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Toward an Integrated Tsunami Disaster Mitigation: Lessons Learned from Previous Tsunami Events in Indonesia

Abdul MUHARI[1], Subandono DIPOSAPTONO[1] and Fumihiko IMAMURA[2]
[1] Ministry of Marine Affairs and Fisheries, Republic of Indonesia
[2] Disaster Control Research Center, Tohoku University, Japan

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ABSTRACT

In the last two years, the tsunami phenomenon has become a very serious issue in Indonesia. The 2004 Sumatra tsunami caused 130,000 casualties with another 37,000 missing, presumed dead, and financial loss suffered reached $ 4.3 billion. A tsunami struck the Pangandaran area again, West Java Province, on July 17, 2006, which caused 668 casualties with another 45 missing and financial loss reaching $ 44.7 million. The damage to these infrastructures and lives clearly shows that disaster mitigation and disaster countermeasure efforts are still not running well. This is becoming the background to the urgent need for integrated tsunami disaster mitigation to build a well-prepared coastal disaster community in the near future.

1. INTRODUCTION

Tsunamis have become the biggest killer specter for communities in coastal tsunami-prone areas in the last decade. In Indonesian regions overall, there are no seasides in Indonesia safe from tsunamis except the west coast of Borneo and the east coast of Sumatra. The large scale of this natural disaster hazard potency is accompanied by vulnerability of social condition, infrastructures, economics, policies, and the local state of bureaucracies as the effect of complexity and its fast growth. This results in most coastal districts in tsunami-prone areas often neglecting natural disaster mitigation aspects in their development.

The tsunami that was generated by a mega earthquake on the western coast, northern Sumatra, December 26, 2004 was a breakthrough that awakened the government and all Indonesians to the susceptibility of Indonesian coastal areas to tsunamis. Although historical tsunami records in Indonesia indicate that tsunamis happen almost every two and a half years on average (**Table 1**), there is no significant intention towards tsunami mitigation because there are only few people with knowledge of the past.

After the 2004 Indian Ocean tsunami, the government of Indonesia focused on activities of tsunami risk reduction to develop an tsunami early warning system, which is known as the Indonesian Tsunami Early Warning System (INA-TEWS). It has been making quite a lot of progress in its infrastructure development, but the 2006 West Java tsunami showed that its dissemination technology still needs to be improved, so the information can reach localities in tsunami-prone areas before a tsunami comes.

This paper will review the effect of the 2004 Indian Ocean tsunami and its reconstruction progress. Furthermore, it will evaluate the physical characteristics of the 2006 West Java tsunami and local community responses by analyzing the results of a questionnaire survey that was conducted by the Ministry of Marine Affairs (MMAF) Republic of Indonesia. The results of this analysis will become an additional point to enhance coastal community resilience with implementation of an improved plan, which will be discussed in this paper.

2. GREAT 2004 INDIAN OCEAN TSUNAMI AND RECONSTRUCTION PROGRESS

On December 26, 2004 on 00:59 GMT or 07:59 AM local time, an earthquake of 9 Mw created a sudden vertical rise of the seabed and triggered the displacement of massive volumes of water, resulting a giant tsunami devastating some 800 kilometers of Aceh's coast line where 16 districts and 654 village lie in its region. The tsunami killed some 130,000 people and left a further 37,000 missing, presumed dead, as well as 514,000 refugees. Furthermore, this tsunami was also responsible for 4.3 billion US$ loss of the social sector, infrastructures, transportation, communications, fisheries, energy, and the environment. A further earthquake on March 28, 2005 affected the islands of Simuelue and Nias and southern Aceh, creating significant further loss of 900 dead and 13,500 families displaced.

In response to the 2004 Indian Ocean tsunami, the emergency responses conducted by Indonesian government were followed by reconstruction and rehabilitation works. President Instruction (INPRES) No. 1, 2005, which covers thirteen ministries, the National Coordinating Board for Disaster Management, the Indonesian Army, Police, National Board for Land Affairs, and also the Governor of Nanggroe Aceh Darussalam and North Sumatra gives the direction to perform emergency response activities and preparation of the reconstruction and rehabilitation phase after the 2004 earthquake and tsunami. Starting with clearing duty

KEY WORDS: tsunami, disaster, mitigation, questionnaire

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Table 1. Historical tsunami record in Indonesia (1965-2006)

No.	Year	Location	Magnitude	Max. Run-up (meters)	Death Toll
1	1965	Seram - Molluca	7.5	4	71
2	1967	Tinabung – Sulawesi	5.8	---	58
3	1968	Tambu – Sulawesi	7.4	10	200
4	1969	Majene – Sulawesi	6.9	10	64
5	1977	Sumba	8	15	189
6	1982	Larantuka	5.9	---	13
7	1992	Flores	7.7	26	2100
8	1994	Banyuwangi – Java	7.8	14	208
9	1996	Palu – Sulawesi	7.9	6	68
10	1996	Biak – Papua	8.2	12	160
11	1998	Taliabu – Molluca	7.7	3	34
12	2000	Banggai - Sulawesi	7.5	---	4
13	2004	Aceh - Sumatera	9	34.5	167000
14	2006	Pangandaran - West Java	7.7	8.25	668

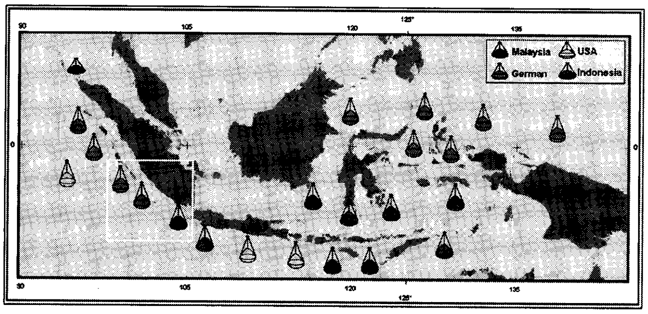

Fig. 1 DART buoy position along Indonesian waters

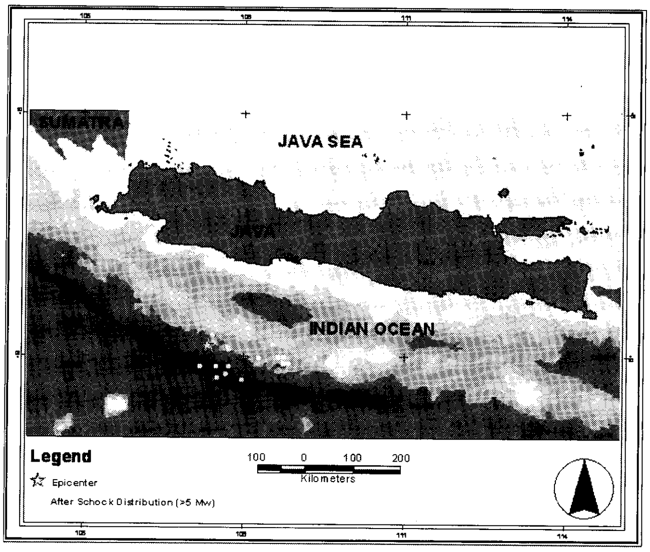

Fig. 2 Epicenter of West Java' fs tsunam

for almost 5,765,000 cubic meters of tsunami waste and debris, the work is continuing with housing reconstruction programmed for households who have completely lost their houses and their land, houses that are irreparable and need to be rebuilt, tenants who have lost their accommodation, and squatters who have lost their temporary shelters in totally around 80,000-110,000 houses in Aceh and another 13,500 in the Nias Area. These works were conducted together with establishing coastal land and spatial planning based on the disaster characteristics of the region.

In providing social services, institutional development needs to be re-established to build the institutional capacity for administration and government duties in Aceh and Nias because the tsunami took the lives of well over 5,000 local government staff in its region. From more than 2000 school buildings that were damaged in December 2004, 632 permanent schools in Aceh and another 124 in the Nias region have been built up to 2006, supplemented by 379 temporary schools. This is accompanied by the provision of 5,100 teachers in Aceh and 285 in Nias in order to replace approximately 2,500 teachers who died in the event. The overall progress of the reconstruction is presented in **Table 2**.

In order to manage future tsunami disaster risk, it is a very important step to create an end-to-end tsunami warning system in Indonesia. Although there are still many contradictory opinions

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Table 2. Reconstruction progress in Aceh and Nias

No	2004 Damage	2005 & 2006 Progress (April, 2006)
1	80,000 – 110,000 houses destroyed in Aceh and 13.500 houses destroyed in Nias	57,000 houses targeted will be built by the end of 2006
2	2,000 school buildings damaged	632 permanent schools in Aceh and 124 schools in Nias, supplemented by 379 temporary schools
3	Approximately 2,000 teachers died	More than 5,100 teachers trained in Aceh and 285 teachers trained in Nias
4	8 hospitals and 114 health centers and sub-centers damaged	3 hospitals and 305 health facilities built in Aceh, 1 hospital and 19 health facilities built in Nias
5	No tsunami early warning system	Indonesian Tsunami Early Warning System developed
6	No coastal structure for protection against tsunami	Over 33 km of coastal protection built in Aceh and over 24 km of saltwater dykes
7	3,000 km of roads impassable	1,200 km of all types of roads in Aceh and 300 km in Nias repaired
8	14 of 19 seaports badly damaged	All ports fully operated
9	8 of 10 airports damaged	All ports fully operated
10	120 arterial bridges destroyed, 1,500 minor bridges destroyed	121 bridges built in Aceh and 31 bridges built in Nias

about the effectiveness and high cost of its equipment. The national tsunami warning system in Indonesia is known as INA-TEWS (Indonesian Tsunami Early Warning System). In collaboration with another country, Indonesia will deploy twenty-two buoy systems of Deep-ocean Assessment and Reporting of Tsunamis (DART) (**Fig. 1**). The yellow inset box contains three DART buoys that have already been deployed: the red one is made by Indonesia and was deployed near the Sunda Strait on April, 2007. The other two are made by Germany and were deployed in Bengkulu Province and Siberut Island, West Sumatra Province offshore on November 2005.

The DART system will be combined with seismograph and tide gauge networks along Indonesian waters starting in 2006. The Indonesian government through the Meteorology and Geophysics Agency (BMG) will install 160 seismic censors every 100 km along earthquake disaster-prone areas in Indonesia.

3. WEST JAVA TSUNAMI

One and half years after the 2004 Indian Ocean tsunami, it again struck Indonesia on the south coast of West Java Province on July 17, 2006, triggered by an earthquake of 7.7 Mw, located at 9.295 S and 107.347 E (**Fig. 2**).

The earthquake followed by a tsunami that had a maximum run-up height of 8.5 meters (MMAF Tsunami Survey Team, 2006), swept most of the coastal villages along the south coast of West Java Province and Middle Java Province (**Figs. 3** and **4**), causing more than 668 casualties and financial loss of $ 44.7 million up to July 2006. This financial loss is still increasing because of the collapse of the tourism sector that has been become the primary sector in local economic development.

In order to analyze the characteristics of the tsunami and local response at the time tsunami happened, Ministry of Marine Affairs and Fisheries, Republic of Indonesia, conducted a questionnaire survey in tsunami-affected areas in October up to November 2006. This survey was held in five villages: Cikembulan Village, Pangandaran Village, Wonoharjo Village, Sukaresik Village in Ciamis District, and Cilacap Village in Cilacap District (**Fig. 5**). This region represents the area most damaged by the West Java tsunami on July 17, 2006.Thirty to hundred questionnaires were disseminated in each village. In Cikembulan Village, seventy questionnaires were circulated. From this number of questionnaires, fifty-nine were collected and analyzed. In Pangandaran Village, fifty questionnaires were disseminated but only twenty-

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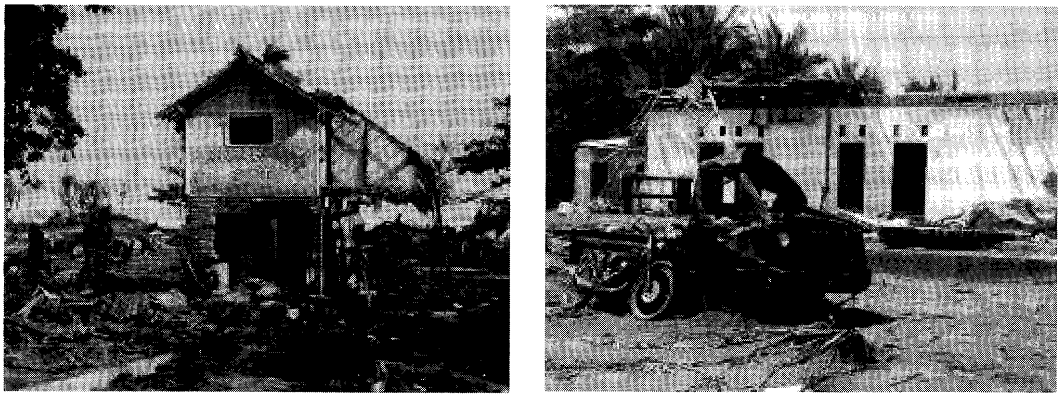

Fig. 3 Impact of West Java' fs tsunami on houses (Photo from MMAF tsunami survey team, 2006)

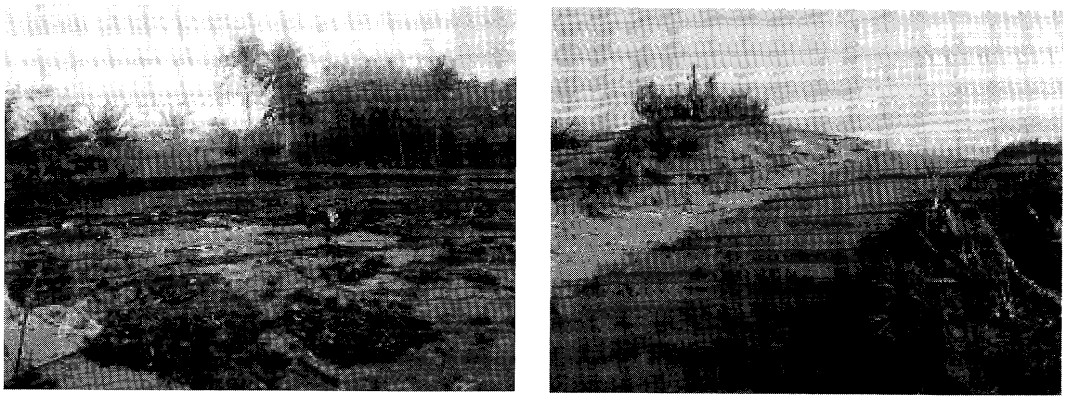

Fig. 4 Impact of West Java' s tsunami on rice fields and sand dunes (Photo from MMAF tsunami survey team, 2006)

four were collected. In Wonoharjo Village, a hundred questionnaires were disseminated and eighty-six were collected. In Sukaresik Village, fifty questionnaires were circulated but only twenty-seven were collected. In Cilacap Village, thirty questionnaires were circulated and eighteen were collected and analyzed.

The analyzed parameters from the questionnaire were: i) establishing of tsunami warning by the government and tsunami education held either by governmental or non-governmental institutions before a tsunami takes place; ii) tsunami characteristics that are analyzed by the question of the existing water receded before the tsunami came and whether the earthquake was felt by the coastal community and its intensity according the MMI scale of intensity; iii) community response at the time of the tsunami happened quantified by quick response by the locality on that time of the tsunami and the evacuation site chosen by the locality.

For tsunami warning issued by the goverment, 11% of the respondents in Cilacap Village felt that they received a warning, while the remaining 89% said that there was no warning from the government. Here, 72% of overall respondents mentioned that they received some information about tsunamis from brochures and leaflets disseminated by the government and the mass media, and the other 28% felt that they had never received any information concerning previous as well as future tsunami hazards in their area. In Cikembulan Village, 22% respondents said that they receive a warning before a tsunami comes, while the other 78% felt that there was utterly no warning from the government. Thirty-one percent of the total respondents in this area say that they receive information about tsunamis, while the other 69% felt that they never received any kind of information about tsunamis (**Fig. 6**). However, most of the respondents include an uncontrollable situation and people screaming as warning.

Respondents in Sukaresik Village say that a mere 7% of them felt that they receive warning and have received information concerning previous and future tsunami hazards. The rest of respondents in this area felt that they never receive information about tsunamis and have not been warned about the possibility of tsunami occurrence after an earthquake by anyone. In Pangandaran Village, 50% of the respondents felt that they have received warning about the possibility of a tsunami after an earthquake, also counting 62% of the total respondents who felt that they have received information about tsunamis.

From the questionnaire results in Wonoharjo Village, 6% of the respondents said that they were given warning, while the rest felt that there was no warning from the government (94%). Nine percent of the respondents felt that they had been given information about tsunamis, and the others (91%) felt they had never been informed about tsunamis. From direct interviews in the study area with respondents who felt that warning was disseminated, it was not warning about the possibility of tsunami occurrence established by a government institution, but the warning was the sounds of people screaming while running in a panic situation. These respondents also mentioned that warning in the locality comprises natural pre-tsunami characteristics such as dark sky, thundering sounds, continuous tremor that follows the tsunami wave, and the salt smell

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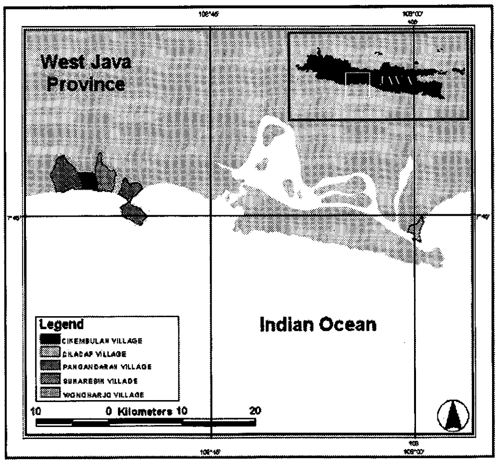

Fig. 5 Tsunami questionnaire survey area

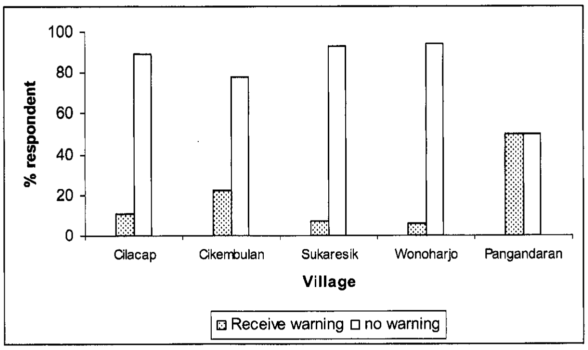

Fig. 6 Questionnaire survey results for establishing warning by the government

before the tsunami comes.

Local community response at the time of the tsunami was analyzed from the prompt responses of coastal society against tsunami threat, and the meaning of evacuation that was conducted by the locality was also analyzed. Generally, when coastal people realize the existence of a tsunami, they instinctively run to avoid the tsunami wave. In Cikembulan Village, 75% of the respondents evacuated, while the rest had no time to evacuate because they were already trapped by the tsunami or they lived on high ground.

In Sukaresik Village, all respondents evacuated, as was the case with Pangandaran Village. In Wonoharjo Village, 84% of the respondents evacuated, while the rest (16%) did not evacuate for two reasons: first, some people were already swept away by the tsunami and the others stay wherever they were at the time the tsunami happened because of shock. Sixty-one percent of the respondents in Cilacap Village did not evacuate. Those people are persons living on high ground (**Fig. 7**).

Some alternative places that were chosen by the coastal people for evacuation represent instinctive emergency response by local people. Hills and coconut trees are the most chosen by localities, but some people chose rice fields or going back to their houses as the best place to escape from the tsunami. These are the indicators of the locality's understanding of emergency response at the time of tsunami.

To investigate the earthquake characteristics of the 2006 West Java tsunami, the questionnaire results for earthquake intensity that

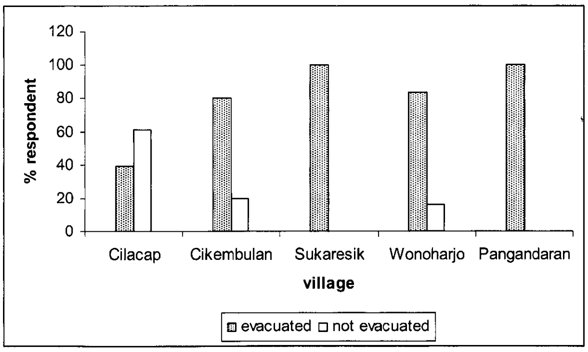

Fig. 7 Questionnaire survey results for evacuation by locality

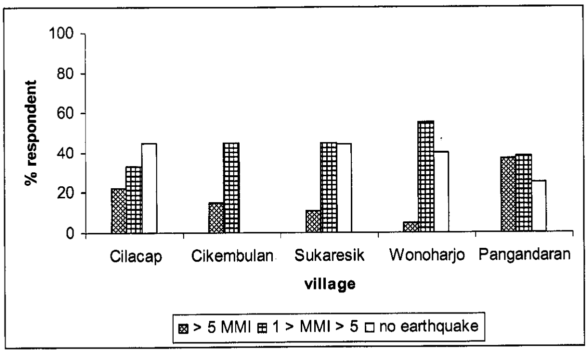

Fig. 8 Questionnaire survey results for earthquake intensity

was felt by local people indicated that almost all respondents in the survey felt no significant shock and some people felt a strong earthquake (>5 MMI) located in Pangandaran Village (37%) and Cilacap Village (45%). Many respondents felt continuous tremor following tsunami propagation onto the shoreline. Before it reaches the shoreline, a tsunami gives a sign by abnormal receding of the water. Except in Cilacap Village (22%), most of the respondents observed unusual receding of the water before the tsunami came (**Fig. 8**).

4. INTEGRATED CONCEPT FOR TSUNAMI DISASTER MITIGATION

In general, the policy of tsunami disaster mitigation in Indonesia is directed towards minimizing the risk caused by tsunami to lives, the economy, livelihoods, societies, natural resources, and the environment. The concept is based on three connected components (**Fig. 9**). An early approach to obtaining appropriate conditions for development and implementation of the concept is establishing a national law to shade and direct the state and district policy of land use and general development based on mitigation. This year, Indonesia already has a national law for disaster management and a national action plan for disaster risk reduction.

Risk identification and assessment is conducted comprehensively and involves stake holders, which are national and local government, scientists and experts, NGOs and also prominent local figures. In addition to a scientific approach, risk identification and assessment also performed by a social approach to obtain local knowledge and experiences of each society against tsunamis.

The approach consists of establishing coastal land use plan-

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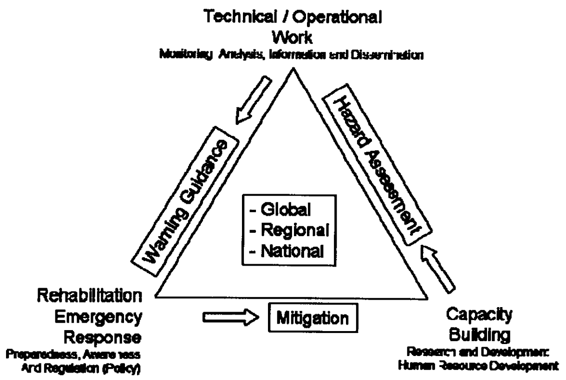

Fig. 9 Three integrated components of tsunami disaster management (International Tsunami Information Center, 2005)

ning based on vulnerability assessments and risk analysis, developing education through formal and informal institutions/schools to educate vulnerable coastal communities, establishing a detailed plan for emergency evacuation routes that are provided by hazard maps and disaster prevention maps, organizing tsunami drills or other types of exercise in order to make the appropriate response that is more than an instinctive reaction, and raising the awareness of coastal communities about tsunamis (**Fig. 10**).

Dissemination of tsunami brochures, posters, calendars, announcements, or exclusive reports and interviews on radio and television can be categorized as non-structural mitigation approaches. In this classification, further development of a national and local tsunami warning system is also taken into consideration.

For coastal community resettlement, appropriate incentive

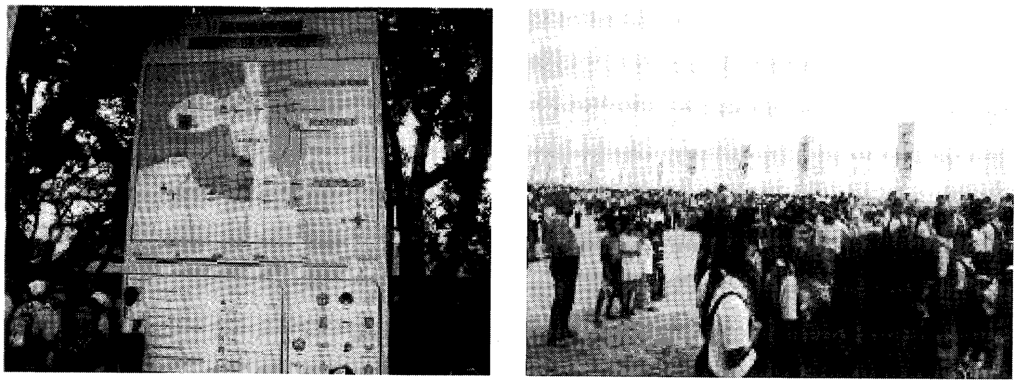

Fig. 10 Hazard map and tsunami drill activity in Bali (Photo from MMAF, 2006)

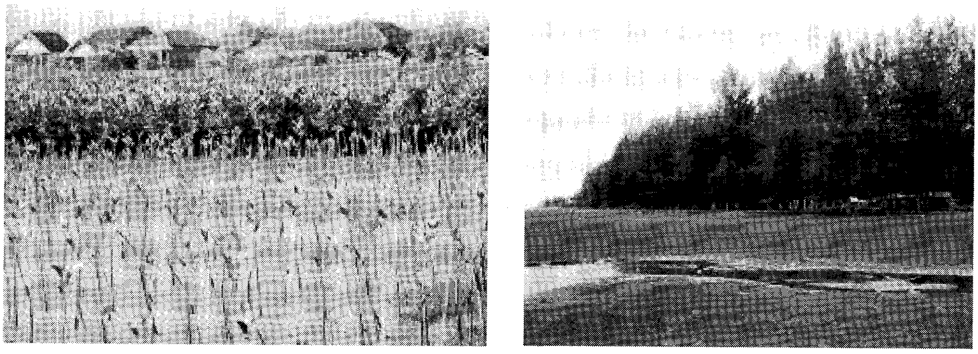

Fig. 11 Mangrove and coastal forest rehabilitation in Indonesia (Photo from MMAF, 2005)

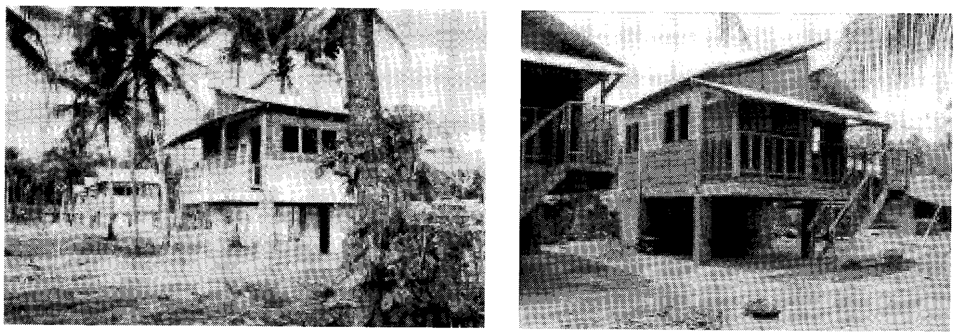

Fig. 12 Fishermen's safer house in Pangandaran Village constructed by MMAF (Photo from MMAF, 2006)

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packages as livelihood opportunities to encourage coastal communities to abandon settling in vulnerable locations should be provided. In the case of fishing villages, workshops and warehouses cannot be swept away from low land near the beach. However, residential houses, schools, and other public facilities should be located at high ground. For the convenience of fishermen's daily work, roads from residences to the beach should be built.

Maintenance of the environmental and ecological stability of the coastal areas through the rehabilitation of mangroves and beach forests, and also of lost and degraded coral reefs and sea grass beds, to help stabilize the coastline and prevent beach erosion, the reconstruction of swept away coastal sand dunes, the protection of remaining sand dunes, and the creation of buffer zones (green belts) along the coastlines are classified into as natural approaches to structural measures (**Fig. 11**).

Structural methods with artificial protection are not usually appropriate for developing countries because of their cost. In Indonesia, this method is implemented only for fishery house retrofitting so far. The concept of this house is based on Indonesian traditional architecture by strengthening the platform of the house and raising it up from the ground, with the section below the (second) floor remaining empty, so the dynamic force of tsunami current flow only affects the pole of the house. The direction of the house should be perpendicular to the shoreline (**Fig. 12**).

As further steps of this work, collaboration between international tsunami research communities to share experiences, scientific knowledge, and expertise should be encouraged to increase the capacities of relevant authorities and vulnerable communities. An integrated tsunami disaster concept should be implemented by government departments and non-governmental organizations and by involving local communities in planning and implementing the measures. By continuing assistance to coastal communities on its implementation, a community-based tsunami disaster risk management system will be created as the final goal of the concept proposed in this paper.

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