x						
6	45		x					x		300,000	10		x	x				-		x	x							
7	22			x			x			75,000	6		x	x				-		x	x							
8	50		x					x		100,000	10		x			x		-		x	x							
9	45	x						x		50,000	6		x	x				-		x	x							
10	52	x					x			36,000	4		x	x				-		x	x							
11	35	x						x		150,000	7		x			x		-		x	x							
12	65		x					x		80,000	5		x			x		-		x	x							
13	60	x						x		90,000	4	x		x				-		x	x							
14	50				x			x		80,000	6	x		x				-		x	x							
15	45			x				x		100,000	10		x		x			-		x		x						
16	35			x			x			60,000	5	x			x			-		x	x							
17	60			x				x		335,000	15		x			x		-		x		x						
18	35		x				x			70,000	2		x	x				-		x		x						
19	50				x			x		200,000	10		x	x				-		x		x						
20	35				x		x			90,000	3		x	x				-		x		x						
21	60		x					x		60,000	3		x	x				-		x		x						
22	42			x				x		70,000	5		x	x				-		x		x						
23	28			x				x		70,000	8		x			x		-		x		x						
24	36	x					x			60,000	2		x	x				-		x		x						
25	45			x			x			70,000	3		x			x		-		x		x						
26	30	x						x		80,000	5		x			x		-		x		x						
27	37	x						x		100,000	8		x	x				-		x		x						
28	36		x				x			65,000	9		x			x		-		x		x						
29	58					x	x			150,000	5		x	x				-		x		x						
30	66	x						x		80,000	4		x			x		-		x		x						
31	43			x				x		150,000	8		x	x				-		x		x						
32	27				x			x		90,000	2		x			x		-		x		x						
33	37			x			x			65,000	4		x			x		-		x		x						
34	26				x		x			95,000	2		x	x				-		x		x						
35	35		x				x			80,000	7		x	x				-		x		x						
36	40	x				x	x			150,000	7		x			x		-		x		x						
37	28							x		70,000	4		x			x		-		x		x						
38	55				x		x			150,000	13		x	x				-		x		x						
39	25			x					x	50,000	1		x				x	-		x		x						
40	28	x						x		50,000	4		x	x				-		x		x						
41	45				x			x		100,000	3		x	x				-		x		x						
70	1677	10	10	11	7	3	17	23	1	4,551,000	247	3	38	22	2	15	2	0	0	41	12	29	0	0	0	0	0	0	0
%	41	24	24	27	17	8	41	56	3	111,000	6	8	93	54	5	36	5	0	0	100	29	71	0	0	0	0	0	0	0

QUESTIONNAIRE 1-C: BENEFICIARIES OF REPAIR PROGRAMME

				Reconstruction Programme																									
d		e		7				8		9			10			11		12							13		14		
i	ii	i	ii	a	b	c	d	a	c	a	b	c	a	b	c	a	b	a	b	c	d	e	f	g	a	b	a	b	c
			x		x				x				x			x						x			x		x		
			x		x				x				x			x						x			x		x		
			x		x				x				x			x						x			x		x		
		x			x				x	x		x	x			x						x			x		x		
			x		x				x				x			x			x				x			x			
		x			x			x		x		x	x			x						x			x		x		
		x			x			x		x			x			x						x			x		x		
		x			x				x	x			x			x						x	x		x		x		
		x			x				x	x			x			x						x				x			
		x			x				x	x	x				x	x						x			x				
		x			x				x	x			x			x						x				x			
		x			x				x	x			x			x						x			x				
		x			x				x				x			x						x			x		x		
		x			x				x				x			x						x			x		x	x	
			x		x				x						x	x						x				x			
		x			x				x				x			x		x	x		x	x	x		x		x		
			x		x				x		x				x	x						x				x			
			x		x				x						x	x						x			x		x		
			x		x				x				x			x						x			x		x		
			x		x				x				x			x						x				x			
			x		x				x						x	x						x			x		x		
			x		x				x				x			x						x			x		x		
			x		x				x				x			x						x			x			x	
			x		x				x						x	x						x			x		x		
			x		x				x						x	x						x			x		x		
			x		x				x		x				x	x						x			x		x		
			x		x				x				x			x						x			x			x	
			x		x				x				x			x		x				x			x		x		
			x		x				x				x			x						x			x		x		
			x		x				x						x	x						x			x		x		
			x		x				x				x			x						x				x			
			x		x				x				x			x						x					x		
			x		x				x				x			x						x			x		x		
			x		x				x						x	x						x			x		x		
		x	x		x				x						x	x		x				x			x			x	
			x		x				x						x	x						x			x				
			x		x				x				x			x						x			x		x		
			x		x				x				x			x						x			x		x		
			x		x				x				x			x						x			x		x		
			x		x				x				x			x		x	x		x	x			x		x		
			x		x				x				x			x						x			x		x		
0	0	12	29		41	0	0	2	39	8	3	2	29	0	12	41	0	3	3	0	2	38	3	0	34	7	28	4	0
0	0	29	71		100	0	0	5	95	20	7	5	71	0	29	100	0	7	7	0	5	93	7	0	83	17	68	10	0

QUESTIONNAIRE 1-C: BENEFICIARIES OF REPAIR PROGRAMME

																	Other Infrastructure												
15		16					17		18				19				20		21								22		
a	c	a	b	c	d	e	a	b	a	b	c	d	a	b	c	d	a	b	a	b	c	d	e	f	g	h	a	b	a
x							x		x								x											x	x
	x				x			x								x	x								x			x	x
	x		x		x		x										x		x			x	x	x				x	x
	x				x			x					x					x											
x					x			x					x				x								x			x	x
x	x				x			x					x																
x	x			x	x			x					x					x											
							x			x	x																		
	x						x										x		x						x			x	
x	x				x			x		x							x			x					x			x	
								x	x				x				x		x						x			x	
x	x		x					x					x				x		x						x			x	
							x			x								x									x		
x	x						x			x								x										x	x
							x			x								x										x	
x	x						x			x								x										x	x
								x					x					x										x	x
x	x				x		x			x								x										x	
x							x			x								x										x	
							x			x								x										x	
	x		x					x					x					x										x	x
x	x				x		x			x								x										x	
								x					x					x										x	x
x	x				x		x			x								x										x	
x				x			x			x																		x	
								x				x	x					x										x	x
x	x			x			x			x	x							x										x	
							x											x										x	x
x	x						x			x				x				x										x	x
								x					x						x									x	x
x	x												x					x										x	
x					x			x										x										x	
				x			x			x								x										x	
	x		x				x			x							x	x										x	x
x	x						x			x									x										
								x					x					x										x	
	x				x		x											x										x	x
	x						x			x								x										x	
	x					x	x			x	x							x										x	
	x	x					x											x										x	
	x					x		x		x			x					x										x	x
17	24	1	4	4	12	2	26	16	2	20	3	1	14	1	0	0	9	29	6	1	0	1	1	1	6	0	1	35	16
41	69	2	10	20	29	5	61	39	5	49	7	2	34	2	0	0	22	71	15	2	0	2	2	2	15	0	2	85	39

QUESTIONNAIRE 1-C: BENEFICIARIES OF REPAIR PROGRAMME

b	c	a	b	c	i	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
			x													
x		x														
x																
x																
x																
	x															
	x															
	x															
x		x														
x																
		x														
	x															
	x															
	x	x														
	x															
	x															
x																
x																
	x															
x																
	x	x														
	x															
	x															
	x															

QUESTIONNAIRE 1D: NON BENEFICIARIES OF HOUSING PROGRAMME

Respondent's Particulars												Victims Immediate Response									Government's Response/Immediate Relief							
Resp No	Age Yrs	Education					Occupation			Average Annual Income (YR)	Min Size	1		2				3	4		5		6					
																							a		b		c	
		0	1	2	3	4	GS	PS	HW			a	b	a	b	c	d	YR	a	b	a	b	i	ii	i	ii	i	ii
1	46			x				x		100,000	14	x				x		-		x		x						
2	37			x				x		200,000	14	x		x				20,000		x		x						
3	60	x						x		120,000	17	x				x		-		x		x						
4	65		x					x		100,000	8	x		x				-		x		x						
5	35	x						x		80,000	9	x		x				-		x		x						
6	35		x					x		300,000	15	x		x				-		x		x						
7	50	x						x		60,000	10	x		x				-		x		x	x		x		x	
8	40	x						x		90,000	10	x		x				-		x		x						
9	32	x						x		70,000	5	x				x		-		x		x						
10	27	x						x		50,000	4	x		x				-		x		x						
11	36	x						x		90,000	4	x				x		-		x		x						
12	29				x		x			70,000	6		x	x				-		x								
13	43	x			x			x		100,000	9	x				x		-		x	x	x						
14	42	x								50,000	12		x		x			-		x								
15	38							x		70,000	11	x						-		x	x	x						
16	30	x			x		x			50,000	4		x	x				-		x								
17	50	x						x		80,000	12	x		x	x			-		x	x	x						
18	45							x		100,000	9	x			x			-		x		x						
19	49	x	x					x		90,000	7	x						-		x		x						
20	46	x						x		150,000	4	x		x				-		x		x						
21	37							x		90,000	6	x		x				-		x		x						
22	55		x					x		150,000	15	x		x				-		x		x						
23	40	x		x				x		60,000	9	x			x	x		-		x		x						
24	45							x		120,000	6	x						-		x		x						
25	53	x					x			90,000	6		x		x	x		-		x		x						
26	35							x		100,000	5	x		x				-		x		x						
27	34	x			x		x			150,000	14		x	x		x		-		x		x						
28	34				x		x			70,000	7	x		x				-		x								
29	48			x				x		100,000	8		x	x				-		x	x							
30	55						x			60,000	11	x		x				-		x	x							
31	37	x		x		x		x		200,000	6	x	x	x				-		x	x	x						
32	35							x		80,000	8			x				-		x	x							
33	45			x			x			75,000	10	x						-		x	x							
34	30						x			90,000	4	x		x	x			-		x	x	x						
35	28	x		x		x				60,000	3	x		x				-		x		x						
36	28							x	x	90,000	5	x	x	x				-		x		x						
37	26			x						60,000	2					x		-		x		x						
38	25				x		x			70,000	4	x		x				-		x		x						
39	35				x			x		180,000	5	x		x				-		x		x						
40	45		x					x		100,000	10	x		x				-		x		x						
41	30			x			x			80,000	2	x				x		-		x		x						
Total	1634	18	6	9	6	2	10	29	2	4,085,000	330	33	8	26	6	9	0	-	0	41	8	33	1	1	1	1	1	1 1
%	40	44	15	21	15	5	24	74	5	99634	8	80	20	63	15	22	0	-	0	100	20	80	2	2	2	2	2	2 2

6				7				8			9			10		11			12						
d		f																							
i	ii	i	ii	a	b	c	d	a	b	c	a	b	c	a	c	a	e	f	a	b	c	d	e	f	g
			x	x					x			x		x	x				x				x		
			x	x				x					x		x								x		
			x	x					x			x			x				x	x					
			x	x						x			x		x				x			x		x	
			x	x						x					x										
			x	x				x			x	x			x		x								
		x	x	x				x					c		x			x							
			x	x						x				x											
			x						x		x			x											
			x	x			x	x			x	x			x										
			x	x						x					x				x						
			x	x						x	x	x			x										
			x	x				x							x				x						
			x	x				x			x	x			x				x						
			x	x				x					x		x				x			x			
		x		x					x			x			x					x					
			x	x						x		x			x				x						
			x	x						x				x											
			x	x					x		x	x							x	x					
			x	x				x		x	x	x			x				x			x	x	x	x
			x	x								x			x				x						
			x	x				x	x				x		x				x		x				
			x	x				x						x	x	x									
			x	x									x	x		x									
			x	x					x			x	x	x											
			x	x						x	x								x						
			x	x				x	x			x			x				x						
		x		x				x					x		x				x						
		x		x								x			x				x						
		x				x				x					x				x						
		x	x	x						x	x		x		x				x						
				x						x					x				x						
		x	x	x						x					x				x	x		x		x	
			x	x						x	x				x				x	x	x	x	x	x	
			x		x				x		x		x		x				x			x	x		
			x	x						x			x		x				x		x				
			x		x			x	x				x		x				x						
			x		x								x		x				x			x			
			x		x			x		x			x		x					x	x	x		x	
			x								x				x				x			x			
			x		x		x			x		x			x				x	x		x	x		
		7	34	33	6	1	2	14	10	17	12	15	14	6	35	2	1	1	27	7	4	10	6	6	1
		17	83	80	13	2	5	34	26	41	29	37	34	16	85	5	2	2	66	17	10	26	16	16	2

13				14		15								16		17			18		
a	b	c	d	a	b	a	b	c	d	e	f	g	h	a	b	a	b	c	a	b	c
					x									x		x					x
					x				x					x							x
					x									x			x				x
					x									x		x	x				x
	x	x			x									x							x
					x			x						x			x				x
					x									x			x	x			x
					x									x				x			x
					x									x							x
x					x			x						x			x	x		x	
					x							x		x							x
x					x			x						x			x	x		x	
					x			x				x		x						x	
					x							x		x			x				x
					x									x		x	x	x			x
					x									x				x			x
					x									x							x
					x									x				x			x
					x			x						x			x	x		x	
					x			x				x		x				x		x	
					x			x				x		x				x		x	
					x							x		x							x
					x			x						x						x	
					x							x		x		x	x	x			x
					x			x						x							x
					x									x				x	x		x
					x									x			x				
					x	x		x	x					x							
					x	x	x		x			x		x		x	x	x		x	
					x	x		x	x			x		x						x	x
					x							x		x			x				x
					x	x	x	x						x							
					x	x	x	x						x			x	x		x	
					x									x			x			x	x
					x									x		x					x
					x									x			x				x
					x									x				x			x
					x	x	x	x	x					x				x		x	
					x	x	x	x	x					x			x			x	
					x	x	x	x	x					x				x		x	
					x	x	x	x	x					x				x		x	
2	1	1	0	0	41	9	7	17	8	0	0	10	0	41	0	5	17	19	1	15	25
5	2	2	0	0	100	22	17	41	20	0	0	24	0	100	0	13	41	46	3	37	61

QUESTIONNAIRE NO. 2: SHEIKHS OF THE SURVIVING COMMUNITIES

THE RESPONDENT									INFRASTRUCTURE DETAILES							IMMEDIATE RESPONSES											
Res No	Location	District	Education					Sheikh since (year)	2	3	4	5		6		7						8	9	10			
			0	1	2	3	4		No	No	No	a	b	a	b	a	b	c	d	e	f	DAYS	%	a	b	c	d
1	AL-KOLA	ANS			x			1973	67	43	460	x		x		x						15	80			x	
2	AL-MARWAN	DAWRAN		x				1970	120	100	100	x		x		x					x	15	50	x			
3	MOWGHAR	ANS		x				1970	45	24	350	x		x							x	30	0				
4	RUSABAH	JAHRAN			x			1980	1400	1400	3400	x		x		x						01	70				x
5	AL-HUSEIN	ANS		x				1962	50	35	400	x		x		x					x	15	50	x			x
6	WATHAN	DUBAH			x			1954	600	80	6000	x		x		x					x	20	60	x			
7	DUBAH	DUBAH						1980	1000	150	10,000	x		x		x						20	90		x		
8	AL-MAHILLA	DHAMAR				x		1976	250	125	3000	x		x		x						15	0			x	
9	AL-HARF	DAWRAN				x		1978	50	10	450	x		x		x					x	30	50	x			
10	AR RIZWAH	DAWRAN				x		1970	75	19	690	x		x							x	20	60	x			
	TOTAL			4	3	3	0		3647	1986	25740	10		10		8	0	0	0	0	6	181	510	5	1	2	2
11	AL-SULAH	DHAMAR						1964	440	78	3500	x	x	x													
12	HAMMAM	HAMALI						1984	200	120	120	x	x	x													
13	MOWSHAK	DUBAH	x		x			1964	550	300	4900	x	x	x													
14	AL-HUDAH	DHAMAR				x		1960	1200	350	10,500	x	x	x													
15	AL-MAHAL	DHAMAR		x	x			1974	135	80	580	x	x	x													
16	AL-NASIR	DHAMAR						1975	550	78	2750	x	x	x													
17	AL-KHADAR	DHAMAR		x		x		1969	300	50	1800	x	x	x													
18	AL-GUHAIFAH	DHAMAR						1970	700	110	4000	x	x	x													
19	JAB JAB	DHAMAR		x	x			1965	400	30	2000	x	x	x													
20	BAITAL	DHAMAR		x				1984	350	10	1760	x	x	x													
21	M.SAKANIYAN	DHAMAR						1972	300	95	1600	x	x	x													
	TOTAL		1	8	7	6	0		6772	3287	60320	21	21	19	0	0	0	0	0	0	7	232	1375	14	1	3	3
	Averages/	% ages							417.7	166.5	2872	100 %	100%	90	0	0	0	0	0	0	33	11.0	65%	67	5	14	14

QUESTIONNAIRE NO. 2: SHEIKHS OF THE SURVIVING COMMUNITIES

LOSSES ASSESSMENT, PLANNING AND COMMUNITY MANAGEMENT																									
11		12						13		14															
										a		b		c		d		e		f		g		h	
a	b	a	b	c	d	e	f	a	b	i	ii	i	ii	i	ii	i	ii	i	ii	i	ii	i	ii	i	ii
x			x						x																
x		x	x		x			x			x		x				x								
x		x					x	x									x								
x		x	x					x			x						x	x							
x		x	x					x			x					x									
x		x	x		x				x																
x			x	x					x																
x		x	x					x					x						x						
x		x	x					x				x						x							
x		x	x					x				x						x							
10	0	8	9	1	2	0	1	7	3	0	3	2	2	0	0	1	3	3	1	0	0	0	0	0	0
	x	x							x																
x			x				x			x						x									
	x	x	x		x			x			x	x					x								
x		x	x		x			x				x				x									
x		x	x					x			x					x									
	x								x																
	x								x																
	x																								
	x																								
x			x		x		x	x		x															
x		x	x		x		x		x																
16	6	13	14	1	6	0	4	11	7	2	5	4	2	0	0	4	4	3	1	0	0	0	0	0	0
71	29	62	67	5	29	0	19	52	33	10	24	19	10	0	0	19	19	14	5	0	0	0	0	0	0

QUESTIONNAIRE NO. 2: SHEIKHS OF THE SURVIVING COMMUNITIES

LOSSES ASSESSMENT, PLANNING AND COMMUNITY MANAGEMENT																			RECONSTRUCTION PROGRAMME						
15		16							17		18		19		20				21			22			
a	b	a	b	c	d	e	f	h	a	b	a	b	a	b	a	b	c	d	a	b	c	a	b	c	d
x		25							x			x		x	x				x			15	1	1	
x		120	2		1	1			x		x			x	x						x	40	1	1	
x		16								x	x			x	x						x	11			
x		540		1	1	1		1	x		x			x	x						x	100	1	1	
x		35			1			1	x		x			x		x				x		13			
x		60		1	1	1				x	x			x	x				x			35	1	1	
x		110	40	1					x		x			x	x				x			95	1		
x		120			1			1		x		x		x	x					x		60	1		
x		10			1			1		x		x		x	x					x		8			
x		19			1			1		x		x		x	x					x		12			
10	0	1046	42	3	7	3	0	5	5	5	6	4	0	10	9	1	0	0	3	4	3	387	6	4	0
x		60								x		x		x	x					x		50			
x		95								x		x		x	x						x	75			
x		300			1			1		x		x		x	x					x		150	1		
x		350							x			x		x	x					x		100			
x		65								x		x		x	x						x	20			
x		78								x		x		x	x					x		50			
x		50								x		x		x	x					x		45			
x		110								x		x		x	x					x		93			
x		30								x		x		x	x				x			16			
x		10				1		1		x		x		x	x				x			6	1	1	
x		95			1	1		1		x		x		x	x					x		60	1	1	
21	0	2288	42	3	9	5	0	8	6	16	6	15	0	21	20	1	0	0	5	11	5	1051	8	6	0
100	0	109									29	71	0	100	95	5	0	0	24	52	24	50			

QUESTIONNAIRE NO. 2: SHEIKHS OF THE SURVIVING COMMUNITIES

RECONSTRUCTION PROGRAMME																					
22					23					24	25					26				27	
e	f	g	h	i	a	b	c	d	e	%	a	b	c	d	e	a	b	c	d	a	b
1										40	x										x
									x	70	x										x
										30	x										x
1		1							x	80	x										x
						x				65	x										x
1			1							30				x					x		x
		1	1							90	x										x
1										50	x										x
										40	x	x									x
										35	x										x
4	0	2	2	0	0	1	0	0	2	630	9	1	0	1	0	0	0	0	1	0	10
										15	x										x
										20	x										x
1										60	x										x
										70	x										x
										30	x										x
										36	x	x	x								x
										10				x		x					
										15	x	x	x								x
										50	x										x
										40	x										x
1	1									37	x	x	x								x
6	0	2	2	0	0	1	0	0	2	903	19	4	3	2	0	1	0	0	1	0	20
										43%	90	19	14	10	0	5			5	0	95%

QUESTIONNAIRE NO. 3: GOVERNMENT ENGINEERS AND OTHERS

PARTICULARS OF RESPONDENT					SITUATION BEFORE THE 1982 EARTHQUAKE																EMERGENCY RELIEF AFTER EARTHQUAKE					
Res No	Occupation	Employer Ministry	Present position	Position during Reconstruction programme	2		3		4		5		6		7		8		9		10					
					a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	c	d	e	g
1	Architect	Construction	Dy Gen Manager	Res Architect		x		x				x		x		x				x	x					x
2	Civil Engineer	Urban Planning	Senior Engineer	Res Engineer		x		x				x		x		x				x	x	x				x
3	-do-	-do-	Director	-do-		x		x				x		x		x				x	x					x
4	-do-	Construction	Director General	Gen Man (S/H)		x		x				x		x		x				x	x	x				x
5	-do-	-do-	Dy Dir Gen (M)	D/Dir Gen (S/H)		x		x				x		x		x				x	x	x				x
6	-do-	-do-	Civil Engineer	Civil Engineer		x		x				x		x		x				x	x					x
7	-do-	-do-	Dir Gen (Recons)	Manager (Cons)		x		x				x		x		x				x	x					
8	-do-	-do-	Manager (Lab)	Res Engr (Cons)		x	x			x		x		x		x				x	x	x	x	x	x	
9	Civil Tech	-do-	Civ Works Supr.	Supervisor (T/K)		x		x				x		x		x				x	x	x		x	x	
10	-do-	-do-	-do-	Foreman (S/H)		x		x				x		x		x				x	x	x				
11	-do-	-do-	-do-	-do-		x		x				x		x		x				x	x					
12	Civil Engineer	-do-	Dir Gen (Maint)	Dir (Repairs)		x		x				x		x		x				x	x					
13	Architect	-do-	Senior Architect	Res Architect		x		x				x		x		x				x	x					
14	Civil Engineer	-do-	Senior Engineer	Res Engr (S/H)		x		x				x		x		x				x	x					
15	-do-	-do-	Dy Dir General	Civ Engr (T/K)		x		x				x		x		x				x	x					
16	-do-	-do-	Civ Engr (R & M)	Civil Engr (R/P)		x		x				x		x		x				x	x					
17	-do-	O/M Resources	Civil Engineer	-do-		x		x				x		x		x				x	x					
18	Geologist	-do-	Senior Geologist	Geologist		x		x				x		x		x				x	x					
19	-do-	-do-	Dy Dir General	Sr Geologist		x		x			x			x		x				x	x					
20	-do-	-do-	Director General	Chairman (E/O)		x		x			x			x		x				x	x					x
	Total				0	20	1	19	0	1	2	18	0	20	0	20	0	0	0	20	20	8	1	2	2	7
	Percentage					100	5	95		5	10	90		100		100				100	100	40	5	10	10	35

QUESTIONNAIRE NO. 3: GOVERNMENT ENGINEERS AND OTHERS

EMERGENCY RELIEF AFTER EARTHQUAKE																							HOUSING RECONSTRUCTION PROGRAMME							
11	12				13				14				15		16							17		18						
Days	a	b	c	d	a	b	c	d	a	b	c	d	a	b	a	b	c	d	e	f	g	a	b	a	b	c	d	e	f
1-30		x				x			x					x							x		x						x
1-60		x				x			x		x			x							x		x	x			x		
1-30		x			x	x			x					x	x						x		x						x
1-30		x							x					x	x	x	x	x	x	x	x		x						x
1-30		x							x					x	x					x			x	x					
1-7			x		x	x			x			x		x	x	x			x	x			x	x					x
2-30		x							x	x				x	x	x	x	x	x	x			x	x		x	x	x	
1-15		x							x	x				x	x				x	x			x	x					
1-30			x			x			x		x			x	x								x	x		x			
1-30		x			x				x					x	x					x			x	x					
1-7				x	x							x		x	x				x				x	x	x		x		
1-21		x							x					x	x						x		x	x					
1-15		x							x					x	x								x						x
2-15		x							x					x	x								x	x					
1-30		x							x					x	x								x						x
1-15		x			x				x					x					x				x				x		x
1-15		x							x					x							x		x	x					x
1-15		x							x					x							x		x	x					
1-15		x							x					x							x		x	x					
1-15		x							x					x							x		x	x				x	
Total	0	17	2	1	5	5	0	0	19	2	2	2	0	20	13	3	2	2	6	6	9	0	20	14	1	2	4	2	8
%age	0	85	10	5	25	25	0	0	95	10	10	10	0	100	65	15	10	10	30	30	45	0	100	70	5	10	20	10	40

QUESTIONNAIRE NO. 3: GOVERNMENT ENGINEERS AND OTHERS

HOUSING RECONSTRUCTION PROGRAMME																															
19				20								21																			
												a		b		c		d		e		f		g		h		i	
a	b	c	d	a	b	c	d	e	f	g	h	i	ii	i	ii	i	ii	i	ii	i	ii	i	ii	i	ii	i	ii	i	ii
		x										x	x			x	x	x	x			x	x	x	x				
			x									x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
			x									x	x			x	x	x	x			x	x	x	x				
			x									x		x		x	x	x	x	x	x	x	x	x	x	x	x		
			x									x	x	x		x	x	x	x	x	x	x	x			x	x		
			x									x	x	x		x	x	x	x	x	x	x	x	x	x				
		x										x	x			x	x	x	x	x	x	x	x	x	x				
		x										x	x	x		x	x	x	x					x	x				
			x									x	x	x		x	x	x	x	x	x	x	x	x	x	x	x		
	x											x	x	x		x	x	x	x	x	x	x	x	x	x				
	x											x	x	x		x	x	x	x	x	x	x	x	x	x				
		x										x	x			x	x	x	x	x	x	x	x	x	x			x	x
		x										x	x			x	x	x	x			x	x						
	x						x																						
		x										x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
	x																												
		x										x	x			x	x	x	x	x	x	x	x	x	x				
			x									x	x			x	x	x	x			x	x	x	x			x	x
	x											x	x			x	x	x	x	x	x	x	x	x	x			x	x
		x										x	x			x	x	x	x			x	x	x	x			x	x
0	5	8	7	0	0	0	1	0	0	0	0	18	17	9	0	18	18	18	18	12	14	17	17	16	16	5	5	6	6
0	25	40	35	0	0	0	5	0	0	0	0	90	85	45	0	90	90	90	90	60	60	85	85	80	80	25	25	30	30

QUESTIONNAIRE NO. 3: GOVERNMENT ENGINEERS AND OTHERS

HOUSING RECONSTRUCTION PROGRAMME																OTHER INFRASTRUCTURE													
21								22				23		24		25		26		27				28					
j		k		l		n		Location		Design																			
i	ii	i	ii	i	ii	i	ii	a	b	a	b	a	b	c	d	a	b	a	c	a	b	c	d	a	b	c	d	e	f
					x			x			x		x	x		x			x			x				x			
		x			x	x	x	x			x		x	x	x	x			x			x			x				
					x	x	x	x			x		x		x	x			x		x	x			x				
x	x	x			x			x			x		x	x	x	x		x								x	x		
x	x				x			x			x		x	x	x	x			x		x	x		x	x	x			
x	x	x			x				x		x		x	x	x	x			x		x	x		x	x		x		x
x	x								x		x		x	x	x	x	x		x		x	x			x	x	x		
								x			x		x	x		x	x	x				x		x		x			
x	x				x				x		x		x	x	x	x	x		x		x	x		x		x			x
x	x	x	x	x					x		x		x	x	x	x			x		x	x		x	x				x
x	x							x			x		x	x	x	x			x		x	x							x
				x				x			x		x	x	x	x		x								x			
		x			x	x	x	x			x		x	x	x	x		x								x			
								x			x		x	x	x	x		x						x		x			
		x			x	x	x	x			x		x	x	x	x		x						x		x			
x	x												x		x	x		x					x						x
					x				x		x		x		x	x		x						x	x				
				x		x	x	x			x		x	x	x	x		x				x		x		x			
		x			x	x	x		x		x		x		x	x			x			x		x					
		x			x	x		x			x		x	x	x	x			x			x				x			
8	8	8	1	3	12	7	6	14	6	0	19	0	20	16	18	20	3	9	11	0	7	13	1	10	7	12	3	0	5
40	40	40	5	15	60	35	30	70	30	0	95	0	100	80	90	100	15	45	55	0	35	65	5	50	35	60	15	0	25

QUESTIONNAIRE NO. 3: GOVERNMENT ENGINEERS AND OTHERS

OVERALL VIEWS ON RECONSTRUCTION PROGRAMME																									
29		30																31		32					
		a							b				c												
a	b	i	ii	iii	iv	v	vi	vii	i	ii	iii	iv	i	ii	iii	iv	a	b	a	b	c	d	e	f	g
x			x				x	x	x				x		x		x								
x							x	x			x				x			x	x	x					
x		x	x			x	x	x	x						x			x				x			
x							x	x	x		x	x			x			x	x	x	x	x		x	x
x			x			x	x		x		x		x		x	x		x	x	x	x				x
x			x			x	x	x	x		x		x		x	x		x	x	x	x	x			
x			x		x		x	x	x	x			x	x	x			x	x			x	x	x	
	x																	x	x	x	x				
x			x				x			x	x		x	x				x	x	x	x		x		
x			x				x	x	x		x							x	x	x	x				
	x		x			x	x		x	x	x		x		x			x	x	x	x				
x		x	x		x			x			x		x					x	x	x		x			
x			x					x			x		x					x	x	x		x			
x			x			x	x	x			x		x					x	x	x					x
x			x					x		x	x		x		x			x		x	x		x		
x			x				x											x					x		
	x																x								
	x																x								
	x																x								
x		x	x		x		x	x	x	x	x		x		x	x		x	x						x
15	5	3	14	0	3	5	13	12	9	5	12	1	11	2	10	3	4	16	13	12	8	6	4	2	4
75	25	15	70	0	15	25	65	60	45	25	60	5	55	10	50	15	20	80	65	60	40	30	20	10	20

Annex 6

TECHNICAL SURVEY DATA

QUESTIONNAIRE NO. 4: TECHNICAL OBSERVATIONS OF THE SURVEYORS

Sr No	GENERAL INFORMATION									HOUSING PROGRAMME																
	Location	District	Type of Building	Year of Construction	Surveyor			Owner		1				2												
					Engr	Supr	Tech	Govt	Pvt	a	b	c	d	a	b	c	d	e	f	g	h	i	j	k	l	m
1	Manqadah	Dhamar	House	1985			x		x	x				x	x	x				x	x					
2	Marwan	Anis	-do-	1988	x				x				x	x	x	x	x	x	x	x	x	x		x	x	
3	Marwan	Anis	-do-	1984	x				x	x				x	x	x				x	x					
4	Marwan	Anis	Mosque	1983	x			x																		
5	Marwan	Anis	School	1984	x			x																		
6	Marwan	Anis	House	1984	x				x	x				x	x	x				x	x					
7	Beihan	Dawran	-do-	1968		x			x				x	x	x	x	x	x	x	x	x	x	x	x	x	
8	Beihan	Dawran	-do-	1988		x			x		x			x	x	x				x	x					
9	Beihan	Dawran	-do-	1988		x			x		x			x	x	x				x	x					
10	Beihan	Dawran	-do-	1988		x			x		x			x	x	x				x	x					
11	Al-Jami	Dhamar	-do-	1966		x			x			x		x	x	x	x	x	x	x	x	x				
12	Al-Jami	Dhamar	-do-	1962		x			x			x		x	x	x	x	x	x	x	x	x	x	x	x	
13	J At-Tahir	Dawran	-do-	1986	x				x		x			x	x	x				x	x					
14	J At-Tahir	Dawran	-do-	1986	x				x		x			x	x	x				x	x					
15	J At-Tahir	Dawran	-do-	1920	x				x				x	x	x	x	x	x	x	x	x	x	x	x	x	x
16	J At-Tahir	Dawran	-do-	1925	x				x				x	x	x	x	x	x	x	x	x	x		x	x	
17	Manqadah	Dhamar	-do-	1987			x		x				x	x	x	x	x	x	x	x	x	x	x	x	x	
18	Ar-Rizwah	Dawran	-do-	1968		x			x				x	x	x	x	x	x	x	x	x	x		x	x	
19	Bir Khabut	Dhamar	-do-	1945			x		x			x		x	x	x	x	x	x	x	x	x	x	x		
20	Bir Khabut	Dhamar	H/Centre	1985			x	x																		
21	Bab Al-Falak	Dhamar	House	1984		x			x	x				x	x	x				x	x					
22	Bab Al-Falak	Dhamar	House	1970		x			x				x	x	x	x	x	x	x	x	x	x		x	x	
23	Bab Al-Falak	Dhamar	House	1984		x			x	x				x	x	x				x	x					
24	Al-Salah	Dhamar	House	1965		x			x			x		x	x	x	x	x	x	x	x	x	x	x	x	
25	Ar-Rusabah	Jahran	House	1950			x		x				x	x	x	x	x	x	x	x	x	x	x	x	x	
26	Ar-Rusabah	Jahran	Mosque	1984			x	x																		
27	Ar-Rusabah	Jahran	House	1984			x		x	x				x	x					x	x					
28	Al-Kola	Ans	House	1984			x		x	x				x	x					x	x					
29	Al-Kola	Ans	House	1985			x		x				x	x	x		x	x	x	x	x	x	x	x	x	x
30	Al-Kola	Ans	House	1984			x		x	x				x	x					x	x					
31	Al-Kola	Ans	House	1984			x		x	x				x	x					x	x					
32	M Ash-Sharq	M/A-Sharq	House	1985	x				x		x			x	x					x	x					
33	Hammam Ali	Anis	House	1985	x				x	x				x	x					x	x					
34	Ma'abar	Jahran	House	1988	x				x				x	x	x		x			x	x			x	x	
35	Dhamar	Dhamar	House	1989	x				x				x	x	x		x	x	x	x	x			x	x	
36	Dawran	Dawran	House	1984	x				x	x				x	x					x	x					
37	Dawran	Dawran	H/Centre	1984	x			x																		
38	Dawran	Dawran	School	1984	x			x																		
	Total				16	11	11	6	32	11	6	4	11	32	32	32	15	14	14	32	32	13	8	14	13	2
	Percentages				42	28	29	16	84	34	19	13	34	100	100	100	47	44	44	100	100	41	25	44	41	6

QUESTIONNAIRE NO. 4: TECHNICAL OBSERVATIONS OF THE SURVEYORS

HOUSING PROGRAMME																														
3		4		5		6								EXISTING											ADDITIONAL					
														a			b		c		d		e		a		b		c	
a	b	a	b	a	b	a	b	c	d	e	f	g	h	R	O	I	O	I	O	I	O	I	O	I	O	I	O	I	O	I
x		x			x	x	x	x	x		x	x	x			x		x							x		x		x	
	x		x											x				x		x	x			x						
x		x			x		x	x	x		x					x		x							x		x		x	
x		x			x		x		x			x				x		x							x				x	
	x		x											x				x		x	x			x						
x	x	x			x	x	x	x	x	x	x	x				x		x							x		x		x	
x	x	x			x		x				x					x		x									x			
x	x	x			x		x	x	x		x	x				x		x							x		x		x	
	x		x											x				x		x										
x			x											x				x		x	x			x						
x	x	x					x		x	x	x					x		x							x		x		x	
x	x	x			x		x									x		x							x					
	x		x		x									x				x		x	x			x						
	x		x											x				x		x	x			x						
	x		x											x				x		x	x			x						
	x		x											x				x		x	x			x						
	x		x											x				x		x	x			x						
x			x													x		x												
	x		x											x				x		x	x			x			x			
x			x													x		x												
	x		x											x				x		x	x			x						
	x		x											x				x		x	x			x						
x		x														x		x							x				x	
x			x		x		x	x	x		x	x				x		x												
	x		x											x				x		x	x			x						
x			x													x		x												
x		x														x		x							x				x	
x	x				x		x		x							x		x							x				x	
x					x	x	x	x	x		x	x				x		x												
	x	x			x		x		x		x			x				x		x	x			x						
			x											x				x		x	x			x						
x		x	x													x		x							x				x	
		x			x		x	x	x		x	x																		
18	20	13	19	0	13	3	13	7	11	2	10	7	1	15	0	17	0	32	0	15	14	0	0	14	11	0	8	0	9	0
47	63	40	60	0	41	10	41	22	34	6	31	22	3	47	0	53	0	100	0	47	44	0	0	44	34	0	25	0	28	0

QUESTIONNAIRE NO. 4: TECHNICAL OBSERVATIONS OF THE SURVEYORS

HOUSING PROGRAMME							HOUSING AND OTHER INFRASTRUCTURE																			
7 ADDITIONAL				8			9			10						11		12			13	14			15	
d		e																								
O	I	O	I	a	c	f	a	b	c	a	b	c	d	e	f	a	b	a	c	d	Kg/Cm²	b	c	d	a	b
		x		x			x			x			x	x	x	x		x			2.5	x			x	
				x				x		x	x	x					x	x			3.0		x		x	
		x		x				x		x			x	x	x	x		x			2.8	x			x	
								x		x			x	x	x	x		x			2.3	x			x	
								x		x			x	x	x	x		x			3.1	x			x	
				x				x		x			x	x	x	x		x			2.3	x			x	
				x			x			x	x	x					x	x			2.5		x		x	
x		x		x			x						x	x	x	x		x			2.7		x		x	
		x		x				x					x	x	x	x		x			2.9		x		x	
		x		x				x					x	x	x	x		x			3.2		x		x	
				x			x			x	x	x	x	x	x		x		x		2.8		x		x	
				x			x			x	x	x	x	x	x		x			x	2.8		x		x	
x				x				x					x	x	x	x		x			2.4	x			x	
				x				x					x	x	x	x		x			2.2	x			x	
				x				x		x	x	x					x			x	2.6			x		x
				x			x			x	x	x					x		x		2.3		x			x
				x			x			x	x	x	x				x		x		2.7		x			x
				x				x		x	x	x	x	x	x		x			x	2.8		x		x	
				x			x			x	x	x	x	x	x		x		x		2.8		x		x	
									x	x			x	x	x	x		x			3.1		x		x	
				x				x					x	x		x		x			2.5	x			x	
				x			x			x	x	x					x		x		2.3		x			x
				x				x		x			x	x	x	x		x			2.5	x			x	
				x				x		x	x	x	x	x	x	x		x			3.0		x		x	
				x			x			x	x	x					x			x	3.0		x		x	
							x			x		x	x	x		x		x			2.7			x	x	
		x		x				x		x			x	x	x	x		x			2.9		x		x	
					x				x	x			x	x	x	x		x			2.6		x		x	
				x			x					x	x	x	x		x	x			2.7		x		x	
						x			x	x			x	x	x	x		x			2.9		x		x	
				x				x		x			x	x	x	x		x			2.8	x			x	
		x		x				x					x	x	x	x		x			2.7	x			x	
		x		x			x						x	x	x	x		x			2.7	x			x	
				x			x			x			x	x	x	x		x			2.6		x		x	
				x			x			x			x	x	x	x		x			3.0		x		x	
		x		x				x					x	x		x		x			3.1		x		x	
									x	x			x	x	x	x		x			2.9		x		x	
								x		x			x	x	x	x		x			2.8		x		x	
2	0	9	0	30	1	1	15	19	4	28	12	14	32	31	28	26	12	29	5	4		12	24	2	34	4
5	0	28	0	94	3	3	39	50	11	74	32	37	34	82	74	68	32	76	13	11		32	63	5	89	11

QUESTIONNAIRE NO. 4: TECHNICAL OBSERVATIONS OF THE SURVEYORS

HOUSING AND OTHER INFRASTRUCTURE																						
16				17	18		19		20			21	22			23	24		25			
a	b	c	d	X-section cm²	a	b	a	b	a	b	e	a/b	a	b	d	Cost (YR)	a	b	b	c	d	e
x		x	x	30x20		x		x	x			1/30	x			75,000	x		x		x	x
		x		40x25	x		x			x	x	1/25	x			250,000		x				
x		x	x	30x20		x		x	x			1/30	x			75,000	x		x	x		x
x		x	x	30x20	x			x	x			1/30	x			300,000	x		x		x	
x		x	x	30x20	x			x	x			1/30	x			300,000	x		x		x	
x		x	x	30x20		x		x	x			1/30	x			75,000	x		x	x		
		x		40x30	x		x			x		1/40	x			120,000		x				
x		x	x	30x20		x		x		x		1/30	x			100,000	x		x	x		
x		x	x	30x20		x		x		x		1/30	x			100,000	x		x	x		
x		x	x	30x20		x		x		x		1/30	x			100,000	x		x	x		
		x		30x20	x		x			x	x	1/60		x		38,000	x			x		
		x		30x20	x		x			x		1/30		x		40,000	x		x			
x		x	x	30x20		x		x		x		1/30	x			100,000	x		x			
x		x	x	30x20		x		x		x	x	1/30	x			100,000	x		x			
					x		x			x	x	1/40	x			1,800	x			x		
					x		x			x		1/25	x			2,000	x			x		
					x		x			x	x	1/60		x		250,000		x				
		x		30x20	x		x			x		1/40	x			42,000		x				
		x		30x20	x		x			x		1/40		x		10,000	x		x			
x				30x20		x		x	x			1/30	x			80,000	x		x	x		
x		x	x	30x20		x		x	x			1/30	x			70,000	x		x			
					x			x		x	x	1/25	x			62,000		x				
x		x	x	30x20		x		x	x			1/30	x			70,000	x		x			
		x		30x20	x		x			x		1/40		x		30,000	x		x			
		x		60x30	x		x			x	x	1/60			x	20,000		x				
x		x	x	30x20	x			x	x			1/30	x			200,000	x		x	x	x	
x		x	x	30x20		x		x	x			1/30	x			75,000	x		x	x		
x		x	x	30x20		x		x	x			1/30	x			70,000	x		x			
x		x	x	30x20		x		x		x	x	1/30	x			150,000		x				
x		x	x	30x20		x		x	x			1/30	x			70,000	x		x	x		
x		x	x	30x20		x		x	x			1/30	x			70,000	x		x			
x		x	x	30x20		x		x	x			1/30	x			100,000	x		x	x		
x	x		x	30x20		x		x	x			1/30	x			70,000	x		x	x		
x		x		30x20	x			x	x			1/30	x			210,000		x				
x		x	x	30x20		x		x	x			1/30	x			250,000		x				
x		x	x	30x20		x		x	x			1/30	x			70,000	x		x	x		
x		x	x	30x20	x		x		x			1/30	x			260,000	x		x		x	
x		x	x	30x20	x			x	x			1/30	x			300,000	x		x	x	x	
26	1	32	24		18	20	12	26	20	18	8		32	5	1		29	9	26	16	6	2
68	3	84	63		47	53	32	68	53	47	21		84	13	3		76	24	68	42	16	5

Annex 7

STATISTICAL ANALYSIS CHARTS

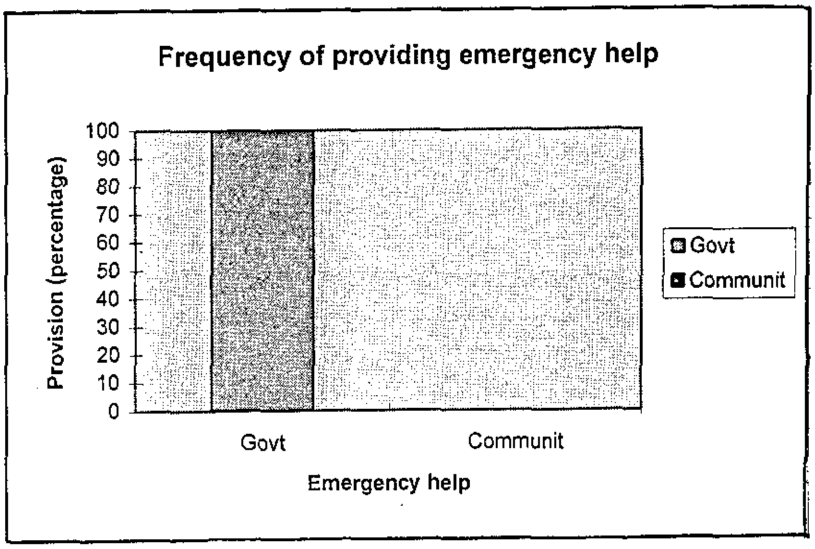


Chart 1

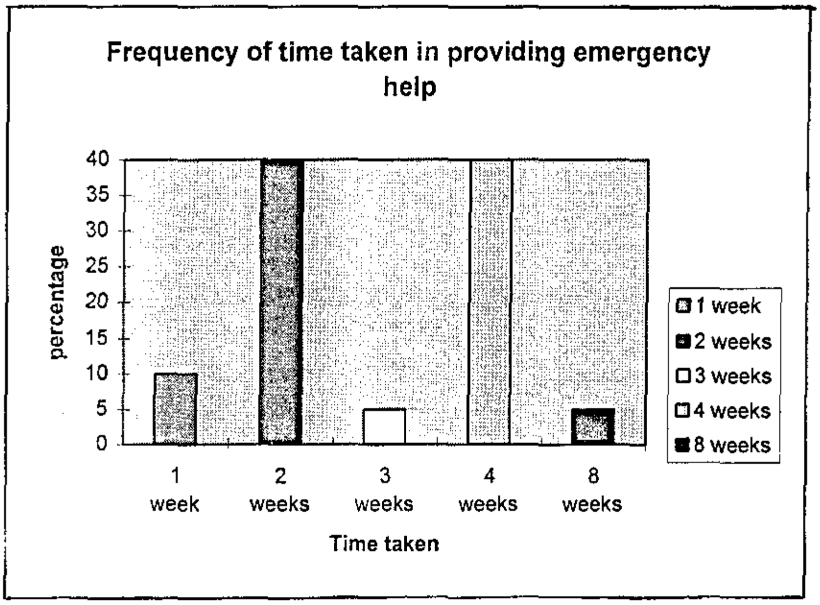


Chart 2

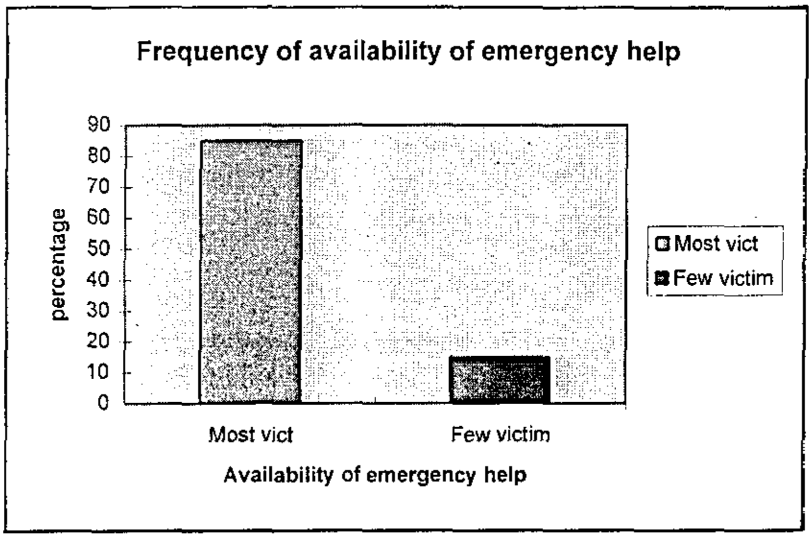


Chart 3

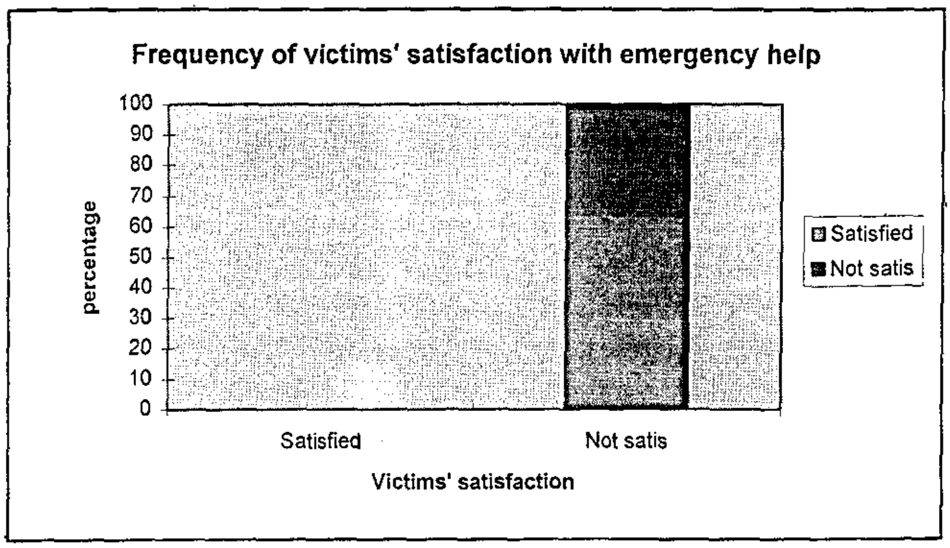


Chart 4

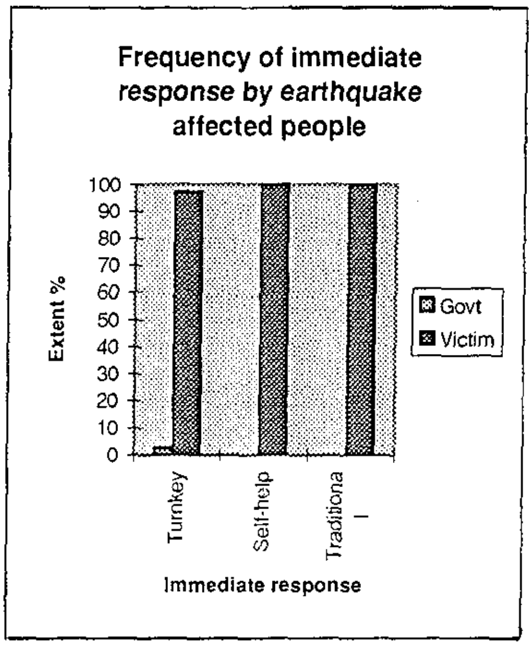


Chart 5

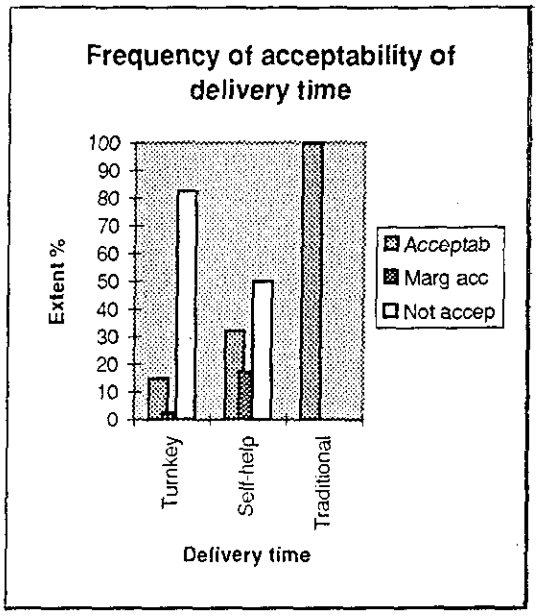


Chart 6

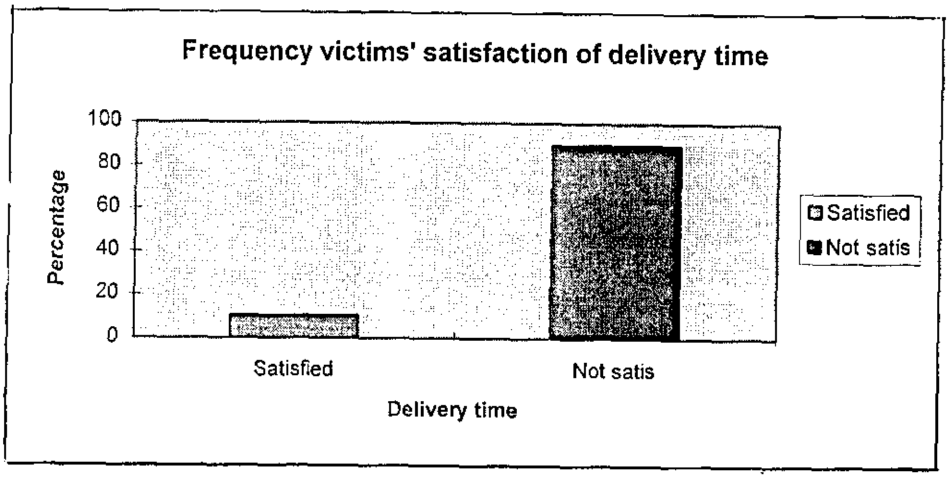


Chart 7

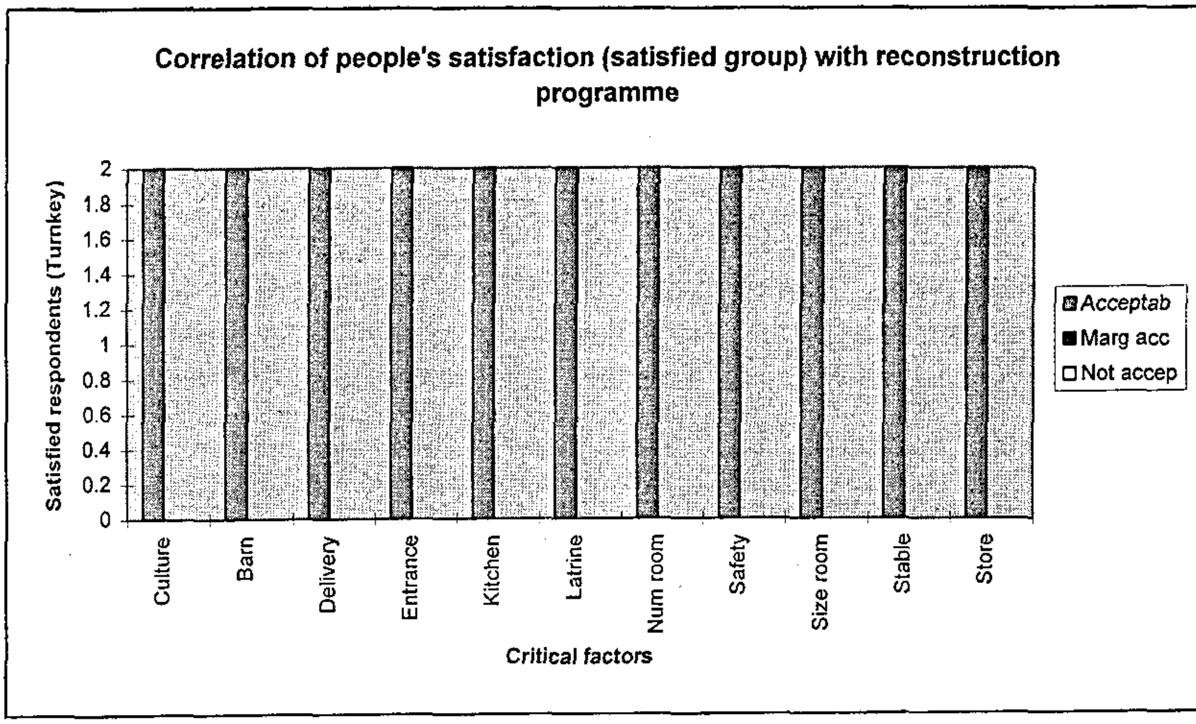


Chart 8

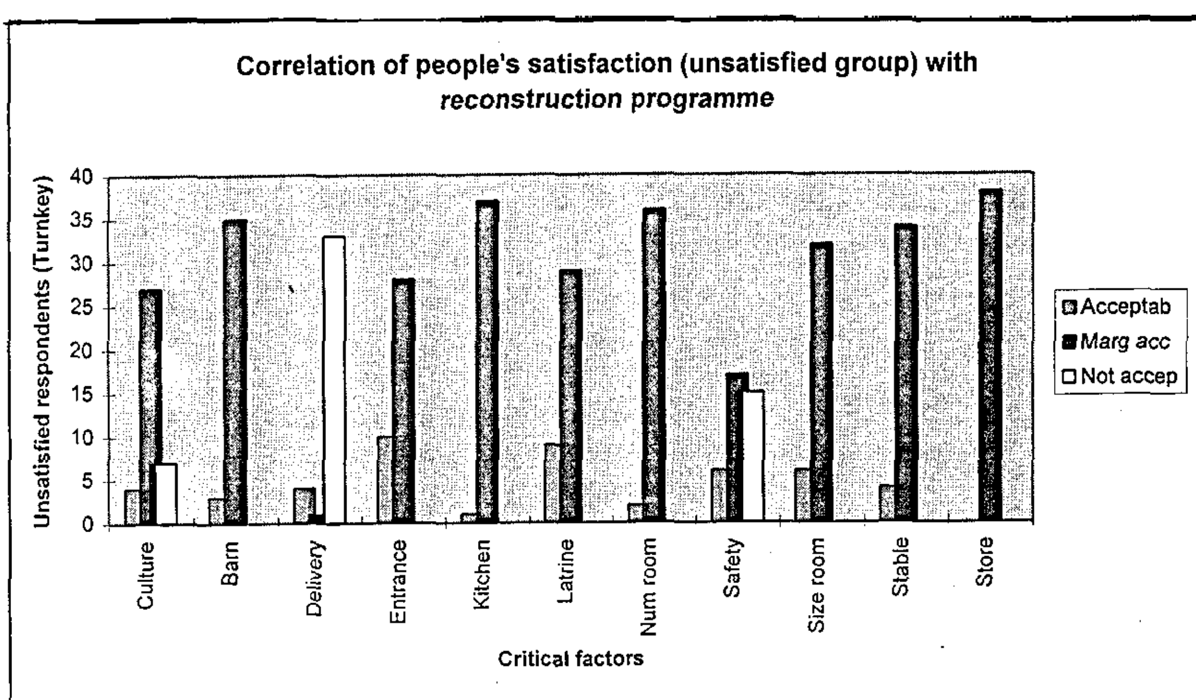


Chart 9

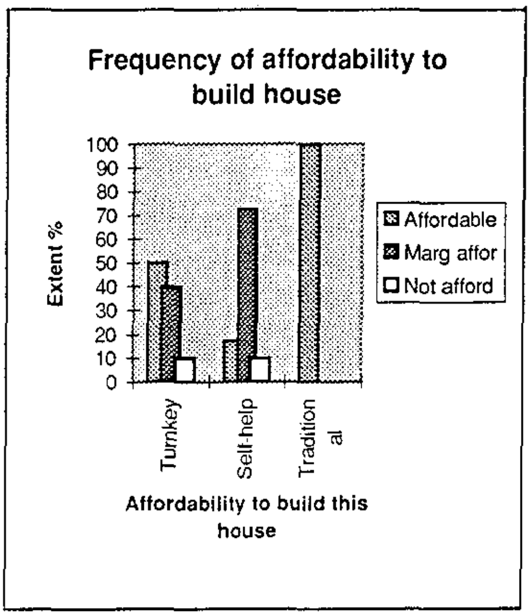


Chart 10

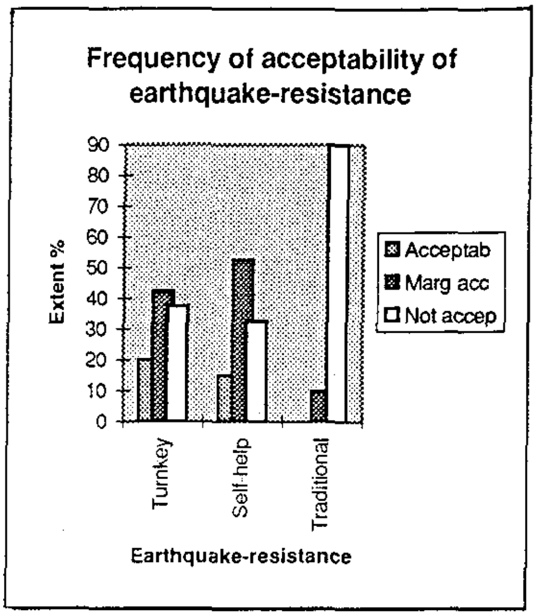


Chart 11

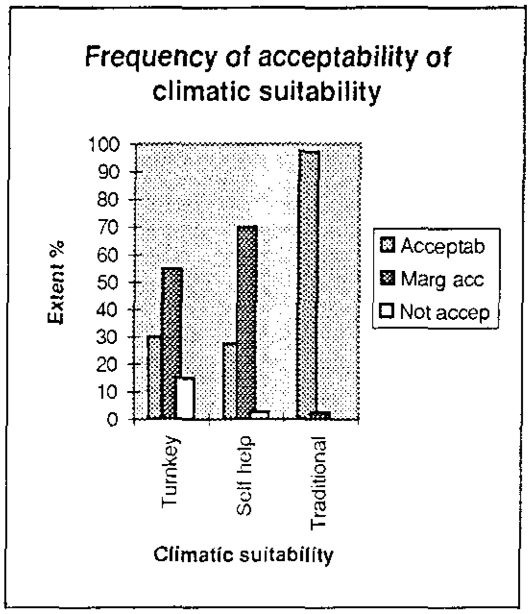


Chart 12

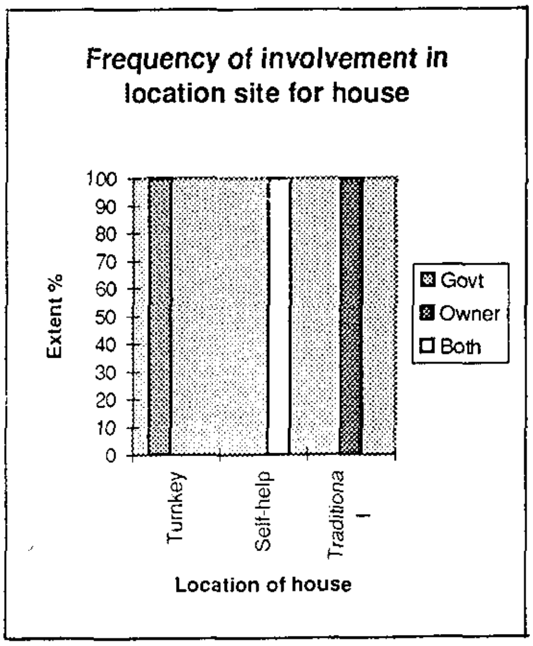


Chart 13

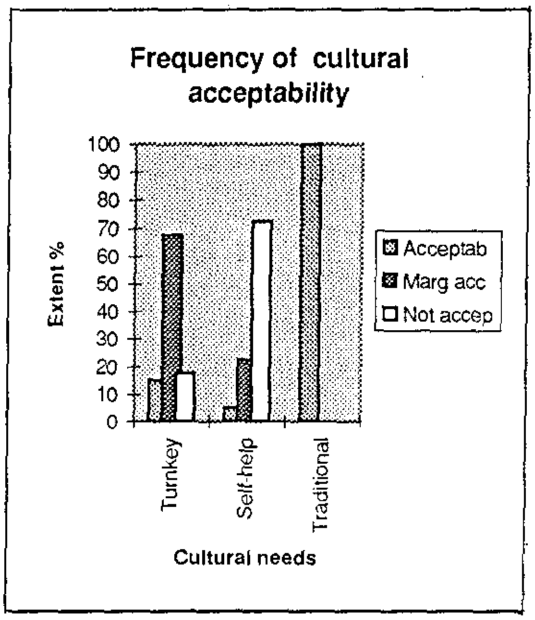


Chart 14

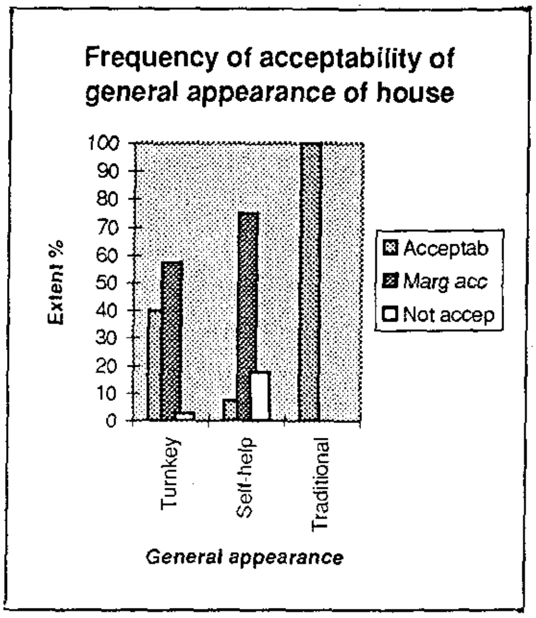


Chart 15

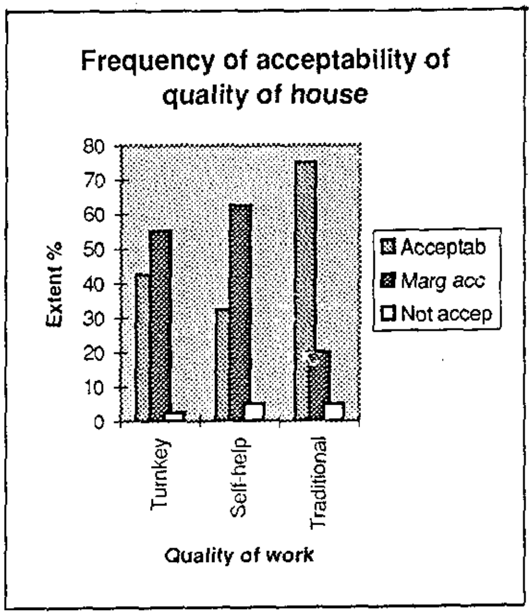


Chart 16

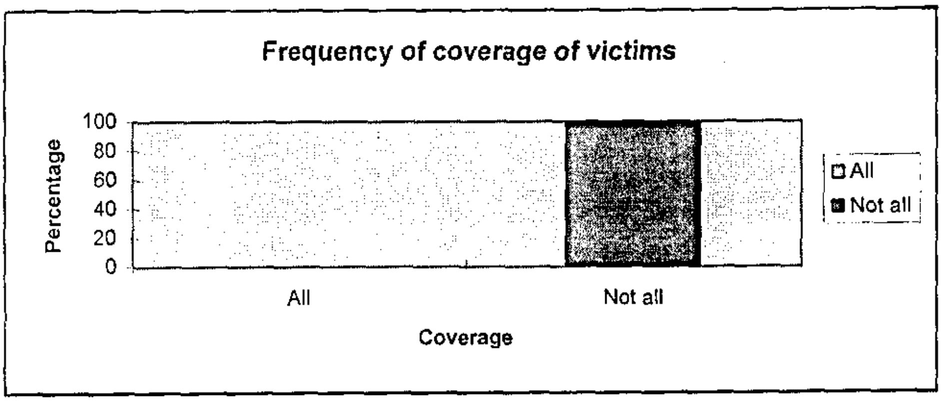


Chart 17

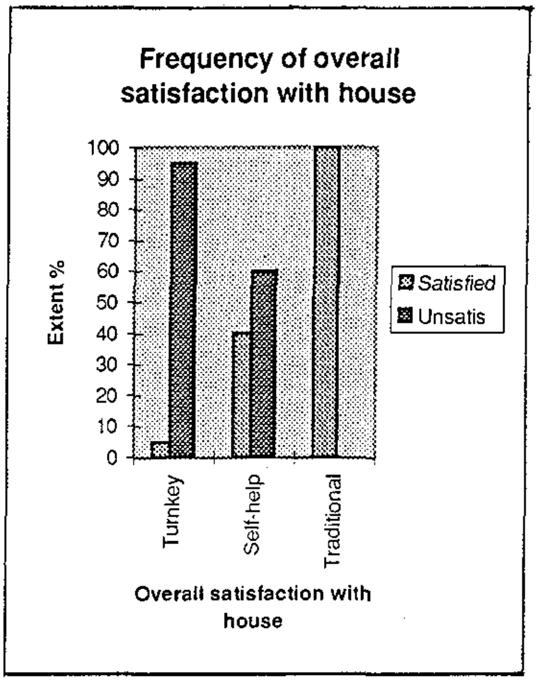
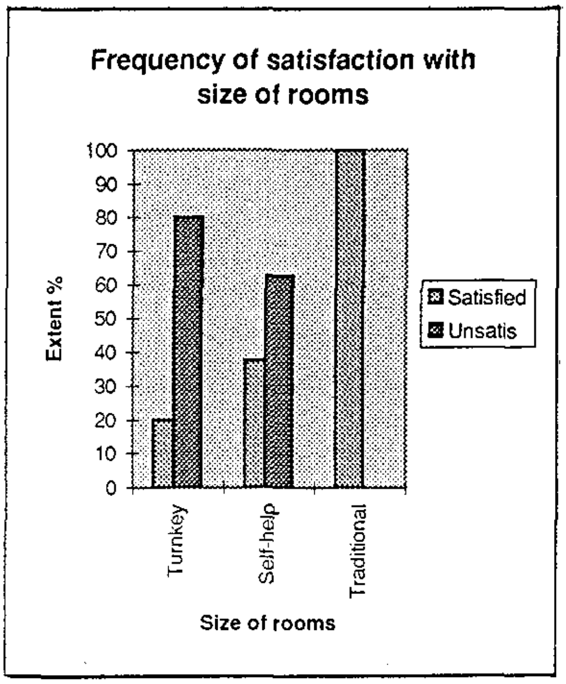


Chart 18



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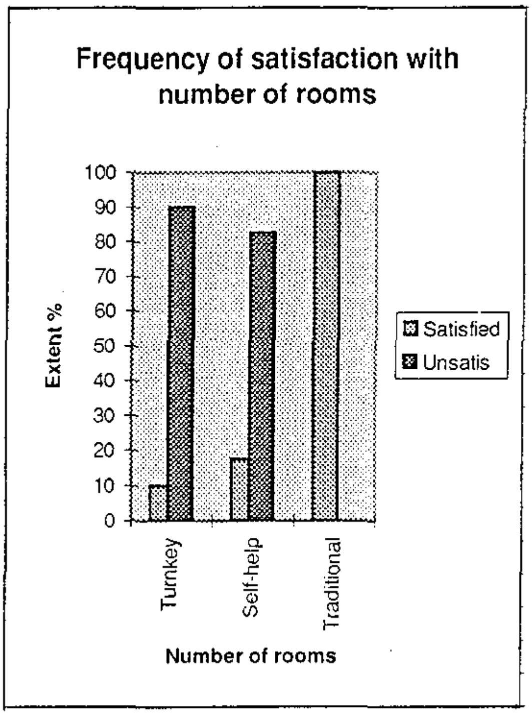


Chart 20

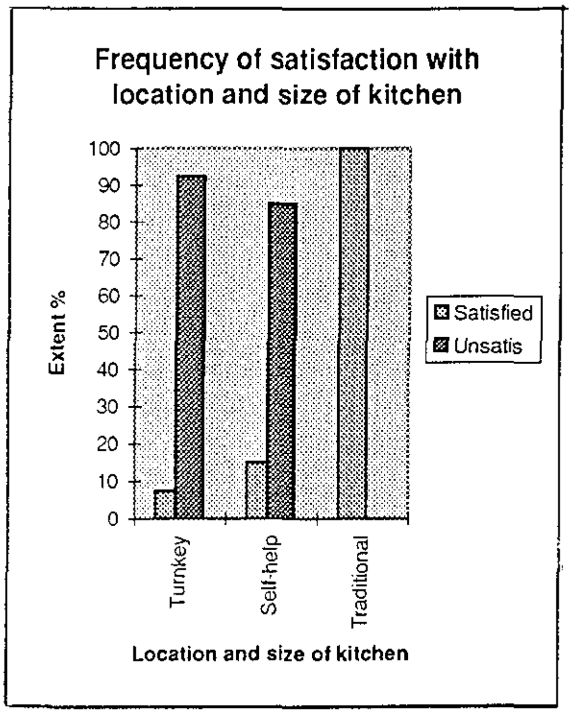


Chart 21

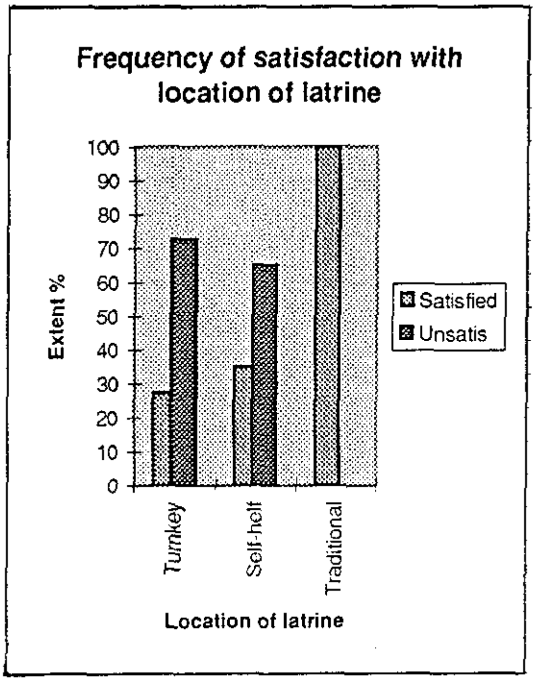


Chart 22

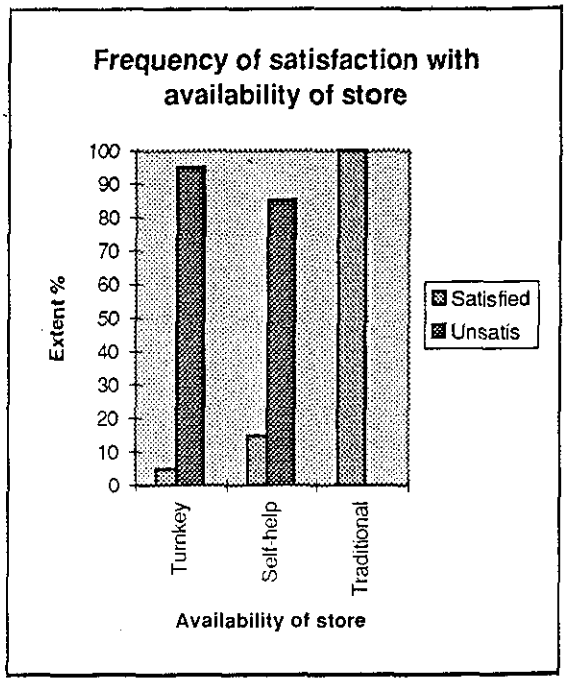


Chart 23

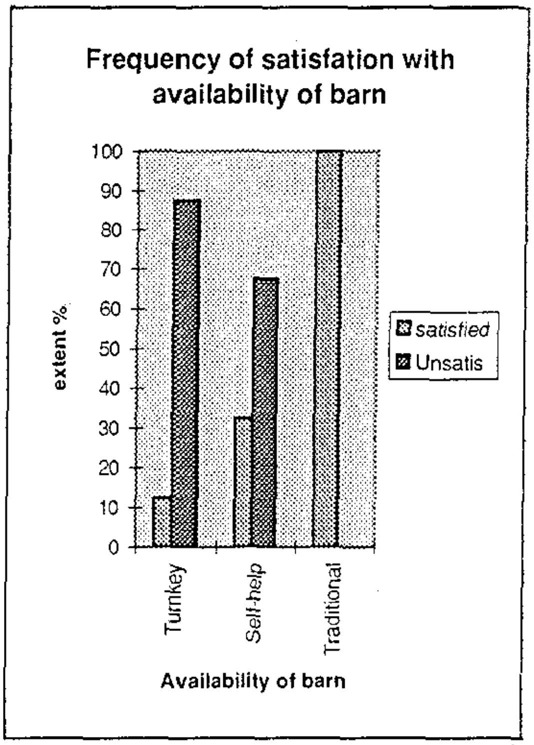


Chart 24

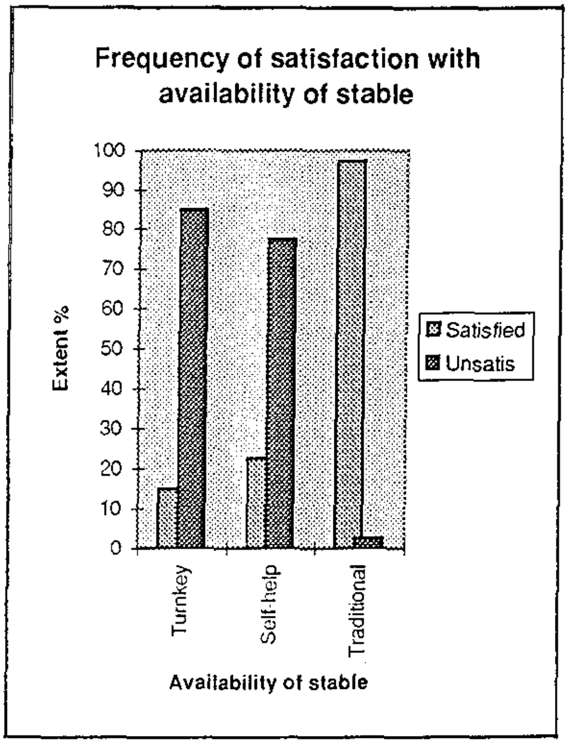


Chart 25

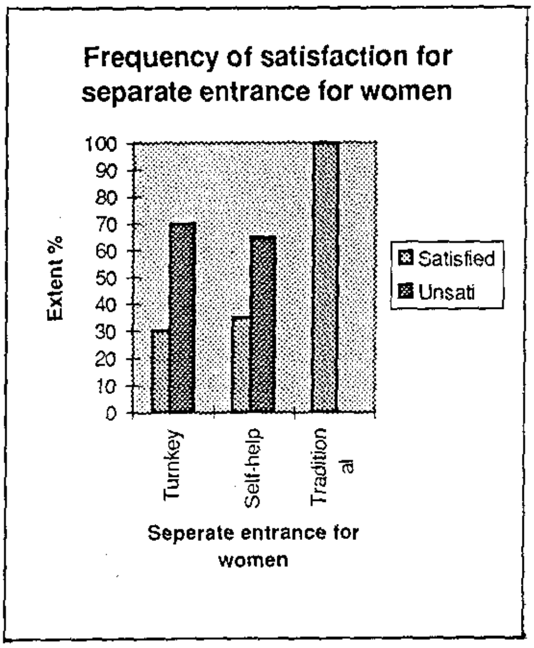


Chart 26

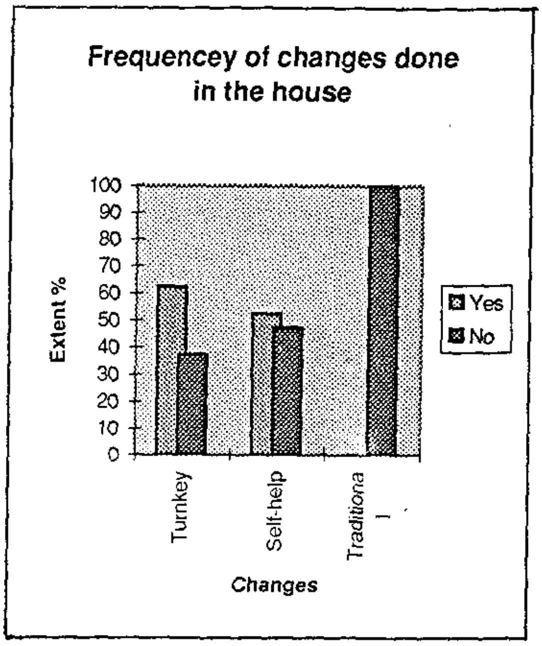


Chart 27

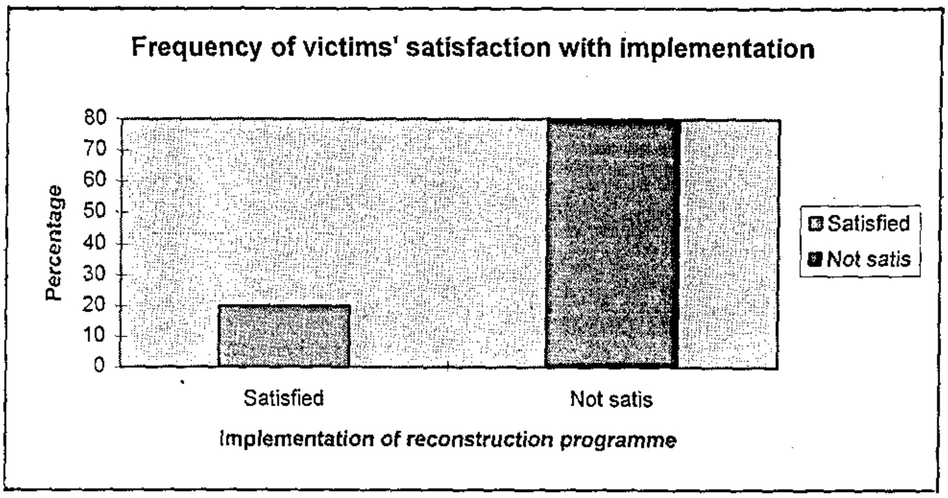


Chart 28

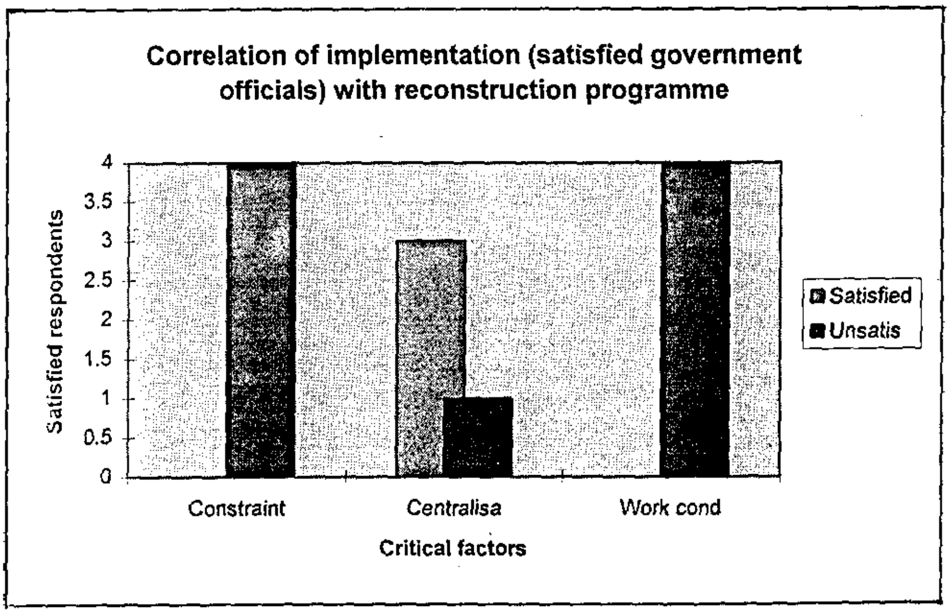


Chart 29

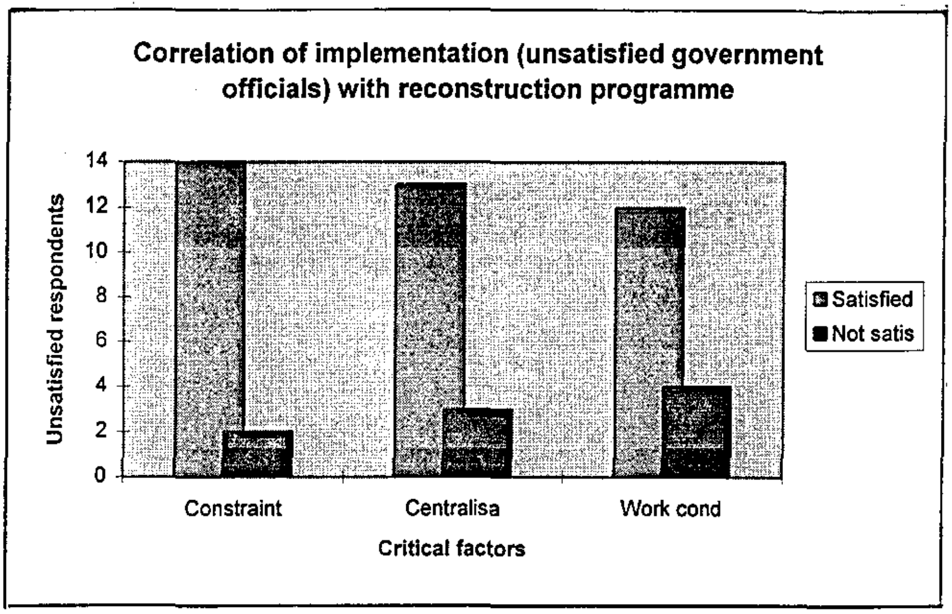
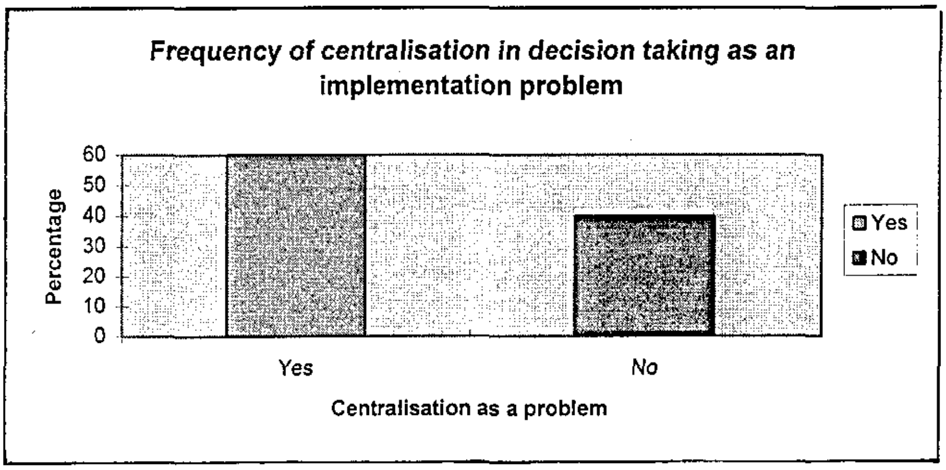


Chart 30



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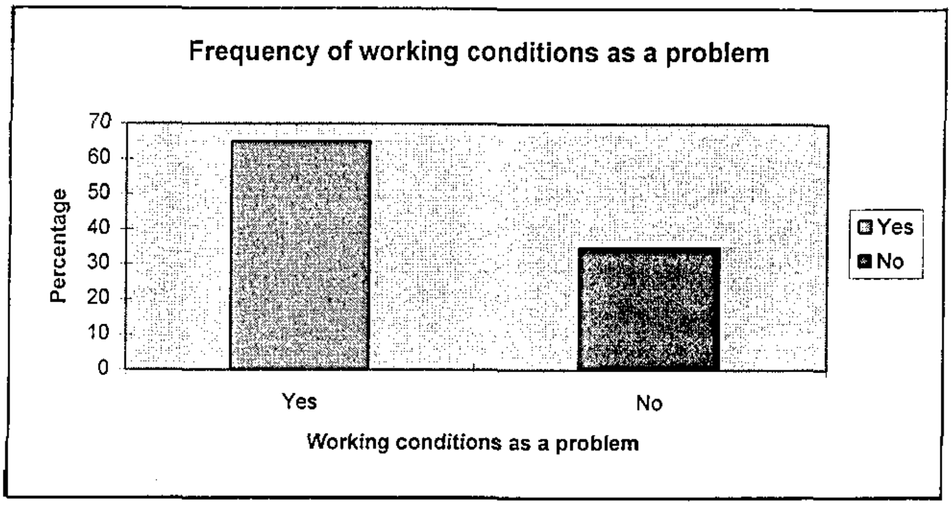

Chart 32

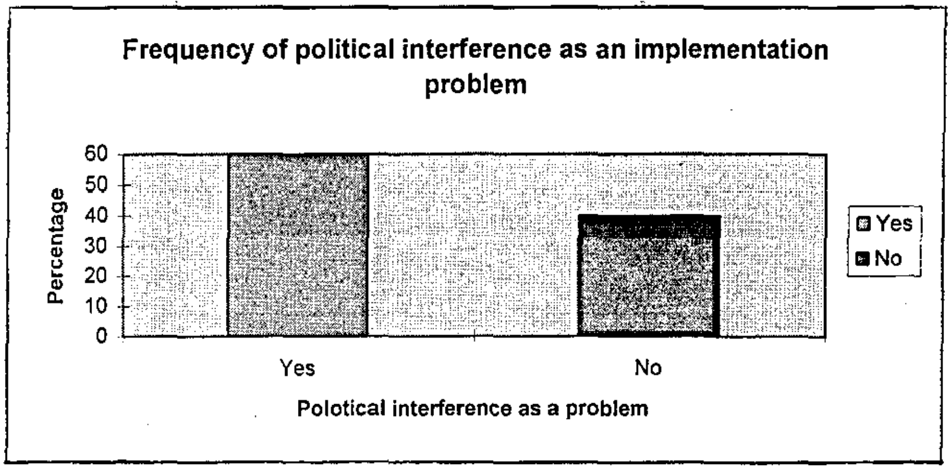

Chart 33

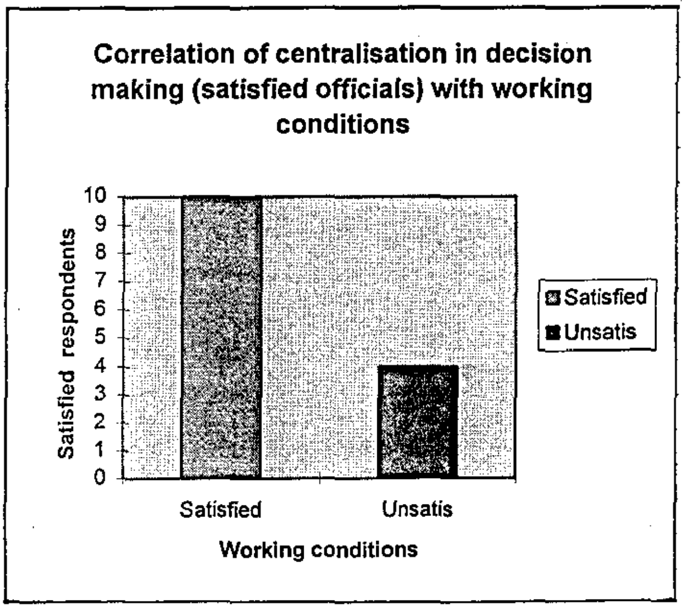

Chart 34

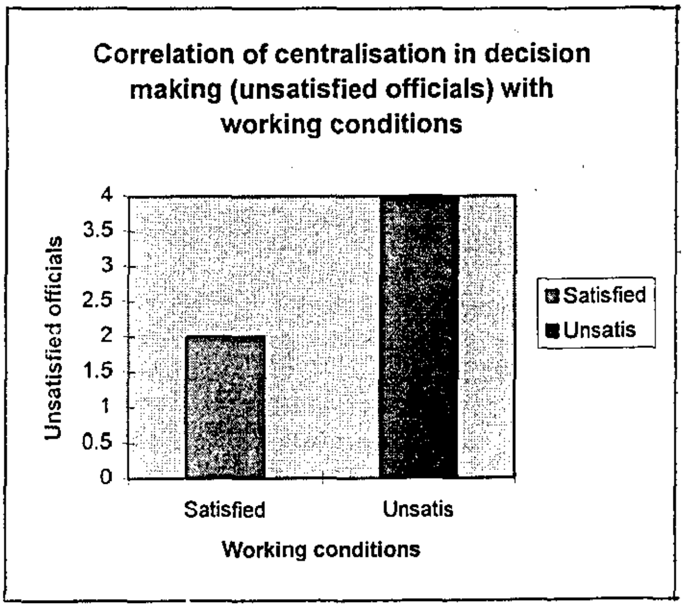

Chart 35

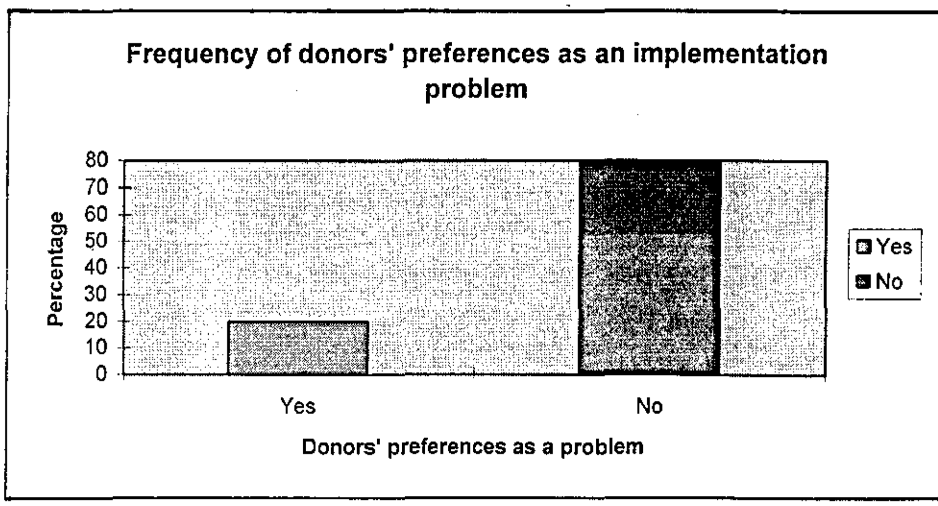

Chart 36

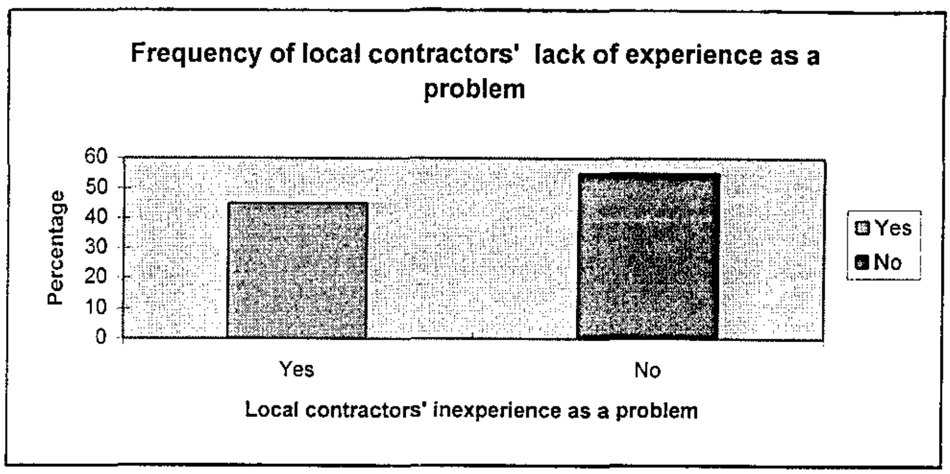

Chart 37

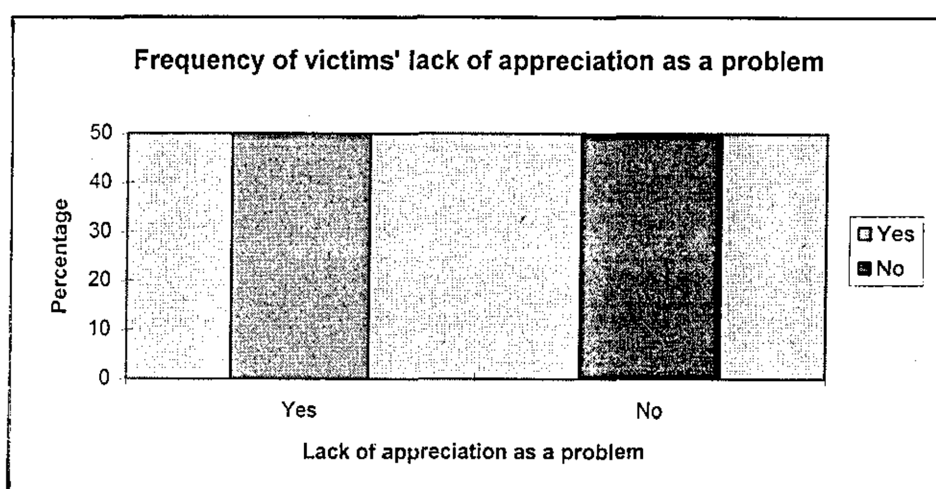

Chart 38

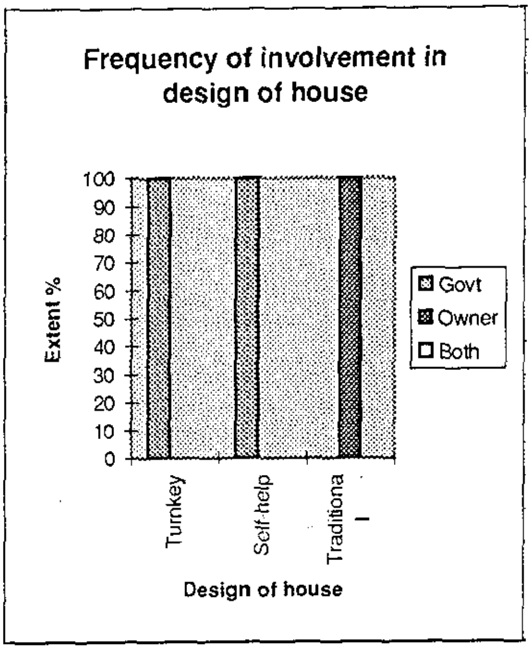

Chart 39

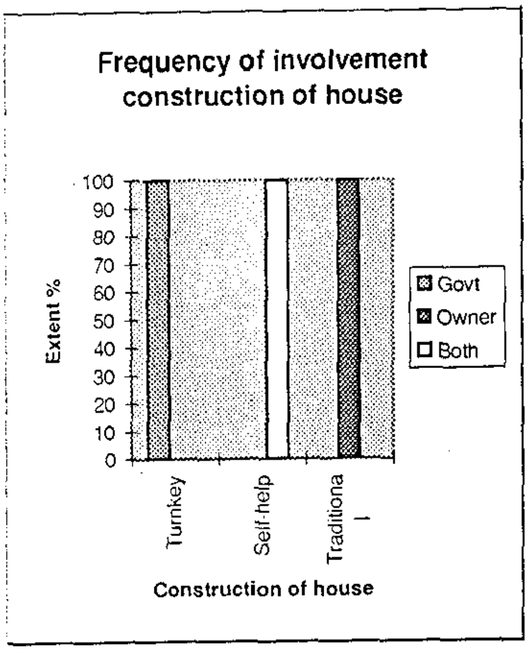

Chart 40