Feasibility Study Report

Development and Commoditization of the Pre-Fabricated Modular Bamboo Housing

The ‘Nature BOX’ project

International Centre for Bamboo and Rattan

Report by:
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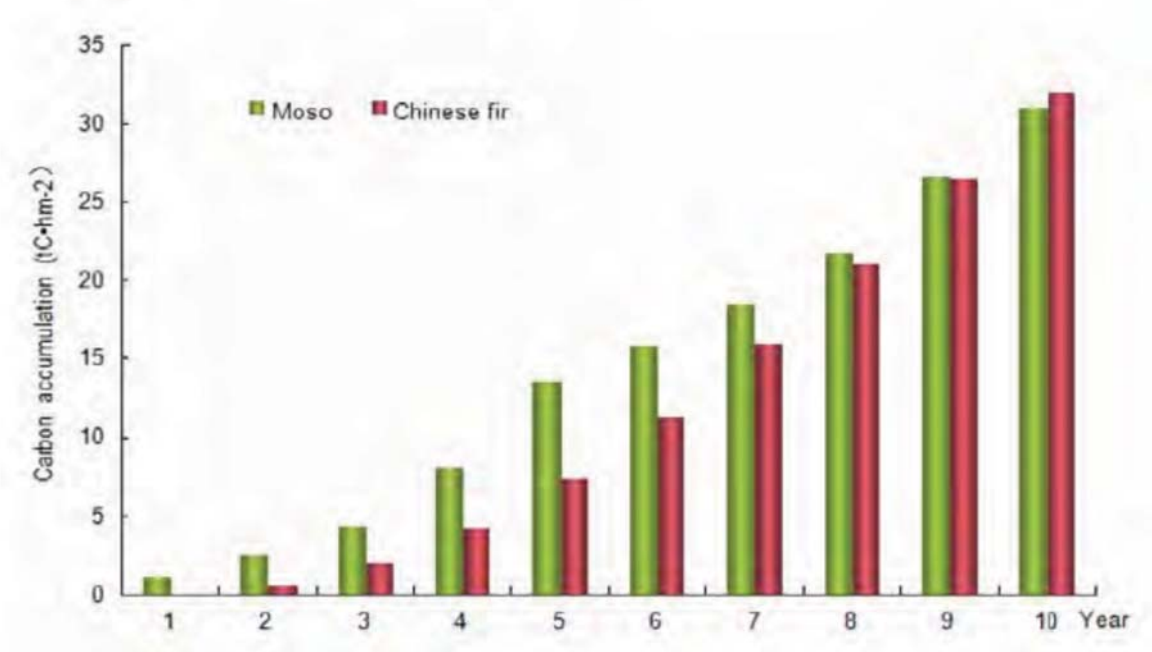
SUMMARY

Bamboo is one of the fast growing materials in the world. It helps in the binding of CO_2. In general one hectare of bamboo can bind 70 t C/ha. Just after the Copenhagen conference it becomes very clear that the reduction of CO_2 is necessary. INBAR's modeling indicates that the carbon content of newly-planted Moso bamboo stands increases more rapidly per unit area than Chinese Fir (*Cunninghamia lanceolata)* stands growing in similar conditions for about the first six or seven years.



Carbon accumulation in new Chinese fir and Moso bamboo plantations (t C/ha)

'International modern housing' is moving more and more in the direction of reinforced concrete. This means more CO_2 emission cause by the building industry. Change to more environmental friendly materials or combination of materials can help to solve this huge problem. Bamboo is one of the under estimated materials to use in this case.

It is hard to tell any negative aspects of bamboo applications. The material is very useful in different fields. Bamboo is used for food, oil and cosmetics. Bamboo is used for clothes and for packing material. Bamboo is used for construction, furniture and daily things like chop sticks.

This project has great potential to contribute to improve human and natural ecosystems and environmental sustainability. The project would contribute to alleviate poverty by making affordable high quality engineered bamboo houses attainable for poor and homeless people. Similarly, the project will generate employment for farmers and local communities by linking bamboo resources management with community based pre-processing mechanisms and industries.

This reports shows the possibilities of Modular Bamboo Panel Housing Construction for China, Ethiopia and Nepal. There is a large potential for these products as these countries have rich resources of bamboo. The bamboo products can be easily manufactured and are used for furniture and interior decoration. The same material can be used for the construction of houses. The market potential can be compared with

North-America where 85% of all one family houses is constructed with wood. In Europe and North America there is more interest for the application of bamboo, especially because of the ecological and green aspects. Assessment systems like BREEAM (EU) and LEED (UK) give a high value to the application of bamboo. Nowadays, bamboo is used in high-end architecture like the Kempinski 'By-the-Wall' Hotel (Beijing, Badeling) and the interior of the World Financial Tower (Shanghai, Pudong).

The use of bamboo and the production of bamboo matts can be done by the farmers and adds value to the product and give them extra income as well. The production and use in constructions will create new jobs and will also give the low income people a chance to earn more and make it possible to own their own (bamboo panel) house.

Recommendations:

1. Recommended is to think of a product line instead of two different model houses. The project should be able to develop a wider range of bamboo panel housing products with basic components and flexible in its combinations, to meet different needs, including low cost houses for the poor. That means even for the same sizes, the project should be able to provide housing products in different comfort level/costs.
2. To avoid mistakes and a lot of new research it is recommended to follow an existing wood frame technology. Based on experience the "Canadian Wood-frame House Construction" (supported and published by CMHC Canada) is very suitable for this purpose.
3. The demonstration should focus on different levels of comfort and quality to achieve a range of houses that will show the possibilities.
4. In Ethiopia and Nepal, there is a need for very low cost housing (between US $ 2,000 and 3,000). This goal can be reached with the low cost bamboo panel house.
5. In China and Nepal there is a market for more high end housing that should focus on plastered or brick facades. It is recommended to produce for this market to increase the production and to make the development profitable.
6. In Ethiopia and Nepal there is a market for plybamboo panels as in-fill in for concrete buildings. It is recommended to produce for this market to increase the production. In particular Ethiopia has an interesting governmental housing development program that has possibilities for new building products like prefabricated plybamboo walls.
7. It is recommended to find a commercial 'good selling' name for the bamboo house.
8. It is recommended to make bamboo panels in decimal dimensions and also in lengths of 3 meters instead of 2,40 or 2,50 m. This will increase the efficiency.
9. The overall recommendation, based on the good potential for the project, is to go ahead immediately with the next step and construct the show case houses.

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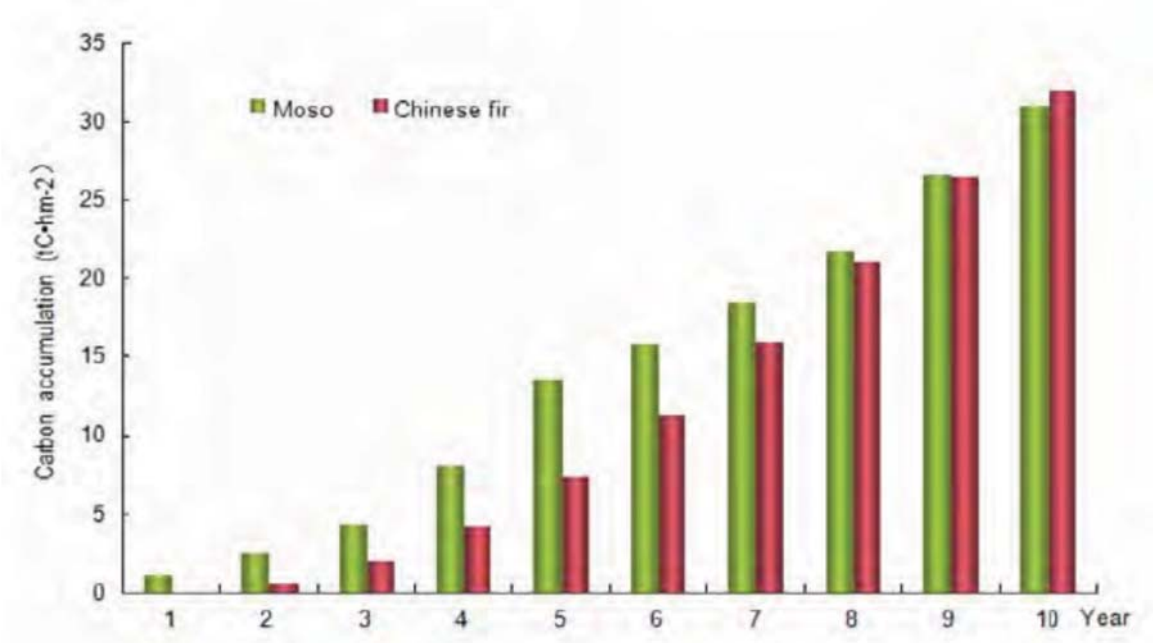
1 INTRODUCTION

The aims and the purpose of this study is to promote the use of Bamboo Panels and to develop two kinds of Pre-Fabricated Modular Bamboo Panel houses for China, Ethiopia and Nepal. This feasibility study shows how to develop these houses and how to make them successful in the market. Besides the development of modular houses the study also shows other possibilities for the use of laminated bamboo panels.

The project has a double task: “design houses for the poor” and “make the production of Bamboo Panels successful”. Houses for the poor means that the houses have to given away as the poor can not afford to buy houses. Chapter 3.5 shows the level of affordable housing. To make the production of bamboo panels successful, we will need to create a larger market. In Canada and the US about 85% of all detached houses are made of wood-frames.

Bamboo is one of the fast growing materials in the world. It helps in the binding of CO_2. In general one hectare of bamboo can bind 70 t C/ha. Just after the Copenhagen conference it becomes very clear that the reduction of CO_2 is necessary. INBAR’s modeling indicates that the carbon content of newly-planted Moso bamboo stands increases more rapidly per unit area than Chinese Fir (*Cunninghamia lanceolata)* stands growing in similar conditions for about the first six or seven years.



Carbon accumulation in new Chinese fir and Moso bamboo plantations (t C/ha)

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It is hard to tell any negative aspects of bamboo applications. The material is very useful in different fields. Bamboo is used for food, oil and cosmetics. Bamboo is used for clothes and for packing material. Bamboo is used for construction, furniture and daily things like chop sticks.

The “preconception” that bamboo is a poor man’s material seems to be a main problem in marketing bamboo. In Europe and North America there is more interest for the application of bamboo, especially because of the ecological and green aspects. Nowadays, bamboo is used in high-end architecture like the Kempinski ‘By-the-Wall’ Hotel (Beijing, Badeling) and the interior of the World Financial Tower (Shanghai, Pudong).
A good name is needed for the marketing of this type of houses. A new suggested work title is the “Nature BOX” house based on the natural and green material. For real marketing and advertisement more suitable names are needed. The final product should look like a common attractive house.

The basic residential designs are units of 40 and 60 m^2. This unit scale is also very suitable for resorts, schools and hospitals.

The six designs vary in volume and level of decoration. The cost per unit is between ¥ 20,900 ($ 3,070) for a 40 m^2 low level unit and ¥ 131,300 ($ 19,300) for a 60 m^2 high level unit.

Recommendations:

1. Recommended is to think of a product line instead of two different model houses. The project should be able to develop a wider range of bamboo panel housing products with basic components and flexible in its combinations, to meet different needs, including low cost houses for the poor. That means even for the same sizes, the project should be able to provide housing products in different comfort level/costs.
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8. It is recommended to make bamboo panels in decimal dimensions and also in lengths of 3 meters instead of 2,40 or 2,50 m. This will increase the efficiency.
9. The overall recommendation, based on the good potential for the project, is to go ahead immediately with the next step and construct the show case houses.

2 FEASIBILITY STUDY REPORT

2.1 Project Information

The project “Development and Commoditization of the Pre-Fabricated Modular Bamboo Housing in Asia and Africa” is approved by CFC (Common Fund for Commodities). Information from the Final Appraisal Report from the CFC :

• There are various kinds of laminated bamboo products such as mat board, flooring board and chip boards in the market. Most of these panels don’t meet standards to be used as external wall panels. However, there has been research and sample production on various alternative types of bamboo panels that show that some can be used as building panels and can resist harsh weather conditions, fire and earthquakes.

• Currently, INBAR is actively developing pilot production of a panel-based modular housing system with funding support from Blue Moon Fund (BMF). INBAR collaborated with Chinese Academy of Forestry (CAF) to develop two types of high quality laminated bamboo panels. Test results indicate that the panel meets all the international standards for use as wall panel. The project has also developed bamboo beams that could be used for the load bearing structural parts of the bamboo building.

• UN-HABITAT estimated about one billion rural dwellers and over 600 million urban residents in developing countries live in overcrowded housing with poor water quality, lack of sanitation and garbage facilities. The above situation clearly indicates the massive and rising need for low cost housing units world wide.

• This modular housing approach would allow rural poor to gradually improve their dwelling conditions by expanding the house size when their budgets allow. Prefabricated houses can be easily packed flat and shipped in containers to any destination in the world. They can be quickly assembled at the site with minimum cost, labor and time. Such bamboo prefabricated houses would be an ideal solution for disaster victims (after major flooding, tsunamis, earthquakes, fires etc.), for refugees, for improving the conditions of the slum dwellers, and for UN peace keeping missions amongst other uses. Such panel-based housing is likely to have a large market, both for low-cost and high-end houses, under all kinds of climatic conditions. In particular, non-structural wall panels could easily be replaced by bamboo panels.

• In addition to low cost housing, bamboo has a great potential to solve the scarcity of sustainable building materials for high-end buildings in urban areas. Bamboo has great potential to substitute these materials to a large extent, especially for the non-load bearing parts of large structures.

2.2 Introduction

The aims and the purpose of this study is to promote the use of Bamboo Panels and to develop two kinds of Prefabricated Bamboo Panel houses for several locations. The feasibility study has to prove how to develop these houses and how to make them successful in the market.

The project has a double task: “design houses for the poor” and “make the production of Bamboo Panels successful”.

Houses for the poor means that the houses have to given away as the poor can not afford to buy houses. We try to find the level where people are able to buy a house. That will be the basic level of the design.

To make the production of bamboo panels successful, we will need to create a larger market. Bamboo/wood framed houses can be a huge market. In Canada and the US

about 85% of all detached houses are made of wood-frames.

In the marketing we have to focus on a wide range of building designs that can attract both the home buyers on the top of the market and the buyers at the bottom of the market.

Beside home buyers there are many small home developers; people who buy a piece of land first, then build a small house and let that house grow with the growth of their financial possibilities. So flexibility and the possibility to add elements to a house are important as well.

This research is based on the assumption that both Ethiopia and Nepal can produce the right quality of bamboo panels needed for building construction. This means that a further introduction and training program will be necessary. This part is also covered by the CFC proposal.

2.3 Methodology

We made several steps in the research:

1. Desk research on the countries and the climate of the countries. General idea of the concept of the buildings based on traditional architecture, climate and brief. Analyses of earlier bamboo houses.

2. Questionnaire with specific questions about each country and culture.

3. Field trips to Nepal and Ethiopia to visit the sites and to understand more in detail the needs of the people, the possibilities of the country (availability, capacity and logistics), the acceptance of buildings (market research), the cultural difference and the affordable cost.

4. Main opportunities for Pre-Fabricated Modular Bamboo Housing in different regions.

5. First draft designs for the houses.

6. Construction principles based on bamboo panel dimensions, on construction method, on availability of materials and on cost.

2.4 Marketing

Different papers mention the “preconception” that bamboo is a poor man’s material. In Asia this seems to be a main problem in marketing bamboo. In Europe and North America there is more interest for the application of bamboo, especially because of the ecological and green aspects. Assessment systems like BREEAM (EU) and LEED (UK) give a high value to the application of bamboo.

Nowadays, bamboo is used in high-end architecture. An early example of the use of bamboo in architecture is the Kempinski ‘By-the-Wall’ Community (Beijing, Badeling) and the interior of the World Financial Tower (Shanghai, Pudong).

The official title of this project is “Development and Commoditization of the Pre-Fabricated Modular Bamboo Housing”. From a marketing perspective it is better to have a good recognisable term for this type of construction. A first idea is to say “Nature BOX” house based on the natural and green material, the the way it is constructed and the pre-fabrication. We can compare this name with the “BENTO Box”. From just a name it became a way of healthy eating, a way of life.

fig 2 – The Bento Box an organised solution (Source: 4AsianLife.com).

2.5 Options Analysed

Several possible areas of use came up during the research and field-trips. These are:
• Residential
• Schools, Tourism and Resorts
• Building components.
The project focus on residential but to make the promotion of Bamboo Panels successful, it is necessary to promote the material on different levels. For that reason we looked at building components as well. As the dimensions of the model designs (40 and 60 m^2) can easily fit to a school (classroom is about 60 m^2), hospital (rooms of 40 m^2) or a resort (rooms of 40 m^2).

The final product should look like a common attractive house. From all different bamboo house demonstrations before, the Black Bamboo Garden House in Beijing seems to be one of the few that can serve a large group of consumers.

fig 3 – The Black Bamboo Garden house fully constructed with bamboo panels but with a nice and temporarily look. (Pictures Tjerk Reijenga)

2.6 Recommendations

1. Recommended is to think of a product line instead of two different model houses. The product line should be flexible in its basic components and flexible in its combinations to achieve a wider range of building types.
2. To avoid mistakes and a lot of new research it is recommended to follow an existing wood frame technology. Based on experience the “Canadian Wood-frame House Construction” (supported and published by CMHC Canada) is very suitable for this purpose.
3. The demonstration should focus on different levels of comfort and quality to achieve a range of houses that will show the possibilities.
4. In Ethiopia and Nepal, there is a need for very low cost housing (structure A and B).
5. In China and Nepal there is a market for more high end housing that should focus on structure C and D (plastered or brick).
6. In Ethiopia and Nepal there is a market for plybamboo panels as in-fill in concrete buildings.
7. It is recommended to make bamboo panels in decimal dimensions and also in lengths of 3 meters instead of 2,40 or 2,50 m. This will increase the efficiency.

3 OPPORTUNITIES

For Ethiopia and Nepal it is not so easy to define the right requirements for a housing design. The input for the design comes from the different climates, living culture, housing development and affordable cost levels in the countries. At the same time it is almost impossible to introduce houses for the very poor.

3.1 Housing development in Ethiopia

The situation in Ethiopia is the worst compared to China and Nepal. Income is very low and most people can not afford to buy a house. Government policy has two directions:

1. Support community development,

2. Built affordable apartments.

The support for community development is a good possibility to introduce the “Nature Box” concept. These groups can rent a site from the government and are able to develop there own houses. In general this is mainly concrete and concrete blocks as the most basic building material. However with concrete prices doubled in the last three years it will be more and more attractive to look for other low cost solutions. The “Nature Box” concept has a much higher quality then the concrete block and it is more easy to build without big equipment. It is mainly a timber solutions based on small components.

The apartments (condominiums) are build for the lower income. However for most people it is not possible to buy or rent these apartments. These apartments, made of concrete, use interior walls of different materials. Low cost materials have an opportunity. Locally made ply-bamboo sandwich panels can be used as interior walls. The benchmark is the use of Agrostone, a straw and magnesium composite wall element. Another option is to replace concrete blocks that are used as filling in the concrete structure for ply-bamboo sandwich panels.

3.2 Housing development in Nepal

The situation in Nepal is different. In and around urban areas there is a lot of residential construction. Most construction work is organised by the residents itself. It is rather common to built a house phase by phase. So the house grows with the family situation and the income. For the existing houses, bamboo can be a good solution for interior walls and for replacement of concrete blocks.
More recent is the project development of real estate. In general this is more high end and difficult to achieve for the majority of Nepalese. This real estate development focus both on apartments and on townhouses.

The situation is a little the same as in Ethiopia. There are two main markets:

1. The “Nature Box” concept as a complete house design,

2. The prefabricated walls (both interior and exterior).

The complete house design can be done on a clean new site but it is also possible for an addition to an existing house. As the tradition is to extend houses several times and to add extra rooms on top, this principle can be done with the “Nature Box” concept. The Lekhnath bamboo house is a good example of such an addition to an existing building.

3.3 Technical specifications

Technical specifications for the “Nature Box” concept are based on construction, earth-quake resistance, climate (building physics), availability and affordability.

Construction.
Basic construction should be suitable for a two storey house. In general this can be achieved with the same wall dimensions but with more inside structural studs.
The basic idea for bamboo panel construction is the use of plybamboo. This can be produced in the same dimensions and the same qualities as plywood. Second idea is to use an existing and proven technology instead of completely new technology. The most proven and most widely used construction method is the North American Wood-Frame House Construction method. Around 90% of all North American one family houses are constructed following this construction system. As North America has most of the climates that we access in this study, we can depend on a lot of research done for different climate types.

Earthquake resistance
All areas in Ethiopia and Nepal have a earthquake risk. Big advantage of Wood-Frame House Construction method is the flexibility and the resistance against earthquakes.

Climate.
The main two climate types in Ethiopia are : Bsh in the east lowlands (Dire Dawa) and Cwb the High Plateau (Addis Ababa). In Nepal we partly have the same type of climate. In the middle of the country it is : Cwb - Mid-hills (Kathmandu, Pokhara) and in the Tarai it is Cwa - Lowlands (Tarai & Siwalik Hills).

	Average temperature	Min. temperature	Max. temperature
Bsh (E)	22° - 28° C	10° C	47° C
Cwb (E)	18° - 23° C	8° C	27° C
Cwb (N)	3° - 26° C	0° C	31° C
Cwa (N)	6° - 33° C	2° C	39° C

Thermal insulation is needed for temperatures below 10°C and above 26°C. This to minimise or prevent heating and cooling. The amount of thermal insulation should be a minimum of 100 mm mineral wool (based on European Standards).

	Yearly rainfall	Dry month	Wet month
Bsh (E)	570 mm	13 mm	102 mm
Cwb (E)	1200 mm	20 mm	257 mm
Cwb (N)	1332 mm	10 mm	375 mm
Cwa (N)	709 mm	6 mm	227 mm

Rainfall is an indicator for the roof form. In areas with a lot of rainfall (over 1000 mm/ year) a steep roof with overhangs is recommended. In dry areas a flat roof can be used in general without much problems.

Availability of materials
The basic material, the bamboo panels are not available yet in both countries yet. The project foresees the training and the production of this panels with local companies. Post and beams will be in principal be produced from laminated plybamboo as well. Ethiopia

has no good wood resources (except Eucalyptus) that is available for building construction. Nepal has a lot of wood resources that is used for construction work. In that case, wood instead of ply bamboo is used. Gypsum board is in general used as fire protection (and cost reduction as well) on the inside. Doors and windows will be wood in Nepal but probably aluminium in Ethiopia. In the future this can be replaced for bamboo window frames. In both countries metal roofing is rather common and easy to use. The foundation will be traditional materials (cement and cement blocks). The ground floor can be both concrete or a wooden floor consisting of sills, beams and joist. Wooden floors will need extra support as the span is maximum 4 meters.

Plan layout

The goal is to design two different houses with 40 respectively 60 m^2 floor plan. The designs should be based on regular dimensions of plybamboo (1200 x 2400 mm).

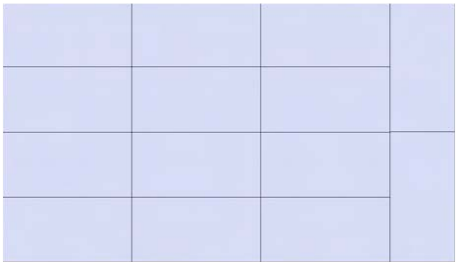


Fig 4. Plan A (40 m^2) - main dimensions: 4,80 x 8,40 = 40,3 m^2.

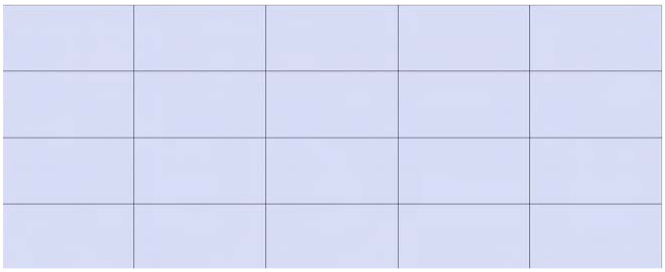


Fig 5. Plan B (60 m^2) - main dimensions: 4,80 x 12,00 = 57,6 m^2 .

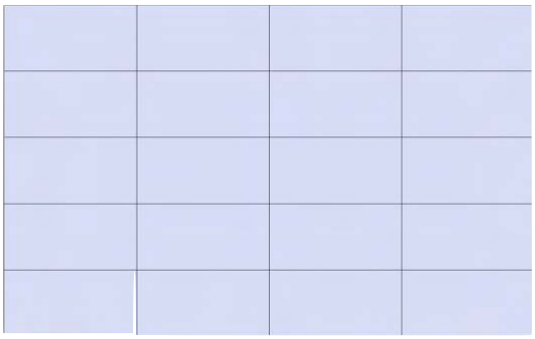


Fig 6. Plan C (60 m^2) - main dimensions: 6,00 x 9,60 = 57,6 m^2 .

The perimeter of plan C is 2.40 meter less then the perimeter of plan B. But the lower span will decrease the dimension of beams needed. The other advantage is that the smaller trusses can be lifted by hand and safe the cost of a crane.

Easy combinations of plan A + A or plan A + B are possible to make houses of 80.6 or 97.9 m^2.

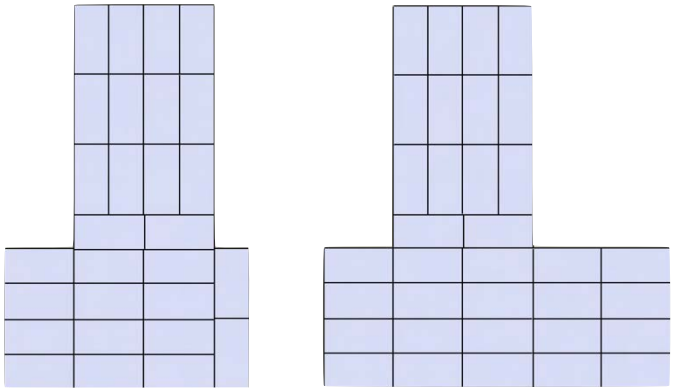


Fig 7. Plan A+A - 80,6 m² and plan A+B - 97,9 m².

Floor plan

The basic floor plan for the 60 m² house has a living space, two bedrooms a kitchen and a bathroom. The basic floor plan for the 40 m² house has a living space and two bedrooms. The 60 m² house is the main design and the 40 m² house is more or less the smaller variety without kitchen and bathroom. The internal walls are non-bearing walls and can be removed or left away if needed. The wall between the living space and the kitchen/bathroom can be removed as well but is designed in a way that it is not needed. The same construction is used for the outside wall of the 40 m² house. The kitchen/ bathroom part has two varieties: a. Simple gable roof and b. Roof with solar hot water system, fresh water storage and ventilation duct. In most regions a fresh water storage is used to have enough water and to have pressure on the water system.

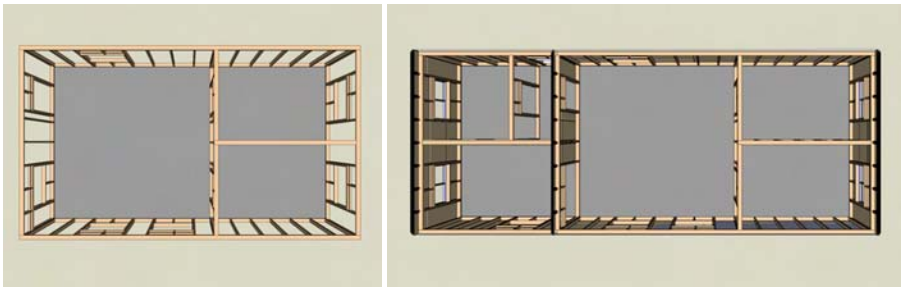


Fig 8. Floor plan for 40 m² and 60 m² unit.

The floor has the living space in the middle with south facing windows. The kitchen is on the south-west side of the house. Kitchen will be heated in the afternoon and good shading on the west window is needed. The bedrooms are on the east side of the house and will be rather cool at night. The entrance and bathroom are on the north west side of the house.

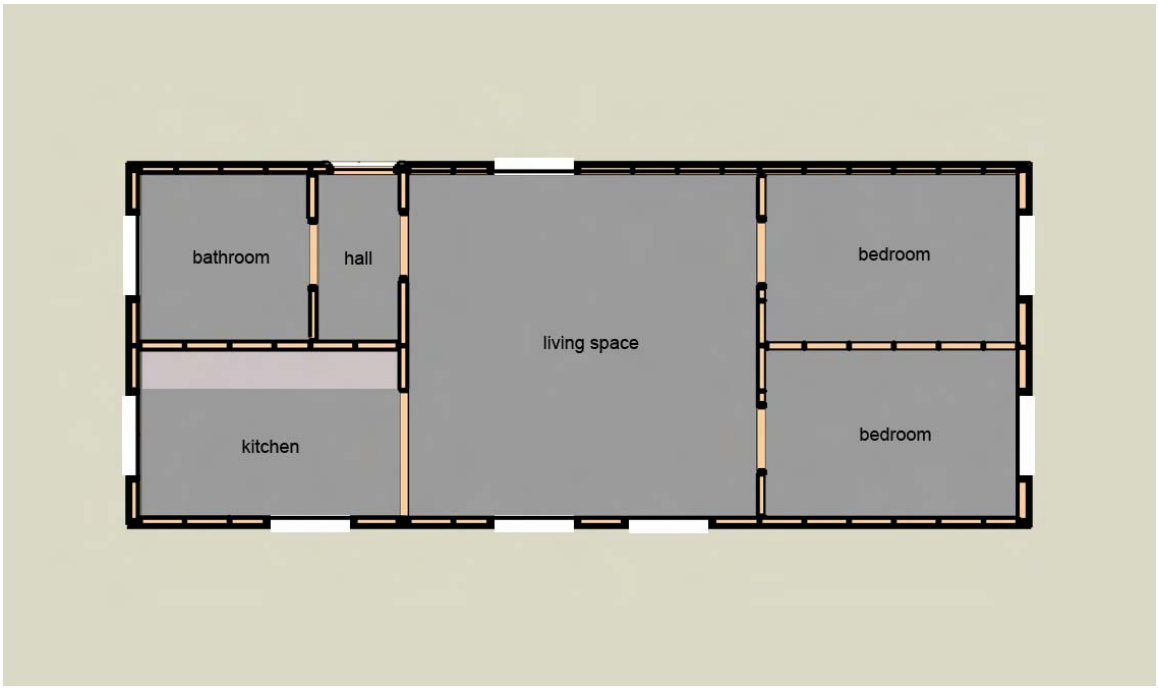


Fig 9. Detailed floor plan for 60 m² unit.

To make it possible to extend the 40 m² house in the future to a 60 m² house, the design has the possibility to make changes without big interventions in the construction of the original house. A longer beam is needed to make this possible.

Fig 10. South-east, south-west and north-east facades for 40 m² unit.

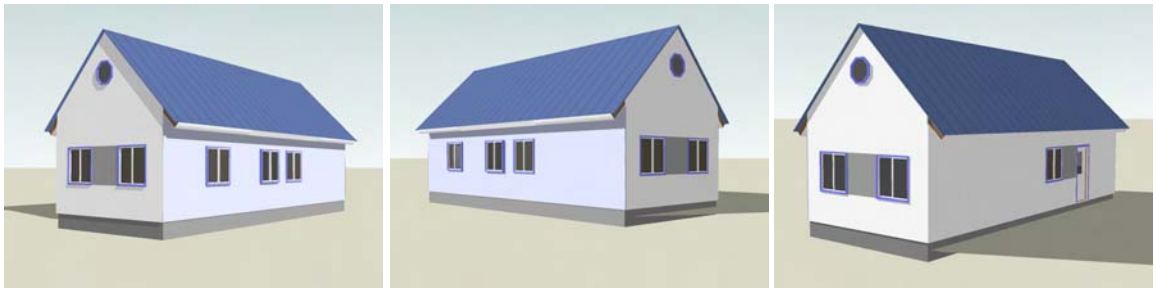


Fig 11. South-east, south-west and north-east facades for 60 m² unit.

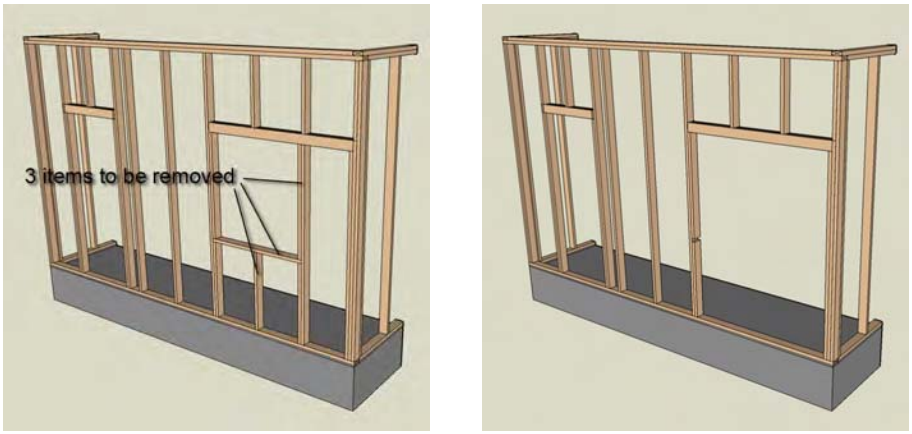


Fig 12. Detail of the wall of the 40 m^2 house and the changes that has to be made for future extension to the 60 m^2 house.

Construction

The design is based on the Canadian Wood Frame Construction (Platform method). This system use wood studs and joist that can be easily displaced by laminated bamboo. The main construction design will be the same. Dimensions are all metric and as the system is based on laminated bamboo we do not use the general lumber dimensions.
Plybamboo in a thickness of 10 or 20 mm is very useful. Combined it is possible to make beams of 40 x 100 mm.

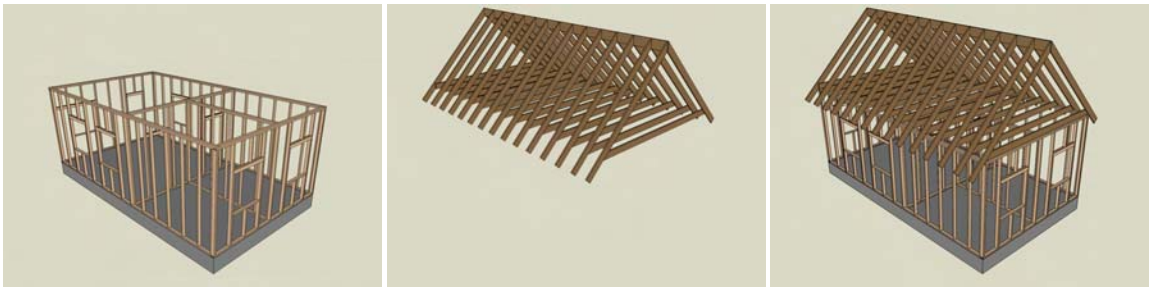


Fig 13. Basic construction system following Canadian wood frame construction.

The walls can be prefabricated or built on site. Prefabricated walls will use more studs as the elements has to be stabile for transportation. Doors and windows ask for extra studs to secure the strength of this 'weak' spots in the construction.

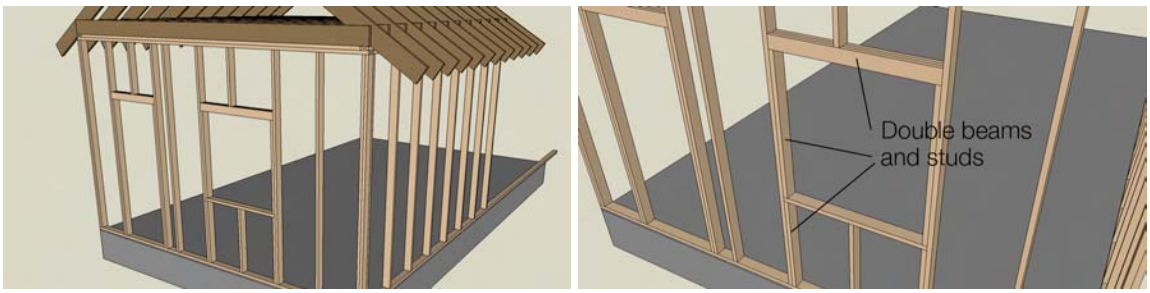


Fig 14. Double beams are used to strengthen the construction.

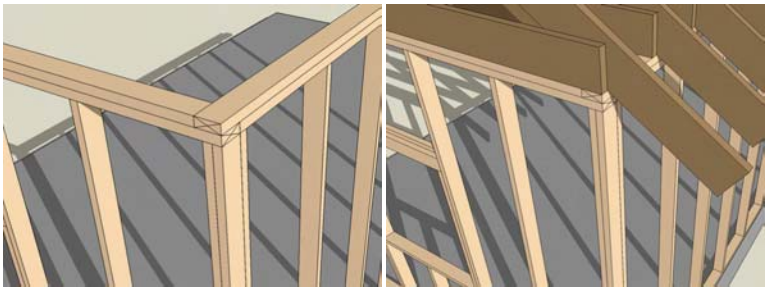


Fig 15. Overlapping beams in the corner and for the roof construction.

Walls

The walls are seen as an expanding system. Related to the requirements the walls can be as simple as a single sheet of plybamboo, an insulated sandwich or a cavity wall with an outside cover of plaster, adobe or brick.
The exterior finish will be important to extend the life time of the plybamboo panels. In the simplest construction this will be the only finish.

In the basic construction the wall-elements can be prefabricated as well and mounted on site. Basic wall element will be 1200 x 3000 mm. Studs will be 40 x 100 mm with a interval of 600 mm. For the use of two floors, the element on the ground floor has to be have an extra stud in the middle and the interval will become 300 mm. This element can include a door and/or a window. Alternatively to reduce cost, wall elements of 1200 x 2400 mm can be used.

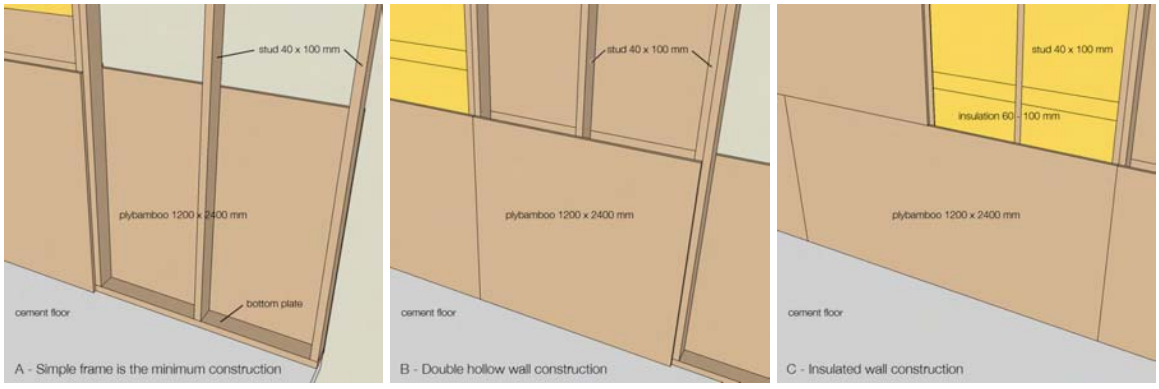


Fig 16. Expanding wall system. From single sheet wall to complete insulated sandwich wall. (Structure A to C)

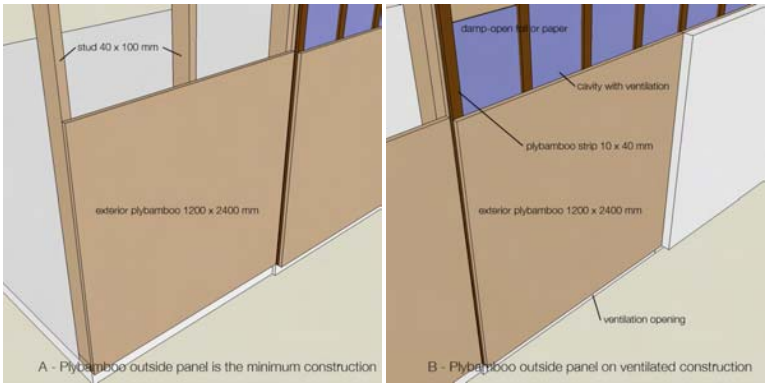


Fig 17 - Expanding wall system with different cover and increased quality. (Structure A and B)

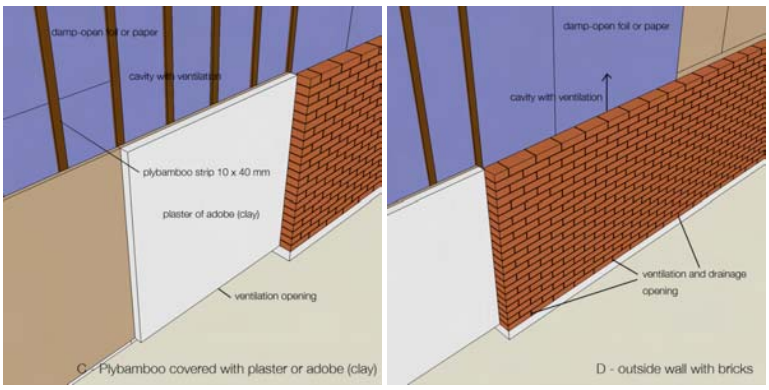


Fig 18 - Expanding wall system with plaster and brick cover. (Structure C and D)

Roof
The roof will be made with plybamboo panels as well. The roof construction depends on the climate. Also here it is possible to make several different types of roofs within the same design varying from a single metal sheet, a sandwich construction to a tile of shingles covered roof.

Fig 19 - Plybamboo roof, corrugated iron roof or plybamboo roof with protective (damp-open) sheet and corrugated iron roofing.

3.4 Sustainable aspects

The sustainable aspects of the project cover: material, water and energy.

Materials
Bamboo as basic material is a sustainable choice. For all other main construction elements like beams and window frames it is also possible to use laminated bamboo. This is the best demonstration of the possibilities of bamboo. For budget and practical reasons, this is not directly possible in each situation.
Steels seems to be the most common solution for a roof. In combination with the plybamboo under it, it is possible to reduce the amount of steel (thinner sheets) (fig. 19c). Interior decoration can be done with plybamboo as well. However this can be gypsum board as well.

Water
Rain water can be collected on the roof. This is only useful in areas that are not too dry. A gutter on the roof and a tank is needed. To use the rain water, a pump is needed. For a more easy use, a second tank on a higher level is needed to give pressure.
In many countries, like Ethiopia and Nepal, there is not enough pressure for the fresh water. For this reason a tank is needed as well. Both tanks can be placed under the roof or in a special outside space above the roof.

All appliances in use should be water saving appliances.

Energy

The double facade has a function in both cold and warm circumstances. The air in the cavity will insulate and more insulation material can be added depending on the climate zone and the available budget. The cavity wall will insulate between inside and outside temperature. In some very temperate areas the function is less important as in- and outdoor temperatures are more or less the same.

In very sunny areas the double roof is needed to keep the house cool. The air in the cavity between the two layers should easily flow away at the highest point of the roof (fig. 20).

The main living space and kitchen are facing south to receive passive solar energy in the heating season. For each climate and each region care has to be taken to prevent overheating in summer. The basic lay-out put the different spaces in the right orientation. If it is necessary to turn around the building in a certain location, this issue should be taken into consideration.

Solar hot water for domestic use is also foreseen as part of the roof above the kitchen.

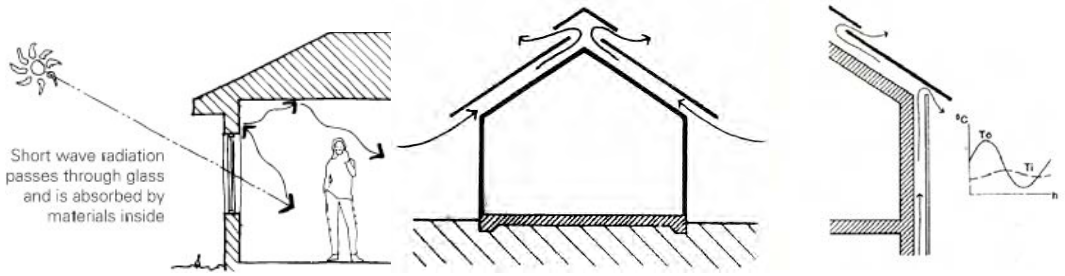


Fig 20 - Passive solar energy, double roof and double facade with temperature diagram. (Source: P. Gut SKAT, Climate responsive building)

3.5 Affordable housing

Ethiopia and Nepal are number 171 respectively 144 out of 182 countries in the UNDP publication Human Development Report 2009. The average pro capita income in both countries is $ 216 respectively $ 254. An average income for a civil servant in Ethiopia is 1,200 Birr/month ($ 88/month) and for a civil servant in Nepal is 10,000 NPR/month ($ 130/month).

The group that can afford to buy a house has an income above these average salaries. With a 25% extra income generated within a family we can take the following assumptions:

	Income/year	Housing cost/year	Investment x 1000
Nepal Urban	160,000 NRs	40,000 - 80,000 NRs	800 - 1,600 NRs
Nepal Rural	65,000 NRs	16,000 - 32,000 NRs	300 - 650 NRs
Ethiopia Urban	18,000 ETB	4,500 - 9,000 ETB	90 - 180 ETB

The cost for an affordable house is resp. 800,000 to 1,600,000 NRs ($ 10,600 to $ 21,200), 300,000 NRs to 650,000 NRs ($ 4,000 to 8,600) and 90,000 to 180,000 ETB ($ 6,600 to 13,200).

The six designs vary in volume and level of decoration. The cost per unit is between ¥ 20,900 ($ 3,070) for a 40 m^2 low level unit and ¥ 131,300 ($ 19,300) for a 60 m^2 high level unit. Final cost depends on the local production cost for bamboo panels.

4 NEPAL

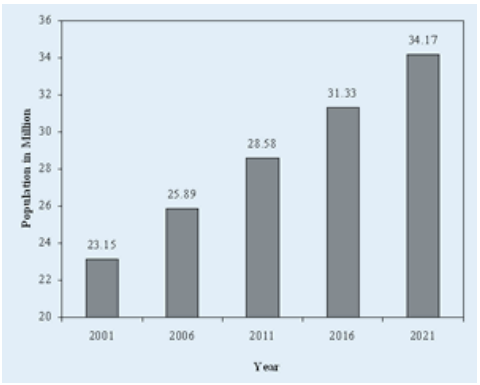
4.1 Country facts

Nepal is situated on the southern slopes of the central Himalayas and occupies a total area 147,181 km^2. The country is located between latitudes 26°22' and 30° 27' N and longitudes 80°40' and 88°12' E. The average length of the country is 885 km from east to west and the width varies from 145 km to 241 km, with a mean of 193 km north to south. Hills and high mountains cover about 86% of the total land area and the remaining 14% are the flatlands of the Tarai. Altitude varies from some 60 m above sea level in the Tarai to Mount Everest (Sagarmatha) at 8,848 m, the highest point in the world. (Source: Nepal Biodiversity Strategy – Ministry of Forests and Soil Conservation 2002)
Nepal has three main areas: the Tarai (plains below 500 m), the hills (500 – 2500 m) and the mountains (above 2500 m).

CHARACTERISTIC	Tarai	HILLS	MOUNTAINS	NEPAL
Area (km^2)	34,019	61,344	51,818	147,181
Area (%)	23.1	41.7	35.2	100
Population (%)	48.5	44.2	7.3	100
Eastern Development Region (%)	14.3	7.1	1.7	23.1
Central Development Region (%)	17.0	15.3	2.4	34.7
Western Development Region (%)	7.5	12.0	0.1	19.6
Mid-Western Development Region (%)	5.3	6.3	1.3	12.9
Far-Western Development Region (%)	4.3	3.5	1.7	9.5
Density (per km2)	330.78	167.44	32.62	157.73

fig 21 – Population density and distribution (Source Population Census 2001)

Since 1971 the exponential growth rate is around 2% each year. This means that the population of 11.5 million in 1971 became 23 million in 2001 and 26 million in 2006. In Kathmandu the growth is around 6.5% and the city is becoming a chaos of settlements. At the same time the shortage in housing is growing rapidly. Kathmandu city reports in 2001 a yearly deficit of over 33,000 houses (KMC &WB 2001).



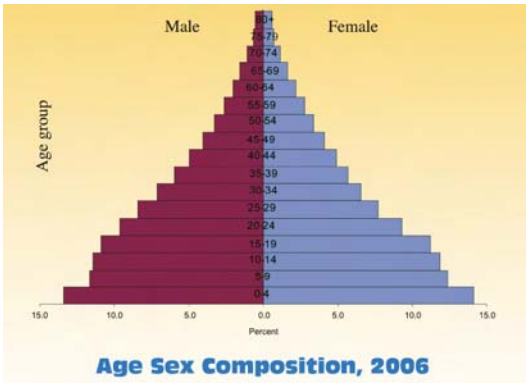


fig 22 – Population growth and age (Source Population Census 2001)

Main economic activities are in Kathmandu Valley, in Pokhara and in the Tarai. Touristic activities are mainly in Kathmandu Valley, Pokhara and in the mountains.
According to the UNDP publication Human Development Report 2009, Nepal is ranked 144th out of 182 countries with HDI value of 2.16. Table 23 shows the average household income and per capita income of Kathmandu valley is NRs.222,666 ($ 2,960) and NRs.45,816 ($ 609) respectively whilst those of the country was NRs 80,111 ($ 1,065) and NRs 15,162 ($ 202) respectively. The average per capital income of Kathmandu is hence three times that of the national level and 6 times average per capita income of poorest groups. This income gap triggers migration into the Kathmandu Valley, thus rising the number of urban poor in the Valley.

Description	Nepal Living Standards Survey	
	1995/96	2003/04
Nominal average household income in nominal NRs.	43,732	80,111
Nominal average per capita income in nominal NRs.		
All Nepal	7,690	15,162
Poorest 20% of population	2,020	4,003
Richest 20% of population	19,325	40,486
Share of farm income in household income	61%	47,8%
non-farm income	22%	27,6%
other income	16%	24,5%

fig 23 – Income Summary Statistics (Source CBS(b) 2003-04, table 11.0)

Katmandu has an international airport and all main cities have a domestic airport. Personal traffic between the main cities through the air is easy and does not take much time.

The primary road net (red on the map) is average to good in the Tarai but severe in the hills and mountains. A trip from Katmandu to Pokhara through the hills takes 4 - 5 hours (200 kilometres). In general all types of cars except long trucks (40’ containers) can cross the country.

fig 24 – Different road conditions a. Highway b. Hill road c. Single lane bridge. (Pictures Tjerk Reijenga)

fig 25 – Map of Nepal with main areas and main infrastructure (Source OCHA UN Nepal)

4.2 Climate

According to Köppen-Geiger climate classification system, Nepal has three main climate types :
- Cwa in the Tarai,
- Cwb the hills,
- Dwc the mountains.

Explanation of these codes are:

1st	*2nd*	*3rd*	*Description*	*Criteria*
C			*Temperate*	$T_{hot}>10$ & $0<T_{cold}<18$
	w		*- Dry Winter*	$P_{wdry}<P_{swet}/10$
		a	*- Hot Summer*	$T_{hot}\geq 22$
		c	*- Warm Summer*	*Not (a) &* $T_{mon10}4$
D			*Cold*	$T_{hot}>10$ & $T_{cold}\leq 0$
	w		*- Dry Winter*	$P_{wdry}<P_{swet}/10$
		c	*- Cold Summer*	*Not (a, b or d)*
E			*Polar*	$T_{hot}<10$
	t		*- Tundra*	$T_{hot}> 0$

** T_{hot} = temperature of the hottest month, T_{cold} = temperature of the coldest month, T_{mon10} = number of months where the temperature is above 10, P_{dry} = precipitation of the driest month, P_{sdry} = precipitation of the driest month in summer, P_{wdry} = precipitation of the driest month in winter, P_{swet} = precipitation of the wettest month in summer, P_{wwet} = precipitation of the wettest month in winter.*

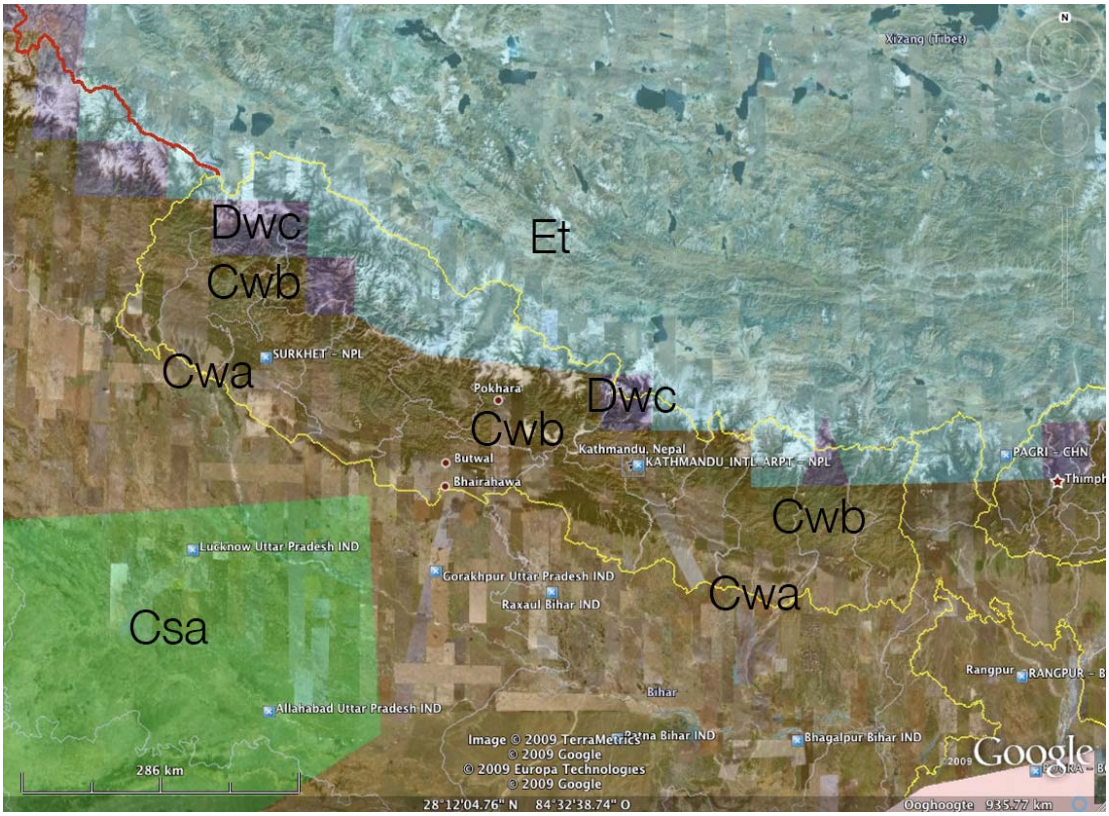


fig 26 – Map of Nepal with main climate classification. (Source Google-earth with Köppen-Geiger plug-in)

PHYSIO-GRAPHIC ZONE	SURFACE AREA (%)	ELEVATION (m)	CLIMATE
Et - High Himalaya	23	above 5,000	Tundra-type & Arctic
Dwc - High Mountains	20	4,000-5,000 3,000-4,000	Alpine Sub-alpine
Cwb - Mid-hills	30	2,000-3,000 1,000-2,000	Cool temperate monsoon Warm temperate monsoon
Cwa - Lowlands (Tarai & Siwalik Hills)	27	500-1,000 below 500	Hot monsoon & Subtropical Hot monsoon & Tropical

fig 27 – Physiographic zones of Nepal with detailed climate types. (Source LRMO 1986)

4.3 Traditional architecture

All types of houses can be seen in Nepal. During the field-trip (Kathmandu – Pokhara – Narayangadh – Hetauda – Kathmandu) a good overview is given of the main building structures of Central Nepal. This overview has a range from the traditional, vernacular bamboo house to 14 stories reinforced concrete apartment buildings.

Bamboo house.
The bamboo house can be found in the Tarai. It is a simple construction based on bamboo culms and walls of split bamboo. In general the house has only one story. To protect against the cold in winter the walls are plastered with mud or clay. Originally

these houses have thatch roofs. Nowadays corrugated steel roofs are used.

fig 28 – Traditional bamboo houses in Chitwan National Park (Pictures Tjerk Reijenga)

Wood house.
Mainly in the east part of Nepal, due to rich resources, the wooden house is rather common.

fig 29 – Traditional wooden houses in East Nepal (Pictures Keshab Adhikari)

Masonry house.
In the hill area the masonry house is more common. The house is plastered with mud like the bamboo house to make it more airtight and keep the heat inside in winter and in cold nights. Roofs are covered with thatch or slate stone.

fig 30 – Traditional masonry houses near Bandipur (Pictures Tjerk Reijenga)

Newer houses have two stories and look like the Newari house. The roof is mainly corrugated steel as a rather common roofing material nowadays.

fig 31 – Recent masonry houses along the road between Kathmandu and Pokhara (Pictures Tjerk Reijenga)

Newar house.

The typical traditional Newar house in Kathmandu Valley is usually three or four stories high. It has a simple rectangular plan with depth about 6 m and length varying from 3 to 10 meters. The foundation is usually shallow, made out of stones. The superstructure is constructed with locally available sun-dried bricks and mud-mortar. Three walls, two outside walls and one spine wall at the centre, support the whole structure. Timber joists over which wooden boards with a thick layer of mud topping is applied support the floors and roof. The roof is double pitched and has brick tile roofing.

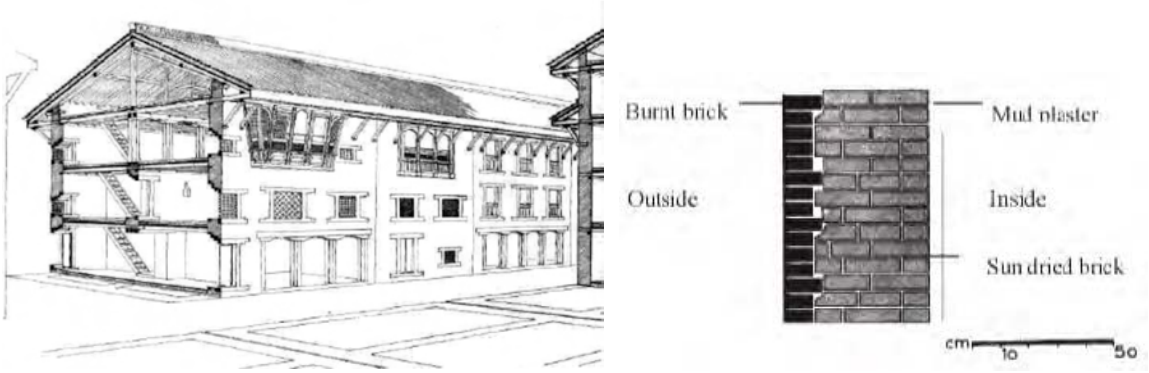


fig 32 – Cross-section of Newar house and wall detail. (Source: Korn 1976)

Most of the traditional houses are simple and symmetric in plan and have uniform distribution of mass and stiffness. Also the openings have been symmetrically arranged the centreline of the structure. This may result to avoiding torsion effects while centre of mass and the centre of rigidity coincide. However, traditional houses can be slender and thus vulnerable to damage.

fig 33 – Examples of Newar style houses. fig. c. is a typical example of an old urban Newar house. (Pictures Tjerk Reijenga)

4.4 Construction

Bamboo buildings
During the field-trip several project with bamboo buildings have been visited.

a. Traditional bamboo house in the Tarai.
This is the type as house as used in the Tarai for a very long time. The split bamboo is vertically mounted on a bamboo frame and the bamboo is covered with mud. See fig. x under Traditional Architecture.

b. Bamboo school in Bakhtapur.
In this project low cost schools are being build. The main structure is bamboo with bamboo strips. The bamboo is visible at the outside and covered with mud on the inside.

fig 34 – Bamboo school building in Thimi close to Bakhtapur. This construction is plastered with mud on the inside. (Pictures Tjerk Reijenga)

c. Bamboo house in Hetauda

This house is at the factory of Himalaya Bamboo Pvt. Ltd. and is in use as a demonstration and training building for construction of these type of houses.

fig 35 – Bamboo house in Hetauda at the Himalaya Bamboo Pvt. Ltd.. (Pictures Tjerk Reijenga)

d. Bamboo house in Baireni

This house is one of the first bamboo houses constructed by Himalaya Bamboo Pvt. Ltd.

fig 36 – Bamboo house in Baireni. One of the first of this type. (Pictures Tjerk Reijenga)

e. Bamboo house in Lekhnath.

This house is build by Himalaya Bamboo Pvt. Ltd as an extension on the roof of the Leknath Chamber of Commerce office building. This can be seen as the state-of-the-art bamboo construction in Nepal.

fig 37 – Bamboo house in Lekhnath. Built as an extension on the roof of a concrete building. (Pictures Tjerk Reijenga)

Modern house.

The structure of modern houses consists of reinforced concrete frame infilled with masonry. Houses are usually 2 to 4 story houses high and have irregular plan with several terraces and different types of cantilevers. Roof is gently sloping with tile or sheet metal roofing or flat with a terrace. Walls are either face-bricked or covered with plaster and painted with pastel colours.

Houses have lot of detailing for example in stair, columns, and railings. One typical feature of Kathmandu houses is that on upper floors the intermediate floor slab continues trough the outer wall. This cantilever is used for decorative and sometimes storage purposes.

fig 38 – Private built concrete and masonry houses in Kathmandu Valley. The construction is a long process by adding terraces and volumes. (Pictures Tjerk Reijenga)

Modern houses in Kathmandu Valley are nearly always irregular both horizontally and vertically. Because of terraces they often have vertical setbacks, which causes changes of strength and stiffness in structure. Because of the high cost of building sites in Kathmandu some residential buildings areas also very slender in plan.

(Source: Temples and buildings standing over Kathmandu Valley which is vulnerable to earthquakes - Naresh Man Shakya, Heritage and Tourism Department Kathmandu Metropolitan City, NEPAL 2007)

Characteristics of self-built houses are:

- Buildings are mainly built from concrete and bricks.
- More expensive houses have a concrete column, beam and slab construction.
- Walls will be filled with bricks.
- Low cost housing will be massive walls of concrete blocks or bricks.

The materials used are:

- Foundation is cement and gravel stones.
- The floors are gravel stone, broken bricks and cement.
- Walls are of 230 mm (9 inch) bricks in a single layer.
- Floors are 120 mm (5 inch) concrete in a single layer.
- Roofs are made of concrete (flat roofs), single layer galvanised steel (sloped roofs) or single layer RCC concrete roofs (reinforced concrete).
- The use of wooden window frames, windows and doors is quite common in general with single glazing.

fig 39 – Development on project scale is growing. Multi-storey buildings become more popular in Kathmandu. (Pictures Tjerk Reijenga)

4.5 Installation

Sanitation
In general both toilet (asian model) and shower are combined in one room. In villages the toilet will be outside of the house. Modern buildings (apartments) have more then one bathroom.

Energy, heating and cooling.
On this moment the availability of electricity depends strongly on hydro power. In the rain season (July – September) there will be electricity most of the day. The rest of the year the supply of electricity is not secured. Power cuts of 16 hours a day are quite regular. Nepal has a total consumption of electricity of 2300 GWh/year and 0.2% comes from imported oil and 99.8 % comes from hydropower. (Source: Statical Yearbook of Nepal 2007)

Ventilation is based on natural ventilation with windows. This is very critical in the kitchen. Many houses have insufficient kitchen ventilation during cooking.

For comfort, a ceiling fan is used in many houses and buildings. The ceiling fan has a lower energy consumption then the air-conditioning. Most common air-conditioning are split systems with a rather low energy efficiency.

Solar panels are often used for hot water. In special on hotels.

Although the main source for cooking is LPG or kerosine, many people still cook on wood in a clay oven in rural areas and in the suburbs.

fig 40 – Different installations in houses. (Pictures Tjerk Reijenga)

4.6 Earth quake resistance

Nepal is prone to various types of natural disasters. Most part of the country is seismically active. Hence, the geomorphology is very fragile. High mountains and the Himalayan range of Nepal are quite young. They stretch almost 2500 km s from east to west and they fall under the seismically active zone, which is considered to be the result of subduction of the Indian plate under the Tibetan plate. Urban areas are highly vulnerable to earthquake disaster and it is one of the biggest obstacles for sustainable development. Nepal has suffered huge losses of lives and properties due to earthquakes.

The National Building Code (NBC) is the first such document prepared for Nepal in 1994 but it has not been implemented except three municipalities. The NBC provides both regulations and guidelines for the construction of buildings in all areas of Nepal. Lastly, Earthquakes, as such, do not kill people. It is the falling buildings that do. The collapse of engineered and non-engineered building during earthquakes is the main contributor to the loss of lives and injuries to the people. Therefore, good house construction practice sticking with the existing building code will help to minimise the loss of lives and properties. Preparedness is the most important way to minimise the impact of an earthquake. So, implementation of National Building Code is very significant for disaster

mitigation in Nepal.

(Source: Earthquake Resistant Design of Buildings / Nepal National Building Code and its Implementation Strategy for Municipal Engineers, November 2008 - UNDP/ ERRRP-Project: NEP/07/010)

4.7 Nepal National Building Code (NBC)

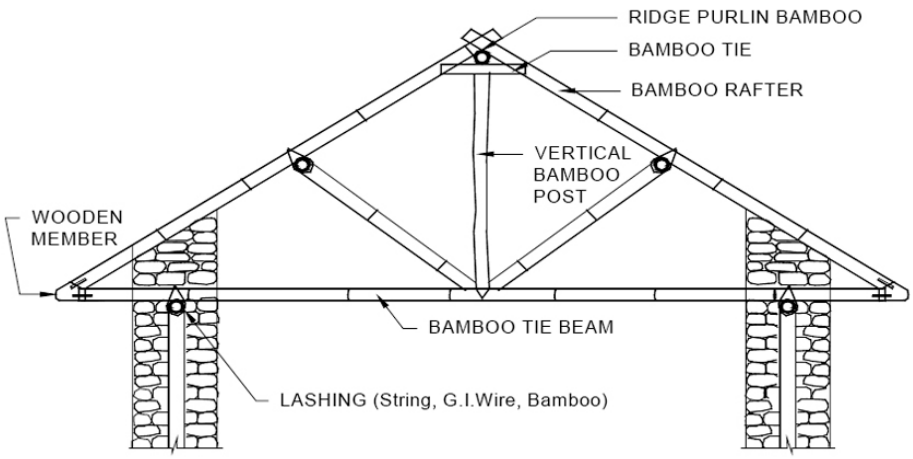
The National Building Code was introduced in 1993. There are three categories of building designs. In general all building > three stories have to be well-designed and professionally engineered.

For building of three or less stories and build in traditional construction, the NBC foresees in ‘Guidelines’. For buildings in other ways of construction the NBC has ‘Mandatory Rules of Thumb’.

NBC 203 - ‘Guidelines for earthquake resistant building construction: Low strength masonry’ give rules for the use of bamboo in traditional floor and roof constructions, the use of bamboo for reinforcement and recommendations for ‘harvesting and preserving bamboo for construction’.

Implementation of the NBC is still ongoing. With support of the UNDP several training programs on capacity building has started. Important thing is to raise awareness for the risk of earth-quakes and the design of earth-quake resistance buildings.

In april 2009 a report is published to update the Nepal National Building Code (Recommendation for update of Nepal National Building Code, april 10 2009 – UNDP/ ERRP-Project: NEP/07/010)



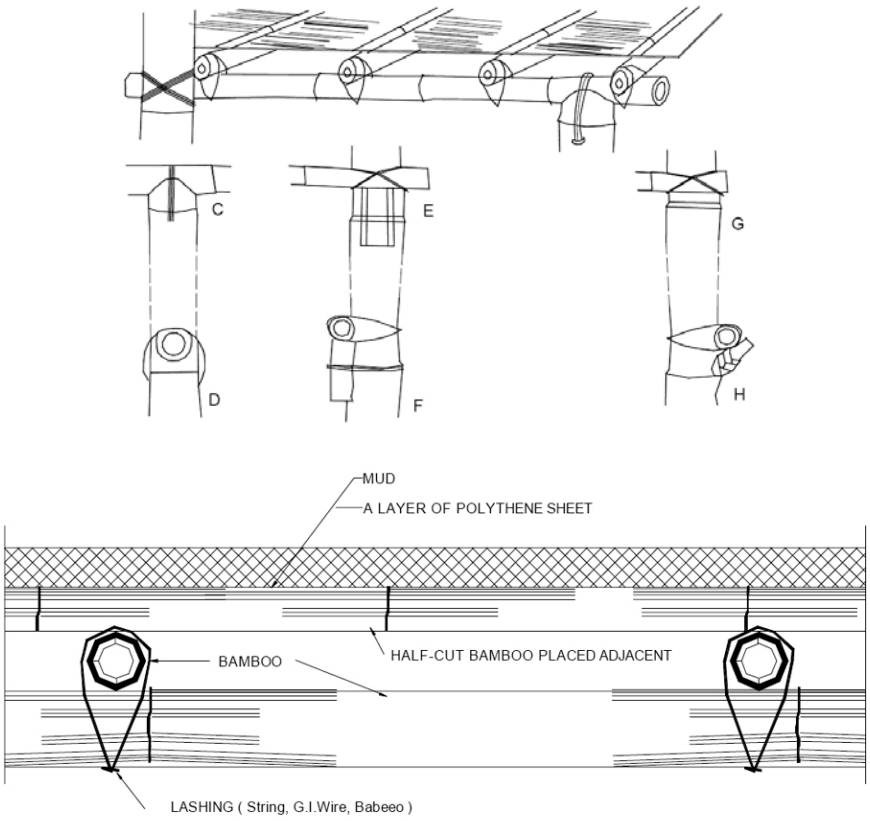


fig 41 – Some illustrations from NBC 203.

4.8 Cost

The cost for construction and building materials is increasing rapidly in the last 5 years. The Nepalese local government has official cost-statements to be used for construction.Compared with 2006 the cost for building materials doubled almost. See appendix 6.4 for Cost tables.

4.9 Residential market

Most Nepalese people live in their own house. The rental market for houses is around 7%. New built houses become larger and are used to rent out by room or by apartment. About 30% of the population in urban areas live in these rented apartments (or rooms).

fig 42 – Development of town houses in modern style by CE Construction Pvt. ltd. (Pictures Tjerk Reijenga)

An average new developed house in Nepal is around 115 m^2 and will be used by one

family with about four to six family members. In general the grandparents live together with their children. The family will live on the 2nd and 3rd floor and the 1st floor will be used for business or rented out.
In urban areas however, the surface of a house goes into the direction of 350 m^2 (source: Thesis Srijana Shakya, Wageningen 2006). These houses with more then 3 floors are used for the own living and for renting out. According to the statistics, in urban areas house owners gain 25 to 40% of there income by renting out there own house.

Description	Nepal living standerd survey	
	1995/96	2003/04
Percentage of household who reside in their own housing unit	93,8%	91,6%
Percentage of households occupying housing units for rent	2,2%	5,4%
Average size of dwelling (sq.ft.)	604 sq.ft	531 sq.ft
Percentage of households living in structures with:		
Cement bonded walls	10,7%	18,3%
Concrete roof	5,7%	13,6%
Galvanized-sheet roof	11,2%	21,0%
Cement/tile floor	5,1%	15,2%
Percentage of households with access to electricity	14,1%	37,2%
Percentage of households having access to piped water	32,8%	43,9%
Percentage of households with own toilet facility	21,6%	38,7%

fig 43 – Ownership and quality of households (Source: CBS(a) 2003/04, table 3.0)

The overall statistics show that around 92% of the population lives in their own house and the others live in rented spaces (houses, apartments or rooms). When we split the statistics in urban and rural we see that in urban areas, 72% of the people live in their own house and the others are renting space while in rural areas this figures are 95,5% and 4,5%. In Kathmandu Valley the population that is renting space is even 36% (Source: CBS(A) 2003/04, table 3.1).

	Household income (NRs.)		Per capita income (NRs.)		Average HH size
	Mean	Median	Mean	Median	
Urban	**157,550**	**105,035**	**32,573**	**22,129**	**4.8**
Kathmandu Valley	222,666	169,250	45,816	33,333	4.9
Other	122,635	78,900	25,420	16,558	4.8
Rural	**65,107**	**47,200**	**12,124**	**8,774**	**5,4**
Consumption quintile					
Poorest	37,243	31,147	5,681	16,558	4.8
Second	49,240	41,771	8,127	7,292	6.1
Third	54,348	44,707	10,617	9,596	5.1
Fourth	75,076	63,942	15,073	13,494	5.0
Richest	156,486	112,962	36,415	28,008	4.3
Nepal	**80,111**	**51,978**	**15,162**	**9,606**	**5.3**

fig 44 – Nominal household income and per capita income (Source CBS(b) 2003-04, table 11.1)

The households with the highest income can be found in urban areas. If we look how the household income is divided, we see that the richest people live in urban areas and the middle group lives in the Rural West Hills. The Rural East Hills are the poorest (except of the mountains). In the Rural West Tarai is close to the Rural West hills while the Rural East Tarai is just under the Rural East Hills.

Quintile	Kathmandu Valley Urban	Other Urban	Rural West Hills	Rural East Hills	Rural West Tarai	Rural East Tarai	Total
Poorest (First)	1,2	8,6	17,5	26,4	17,0	25,9	20
Second	0,6	9,4	18,5	20,1	24,7	25,3	20
Third	3,3	17,0	23,5	16,9	25,4	21,0	20
Fourth	14,9	21,6	23,2	22,9	15,7	18,4	20
Richest (Fifth)	80,0	43,5	17,2	13,7	17,1	9,4	20
Nepal	100	100	100	100	100	100	100

fig 45 – Distribution of population by nominal per capita income quintile and geographic group (Source CBS (b) 2003-04, table 11.6)

The plots of land are smaller in the urban areas and also more expensive. probably one of the main reasons to make small, deep and high houses. In general it is allowed to built 80% of the plot with a FAR of 3 to 5 depending on the area. Resulting in houses of 300 to 450 m^2. In the rural areas the plots are larger and this means that the houses can be lower. In general the FAR will be lower too.

4.10 Market for prefabricated bamboo panels

Looking to the way of building and the income we can divide the market in three interesting groups:

a. urban private development (hills)

b. urban commercial development (hills)

c. rural private development (hills)

In each of these groups is a market for prefabricated bamboo panels or prefabricated bamboo houses.

Urban private development.
As described before this market is based on small and high buildings in a high urban density. The habit is to construct the houses floor by floor and built an extra layer when the family has enough money to invest. This system can be used for hybrid buildings as well. The bamboo house in Lekhnath is a good example. On the roof of an existing structure, a new bamboo house is built. This example can be used by private owners to expand there house. In general bamboo construction cost are lower then concrete construction cost.

The second possibility in this market is to use bamboo panels or bamboo sandwich panels instead of bricks for filling the concrete structure. This method is quite common in northern Europe. Because of the lack of large construction cranes at the site, smaller elements or in situ built elements will be needed.

Urban commercial development.
Main commercial development is concentrated in the urban areas. A new trend is the development of townhouses and villas. These types of houses can be built in wood-frame or in bamboo-frame construction. The most practical construction method is the Canadian wood-frame construction. The number of floors can go up to 3 floors.

Rural private development.
Professional carpenters can easily built bamboo-frame houses in one or two floors. As the approach is easy to learn, it will give self-builders the opportunity to built their own house or to extend their own house.

Building requirements
As the average household now lives in a house of around 50 m^2, it can be expected that the demand for housing surface will increase. Some flexibility in promoting new house types will be necessary. This can be done by designing a prototype house that is strong enough to be built in 2 floors. The same 2 basic designs can be doubled or combined and a range of living surfaces from 40, 60, 80, 100, 120 m^2 can be built.

The climate in Nepal also ask for different floor, wall and roof constructions. The bamboo-frame construction has to be flexible in this aspect. Different layers and different thermal insulation values are necessary.

As the cost of wood in Nepal is rather low, hybrid constructions will a good opportunity as well. Wooden studs and beams (mainly 2’ x 4’ and 2’ x 6’ or 38 x 89 mm and 38 x 140 mm) will be used for small houses.

based on the income, a cost for housing between 25 - 35% and the investment/loan that fits to these cost, the next table is generated.

	Income/year	Housing cost/year	Investment
Urban	160,000 NRs	40,000 - 80,000 NRs	1,600,000 NRs
Rural	65,000 NRs	16,000 - 32,000 NRs	650,000 NRs

The bamboo house in Lekhnath is constructed for NRs 1800/sq.ft. So a house of 60 m^2 (650 sq.ft) will cost around NRs 1,200,000 and a house of 40 m^2 (430 sq.ft) will cost around NRs 800,000. The cost for a concrete house of the same dimensions might be the double of this cost.
The cost is depending on the quality of the construction. In he Hills the quality (because of the climate) have to be higher. In the Tarai the quality can be lower.

5 Ethiopia

5.1 Country facts

Ethiopia has a surface of 1.127.127 km^2. The country is situated between the Equator and the Tropic of Cancer. Ethiopia has borders with Sudan (west), Erithrea (North), Djibouti (East) and Kenya (South).
Ethiopia contains a variety of distinct topographical zones. It is a country of geographical contrasts, varying from as much as 116 m below sea level in the Danakil depression to more than 4,600 m above in the mountainous regions. Ras Dashen, with an altitude of 4,620 m, is the fourth-highest peak in Africa. The most distinctive feature is the northern part of the Great Rift Valley, which runs through the entire length of the country in a northeast-southwest direction, at a general elevation of 1,500 to 3,000 m.

Immediately to the west is the High Plateau region; this rugged tableland is marked by mountain ranges. East of the Great Rift Valley is the Somali Plateau—arid and rocky semi-desert, extending to the Ogaden, which covers the entire south-eastern section of the country. In the north, the Denakil Desert reaches to the Red Sea and the coastal foothills of Eritrea. The western boundary of Ethiopia follows roughly the western escarpment of the High Plateau, although in some regions the Sudan plains extend into Ethiopian territory. The country can be divided in 4 main regions: The High Plateau (Abyssinia) in the North, the Plains of Choa (South-West), the low lands (West and North-West).

Ethiopia's largest lake, Lake T'ana, is the source of the Blue Nile River. This river, which winds around in a great arc before merging with the White Nile in the Sudan, travels through great canyons, which reach depths of more than 1,200 m. Several rivers in the south-west also make up a system of tributaries to the White Nile.
The country has fertile highlands, deep canyons, tropical rain forest, desserts and mountain ranges.

Since 2001 the exponential growth rate is around 2,6% each year. This means that the population of 65 million in 2001 became 80 million in 2009. About 16 to 17% of the population lives in cities but this percentage is growing.
The population of the cities is growing with 4,2% a year. In Addis Ababa the population growth is higher then average. 32% of the inhabitants is unemployed and 70% of the ca. 4 million inhabitants live in slums. Because of the poor population in the city, the city became a chaos of self-built settlements. The other cities are much smaller, Dire Dawa has 384,000 inhabitants and Ambo has 50,000 inhabitants. In both cities 60-70% of the population lives in slums. *(Source: UN-HABITAT, Ethiopia Urban Profile 2008)*

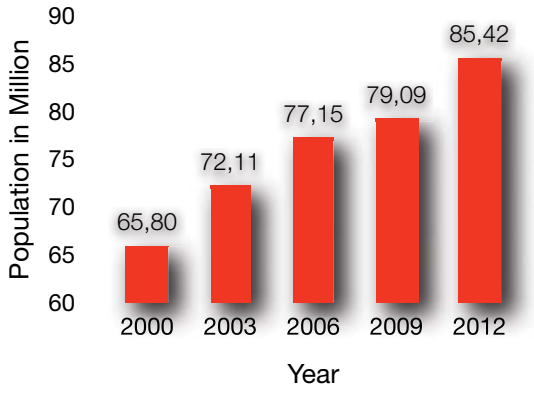


fig 46 – Population growth (Source UN-HABITAT, Ethiopia Urban Profile 2008)

Ethiopia is an old country with a very young population. 45 percent of its 80 million people are under 15 years. Large families, or rather, large dependency ratios, is closely linked with poverty. If the dependency ratio increases with one, the probability of falling into poverty increases with 30 percent. Some international aid organisations think population growth will become the most important challenge for the Ethiopian Government in the future. Life expectancy at birth is 44 years; 6 years shorter than the sub-continental average. It is estimated that 40 percent of the population lives below the national poverty line of USD $ 1 a day, adjusted for purchasing power parity. As much as a third of household spending is non-monetary; informal trade for goods or services. According to the UNDP publication Human Development Report 2009, Ethiopia is ranked 171st out of 182 countries. Ethiopia is one of the poorest countries in the world, with a per capita income (GDP) of only USD $ 220. This is low even by African standards, where the average is USD $ 450. The poverty of Ethiopia is aggravated by its huge, and growing, population of 77 million people. With an average of 6 children borne by each Ethiopian woman, the country has to feed, educate and accommodate 2 million new inhabitants each year, or an additional 2.7 percent to the population.

The majority (80%) of the population works in the agricultural sector, and contributes to 40 percent of the economy - three times the average of sub-Saharan Africa. Agricultural self-sufficiency has been a priority for the Ethiopian government in its entire modern history, and is indeed the main priority goal for the current government.

Main economic activities are in Addis Ababa, Dire Dawa and Bahir Dar. The government invest a lot in infrastructure together with the world bank. Six new airports are built all over the country, a new railroad company (ERC) is founded to extend the existing railroad to over 5,000 km and about 11,000 km federal roads and 5,500 km regional roads are constructed or planned.

Ethiopia is a parliamentary democracy with federal elements, as outlined in the 1994 constitution. Parliament (Shengo) is divided between the upper constitutional House of the Federation (108 seats), and the lower legislative House of People's Representatives (547 seats). The country is divided into 9 ethnically based states (killils), plus two autonomous administrative areas, Addis Ababa and Dire Dawa. Each regional state has its own parliament, the State Council. Each state is divided into zones, districts (woreda), cities, and urban or peasant dweller associations (kebeles). Larger cities are divided into quarters (ketama).
The state owns all land, and is represented in all regions, districts and municipalities.

5.2 Infrastructure

Infrastructure intersects with all economic activities. As a result, the Government has made huge investment on the provision of infrastructure in terms of expansion of the road network, irrigation, and electricity supply and telecommunication services.

The predominance of smallholder agriculture in Ethiopia underscores the importance of good access to markets and transhipment centres for their produce and input supply. As Ethiopia faces food security problems, access to markets and road infrastructure and transport services in order to reduce isolation of communities and creating a link to regional and national markets is essential.

Recognising the importance of road transport for national economic and social development, the Government of Ethiopia is devoting high priority to improving road infrastructure. It has developed and is implementing a 10-year Road Sector Development Program (RSDP) launched in 1997, the aim of which is to tackle the constraints of economic and social development arising from the inadequacy of infrastructure. The Government is pursuing this by creating adequate capacity in the road sector by constructing and rehabilitating the essential road network.

In summary, the major achievements during the period include:

• Total road network of the country reached to 39,477 km (excluding community roads) as of June 2006.

• During 2005/06, 429.5 km of rehabilitation and upgrading of primary roads, construction of 1945.7 km of primary and rural roads, and 33,302 km of community roads construction have been completed;

• Road network density has increased from 32.3 km/1,000 km^2 in 2001/02 to 35.9 km/ 1,000 km^2 by the end of 2005/06; and,

• Proportion of roads in good condition has increased from 30% to 64% during the period 2001/02 to 2004/05. The target for the PASDEP period is to increase further to 84%.

(Source Ethiopia: Building on Progress: A Plan for Accelerated and Sustained Development to End Poverty (PASDEP) Annual Progress Report 2005/06)

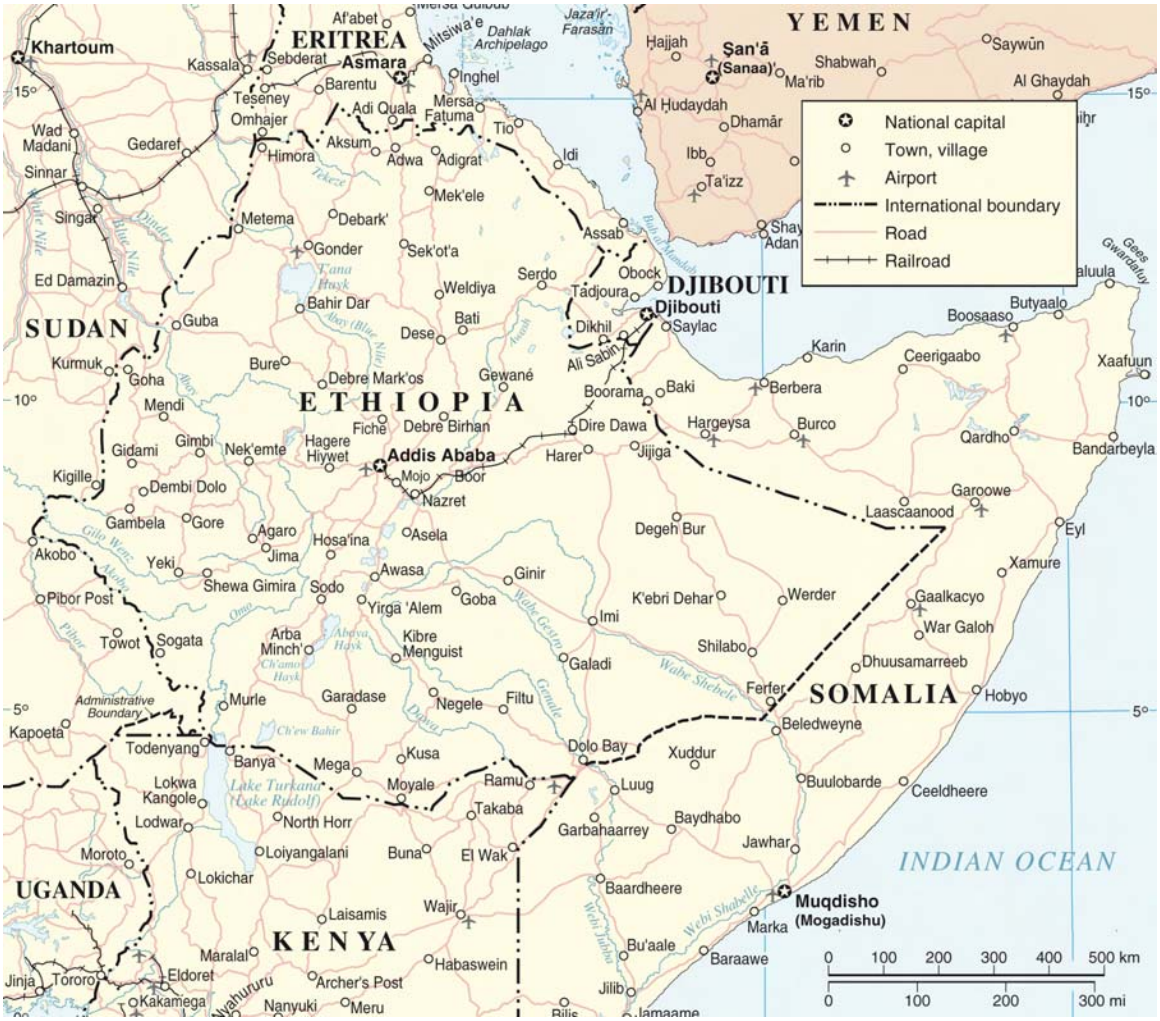


fig 47 – Map of Ethiopia with main areas and main infrastructure (Source UNDP)

5.3 Climate

Because of the high altitude of Ethiopia, in general the climate is temperate and pleasant. The average day temperature is 20°C. There is no real difference in seasons. In the Abyssinian High Plateau, the month from October to May are the warmest and in general this period is seen as summer. The less populated lowlands have a sub-tropical to tropical climate. Average rainfall for the whole country is around 850 mm but long periods of drought occur (like this summer 2009). In the High Plateau are two moon-soon periods: in Februari/March and from June to September.

Typical climate in some cities.

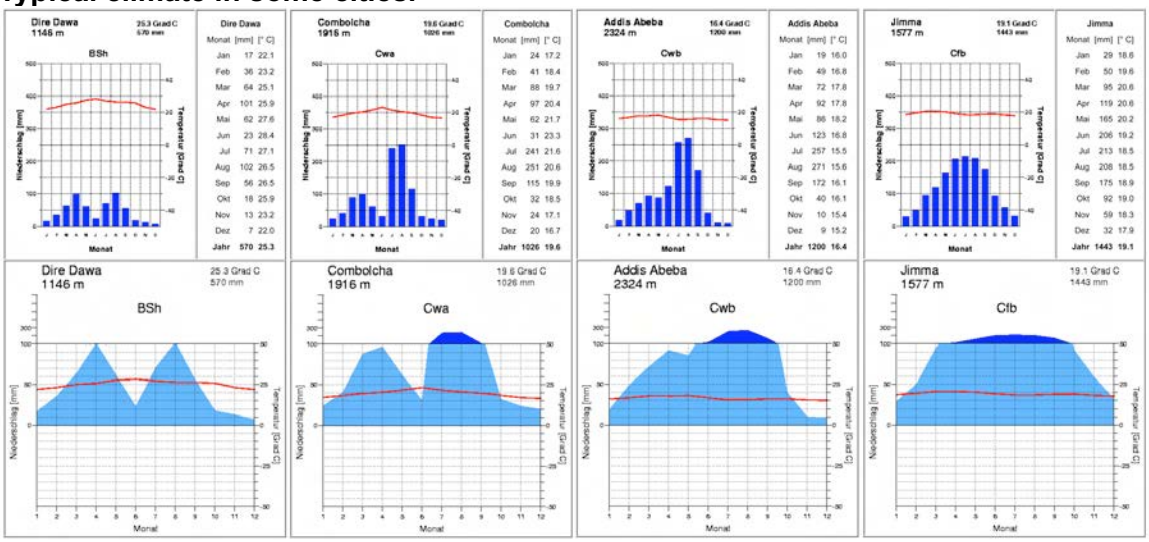


fig 48 – Climate in different cities in different climate areas.

According to Köppen-Geiger climate classification system, Ethiopia has five main climate types :
- Aw in the west and south-west,
- Bsh in the east lowlands,
- Bwh in the area along the Somalian border,
- Cfb in the south High Plateau,
- Cwb the High Plateau around Addis Ababa.

Explanation of these codes are:

1st	*2nd*	*3rd*	*Description*	*Criteria*
A			*Tropical*	$T_{cold} \geq 18$
	w		*- Savannah*	*Not (Af) &* $P_{dry} < 100 - MAP/25$
B			*Arid*	$MAP < 10 \times P_{threshold}$
	s		*- Steppe*	$MAP \geq 5 \times P_{threshold}$
		h	*- Hot*	$MAT \geq 18$
B			*Arid*	$MAP < 10 \times P_{threshold}$
	w		*- Desert*	$MAP < 5 \times P_{threshold}$
		h	*- Hot*	$MAT \geq 18$
C			*Temperate*	$T_{hot} > 10$ & $0 < T_{cold} < 18$
	f		*- Without dry season*	*Not (Cs) or (Cw)*

		b	*- Warm Summer*	*Not (a) & T_{mon10} ≥4*
C			*Temperate*	*T_{hot}>10 & 0<T_{cold}<18*
	w		*- Dry Winter*	*P_{wdry}<P_{swet}/10*
		a	*- Hot Summer*	*T_{hot}≥22*

** MAP = mean annual precipitation, MAT = mean annual temperature, T_{hot} = temperature of the hottest month, T_{cold} = temperature of the coldest month, T_{mon10} = number of months where the temperature is above 10, P_{dry} = precipitation of the driest month, P_{sdry} = precipitation of the driest month in summer, P_{wdry} = precipitation of the driest month in winter, P_{swet} = precipitation of the wettest month in summer, P_{wwet} = precipitation of the wettest month in winter, $P_{threshold}$ = varies according to the following rules (if 70% of MAP occurs in winter then $P_{threshold}$ = 2 x MAT, if 70% of MAP occurs in summer then $P_{threshold}$ = 2 x MAT + 28, otherwise $P_{threshold}$ = 2 x MAT + 14). Summer (winter) is defined as the warmer (cooler) six month period of ONDJFM and AMJJAS.*

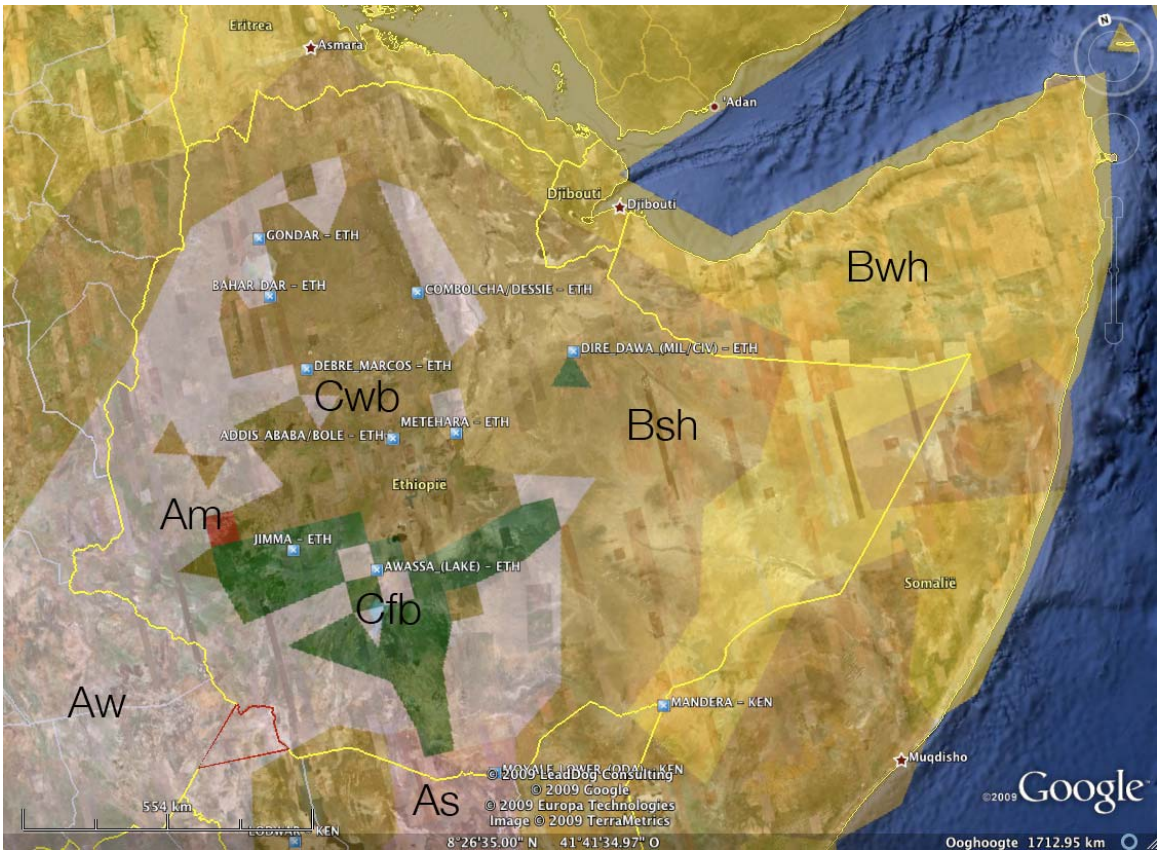


fig 49 – Map of Ethiopia with main climate classification. (Source Google-earth with Köppen-Geiger plug-in)

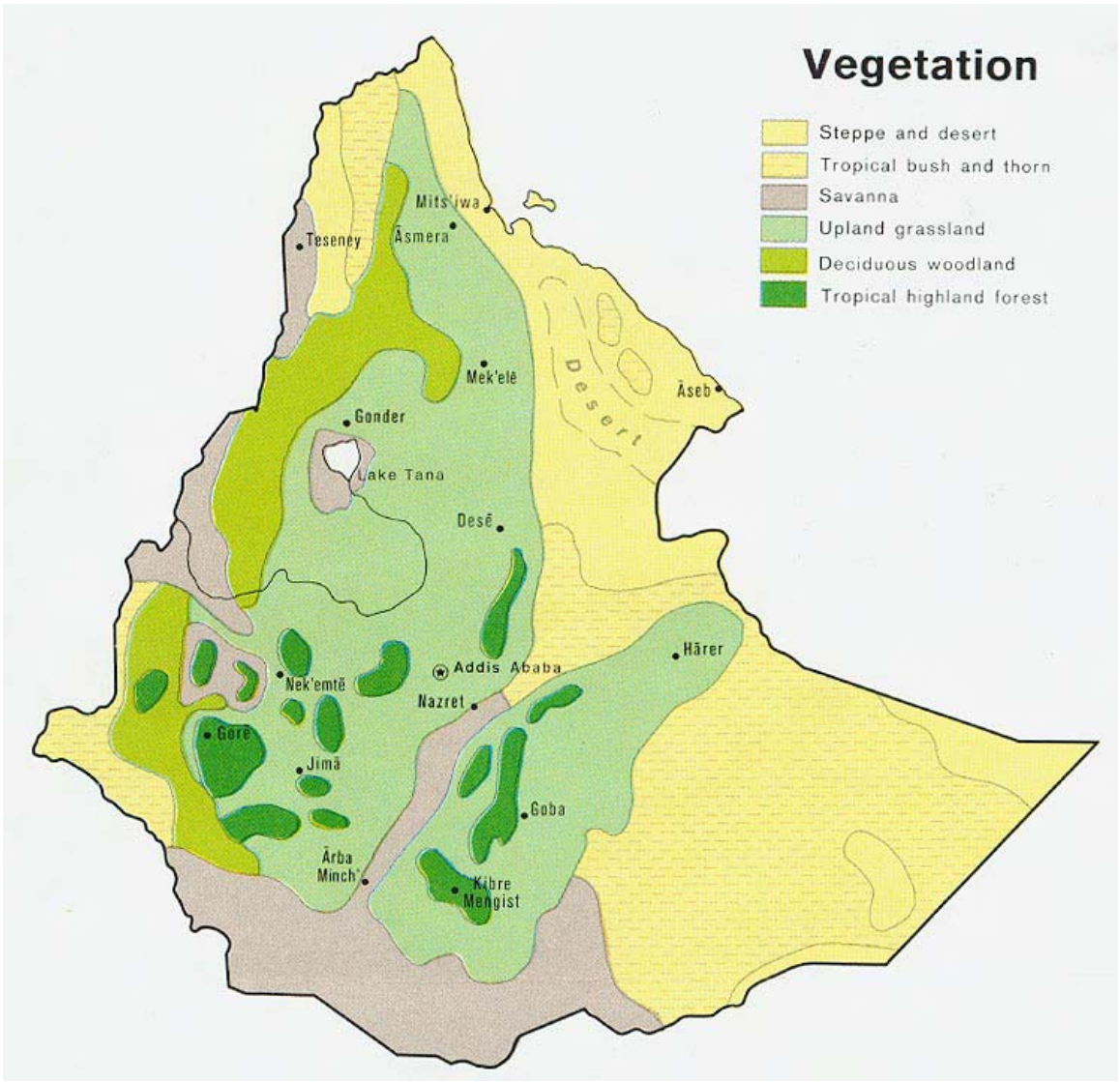


fig 50 – Map of Ethiopia with main vegetation. (Source)

5.4 Traditional architecture

A typical traditional house in Ethiopia is the mud house with thatched or tin roofs. In the rural areas the traditional thatched hut (tukul) is still the most common dwelling. In and around the cities many poor shelters made with corrugated steel can be seen. In and around Addis Ababa many brick and concrete apartment blocks can be seen as well as private houses in the suburbs. As of the mid-1980s, over two-thirds of all housing units were constructed of wood and mud, and a lesser number of wood and thatch.

Western style house.
Although Ethiopia always was an independent country and beside 6 years of Italian occupation during WW II it has never been a colony, some of the older houses look like the western style houses in other regions of Africa. Nowadays there is more interest to preserve these old houses.

fig 51 – Traditional houses in Addis Ababa (Pictures Addis Ababa National Museum)

Bamboo house.
The bamboo house can be found everywhere in the High Plateau. It is a simple construction based on bamboo culms and walls of split bamboo. In general the house has only one story. The more traditional constructions have woven bamboo roofs.

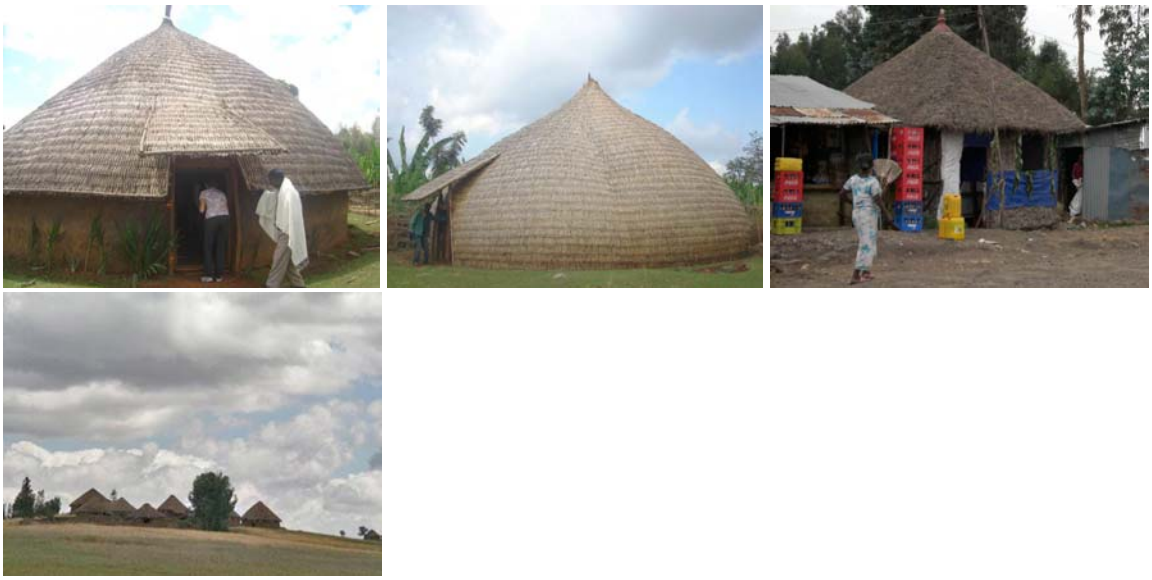


fig 52 – Traditional bamboo/thatch houses in Ethiopia (Pictures a+b Melaku Tadesse, picture c Tjerk Reijenga)

A modern bamboo house is constructed at the FEMSEDA site. It is in use by the INBAR organisation in Ethiopia.

fig 53 – Modern bamboo house for INBAR in Addis Ababa (Pictures Tjerk Reijenga)

Mud house.
All over Ethiopia the mud house is more common. The house is plastered with mud like the bamboo house to make it more airtight and keep the heat inside in winter and in cold nights. Roofs are covered with thatch or slate stone.

fig 54 – Traditional mud houses in Harar (Pictures Iconotec Stock Photography)

Slum house.
60 to 70% of the urban population lives in slums. The typical slum house is constructed out of waste and corrugated steel.

fig 55 – View over the slums of Addis Ababa (Pictures Tjerk Reijenga)

5.5 Urban Development and Construction

It is estimated that 80 percent of the urban population is living in sub-standard housing. Half of these are either living in shacks or homeless. The abysmal living conditions may contribute to the continued low proportion (16 %) of Ethiopians living in urban areas. 80 percent of the housing stock in the cities needs either upgrading or replacement. Only half of the urban structures have private or shared water connections. The government estimates that 35 percent of urban solid waste is never collected, while only ten percent of the population reports using a municipal waste collection system. 70 percent of the road network in the capital is gravel, slightly better than the national average of 85 percent.

The Ethiopian Government launched a National Urban Development Policy that was approved by the Council of Ministers in March 2005. The main objective is to achieve the goals of that stipulates that:

- Ethiopia's cities provide efficient and effective public services to their residents;
- Complement and facilitate rural development; and,
- Serve as models of participatory democracy and help build accelerated economic opportunities that create jobs.

The strategy has four pillars:

- Support for small and micro enterprises and job creation;
- Integrated housing development;
- Improved access to land, infrastructure, and services; and
- Promoting urban-rural and urban-urban linkages.

The focus of activities during the first year of PASDEP implementation was on preparing the groundwork for full-scale implementation of the pillars of the urban development strategy.

The Urban and Industrial Development Package that constitute three major programs and one implementation plan have been prepared during 2005/06. The programs that constitute this package are Integrated Housing Development Programs, Small and Micro Enterprise Development Program, and Youth-Oriented Local Development Program. The following activities have been undertaken during 2005/06:

- Preparatory work for the construction of 60,500 housing units in 2006/07 has been completed;
- Completion of the low cost housing construction work that started earlier in Addis Ababa, Adama, Dire Dawa, Awassa, and others;
- Priority has been given to preparatory works to launch the Urban and Industrial Development package. The preparatory work has focused on building implementation capacity that include institutional capacity for regions and municipalities, design of working systems and procedures, training and recruitment of professionals, feasibility study, supply of construction materials, land preparation and financing, etc.
- In regard to micro and small enterprise development, the activities undertaken in 2005/06 include:
  - •• Preparation of detail plan for the program; and,
  - •• Preparatory work for full-scale implementation of the program.

  These activities in the main relate to building implementation capacity of the sub-sector which focus on devising working systems and procedures, conduct training, etc.;
- Given that the construction industry plays a critical role in urban development, the Ministry of Works and Urban Development has undertaken a number of activities to enrich and fine-tune the already prepared construction policy document. The policy is about to be submitted to the appropriate Government body for approval. The policy is expected to be put in to effect during the 2006/07 fiscal year;
- In an effort to standardise the activities of the construction industry, the Draft National Building Code Proclamation has been prepared and submitted to the appropriate Government body for approval. Model Rules and Regulation to facilitate implementation of the policy is also already prepared;
- In an effort to maintain international standards and quality of building construction works, particular focus has been made on public buildings to render them efficient, planned and purpose- oriented. Special attention will be given to federal ministries that have not had enough office space; and,
- Maintaining the quality and standard of buildings has remained a challenge that needs to be addressed in the subsequent years of the PASDEP.

As indicated above, the road network contributes to rural–urban linkages, and the spatial

dimensions of regional development. It is also worth looking from the perspective of urban rural linkages and their contribution to the intensification of small towns through creating demand for agricultural produce.

Urban Development in short:
• Reduce urban unemployment rate in towns with 50,000+ populations from 40 to 20%,
• Provision of housing and basic services from 30 to 65%
• Number of new houses built : 100,000 (yearly average)
• Provision of land and infrastructure : 3,800 hectares/annum
• Reduction of slum areas from 70 to 35%
• Number of micro and small enterprises : 12,000 per annum

(Source: Ethiopia: Building on Progress: A Plan for Accelerated and Sustained Development to End Poverty (PASDEP) Annual Progress Report 2005/06 Ministry of Finance and Economic Development (MoFED))

The deplorable urban housing situation has not improved by the continued state ownership of urban rental houses and land. The private sector is just now being involved in upgrading and building urban housing, and will be expected to cover about a third of the cost. They are supported by the Federal Integrated Housing Development Programme (IHDP), where the government want to prepare existing open spaces with basic infrastructure for medium to low-income housing.

The project is supposed to be part-financed by the new home owners. Given their extreme poverty and lack of collateral, it is not clear how they will ever be able to repay their subsidised loans. A study by the German Technical Co-operation and the Urban Institute indicates that only 20 percent of the urban population can afford even the traditional Chika mud and wood housing.
(Source: UN-HABITAT, Ethiopia Urban Profile 2008 and Capacity Building for Decentralised Service Delivery GTZ)

Modern house.
Modern residential constructions can be divided in three main categories:

- Private co-operation development
- Private commercial development
- Social development

The structure of modern constructions consists of reinforced concrete frame in filled with concrete brick. Low rise houses are usually 2 floor houses and apartment buildings are 4 to 5 story buildings.

It is possible to lend a site from the government and built a house. In general this is done by co-operations of building owners.

fig 56 – Private built concrete houses in Addis Ababa. (Pictures Tjerk Reijenga)

The Social Housing Program only builds condominiums. To keep the cost as low as possible the floor plan is around 50 m^2 and the construction is based on a concrete

skeleton, concrete hollow bricks. The roof is gently sloping with metal sheet roofing. Walls are mostly covered with plaster and painted with pastel colours.

fig 57 – Government built concrete condominiums according to the Social Housing Program. (Pictures Tjerk Reijenga)

Interior walls are made of Agrostone. Originally a Chinese product and now manufactured in Addis Ababa. The Agrostone is manufactured from organic agriculture waste (sugar cane) and Magnesium Oxide and Magnesium Chloride. It is easy to make different forms and elements up till 3.5 meters length. The material is reinforced with fibreglass but thin bamboo reinforcement is under research. The application up till now is only in protected areas (inside).

fig 58 – Agrostone production facility and use in social housing. (Pictures Tjerk Reijenga)

fig 59 – Commercial built condominiums in the suburbs of Addis Ababa. (Pictures Tjerk Reijenga)

fig 60 – Commercial built compounds with individual houses in the suburbs of Addis Ababa. (Pictures Tjerk Reijenga)

The private sector can be found in older areas in the city centre (older houses) and in the suburbs (new development). Due to the new and modern road system around Addis Ababa it is easier to develop suburbs.

The materials used are:

- Foundation is cement and gravel stones.
- The floors are gravel stone and cement.
- Walls are of 200 mm concrete bricks in a single layer.
- Interior walls 200 mm Agrostone.
- Floors are 120 mm concrete in a single layer.
- Roofs are made of concrete (flat roofs) or steel thrushes with single layer galvanised steel (sloped roofs).
- The use of steel frames, windows and doors is quite common in general with single glazing.

5.6 Installation

Sanitation
In general both toilet and shower are combined in one room. In slums and villages there will be no sanitation in the house. Social housing (apartments) has a combined bathroom and a kitchen.

Energy, heating and cooling.
On this moment the availability of electricity depends strongly on hydro power. Power cut-offs occur regular.
Ventilation is based on natural ventilation with windows. This is very critical in the kitchen. Many houses have insufficient kitchen ventilation during cooking.
Heating and cooling is not required due to the rather stable temperature during the year.
Electrical appliances are used for hot water.
The main source for cooking is electricity or kerosine. In the country side many people still cook on wood.

fig 61 – Kitchen and bathroom in social apartments. (Pictures Tjerk Reijenga)

5.7 Earthquake resistance

Although Ethiopia is not one of the most dangerous areas in the world, earthquakes can occur. During the past century around 10 earthquakes with a force of 6 to 7 have been registered.

5.8 Ethiopian Building Code Standards (EBCS)

The Ethiopian Building Code Standards are introduced in 1995. Besides two general chapters on construction there are five categories of building designs : concrete, steel, steel and concrete, timber and masonry. One chapter on earthquake analysis and two chapters on plumbing and electrical installations.

5.9 Cost

The cost for construction is increasing rapidly in the last 5 years. All building materials have to be imported. There is a shortage in cement and 50% of the cement has to be imported. New factories are under construction to solve this problem for the future.
At the same time there is a big interest in new materials (like the Agrostone). Because the Agrostone factory is State owned the cost is around 81 Birr/m^2 ($ 6.00/m^2). See appendix 6.3 for Cost tables.
The Addis Ababa Social Housing Program develops apartments with an investment of 1570 Birr/m^2 ($ 116/m^2). For a 50 m^2 apartment this will this be an investment of 78,500 ETB ($ 5,790).

5.10 Residential market

The deplorable urban housing situation has not improved by the continued state ownership of urban rental houses and land. The private sector is just now being involved in upgrading and building urban housing, and will be expected to cover about a third of the cost. They are supported by the Federal Integrated Housing Development Programme (IHDP), where the government want to prepare existing open spaces with basic infrastructure for medium to low-income housing.

The goal is to reduce the proportion of slum-dwellers by 50 percent by 2010. The project is supposed to be part-financed by the new home owners. Given their extreme poverty and lack of collateral, it is not clear how they will ever be able to repay their subsidised loans. A study by the German Technical Co-operation (GTZ) and the Urban Institute indicates that only 20 percent of the urban population can afford even the traditional Chika mud and wood housing (source: German Technical Co-operation (GTZ) and Urban Institute (UI), Capacity Building for Decentralised Service Delivery (CBDSD) MoFED, PASDEP 2006-2010.).

The government is relying on considerable international support, given its own poor financial base. It is estimated that housing will take a full 56 percent of the total urban development bill the next ten years.

The Ministry of Works and Urban Development (MWUD) is in general responsible for overall policy, strategy formulation and capacity building. The National Urban Planning Institute, organised under MWUD, prepares physical urban development plans. The Urban Development Support Services, also organised under MWUD prepares urban human planning, such as financial planning, human resources and capacity building.

The households with the highest income can be found in urban areas. But even the social housing (condominiums) that are developed by the Addis Ababa Housing Development Project Office can not be afforded by over 80% of the population. Also the yearly production of 60,000 apartments in Addis Ababa is not enough to cover the needs of the people who can afford these apartments. On this moment there is a waiting list of over 400,000 people (*Source: Interview with Ms. Tsedal Mamo General manager of the Addis Ababa Housing Development Project Office*).

5.11 Market for prefabricated bamboo panels

Looking to the way of building and the income we can divide the market in three interesting groups:

a. very low income, self builders

b. low income depends on social housing

c. co-operation housing

d. commercial market

In each of these groups is a market for prefabricated bamboo panels or prefabricated bamboo houses.

Own development in slums.
The very low income people built there own house. Part of the population that live in the slums has a job and can spend some of there income on improving there homes. Local made bamboo panels can be useful for this group. Especially with good information about how to use bamboo panels.

Social housing.
There are two possibilities to use bamboo panels and/or bamboo panel sandwich in the condominiums developed by the Addis Ababa Housing Development Project Office. For filling the concrete structure (exterior walls) hollow concrete blocks are used and for interior walls hollow Agrostone blocks are used. Both applications can be done with bamboo panels or bamboo sandwich panels.

Co-operation housing.
This is a common private development for a group of home owners. For this group it is interesting to use one of the design with bamboo panels. The dimensions of 40 and 60 m^2 seems to be acceptable for this group. Possibility to built in 2 floors so that a house of 80 and 120 m^2 is also possible.

Commercial and non-residential market.
A simple structure that can be used for school class or a small hospital or other community buildings can be built in one-floor bamboo panel construction. This can be the same type of basic construction that is used for co-operative housing.
Commercial development with bamboo panels can be high-end as well. Using the Canadian Wood Frame method makes it possible to built nice looking and comfortable houses.

Building requirements
As the average household now lives in a non-existing house, a start with a small house is already a big step. Some flexibility in promoting new house types will be necessary. This can be done by designing a prototype house that is strong enough to be built in 2 floors. The same 2 basic designs can be doubled or combined and a range of living surfaces from 40, 60, 80, 100, 120 m^2 can be built.
The climate in Ethiopia is very moderate. No special requirement beside of rain protection are necessary. Some flexibility in wall and roof construction is needed to meet different needs and quality demands.
The widely available wood in Ethiopia is Eucalyptus wood. The wood is not suitable for building constructions. So bamboo plywood studs and beams (mainly 2' x 4' and 2' x 6' or 38 x 89 mm and 38 x 140 mm) will be used for small houses.
The cost will be very critical. On this moment the social housing condominiums are developed for 1570 birr/m^2 ($ 115.-)

6 APPENDICES

6.1 Questionnaire

Questionnaire for basic house design based on local requirements

Shanghai September 2009
Prepared by Tjerk Reijenga

Questions of location

Location

Which location(s) are in mind for the demonstration project

Name, village

Coordinates (Google earth)

Goals

What type of housing is required?

What income has the target group(s)

What budget for a house has this group(s)

Are there other market opportunities for the introduction of bamboo panels?

Is there a possibility to introduce bamboo panels in hybrid (wood/concrete) constructions?

Is there a market for resorts / tourist housing?

Is there a market for high-end housing with bamboo panel / wood construction?

How is the general attitude about the use of bamboo for housing?

Climate

Climate information (monthly)

yearly average max. temperature
yearly average temperature
yearly average min. temperature
precipitation
humidity
wind direction
windspeed

Hourly information for typical spring-day

Hourly information for typical summer-day

Hourly information for typical autumn-day

Hourly information for typical winter-day

Questions of living and culture

Housing

1. What are the average size of houses ?

   How many people is a family (average)

   Will grandparents live with the children and grandchildren?

   What work will people do?

   Inside work (home work, home office)
   Outside work (office, commercial, farming)

Cooking

What is the general way of cooking (boiling, baking, fry-stirring, etc)

What applications are used (open fire, wood, gas fire, electricity, others)

Bathroom

What type of toilet is used? (picture if available)

Are toilet, shower and washing combined?

Rooms

What is the typical use of the living room by day. Will people sit inside or prefer outside

What is the typical use of the living room by night (evening)?

Installation

What kind of installation is used for hot water?

What kind of installation is used for room heating?

What kind of installation is used for room cooling?

What kind of ventilation is used?

Natural ventilation
Mechanical ventilation

If natural ventilation is used, which elements are used:

windows
chimney

duct

If mechanical ventilation is used, can you describe the installation?

Comfort

What is an acceptable minimum temperature in winter

What is an acceptable maximum temperature in winter

What is an acceptable minimum temperature in summer

What is an acceptable maximum temperature in summer

Questions of construction

What is the regular, most common way for construction?

What materials are used for:

the roof
for external walls
for internal walls
for floors
for the foundation
for windows
for doors

What details are used for construction?

thickness and layers of the roof
thickness and layers of external walls
thickness and layers for floors

Give a detail drawing

Which materials are local?

Which materials are imported?

Which building parts are prefabricated?

Which building parts are made on site?

Questions of cost

What are regular building cost / m2

Give a detailed overview of building cost like:

the roof
external walls
internal walls
floors
foundation
windows

doors
others

Is there an example of a building cost calculation available?

Questions of capacity

How many companies produce bamboo products?
How many companies built bamboo houses?
How many companies produce bamboo panels?
Is more training needed for the construction with bamboo?
Is more training needed for the production of bamboo?

6.2 Interviews

Interviews have been held with the following representatives in Ethiopia and Nepal:

Ethiopia:

Mr. Yaregal Meskir, FEMSEDA

Mr. Girma Deriba, FEMSEDA

Mr. Tesfaye Hunde, INBAR

Ms. Tsedale Mamo, Addis Ababa Housing Development Project

Mr. Haile Michael Fentaw, Addis Ababa Housing Development Project

Dr.ing. Heyaw Terefe, Addis Ababa University

Mr. Melaku Tadesse, UNIDO

Mr. Adane Berhe, Adal Industrial P.L.C.

Ms. Myriam Fernando, ECBP / GTZ

Prof. Dr.Ing. Dirk Donath, ECBP / GTZ

Prof.Diopl.-Ing. Herbert Schmitz, ECBP / GTZ

Mr. Karsten Schlesier, ECBP / CIM

Visit to Addis Ababa Housing Development building site.

Visit to Adal Industrial P.L.C. Factory (bamboo)

Nepal:

Mr. Krishna P. Tamrakar, FNCCI

Mr. Keshab Adhikari, FNCCI

Mr. Ajaya Kumar Mudbhary, Himalayan Bamboo Pvt. Ltd.

Mr. Kiran Kumar Mudbhary, Mudbhary and Joshi Construction Pvt. Ltd.

Mr. Lekh Raj Pokhrei, Himalayan Bamboo Pvt. Ltd.

Mr. Babu Ram Jamarkattel, Leknath Chamber of Commerce & Industries

Visit to CE Construction Pvt. Ltd. Building site.

Visit to Himalayan Bamboo Pvt. Ltd factory.

6.3 Cost for Ethiopia

No	Type of material	Unit	Unit price at factory or source	Unit price in euro
1	Cement (PPC at Mugher)	Qnt.	134,78	€ 7,49
2	Cement (PPC at Mekelle	Qnt.	130,43	€ 7,25
3	Cement (OPC at Mekelle	Qnt.	165,22	€ 9,18
4	EGA sheet 400, 4 mm thick (KMPF)	m^1	88,06	€ 4,89
5	Structural steel (RHS) (KMPF)	kg	19,36	€ 1,08
6	Black iron Sheet 5 mm thick (KMPF)	kg	12,51	€ 0,70
7	Black iron Sheet 6 mm thick (KMPF)	kg	12,51	€ 0,70
8	Black iron Sheet 8 mm thick (KMPF)	kg	12,51	€ 0,70
9	Black iron Ribbed Sheet 0.8 mm thick (KMPF)	m^2	178,68	€ 9,93
10	Black iron Ribbed Sheet 1 mm thick (KMPF)	m^2	208,86	€ 11,60
11	Galvanized sheet Metal G-28 (KMPF)	m^2	81,20	€ 4,51
12	38x1.5 mm L profile	Pcs.	190,00	€ 10,56
13	38x1.5 mm T profile	Pcs.	190,00	€ 10,56
14	38x1.5 mm Z profile	Pcs.	190,00	€ 10,56
15	Ceramic wall tiles 150x150mm (Tabor)	m^2	54,29	€ 3,02
16	Clear glass 4mm thick (Local suppliers)	m^2	93,91	€ 5,22
17	Chip wood 1250x2500mm (ECAFCO)	Pcs.	108,70	€ 6,04
18	Plastic paint white	Gal.	68,00	€ 3,78
19	Plastic paint Except white	Gal.	65,00	€ 3,61
20	Metal paint	Gal.	120,00	€ 6,67
21	Benzin (Regular)	Lit.	7,47	€ 0,42
22	Diesel	Lit.	7,13	€ 0,40
	Electric wire (Ethiopian Plastic Factory)			
24	Size : 1x1.5mm2 (Roll = 100m)	Roll	147,00	€ 8,17
25	Size : 1x2.5mm2 (Roll = 100m)	Roll	260,00	€ 14,44
26	Size : 1x4mm2 (Roll = 100m)	Roll	400,00	€ 22,22
	Power Cable (Ethiopian Plastic Factory)			
27	Size : 2x2.5mm2 (Roll = 100m)	Roll	-	
28	Size : 3x2.5mm2 (Roll = 100m)	Roll	-	
29	Size : 3x4mm2 (Roll = 100m)	Roll	-	
30	Size : 3x6mm2 (Roll = 100m)	Roll	-	

31	Size : 5x6mm2 (Roll = 100m)	Roll	-	
	Electric wire (local supplier)			
32	Size : 1x1.5mm2 (Roll = 100m)	Roll	200,00	€ 11,11
33	Size : 1x2.5mm2 (Roll = 100m)	Roll	305,00	€ 16,94
34	Size : 1x4mm2 (Roll = 100m)	Roll	500,00	€ 27,78
	Power Cable (Local supplier)			
35	Size : 2x2.5mm2 (Roll = 100m)	m^1	12,36	€ 0,69
36	Size : 3x2.5mm2 (Roll = 100m)	m^1	13,50	€ 0,75
37	Size : 3x4mm2 (Roll = 100m)	m^1	24,66	€ 1,37
38	Size : 3x6mm2 (Roll = 100m)	m^1	37,68	€ 2,09
39	Size : 5x6mm2 (Roll = 100m)	m^1	70,00	€ 3,89
40	Size : 5x10mm2 (Roll = 100m)	m^1	115,00	€ 6,39
41	Size : 5x16mm2 (Roll = 100m)	m^1	165,00	€ 9,17
	Galvanized steel pipes (Akaki Meatl Products Factory)			
42	GSP 15mm with 1 socket	Pcs	185,00	€ 10,28
43	GSP 20mm with 1 socket	Pcs	195,00	€ 10,83
44	GSP 25mm with 1 socket	Pcs	220,00	€ 12,22
45	GSP 32mm with 1 socket	Pcs	280,00	€ 15,56
46	GSP 40mm with 1 socket	Pcs	325,00	€ 18,06
47	GSP 50mm with 1 socket	Pcs	485,00	€ 26,94
48	GSP 65mm with 1 socket	Pcs	550,00	€ 30,56
49	Sand	m^3	60,00	€ 3,33
50	Stone (Basaltic)	m^3	60,00	€ 3,33
51	Stone (Masonry)	m^3	60,00	€ 3,33
	Skilled and unskilled laborer			
53	Carpenter		45 Birr/Day	€ 2,50
54	Mason		43 Birr/Day	€ 2,39
55	Daily laborer		17 Birr/Day	€ 0,94
56	Bamboo flooring	m^2	420,00	€ 23,33

6.4 Cost for Nepal

OLD Rate For Kaski (2063/64)(2006/07)

SN	Particular	General Rate	Unit
1	Skill Labour	295	md
2	Unskill Labour	175	md
3	Cement	8400	mt
4	Sand	680	m3
5	Aggrigate 40mm	680	m3
6	Aggrigate 20mm	680	m3
7	Aggrigate 10mm	680	m3
8	Stone	680	m3
9	Sal wood	37749,6	m3
10	Local Wood	15876	m3
11	Bamboo	200	nos
12	Rope	60	kg
13	Nail	55	kg
14	Reinforcement Bar	44900	mt
15	GI Wire 12Swg (Heavy Coating)	71	kg
16	GI Wire 10Swg (Heavy Coating)	68	kg
17	GI Wire 8Swg (Heavy Coating)	68	kg
18	3.5mm Glass	591,8	Sq. m.
19	4mm Glass	645,6	Sq. m.
20	Lime	18	kg
21	Gum	160	kg
22	Primer	225	Ltr
23	Enamel	245	Ltr
24	Alumunium Paint	325	Ltr
25	Sand Paper	5	Sheet
26	Red Oxide	130	Ltr
27	Binding wire	55	kg
28	CGI Sheet 26g	5350	bun.
29	Plain sheet	260	sq m
30	Slate	340	sq m
31	3mm plywood	139,88	sq m
32	Snowseem Paint	50	kg
33	Brick (Tarai Local)	5,25	nos
34	Wall Tile (Indian)	408,88	sqm
35	Tile floor (Indian)	484,2	sqm
36	White Cement	19,48	kg

	New Rate For Kaski (2066)(2009)		
SN	**Particular**	**General Rate**	**Unit**
1	Skill Labour	500,00	md
2	Unskill Labour	250,00	md
3	Cement	13.000,00	mt
4	Sand	1.400,00	m3
5	Aggrigate 40mm	1.800,00	m3
6	Aggrigate 20mm	1.800,00	m3
7	Aggrigate 10mm	2.000,00	m3
8	Stone	1.500,00	m3
9	Sal wood	70.000,00	m3
10	Local Wood	35.000,00	m3
11	Bamboo		nos
12	Rope	90,00	kg
13	Nail	90,00	kg
14	Reinforcement Bar	72.000,00	mt
15	GI Wire 12Swg (Heavy Coating)	90,00	kg
16	GI Wire 10Swg (Heavy Coating)	90,00	kg
17	GI Wire 8Swg (Heavy Coating)	90,00	kg
18	3.5mm Glass	600,00	Sq. m.
19	4mm Glass	600,00	Sq. m.
20	Lime	18,00	kg
21	Gum	200,00	kg
22	Primer	250,00	Ltr
23	Enamel	360,00	Ltr
24	Alumunium Paint	400,00	Ltr
25	Sand Paper	10,00	Sheet
26	Red Oxide	220,00	Ltr
27	Binding wire	90,00	kg
28	CGI Sheet 26g	5.000,00	bun.
29	Plain sheet	400,00	sq m
30	Slate	450,00	sq m
31	3mm plywood	185,00	sq m
32	Snowseem Paint	50,00	kg
33	Brick (Tarai Local)	8,00	nos
34	Wall Tile (Indian)	800,00	sqm
35	Tile floor (Indian)	800,00	sqm
36	White Cement	30,00	kg

New Rate For Kathmandu (2066)(2009)

SN	Particular	General Rate	Unit
1	Skill Labour	550,00	md
2	Unskill Labour	300,00	md
3	Cement	13.000,00	mt
4	Sand	2.000,00	m3
5	Aggrigate 40mm	2.200,00	m3
6	Aggrigate 20mm	2.300,00	m3
7	Aggrigate 10mm	2.400,00	m3
8	Stone	2.200,00	m3
9	Sal wood	75.000,00	m3
10	Local Wood	45.000,00	m3
11	Bamboo	200,00	nos
12	Rope	90,00	kg
13	Nail	90,00	kg
14	Reinforcement Bar	72.000,00	mt
15	GI Wire 12Swg (Heavy Coating)	90,00	kg
16	GI Wire 10Swg (Heavy Coating)	90,00	kg
17	GI Wire 8Swg (Heavy Coating)	90,00	kg
18	3.5mm Glass	550,00	Sq. m.
19	4mm Glass	550,00	Sq. m.
20	Lime	18,00	kg
21	Gum	200,00	kg
22	Primer	250,00	Ltr
23	Enamel	360,00	Ltr
24	Alumunium Paint	400,00	Ltr
25	Sand Paper	10,00	Sheet
26	Red Oxide	220,00	Ltr
27	Binding wire	90,00	kg
28	CGI Sheet 26g	5.000,00	bun.
29	Plain sheet	400,00	sq m
30	Slate	800,00	sq m
31	3mm plywood	185,00	sq m
32	Snowseem Paint	50,00	kg
33	Brick (Tarai Local)	9,00	nos
34	Wall Tile (Indian)	800,00	sqm
35	Tile floor (Indian)	800,00	sqm
36	White Cement	30,00	kg

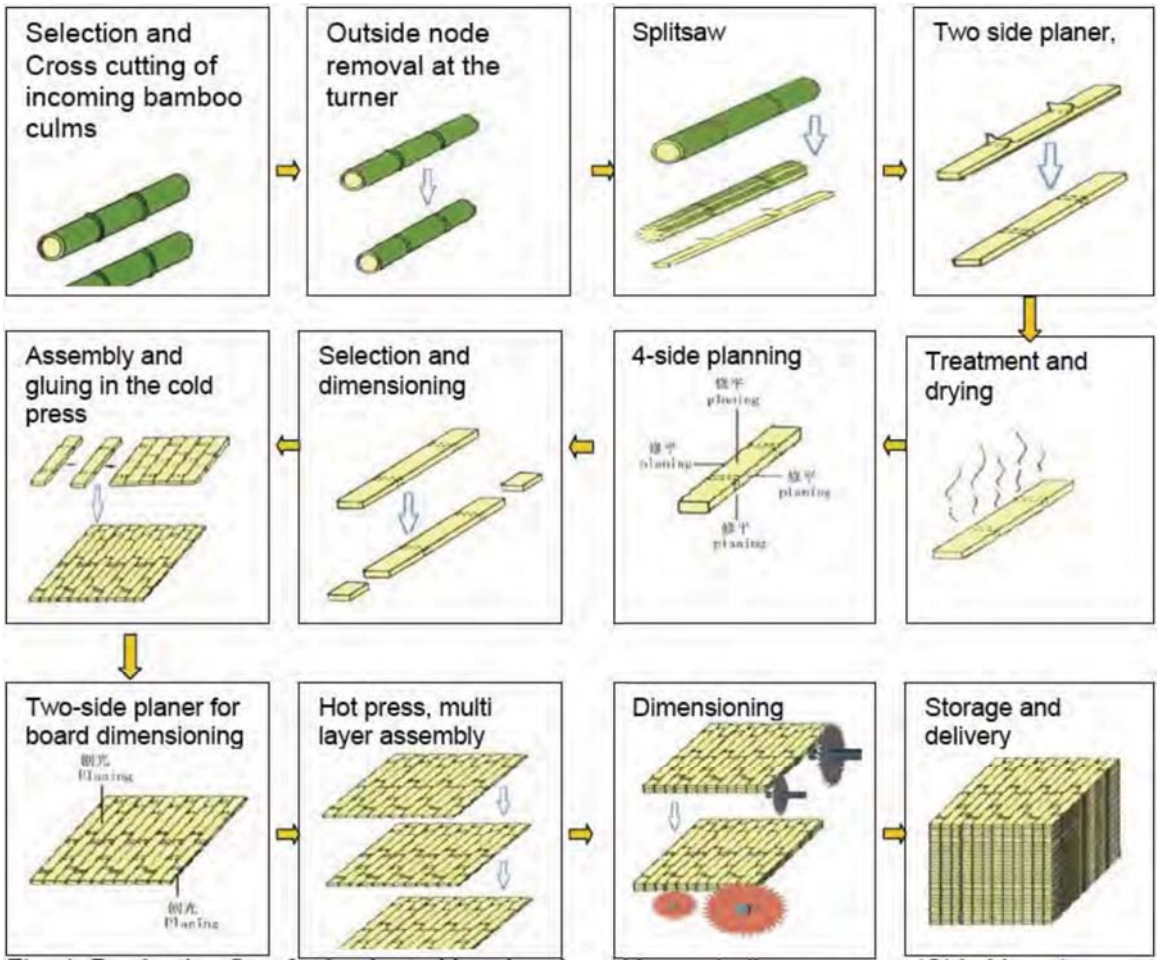
New Rate For Purbanchal (2066)(2009)

SN	Particular	General Rate	Unit
1	Skill Labour	450,00	md
2	Unskill Labour	250,00	md
3	Cement	12.500,00	mt
4	Sand	1.200,00	m3
5	Aggrigate 40mm	1.500,00	m3
6	Aggrigate 20mm	1.500,00	m3
7	Aggrigate 10mm	1.500,00	m3
8	Stone	1.500,00	m3
9	Sal wood	70.000,00	m3
10	Local Wood	35.000,00	m3
11	Bamboo		nos
12	Rope	90,00	kg
13	Nail	90,00	kg
14	Reinforcement Bar	72.000,00	mt
15	GI Wire 12Swg (Heavy Coating)	90,00	kg
16	GI Wire 10Swg (Heavy Coating)	90,00	kg
17	GI Wire 8Swg (Heavy Coating)	90,00	kg
18	3.5mm Glass	550,00	Sq. m.
19	4mm Glass	550,00	Sq. m.
20	Lime	18,00	kg
21	Gum	200,00	kg
22	Primer	250,00	Ltr
23	Enamel	300,00	Ltr
24	Alumunium Paint	350,00	Ltr
25	Sand Paper	5,00	Sheet
26	Red Oxide	200,00	Ltr
27	Binding wire	90,00	kg
28	CGI Sheet 26g	5.000,00	bun.
29	Plain sheet	400,00	sq m
30	Slate	-	sq m
31	3mm plywood	185,00	sq m
32	Snowseem Paint	50,00	kg
33	Brick (Tarai Local)	6,00	nos
34	Wall Tile (Indian)	700,00	sqm
35	Tile floor (Indian)	700,00	sqm
36	White Cement	30,00	kg

New Rate For Chitwan (2066)(2009)

SN	Particular	General Rate	Unit
1	Skill Labour	450,00	md
2	Unskill Labour	250,00	md
3	Cement	12.000,00	mt
4	Sand	1.000,00	m3
5	Aggrigate 40mm	1.500,00	m3
6	Aggrigate 20mm	1.500,00	m3
7	Aggrigate 10mm	1.500,00	m3
8	Stone	1.500,00	m3
9	Sal wood	70.000,00	m3
10	Local Wood	35.000,00	m3
11	Bamboo		nos
12	Rope	90,00	kg
13	Nail	90,00	kg
14	Reinforcement Bar	68.000,00	mt
15	GI Wire 12Swg (Heavy Coating)	90,00	kg
16	GI Wire 10Swg (Heavy Coating)	90,00	kg
17	GI Wire 8Swg (Heavy Coating)	90,00	kg
18	3.5mm Glass	550,00	Sq. m.
19	4mm Glass	550,00	Sq. m.
20	Lime	18,00	kg
21	Gum	200,00	kg
22	Primer	250,00	Ltr
23	Enamel	300,00	Ltr
24	Alumunium Paint	350,00	Ltr
25	Sand Paper	5,00	Sheet
26	Red Oxide	200,00	Ltr
27	Binding wire	90,00	kg
28	CGI Sheet 26g	5.000,00	bun.
29	Plain sheet	400,00	sq m
30	Slate	-	sq m
31	3mm plywood	185,00	sq m
32	Snowseem Paint	50,00	kg
33	Brick (Tarai Local)	6,00	nos
34	Wall Tile (Indian)	700,00	sqm
35	Tile floor (Indian)	700,00	sqm
36	White Cement	30,00	kg

6.5 Plybamboo laminating process



Chin Yung Bamboo & Wood Company Website: www.ckbambooflooring.com

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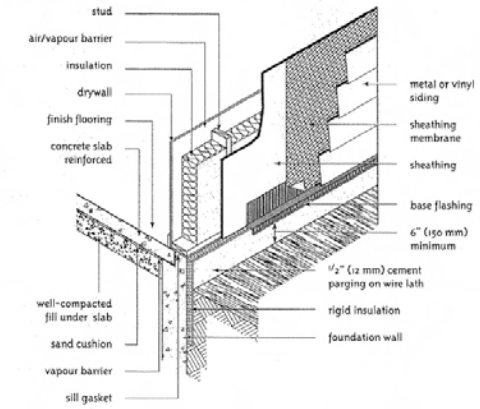
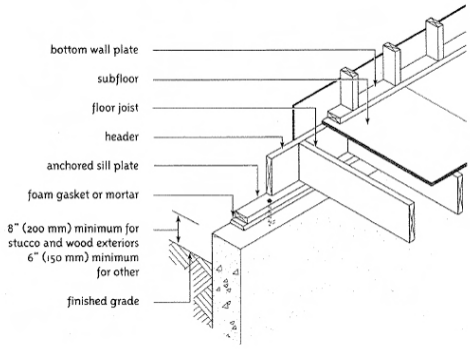
6.7 Canadian Wood frame construction - main details

All details use plybamboo sheeting and plybamboo beams and studs.

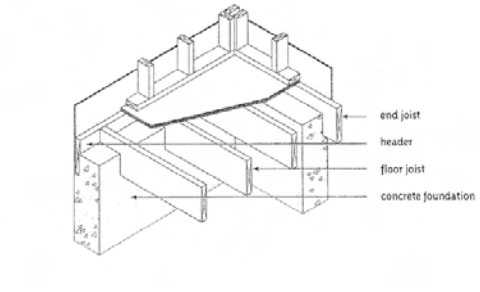
Independent concrete floor slab and foundation wall. Slab is supported on 5 in. (125 mm) of coarse fill and on a ledge formed in the foundation wall.



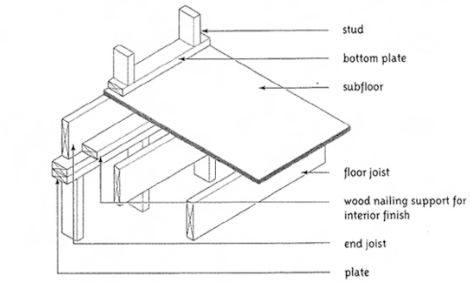
Sill-plate method used in platform construction.



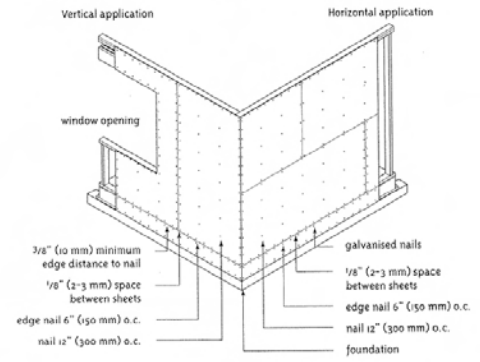
Floor joists embedded in the top of the foundation wall.



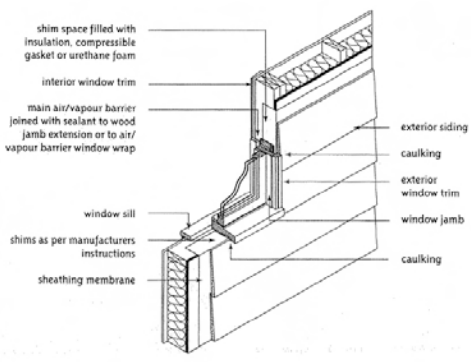
End-wall framing and nailing support for interior finish using platform construction method.



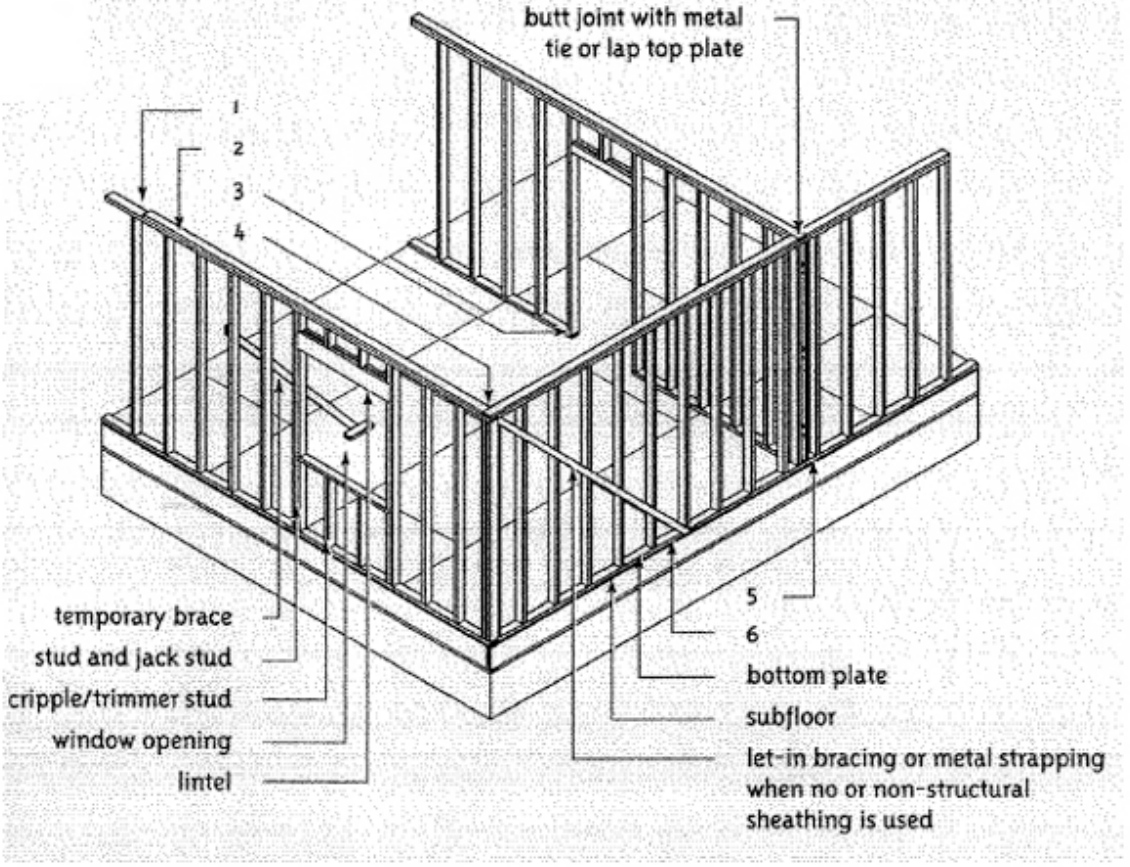
Vertical and horizontal application of panel-type sheathing.



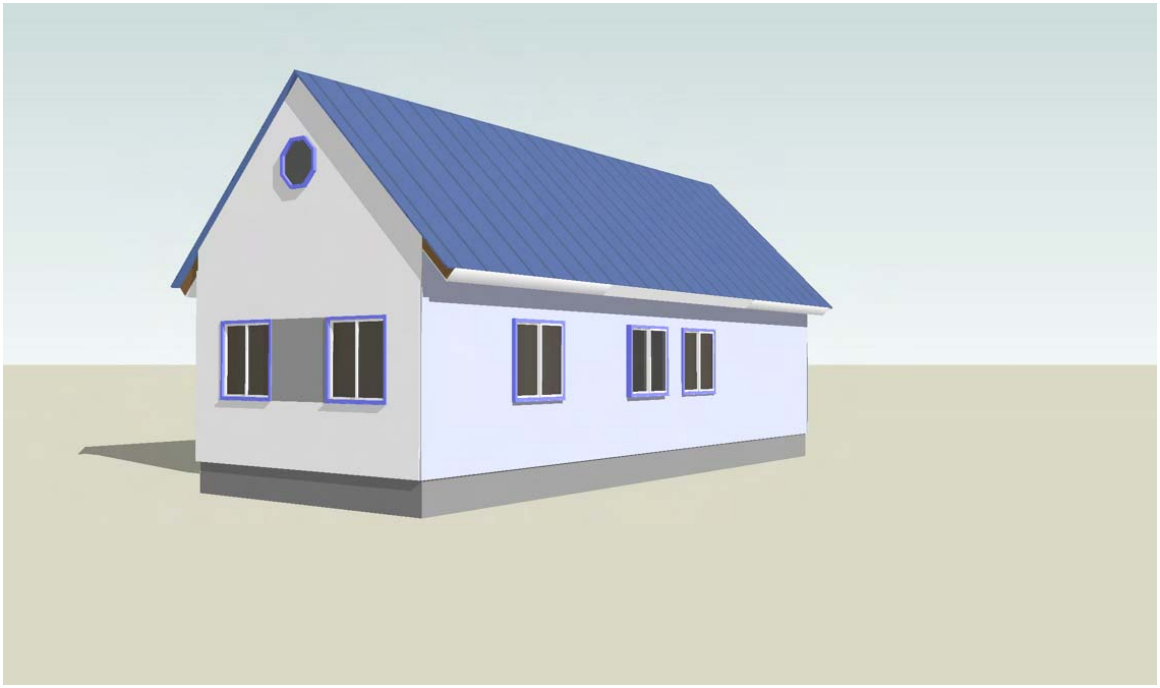
Typical window frame installation.



Wall framing used with platform construction: (1) top plate end-nailed to each stud with two 3 1/4 in. (82 mm) nails; (2) top plates nailed together with 3 in. (76 mm) nails 24 in. (600 mm) on centre; (3) stud toenailed with four 2 1/2 in. (63 mm) nails or end-nailed to bottom plate with two 3 1/4 in. (82 mm) nails; (4) top plates at corners and loadbearing partitions are lapped and nailed together with two 3 1/4 in. (82 mm) nails or the plates are butted together and tied with a metal plate fastened to the top plates with three 2 1/2 in. (63 mm) nails on each side of the joint; (5) doubled studs at openings and multiple studs at corners and intersections nailed with 3 in. (76 mm) nails 30 in. (750 mm) on centre; (6) bottom plate nailed to joist or header joist with 3 1/4 in. (82 mm) nails 16 in. (400 mm) on centre.



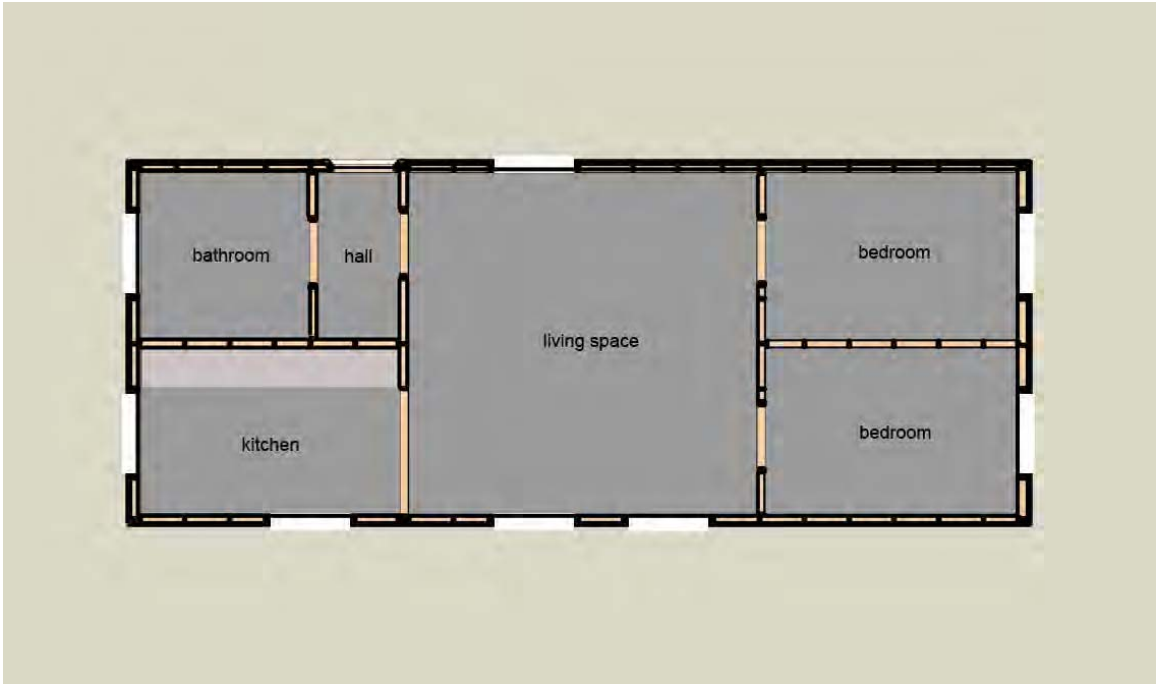
6.8 Drawings



60 m^2 unit - South-west view

60 m^2 unit - North-east view

60 m^2 unit - South-east view

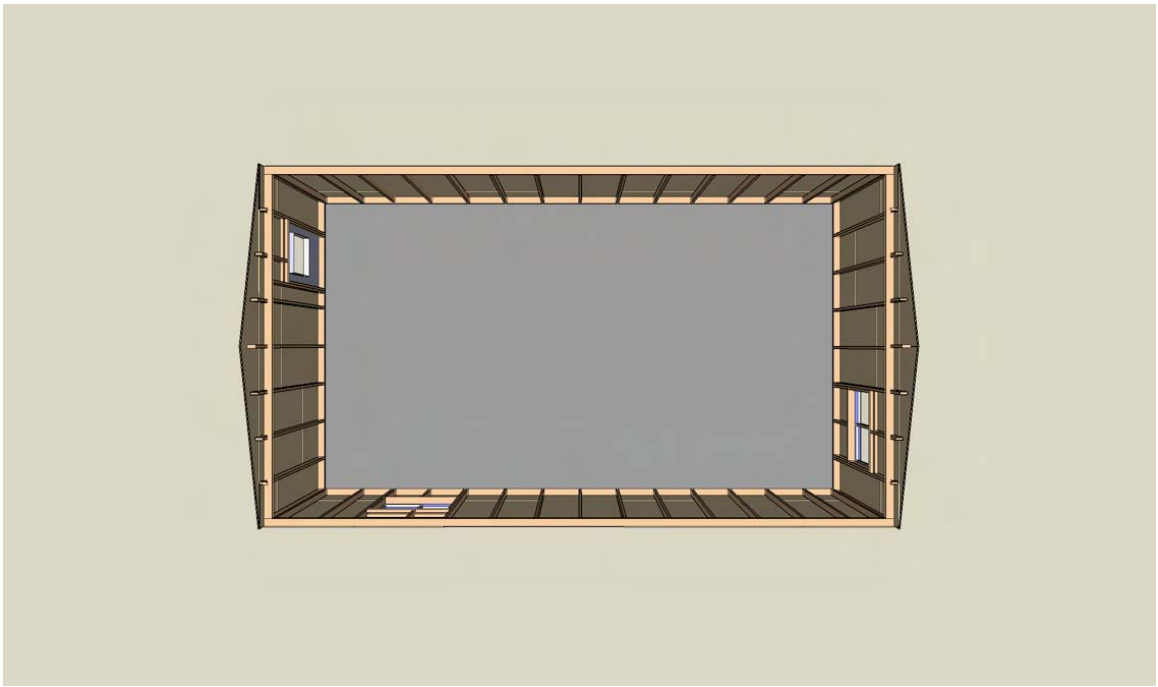


60 m^2 unit - Top view - Floor plan

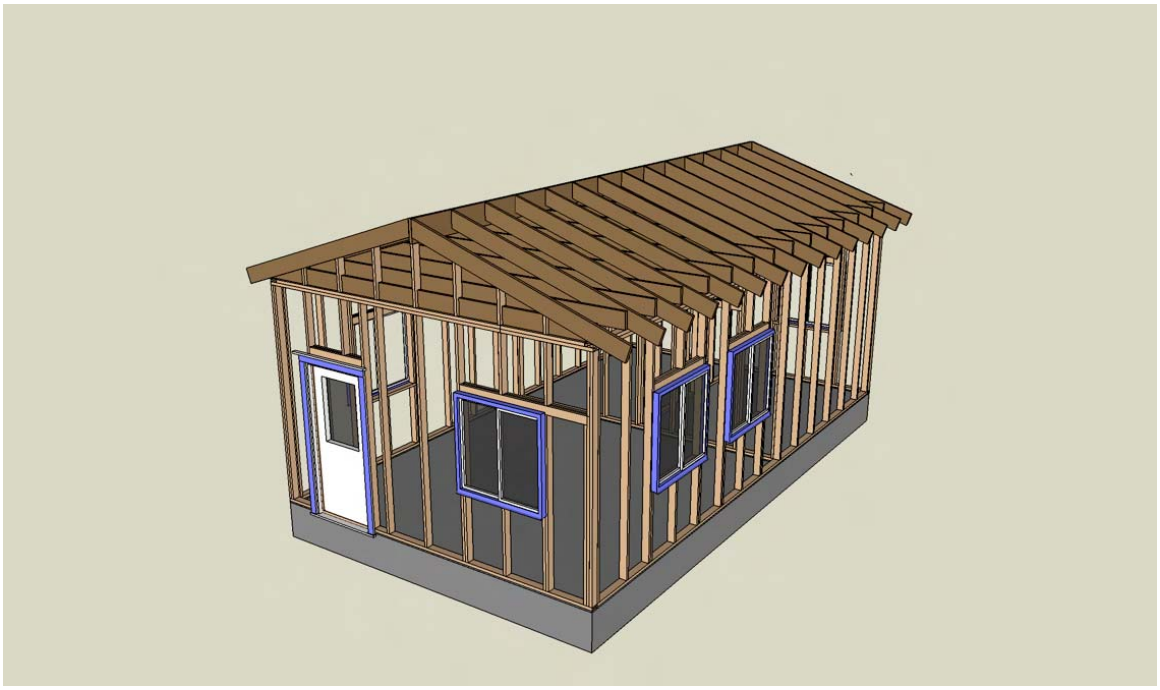
40 m^2 unit - North-east view. Low angle asphalt roof.

40 m^2 unit - South-east view

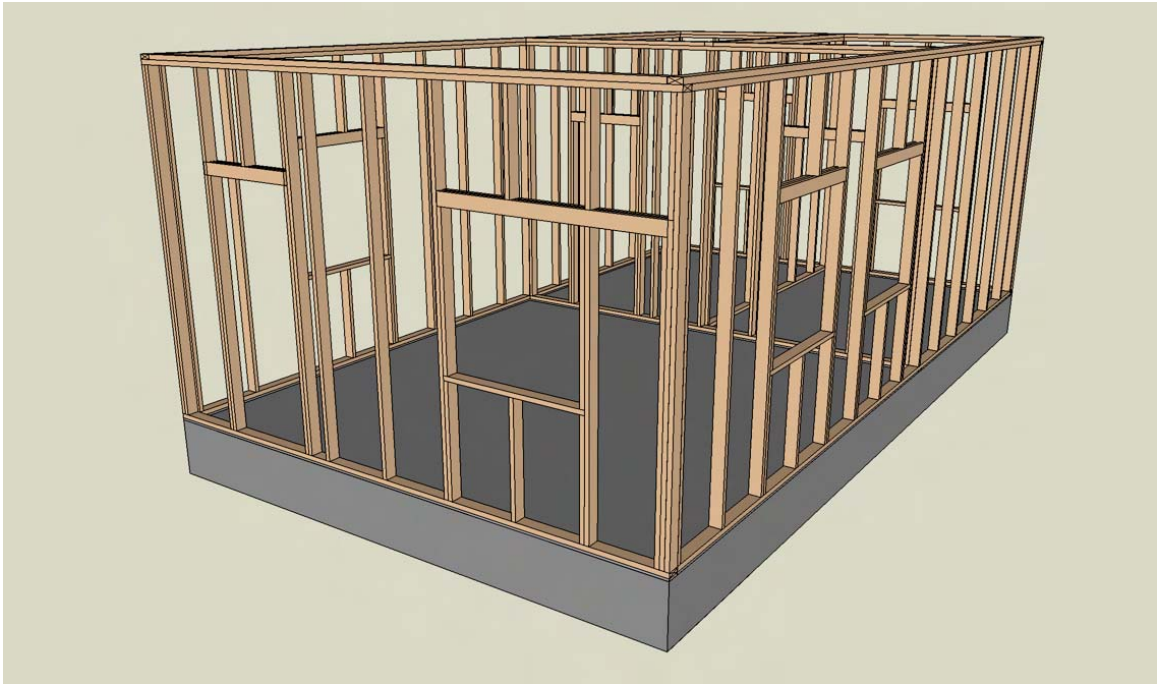
40 m^2 unit - South-west view



40 m^2 unit - Top view - Floor plan



40 m^2 unit - Basic construction with roof



40 m^2 unit - Basic construction

6.9 Calculation sheets

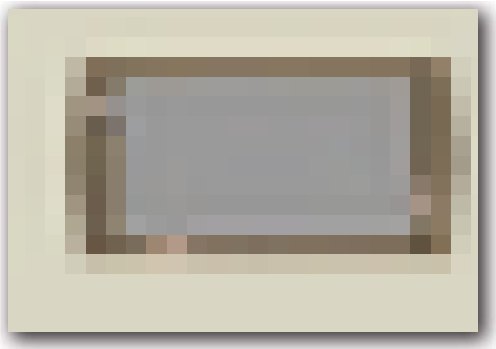
The cost for bamboo panels is calculated by prof. Wang Zheng from CAF in Beijing.

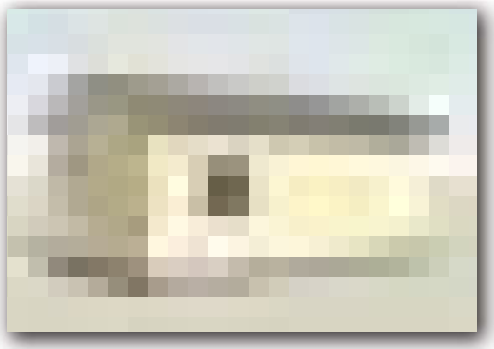
	Cost of bamboo plywood (2440 x 1220 x 12 mm)							
			China		Nepal		Ethiopia	
Description	**Unit**	**Quantity (m^3)**	**¥/Unit**	**Cost (¥/m^3)**	**¥/Unit**	**Cost (¥/m^3)**	**¥/Unit**	**Cost (¥/m^3)**
Material								
Bamboo curtain	Sheet	140	8	1120	7	980	4	560 (6)
Bamboo mat	Sheet	56	9	504	8	448	4,5	252 (6)
Glue (Phenol aldehyde resin)	Kg	156	3,5	546	5	780 (5)	7	1092 (5)
Fuel + Power								
Water	m^3	0,5	4	2	1,5	0,75	1,5	0,75
Electricity	kWh	203	1	203	0,35	71,05	0,5	101,5
Coal	ton	0,54	400	217	400	216	400	216
Labor								
				320		220		160 (6)
Equipm. depreciation								
				56		56		56
Total				2968		2771,8		2438,25
28 sheets/m3				106,00		98,99		87,08
Notes:								
1.	Cost of bamboo in China is about ¥ 800/ton							
2.	12 mm thick bamboo plywood made of 5 bamboo curtains and 2 bamboo mats.							
3.	The bamboo curtain used is 2,5 mm thick.							
4.	The cost of bamboo plywood in China is 35,60 ¥/m2.							
5.	Glue hast be imported and is expensive in Ethiopia + Nepal							

ICBR Modular housing project

40 m2 unit - low level

date: 2009-11-30/2010-05-18





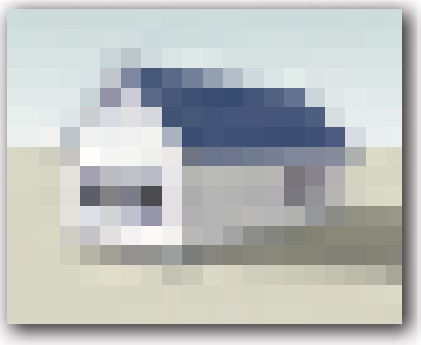
description	unit		cost/unit
cost in rmb			
plybamboo 12 mm	m2	Y	35,33
wood / plybamboo beam	m1	Y	12,50
roof rafters	m1	Y	25,00
gypsum board 10 mm	m2	Y	20,00
brick 10 mm	m2	Y	40,00
primer	m2	Y	5,00
thermal insulation 100 mm	m2	Y	40,00
roof asphalt tiles	m2	Y	25,00
sheet plybamboo	3	Y	106,00

	nr.	description	cost/unit	unit	volume	amount	total cost	sub total		
		Concrete						**Y 1.612,80**		
	1	concrete foundation	Y 40,00	m2	40,32	1	1.612,80			
	2	concrete under floorplate	Y 80,00	m2	3,43	0	0,00			
	3	concrete floor finish	Y 80,00	m2	36,89	0	0,00			
		Wood frame						**Y 2.931,25**		
	4	floorplate joist 100x40 mm	Y 12,50	m1	8,20	2	205,00			
	5	floorplate joist 100x40 mm	Y 12,50	m1	3,50	0	0,00			
	6	floorplate joist 100x40 mm	Y 12,50	m1	4,80	2	120,00			
	7	floorplate joist 100x40 mm	Y 12,50	m1	2,25	0	0,00			
	8	topplate joist 100x40 mm	Y 12,50	m1	8,20	4	410,00			
	9	topplate joist 100x40 mm	Y 12,50	m1	3,50	0	0,00			
	10	topplate joist 100x40 mm	Y 12,50	m1	4,80	4	240,00			
	11	topplate joist 100x40 mm	Y 12,50	m1	2,25	0	0,00			
	12	studs 100x40 mm	Y 12,50	m1	2,90	46	1.667,50			
	13	studs 100x40 mm door	Y 12,50	m1	2,10	2	52,50			
	14	studs 100x40 mm window	Y 12,50	m1	1,20	4	60,00			
	15	studs 100x40 mm door + window	Y 12,50	m1	0,90	6	67,50			
	16	studs 100x40 mm window	Y 12,50	m1	0,70	3	26,25			
	17	internal double beam 100x40 mm	Y 12,50	m1	1,70	0	0,00			
	18	window double beam 100x40 mm	Y 12,50	m1	1,20	4	60,00			
	19	door double beam 100x40 mm	Y 12,50	m1	0,90	2	22,50			
		Roof frame						**Y 4.340,00**		
	20	ceiling joist 200x40 mm	Y 25,00	m1	4,80	15	1.800,00			
	21	rafters 200x40 mm	Y 25,00	m1	3,00	30	2.250,00			
	22	ridge beam 200x40 mm	Y 25,00	m1	8,40	1	210,00			
	23	roof studs 100x40 mm	Y 12,50	m1	0,80	2	20,00			

	nr.	description	cost/unit		unit	volume	amount	total cost	sub total		
	24	roof studs 100x40 mm	Y	12,50	m1	0,60	4	30,00			
	25	roof studs 100x40 mm	Y	12,50	m1	0,40	4	20,00			
	26	roof studs 100x40 mm	Y	12,50	m1	0,20	4	10,00			
	27	**Walls-outside**							**Y 3.039,73**		
	28	plybamboo sheet 1200x2400 mm	Y	35,33	m2	2,88	12	1.221,12			
	29	plybamboo sheet 1200x600 mm	Y	35,33	m2	0,72	10	254,40			
	30	plybamboo sheet 600x2400 mm	Y	35,33	m2	1,44	6	305,28			
	31	plybamboo sheet 600x600 mm	Y	35,33	m2	0,36	4	50,88			
	32	plybamboo sheet 1200x900 mm door	Y	35,33	m2	0,98	1	34,63			
	33	plybamboo sheet 300x2100 mm door (7)	Y	35,33	m2	0,61	1	21,55			
	34	plybamboo sheet 1200x1000 mm window	Y	35,33	m2	1,18	6	249,31			
	35	plybamboo sheet 1200x800 mm window	Y	35,33	m2	0,98	6	208,61			
	36	plybamboo sheet 1200x2200 mm (3)	Y	35,33	m2	2,62	2	185,15			
	37	plybamboo sheet 1200x1200 mm cut (4)	Y	35,33	m2	1,44	4	203,52			
	38	plybamboo sheet 600x1200 mm cut (5)	Y	35,33	m2	0,72	4	101,76			
	39	plybamboo sheet 1200x1400 mm cut (1)	Y	35,33	m2	2,88	2	203,52			
	40	**Walls-inside (roof space closed for storage)**					0		**Y 0,00**		
	41	gypsum board	Y	20,00	m2	10,50	0	0,00			
	42	gypsum board	Y	20,00	m2	6,75	0	0,00			
	43	gypsum board	Y	20,00	m2	9,50	0	0,00			
	44	gypsum board (triangel)	Y	20,00	m2	7,40	0	0,00			
	45	gypsum board (inside facade)	Y	20,00	m2	17,40	0	0,00			
	46	gypsum board (inside facade)	Y	20,00	m2	29,5	0	0,00			
	47	**Ceiling (above bedrooms, kitchen + bathroom)**							**Y 0,00**		
	48	plybamboo sheet 1200x2400 mm	Y	35,33	m2	2,88	0	0,00			
	49	gypsum board	Y	20,00	m2	32,20	0	0,00			
	50	**Facade outside**							**Y 480,00**		
	51	Primer/paint	Y	5,00	m2	96	1	480,00			
	52	Bricks 10 mm (Tiles)	Y	40,00	m2	96	0	0,00			
	53	Thermal insulation (100 mm)	Y	40,00	m2	96	0	0,00			
	54	Plastic foil inside 0,1 mm PE		0,1	m2	96	0	0,00			
	55	**Roof outside**							**Y 1.479,00**		
	56	plybamboo sheet 1200x2400 mm	Y	35,33	m2	2,88	0	0,00			
	57	plybamboo sheet 1200x1200 mm	Y	35,33	m2	1,44	0	0,00			
	58	plybamboo sheet 600x2400 mm	Y	35,33	m2	1,44	0	0,00			
	59	plybamboo sheet 200x2400 mm	Y	35,33	m2	0,48	0	0,00			
	60	plybamboo strips 50x15 mm (each 300 mm)	Y	1,77	m1	3,6	0	0,00			
	61	asphalt tiles	Y	25,00	m2	29,58	2	1.479,00			

	nr.	description		cost/unit	unit	volume	amount	total cost		sub total		
	62	rain gutter	Y	60,00	m1	8,4	0	0,00				
	63	rain pipe	Y	60,00	m1	3,5	0	0,00				
	64	**Window frames**							**Y**	**900,00**		
	65	Outside door	Y	500,00	pcs	1,00	1	500,00				
	66	Window frames	Y	200,00	pcs	1,00	2	400,00				
	67	Int doors	Y	300,00	pcs	1,00	0	0,00				
	68	**Other cost**							**Y**	**4.200,00**		
	69	Plumbing+sanitation	Y	5.000,00	pcs	1,00	0	0,00				
	70	Heating	Y	4.000,00	pcs	1,00	0	0,00				
	71	Lighting	Y	4.000,00	pcs	1,00	0,05	200,00				
	72	Nails. bolts	Y	2.000,00	pcs	1,00	1	2.000,00				
		Labour	Y	100,00	day	4,00	5	2.000,00				
									Y	**18.982,78**		
		Overhead					10%		**Y**	**1.898,28**		
									Y	**20.881,05**	6,8	USD 3.070,74

ICBR Modular housing project
60 m2 unit - high level
date: 2009-11-30/2010-05-18



description	unit		cost/unit
cost in rmb			
plybamboo 12 mm	m2	Y	35,33
wood / plybamboo beam	m1	Y	12,50
roof rafters	m1	Y	25,00
gypsum board 10 mm	m2	Y	25,00
brick 10 mm	m2	Y	40,00
primer	m2	Y	5,00
thermal insulation 100 mm	m2	Y	40,00
roof ribbed sheets	m2	Y	150,00
sheet plybamboo	3,0	Y	106,00

	nr.	description		cost/unit	unit	volume	amount	total cost		sub total			
		Concrete							**Y**	**21.888,00**			
	1	concrete foundation	Y	300,00	m2	57,60	1	17.280,00					
	2	concrete under floorplate	Y	80,00	m2	4,71	1	376,40					
	3	concrete floor finish	Y	80,00	m2	52,90	1	4.231,60					
		Wood frame							**Y**	**6.469,38**			
	4	floorplate joist 100x40 mm	Y	12,50	m1	8,20	2	205,00					
	5	floorplate joist 100x40 mm	Y	12,50	m1	3,50	4	175,00					
	6	floorplate joist 100x40 mm	Y	12,50	m1	4,80	3	180,00					
	7	floorplate joist 100x40 mm	Y	12,50	m1	2,25	1	28,13					
	8	topplate joist 100x40 mm	Y	12,50	m1	8,20	4	410,00					
	9	topplate joist 100x40 mm	Y	12,50	m1	3,50	8	350,00					
	10	topplate joist 100x40 mm	Y	12,50	m1	4,80	6	360,00					
	11	topplate joist 100x40 mm	Y	12,50	m1	2,25	2	56,25					
	12	studs 100x40 mm	Y	12,50	m1	2,90	94	3.407,50					
	13	studs 100x40 mm door	Y	12,50	m1	2,10	10	262,50					
	14	studs 100x40 mm window	Y	12,50	m1	1,20	16	240,00					
	15	studs 100x40 mm window + door	Y	12,50	m1	0,90	27	303,75					
	16	studs 100x40 mm window	Y	12,50	m1	0,70	11	96,25					
	17	internal double beam 100x40 mm	Y	12,50	m1	1,70	2	42,50					
	18	window double beam 100x40 mm	Y	12,50	m1	1,20	16	240,00					
	19	door double beam 100x40 mm	Y	12,50	m1	0,90	10	112,50					
		Roof frame							**Y**	**7.710,00**			
	20	ceiling joist 200x40 mm	Y	25,00	m1	4,80	21	2.520,00					
	21	rafters 200x40 mm	Y	25,00	m1	4,20	42	4.410,00					
	22	ridge beam 200x40 mm	Y	25,00	m1	12,00	1	300,00					
	23	roof studs 100x40 mm	Y	12,50	m1	2,40	4	120,00					
	24	roof studs 100x40 mm	Y	12,50	m1	1,80	8	180,00					

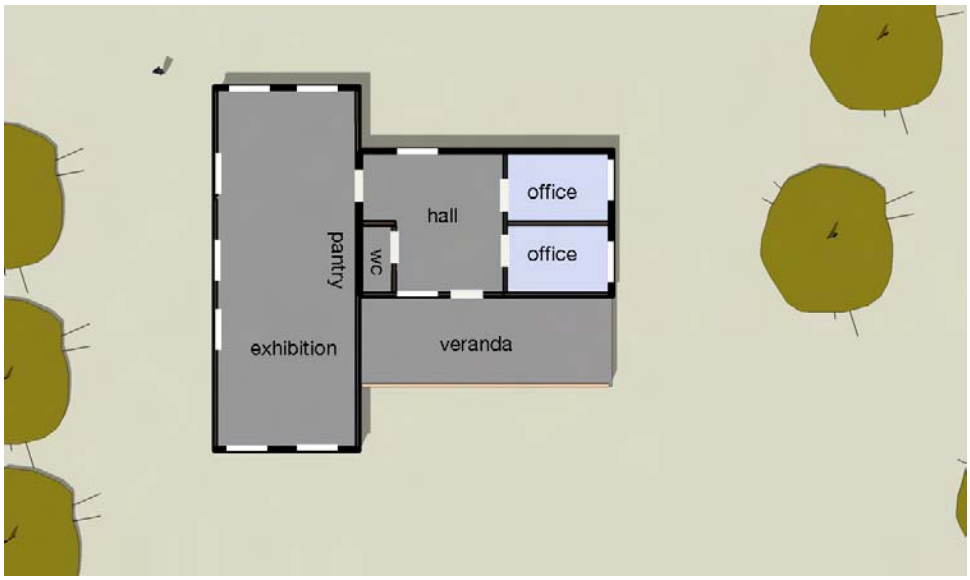
	nr.	description	cost/unit	unit	volume	amount	total cost	sub total			
	25	roof studs 100x40 mm	Y 12,50	m1	1,20	8	120,00				
	26	roof studs 100x40 mm	Y 12,50	m1	0,60	8	60,00				
	27	**Walls-outside**						**Y 3.791,05**			
	28	plybamboo sheet 1200x2400 mm	Y 35,33	m2	2,88	15	1.526,40				
	29	plybamboo sheet 1200x600 mm	Y 35,33	m2	0,72	13	330,72				
	30	plybamboo sheet 600x2400 mm	Y 35,33	m2	1,44	8	407,04				
	31	plybamboo sheet 600x600 mm	Y 35,33	m2	0,36	4	50,88				
	32	plybamboo sheet 1200x900 mm door	Y 35,33	m2	0,98	1	34,63				
	33	plybamboo sheet 300x2100 mm door (7)	Y 35,33	m2	0,61	1	21,55				
	34	plybamboo sheet 1200x1000 mm window	Y 35,33	m2	1,18	8	332,42				
	35	plybamboo sheet 1200x800 mm window	Y 35,33	m2	0,98	4	139,07				
	36	plybamboo sheet 1200x2200 mm (3)	Y 35,33	m2	2,62	2	185,15				
	37	plybamboo sheet 1200x2400 mm cut (4)	Y 35,33	m2	2,88	4	407,04				
	38	plybamboo sheet 600x1800 mm cut (5)	Y 35,33	m2	1,08	4	152,64				
	39	plybamboo sheet 1200x2400 mm cut (1)	Y 35,33	m2	2,88	2	203,52				
	40	**Walls-inside (roof space closed for storage)**						**Y 5.422,50**			
	41	gypsum board	Y 25,00	m2	10,50	4	1.050,00				
	42	gypsum board	Y 25,00	m2	6,75	2	337,50				
	43	gypsum board	Y 25,00	m2	9,50	4	950,00				
	44	gypsum board (triangel)	Y 25,00	m2	7,40	4	740,00				
	45	gypsum board (inside facade)	Y 25,00	m2	17,40	2	870,00				
	46	gypsum board (inside facade)	Y 25,00	m2	29,5	2	1.475,00				
	47	**Ceiling (above bedrooms, kitchen + bathroom)**						**Y 2.026,12**			
	48	plybamboo sheet 1200x2400 mm	Y 35,33	m2	2,88	12	1.221,12				
	49	gypsum board	Y 25,00	m2	32,20	1	805,00				
	50	**Facade outside**						**Y 8.169,60**			
	51	Primer	Y 5,00	m2	96	1	480,00				
	52	Bricks 10 mm (Tiles)	Y 40,00	m2	96	1	3.840,00				
	53	Thermal insulation (100 mm)	Y 40,00	m2	96	1	3.840,00				
	54	Plastic foil inside 0,1 mm PE	0,1	m2	96	1	9,60				
	55	**Roof outside**						**Y 15.108,88**			
	56	plybamboo sheet 1200x2400 mm	Y 35,33	m2	2,88	26	2.645,76				
	57	plybamboo sheet 1200x1200 mm	Y 35,33	m2	1,44	8	407,04				
	58	plybamboo sheet 600x2400 mm	Y 35,33	m2	1,44	20	1.017,60				
	59	plybamboo sheet 200x2400 mm	Y 35,33	m2	0,48	10	169,60				
	60	plybamboo strips 50x15 mm (each 300 mm)	Y 1,77	m1	3,6	58	368,88				
	61	metal sheets	Y 150,00	m2	30,24	2	9.072,00				
	62	rain gutter	Y 60,00	m1	8,4	2	1.008,00				

	nr.	description	cost/unit	unit	volume	amount	total cost	sub total			
	63	rain pipe	Y 60,00	m1	3,5	2	420,00				
	64	**Window frames**						**Y 6.800,00**			
	65	Outside door	Y 800,00	pcs	1,00	1	800,00				
	66	Window frames	Y 600,00	pcs	1,00	8	4.800,00				
	67	Int doors	Y 300,00	pcs	1,00	4	1.200,00				
	68	**Other cost**						**Y 42.000,00**			
	69	Plumbing+sanitation	Y 5.000,00	pcs	1,00	1	5.000,00				
	70	Heating	Y 4.000,00	pcs	1,00	1	4.000,00				
	71	Lighting	Y 4.000,00	pcs	1,00	1	4.000,00				
	72	Nails. bolts	Y 5.000,00	pcs	1,00	1	5.000,00				
		Labour	Y 400,00	day	4,00	15	24.000,00				
								Y 119.385,53			
		Overhead				10%		**Y 11.938,55**			
								Y 131.324,08			

6.10 Case study : First concept for Nepal

A request came from Nepal to make a demonstration with the two demo designs. A 40 m^2 and a 60 m^2 demo design are combined to a 100 m^2 office and exhibition centre for bamboo.

Bird-eye view



Floorplan

South-west view

North-west view

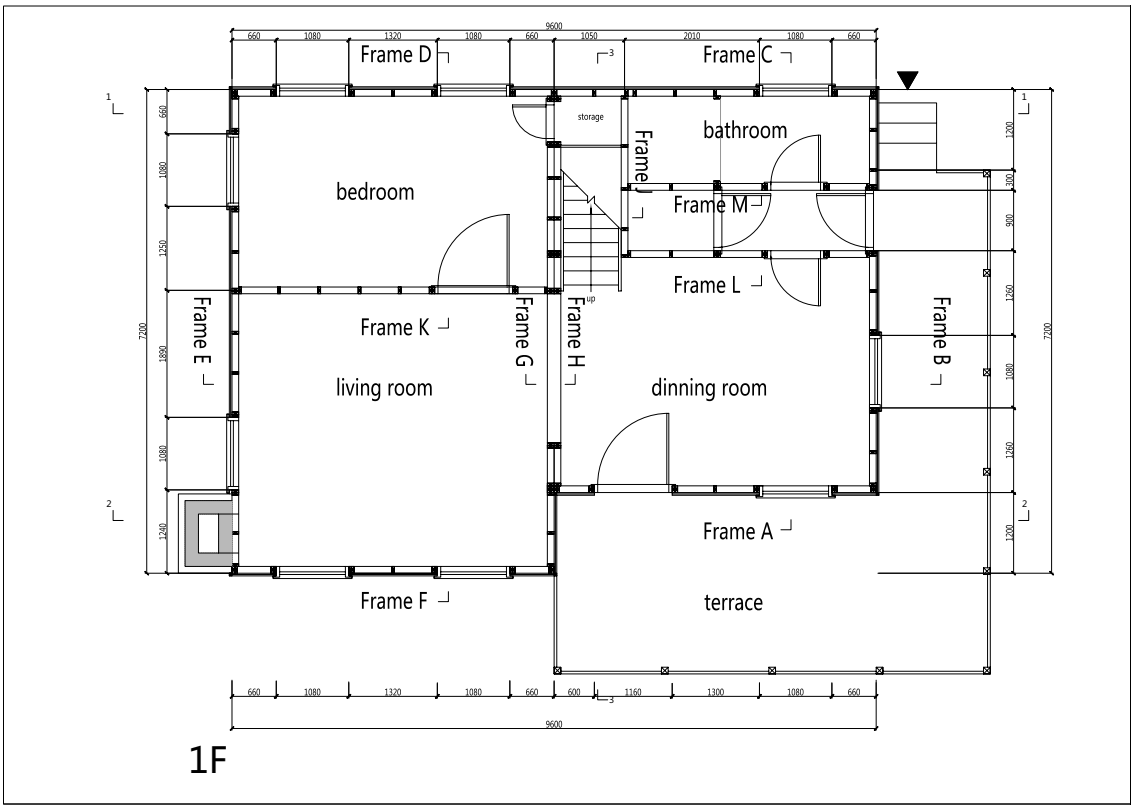
South-east view

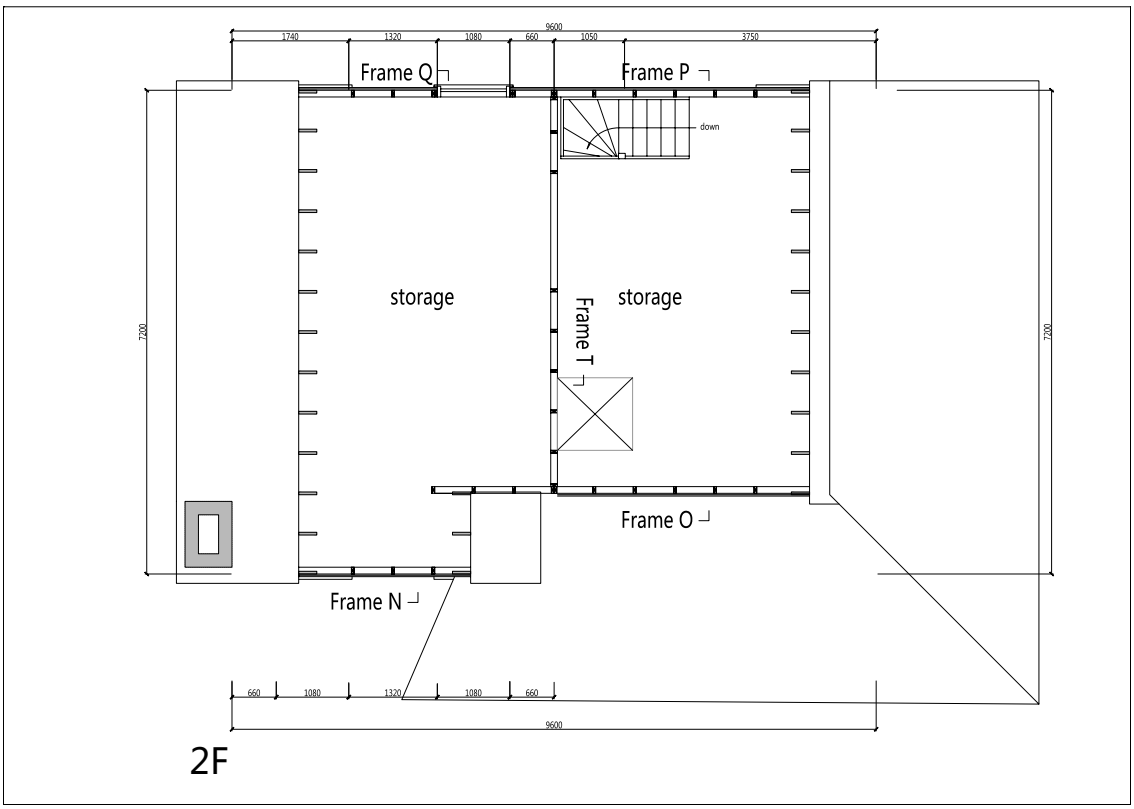
6.11 Case study : First concept for China (Yong'an)

A second case-study is made for an attractive house for China. This design is not based on the two demo houses but on the same construction methodology.

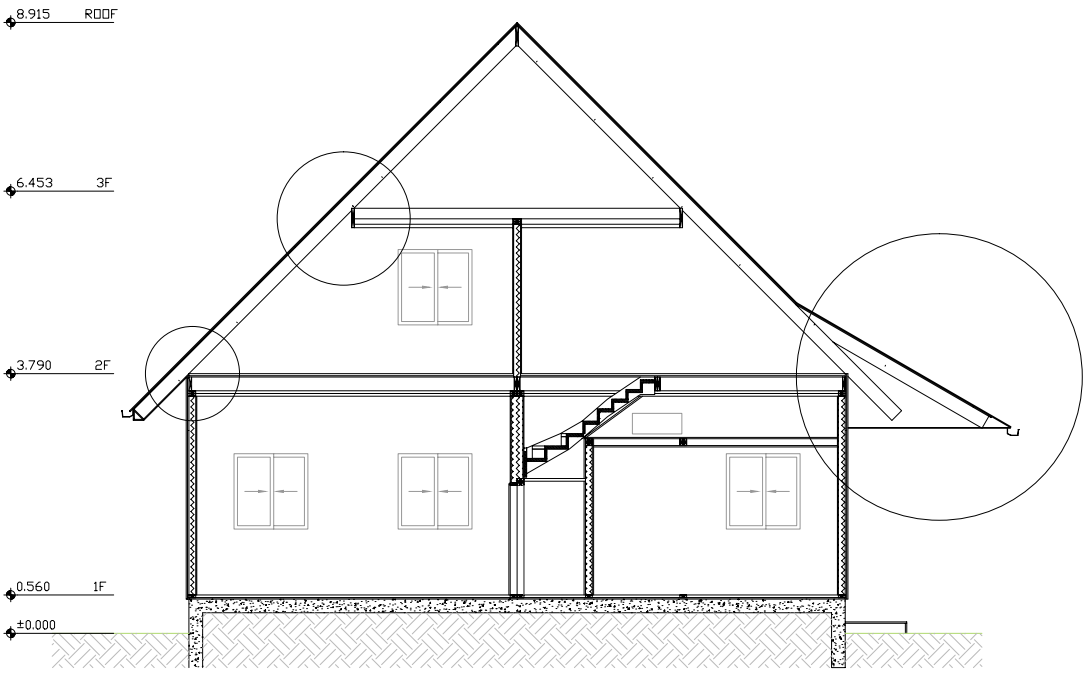
In this stage of the project beams can not be longer then 2.4 meters (max. press dimensions). So for all longer beams the material has to be wood.

Front facade of the house.

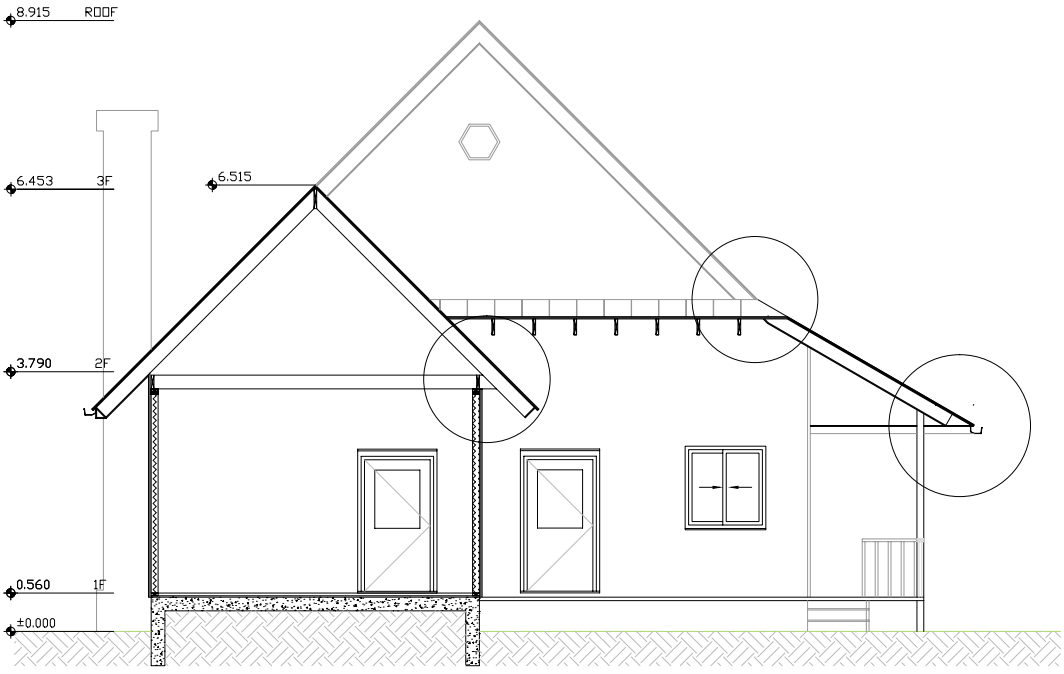

Frame D
Frame C
storage
bathroom
bedroom
Frame J
Frame M
Frame L
Frame E
Frame K
Frame G
Frame H
Frame B
living room
dinning room
Frame A
Frame F
terrace
1F


Frame Q
Frame P
down
storage
storage
Frame T
Frame O
Frame N
2F

Floorplans

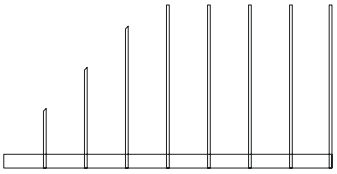


Section 1

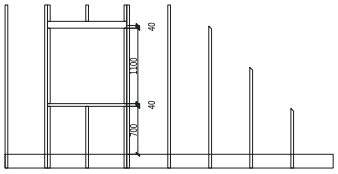


Section 2

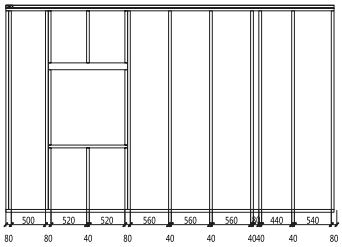
Sections



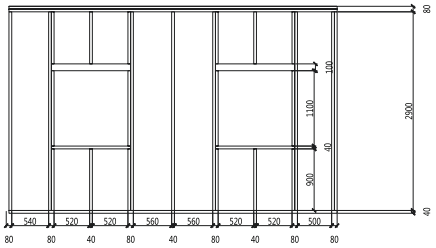
Frame P



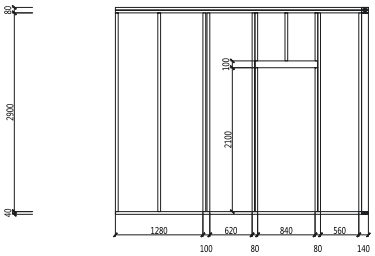
Frame Q



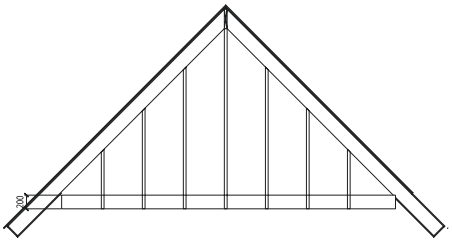
Frame C



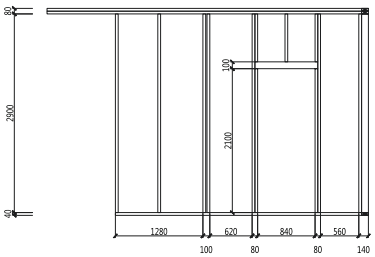
Frame D



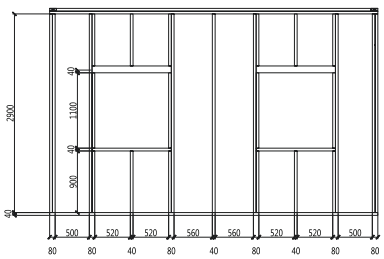
Frame M



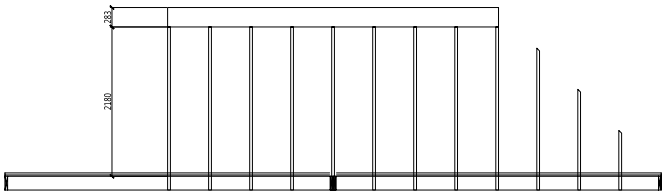
Frame N



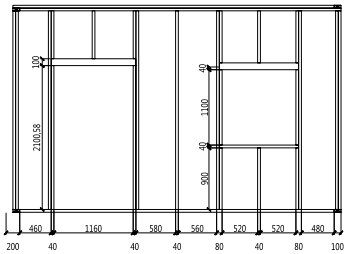
Frame L



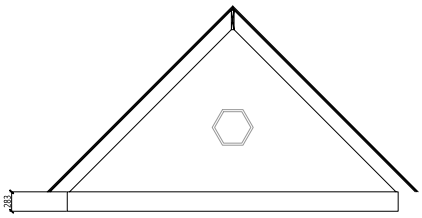
Frame F



Frame O



Frame A



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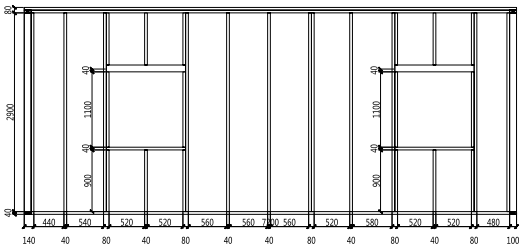

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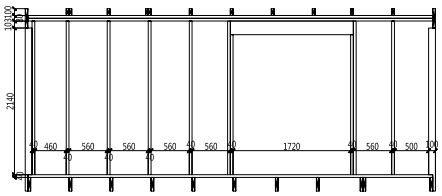

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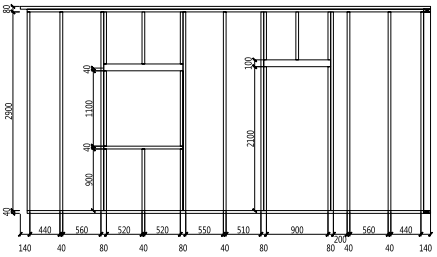
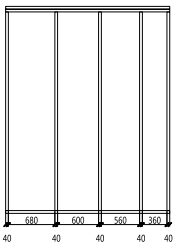


Frame B



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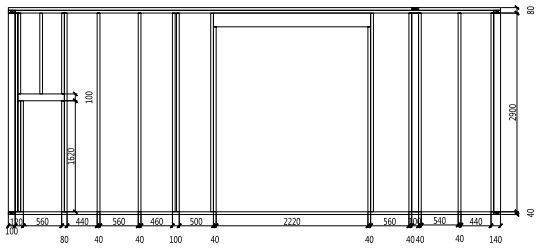
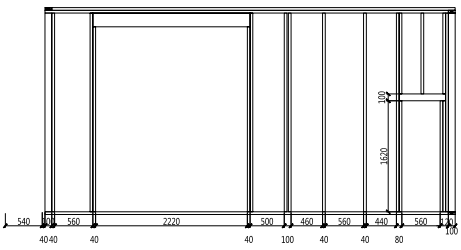
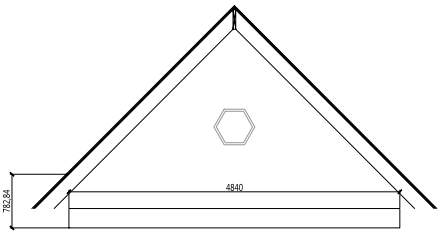


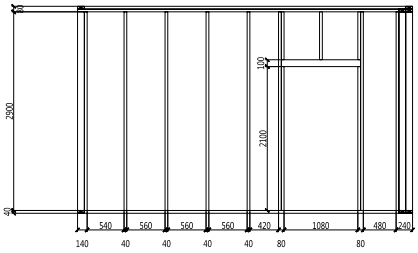
Frame G



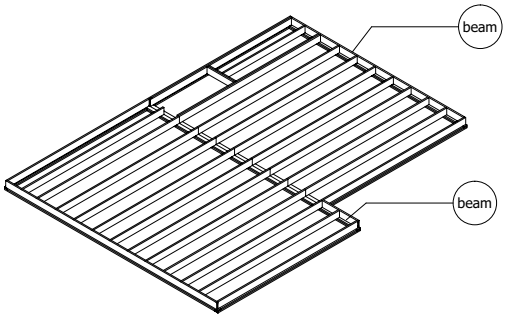
Frame H



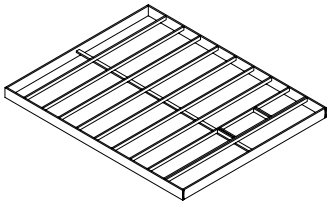
Frame S



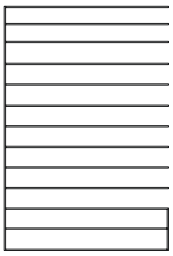
Frame K



2F FRAME



3F FRAME



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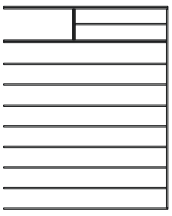

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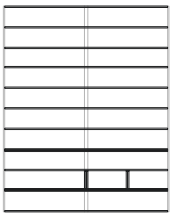
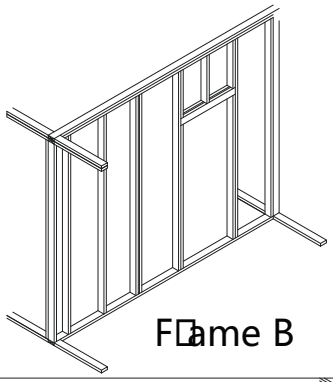
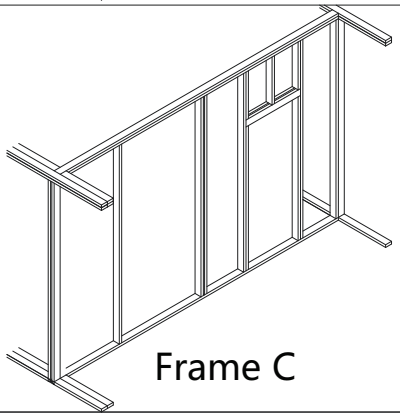


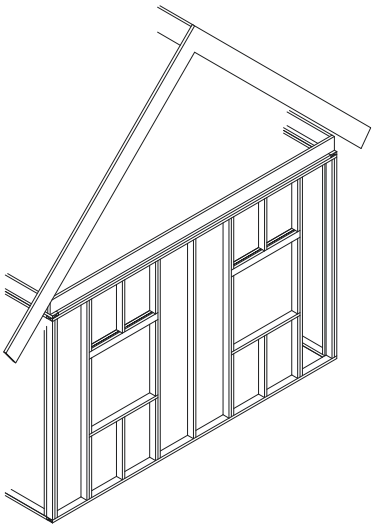
3F FRAME



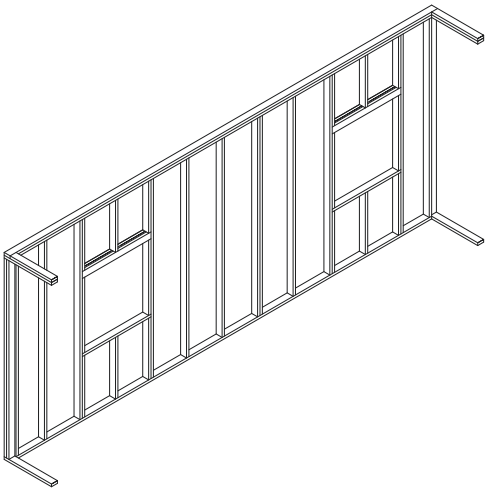
Frame B



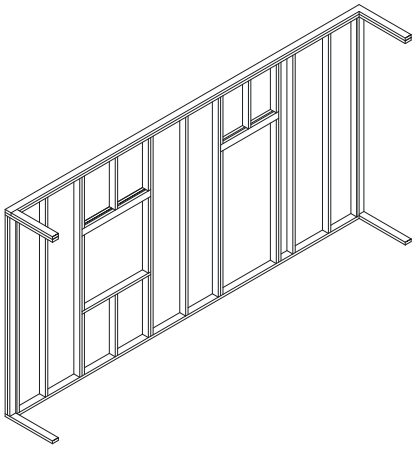
Frame C



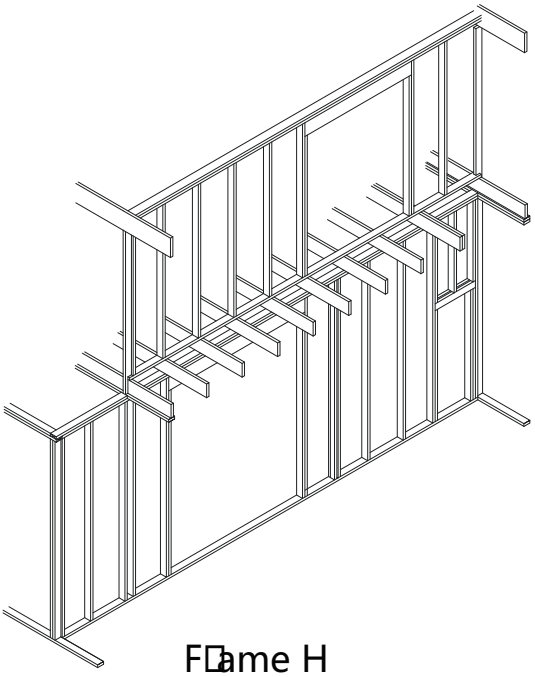
Frame F



Frame G



Frame I



Frame H