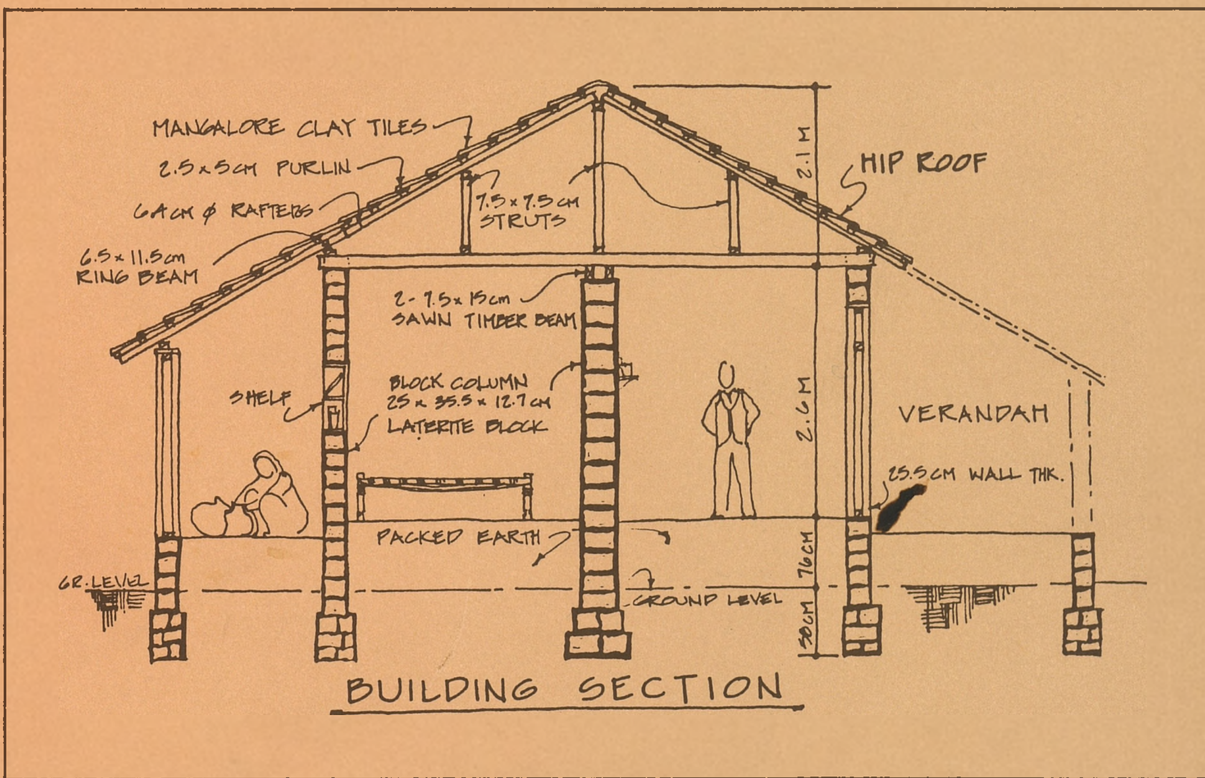
Vernacular Housing in Seismic Zones of India



Joint Indo-U.S. Program
To Improve Low-Strength Masonry Housing

INTERTECT

UNIVERSITY OF NEW MEXICO

VERNACULAR HOUSING
IN SEISMIC ZONES OF INDIA

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I. INTRODUCTION

BACKGROUND

India and the United States have a long history of mutual interest in seismic research. In 1978 an Indo-US Workshop on Natural Disaster (Earthquake and Wind Effects) Mitigation Research was jointly sponsored by the Department of Science and Technology, Government of India, and the United States National Science Foundation. Recommendations were made regarding areas of collaboration and exchange of research to optimize use of the facilities and expertise existing in both countries. The interest generated at that time led to discussions in 1981 at the International Workshop on Earthen Buidings in Seismic Areas held at the University of New Mexico. The informal discussions there resulted in the emergence of a proposal to pursue research regarding testing of low-cost, low-income non-engineered earthen and masonry housing in India.

A plan was outlined which eventually became the basis a joint Indo-US Research Program on improvement of Low-Strength Masonry Buildings in Seismic Areas. The broad objectives called for an integrated program of research. The goals of Phase I of the research were to:

1. identify and test proposed structural improvement techniques;
2. identify and test proposed material improvement techniques;
3. research improved testing techniques;
4. identify existing construction technologies of non-engineered masonry and earthen housing in the earthquake-prone areas;
5. identify the socio-economic factors that relate to all of the above objectives.

The goal of Phase II of the Indo-US Project is to conduct detailed investigation of selected improvement techniques using a combination of small-scale and large-scale laboratory testing. Phase III would be a field study of selected structural and material improvement techniques. The methodology of Phase III would use prototype construction in regions of high seismicity to examine the feasibility of various proposals under typical construction conditions, accounting for cultural and economic constraints.

In March of 1984, the College of Engineering, University of New Mexico, was awarded a grant by the Office of US Foreign Disaster Assistance, Agency for International Development, to support the field research related to goals 4 and 5 of phase I. INTERTECT was subcontracted to conduct the vulnerablility analysis.

The first objective of the research was to identify basic data regarding buildings, construction techniques and socio-economic constraints to housing modification and vulnerability reduction efforts in support of the Indo-US program. The second objective was to provide a study that could be used by the National Buildings Organisation of India to provide guidance for planning housing improvement programs in earthquake-prone regions.

Three kinds of information were identified to be included in the field research:

A. Data on non-engineered and low-strength masonry construction in the rural seismic regions of India;

B. Socio-economic data which will influence the test program as well as implementation efforts following the conclusion of the reaseach program;

C. Data relating to local construction practices, the local building trade, and the skills level of those who participate in the normal building process.

All of the research for this project was focused on the rural areas of the targeted seismic zones. A primary reason for this was because that is where the largest population is found. It is also far more feasible to implement a housing improvement program in rural rather than urban areas. Because the problem is so large, and the difficulties of implementing change are similarly large, it is necessary to start the process where it is most manageable.

The ultimate goal of this Indo-U.S. program is simple: the people in earthquake-prone areas of India should live in buildings that are safe. Achievement of this goal will require to modifications in the way future housing is built and improvements to the existing housing. The process, however, is not so simple.

The Indo-U.S. Team recognizes that housing modification efforts have usually failed more for social and economic reasons than for technical reasons. Housing must satisfy more than safety requirements. It must be economic, provide protection from the elements, and provide a liveable atmosphere for the occupants. The design of vernacular housing has often been influenced by social needs as well as structural considerations. Buildings may be used, for example, to store agricultural supplies, to shelter animals, or to serve as a focal point for business or cultural endeavors. Vernacular housing may also be a response to climatic conditions. The use of heavy earthen roofs in many areas, despite the implications for seismic vulnerability, is related more to a response to day-to-day comfort and functional needs than to concern for costs.

These social, cultural and economic constraints are manifested in the vernacular architecture. In order to assist the program of research on low-strength masonry buildings, it is important to identify and isolate those factors that are critical in vernacular housing to provide a starting point for the structural and materials research. The influence of popular features on the overall performance of a building may prove crucial to both the research effort and subsequent implementation activities. Economic constraints also play a major part in determining whether recommendations for modification will be accepted on a broad scale. Finally, the skill levels and common construction practices must be understood in order to determine how best to transfer the information developed in the research program to ensure that it is used.

KEY ISSUES

Improvement of vernacular housing to better withstand earthquakes should be viewed as part of a comprehensive response to the overall housing problem in India. The need and urgency for such improvement is made clear by the country's long history of earthquakes, in conjunction with current problems in the housing sector.

Recent reports entitled Appropriate Technology in Improved Mud Houses(1) and Rural Housing in Jammu & Kashmir State(2) detail the existing housing shortage, point to the high number of substandard housing units, and correlate this shortage to the national economic problems. At the country level, for example, it is estimated that in India, at the beginning of 1981, the total shortage of houses was on the order of 21.3 million: 4.8 million in urban areas and 16.5 million in rural areas. The total existing housing stock in the country in 1971 was calculated at 93 million dwelling units in the rural areas. Out of this total, 72 per cent of the dwelling units, (67 million) employ mud as the principal building material.

The annual demand for new houses, assuming a 20-year program designed to overcome the shortfall, is estimated at 1.25 million units in urban areas and 3.5 million units in the rural areas.[3] The principal approaches used by the government through the various housing-related agencies probably produce less than 1% of the annual need. If a major disaster were to occur, the sudden need for replacement housing would significantly worsen the already acute problem.

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1. G.C. Mathur, Appropriate Technology in Improved Mud Houses, National Buildings Organisation and U.N. Regional Housing Centre.
2. Prepared by the National Buildings Organisation, Rural Housing Wing, Regional Engineering College, Srinagar, Kashmir, December, 1982.
3. Report of the Development Group on Low Cost Housing Including Minimum Economic Specifications, National Buildings Organisation, Govt. of India, New Delhi 1977, pp. 14-15.

It is clear, then, that India cannot afford the additional burden of replacing houses lost in a disaster. This highlights the need to upgrade the existing housing stock to preclude the need to replace them after a disaster. In a previous study of vernacular housing in disaster-prone areas the following observations were made:

> Structural upgrading of houses can be viewed in terms of its advantages vis-a-vis disasters as well as its contribution to the resolution of existing housing problems. In terms of disasters, by emphasizing modification and upgrading, the number of units lost to a disaster will be lowered and the reconstruction burden on both the government and the people will be reduced. A house that withstands a disaster not only represents a safe refuge for its occupants, but also eliminates the tremendous discontinuity and economic burden resulting from damage to the building, and it represents a lessening of the foreign exchange problem and reduction of further strains on a reconstruction economy.
>
> Upgrading is cheaper than replacement of substandard units, and many of the measures taken to improve disaster resistance will help make the housing more livable as well as more durable. Furthermore, upgrading places the majority of the burden on the homeowner rather than on the government, thereby enabling policy-makers to spread financial resources to a greater number of beneficiaries.(4)

DEFINITION OF TERMS

The following are brief definitions of the terms used in this report:

A. Design Changes: the process of altering the design of a structure before it is erected to make it more disaster resistant.

B. Disaster Resistant Construction: a term used to denote the degree to which a structure can be made more resistant (or safe) to certain natural phenomena. The term recognizes that no building can be considered totally safe, but that certain steps can be taken to improve performance or survivability.

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4. INTERTECT, Improvement of Vernacular Housing in Jamaica to Withstand Hurricanes and Earthquakes, prepared for Office of U.S. Foreign Disaster Assistance, Agency for International Development, Washington, D.C., 1981, p. 2.

C. Epicenter: the geographical point on the surface of the earth vertically above the focus of the earthquake.

D. Housing Education Program: a program offering instruction to homeowners or builders on how to build a safer or more disaster resistant house.

E. Housing Modification: changes in the configuration of an existing building to make it stronger. Modifications might include reinforcing roof framing, adding a room, etc.

F. Intensity of Earthquake: the intensity of an earthquake at a place is a measure of the effects of the earthquake, and is indicated by a number according to the Modified Mercalli Scale of Seismic Intensities (see Appendix VII).

G. Magnitude of Earthquake (Richter Magnitude): the measure of energy released in an earthquake; it is a logorithmic scale so that a recording of 7, for example, indicates a disturbance with ground motion 10 times as strong as a recording of 6.

H. Non-Engineered Buildings: those structures built either by home-owners or by local building tradesmen such as carpenters and masons without formal architectural or engineering inputs into the design or construction process. For the purposes of this report, the term only includes those structures which could be considered formal houses; it does not include the temporary, makeshift dwellings often used by transients or families in squatter settlements prior to the construction of a more formal house.

I. Retrofitting: the process of installing additional supports or altering components of an existing building in order to make it more disaster resistant.

J. Risk: the relative degree of probability that a hazardous event will occur. An active fault zone, for example, would be an area of high risk.

K. Vernacular Construction: buildings constructed by homeowners or builders without formal training using local materials and traditional designs, all of which can also be designated as "non-engineered."

L. Vulnerability: a condition wherein human settlements or buildings are exposed to a disaster by virtue of their construction or proximity to hazardous terrain. Buildings are considered vulnerable if they cannot withstand the forces of earthquakes.

II. SEISMIC RISK IN INDIA

EARTHQUAKE RISK

Some of the most seismically active areas of the world are located within India. The country has been divided into five zones of relative seismic activity. They range from Zone 1, where there is the least threat of a seismic event and the greatest distance from an earthquake epicenter, to Zone 5. This zone is where earthquakes occur most frequently and with potentially high levels of intensity (see Figure 1). In terms of people living at risk to earthquakes, the zones of greatest concern are Zones 3 - 5. These zones constitute 56% of the area of India and touch almost all of its states. Regions classified as Locations where Zone 5 range from the extreme west in Gujarat, to the extreme north in Jammu and Kashmir and to the extreme .east in Assam. The Andaman and Nicobar Islands within Zone 5. Zone 4 primarily follows the northern tier of the country running parallel with the Himalayan Mountain range. Geologically this area is one of the most unstable in India. Small areas of Zone 4 are also found in three other widely separate locations. Zone 3 weaves throughout the country and extends to the southern tip of the subcontinent.

A majority of India's vast population live within these three zones. Most of the major cities are also found here. (See Figure 2 for map of housing density). It is these people that are most at risk; that is, there is of probability that an earthquake will occur in those regions. However, only the people who live or work in buildings that are liable to collapse in an earthquake are, in fact, vulnerable to the destructive forces of the earthquake. As noted in the introduction, this report only addresses the vulnerable populations of the rural areas. (See Figure 3 for areas of high density of housing in zones of high seismicity.)

Earthquake forces threaten housing in three basic ways:

* Forces generated by ground-shaking;

* Liquefaction of the soils (a condition where loosely packed soils separate and behave similarly to water when shaken by an earthquake, thus allowing buildings on the surface to partially sink or settle);

* Secondary effects, such as landslides or tsunamis (seismically-generated sea waves).

Low-cost, non-engineered houses are those which suffer the most damage during earthquakes. In India more than 80 percent of the total population lives in rural areas, and almost all the houses in rural areas fall into the category of non-engineered houses. Recent research has indicated that 80 percent of the lives lost during past earthquakes are due to damage of small houses. Refering to Figure 3 again, one can estimate the enormous numbers of people living in danger of large earthquakes.

The range of risk and of vulnerability to earthquakes in India is very wide. The focus of this research has been on the large areas of India where damage can be as high or higher than VI on the Mercalli Scale. The recommendations generated by this report, however, limit their application to earthquakes with intensities of no more than IX Mercali. Although earthquakes with greater intensities of ground shaking occur, they are relatively rare and affect only a small portion of the total area impacted by the earthquake. The technical difficulty and the cost of creating structures capable of withstanding these earthquakes is far greater than it is for those in the range of VI-IX. It is, therefore, the policy of this research team to base its recommendations on what it will take to create relative safety for the occupants of non-engineered houses to withstand earthquakes of intensity VI-IX.

SEISMIC HISTORY OF INDIA

The history of the destructiveness of earthquakes in India is very long. No less than 25 major earthquakes are in recorded history prior to the 20th century (see Figure 4).(1) During this century India has experienced some of the most destructive in history with magnitudes as high as 8.7 in the Assam area. M.S. Balasundaram chronicles some of the most important earthquakes as follows:

Assam Earthquake of 1897

The earthquake was assigned a magnitude of 8.8 on the Richter Scale and produced damages in the highest grade of XII Mercalli. There were spectacular landslides, sometimes entire hillsides being stripped of soil exposing rock. Over 1,600 people were killed and earthshocks felt over 175,000 sq. miles (450,000 sq. km).

Bihar-Nepal Earthquake of 1934

The Bihar-Nepal earthquake was felt over 1.9 million sq. miles (4.92 million sq. km) of area in India and Nepal, and ranks among the most devastating earthquakes. It had a magnitude of 8.4 and attained an intensity of X on the Mercalli Scale.

Kangra Earthquake of 1905

It has been estimated that the Kangra Earthquake of 1905 was one of the most severe that has affected northern India during this century. The loss of life was stated to be about 19,000. The magnitude was 8.6. Significant damage occurred as far as 160 km from the epicenter in Dehra Dun.2

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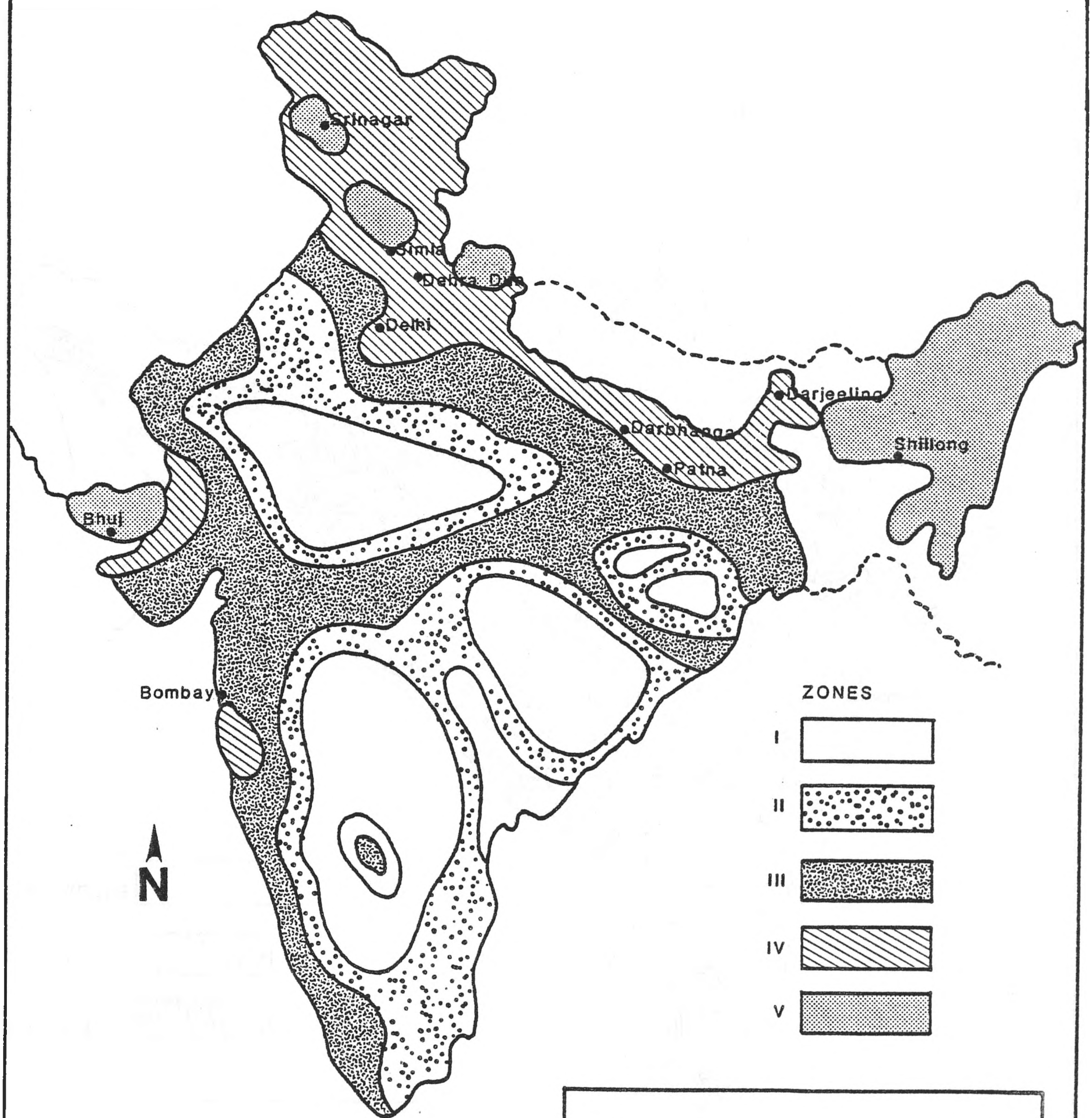
1. Jai Krishna and L.S. Srivastava, "Importance of Earthquake Studies as Part of Investigations for Power Projects," Bulletin, Indian Society of Earthquake Technology, Vol. III, May 1966, Roorkee, India, pp. 23-24.
2. M.S. Balasundaram, "A Review of Geological Studies of Earthquakes in India," Seismology in India, The Committee of Seismologists Formed to Felicitate Dr. Tandon, 1970, p.4-6.

Assam

Within the study of earthquake risk and vulnerability, Assam should be discussed independently. This easternmost portion of India is entirely in Zone 5, an area larger than the rest of the Zone 5's combined. The magnitude, intensity and frequency of earthquake activity is unparalleled in India. Figures 5 and 6 illustrate the density of seismic events just during this century. From the study of seismic activity in North-East India, it is concluded that the region is very unstable, especially near the juncture of the Arakanyoma mountain ranges with the Himalayan tails extending southwards.(3)

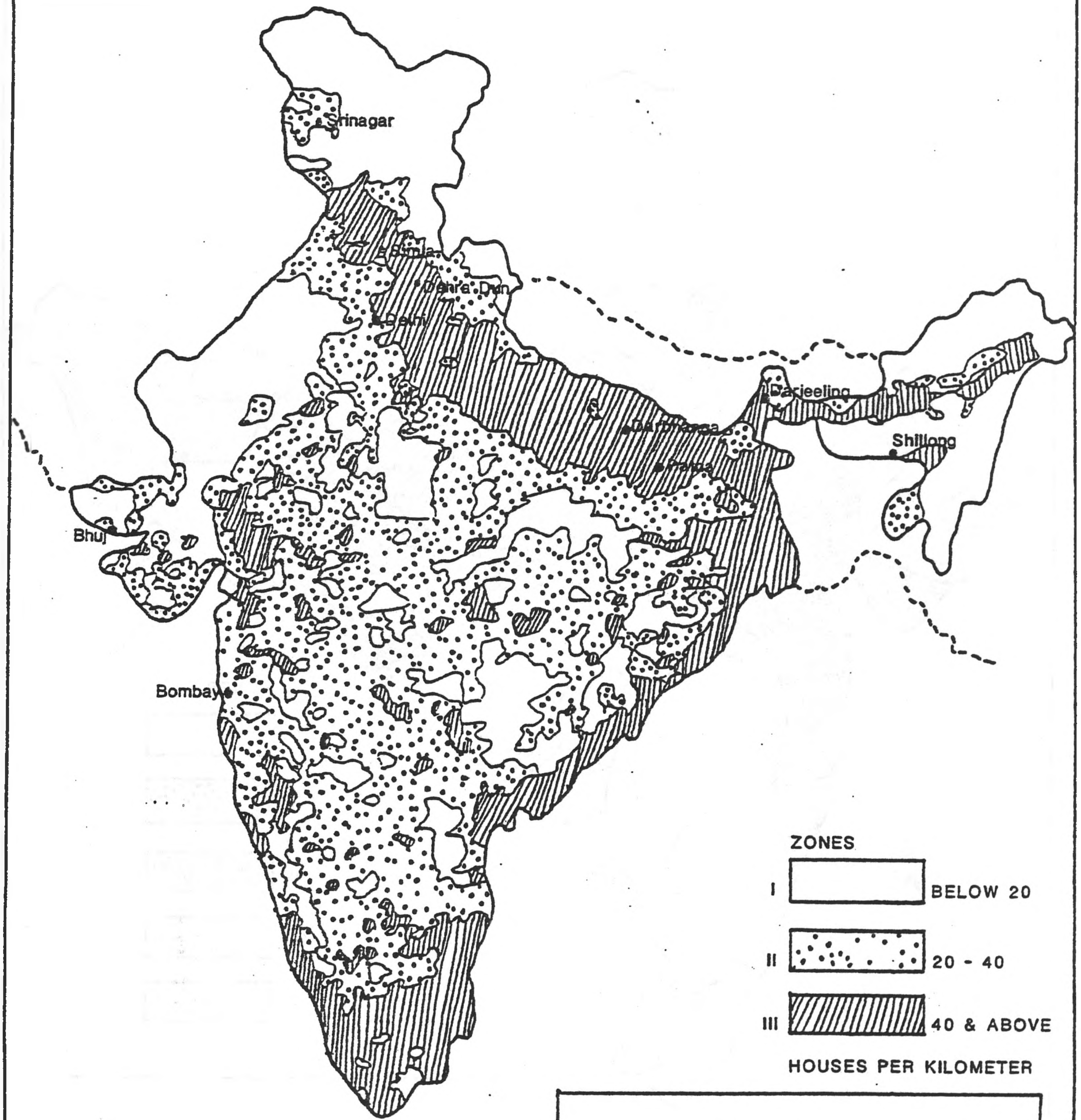
3. G.S Varma, "Seismicity of North-East India," Bulletin of the Indian Society of Earthquake Technology, Vol. 12, No. 3, September 1975, p. 118.

FIGURE 1.



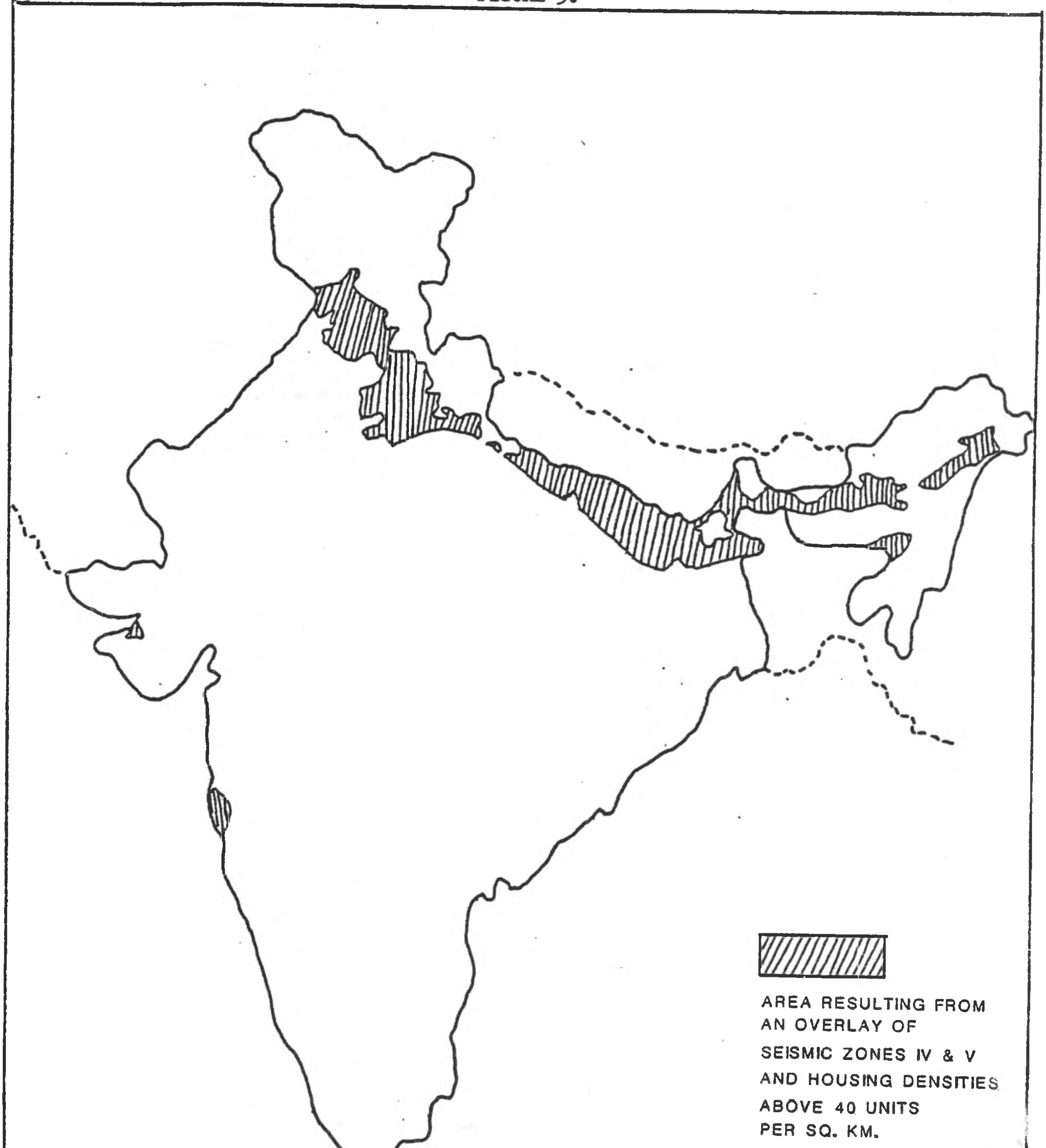
SEISMIC ZONES OF INDIA

FIGURE 2.



HOUSING DENSITY IN INDIA

FIGURE 3.



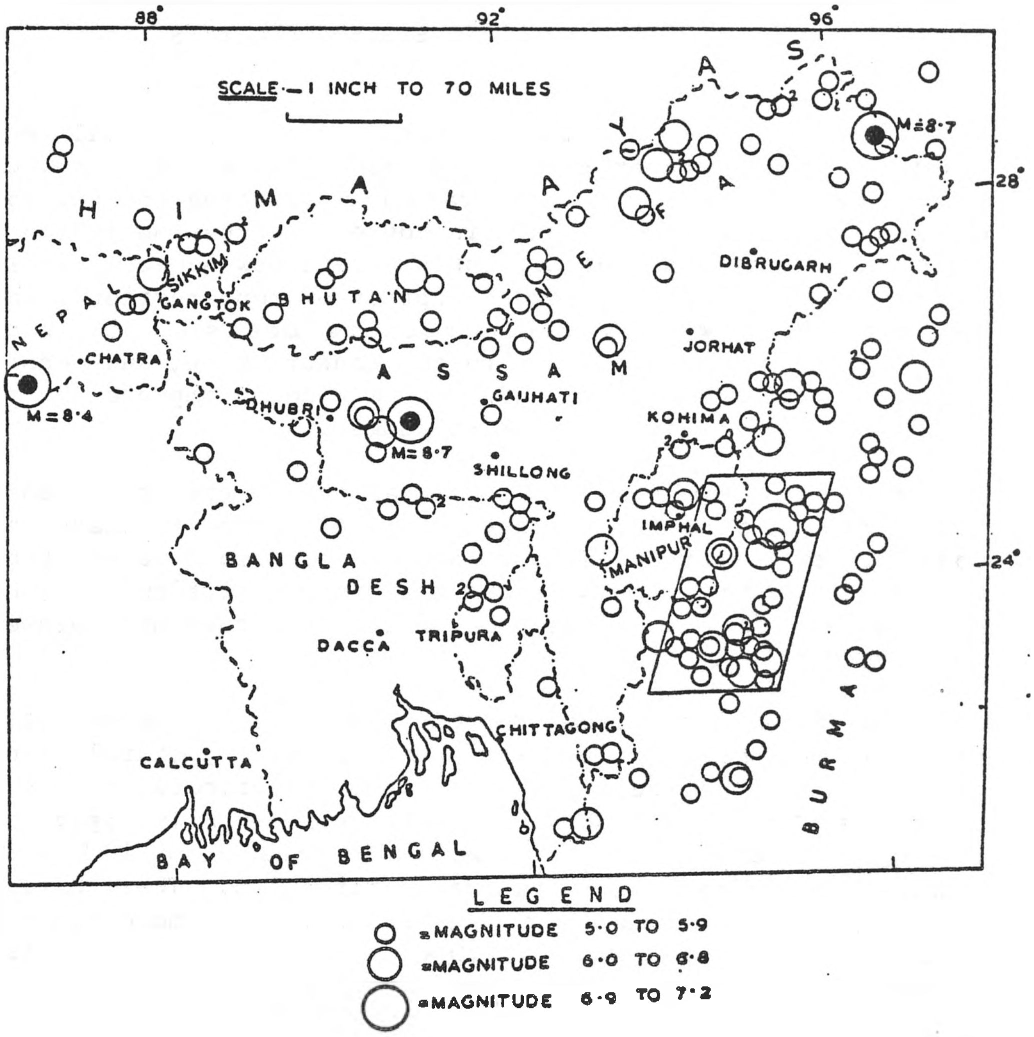
AREAS OF HIGH SEISMIC ACTIVITY AND HIGH HOUSING DENSITY IN INDIA

FIGURE 4.

List of Some Destructive Earthquakes in India and Neighbouring Countries.

Date	Location	Intensity	Remarks
1505, 6th July	Agra	Severe	Great Damage
1618, 26th May	Bombay	Severe	2000 Killed. Voilent sea waves and Hurricane, 30,000 houses burried
1668, May	Indus Delta	Severe	
1669, 22nd Jun.	Kashmir	Violent	Large fissures in ground
1720, 15th July	Delhi	Severe	Great Damage
1737, 11th Oct.	Calcutta	Violent	3 lacks-killed, violent Hurricane and sea waves
1761, 2nd April	East Bengal	Violent	Subsidence of 60 Sq. miles area.
1764, 4th June	Banks of Ganges (Bihar-Bengal)	Violent	Great Damage, many killed
1803, 22nd May	Upper Ganges	Severe	Rumbling noise
1803, 1st Sept.	Mathura	Very Violent	Felt up to Calcutta, Great Demage
1803, 1st Sept.	Garhwal Kumaon	Violent	200-300 killed, great damage
1819, 16th June	Cutch	Very Violnt	Earth rose by 10 feet forming Allah bund very great damage, many thousands dead.
1826, 29th Oct.	Bihar-Nepal	Severe	Damage at Kathmandu and Patna, Eight after shocks
1827, 20th Sept.	Lahore	Violent	1000 killed, slides in Ravi and floods. Buildings in Lahore destroyed
1828, 6 and 15th June	Kashmir	Very Severe	1000 killed, 1200 houses destroyed, sand fountains, 100 to 200 after-shocks per day for two months.
1833, 4th Aug.	Nepal and North Bihar	Very Violent	Great loss of life and property, fissurs, fountains, subsidence, many after shocks upto 11th September.
1833, 4th Oct.	Nepal (Kathmandu)	Violent	Great damage, followed by other shocks on 18th, 28th Oct, 8th, 16th and 26th November.
1842, 19th Feb.	Kabul	Violent	Affected an area of 216,000 sq. miles
1843, 1st April	Deccan	Severe	Preceded by a shock on 12th March, Centre near Bellary. Felt in a widely extended area.
1848, 20th April	Mount Aboo	Violent	Damage to buildings. Felt in Madhya Pradesh and Cutch.
1861, 29th March	Darjeeling	Very Severe	Other shocks on 18th June, 8th July, 11th Aug, 21st and 17th Oct. 1863 of Light to Moderate intensity.
1863, 18th Nov.	Nimar and Barwani	Severe	Felt south of Narbada river, not felt south of Satpura range.
1869, 11th Jan.	Cachar	Violent	Felt over an area of 250,000 sq. mile, great damage.
1881, 31st Dec.	Bay of Bengal	Severe	Felt on 2,000,000 sq. miles of sea.
1885, 14th July	Bengal (Dacca)	Severe	Felt over an area of 230,000 sq. miles.
1827, 12th June	Assam	Violent	Great damage, over 1600 people killed, Felt over 175,000 sq. miles.
1905, 4the April	Kangra	Violent	Great damage, 20,000 people killed, Kangra and Dharmshala completely destroyed.
1918, 8th July	Srimangal (Assam)	Severe	Felt over area of 800,000 sq. miles.
1930, 27th Aug.	Baluchistan	Violent	Great damage, over 200 killed
1934, 15th Jan.	Bihar-Nepal	Violent	Great damage, over 10,000 killed. Total area affected 1,900,000 sq. miles.
1938, 14th April	Chindwin (Burma)	Severe	Damage in Upper Burma
1943, 23rd Oct.	N.E. Assam	Severe	Destructive in N.E. Assam
1947, 29th July	Assam	Severe	Destructive in N.E. Assam
1950, 15th Aug.	Assam	Violent	Great damage in Upper Assam, felt over 650,000 sq. miles, many killed
1954, 22nd March	Manipur-Burma Border	Severe	Felt over a very large area
1956, 21st July	Anjar	Severe	Damage to property
1958, 28th Dec.	Kapkote	Severe	Damage to buildings
1960, 27th Aug.	Delhi	Severe	Damage to buildings
1963, 2nd Sept.	Badgam (Kashmir)	Severe	Great damage in poorly constructed houses, more than 60 killed.

FIGURE 5.



Earthquake epicentres for North-East India and Burma Border Region from 1951 to 1971 alongwith a few great earthquakes of historic times

FIGURE 6.

PARAMETERS OF EARTHQUAKES OF MAGNITUDES GREATER THAN 7.0 IN NORTH-EAST INDIA FROM 1897 TO DATE.

Serial Number	Date	Origin Time (G.M.T)	Epicentre Lat °N	Long °E	Magnitude
1.	1897, June 12	110600	26.0	91.0	8.7
2.	1918, July 8	102207	24.1	91.8	7.6
3.	1923, Sept 9	220343	25.5	91.5	7.1
4.	1930, July 2	210342	25.8	90.2	7.1
5.	1934, Jan. 15	084318	26.5	86.5	8.4
6.	1941, Jan. 21	023015	27.5	92.5	7.1
7.	1943, Oct. 23	172316	27.5	93.5	7.3
8.	1947, July 29	134322	28.5	94.0	7.9
9.	1950, Aug. 15	140930	28.5	96.5	8.7
10.	1954, March 21	234205	24.5	95.0	7.2

III. BUILDING SYSTEMS ANALYSIS

The following is an analysis of the principal housing types found in the earthquake-prone regions of India. A survey was made of these regions to identify various existing housing construction methods, historical trends in house construction in the areas, and general conditions that currently affect how houses are being built. The analysis includes a description of construction techniques, an analysis of how well the structure meets the basic criteria of earthquake resistant design and construction, and recommendations regarding modifications that can be made to improve the performance of these buildings in future earthquakes.

Most recommendations for making the structures more disaster resistant can be incorporated at little or no increase in the total cost of new construction, but some modifications to existing building types are both expensive and technically difficult. Consequently, the recommendations are made with a view towards implementation in new construction.

The recommendations represent a list of improvements -- either of more seismically resistant materials, structural techniques, or methods of construction -- and refer specifically to the house type that was evaluated; they do not necessarily apply to all house designs. Some of the recommendations need illustration to communicate clearly the intended application. These have been shown as diagrams or details and are included immediately after this section of monographs. Each detail is numbered and its number is referred to as the detail reference number (Det. Ref. No.) on the recommendations.

The motivation of a homeowner to use the recommendations is to a large degree a function of their cost and the amount of labor needed to achieve their implementation. Consequently, the recommendations include an estimate of how much their implementation would add to the total cost of construction of the house. Similarly, the estimated number of additional days or partial days required for the labor is shown. For informational purposes and as a base reference, an assumed total cost of an average house of each type is indicated. The percentages used are based on that total cost.

> It is important to remember that the most critical features in making a house disaster resistant are the configuration of the house, the configuration of the roof, attention to detailing, and quality of workmanship. All of these features are more important than the materials which are chosen. <u>For it is not the materials that are used, but rather how they are used, that is important</u>. Any type of structure can be made safe if it is designed properly and fastened together securely.*

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*<u>Improvement of Vernacular Housing in Jamaica to Withstand Hurricanes and Earthquakes</u>, INTERTECT, Dallas, Texas, 1981, p. 34.

SEISMIC DESIGN REQUIREMENTS

A study of building damage during past earthquakes indicates that certain principles may be observed in design and construction of buildings which make them earthquake resistant. The following structural analyses include checklists of the 20 most basic seismic design criteria, and each house type has been evaluated as to how well it meets these criteria. When a criterion has been met, the house is given a rating of "good". When a criterion has only been partially met (thus possibly reducing the strength of the house), it is rated as "fair". If a criterion has not been met and this lack thereby contributes to failure of the house in an earthquake, it is rated as "poor".

Below is a summary of these seismic design criteria, describing their importance in earthquake resistant construction:

Siting: The house site should be level or on very stable slopes which allow for the foundation to be constructed at one constant elevation. Soils should be firm with a high bearing capacity and well-drained.

Separation Between Buildings: To avoid collision during an earthquake, all buildings should be separated from each other. Wood and good-quality reinforced masonry should be separated by at least 2 cm. for each story of construction. Non-engineered buildings which may collapse on their neighbor should be separated by a distance equal to one-half the height of the building. The continuation of the practice of "Aab-chik" — the separation of houses about 1 meter — should be encouraged.

Foundation Design: The foundation must be capable of evenly supporting the weight of the building in the soil and of remaining rigid and intact during an earthquake.

Balance of Structure: Walls should be parallel, of the same height, and with the same mass and rigidity. Openings in a wall should be of equal area to the openings in the opposite wall.

Building Plan: In order to minimize torsion during an earthquake, the building should have a simple rectangular plan and be symmetrical. If symmetry of plan, elevation or mass is not possible, the building should be separated into sections using crush joints. The length of each section should not exceed three times its width.

Center of Gravity: The higher the center of gravity of a structure, the greater is the impact of earthquake forces. Therefore, the structure should be designed so that its center of gravity is as low as possible.

Rigid Walls: Walls should be designed so that they will maintain their integrity under earthquake motions, transmitting the forces to the adjoining walls, floors and ceiling planes at the four edges.

Roof Design: The roof should be constructed so that it will maintain its integrity, i.e., maintain its shape and form during earthquake motion.

Projections and Overhangs: Cornices, balconies, parapets and chimneys generally fail early in an earthquake. When they fall, they can damage the building and injure people who are running out of the houses or moving on the streets. Such projecting and overhanging parts should be avoided as much as possible, or care should be taken to reinforce and anchor them to the main structure adequately.

Door/Window Locations: Door and window openings should be located approximately one meter from corners and from each other. This requirement applies to earthen and unreinforced brick buildings with mud mortar.

Door/Window Areas: For buildings of fired brick and stone constructed with cement mortar, the total width of wall openings should not be more than half the length of the wall between cross walls. For earthen or unreinforced brick buildings with mud mortar, the total width should not be more than one-third this distance.

Foundation-to-Wall Connection: There should be adequate bonding or anchorage between the foundation and the walls so that the walls remain fixed and move with the foundation during an earthquake.

Wall-to-Wall Connections: Connections should firmly join the walls together. Attachments should be fabricated. This may be achieved by using dowel bars or horizontal knee bracing at the corners.

Wall-to-Roof Connection: The roof should be anchored to the walls so that there will be no relative movement between walls and roof. The roof structure should provide lateral bracing to the walls.

Lightweight Walls: Since the earthquake force is mainly a function of impact of ground acceleration on the mass of the building, a building should be constructed to be as light as possible, consistent with structural safety and functional requirements.

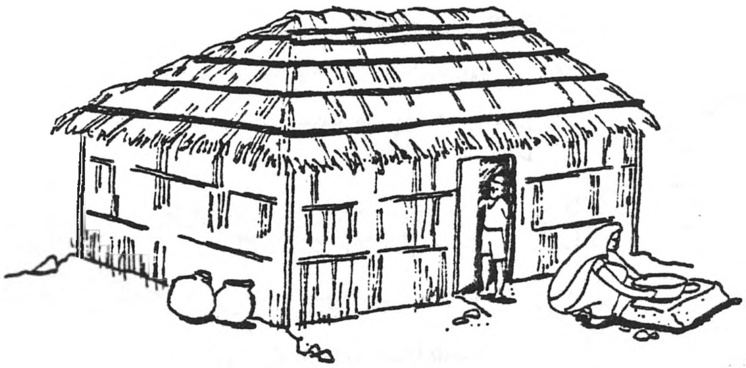
Lightweight Roof: To help lower the center of gravity and reduce the impact of earthquake forces, the roof covering and framing should be as lightweight as possible.

Ring Beam: Ring beams (or bond beams) should be constructed in all loadbearing walls at floor lines and roof line, to tie the various walls of a building together so that the building acts as one unit at the time of an earthquake. Instead of a ring beam at the top of the wall, use only a lintel band if there is no gable and the walls are low.

Strength of Building Materials: Buildings in earthquake areas should be constructed of strong materials that tend to be high strength in compression, tension and shear; small weight density; higher damping coefficient; and have high energy-absorbing capacity.

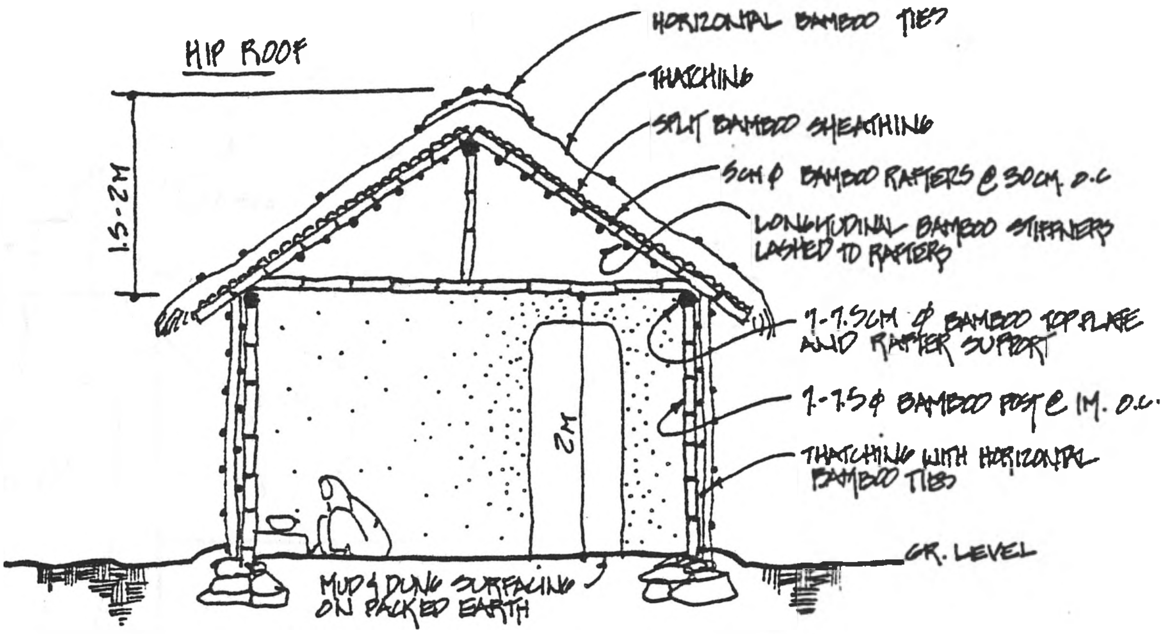
Strength of Mortar: In masonry construction, the mortar should possess high tensile and shear strength and good bonding characteristics.

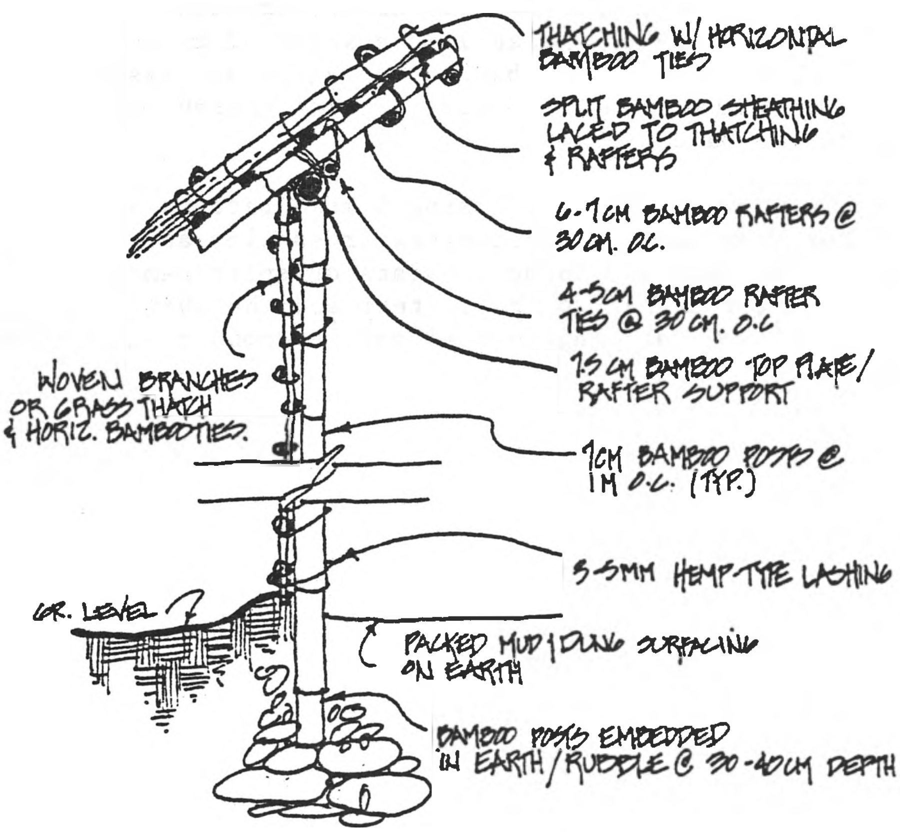
Quality of Workmanship: A building's performance in an earthquake will be affected by how well all of the materials are assembled. All walls should be plumb, square and level. All joints should be strong. For all structures, an improved quality of carpentry, masonry, truss construction, ring beam assembly, joints and connections will substantially improve seismic resistance.



HOUSE TYPE:	Thatch
LOCATION:	N. Bihar; Maharashtra
FOUNDATION:	Rock support is provided for bamboo posts.
WALLS:	Bamboo posts 7-9 cm. in diameter are embedded 30-40 cm. deep in earth and rubble at 1 m. spacing, 2 m. in height. Posts are notched into a bamboo top plate and lashed with a locally-made rope. Branch or reed thatch panels are lashed to the bamboo frame.
ROOF:	The hipped roof is framed using bamboo rafters at 30 cm. on center with bamboo longitudinal cross ties at 30 cm. on center. The roof sheathing consists of split bamboo at 12 cm. on center lashed to the rafters and thatching layers. The thatching has longitudinal split bamboo runners tied to the roof framing.

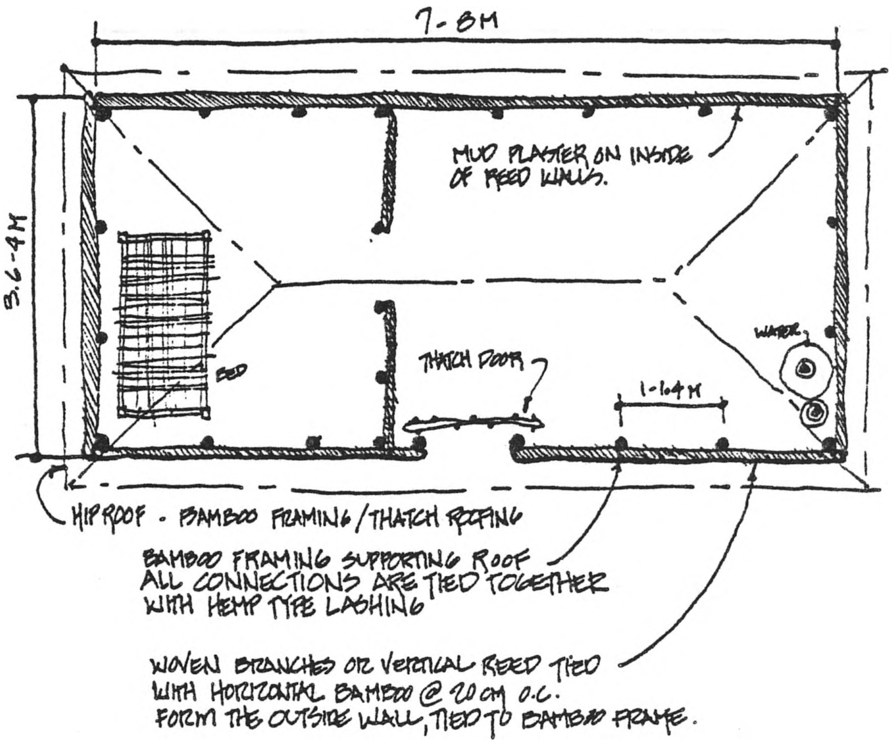
BUILDING SECTION



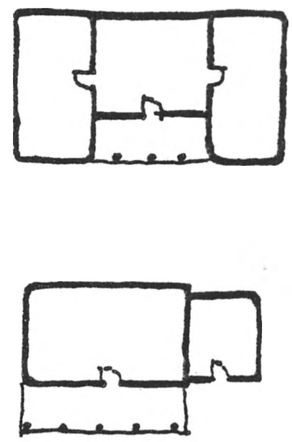


TYPICAL WALL SECTION

TYPICAL PLAN



VARIATIONS

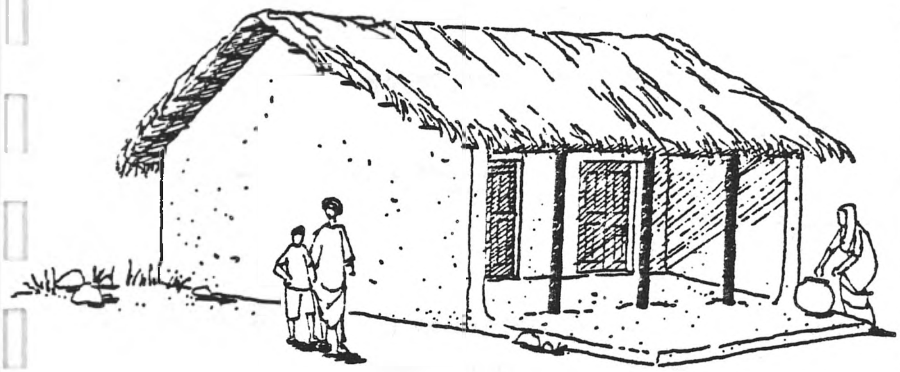


Seismic Resistance Evaluation

GOOD	FAIR	POOR	N/A		GOOD	FAIR	POOR	N/A	
●				SITING	●				DOOR/WINDOW AREAS
●				SEPARATION BETWEEN BLDGS.				●	FOUNDATION-WALL CONNECTION
			●	FOUNDATION DESIGN	●				WALL-WALL CONNECTION
●				BALANCE OF STRUCTURE	●				WALL-ROOF CONNECTION
●				SHAPE OF PLAN	●				LIGHT WEIGHT WALLS
●				CENTER OF GRAVITY	●				LIGHT WEIGHT ROOF
	●			RIGID WALLS	●				RING BEAM
●				ROOF DESIGN	●				STRENGTH OF BLDG. MATERIALS
●				PROJECTIONS & OVERHANGS				●	STRENGTH OF MORTAR
●				DOOR/WINDOW LOCATIONS	●				QUALITY OF WORKMANSHIP

RECOMMENDATIONS FOR IMPROVEMENTS	DET. REF. NO.	% CONST. COST	MAN-DAYS
Add X braces in roof framing	1	1	1
Add knee braces in plane of roof plate	2	1	.75
Add X braces in walls	3	1	1.5
Add corner braces	4	1	1

AVERAGE TOTAL COST OF HOUSE Rs. 300



HOUSE TYPE: Wattle-and-Daub

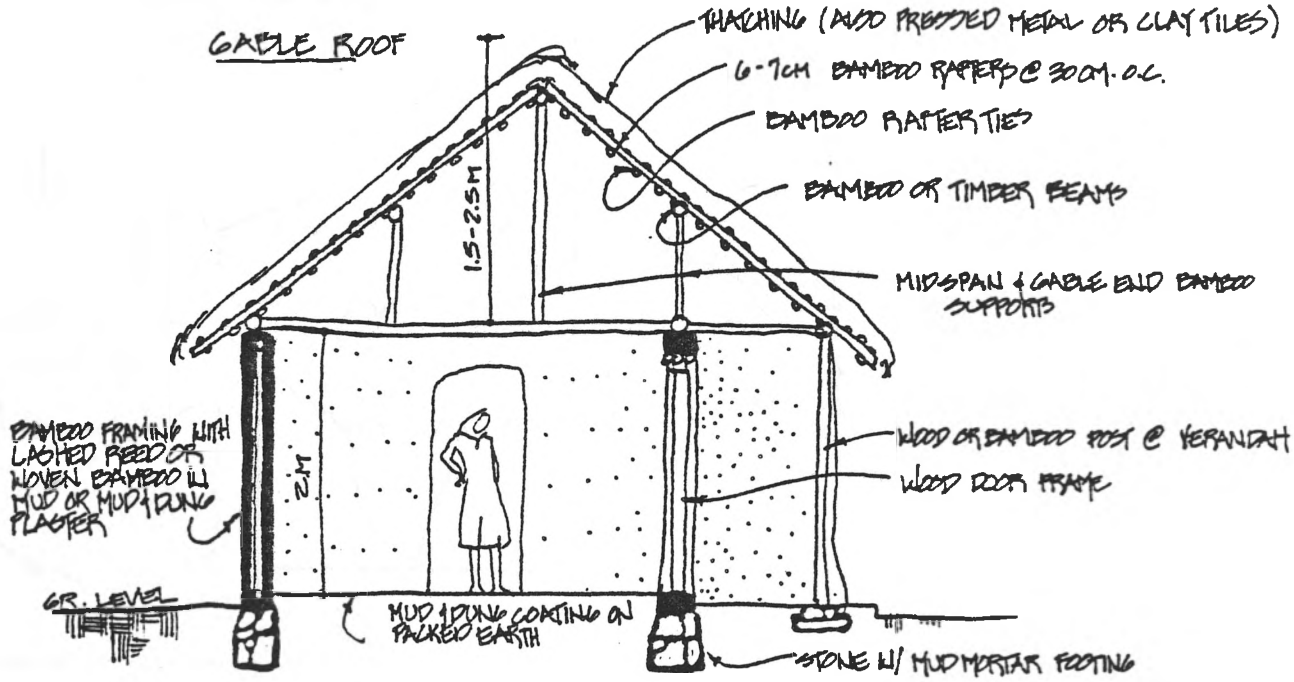
LOCATION: N. Bihar; Maharashtra

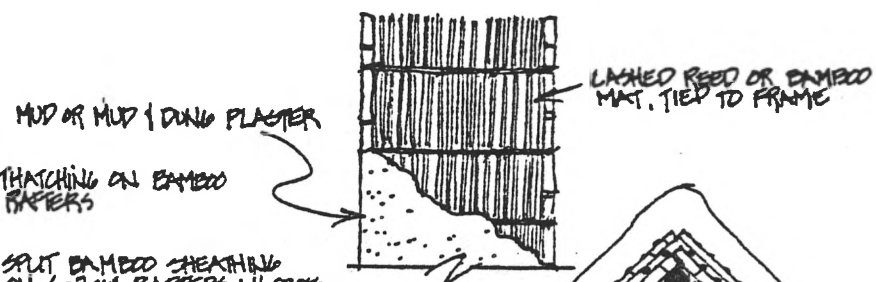
FOUNDATION: The foundation is 45 cm. wide x 40 cm. deep, made of rubble or unfired clay brick in a mud mortar. Often no foundation is constructed.

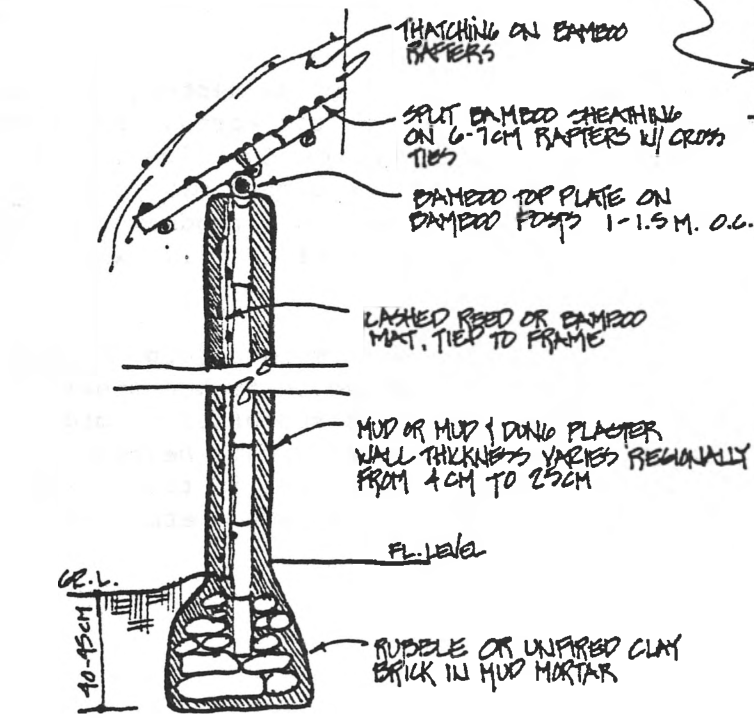
WALLS: Walls consist of bamboo posts at 1 m. on center, embedded 45-60 cm. deep in the foundation or the earth. Posts are notched into the bamboo top plate and lashed with hemp-type rope. A lashed reed or bamboo mat is tied to the frame and plastered inside and out, producing a 4-25 cm. width depending on the type of infill. Walls are typically 2 m. in height.

ROOF: Gable end beams, 10-12 cm. in diameter, support bamboo rafters at 30 cm. on center, lashed to bamboo cross ties at 30 cm. on center. This system is supported at mid-span by longitudinal bamboo or timber beams bearing on an internal wall and end walls. Thatching is tied to split bamboo purlins at 12 cm. spacing. Pressed metal and clay tile roofing are also used.

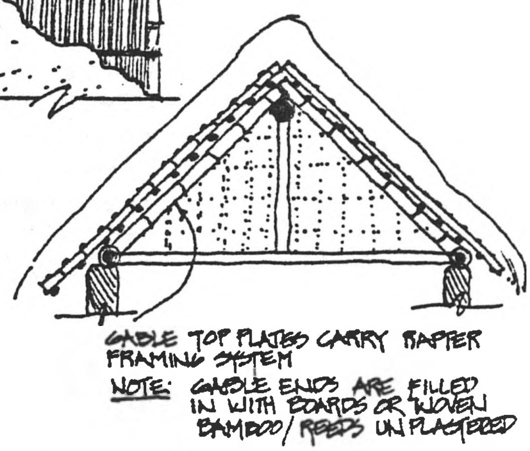
BUILDING SECTION



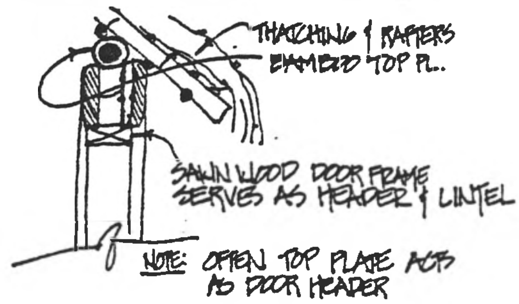




TYPICAL WALL SECTION

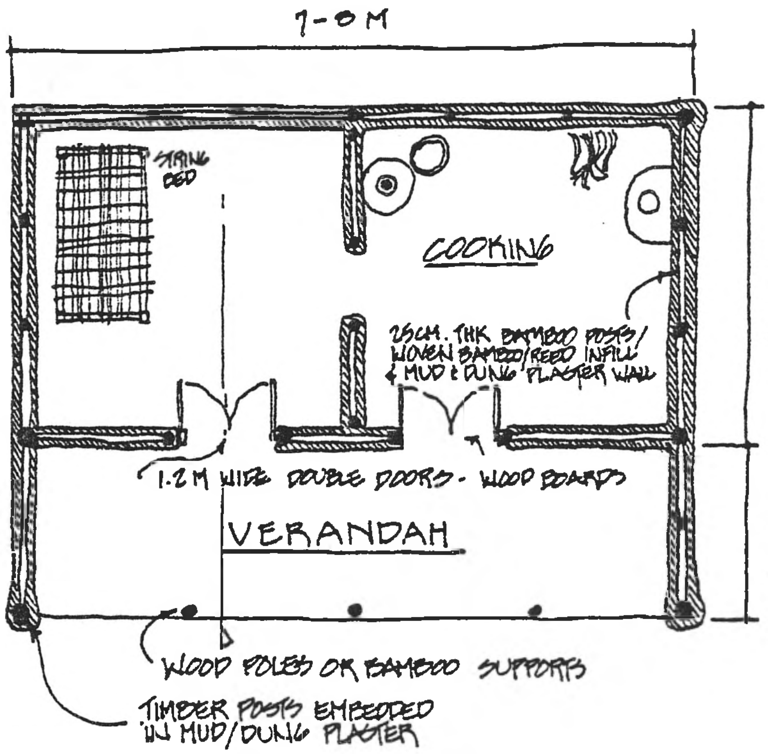


GABLE END DETAIL

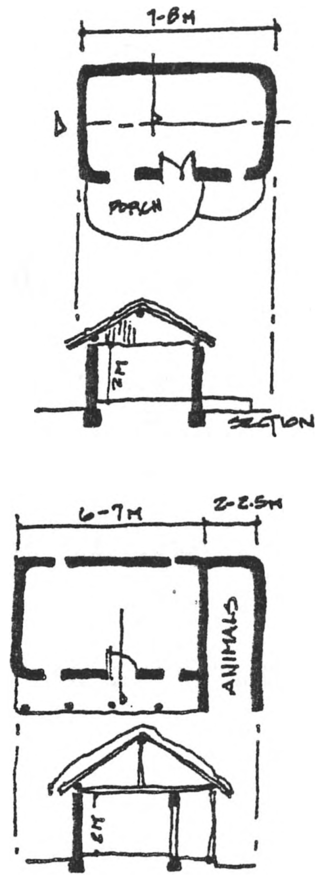


DOOR LINTEL SECTION

TYPICAL PLAN



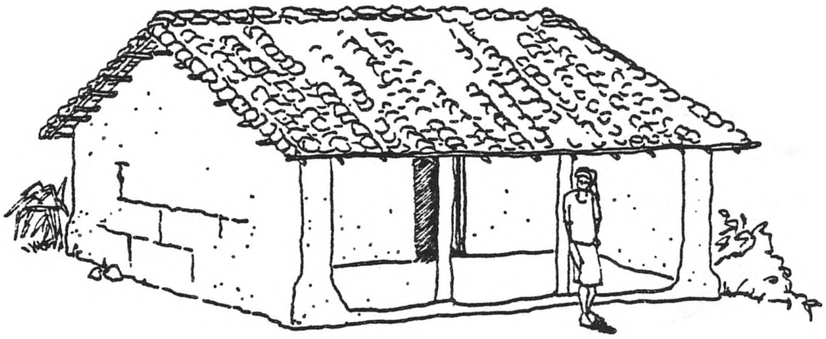
VARIATIONS



Seismic Resistance Evaluation									
GOOD	FAIR	POOR	N/A		GOOD	FAIR	POOR	N/A	
	●			SITING	●				DOOR/WINDOW AREAS
●				SEPARATION BETWEEN BLDGS.		●			FOUNDATION-WALL CONNECTION
	●			FOUNDATION DESIGN			●		WALL-WALL CONNECTION
●				BALANCE OF STRUCTURE		●			WALL-ROOF CONNECTION
●				SHAPE OF PLAN		●			LIGHT WEIGHT WALLS
●				CENTER OF GRAVITY		●			LIGHT WEIGHT ROOF
●				RIGID WALLS		●			RING BEAM
	●			ROOF DESIGN			●		STRENGTH OF BLDG. MATERIALS
	●			PROJECTIONS & OVERHANGS				●	STRENGTH OF MORTAR
●				DOOR/WINDOW LOCATIONS		●			QUALITY OF WORKMANSHIP

RECOMMENDATIONS FOR IMPROVEMENTS	DET. REF. NO.	% CONST. COST	MAN-DAYS
Use stronger lashing in roofs and walls	5	1	.15
Keep walls to about 16-20 cm thickness	-	1	1.5
Embed bamboo posts at least 75 cm below ground level	-	.5	.5
Use intermediate timber columns in concrete footings and timber ring beams, sill plates	-	25	3-4
Use stone and cement mortar for foundation	-	35	3
Treat bamboo for insects and ground contact	-	10	1

AVERAGE TOTAL COST OF HOUSE Rs. 1000



HOUSE TYPE: Cut Mud Block

LOCATION: Gorakhpur, U.P.; N. Bihar

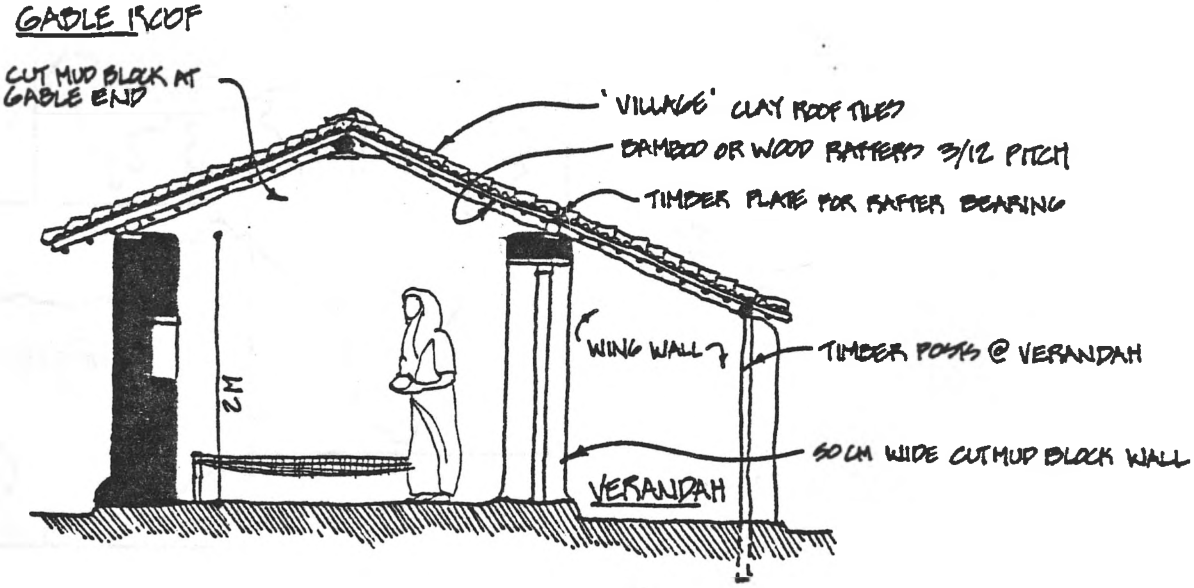
FOUNDATION: No foundation is constructed. The house usually rests on hardened, packed soil.

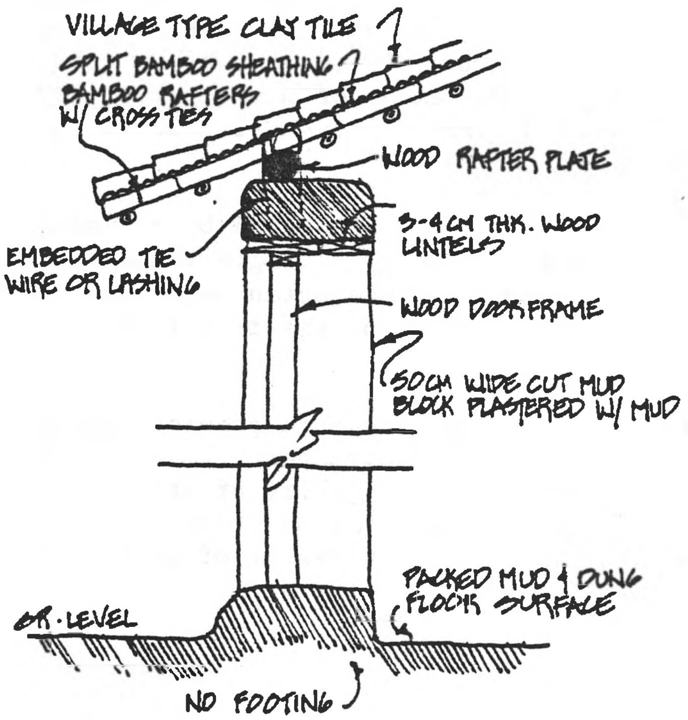
WALLS: Walls are formed by placing a compacted mud and soil mixture in successive lifts, then cutting it with a long knife or "kodal" (local hoe/shovel) into 50 cm. widths. No reinforcement is used. The exterior may be plastered with a dung/soil mixture. The base is typically 10-20 cm. wider to allow for erosion.

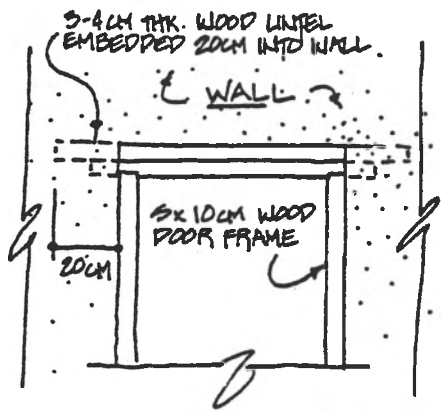
ROOF: The roof is made of tile or thatch supported by a timber frame. The frame is supported by a single ridge pole resting on the gable. A timber plate often rests on top of the walls to distribute the weight of the tile roof.

BEHAVIOR IN EARTHQUAKES: Cut mud houses suffered extensive damage in previous Bihar earthquakes. Gables and tile roofs have been particularly mentioned. Total collapse of the majority of structures of this type could be expected due to the lack of reinforcement in the walls and the high center of gravity.

BUILDING SECTION



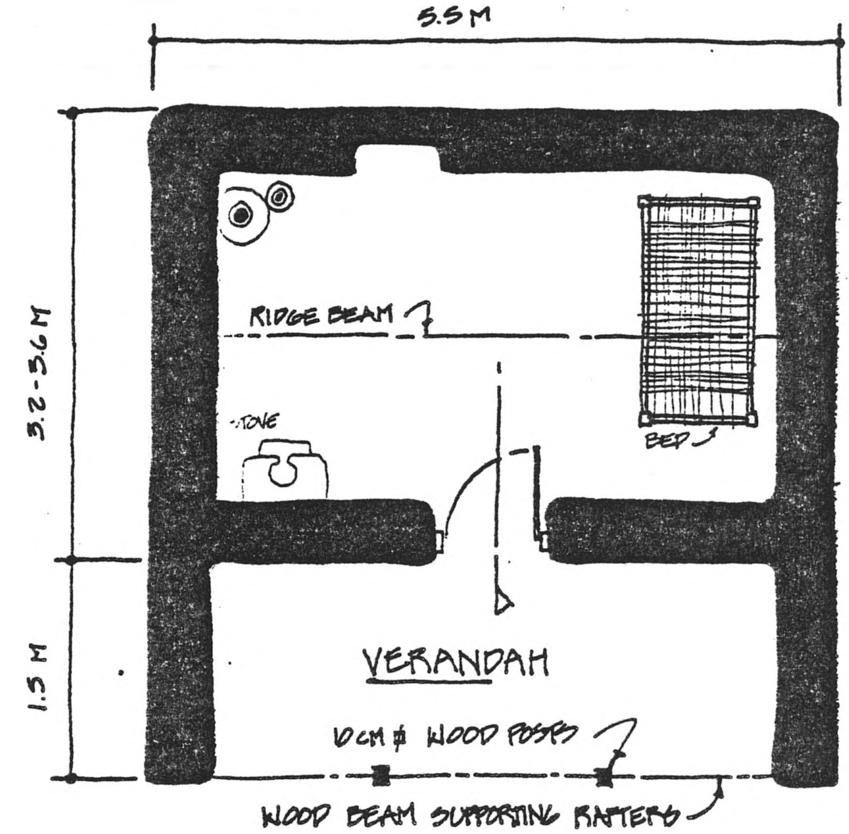




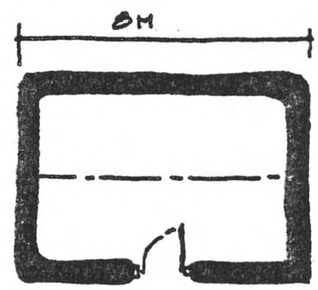
DETAIL OF DOOR LINTEL

TYPICAL WALL SECTION

TYPICAL PLAN



VARIATION

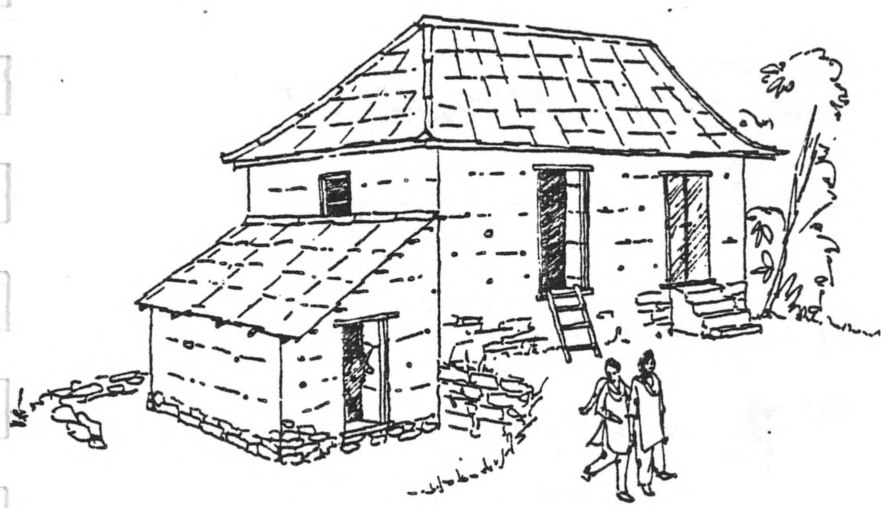


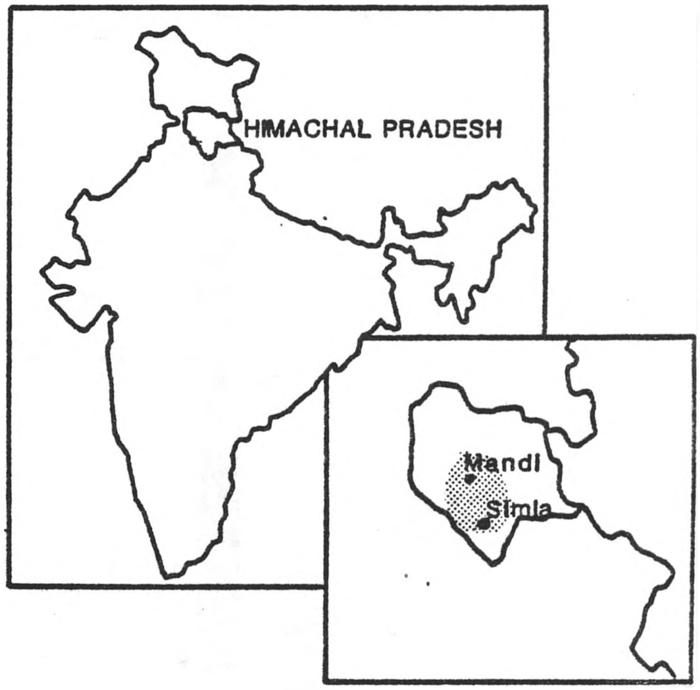
Seismic Resistance Evaluation

GOOD	FAIR	POOR	N/A		GOOD	FAIR	POOR	N/A	
	●			SITING	●				DOOR/WINDOW AREAS
●				SEPARATION BETWEEN BLDGS.			●		FOUNDATION-WALL CONNECTION
			●	FOUNDATION DESIGN				●	WALL-WALL CONNECTION
	●			BALANCE OF STRUCTURE			●		WALL-ROOF CONNECTION
	●			SHAPE OF PLAN			●		LIGHT WEIGHT WALLS
		●		CENTER OF GRAVITY			●		LIGHT WEIGHT ROOF
		●		RIGID WALLS			●		RING BEAM
		●		ROOF DESIGN			●		STRENGTH OF BLDG. MATERIALS
	●			PROJECTIONS & OVERHANGS				●	STRENGTH OF MORTAR
●				DOOR/WINDOW LOCATIONS			●		QUALITY OF WORKMANSHIP

RECOMMENDATIONS FOR IMPROVEMENTS	DET. REF. NO.	% CONST. COST	MAN-DAYS
Taper walls	6	-	-
Insert reinforcing L angle of bamboo or wood at regular interval of height of wall at corners and T junctions	7	5	2
Add X braces in roof plane	1	2	1

AVERAGE TOTAL COST OF HOUSE Rs. 750





HOUSING TYPE: Rammed Earth

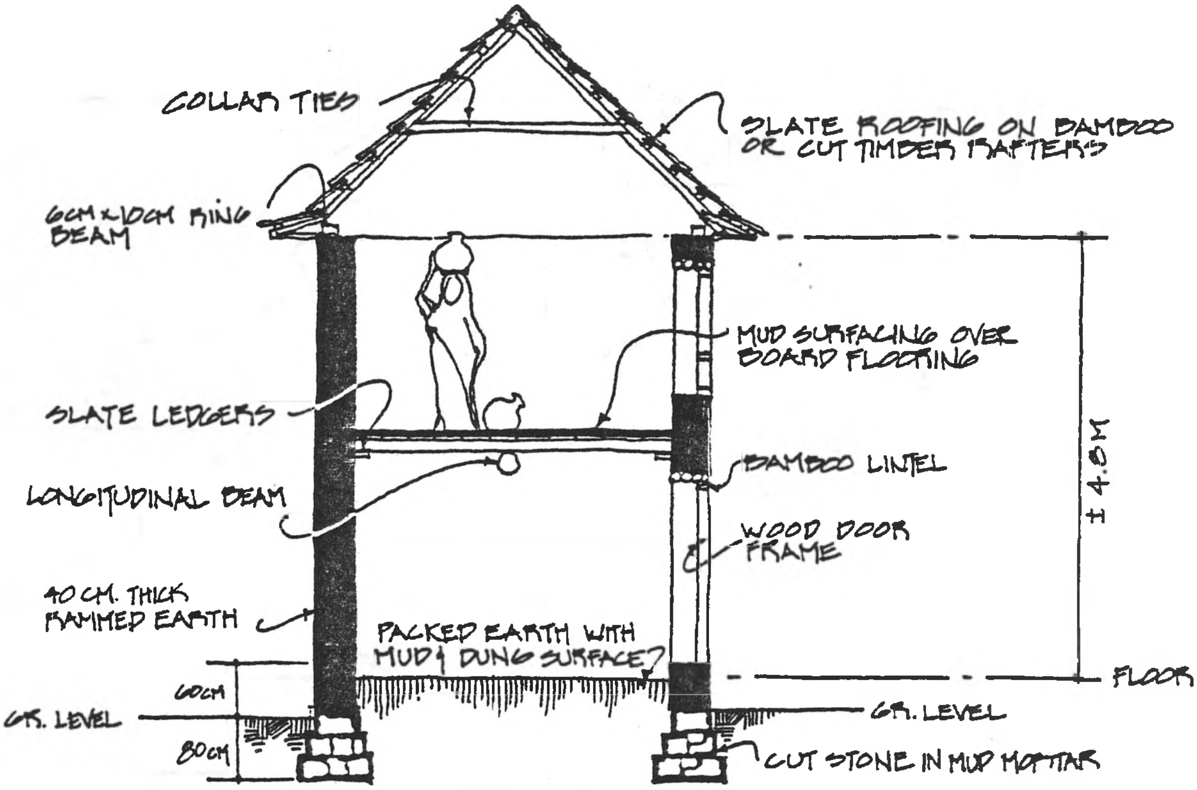
LOCATION: Central Himachal Pradesh

FOUNDATION: The foundation is 90 cm. by 150 cm. high shaped stone with mud mortar. The foundation forms a plinth to about 60 cm. above grade.

WALLS: Walls are 40 cm. thick, constructed of rammed earth. Wood forms with tie rods are filled with straw-reinforced mud; vertical additions of 25 cm. high are made each day. Two-story walls 5 meters high are most common; one-story structures are also found. Walls are finished with a mud plaster. The upper floor is supported on a central longitudinal beam and on slate ledgers embedded in the mud wall. Floor joists are 8 cm. by 8 cm. sawn lumber. The floor boards are covered with mud.

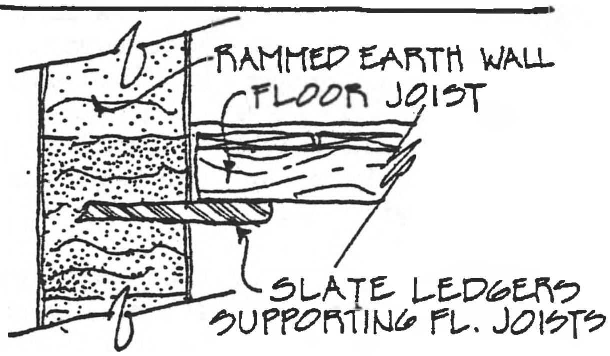
ROOF: Newer roofs are hipped configuration, made with slate; older roofs are gabled using slate or thatch. Hipped roofs rest on top of the wall ring beams. Rafters are typically bamboo or sawn wood with ties. Metal straps are used as nailing ties at rafters. Purlins are 2 cm. x 7 cm. at 40 cm. on center. Slate is either nailed to the purlins or attached with clips.

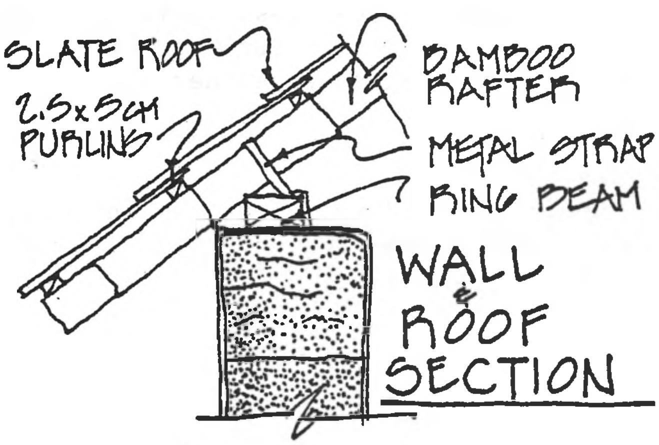
BEHAVIOR IN EARTHQUAKES: Typical damage included wide diagonal cracks in walls and separation of walls along construction joints. Complete collapse of walls occurred often.



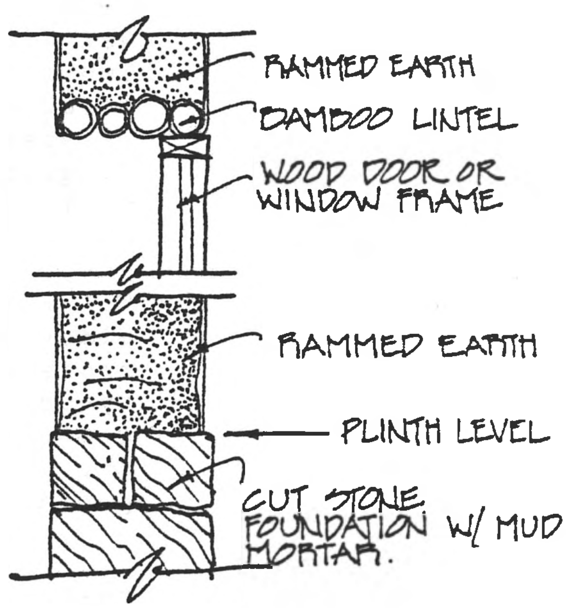
BUILDING SECTION

WALL SECTION @ FLOOR

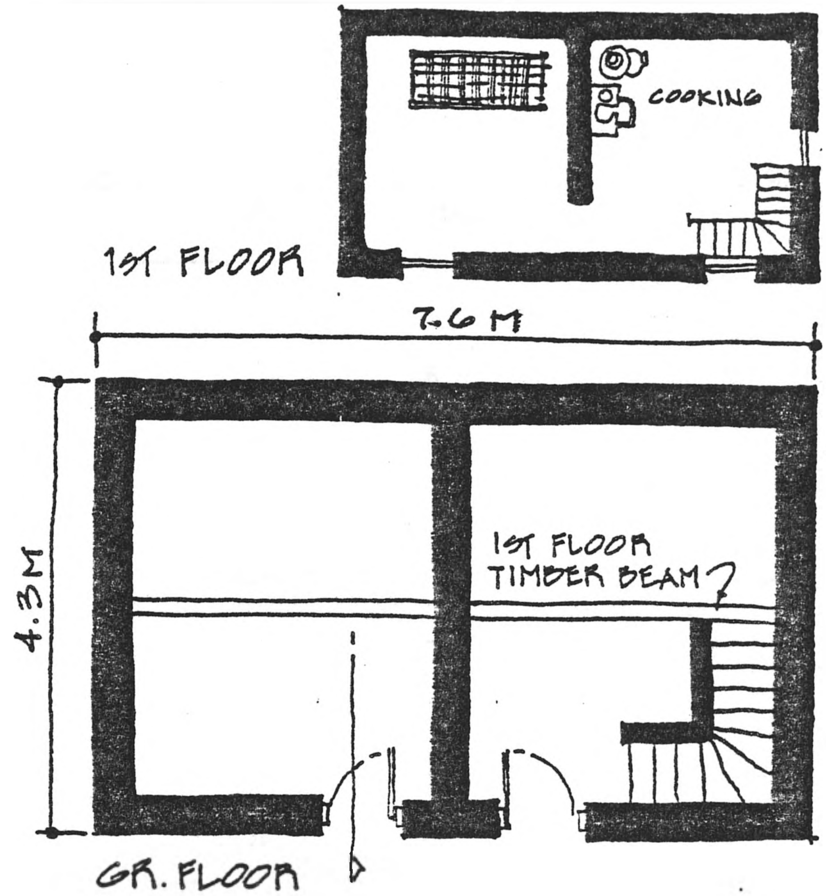




WALL & ROOF SECTION

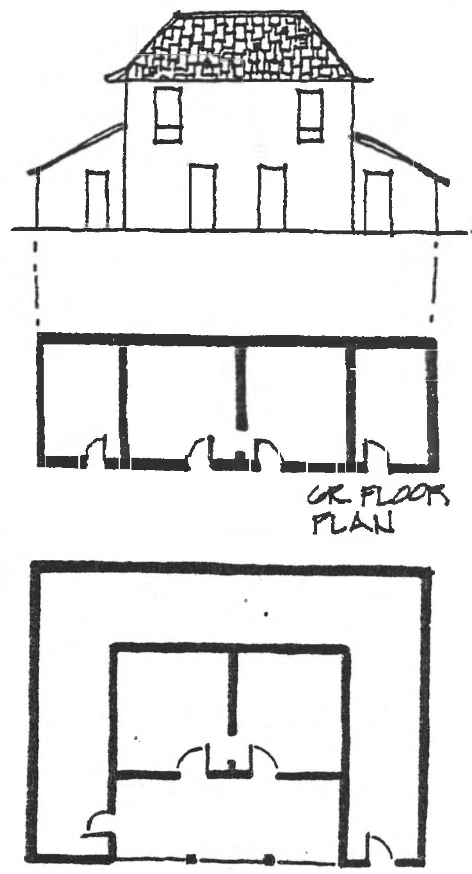


LINTEL DETAIL & WALL/PLINTH JOINT



TYPICAL PLAN

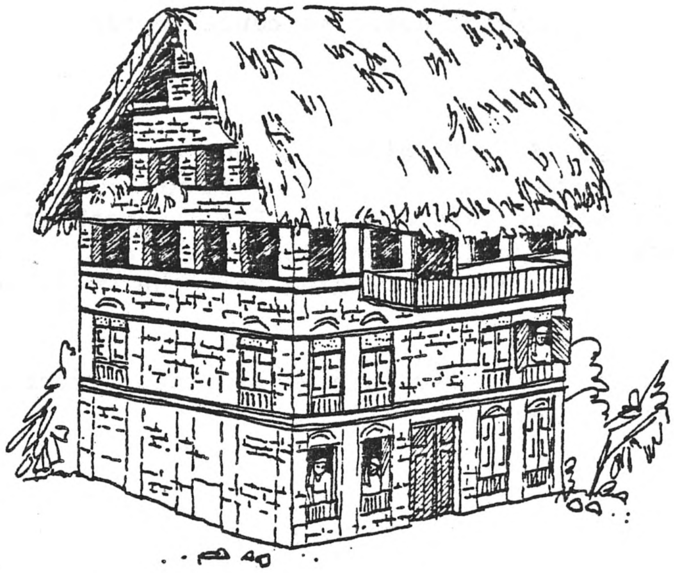
VARIATIONS



Seismic Resistance Evaluation									
GOOD	FAIR	POOR	N/A		GOOD	FAIR	POOR	N/A	
●				SITING		●			DOOR/WINDOW AREAS
	●			SEPARATION BETWEEN BLDGS.		●			FOUNDATION-WALL CONNECTION
	●			FOUNDATION DESIGN			●		WALL-WALL CONNECTION
		●		BALANCE OF STRUCTURE		●			WALL-ROOF CONNECTION
●				SHAPE OF PLAN			●		LIGHT WEIGHT WALLS
	●	●		CENTER OF GRAVITY			●		LIGHT WEIGHT ROOF
		●		RIGID WALLS		●			RING BEAM
●				ROOF DESIGN			●		STRENGTH OF BLDG. MATERIALS
	●			PROJECTIONS & OVERHANGS				●	STRENGTH OF MORTAR
		●		DOOR/WINDOW LOCATIONS		●			QUALITY OF WORKMANSHIP

RECOMMENDATIONS FOR IMPROVEMENTS	DET. REF. NO.	% CONST. COST	MAN-DAYS
Separate additions and L-shaped wings of house with crush joints	-	-	-
Locate doors away from corners and provide adequate separation between openings in the wall	8	-	-
Instead of using stone lodging to support floor joists, extend joists into the wall	9	1	-
Build one-story structures only	-	reduces	-
Use cement mortar in foundation	-	5	1
Use stronger wood lintels	-	1	.5
Use bamboo reinforcing within walls	-	1	2
Decrease wall thickness	-	reduces	-
Install knee braces	-	.2	.5
Insert reinforcing L angle of bamboo or wood at regular interval of height of wall at corners and T junctions	7	.5	2
Taper walls	6	-	-

AVERAGE TOTAL COST OF HOUSE Rs. 16,000-20,000



HOUSE TYPE: Multi-Story Mud Brick (Dhajji-Dewar, Chun and Tuk)

LOCATION: Kashmir

FOUNDATION: A random rubble stone foundation is used with mud or lime mortar. Cut and squared stones are used at the corners. The foundation extends about 60 cm. below grade to 90 cm. above grade.

WALLS: The structural system consists of sun dried brick or fired brick piers about 60 x 60 cm., 1.5 to 2 m. on center. The spaces between the piers are filled in with windows and doors, brick or stone. The spaces at the first floor are frequently completely filled in but are not bonded to the piers. Walls are one-, two- or three-story, the latter being very common. Each story varies in height from 2.5 to 3 m. Floors are sawn timber joists bearing on a ring beam and also capped by a second ring beam. Floor joists are carried by a central longitudinal beam and secondary beam at the third points. The beams bear on wood plates at outside walls and on intermediate walls.

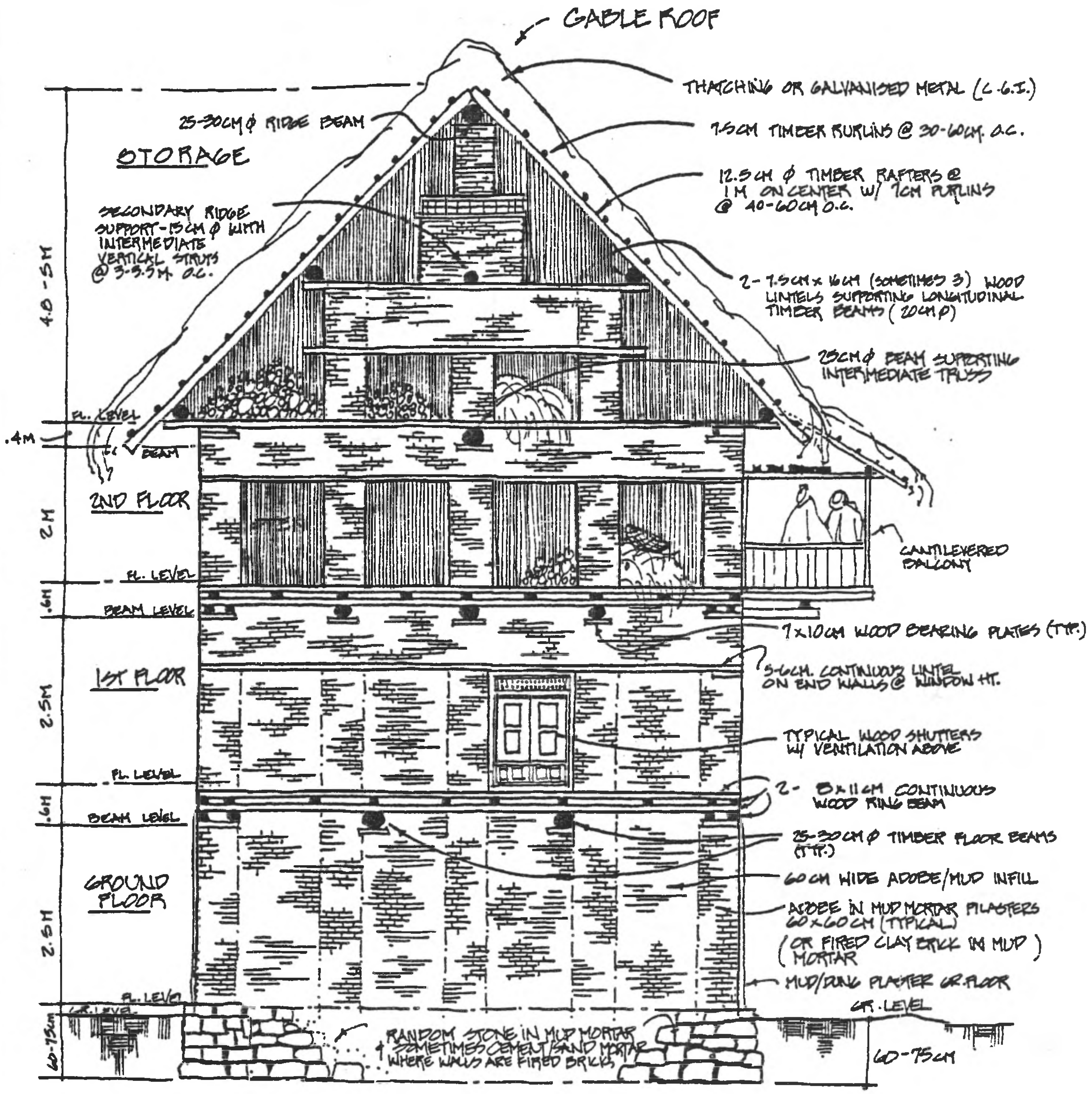
ROOF: Older houses have thatched gable roofs; newer roofs are more likely to be C.G.I. as a gable or hipped roof. Many newer roofs have large dormers, sometimes on all four sides.

The roof framing is constructed of heavy timber ridge poles and secondary beams with joists (8 x 10 cm.) at 1 m. on center. Purlins are used as required for thatch or C.G.I. With older roofs, ridge poles bear on very tall, unbraced brick piers. With newer roofs, framing is heavy timber with complicated framing at concentrated loading points.

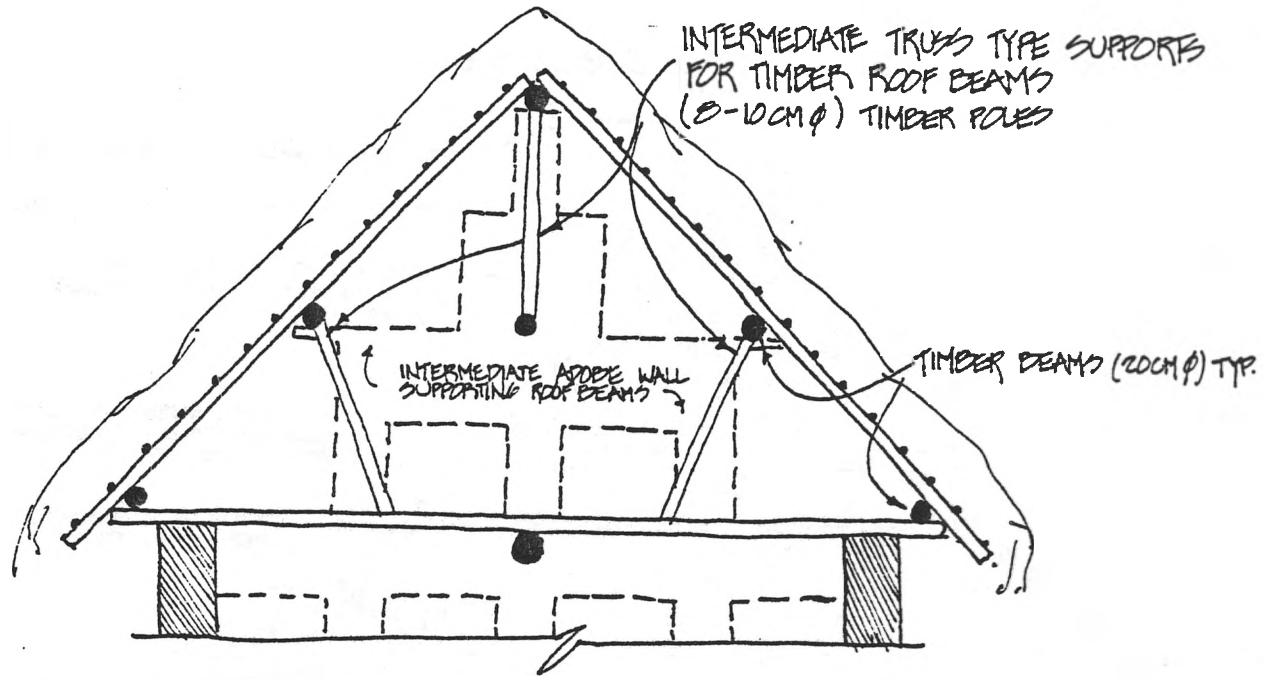
BEHAVIOR IN EARTHQUAKES:

The severe problem of roof failure is due to ridge poles supported on isolated brick piers which experience vigorous shaking during earthquakes. The strength of the piers in the lateral direction is negligible, and they are liable to collapse first, bringing down the whole roof with them.

The ring beams at floor levels have provided structural resistance to earthquakes.

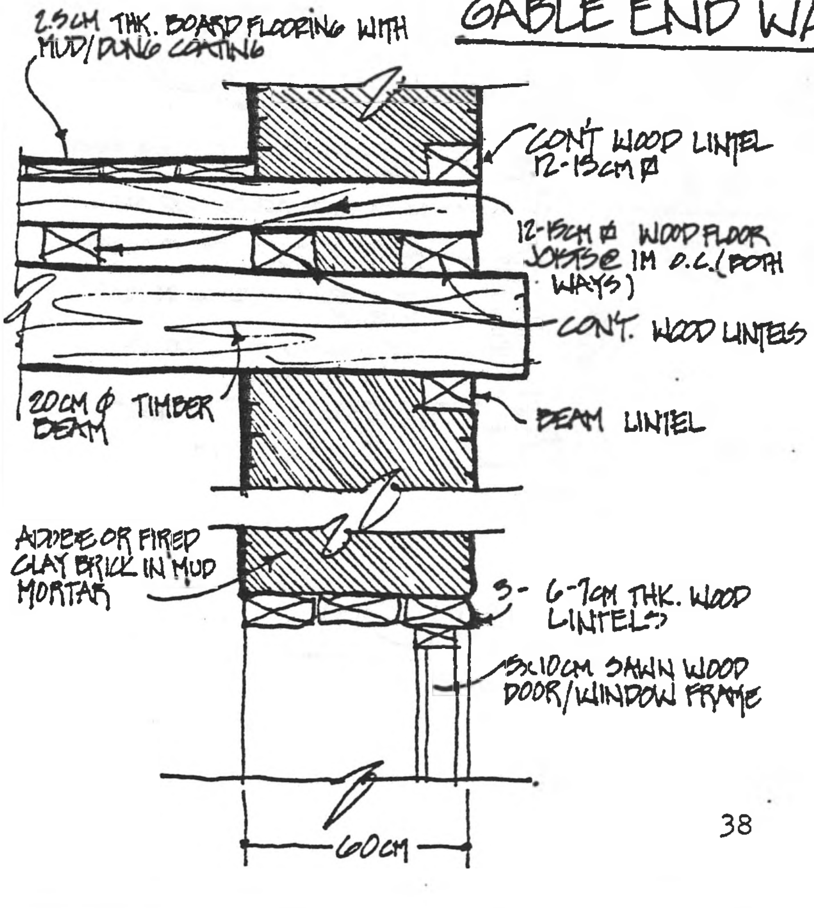


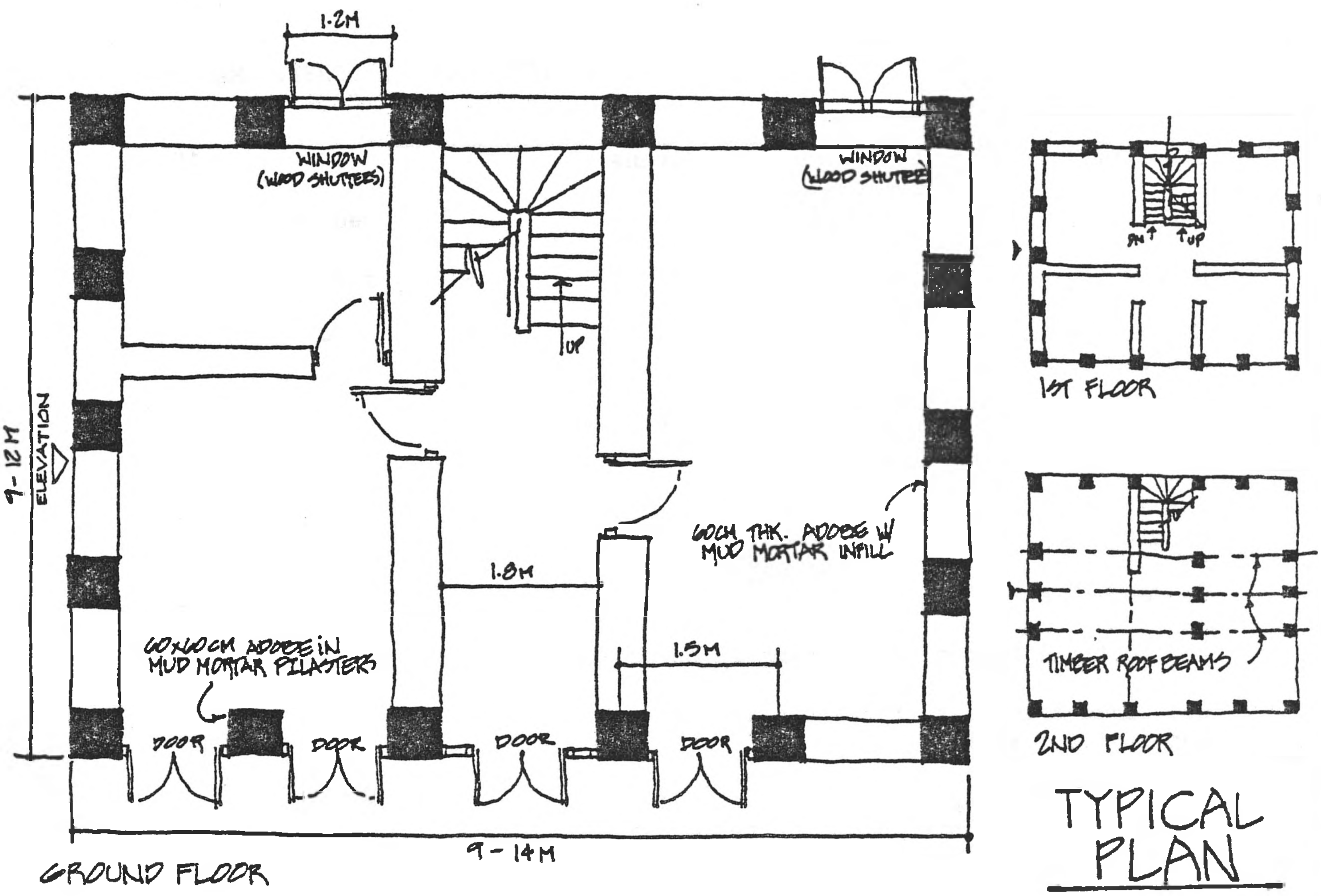
TYPICAL SIDE ELEVATION



SECTION OF ROOF SUPPORT SYSTEMS

TYPICAL SECTION - FLOOR SUPPORT @ GABLE END WALL

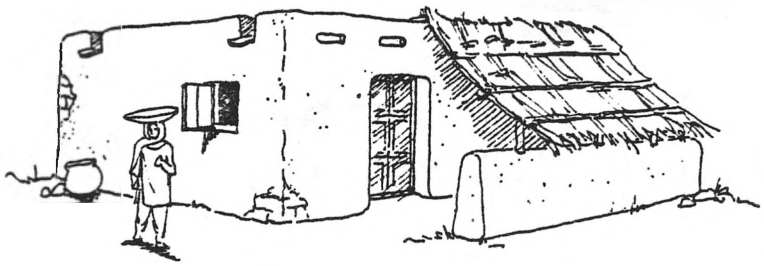




Seismic Resistance Evaluation									
GOOD	FAIR	POOR	N/A		GOOD	FAIR	POOR	N/A	
●				SITING			●		DOOR/WINDOW AREAS
	●			SEPARATION BETWEEN BLDGS.		●			FOUNDATION-WALL CONNECTION
	●			FOUNDATION DESIGN			●		WALL-WALL CONNECTION
●				BALANCE OF STRUCTURE		●			WALL-ROOF CONNECTION
●				SHAPE OF PLAN			●		LIGHT WEIGHT WALLS
		●		CENTER OF GRAVITY	●				LIGHT WEIGHT ROOF
		●		RIGID WALLS	●				RING BEAM
		●		ROOF DESIGN			●		STRENGTH OF BLDG. MATERIALS
	●			PROJECTIONS & OVERHANGS			●		STRENGTH OF MORTAR
		●		DOOR/WINDOW LOCATIONS	●				QUALITY OF WORKMANSHIP

RECOMMENDATIONS FOR IMPROVEMENTS	DET. REF. NO.	% CONST. COST	MAN-DAYS
Structurally tie infill panels to columns	-	.1	10
Reduce projections and overhangs	-	reduces	-
Reduce size and area of windows	8	reduces	-
Maintain minimum distance from corners for windows and doors	8	-	-
Ensure that wood runners at floor levels are assembled to form ring beam	-	.1	2
Where used, construct gable end walls of timber framing, eliminate masonry at gable end	-	.1	4
Use cement mortar in foundation	-	.1	4
Use vertical bamboo reinforcing in columns	-	.01	7
Use fired brick masonry with cement mortar and vertical steel	-	180	-
Insert reinforcing L angle of bamboo or wood at regular interval of height of wall at corners and T junctions	7	1	14
Add X braces in roof plane	1	.5	2

AVERAGE TOTAL COST OF HOUSE Rs. 3000,000



HOUSE TYPE: One-Story Mud

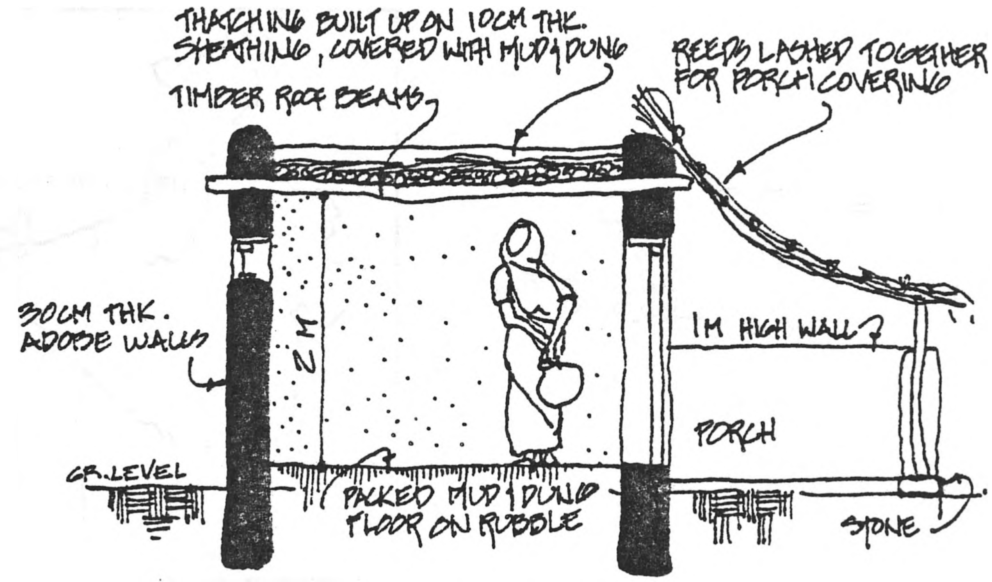
LOCATION: Roorkee, U.P.

FOUNDATION: The foundation is 30 cm. wide x 40-50 cm. deep mud block in mud mortar.

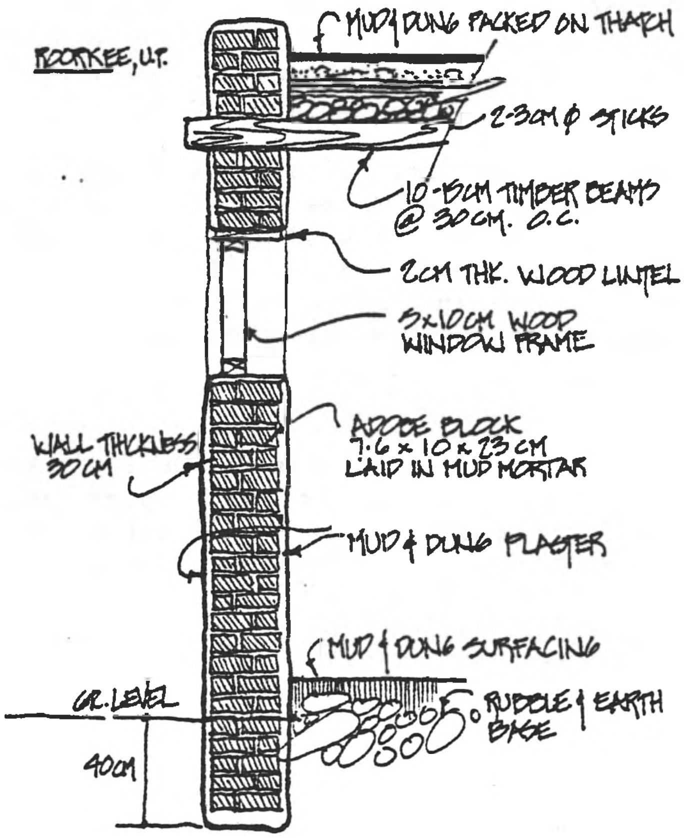
WALLS: Walls are 30 cm. wide mud block in mud mortar (3 block widths), plastered with a mud and dung mixture inside and out and using 2.5 cm. thick wood lintels embedded 15-20 cm. into the walls. The roof beams penetrate the walls at 30 cm. spacing. Walls are generally 2 m. in height.

ROOFS: Many mud houses near Roorkee have flat roofs constructed of 10-15 cm. round timber beams at 30 cm. on center, with a layer of 2-3 cm. round wood and a solid sheathing of small twigs and branches. Thatch is laid on the sheathing about 10 cm. thick and covered with a mud and dung coating. Handmade "country" tile and thatched gable-type roofs are also found in Roorkee.

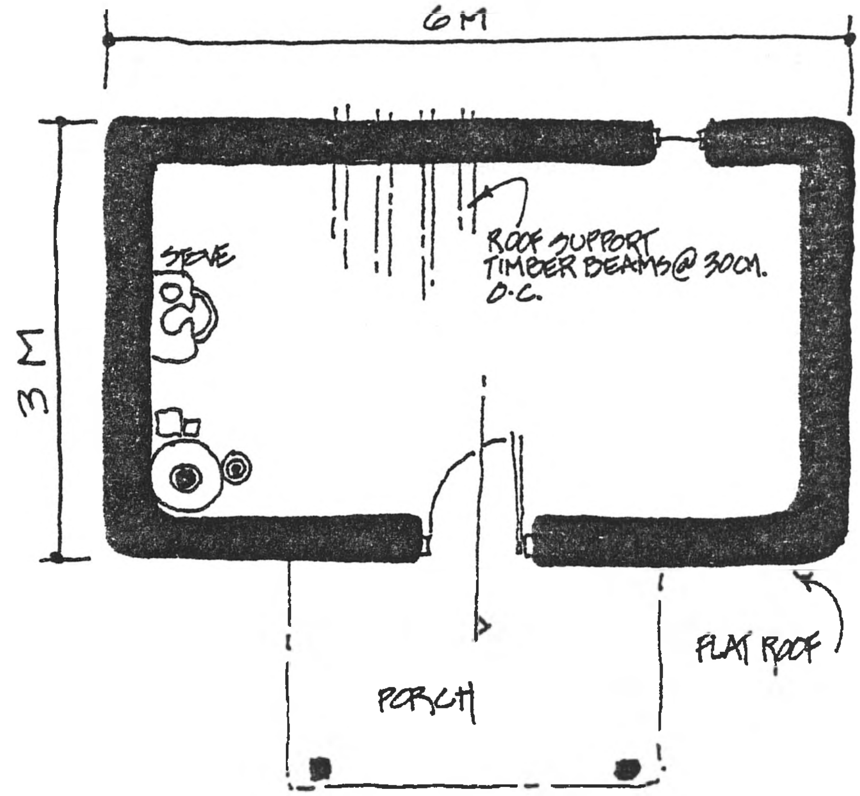
BEHAVIOR IN EARTHQUAKES: Earthquake damage included wide diagonal cracks, cracks along mortar joints in walls, and separation of walls along construction joints. When a wall fails, the bearing and anchorage of the roof structure is destroyed, causing it to collapse.



BUILDING SECTION



WALL SECTION

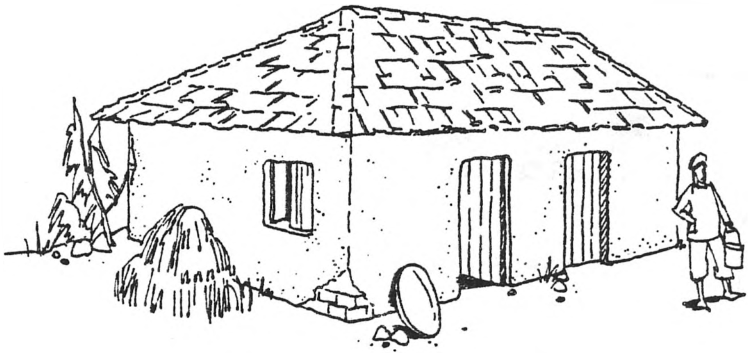


TYPICAL PLAN

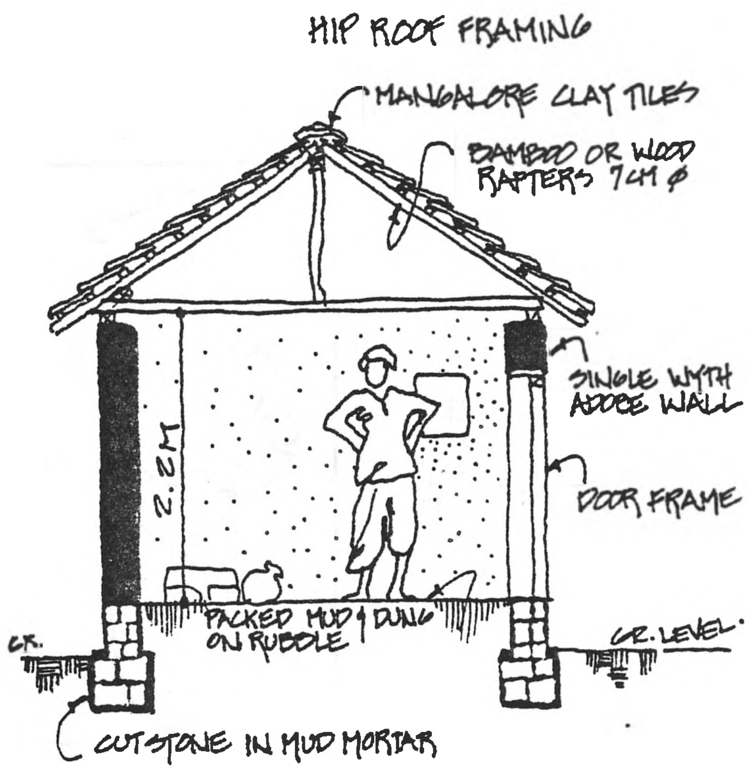
Seismic Resistance Evaluation									
GOOD	FAIR	POOR	N/A		GOOD	FAIR	POOR	N/A	
●				SITING	●				DOOR/WINDOW AREAS
	●			SEPARATION BETWEEN BLDGS.			●		FOUNDATION-WALL CONNECTION
	●			FOUNDATION DESIGN		●			WALL-WALL CONNECTION
●				BALANCE OF STRUCTURE		●			WALL-ROOF CONNECTION
●				SHAPE OF PLAN			●		LIGHT WEIGHT WALLS
	●			CENTER OF GRAVITY			●		LIGHT WEIGHT ROOF
		●		RIGID WALLS		●			RING BEAM
		●		ROOF DESIGN			●		STRENGTH OF BLDG. MATERIALS
●				PROJECTIONS & OVERHANGS			●		STRENGTH OF MORTAR
	●			DOOR/WINDOW LOCATIONS		●			QUALITY OF WORKMANSHIP

RECOMMENDATIONS FOR IMPROVEMENTS	DET. REF. NO.	% CONST. COST	MAN-DAYS
Maintain minimum distance from corners for door and windows	8	-	-
Anchor ring beam to wall at 1 m intervals	-	1	.5
Where used, construct gable ends in wood or bamboo	-	8	3
Use heavier wood for lintels	-	5	.5
Use stone or fired brick in foundation, set in cement/sand or lime/clay mortar	-	60	6
Use fired brick masonry with cement mortar, either as walls or pilasters at corners or 3 m on center	-	300	8-10
Use timber posts embeded in walls to support roof	10	20	2
Use angle braces in walls	7	10	1
Use no flat roofs, use lightweight roofs	-	40	-
Add X braces in roof plane	2	10	1.5

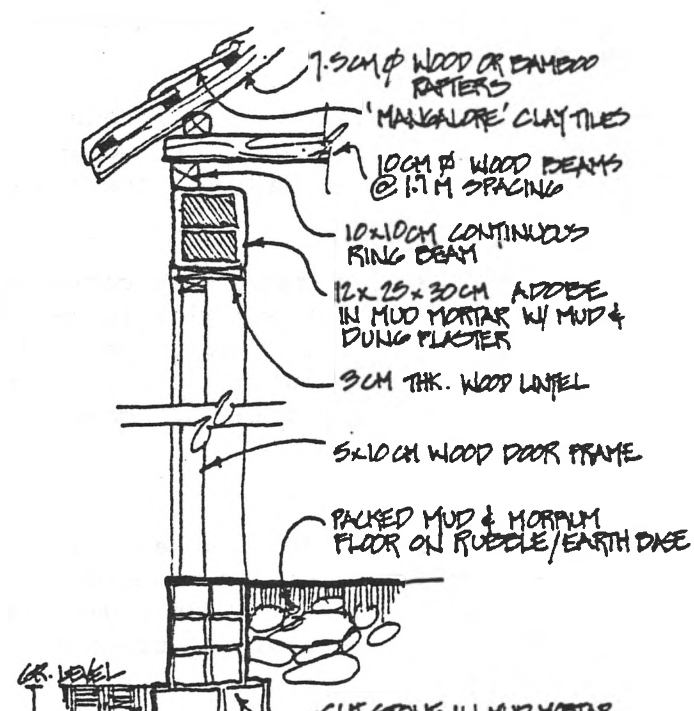
AVERAGE TOTAL COST OF HOUSE Rs. 900-2,000



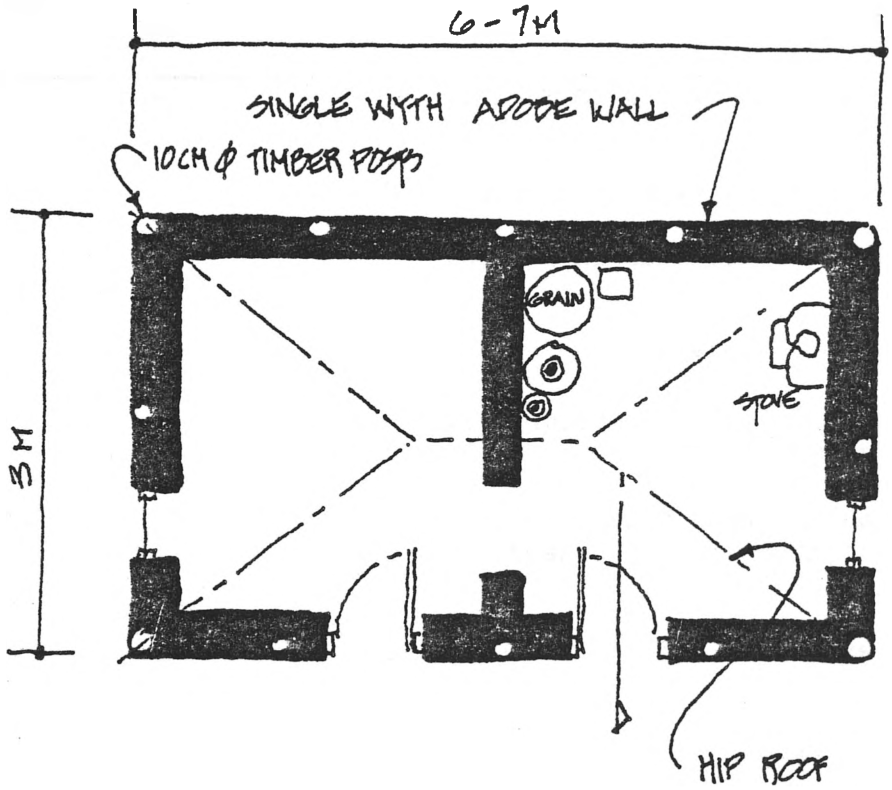
HOUSE TYPE:	One-Story Mud
LOCATION:	Chiplun, Maharashtra
FOUNDATION:	The foundation is made of stone in mud mortar 60 cm. wide x 50 cm. deep below ground and 45 cm. wide x 25 cm. in height above ground, forming a plinth filled with rubble and packed earth.
WALLS:	Walls are single-width mud block 25-28 cm. wide in mud mortar, plastered with a mud and dung mixture, and are typically 2.2 m. in height. The mud block is 12 x 25 x 30 cm.
ROOFS:	Hipped roofs are typically constructed of 7.5 cm. round wood or bamboo rafters with 10 cm. square wood tie beams at 1.7 m. spacing, resting on a 10 cm. square continous wood ring beam. Roofing materials are handmade "village" or "country" clay tiles or "mangalore" manufactured clay roof tiles.
BEHAVIOR IN EARTHQUAKES:	Damage included wide diagonal cracks, cracks along mortar joints in walls, and separation of walls along construction joints. When a wall fails, the bearing and anchorage of the roof structure is destroyed, causing it to collapse.



BUILDING SECTION



WALL SECTION



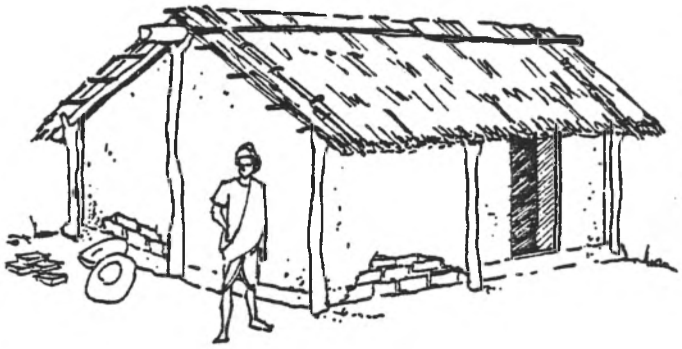
TYPICAL PLAN

Seismic Resistance Evaluation

GOOD	FAIR	POOR	N/A		GOOD	FAIR	POOR	N/A	
●				SITING	●				DOOR/WINDOW AREAS
	●			SEPARATION BETWEEN BLDGS.			●		FOUNDATION-WALL CONNECTION
	●			FOUNDATION DESIGN		●			WALL-WALL CONNECTION
●				BALANCE OF STRUCTURE		●			WALL-ROOF CONNECTION
●				SHAPE OF PLAN			●		LIGHT WEIGHT WALLS
	●			CENTER OF GRAVITY			●		LIGHT WEIGHT ROOF
		●		RIGID WALLS		●			RING BEAM
	●			ROOF DESIGN			●		STRENGTH OF BLDG. MATERIALS
●				PROJECTIONS & OVERHANGS			●		STRENGTH OF MORTAR
	●			DOOR/WINDOW LOCATIONS		●			QUALITY OF WORKMANSHIP

RECOMMENDATIONS FOR IMPROVEMENTS	DET. REF. NO.	% CONST. COST	MAN-DAYS
Maintain minimum distance from corners for door and windows	8	-	-
Anchor ring beam to wall at 1 m intervals	-	1	.5
Where used, construct gable ends in wood or bamboo	-	8	3
Use heavier wood for lintels	-	5	.5
Use stone or fired brick in foundation, set in cement/sand or lime/clay mortar	-	15	4
Use fired brick masonry with cement mortar, either as walls or pilasters at corners or 3 m on center	-	300	8-10
Use timber posts embedd in walls to support roof	10	20	2
Use angle braces in walls	7	5	1
Use lightweight roofs (CGI sheets, thatching)	-	60	-
Install knee braces	-	-	-
Add X braces in roof plane	2	10	1.5

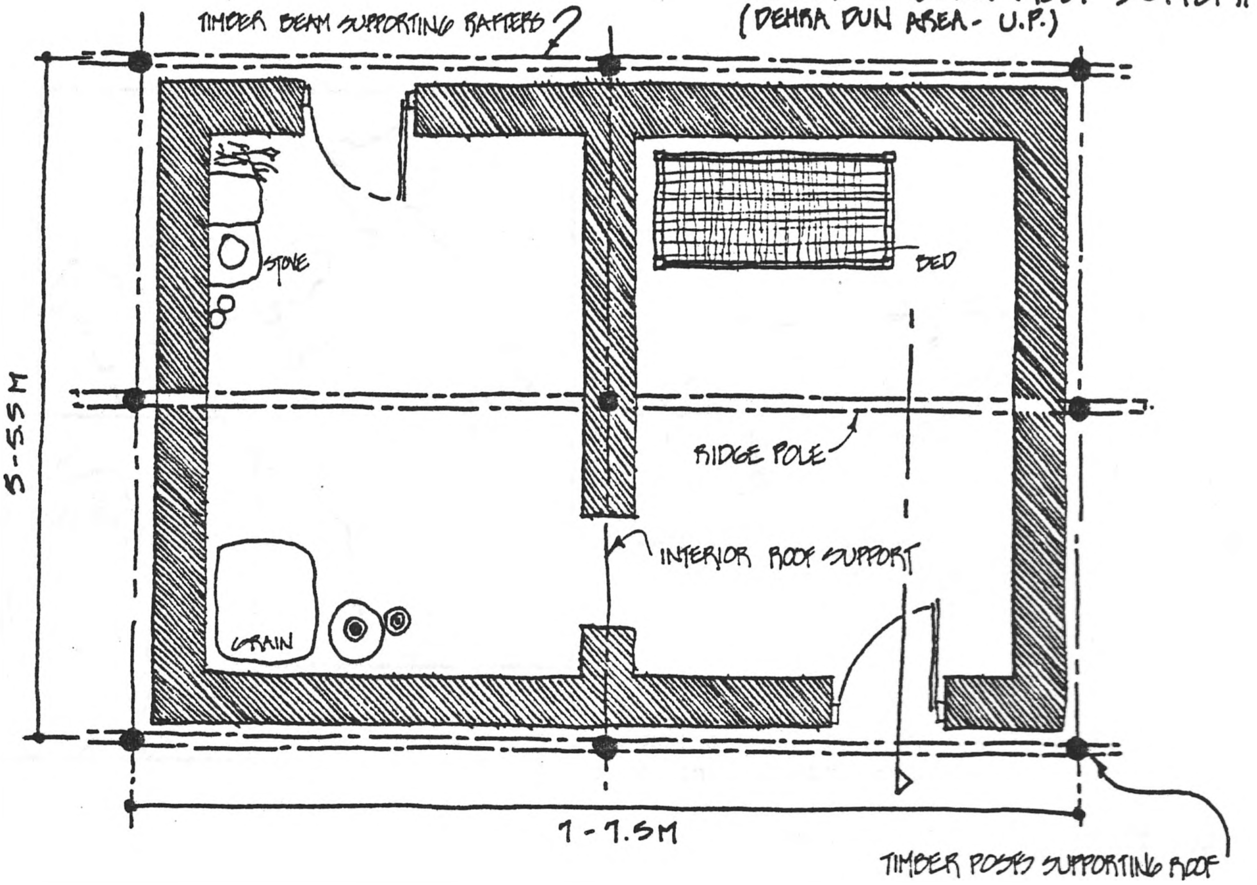
AVERAGE TOTAL COST OF HOUSE Rs. 2,800

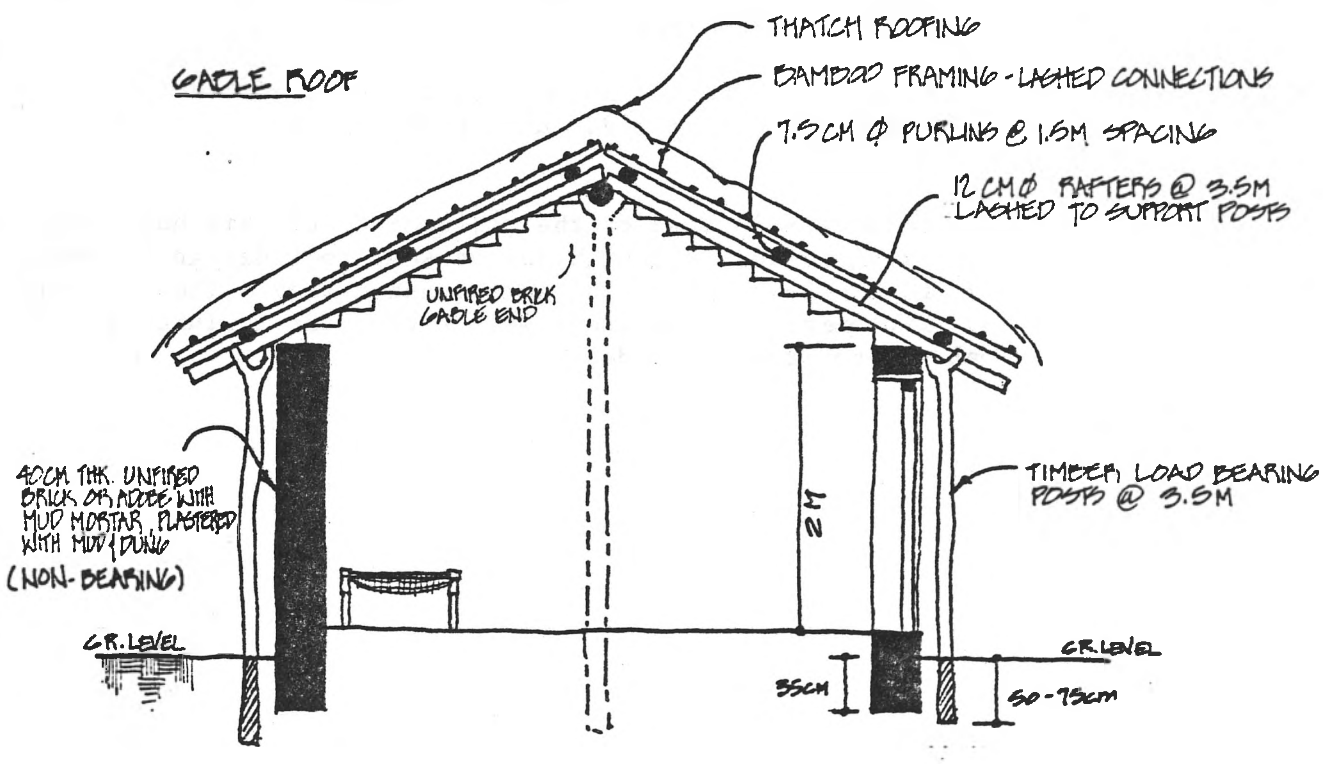


HOUSE TYPE:	Unfired Clay Brick with Independent Roof
LOCATION:	Dehra Dun, U.P.
FOUNDATION:	The foundation consists of unfired (sometimes fired) clay bricks set in the ground 50 to 75 cm. with a mud mortar.
WALLS:	The walls are made of unfired, pressed and formed clay bricks with mud mortar.
ROOF:	The roof is thatch on a wood frame supported by timber load-bearing posts placed outside the walls.
BEHAVIOR IN EARTHQUAKES:	No data was located on the performance of this house type in earthquakes, although the unusual roof design may be a local adaptation to the earthquake hazard. The building should perform moderately well except for failures at the gables and around the doors.

TYPICAL PLAN

UNFIRED BRICK WITH TIMBER POST AND BEAM ROOF SUPPORT
(DEHRA DUN AREA - U.P.)





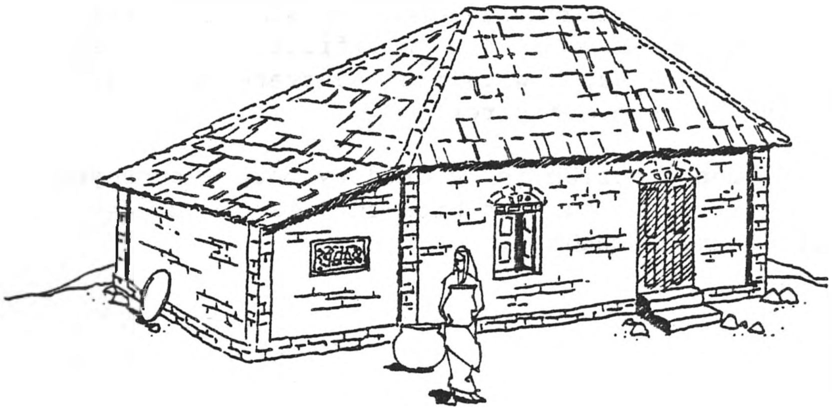
TYPICAL BUILDING SECTION

Seismic Resistance Evaluation

GOOD	FAIR	POOR	N/A		GOOD	FAIR	POOR	N/A	
●				SITING	●				DOOR/WINDOW AREAS
●				SEPARATION BETWEEN BLDGS.			●		FOUNDATION-WALL CONNECTION
		●		FOUNDATION DESIGN			●		WALL-WALL CONNECTION
	●			BALANCE OF STRUCTURE			●		WALL-ROOF CONNECTION
●				SHAPE OF PLAN		●			LIGHT WEIGHT WALLS
	●			CENTER OF GRAVITY	●				LIGHT WEIGHT ROOF
		●		RIGID WALLS			●		RING BEAM
	●			ROOF DESIGN		●			STRENGTH OF BLDG. MATERIALS
●				PROJECTIONS & OVERHANGS			●		STRENGTH OF MORTAR
●				DOOR/WINDOW LOCATIONS			●		QUALITY OF WORKMANSHIP

RECOMMENDATIONS FOR IMPROVEMENTS	DET. REF. NO.	% CONST. COST	MAN-DAYS
Use pilasters in walls	-	100	10
Introduce standard brick masonry techniques	-	-	-
Set posts 75 cm minimum into ground	-	2	2
Add X braces in plane of roof	1	5	1.5
Add X braces in post frame	3	5	3
Construct gable ends of wood or bamboo framing instead of mud or brick	-	15	-

AVERAGE TOTAL COST OF HOUSE Rs. 3,000-4,000



HOUSE TYPE: Fired Brick, Pilasters with Infill

LOCATION: Chiplun, Maharashtra

FOUNDATION: The foundation is 56 cm. x 45 cm. fired brick in mud or mud with pozzolanic mortar, forming a 33 cm. wide x 25 cm. height plinth filled with rubble and packed earth for the floor base. Foundations are continuous.

WALLS: Walls consist of 33 x 33 cm. pilasters at 3 m. spacing, 2.2 m. in height, with 30 cm. wide unfired brick in mud mortar or wattle-and-daub infill, plastered inside and out with a mud mixture. A continuous 8 x 10 cm. wood ring beam is tied to the walls by embedded wire at 1.5 m. intervals or by steel pins embedded in the pilasters. 2 - 2.5 cm. thick wood lintels are used at openings.

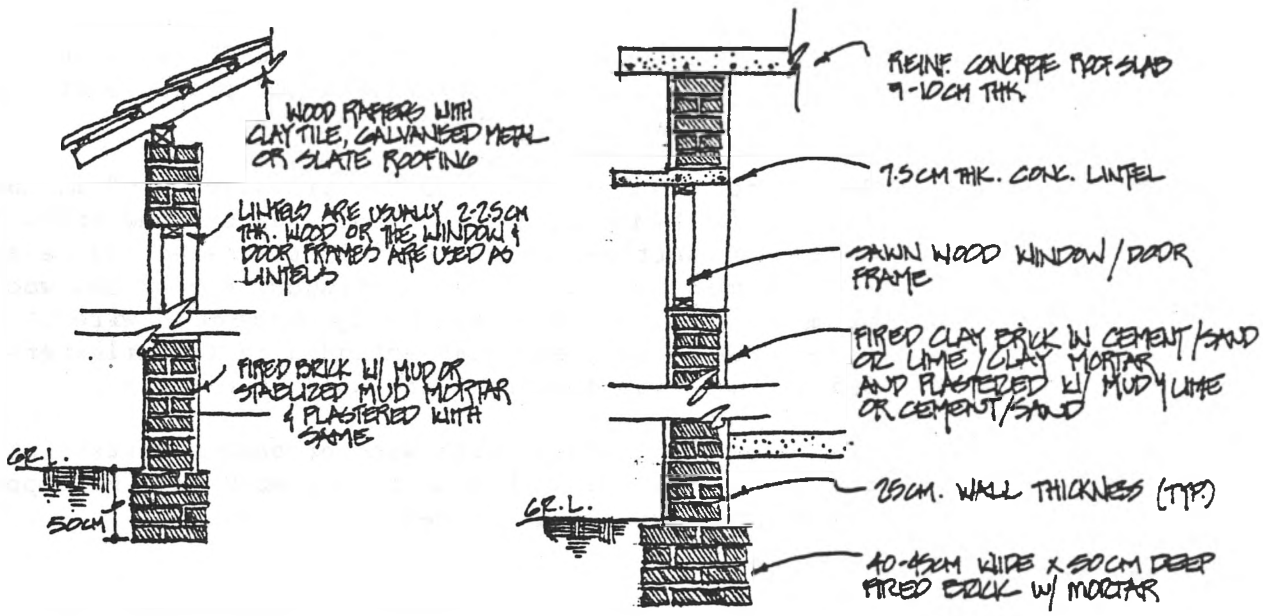
ROOF: The roof is hipped, with wood or bamboo rafters at 40-50 cm. on center and 2.5 x 5 cm. wood purlins supporting "mangalore"-type manufactured clay tiles.

BEHAVIOR IN EARTHQUAKES: Fired brick houses have performed relatively well in past earthquakes. First class brick with cement mortar has encountered little damage. Second and third class brick with mud mortar has suffered more cracking. In one earthquake, most damage to brick houses occurred at the ornamental work, roof balustrades, balconies, chajjas, verandahs and porches with a series of independent pillars.

FIRED BRICK,
ALL REGIONS:

Fired clay brick construction (a house design similar to the above but with brick bearing walls and no pilaster skeleton) can be found in varying forms throughout each region. House forms normally follow similar designs prevalent in the area with some modifications. Often, newer houses are constructed with flat concrete roofs in a style popular in the more urban regions.

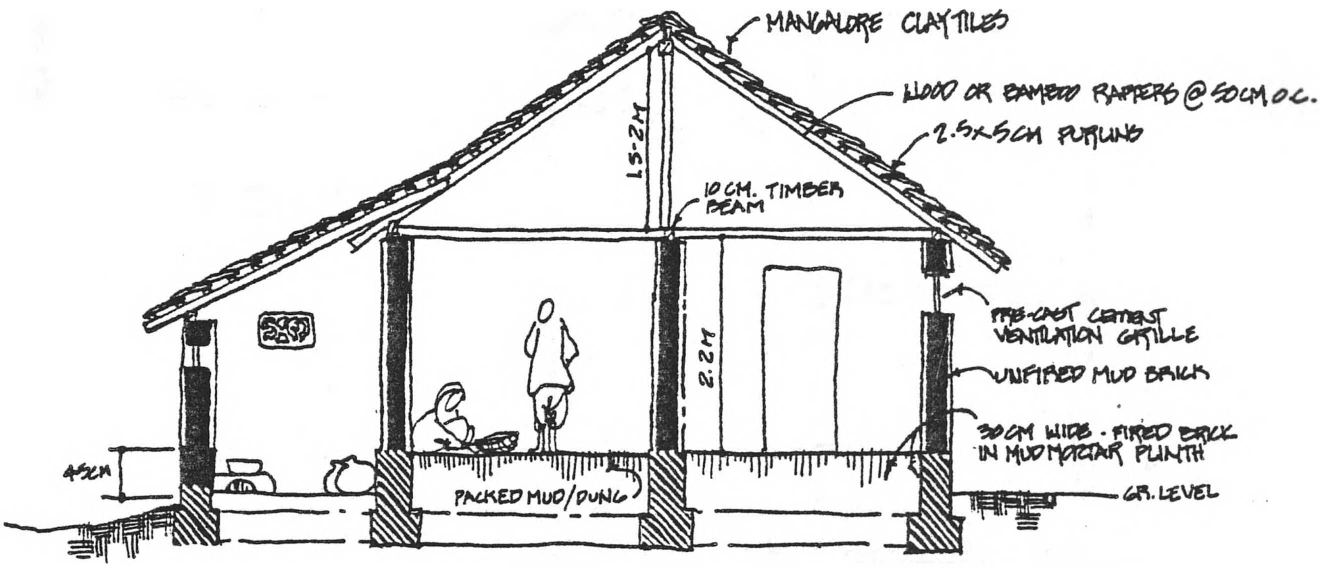
This method of construction is favored by people surveyed in the various regions, but its high cost is out of range for the average rural household.

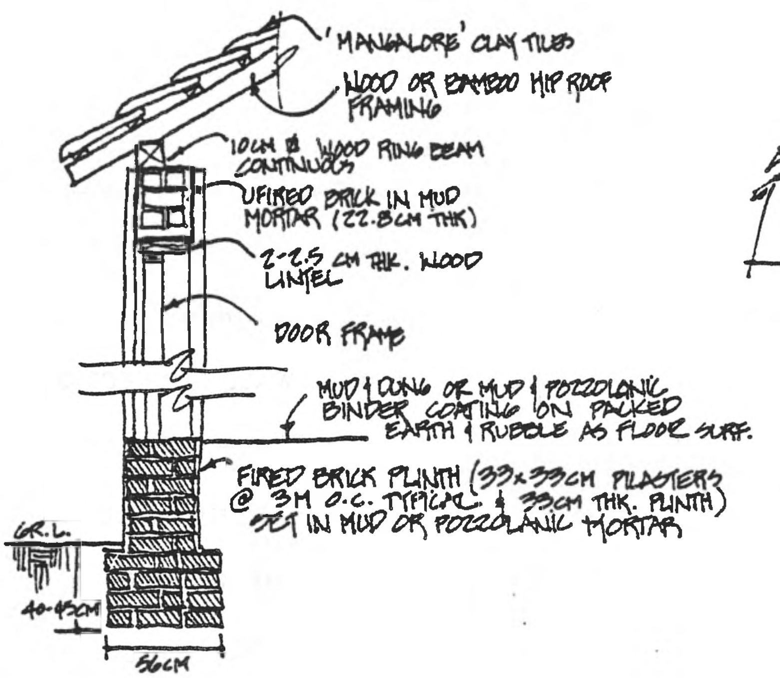


TYPICAL WALL SECTIONS

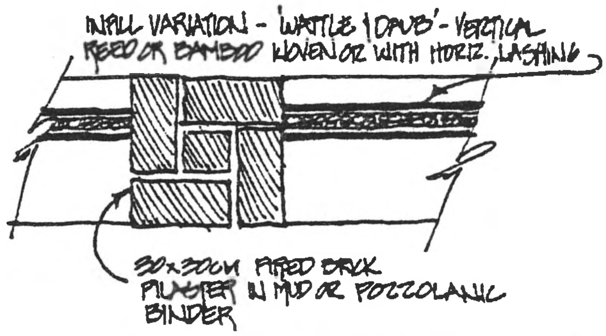
BUILDING SECTION

HIP ROOF



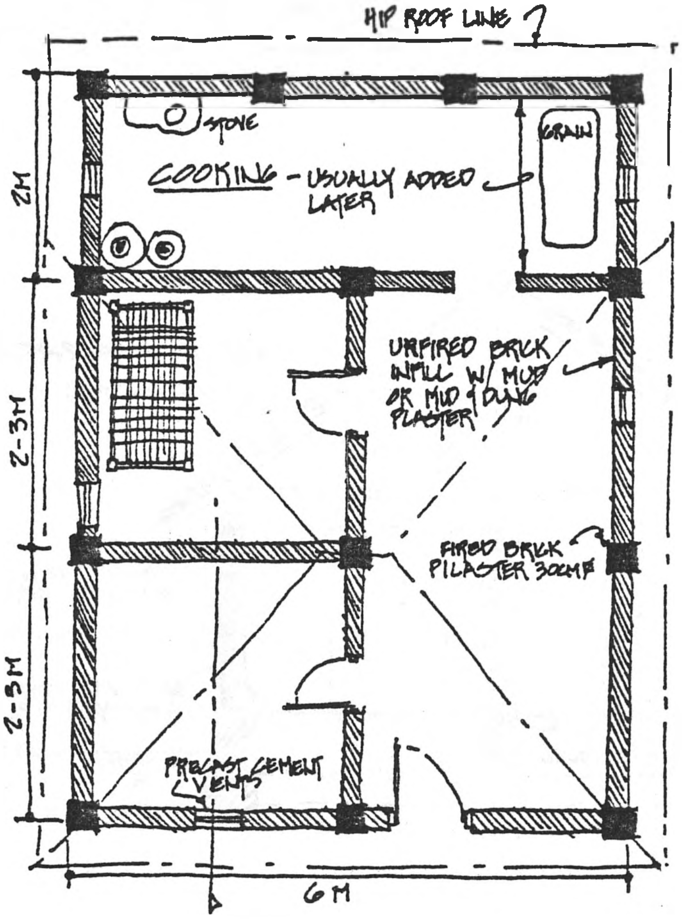


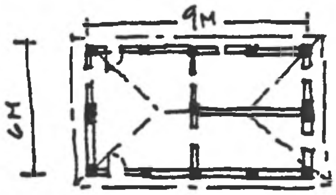
TYPICAL WALL SECTION



SECTION OF PILASTER

TYPICAL PLAN



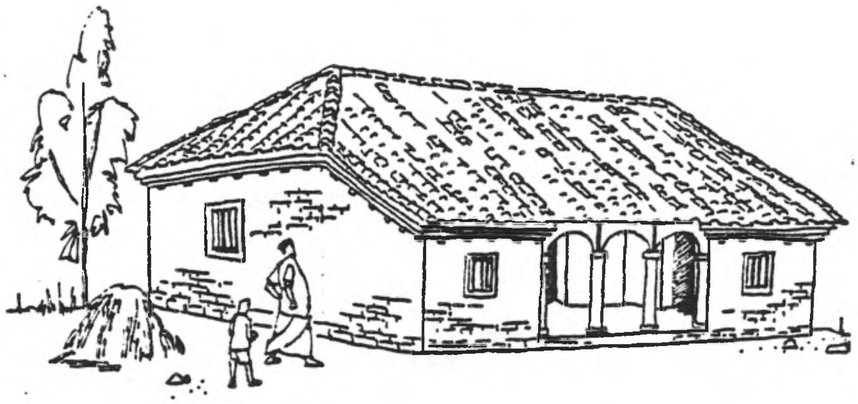


VARIATION

Seismic Resistance Evaluation									
GOOD	FAIR	POOR	N/A		GOOD	FAIR	POOR	N/A	
		●		SITING	●				DOOR/WINDOW AREAS
	●			SEPARATION BETWEEN BLDGS.			●		FOUNDATION-WALL CONNECTION
	●			FOUNDATION DESIGN			●		WALL-WALL CONNECTION
●				BALANCE OF STRUCTURE		●			WALL-ROOF CONNECTION
	●			SHAPE OF PLAN		●			LIGHT WEIGHT WALLS
●				CENTER OF GRAVITY			●		LIGHT WEIGHT ROOF
	●			RIGID WALLS		●			RING BEAM
	●			ROOF DESIGN			●		STRENGTH OF BLDG. MATERIALS
	●			PROJECTIONS & OVERHANGS			●		STRENGTH OF MORTAR
●				DOOR/WINDOW LOCATIONS		●			QUALITY OF WORKMANSHIP

RECOMMENDATIONS FOR IMPROVEMENTS	DET. REF. NO.	% CONST. COST	MAN-DAYS
Use stepped foundation	11	1	2
Place steel rod in each pilaster	-	1	1
Tie unfired brick infill walls into pilasters	12	1	4
Tie ring beam to pilasters	-	.5	1
Use heavier wood lintels at openings (with a depth greater than its width)	-	.4	.5
Nail rafters to ring beam securely	-	.2	.3
Use cement mortar in foundations and pilasters	-	2	2
Construct infill walls of brick with cement mortar	-	150	-
Notch rafters to provide secure seat on ring beam	-	.5	2

AVERAGE TOTAL COST OF HOUSE Rs. 20,000-30,000



HOUSE TYPE: Fired/Unfired Clay Brick

LOCATION: Darbhanga, N. Bihar

FOUNDATION: The foundation consists of fired clay brick in mud mortar, 68 cm. wide x 50-60 cm. below ground level. The plinth is built to 15-25 cm. above grade (typically) and filled with rubble and packed earth.

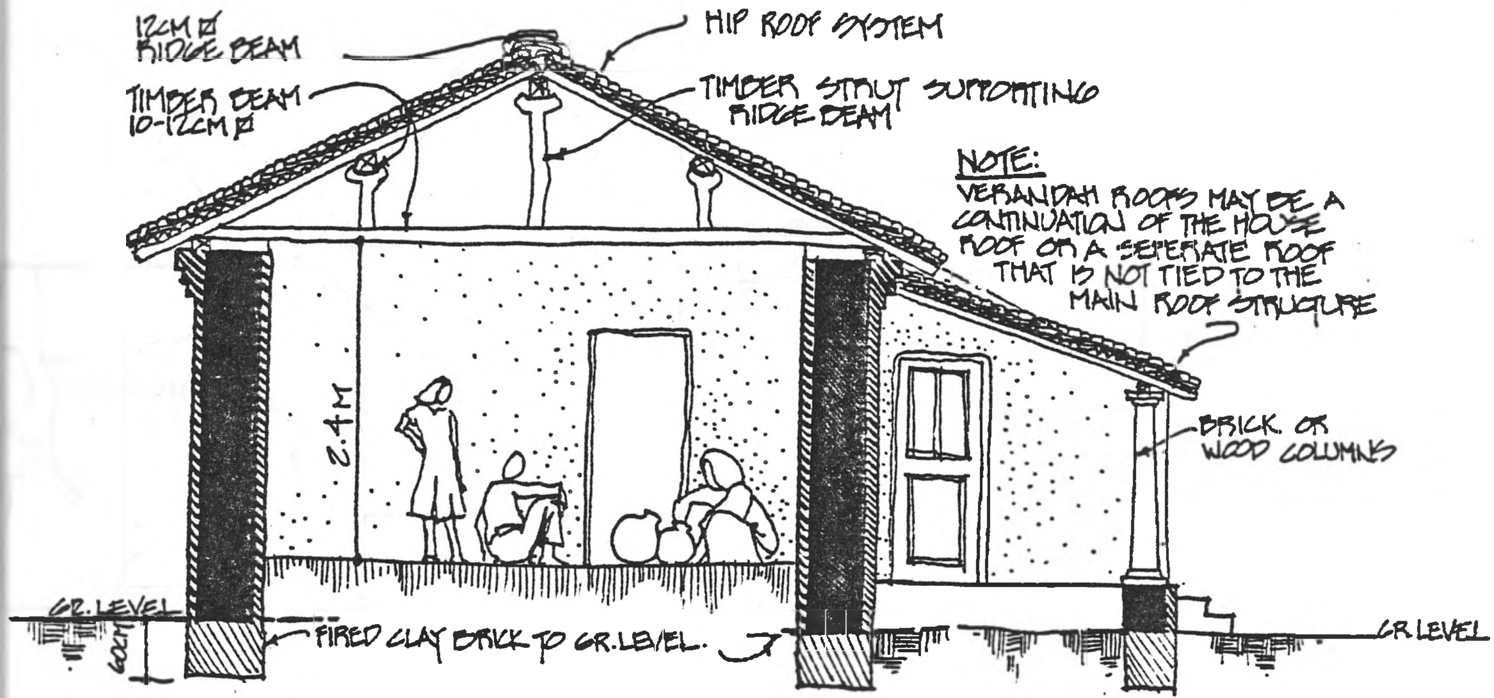
WALLS: Typical wall compositions include: (1) an unfired brick "core" wall in mud mortar 30 cm. wide with a fired brick veneer inside and out in mud mortar and plastered inside and out with a mud and dung mixture (total wall thickness is 60-70 cm.); (2) 30 cm. wide unfired brick in mud mortar plastered on both sides with a mud and dung mixture; (3) 30 cm. wide unfired brick with fired brick veneer on the outside in mud mortar, plastered inside with a mud and dung mixture (total wall thickness is 40-45 cm.).

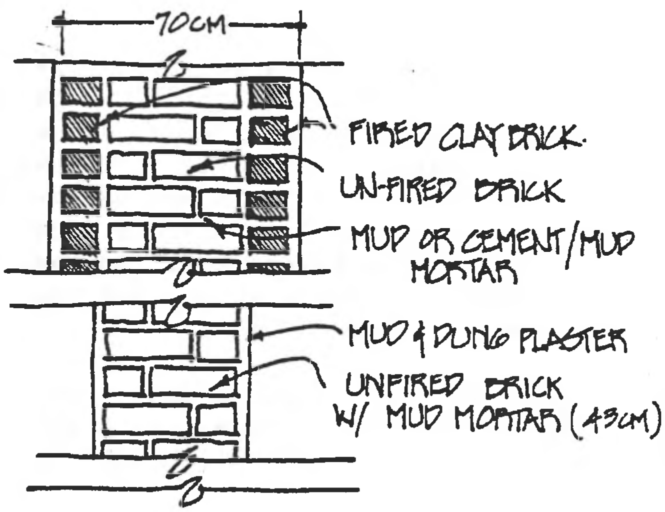
Many houses have a "stepped out" brick cornice when fired brick veneer is used. Most wall constructions use 5 cm. thick wood lintels over door and window frames embedded in the wall 15-20 cm.

ROOF: Roofs are predominantly hipped, constructed of wood or bamboo rafters at 25 cm. on center. 2.5 cm. thick sawn wood slats are nailed to the rafters as sheathing where wood rafters are used; split bamboo sheathing is used with bamboo rafters. Locally-made clay roof tiles are laid on the sheathing using a clay mortar.

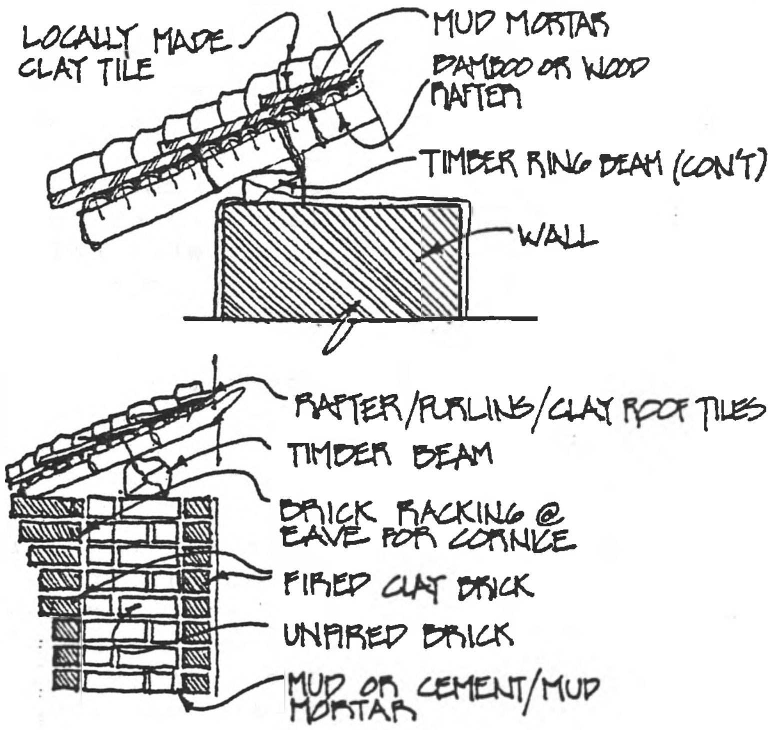
BUILDING SECTION

SECTION OF TILE ROOFING

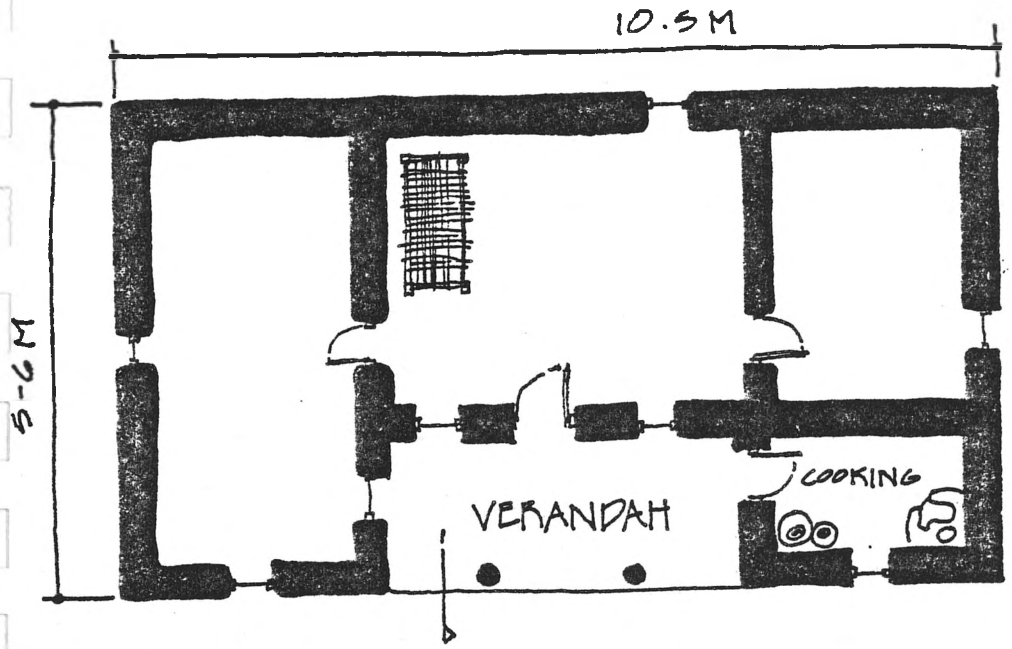




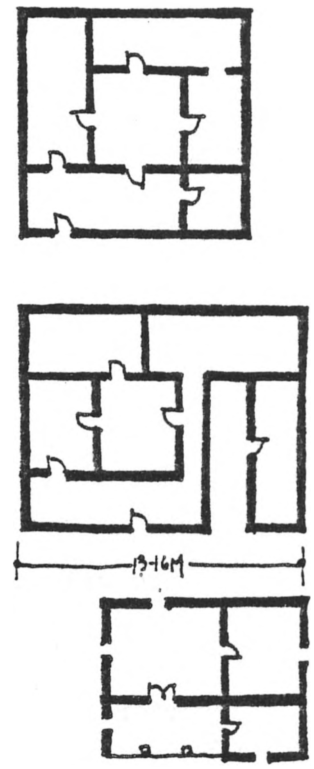
TYPICAL WALL SECTIONS



TYPICAL ROOF/WALL SECTION



TYPICAL PLAN



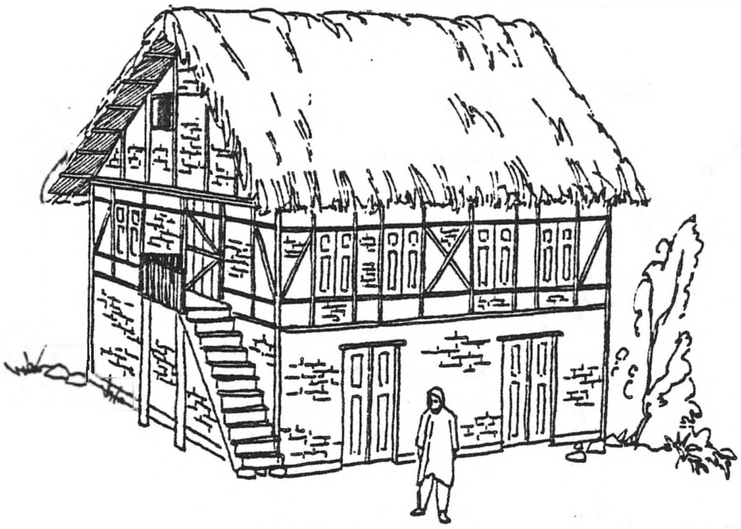
VARIATIONS

Seismic Resistance Evaluation

GOOD	FAIR	POOR	N/A		GOOD	FAIR	POOR	N/A	
●				SITING		●			DOOR/WINDOW AREAS
●				SEPARATION BETWEEN BLDGS.		●			FOUNDATION-WALL CONNECTION
	●			FOUNDATION DESIGN			●		WALL-WALL CONNECTION
	●			BALANCE OF STRUCTURE			●		WALL-ROOF CONNECTION
●				SHAPE OF PLAN			●		LIGHT WEIGHT WALLS
		●		CENTER OF GRAVITY			●		LIGHT WEIGHT ROOF
		●		RIGID WALLS			●		RING BEAM
		●		ROOF DESIGN		●			STRENGTH OF BLDG. MATERIALS
		●		PROJECTIONS & OVERHANGS			●		STRENGTH OF MORTAR
	●			DOOR/WINDOW LOCATIONS			●		QUALITY OF WORKMANSHIP

RECOMMENDATIONS FOR IMPROVEMENTS	DET. REF. NO.	% CONST. COST	MAN-DAYS
Use cement in foundation construction and steps	-	2	3
Reduce height of walls	-	reduces	
Install adequate ring beam connected to top of wall	-	3	1
Use improved X bracing in roof framing	1	.75	1.5
Tie/nail struts to rafters	-	.25	2
Use lightweight roofing (CGI sheets)	-	.15	-
Reinforce wall-to-wall connections	13	3	1.25
Provide wall-to-roof connections	14	3	3
Use cement mortar in wall connections	-	2	-
Insert reinforcing L angle of bamboo or wood at regular interval of height of wall at corners and T junctions	7	3	3
Improve masonry construction techniques	-	-	3-6

AVERAGE TOTAL COST OF HOUSE Rs. 30,000



HOUSE TYPE: Nog

LOCATION: Kashmir and Simla, H.P.

FOUNDATION: The foundation is constructed of random rubble stone, with 20-30 cm. of it extending above grade.

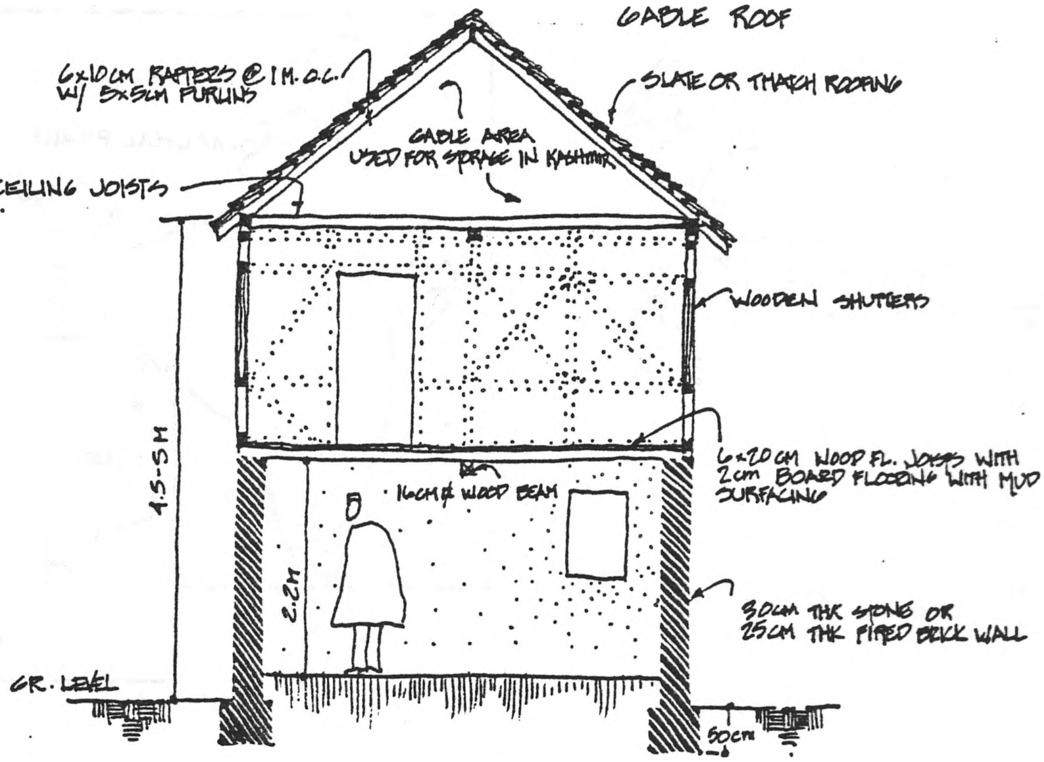
WALLS: Walls have heavy timber framing with vertical members approximately 1 m. on center. Typically, alternate bays include diagonal bracing. All timbers are approximately 10 x 10 cm. The framing is infilled with fired or unfired brick, called nogging. Most houses are two-story, although older houses have three and occasionally four stories. The top plate of the wall functions as a ring beam at floor levels and at the roof line.

ROOF: Older houses have thatch or clay tile roofs. Newer houses have C.G.I. sheets on gable frames, usually with large-size dormers. The framing is heavy timber with some truss triangulation.

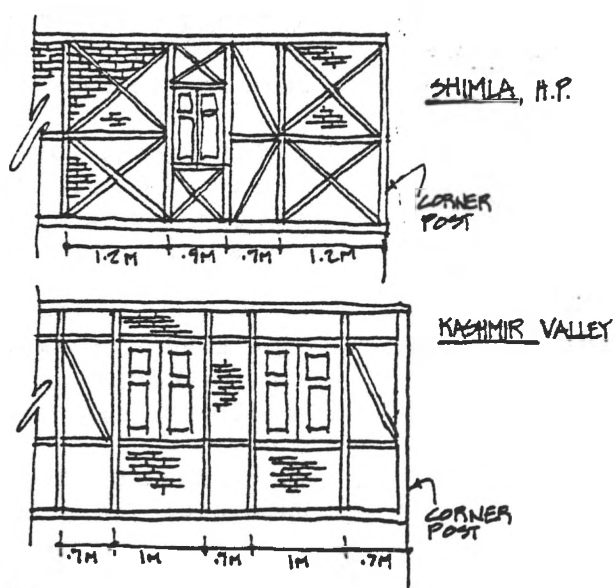
BEHAVIOR IN EARTHQUAKES: The timber frame of nog construction has behaved well in earthquakes. Infill walls of brick work in mud mortar developed cracks and separated from the frame work.

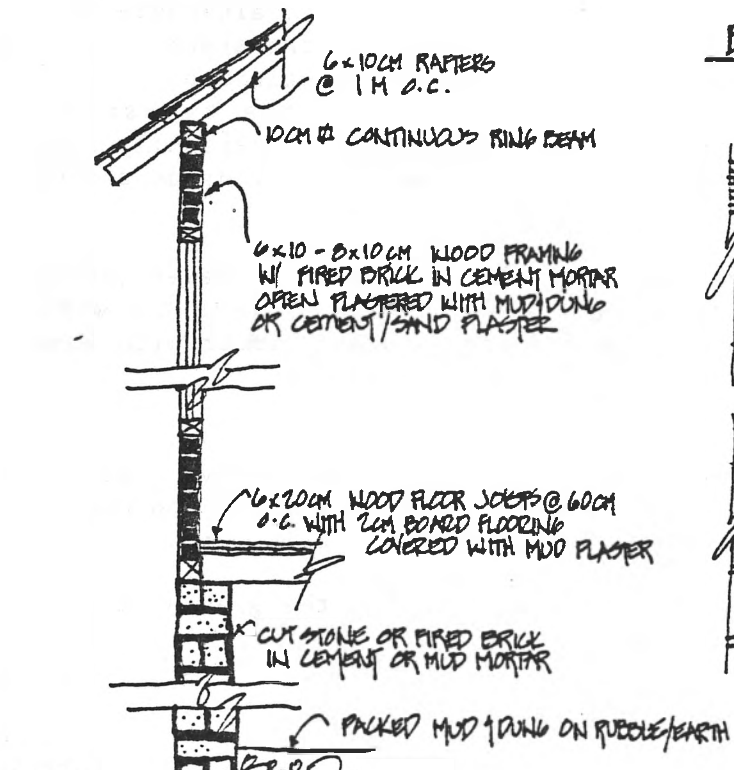
In general, the heavier the infill, the greater is the damage to the wall panels.

BUILDING SECTION

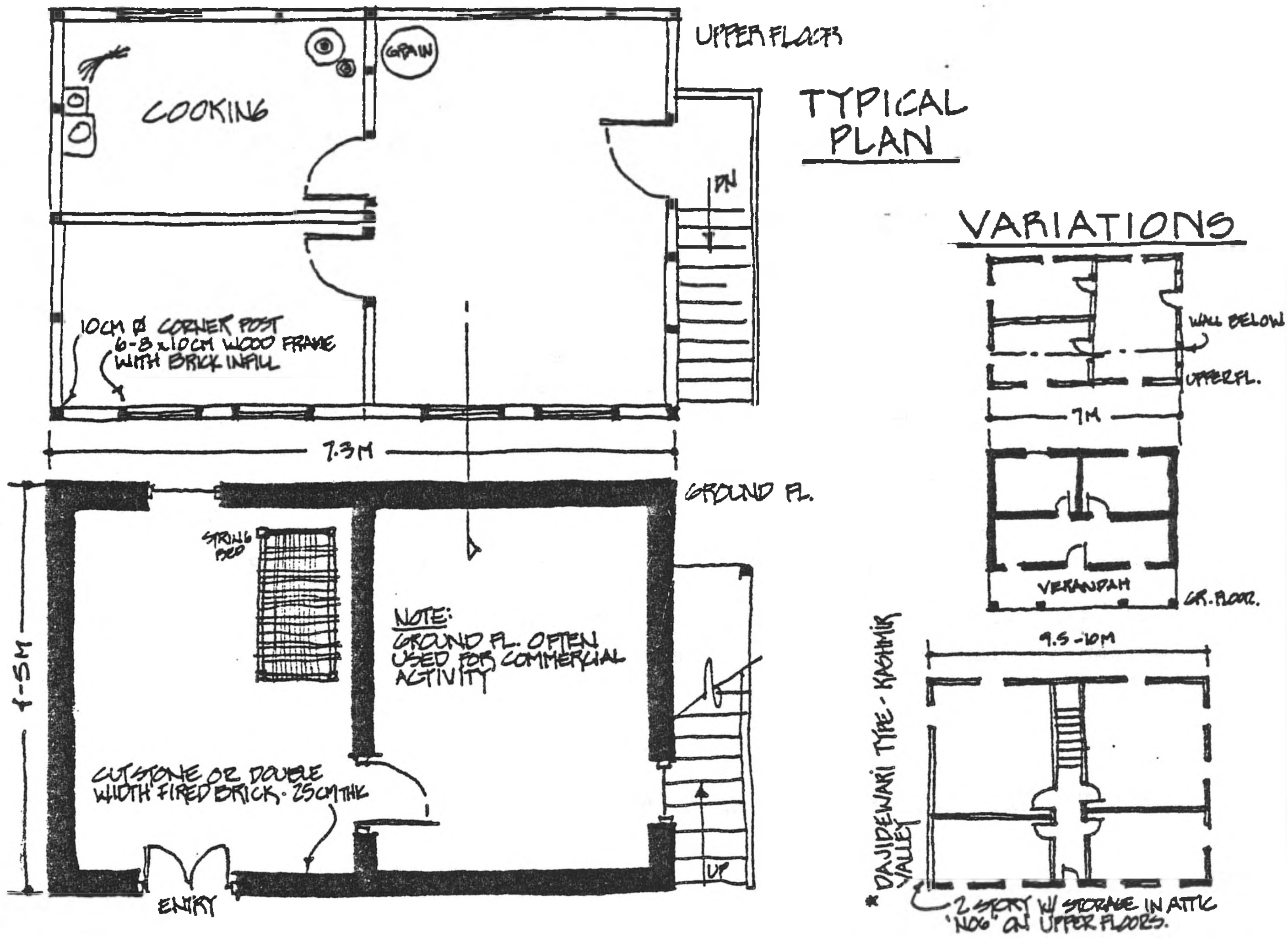


BRICK NOG VARIATIONS ELEVATIONS





TYPICAL WALL SECTION

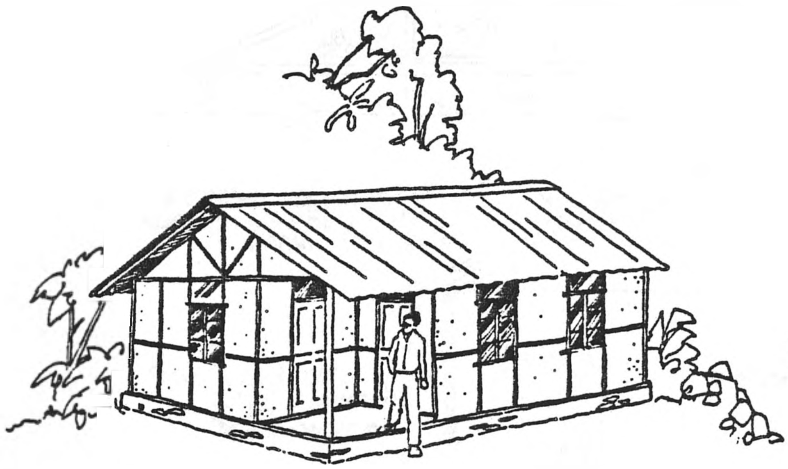


Seismic Resistance Evaluation

GOOD	FAIR	POOR	N/A		GOOD	FAIR	POOR	N/A	
		●		SITING	●				DOOR/WINDOW AREAS
●				SEPARATION BETWEEN BLDGS.			●		FOUNDATION-WALL CONNECTION
		●		FOUNDATION DESIGN		●			WALL-WALL CONNECTION
●				BALANCE OF STRUCTURE	●				WALL-ROOF CONNECTION
●				SHAPE OF PLAN		●			LIGHT WEIGHT WALLS
		●		CENTER OF GRAVITY			●		LIGHT WEIGHT ROOF
	●			RIGID WALLS	●				RING BEAM
	●			ROOF DESIGN	●				STRENGTH OF BLDG. MATERIALS
●				PROJECTIONS & OVERHANGS			●		STRENGTH OF MORTAR
●				DOOR/WINDOW LOCATIONS	●				QUALITY OF WORKMANSHIP

RECOMMENDATIONS FOR IMPROVEMENTS	DET. REF. NO.	% CONST. COST	MAN-DAYS
Increase depth of foundation to 75-90 cm	-	1	2
Use cement mortar	-	6	5
Insert reinforcing L angle of bamboo, steel, or wood at regular interval of height of wall at corners and T junctions	7	1	2
Anchor sill plates to foundation with anchor bolts	15	.3	1
Extend wood framing into gable with X braces	16	.8	3
Place diagonal braces at each corner (in the horizontal plane) to help hold the corners together	2	.2	1.3

AVERAGE TOTAL COST OF HOUSE Rs 45-50,000



HOUSE TYPE: Spring Strip

LOCATION: W. Bengal

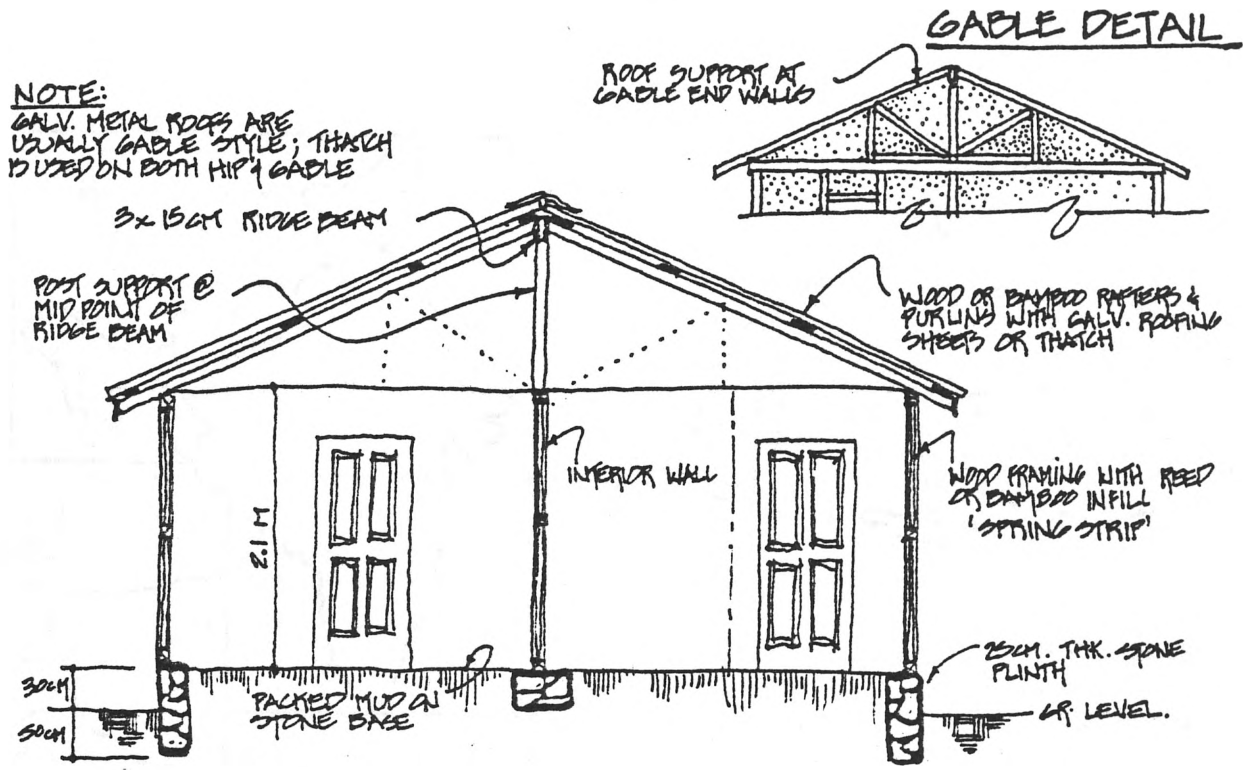
FOUNDATION: The foundation is formed of 25 cm. wide x 50 cm. deep random stone without mortar, plastered with a mud and dung or mud and cement mixture. Plinth height above ground varies from 15-30 cm., and it is filled with rubble and packed earth.

WALLS: Walls are constructed of 6 x 10 cm. sawn wood studs .8 m. on center with a continuous 10 x 10 cm. wood ring beam and sill or bottom plate, and toenailed connections between studs and plates. Woven reed or bamboo is used as infill panels and plastered with a mud and dung mixture inside and out, typically 2.1 m. in height. The sill plate is anchored to the plinth by embedded steel rebar at 2 m. typical spacing or with wire embedded in the plinth. The walls have 6 x 10 cm. wood stiffeners at mid-height.

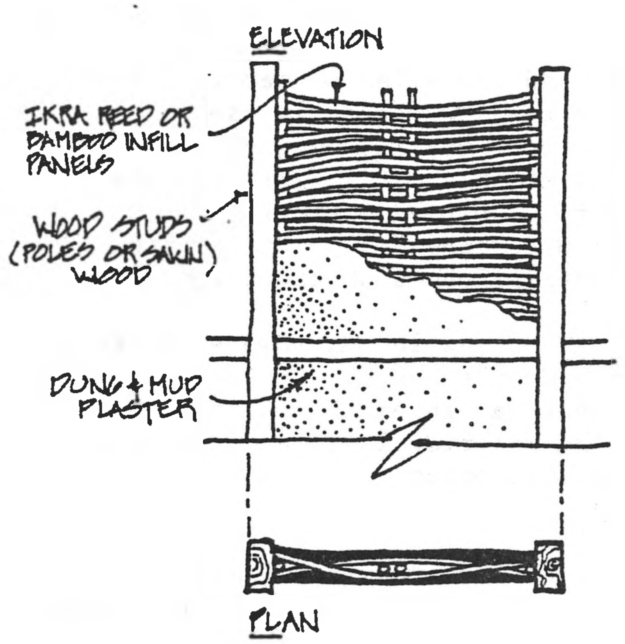
ROOF: The roof frame consists of 5 x 10 cm. sawn wood rafters supported by the walls and ridge beam. The ridge beam is supported near mid-span by an interior wall and vertical wood strut. The roofing material is galvanized metal or thatch, generally 3:12 to 4:12 pitch.

BEHAVIOR IN EARTHQUAKES: Spring-strip houses have performed very well in earthquakes. This is attributed to their relatively lightweight construction.

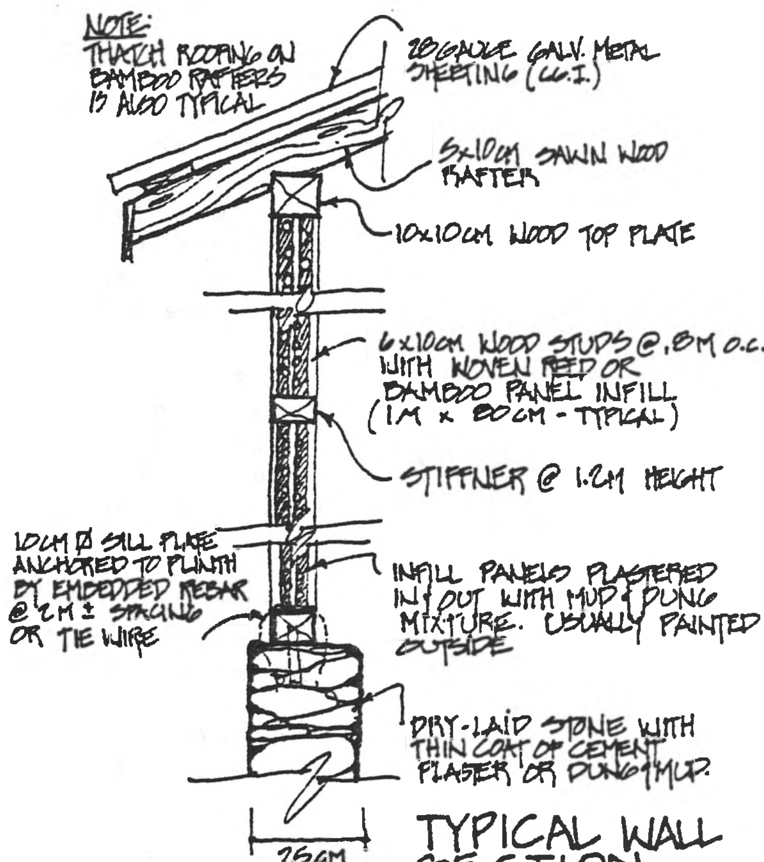
The damage that has been sustained by the timber framing is due to the collapse of heavy stone masonry chimneys.



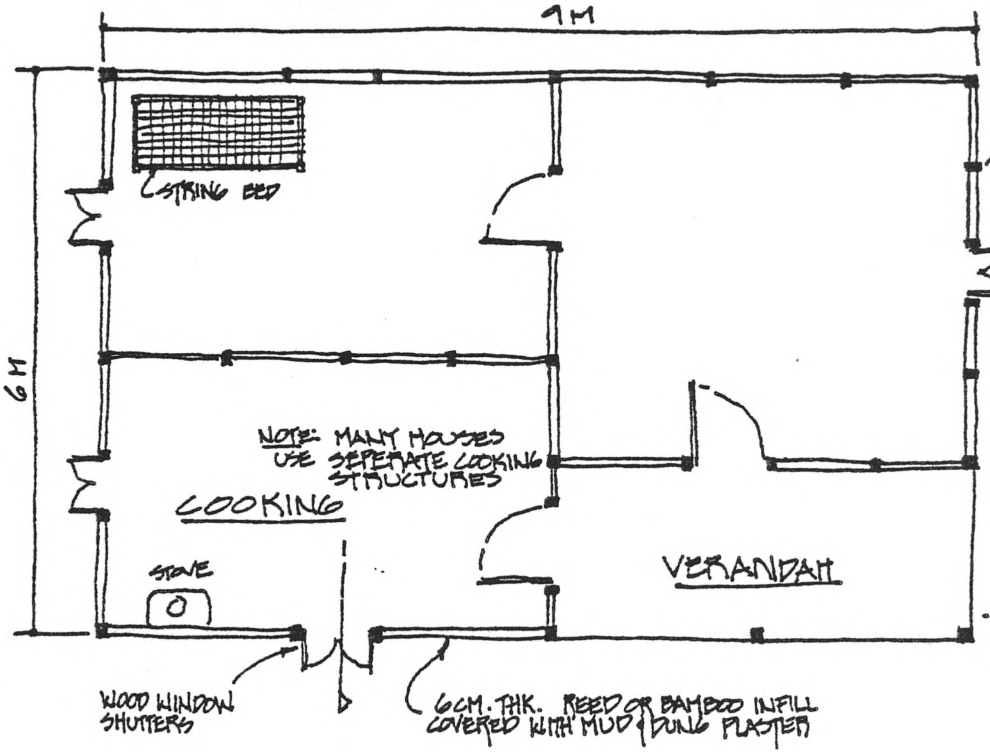
BUILDING SECTION



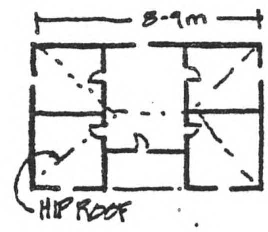
DETAIL OF WALL CONSTRUCTION



TYPICAL WALL SECTION



TYPICAL PLAN

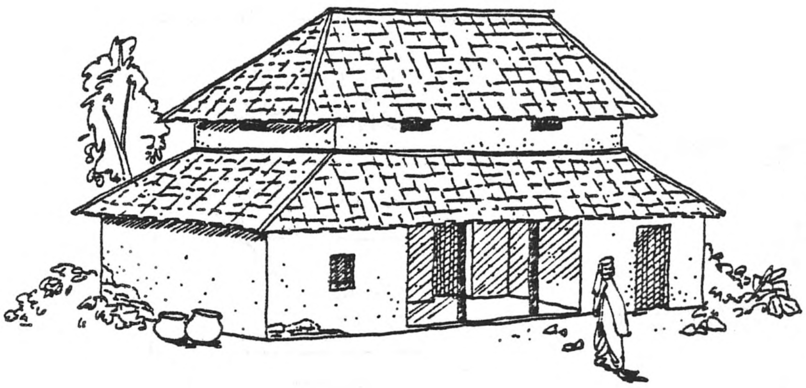


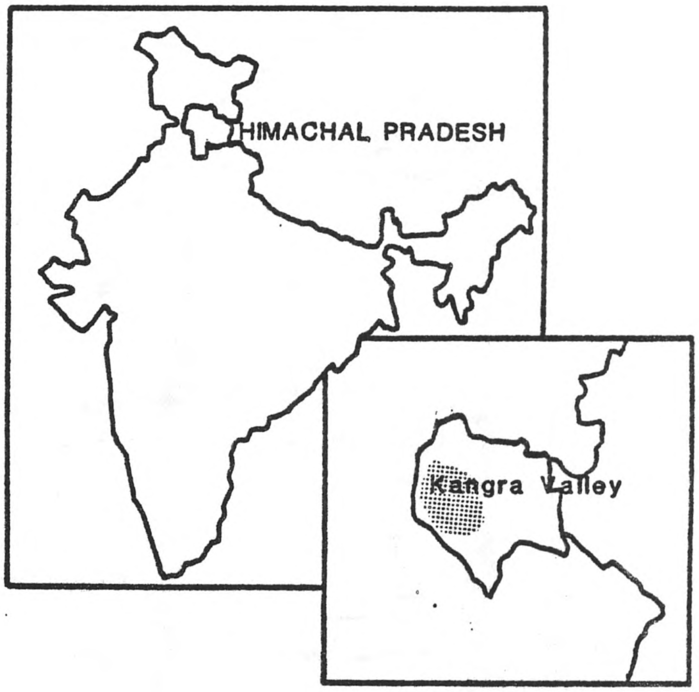
VARIATIONS

Seismic Resistance Evaluation									
GOOD	FAIR	POOR	N/A		GOOD	FAIR	POOR	N/A	
●				SITING	●				DOOR/WINDOW AREAS
●				SEPARATION BETWEEN BLDGS.	●				FOUNDATION-WALL CONNECTION
		●		FOUNDATION DESIGN	●				WALL-WALL CONNECTION
●				BALANCE OF STRUCTURE	●				WALL-ROOF CONNECTION
●				SHAPE OF PLAN	●				LIGHT WEIGHT WALLS
●				CENTER OF GRAVITY	●				LIGHT WEIGHT ROOF
●				RIGID WALLS	●				RING BEAM
●				ROOF DESIGN	●				STRENGTH OF BLDG. MATERIALS
●				PROJECTIONS & OVERHANGS				●	STRENGTH OF MORTAR
●				DOOR/WINDOW LOCATIONS	●				QUALITY OF WORKMANSHIP

RECOMMENDATIONS FOR IMPROVEMENTS	DET. REF. NO.	% CONST. COST	MAN-DAYS
use cement/sand mortar at foundation	-	10	2

ASSUMED 90% SELF-HELP





HOUSE TYPE: Two-Story Mud

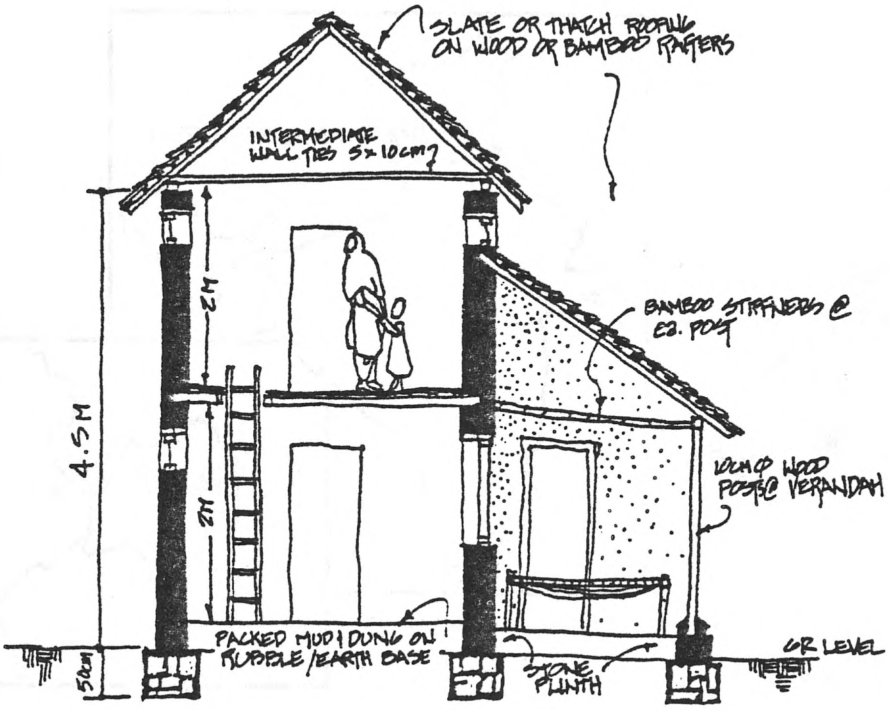
LOCATION: Kangra Valley, H.P.

FOUNDATION: The foundation consists of cut or random stone with mud or mud/lime mortar, 60 cm. wide x 50 cm. deep below ground level and 25-40 cm. height above ground, forming a plinth that is infilled with rubble and packed earth.

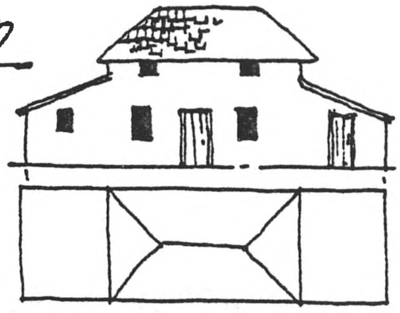
WALLS: Walls are approximately 40 cm. wide, made of mud brick in mud mortar and plastered with a mud and dung mixture. Walls are typically 4.5 m. high with 6-8 cm. thick wood lintels and a continuous 10 cm. wood ring beam. Floor joists and ground floor rafters are embedded in the walls for support.

ROOF: The roof is hipped, with shed roofs on additions and verandahs. It is typically framed with wood rafters at 1 m. on center or bamboo rafters at 30 cm. on center; intermediate rafter ties are used at 2-3 m. on center. The roofing material is either slate shingle or thatch. Wood framing is usually used with slate shingles. The roof pitch is approximately 8:12 to 12:12.

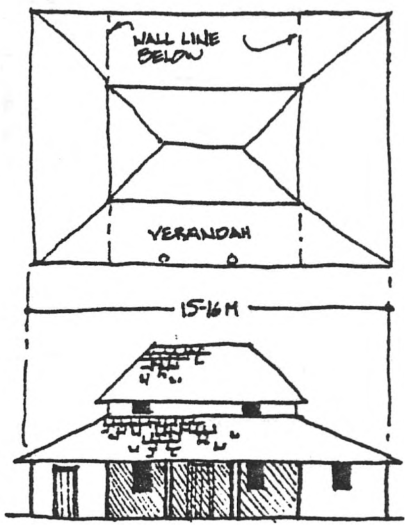
VARIATIONS

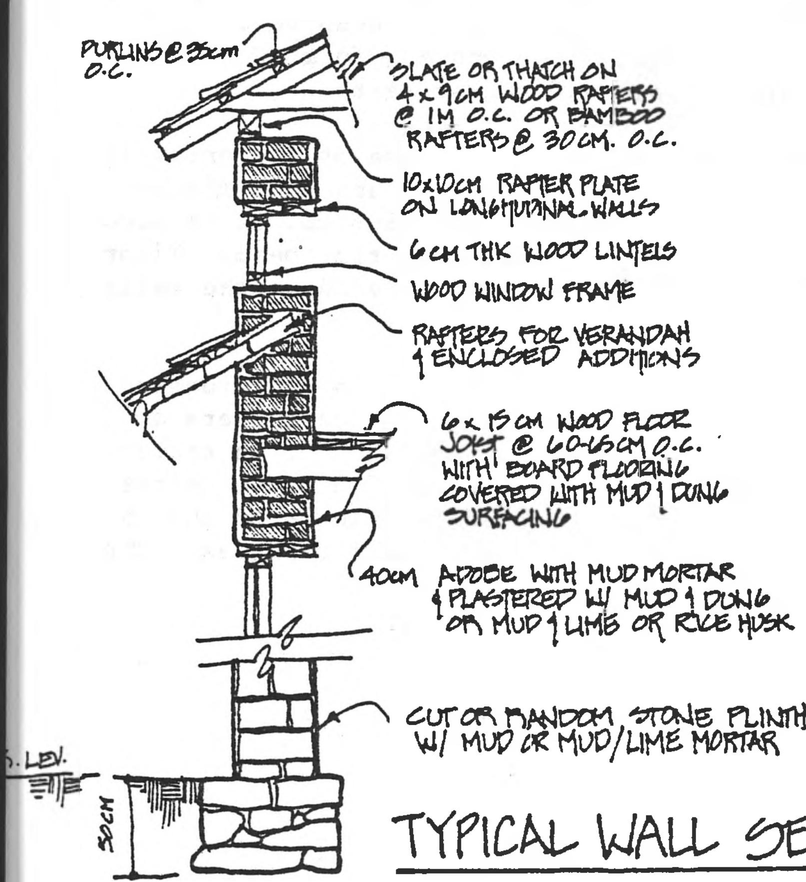


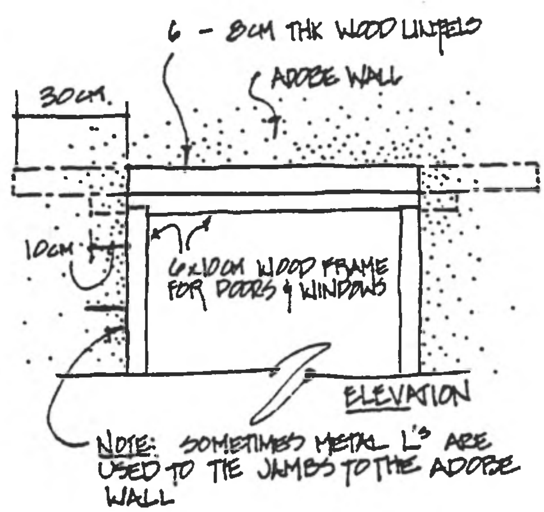
BUILDING SECTION



ROOF, PLANS & ELEVATIONS



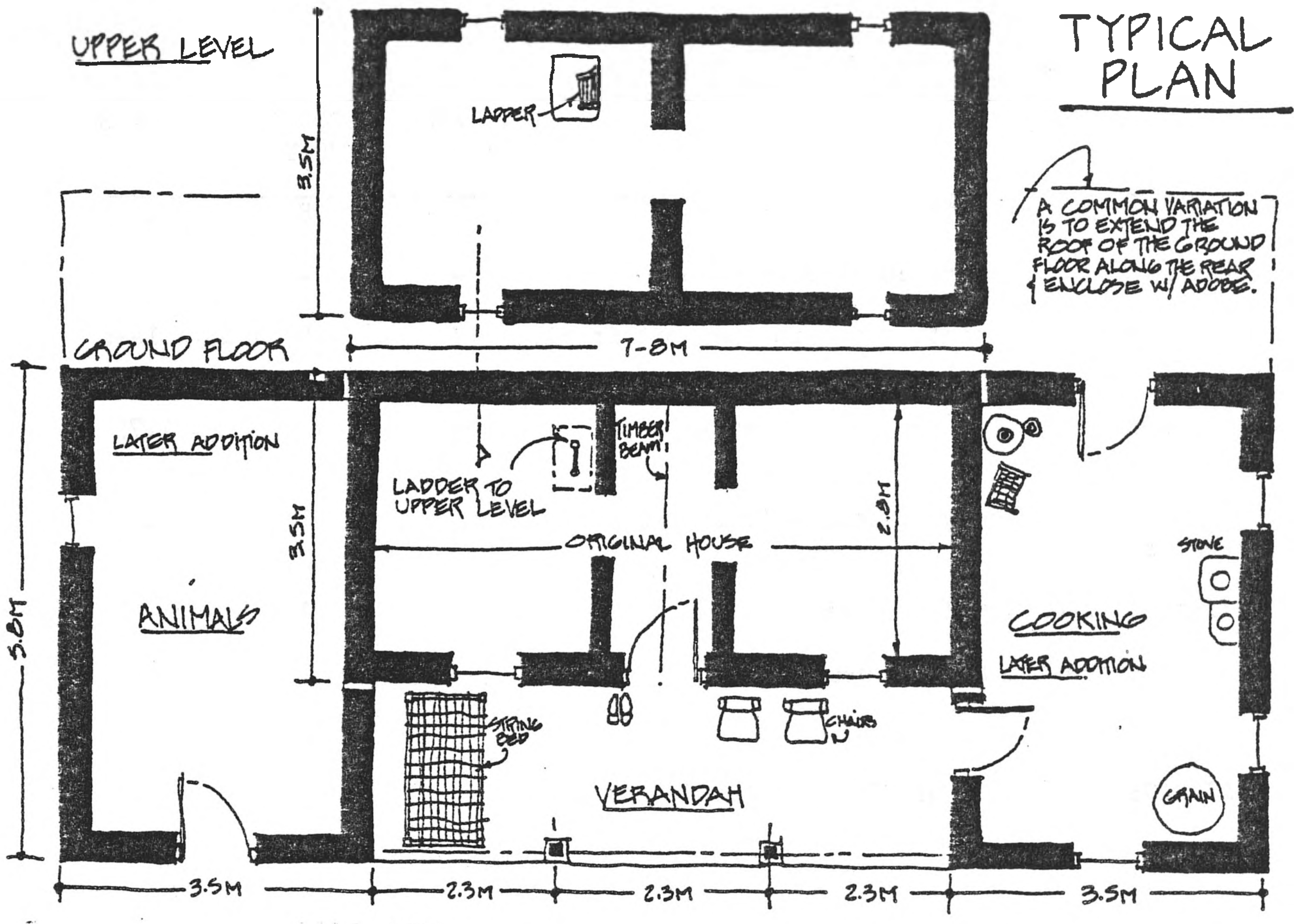




DOOR & WINDOW FRAMING DETAIL

TYPICAL WALL SECTION

TYPICAL PLAN

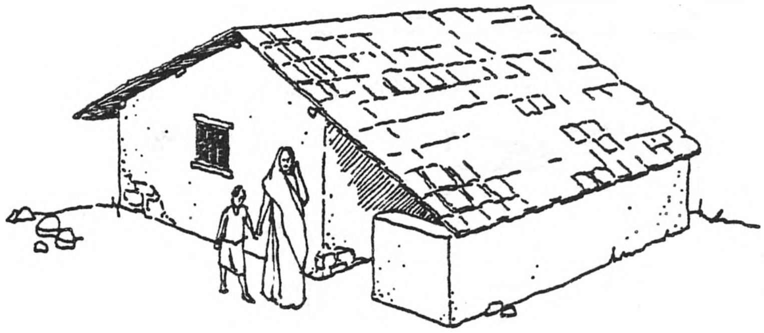


Seismic Resistance Evaluation

GOOD	FAIR	POOR	N/A		GOOD	FAIR	POOR	N/A	
●				SITING	●				DOOR/WINDOW AREAS
●				SEPARATION BETWEEN BLDGS.		●			FOUNDATION-WALL CONNECTION
	●			FOUNDATION DESIGN			●		WALL-WALL CONNECTION
●				BALANCE OF STRUCTURE			●		WALL-ROOF CONNECTION
	●			SHAPE OF PLAN			●		LIGHT WEIGHT WALLS
		●		CENTER OF GRAVITY			●		LIGHT WEIGHT ROOF
		●		RIGID WALLS			●		RING BEAM
	●			ROOF DESIGN			●		STRENGTH OF BLDG. MATERIALS
		●		PROJECTIONS & OVERHANGS			●		STRENGTH OF MORTAR
●				DOOR/WINDOW LOCATIONS		●			QUALITY OF WORKMANSHIP

RECOMMENDATIONS FOR IMPROVEMENTS	DET. REF. NO.	% CONST. COST	MAN-DAYS
Use cement mortar in foundation	-	8	4
Utilize single-story construction only	-	-	-
Use lightweight roofing and independent framing at verandah (CGI sheeting)	17	18	4 days less
Use continuous ring beam anchored to walls with corner bracing	2	1.5	1.75
Reinforce wall-to-wall connections with angle braces	7	2	4
Floor joists should penetrate wall	9	1	-
Add X braces to roof plane	1	1	2

AVERAGE TOTAL COST OF HOUSE Rs 25-30,000



HOUSING TYPE: Stone

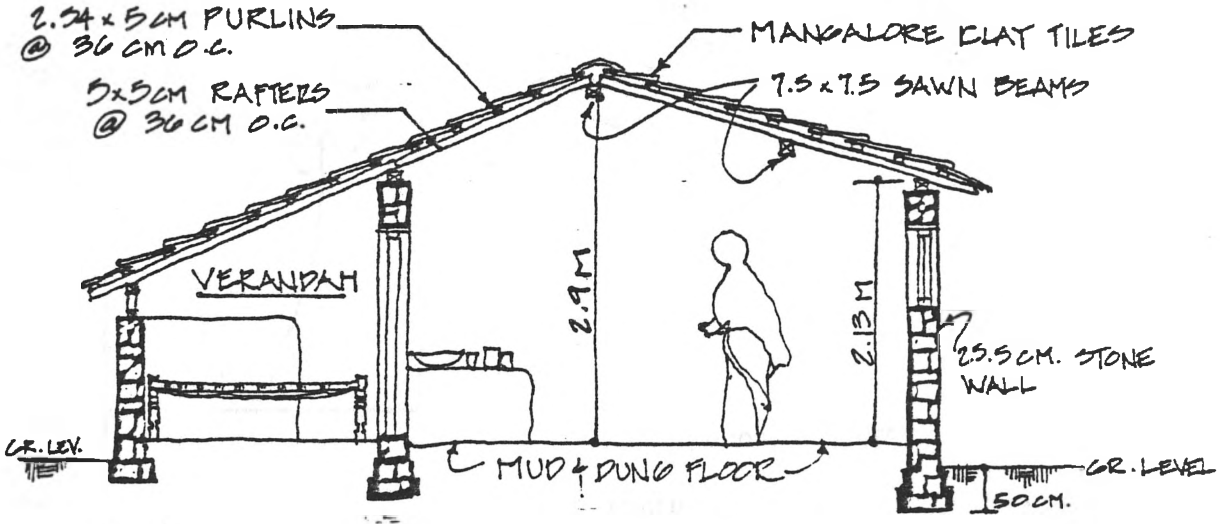
LOCATION: Bhuj/Gujarat

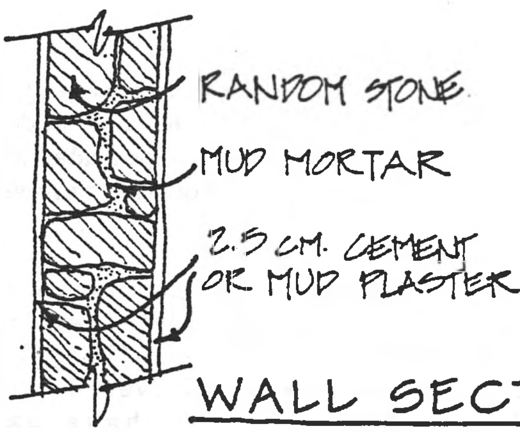
FOUNDATION: The foundation is constructed of random, uncut stone with cement/sand mortar or mud mortar, 60 cm. wide to ground level. The foundation normally extends 50 cm. below ground level with variations from 30 cm. below ground level.

WALLS: Walls are 30 cm. thick random stone masonry in mud mortar, plastered inside and out with mud mortar stabilized with cow dung or with a cement plaster, usually 2.5 cm. thick. 2 x 28 cm. wood lintels are used over door and window openings. Door and window frames have extended top members that are also embedded in the stone walls.

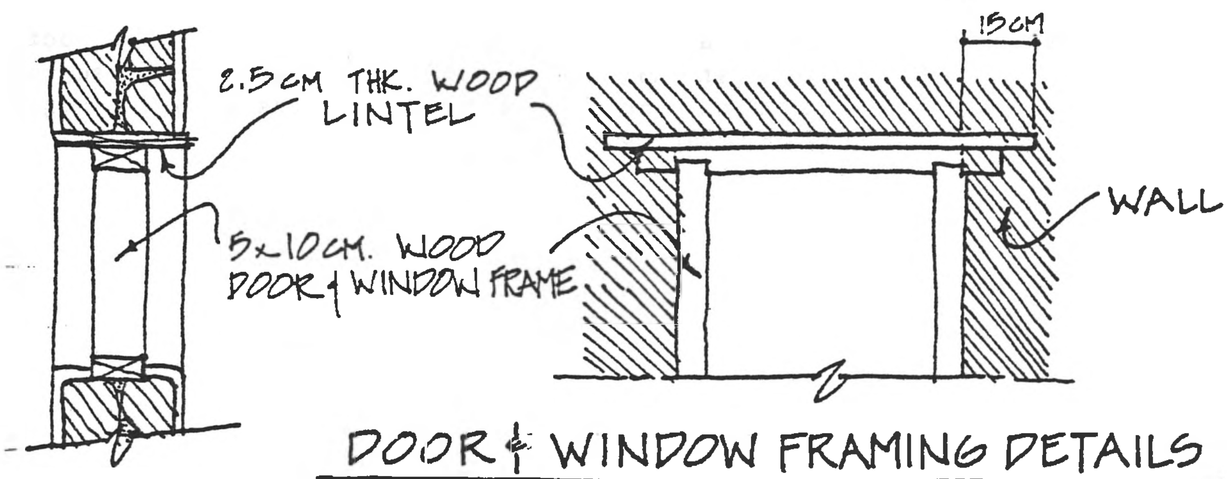
ROOF: Roofs are off-center gable type. The roof structure consists of sawn and pole timber beams supporting sawn rafters and 2.5 x 5 cm. purlins with a "mangalore" clay tile covering.

BUILDING SECTION

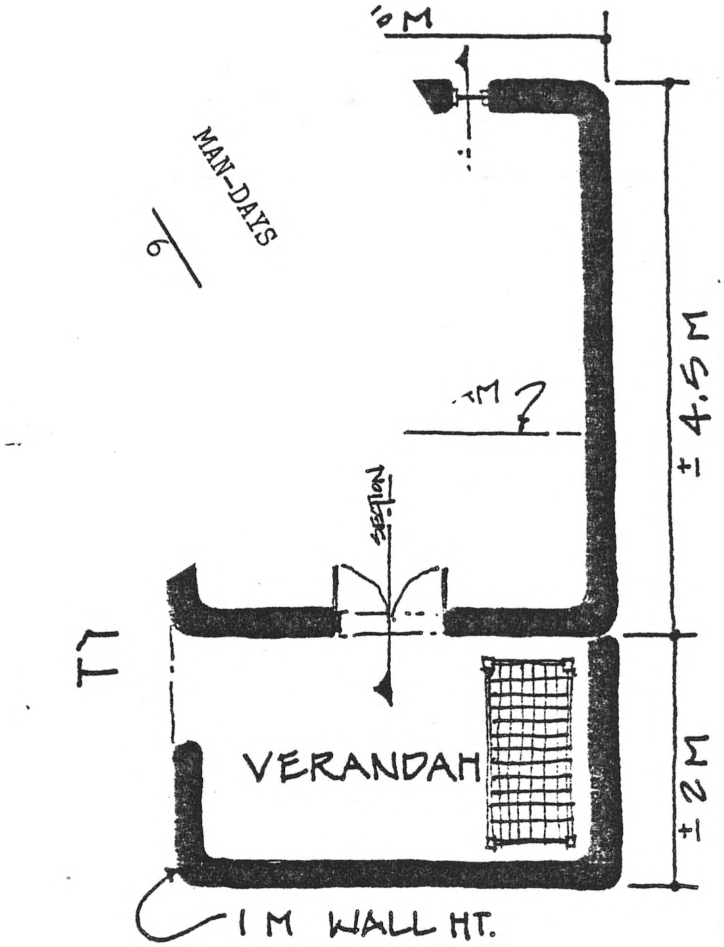


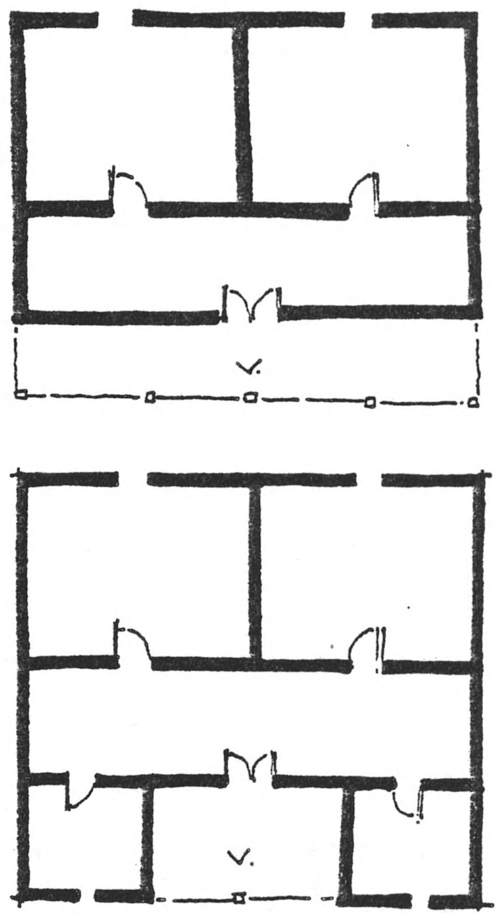


WALL SECTION



DOOR & WINDOW FRAMING DETAILS



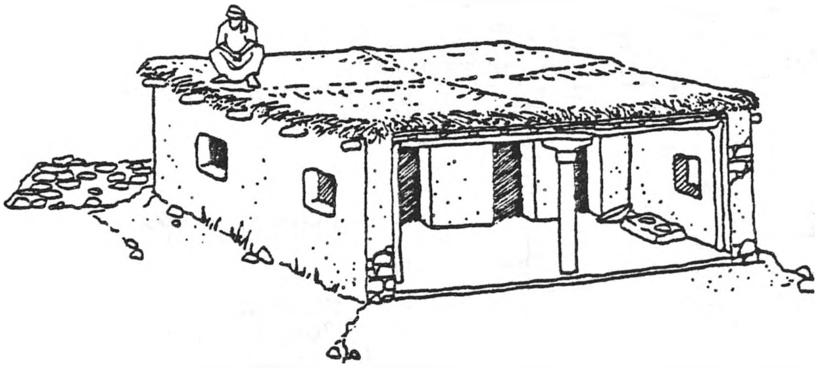


PLAN VARIATIONS

Seismic Resistance Evaluation									
GOOD	FAIR	POOR	N/A		GOOD	FAIR	POOR	N/A	
●				SITING	●				DOOR/WINDOW AREAS
		●		SEPARATION BETWEEN BLDGS.		●			FOUNDATION-WALL CONNECTION
	●			FOUNDATION DESIGN			●		WALL-WALL CONNECTION
	●			BALANCE OF STRUCTURE			●		WALL-ROOF CONNECTION
	●			SHAPE OF PLAN			●		LIGHT WEIGHT WALLS
●				CENTER OF GRAVITY			●		LIGHT WEIGHT ROOF
		●		RIGID WALLS				●	RING BEAM
		●		ROOF DESIGN		●			STRENGTH OF BLDG. MATERIALS
	●			PROJECTIONS & OVERHANGS			●		STRENGTH OF MORTAR
●				DOOR/WINDOW LOCATIONS		●			QUALITY OF WORKMANSHIP

RECOMMENDATIONS FOR IMPROVEMENTS	DET. REF. NO.	% CONST. COST	
Use cement mortar in foundations and walls	-	10	
Use RCC (reinforced concrete) ring beam or wood ring beam	18	5 wood 30 RCC	1-8
Use hipped roof and ring beam	-	15	6
Use cut stone, interlocked at corners	-	27	15
Use bond stone every 1 - 1-1/2 m horizontally and every 3 layers vertically	19	1	
Use vertical reinforcing at corners and at pilasters	-	1.2	1
Improve stone masonry construction techniques	-	-	-
Add X braces in roof plane	1	3	1
Add knee braces in roof	2	1.5	1
Insert reinforcing L angle of bamboo, steel, or wood at regular interval of height of wall at corners and T junctions	7	2-4	2-3

AVERAGE TOTAL COST OF HOUSE Rs 12-15,000



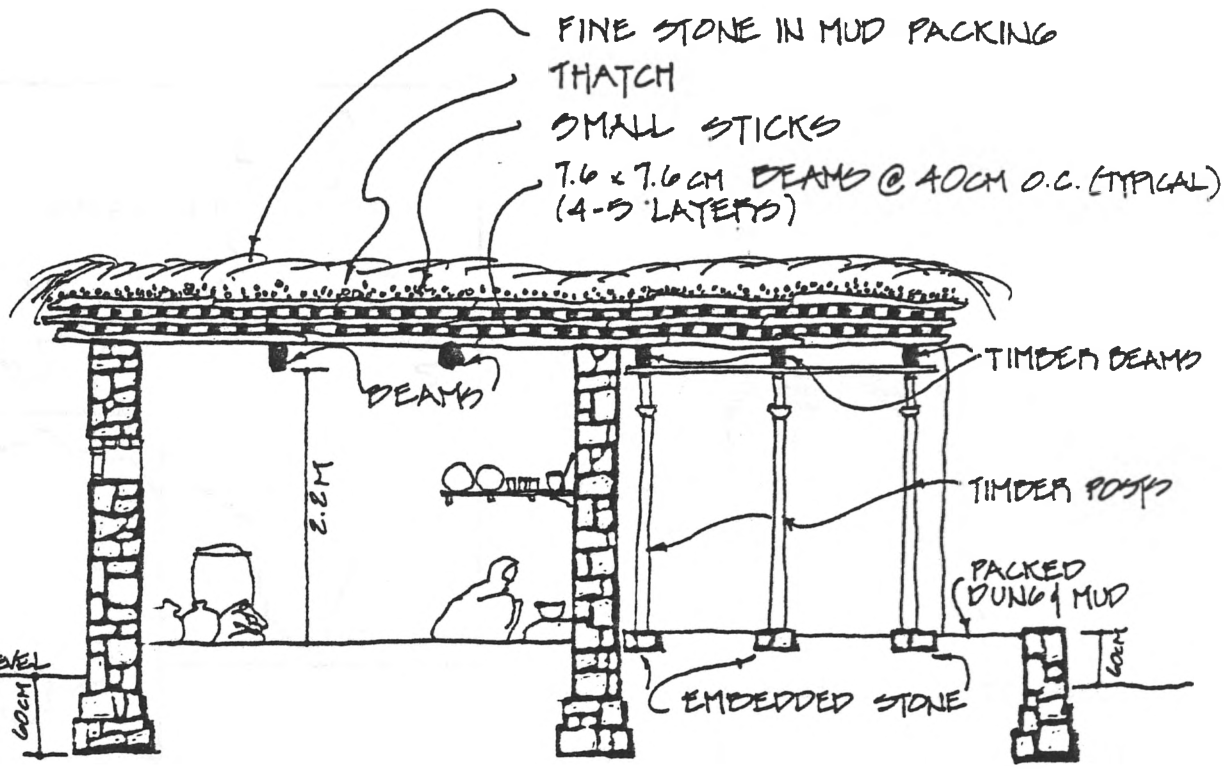
HOUSE TYPE: Stone with Flat Roof

LOCATION: Jammu, Srinagar

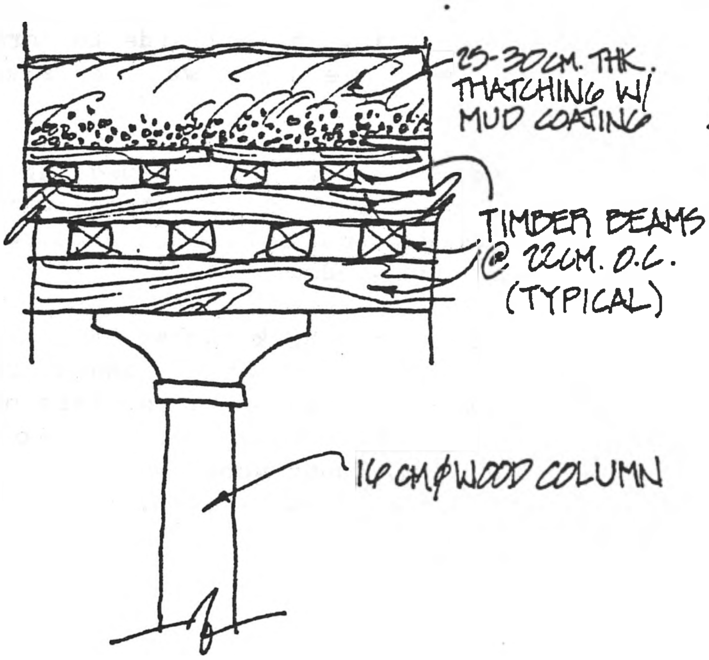
FOUNDATION: The foundation is constructed of cut or random stone in mud mortar 60 cm. wide x 60 cm. deep. Houses are often constructed on slopes, excavating the hillside to form a flat surface for the base. The rear wall acts as a retaining wall.

WALLS: Walls are of cut or random stone with slate wedging (no mortar used), 45 cm. wide x 2x2 m. high, plastered with a mud and dung mixture inside and out. 5 x 5 cm. wood lintels are used above doors and windows.

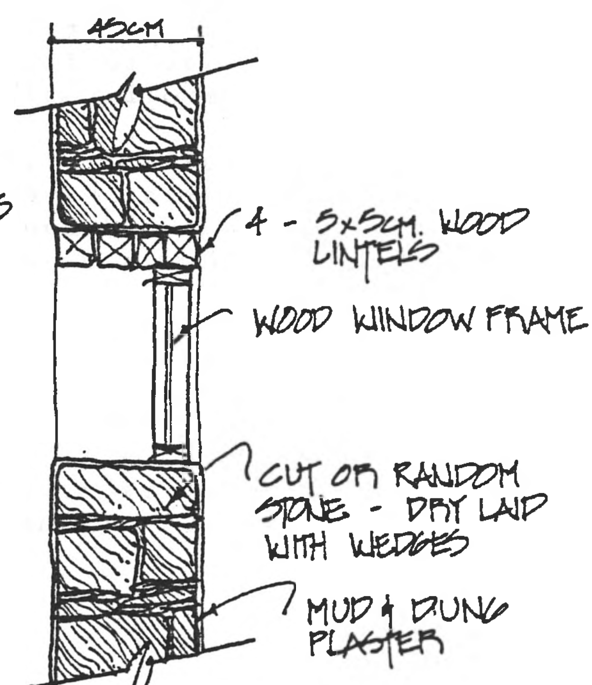
ROOF: The roof consists of .75 - 1 m. thick timber beams with thatch roofing covered with a mud and crushed stone topping. The roof structure typically consists of 4 perpendicular layers of timber beams with a solid sheathing of small 2.5 - 4 cm. round wood, which is then covered with small branches in an 8 cm. thick layer before the thatching is placed.



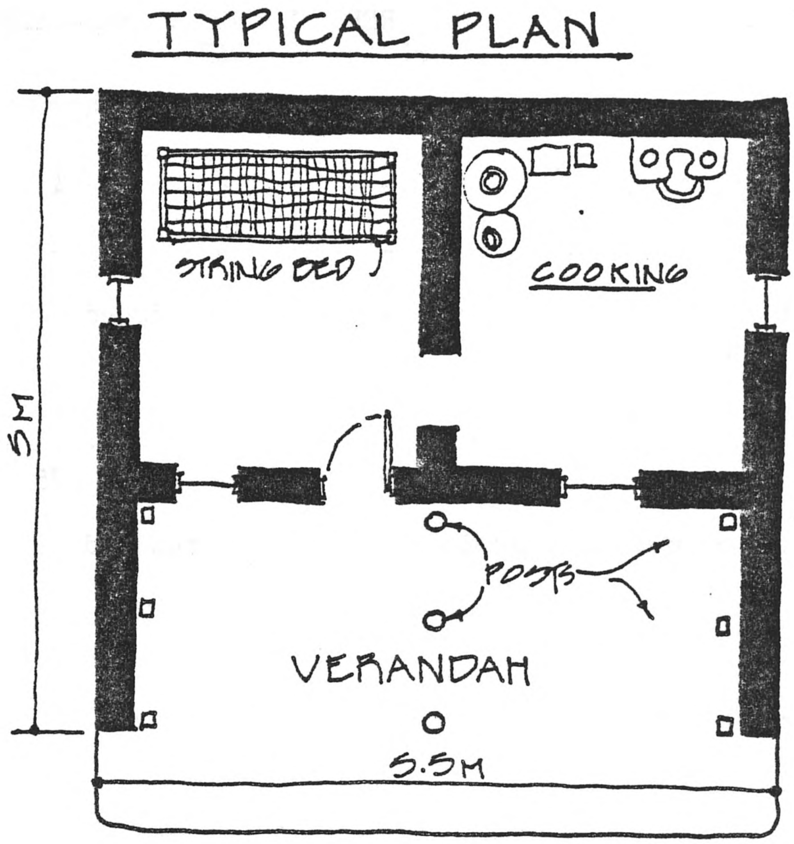
BUILDING SECTION

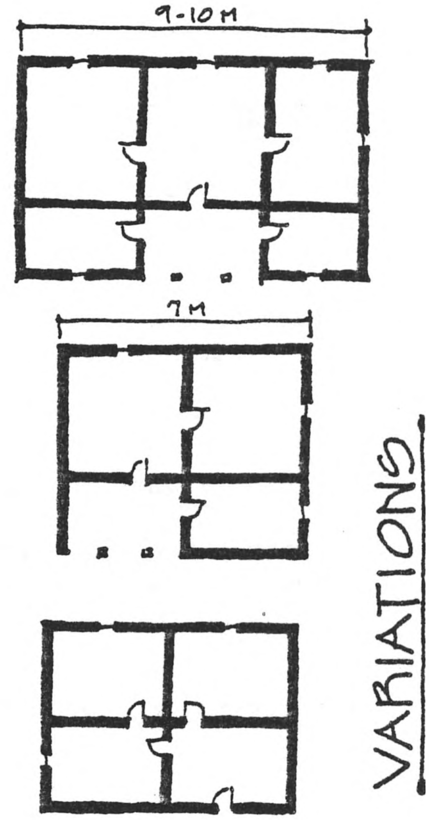


ROOF SECTION @ COLUMN



WALL SECTION

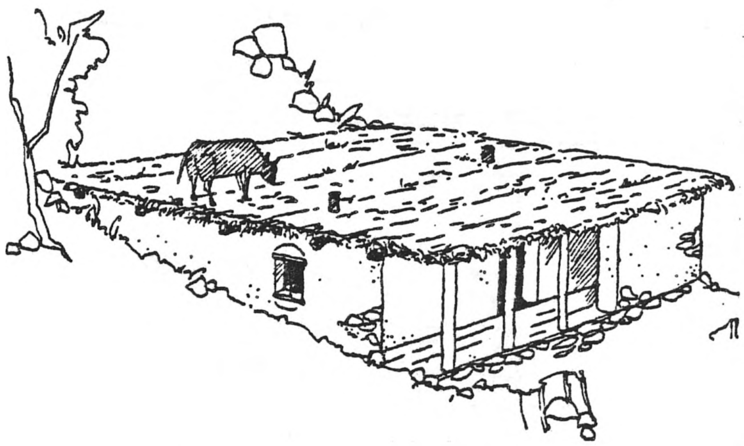




Seismic Resistance Evaluation									
GOOD	FAIR	POOR	N/A		GOOD	FAIR	POOR	N/A	
	●			SITING	●				DOOR/WINDOW AREAS
●				SEPARATION BETWEEN BLDGS.		●			FOUNDATION-WALL CONNECTION
		●		FOUNDATION DESIGN			●		WALL-WALL CONNECTION
		●		BALANCE OF STRUCTURE			●		WALL-ROOF CONNECTION
	●			SHAPE OF PLAN			●		LIGHT WEIGHT WALLS
		●		CENTER OF GRAVITY			●		LIGHT WEIGHT ROOF
		●		RIGID WALLS			●		RING BEAM
		●		ROOF DESIGN		●			STRENGTH OF BLDG. MATERIALS
●				PROJECTIONS & OVERHANGS			●		STRENGTH OF MORTAR
●				DOOR/WINDOW LOCATIONS	●				QUALITY OF WORKMANSHIP

RECOMMENDATIONS FOR IMPROVEMENTS	DET. REF. NO.	% CONST. COST	MAN-DAYS
Increase depth of foundation to 75 cm	-	1	2-4
Use cement/sand mortar at foundations	-	4	4
Utilize principles of balanced plans	-	-	-
Eliminate practice of earth-covered heavy timber roof construction	-	reduced	
Use cement/sand mortar in masonry walls	-	10	10
Use bond stones in wall	19	1	.75
Construct roof of lightweight roofing and wood truss construction	-	reduced	

AVERAGE TOTAL COST OF HOUSE Rs 14,000



HOUSE TYPE: Flat Roof/Stone Walls

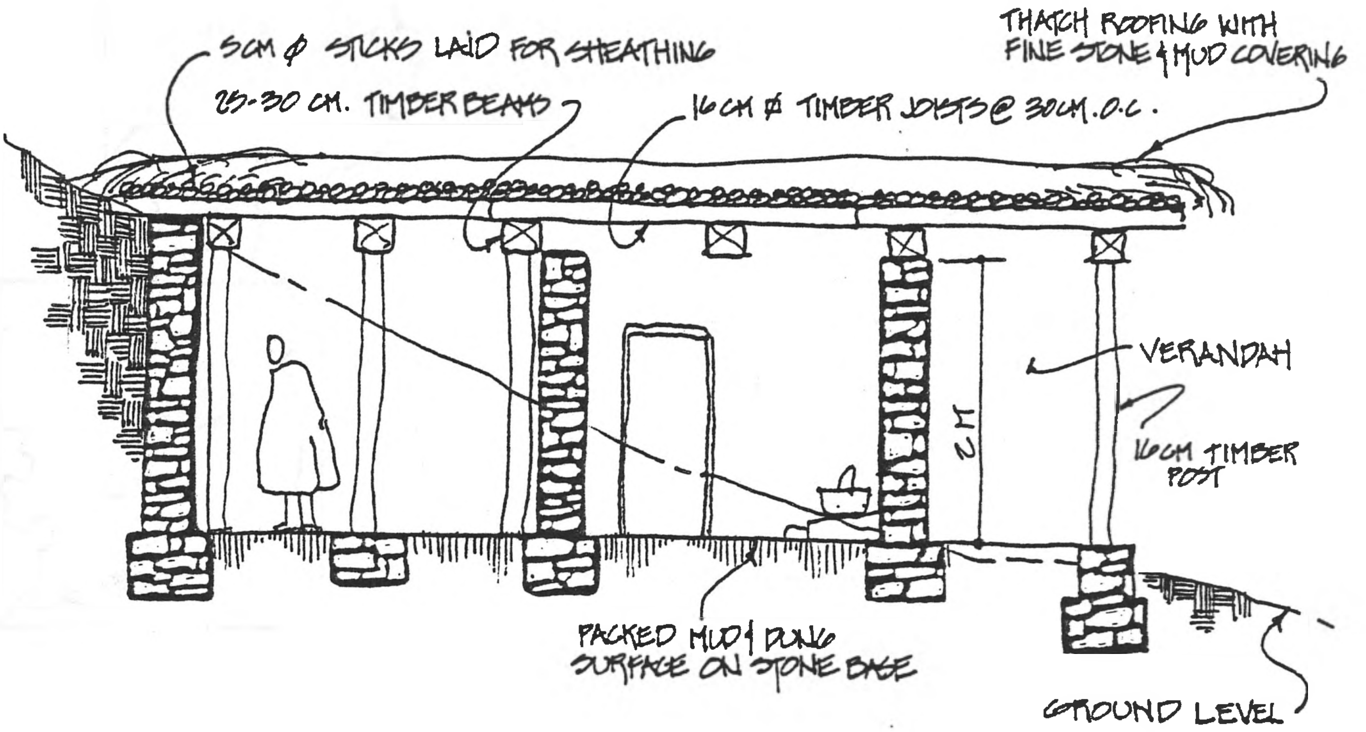
LOCATION: Srinagar, Jammu & Kashmir; Solan, H.P.

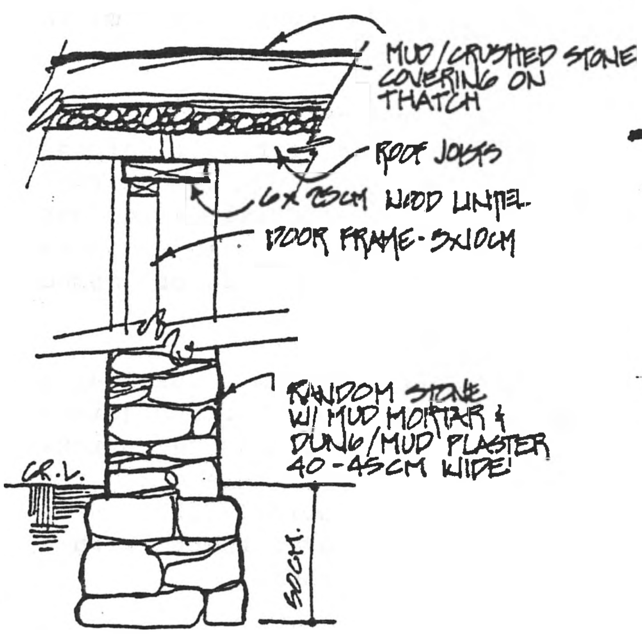
FOUNDATION: The foundation is 60-65 cm. wide x 50 cm. deep random or cut stones in mud mortar. Houses built into slopes use the rear wall as a retaining wall, typically 2 m. in height.

WALLS: Walls are 40-45 cm. wide random stone or cut stone in mud mortar, typically 2 m. in height. Internal timber columns at 1.2 m. on center support much of the weight of the roof structure. The stone walls are plastered inside and out with a mud and dung mixture. 6 x 25 cm. wood lintels are embedded 15-20 cm. into the wall on either side of framed openings.

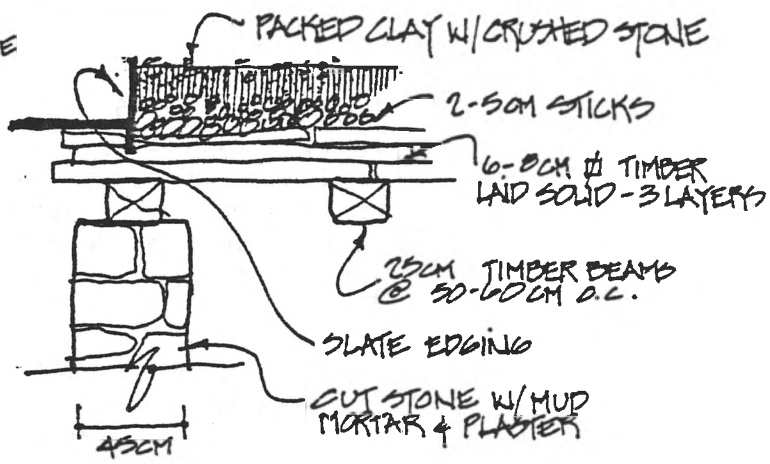
ROOF: 25-30 cm. diameter timber beams at 1.2 m., spanning a maximum of 3 - 3.5 m., support 16 cm. square timber joists at 30 cm. on center and a layer of 5 cm. diameter sticks as solid sheathing. Thatching is then laid and covered with mud and fine stone. Roofs in Solan, H.P., use a packed clay and small stone mixture over thatch with a slate edging around the perimeter of the roof.

BUILDING SECTION





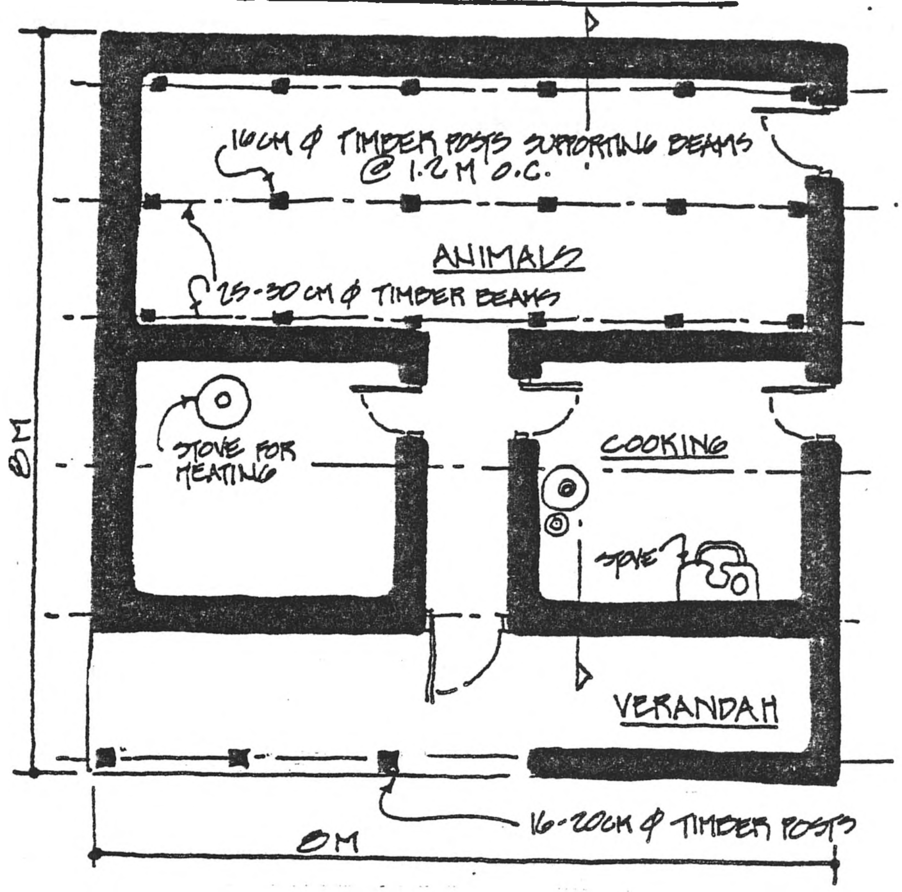
TYPICAL WALL SECTION



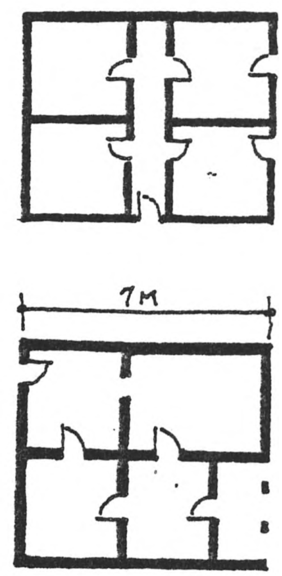
ROOF & WALL SECTION VARIATION

(DOCUMENTED IN SOLAN, H.P.)

TYPICAL PLAN



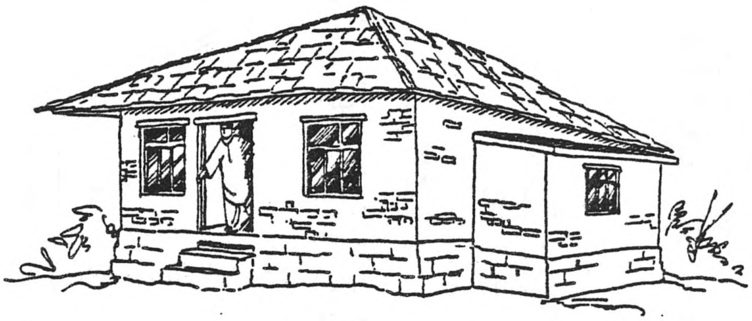
VARIATIONS



Seismic Resistance Evaluation

GOOD	FAIR	POOR	N/A		GOOD	FAIR	POOR	N/A	
		●		SITING	●				DOOR/WINDOW AREAS
●				SEPARATION BETWEEN BLDGS.			●		FOUNDATION-WALL CONNECTION
		●		FOUNDATION DESIGN		●			WALL-WALL CONNECTION
	●			BALANCE OF STRUCTURE			●		WALL-ROOF CONNECTION
	●			SHAPE OF PLAN			●		LIGHT WEIGHT WALLS
●				CENTER OF GRAVITY			●		LIGHT WEIGHT ROOF
		●		RIGID WALLS			●		RING BEAM
		●		ROOF DESIGN		●			STRENGTH OF BLDG. MATERIALS
	●			PROJECTIONS & OVERHANGS			●		STRENGTH OF MORTAR
●				DOOR/WINDOW LOCATIONS			●		QUALITY OF WORKMANSHIP

RECOMMENDATIONS FOR IMPROVEMENTS	DET. REF. NO.	% CONST. COST	MAN-DAYS
It is unlikely that the house could be upgraded at a cost acceptable to the occupants.			
Use X braces in horizontal plane of roof as a minimum improvement	20	1	4



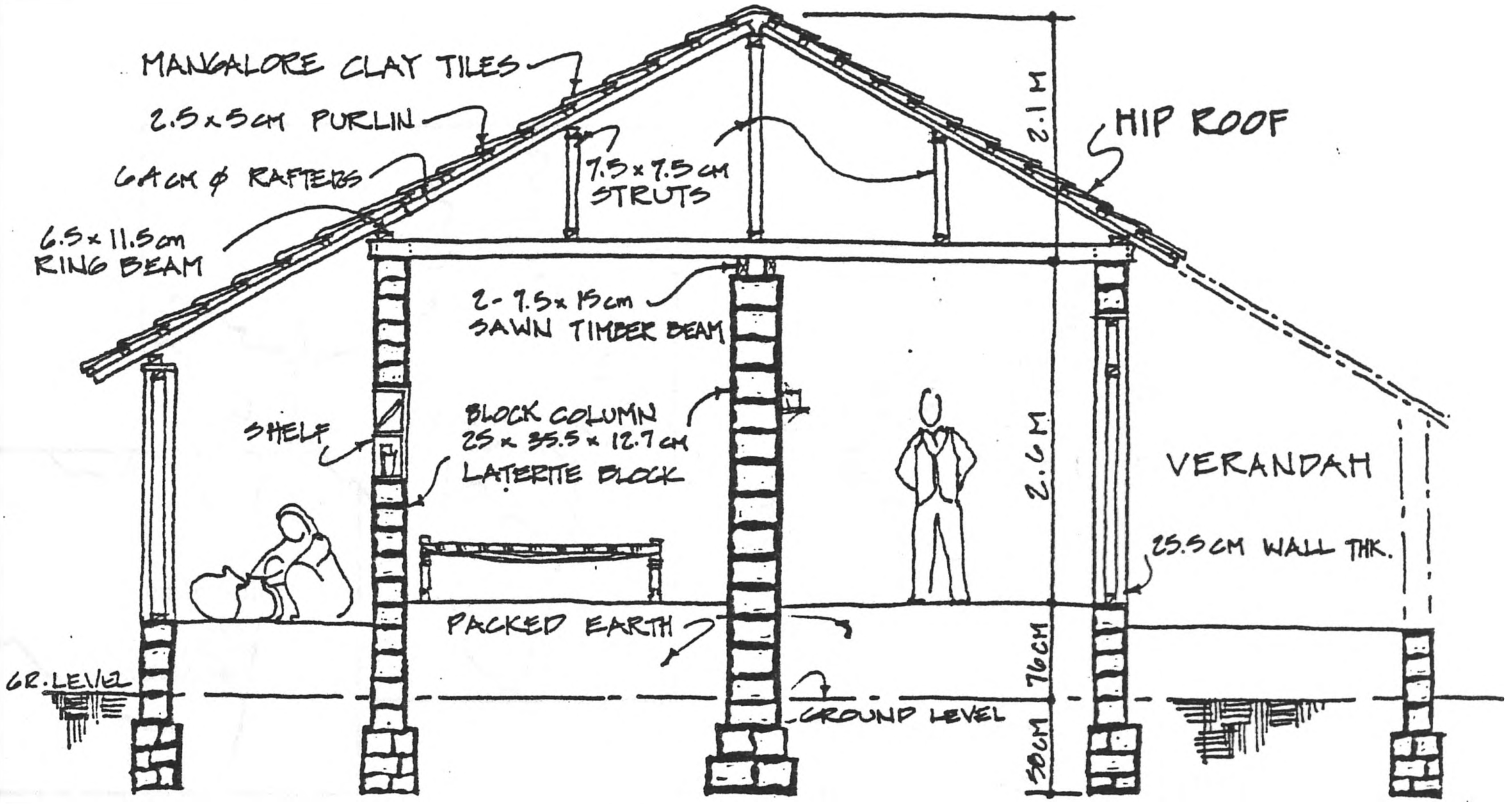
HOUSING TYPE: Laterite Stone

LOCATION: Koyna Dam, Maharashtra

FOUNDATION: The foundation is cut stone 50 cm. wide x 55-68 cm. deep below ground level and 50-60 cm. above ground level, set in morrum (pozzolanic material) mixed with mud or sand mortar.

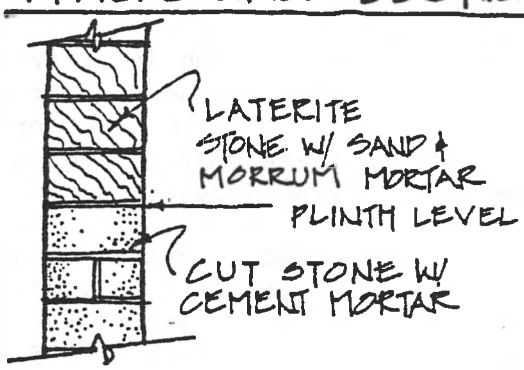
WALLS: The walls are 25 cm. wide x 2.2 - 2.6 m. high laterite cut stone (single width) set in a morrum and sand or mud mortar and plastered inside with mud or mud/morrum plaster. The lintels are 3.8 cm. thick wood extending 10 cm. into the wall on either side of framed openings.

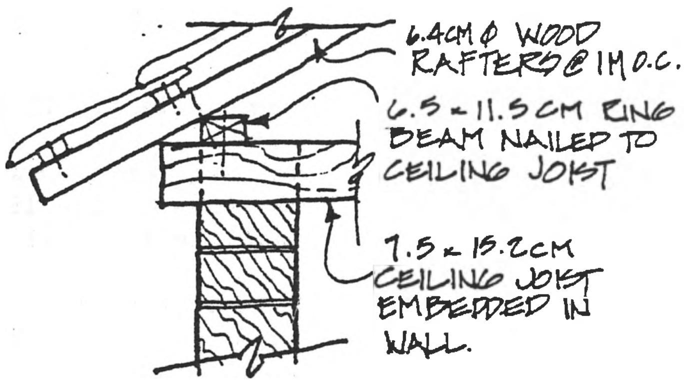
ROOF: The hipped roof is framed with a truss-type system of wood or bamboo bearing on outside walls and 2 - 7.5 x 15 cm. wood beams in the center running longitudinally. The roofing material is "mangalore" clay tile laid on 2.5 x 5 cm. purlins. The roof trusses are about 1 m. on center.



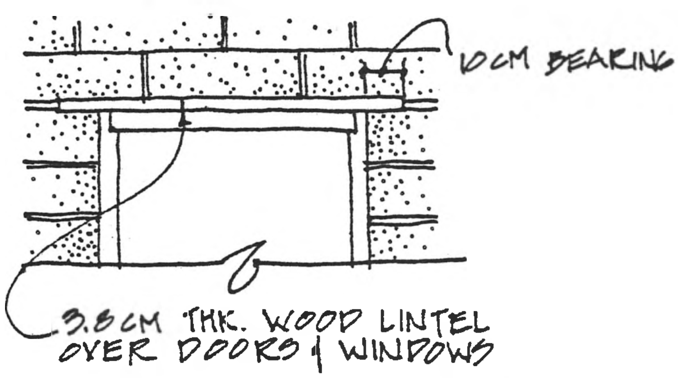
BUILDING SECTION

TYPICAL WALL SECTION



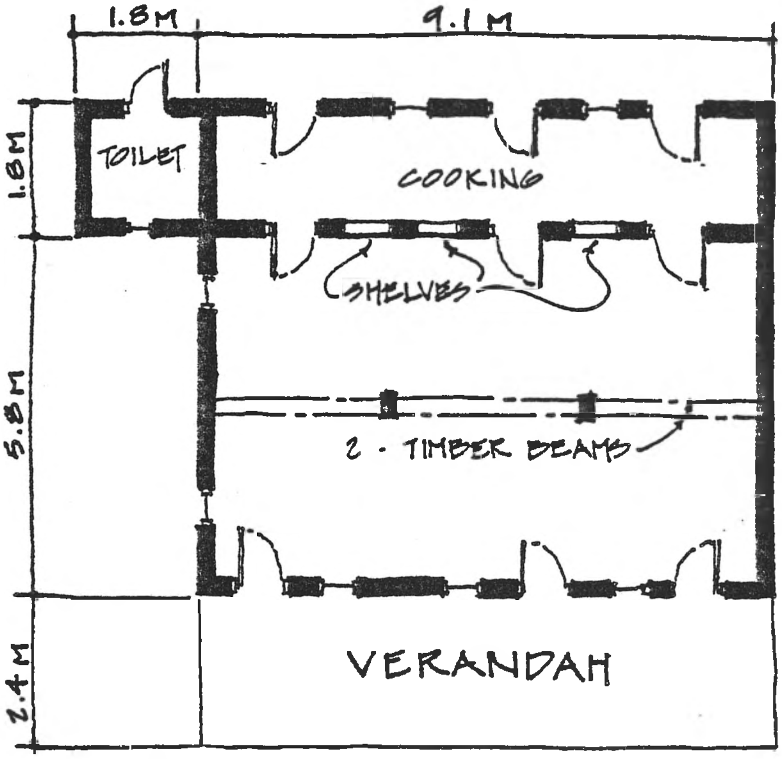


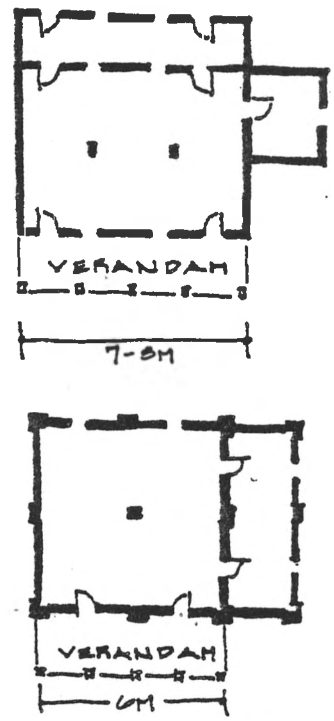
EAVE SECTION



LINTEL DETAIL

TYPICAL PLAN



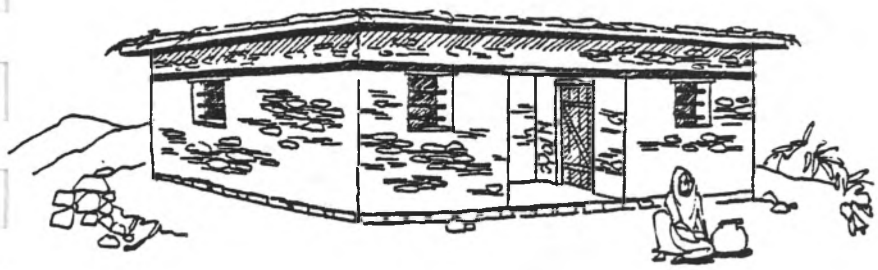


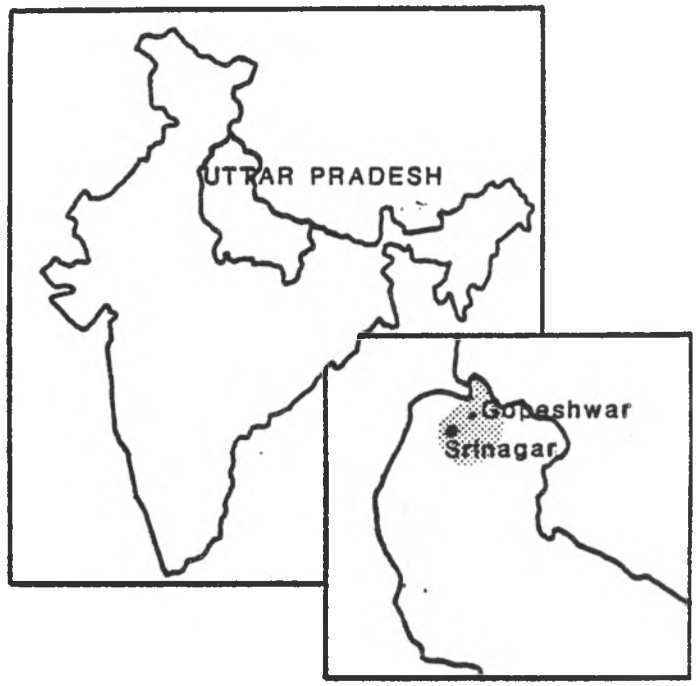
VARIATIONS

Seismic Resistance Evaluation									
GOOD	FAIR	POOR	N/A		GOOD	FAIR	POOR	N/A	
●				SITING		●			DOOR/WINDOW AREAS
●				SEPARATION BETWEEN BLDGS.		●			FOUNDATION-WALL CONNECTION
	●			FOUNDATION DESIGN	●				WALL-WALL CONNECTION
	●			BALANCE OF STRUCTURE		●			WALL-ROOF CONNECTION
	●			SHAPE OF PLAN			●		LIGHT WEIGHT WALLS
	●			CENTER OF GRAVITY			●		LIGHT WEIGHT ROOF
	●			RIGID WALLS	●				RING BEAM
		●		ROOF DESIGN	●				STRENGTH OF BLDG. MATERIALS
		●		PROJECTIONS & OVERHANGS			●		STRENGTH OF MORTAR
		●		DOOR/WINDOW LOCATIONS		●			QUALITY OF WORKMANSHIP

RECOMMENDATIONS FOR IMPROVEMENTS	DET. REF. NO.	% CONST. COST	MAN-DAYS
Utilize design principles of balance and shape of plan	-	-	-
Avoid extending the roof over later additions	-	-	-
Use heavier wood lintels over all openings	-	3	.5
Limit number of door and window openings	-	reduces	
Maintain minimum distances from corners for door and window openings	8	-	-
Improve detailing	-	1	4
Use cement mortar in walls and foundations	-	2	4
Use interior bearing walls or vertically reinforced pipe steel columns	-	2.5	8
Use RCC (reinforced concrete) ring beam	18	2	10
Embed steel reinforcing in wall for wall/ring beam connection with anchor bolts	-	.4	2
Use RCC lintels over openings	-	2	8
Add X bracing in plane of roof	1	.75	2
Add knee bracing in roof	2	.5	1

AVERAGE TOTAL COST OF HOUSE Rs 40,000





HOUSE TYPE: Stone with Flat RCC Roof

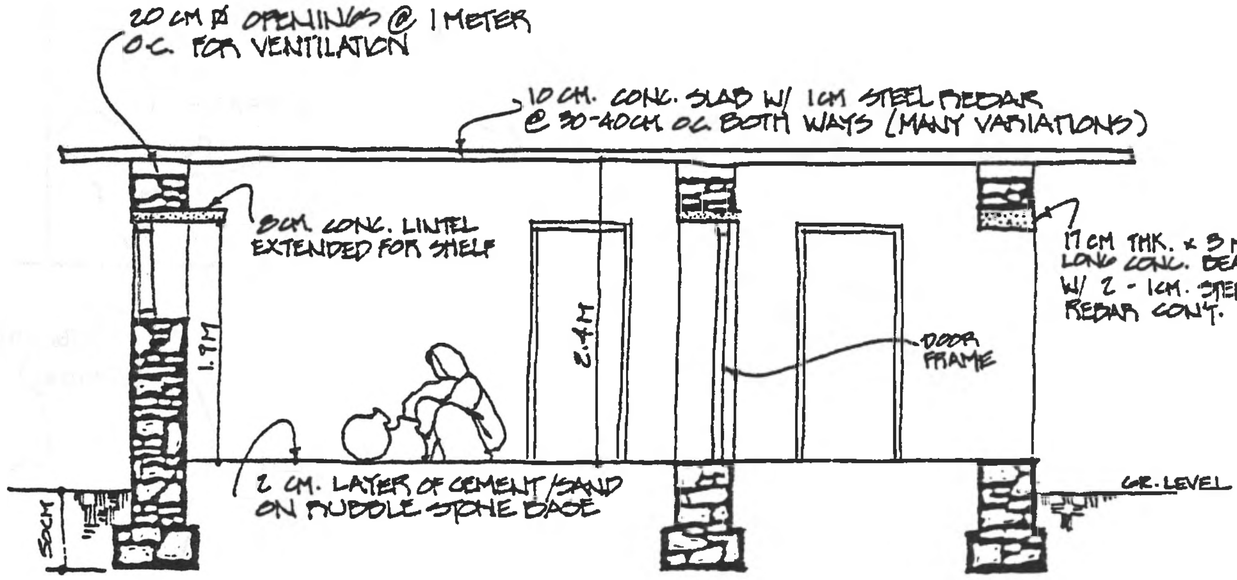
LOCATION: Gopeshwar/Srinagar, U.P.

FOUNDATION: The foundation is of cut stone in "miti" (clay mortar) 60 cm. wide by 50 cm. deep. The plinth level above ground is 15-25 cm., filled with rubble and packed earth as a base for the floor surfacing. The plinth is usually coated with a cement/sand plaster. Houses may be constructed on sloping terrain, in which case the hillside is excavated to form a flat base and the back wall acts as a retaining wall.

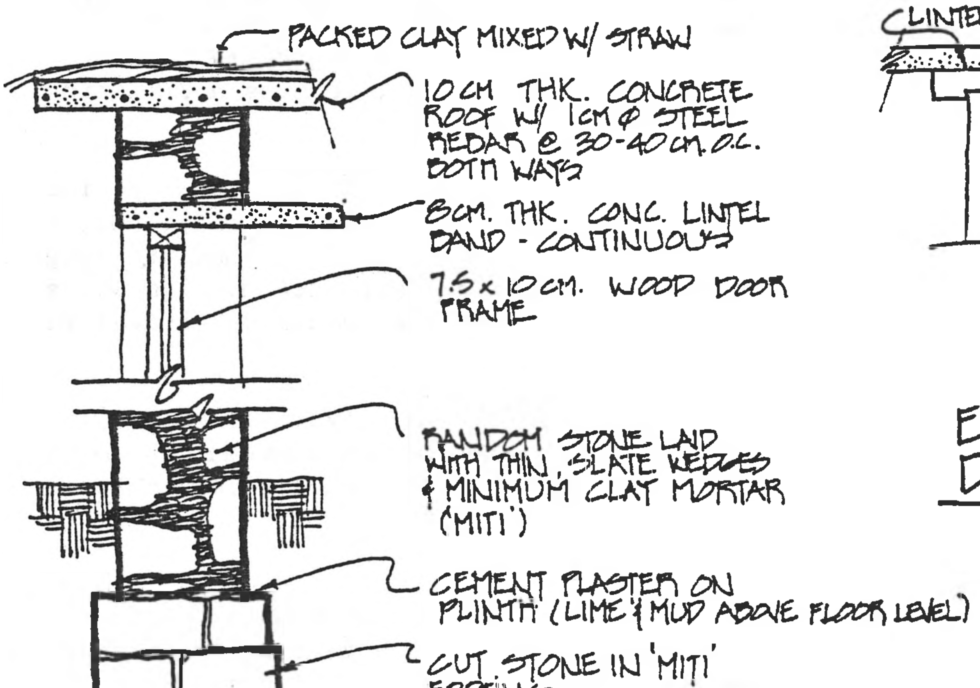
WALLS: Walls are 45 cm. wide random stone with slate composition with minimum use of a clay binder/mortar ("miti"). Walls are usually plastered with a lime and mud or mud and dung mixture. The houses are one-story with 2.4 m. high walls and an 8 cm. thick RCC (reinforced concrete) lintel at door and window height.

ROOF: The flat roof is RCC spanning 3.5 m. (typical) with 1 cm. mild steel rebar at 30-40 cm. on center in both directions. The roof slab is 10-15 cm. thick with some earth packing for surfacing.

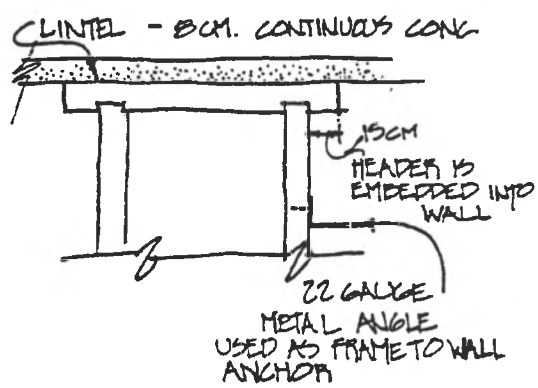
BEHAVIOR IN EARTHQUAKES: Extensive damage has occurred during earthquakes including cracking along mortar joints, both vertical cracks and cracking around wall openings.



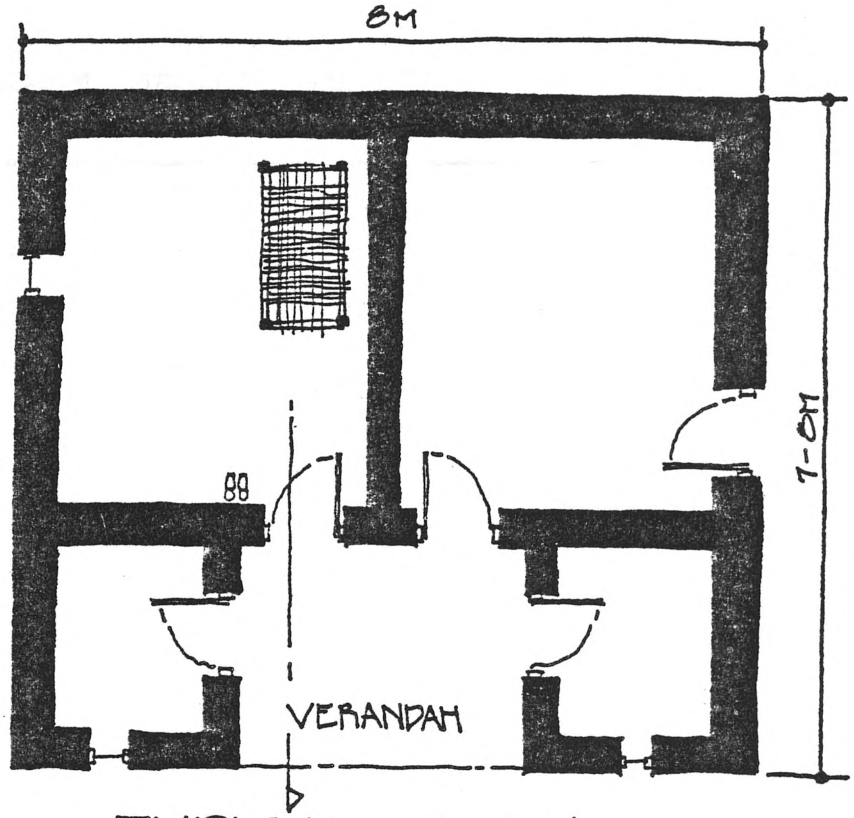
BUILDING SECTION



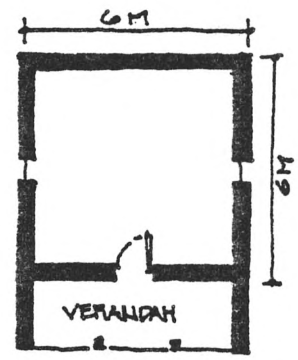
TYPICAL WALL SECTION



ELEVATION OF DOOR FRAME



TYPICAL PLAN



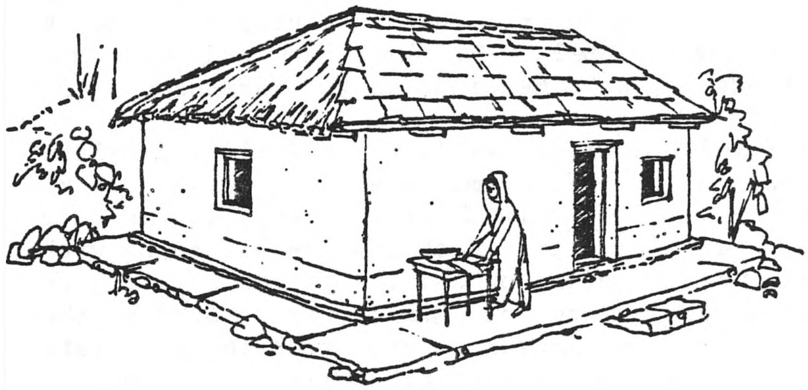
VARIATION

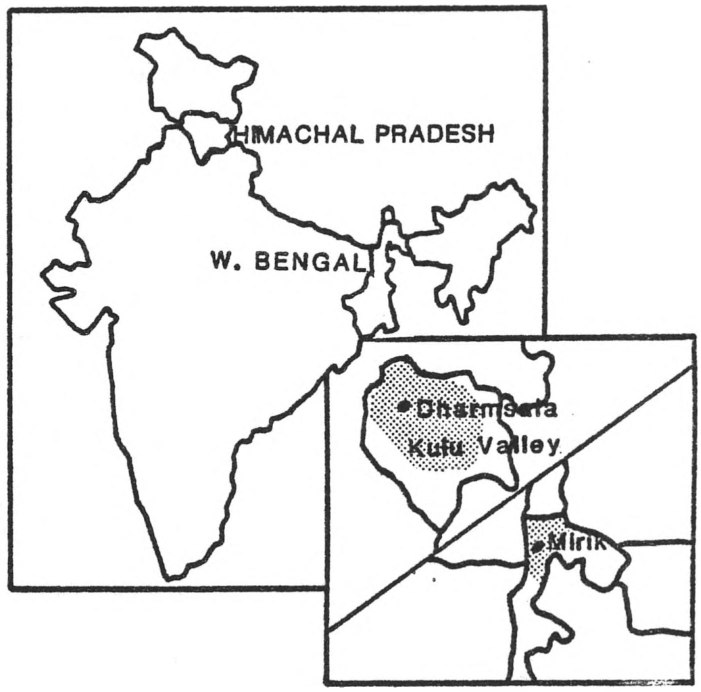
Seismic Resistance Evaluation

GOOD	FAIR	POOR	N/A		GOOD	FAIR	POOR	N/A	
●				SITING	●				DOOR/WINDOW AREAS
●				SEPARATION BETWEEN BLDGS.		●			FOUNDATION-WALL CONNECTION
●				FOUNDATION DESIGN		●			WALL-WALL CONNECTION
●				BALANCE OF STRUCTURE			●		WALL-ROOF CONNECTION
●				SHAPE OF PLAN			●		LIGHT WEIGHT WALLS
●				CENTER OF GRAVITY			●		LIGHT WEIGHT ROOF
		●		RIGID WALLS		●			RING BEAM
	●			ROOF DESIGN		●			STRENGTH OF BLDG. MATERIALS
	●			PROJECTIONS & OVERHANGS			●		STRENGTH OF MORTAR
●				DOOR/WINDOW LOCATIONS	●				QUALITY OF WORKMANSHIP

RECOMMENDATIONS FOR IMPROVEMENTS	DET. REF. NO.	% CONST. COST	MAN-DAYS
Use pilasters in walls	-	4	8
Steel reinforcing in walls	-	.5	2
Introduce bond stone concept	19	.4	1.75
Use cement mortar	-	10	6

AVERAGE TOTAL COST OF HOUSE Rs 20,000





HOUSING TYPE: Single-Story Stone

LOCATION: Darjeeling to Mirik, W. Bengal; Kulu Valley and Dharmsala, H.P.

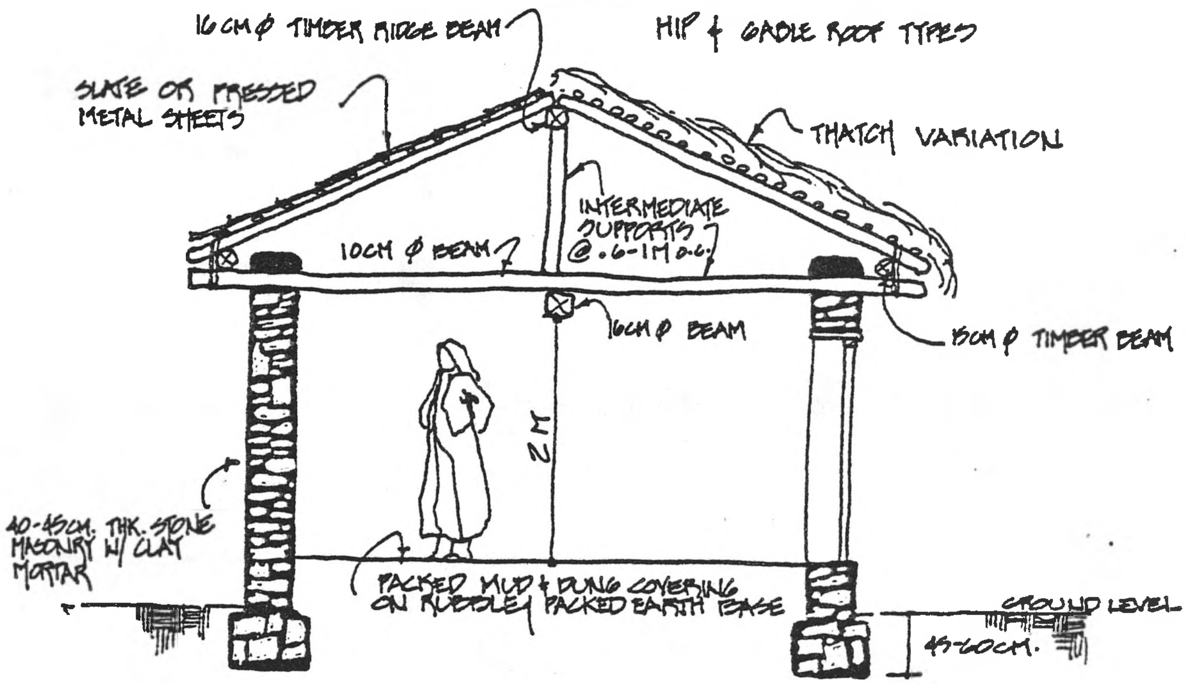
FOUNDATION: The foundation is 60 cm. wide x 45-60 cm. deep random or cut stone set in mud mortar. A mud stabilized with cement mortar is widely used in Darjeeling. The plinth height above ground is typically 20-40 cm. and it is filled with rubble and packed earth.

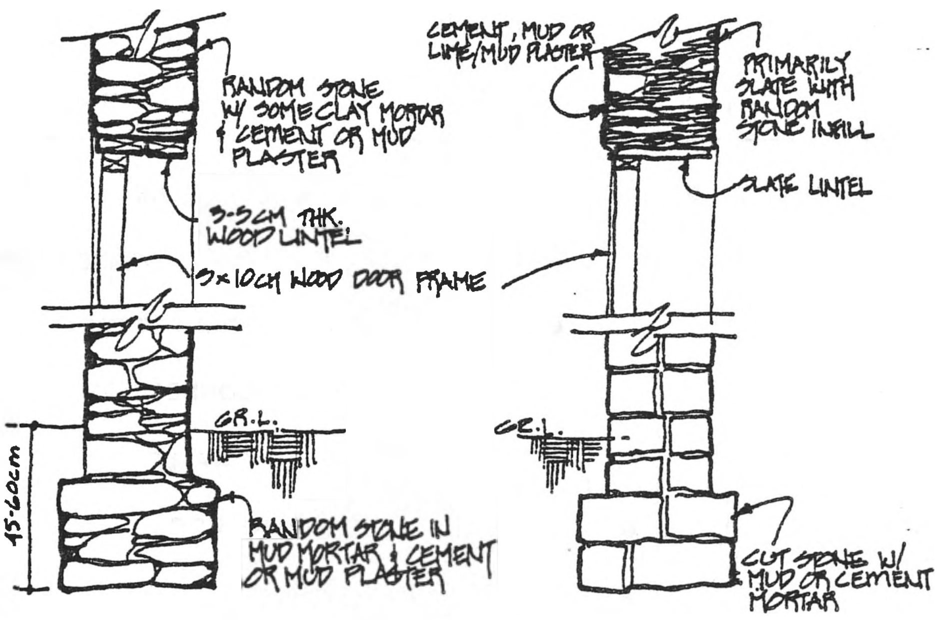
WALLS: Walls are 45 cm. wide x 2 m. height random stone with mud mortar and are plastered with a mud and dung or mud and cement mixture inside and out. Walls in the Kulu Valley and Dharmsala are predominantly slate mixed with random or cut stone laid without mortar and plastered with a mud or lime and mud mixture. Slate lintels extending 20-30 cm. into the wall are used over openings with this construction; and 3-5 cm. thick wood lintels are used in the Darjeeling area. Walls in Dharmsala and the Kulu Valley have 8-10 cm. square continous wood ring beams.

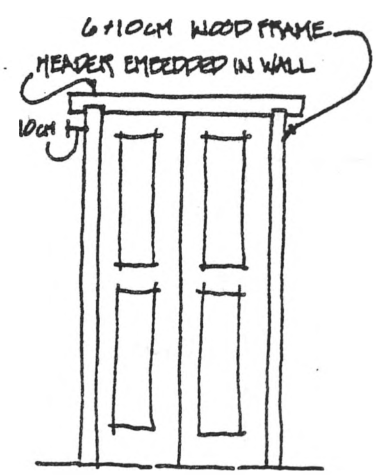
ROOF: Both hipped and gable roof types are found, with timber rafters 7-9 cm. in diameter at .6 - 1 m. spacing supporting slate shingles or thatch roofing. Slate roof pitches vary from 3:12 - 7:12; thatch roofs are typically 7:12 to 9:12 pitch.

HOUSE TYPE:	Slate, Stone and Slate, Stone
LOCATION:	Rural Dharmsala/Kulu Valley, H.P.
FOUNDATION:	The foundation is made of rubble stone, 90 cm. deep x 90 cm. wide, with mud mortar. The top course of stone is usually flat and level. In the Kulu Valley, the foundation extends to the dimensions of the verandah.
WALLS:	Typically in rural Dharmsala, walls are all slate or slate with stone coursing at 40-50 cm. intervals, 40 cm. thick. The stone coursing is itself irregular. In the Kulu Valley, walls are 40-45 cm. thick and are all stone with cut stone at the foundation and top of the walls; more irregular stone is in between. Mud mortar is used in the Kulu Valley, while no mortar is used with the all-slate and stone/slate houses of Dharmsala. Walls are one-story, up to 3 m. in height, and usually are finished with a mud plaster.
ROOF:	Roofs are constructed of cut slate shingles nailed on 2 cm. x 6 cm. purlins at 40 cm. on center. 6 cm. x 10 cm. rafters are placed at about 1.2 m. on center with 4 cm. x 9 cm. double cross ties on each rafter. Less expensive houses use bamboo framing in place of wood. Rafters bear on the ring beam. Both gable and hipped roofs are common. Some houses have a hip at one end and gable at the other.

BUILDING SECTION



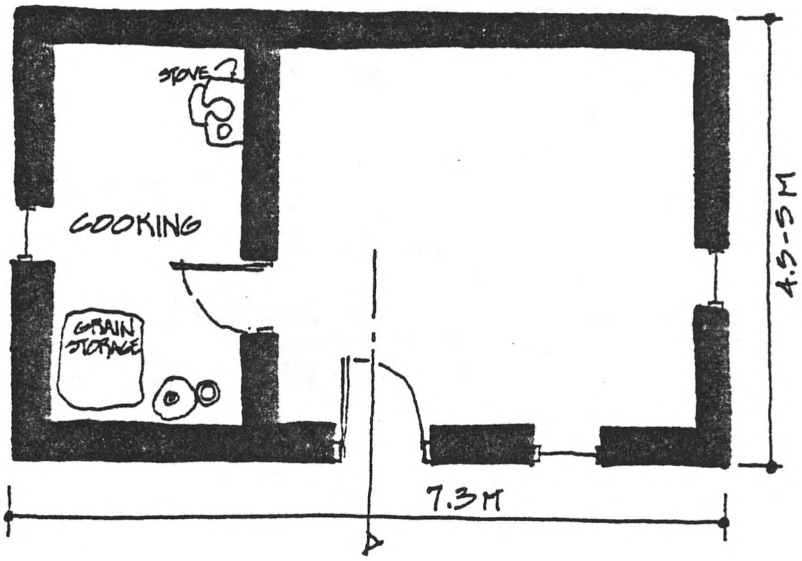




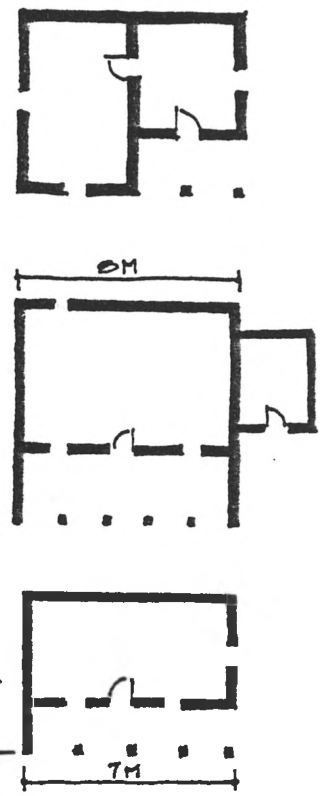
DOOR FRAME

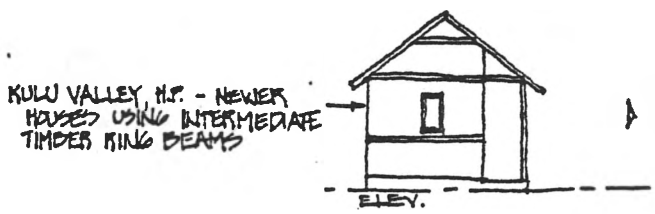
TYPICAL WALL SECTIONS

TYPICAL PLAN



VARIATIONS

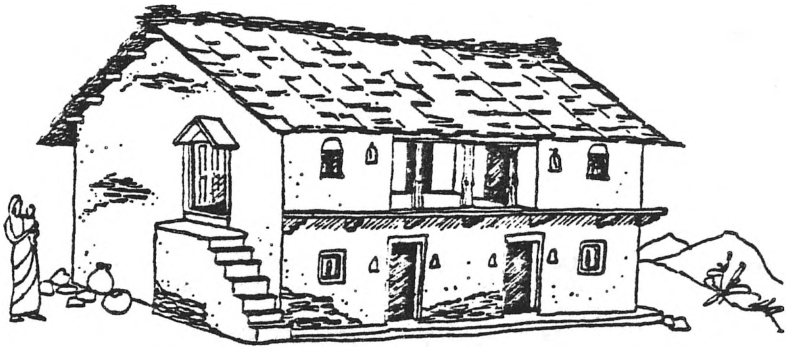




Seismic Resistance Evaluation									
GOOD	FAIR	POOR	N/A		GOOD	FAIR	POOR	N/A	
	●			SITING	●				DOOR/WINDOW AREAS
	●			SEPARATION BETWEEN BLDGS.			●		FOUNDATION-WALL CONNECTION
		●		FOUNDATION DESIGN			●		WALL-WALL CONNECTION
	●			BALANCE OF STRUCTURE			●		WALL-ROOF CONNECTION
	●			SHAPE OF PLAN			●		LIGHT WEIGHT WALLS
		●		CENTER OF GRAVITY		●			LIGHT WEIGHT ROOF
		●		RIGID WALLS		●			RING BEAM
	●			ROOF DESIGN		●			STRENGTH OF BLDG. MATERIALS
●				PROJECTIONS & OVERHANGS			●		STRENGTH OF MORTAR
●				DOOR/WINDOW LOCATIONS			●		QUALITY OF WORKMANSHIP

RECOMMENDATIONS FOR IMPROVEMENTS	DET. REF. NO.	% CONST. COST	MAN-DAYS
Use stepped foundation	11	1	2
Utilize design principles of balance of structure, shape of plan	-	-	-
Lower center of gravity by using lower walls	-	-	-
Use wood ring beam with hipped roof, support roof trusses on ring beam	-	.75-1.5	6
In walls more than one wythe thick, use through wall bond stones	19	.4	.5
Use cement mortar in foundation and in the walls	-	10	4
Use vertical steel reinforcing at corners and openings	-	4	2
Use thatch roof or improve roof construction design with slate roof	-	-	-
Insert reinforcing L angle of bamboo, steel, or wood at regular intervals of height of wall at corners and T junctions	7	2	2
Add X brace in plane of roof	1	1	2
Improve tie of rafters to ridge pole	-	.5	1

AVERAGE TOTAL COST OF HOUSE Rs 12,000



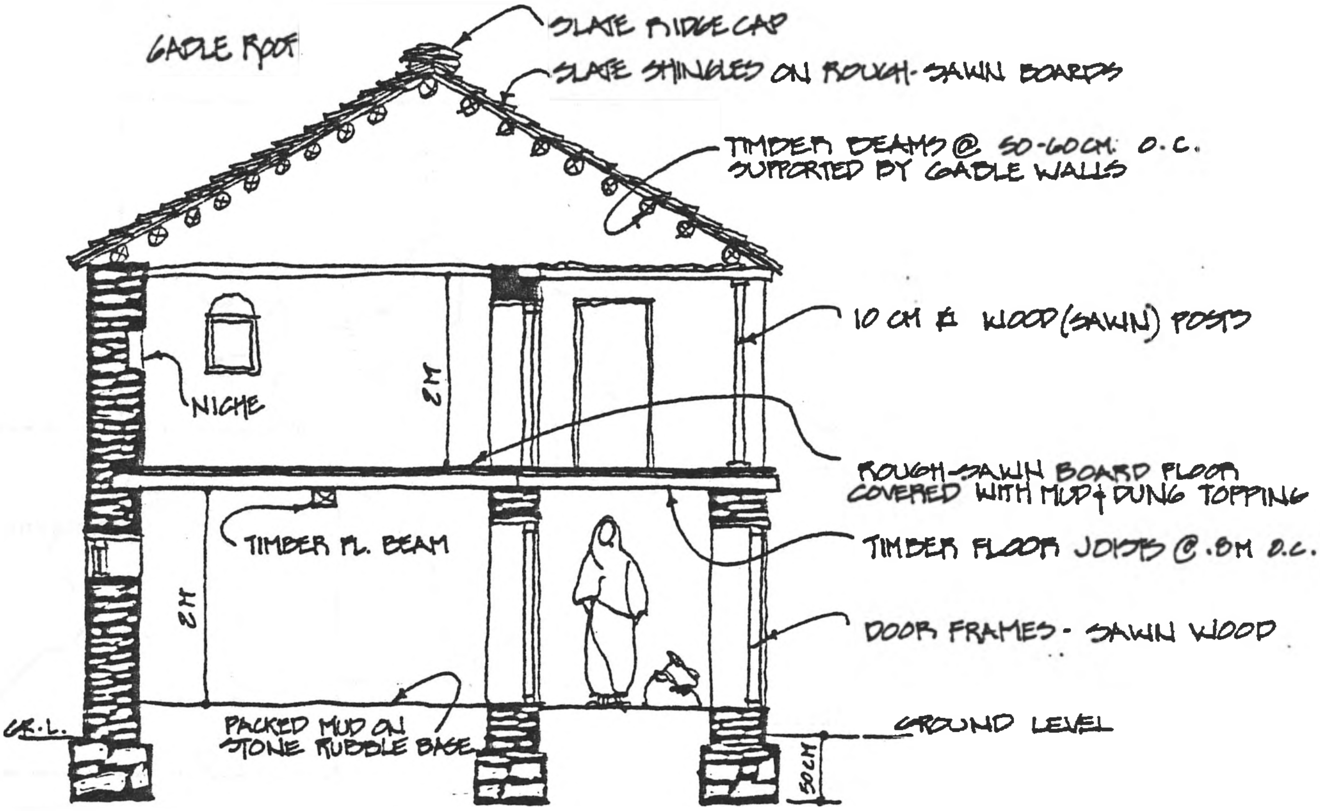
HOUSE TYPE: Two-Story Stone with Slate Roofs, Attached Housing

LOCATION: Upper Ganges Valley, U.P.

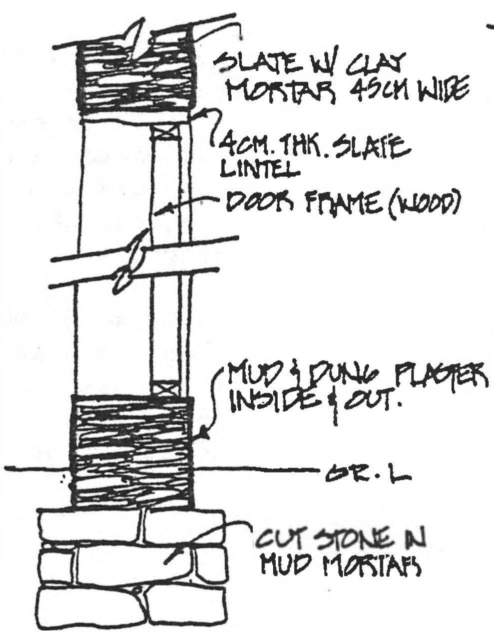
FOUNDATION: The foundation is 60 cm. wide x 50 cm. deep, consisting of cut stone in mud mortar, and forming a 45 cm. wide x 25 cm. height plinth infilled with rubble and packed earth.

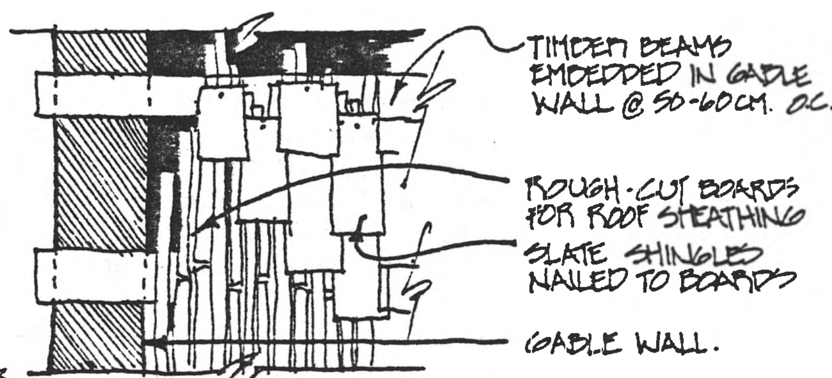
WALLS: The walls are 45 cm. wide x 4.2 m. height of slate with minimum clay mortar and a mud and dung plaster inside and out. Walls in Gujarat are constructed of random or cut stone 25-40 cm. wide x 4.2 m. height with mud mortar and mud and dung plaster inside and out. The second-level floor joists penetrate the walls. Either slate, cut stone or 3 cm. thick wood lintels are used over openings.

ROOF: In U.P., longitudinal timber beams spanning 3 m. at 50-60 cm. on center support wood slat sheathing and slate shingles nailed to the sheathing. Gujarat roofs use sawn or round wood rafters each at 60-70 cm. on center with 2.5 x 7 cm. purlins at 30 cm. on center, clad with "mangalore" clay tile.



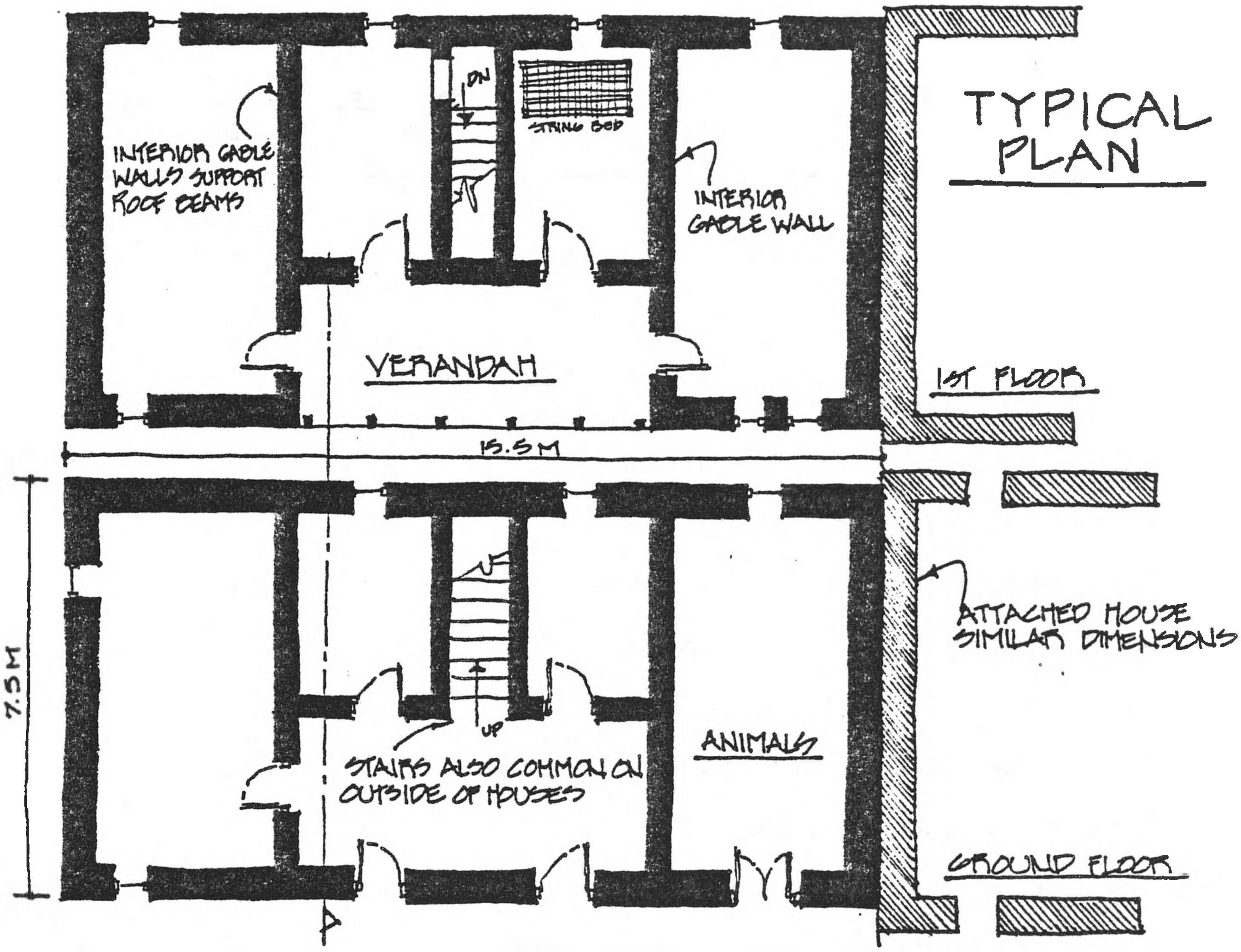
BUILDING SECTION





ROOF CONSTRUCTION
(PLAN VIEW)

TYPICAL WALL SECTION

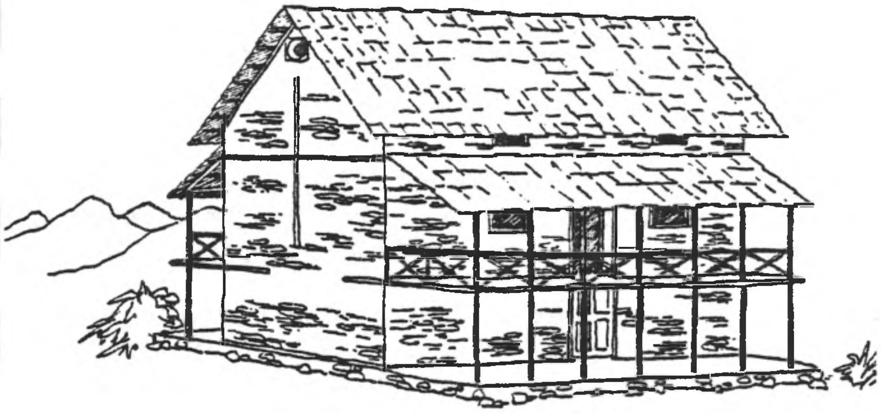


Seismic Resistance Evaluation

GOOD	FAIR	POOR	N/A		GOOD	FAIR	POOR	N/A	
	●			SITING	●				DOOR/WINDOW AREAS
		●		SEPARATION BETWEEN BLDGS.			●		FOUNDATION-WALL CONNECTION
	●			FOUNDATION DESIGN			●		WALL-WALL CONNECTION
●				BALANCE OF STRUCTURE			●		WALL-ROOF CONNECTION
	●			SHAPE OF PLAN			●		LIGHT WEIGHT WALLS
		●		CENTER OF GRAVITY			●		LIGHT WEIGHT ROOF
		●		RIGID WALLS			●		RING BEAM
		●		ROOF DESIGN	●				STRENGTH OF BLDG. MATERIALS
		●		PROJECTIONS & OVERHANGS			●		STRENGTH OF MORTAR
●				DOOR/WINDOW LOCATIONS		●			QUALITY OF WORKMANSHIP

RECOMMENDATIONS FOR IMPROVEMENTS	DET. REF. NO.	% CONST. COST	MAN-DAYS
Ise stepped foundations	11	1	2
Construct houses with crush joints between buildings	-	-	-
Construct only one-story buildings	-	-	-
Reduce or eliminate projections and overhangs	-	reduces	
Use cement in mortar at foundations	-	10	4
Install ring beam anchored to top of wall	18	8	6
Use cement mortar in wall construction	-	30	5
Add X bracing to truss construction	1	4	4
Use lightweight roof mat			
Extend floor joists through wall	9	1	-
Use a timber plate over gable end wall	-	1.5	2
Sse steel pins in corners	-	1	1
Insert reinforcing L angle of bamboo, steel, or wood at regular intervals of height of wall at corners and T junctions	7	1	4

AVERAGE TOTAL COST OF HOUSE Rs 20,000



HOUSE TYPE: Random Rubble Stone

LOCATION: Kulu Valley

FOUNDATION: The foundation is made of random rubble stone about 60 cm. wide with mud mortar. The top course is flat stone for the base of the walls.

WALLS: Walls are 40-45 cm. thick of random rubble stone; at the corners, the stone is typically cut and squared. Walls are typically 2 or 2 1/2 stories at the central "core" house, with one-story stone walls at perimeter additions which infill a surrounding verandah. The second-story verandah is either open or infilled with wood panels and windows. The first and second floors and verandah are framed with 10 cm. x 10 cm. crossbeams that penetrate the walls. The verandah roof frames into a wood ring beam; however, the stone wall continues over it, forming the attic level. The heights of longitudinal walls range from 4.8 m. to 3 m. For gable roofs, the gable end wall is all stone to the ridge and is without a continuous ring beam at the top of the wall.

ROOF: Slate shingles are used on either hipped or gable framing. A central ridge pole bears on the gable end wall and interior partitions. 5 cm. x 10 cm. rafters are located at 1 m. on center with 2 cm. x 7 cm. purlins.

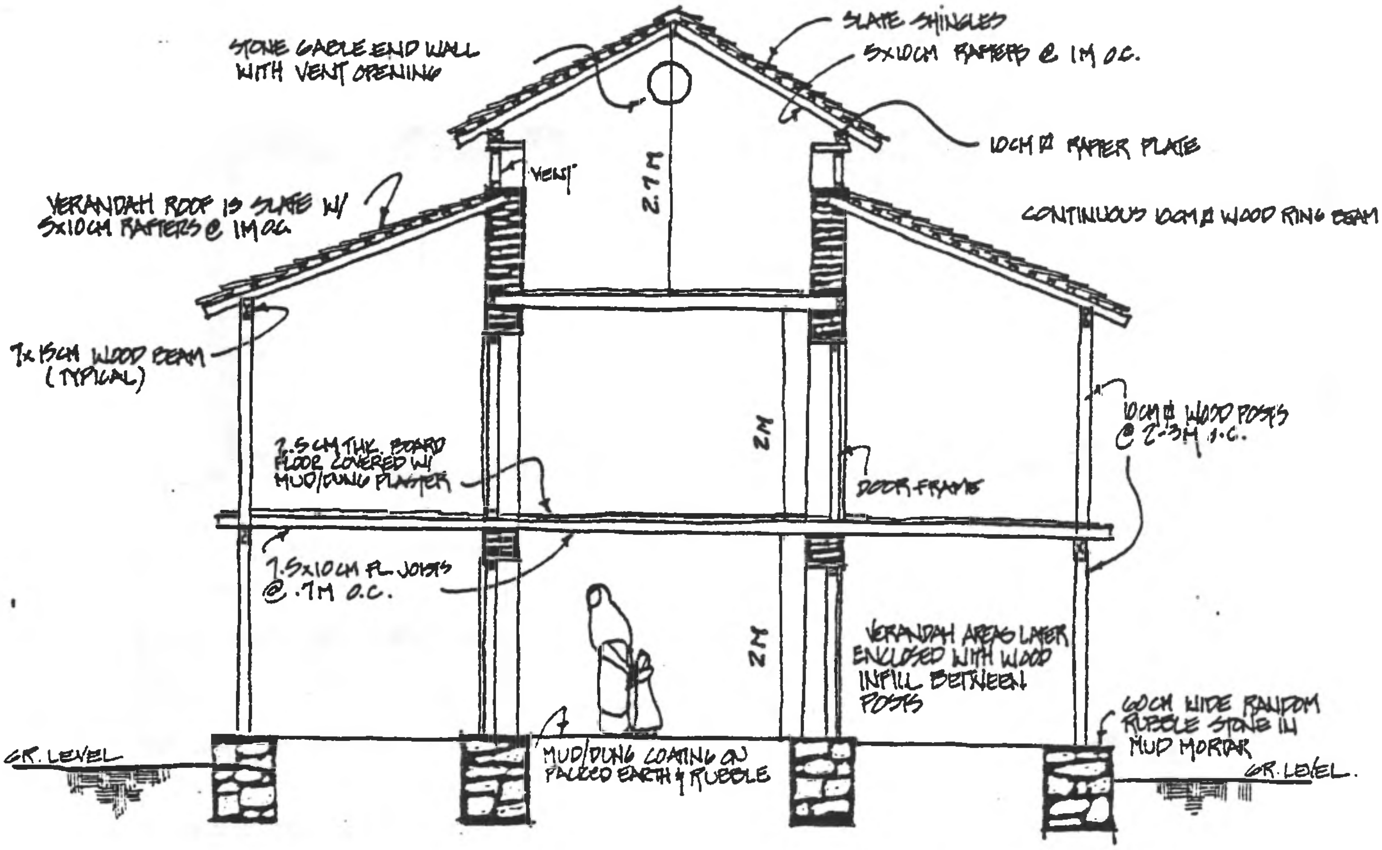
BEHAVIOR IN EARTHQUAKES: Several buildings with heavy roof and timber trusses resting on random rubble stone walls in mud mortar have collapsed completely during earthquakes. Other damage includes vertical cracks from roof to floor, bulging of side walls, failure in roof truss, and falling plaster. Serious cracking around wall openings is frequent.

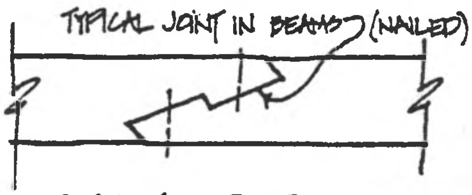
The principal reasons for failure are weak mortar, lack of through stones from outer face to inner face of walls, and poor workmanship.

In the Nepal-India border earthquake of 1980, considerable damage to random rubble stone masonry occurred. Gable end walls collapsed, resulting in partial collapse of the adjacent wall and consequent collapse of the roof. Failure of timber posts and rafters also resulted in collapse of some roofs. Considerable cracking developed in walls. Walls generally failed in the direction in which the least stiffness or support was available.

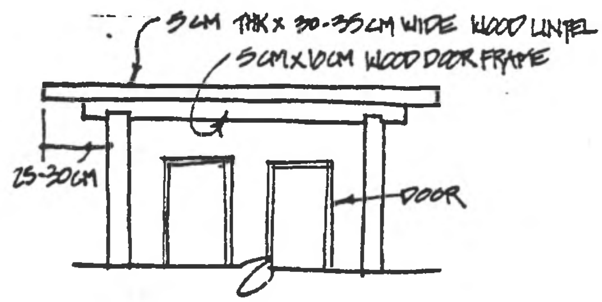
Free-standing random stone masonry walls in cement mortar with vertical steel at corners and openings did not show any damage nor development of cracks in the mortar. Dry-packed stone masonry walls with a continuous lintel band over openings and cross walls did not suffer any damage.

BUILDING SECTION

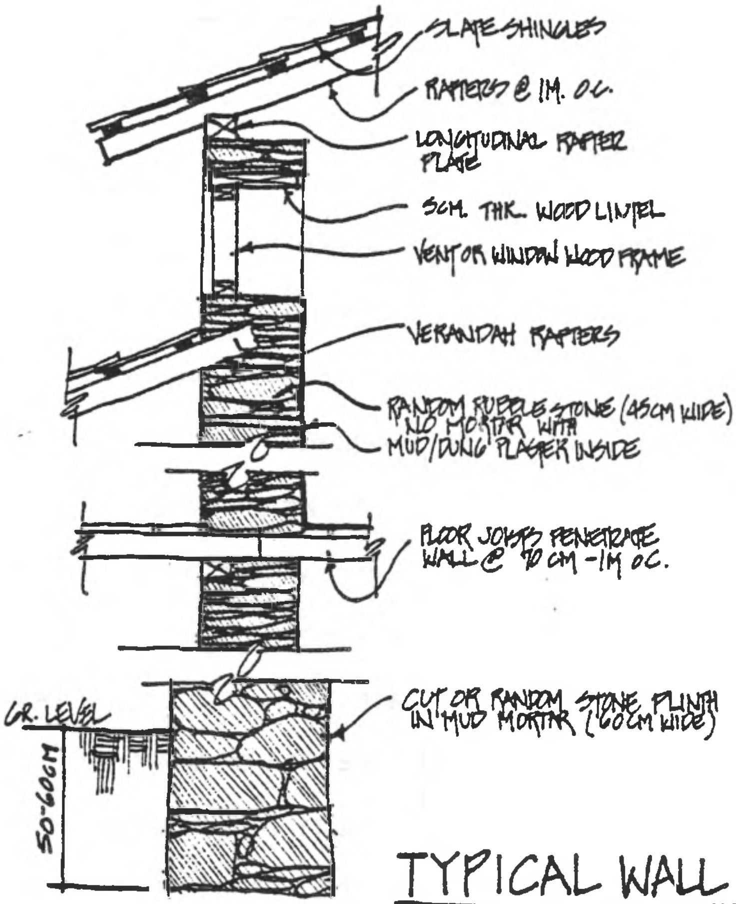




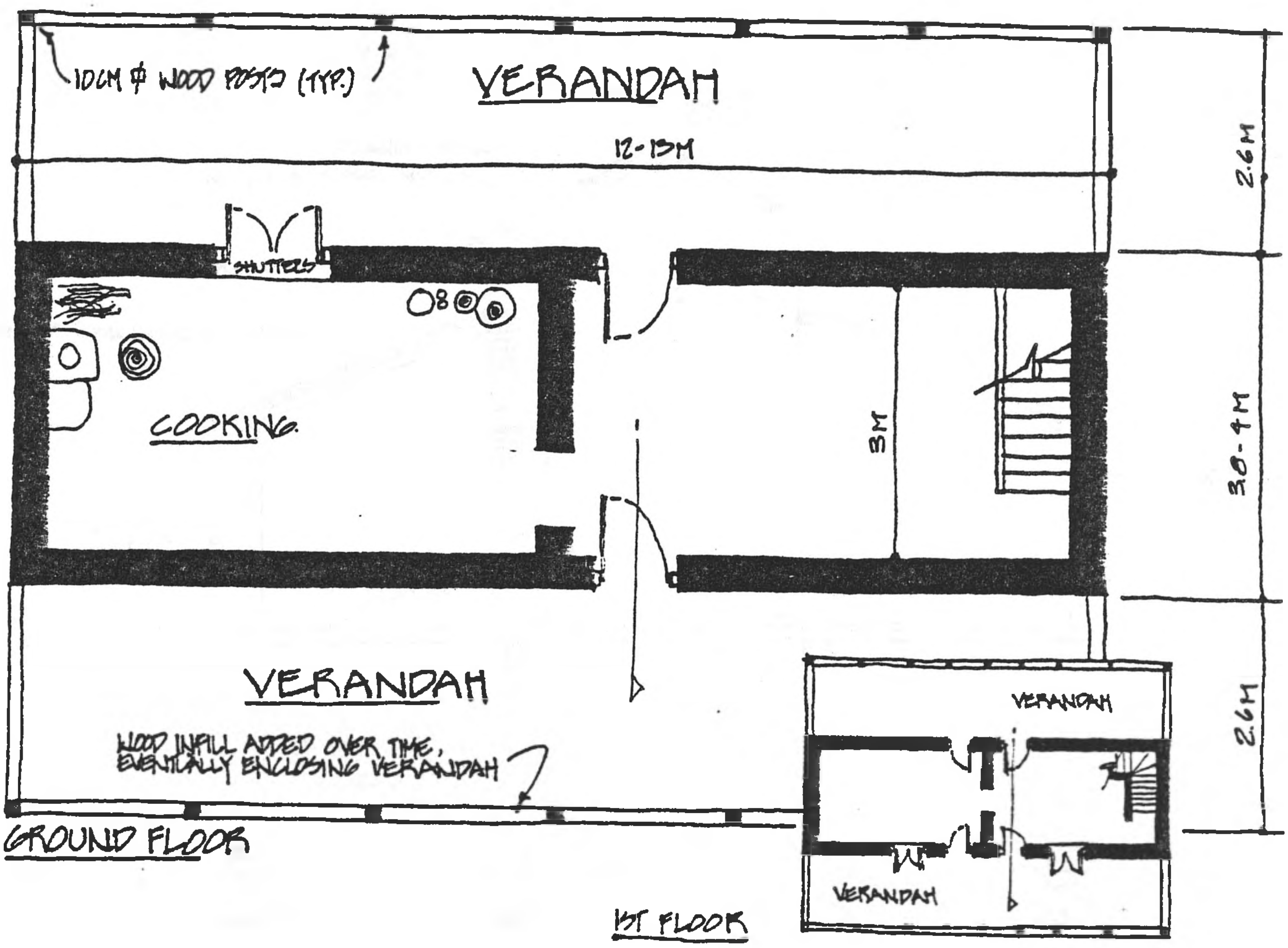
BEAM DETAIL



LINTEL DETAIL



TYPICAL WALL SECTION

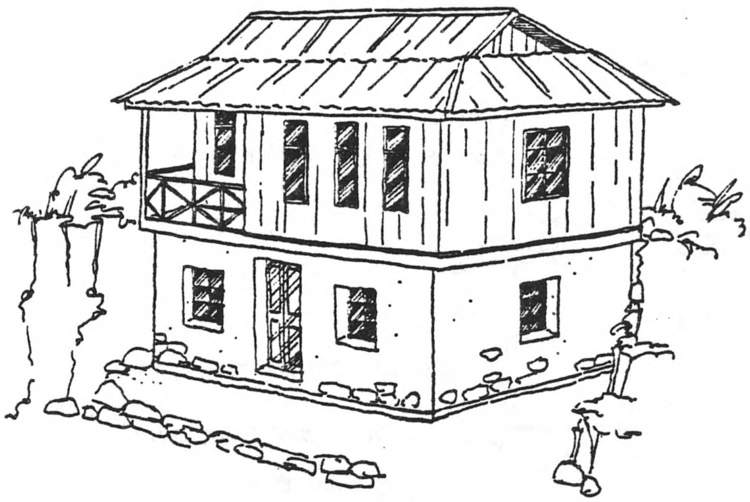


Seismic Resistance Evaluation

GOOD	FAIR	POOR	N/A		GOOD	FAIR	POOR	N/A	
●				SITING		●			DOOR/WINDOW AREAS
●				SEPARATION BETWEEN BLDGS.		●			FOUNDATION-WALL CONNECTION
	●			FOUNDATION DESIGN				●	WALL-WALL CONNECTION
	●			BALANCE OF STRUCTURE				●	WALL-ROOF CONNECTION
		●		SHAPE OF PLAN				●	LIGHT WEIGHT WALLS
		●		CENTER OF GRAVITY				●	LIGHT WEIGHT ROOF
		●		RIGID WALLS		●			RING BEAM
	●			ROOF DESIGN	●				STRENGTH OF BLDG. MATERIALS
		●		PROJECTIONS & OVERHANGS			●		STRENGTH OF MORTAR
	●			DOOR/WINDOW LOCATIONS	●				QUALITY OF WORKMANSHIP

RECOMMENDATIONS FOR IMPROVEMENTS	DET. REF. NO.	% CONST. COST	MAN-DAYS
Use stepped foundations	11	1	2
Construct only one-story buildings	-		reduces
Use ring beam and hipped roof design, eliminate gable end wall	18	3	3
Use cement in mortar at foundations	-	5	4
Use cement mortar in wall construction	-	25	8
Add X bracing to truss construction	1	8	4
Use lightweight roof materials	-	7	-
Use a timber plate over gable end wall	-	1	2
Use steel pins in corners	-	1	1
Insert reinforcing L angle of bamboo, steel, or wood at regular intervals of height of wall at corners and T junctions	7	1	4
Improve connection of lower roof to wall detail	17	1	2
Use diagonal braces in verandah columns	-	3	4

AVERAGE TOTAL COST OF HOUSE Rs 40,000 +



HOUSE TYPE: Two-Story Stone and Wood Frame

LOCATION: Darjeeling area, W. Bengal

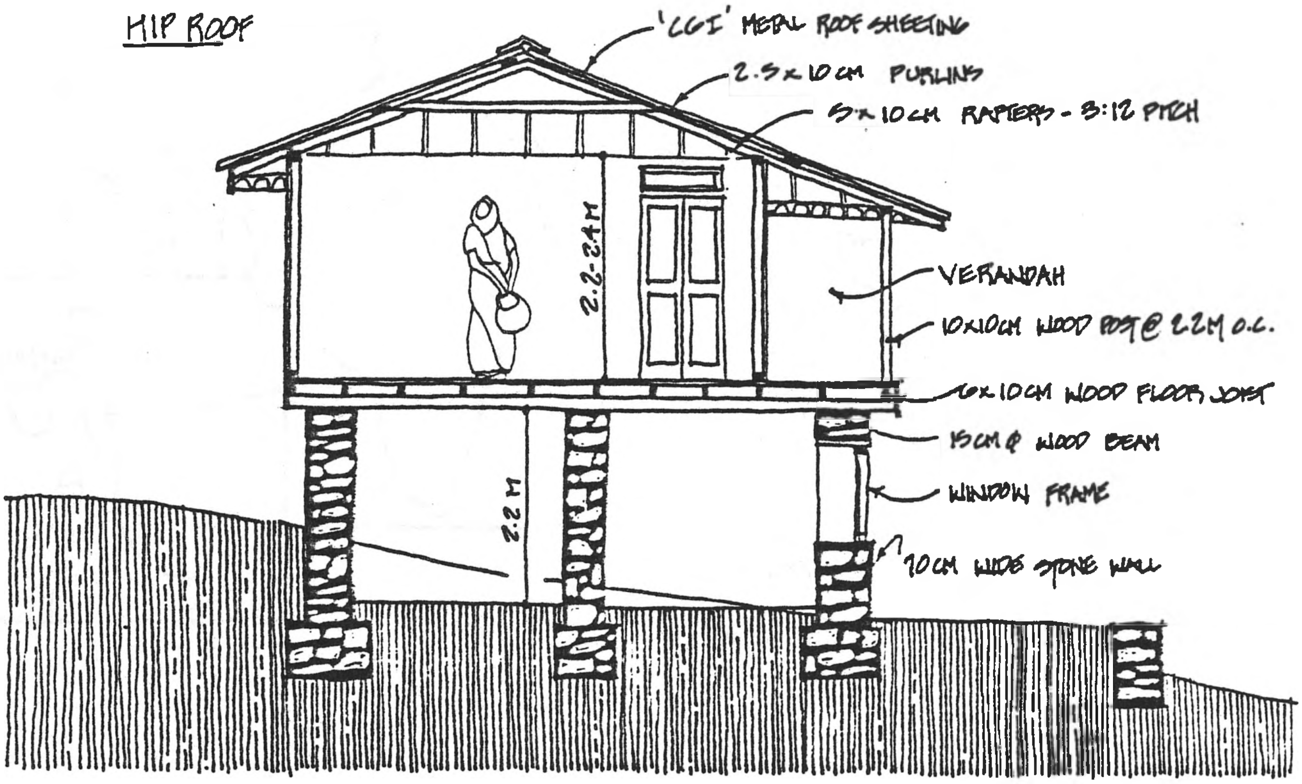
FOUNDATION: The foundation is random stone, without mortar, 50-60 cm. deep.

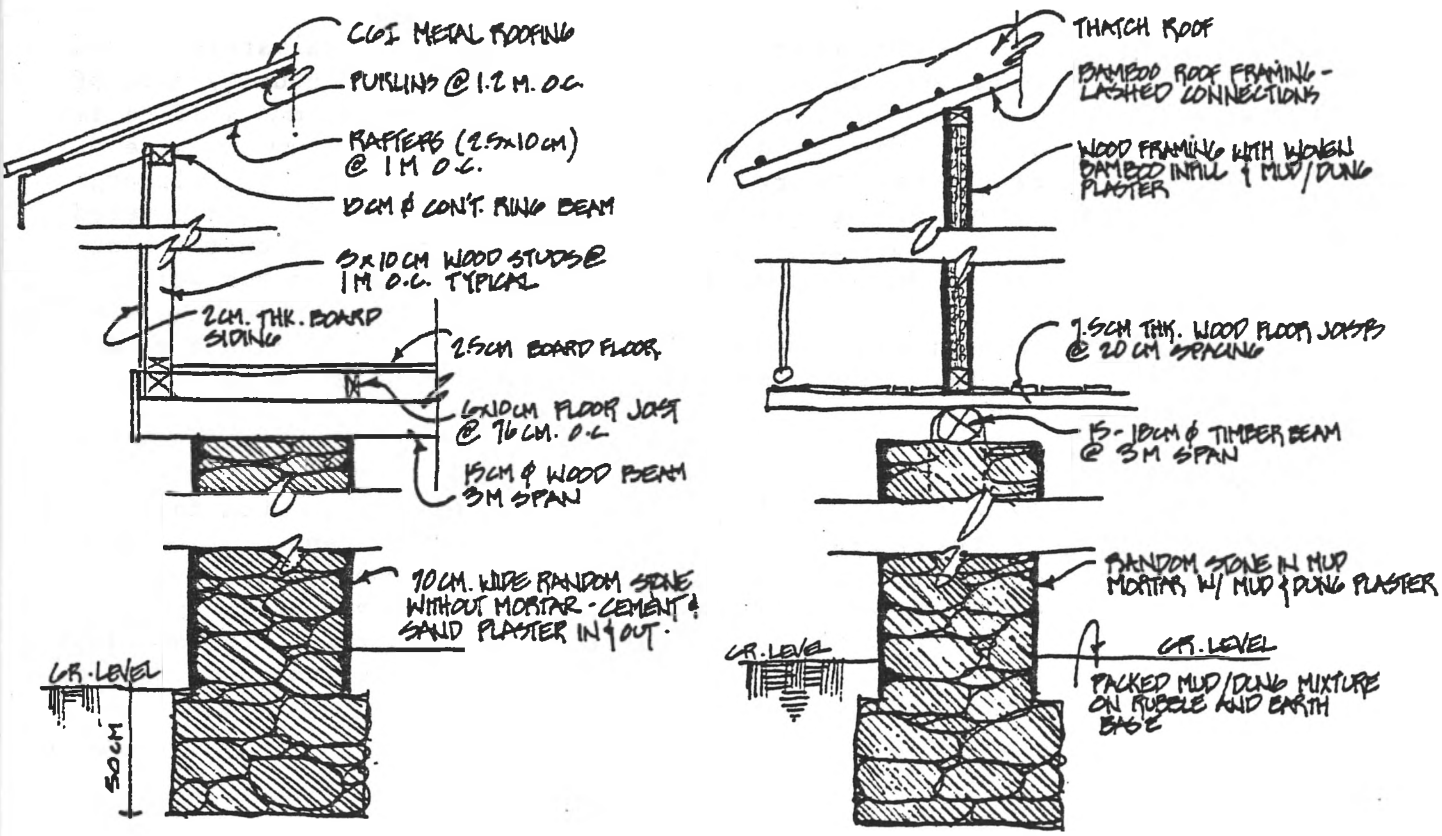
WALLS: The lower story is of random stone approximately 70 cm. wide and 1.9 - 2.0 m. high. The mortar is usually made of mud and dung, although sometimes a lime and mud mixture is used. The wood frame of the upper story is made of rough-cut boards covered with wood siding, although sometimes a woven bamboo frame is attached and covered with mud/dung plaster. The frame rests on the floor joists which either rest on or are embedded in the walls.

ROOF: Most houses have C.G.I. sheet roofs attached to a wooden frame. Some houses with bamboo/mud walls have thatch roofs.

BEHAVIOR IN EARTHQUAKES: This house is believed to be an adaptation for both earthquakes and the climate. The low center of gravity and lightweight upper story, if strongly built, should offer good performance for a two-story house. However, low-strength mortar, lack of vertical reinforcement, and lack of a ring beam at the top of the stone wall would result in poor performance.

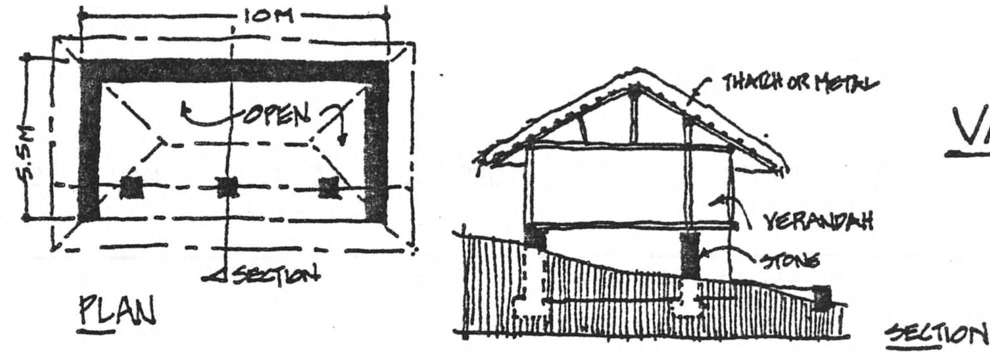
BUILDING SECTION



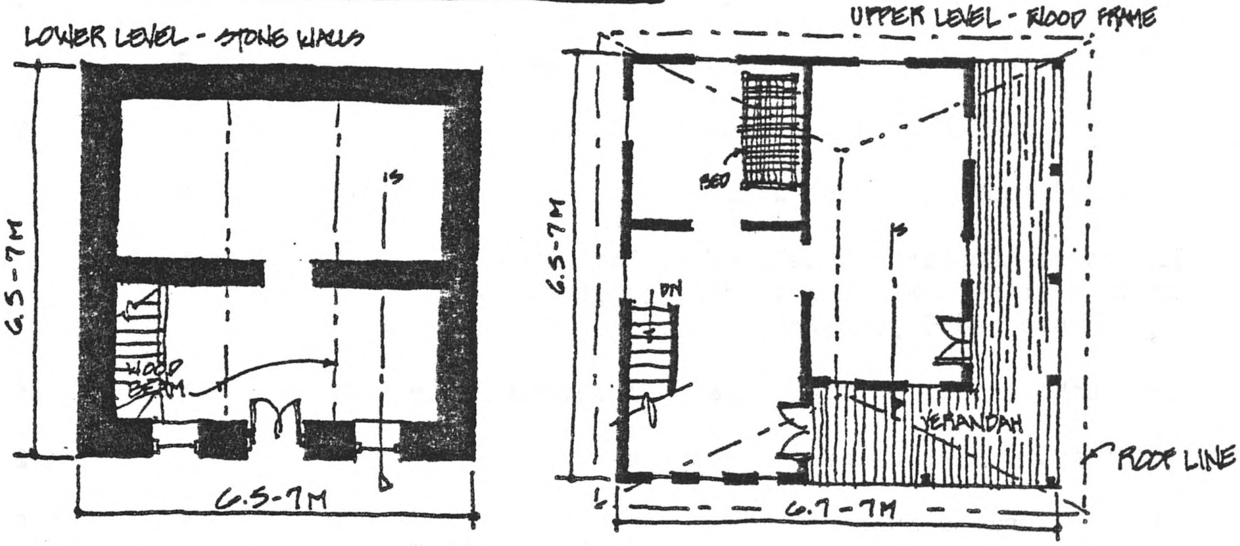


TYPICAL WALL SECTIONS

VARIATION



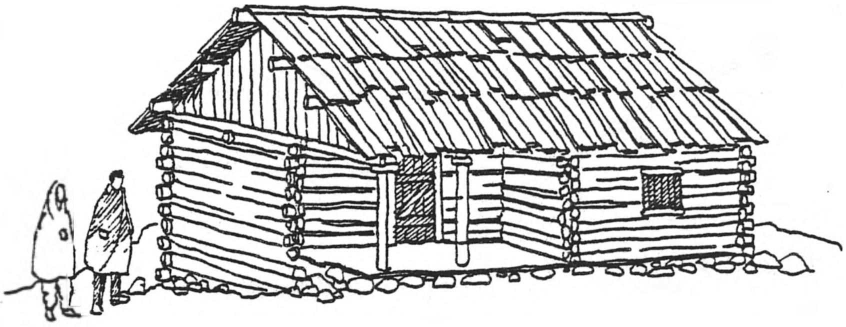
TYPICAL PLAN



Seismic Resistance Evaluation									
GOOD	FAIR	POOR	N/A		GOOD	FAIR	POOR	N/A	
●				SITING	●				DOOR/WINDOW AREAS
●				SEPARATION BETWEEN BLDGS.		●			FOUNDATION-WALL CONNECTION
	●			FOUNDATION DESIGN			●		WALL-WALL CONNECTION
●				BALANCE OF STRUCTURE		●			WALL-ROOF CONNECTION
●				SHAPE OF PLAN	●				LIGHT WEIGHT WALLS
●				CENTER OF GRAVITY		●			LIGHT WEIGHT ROOF
●				RIGID WALLS		●			RING BEAM
		●		FLOOR TO FLOOR CONNECTIONS					
●				ROOF DESIGN	●				STRENGTH OF BLDG. MATERIALS
●				PROJECTIONS & OVERHANGS			●		STRENGTH OF MORTAR
●				DOOR/WINDOW LOCATIONS		●			QUALITY OF WORKMANSHIP

RECOMMENDATIONS FOR IMPROVEMENTS	DET. REF. NO.	% CONST. COST	MAN-DAYS
Use cement mortar for foundations and walls	-	12	5
Use pilasters in walls	-	6	4
Add ring beam at top of stone walls	15	5	7
Increase depth of foundation to 80 cm	-	1.5	4
Reinforce corners with poured RCC columns	-	7	12- 14
Pour RCC ring beam and attach to columns	18	8	9
Use bond stone in stone walls	19	.5	-
Insert reinforcing L angle of bamboo, steel, or wood at regular intervals of height of wall at corners and T junctions	7	1	2
Use anchor bolts between first and second floor	-	1	.5
Add X and corner braces in wood walls	3	4	2
Add knee braces in roof	2	1	1.5

AVERAGE TOTAL COST OF HOUSE Rs 18,000



HOUSE TYPE: Log

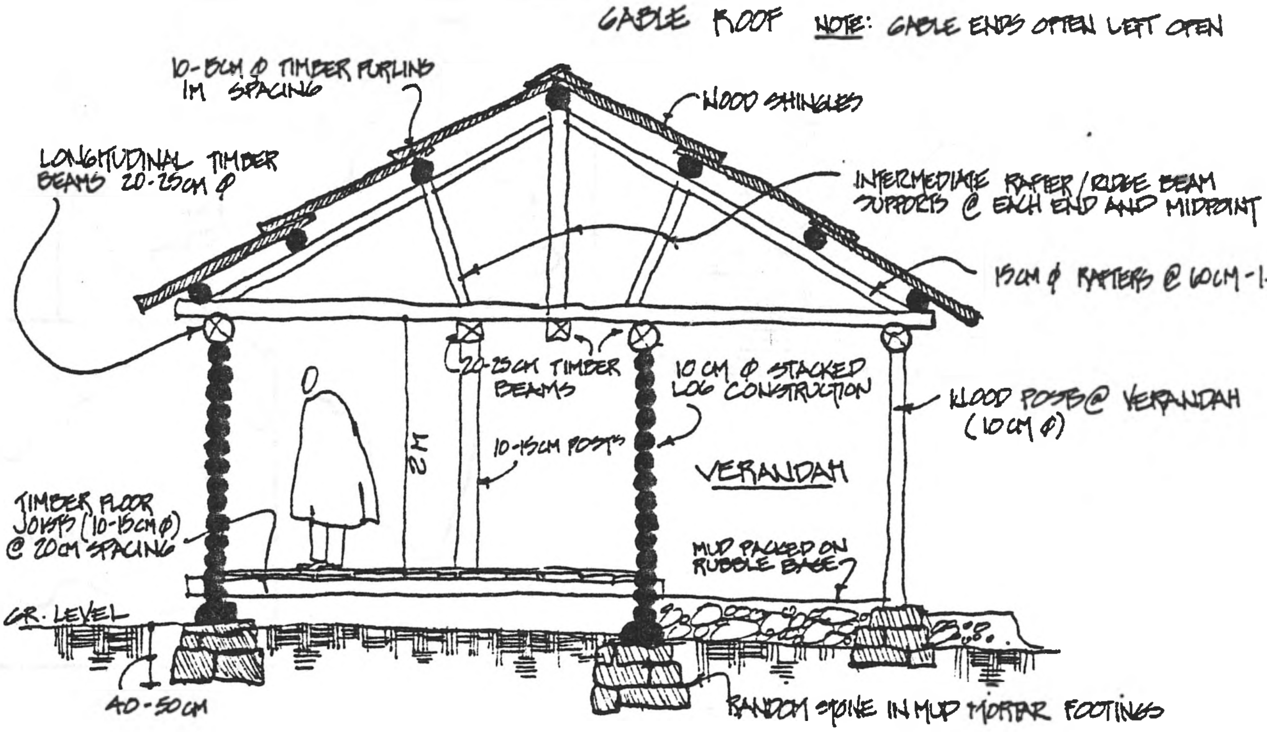
LOCATION: Pahlgam Area, Jammu & Kashmir

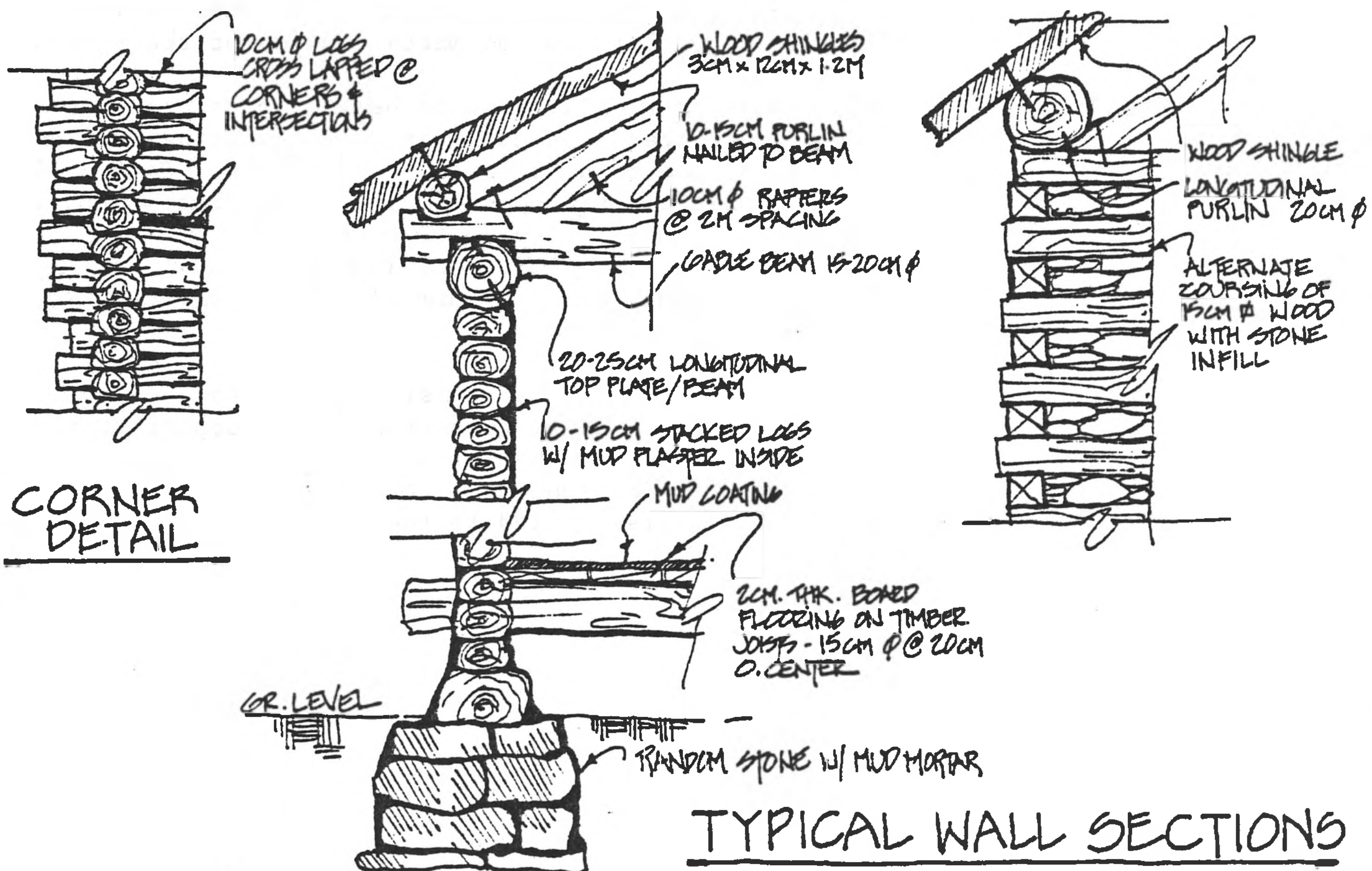
FOUNDATION: The foundation is 60 cm. wide x 40 cm. deep random and cut stone in mud mortar, plastered with mud. A 15 x 22 cm. timber sill is laid in mud mortar on top of the stone.

WALLS: Walls are typically 2 m. in height, constructed of 10-15 cm. round timber logs cut flat on the bearing surfaces and notched at the corners to form cross ties. Some walls are constructed using 15 x 15 cm. square timber with 15 cm. thick stone infill between timbers. A 20 cm. round timber is used as a longitudinal rafter plate. Walls are plastered with mud on the inside and partially outside near the ground.

ROOF: Gable-type roofs are constructed with 20-25 cm. round timber beams at 1.5 m. on center which support timber roof trusses at .6-1 m. spacing with 10-15 cm. diameter timber purlins at 1 m. spacing. The roofing material is 1.2 m. long wood shingles nailed to the purlins.

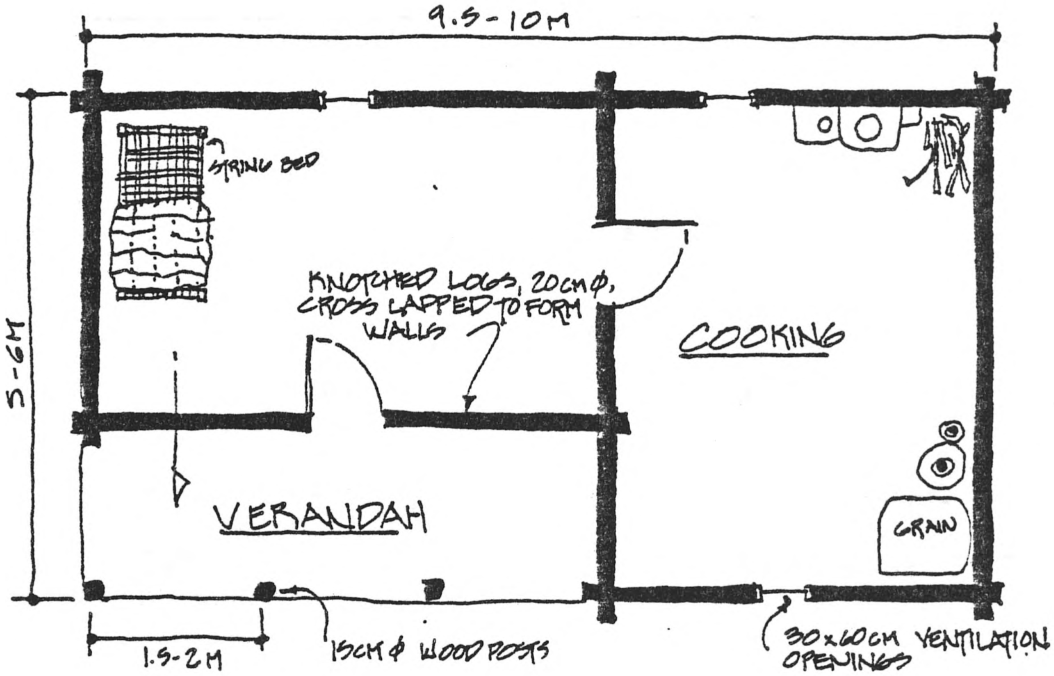
BUILDING SECTION



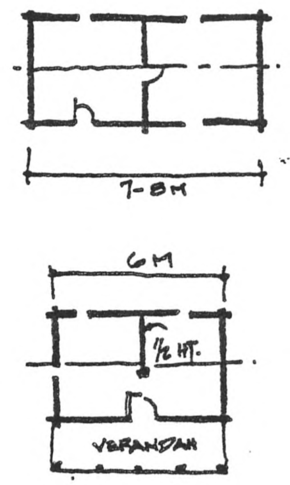


TYPICAL WALL SECTIONS

TYPICAL PLAN



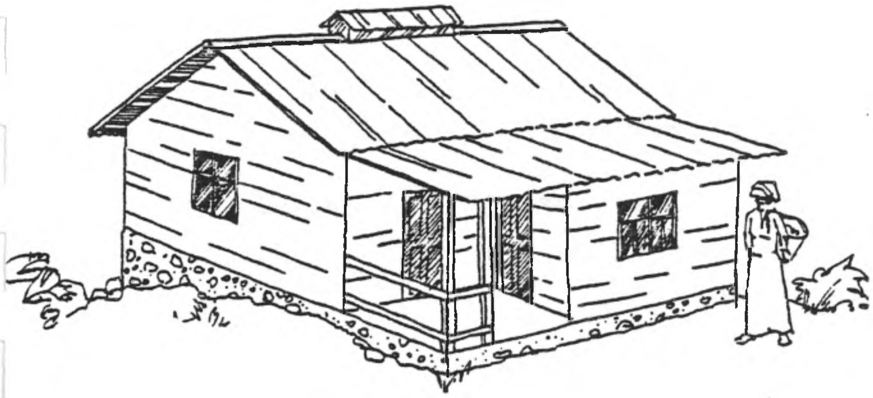
VARIATIONS



Seismic Resistance Evaluation									
GOOD	FAIR	POOR	N/A		GOOD	FAIR	POOR	N/A	
●				SITING	●				DOOR/WINDOW AREAS
●				SEPARATION BETWEEN BLDGS.			●		FOUNDATION-WALL CONNECTION
		●		FOUNDATION DESIGN	●				WALL-WALL CONNECTION
	●			BALANCE OF STRUCTURE		●			WALL-ROOF CONNECTION
		●		SHAPE OF PLAN			●		LIGHT WEIGHT WALLS
		●		CENTER OF GRAVITY		●			LIGHT WEIGHT ROOF
		●		RIGID WALLS			●		RING BEAM
		●		ROOF DESIGN	●				STRENGTH OF BLDG. MATERIALS
	●			PROJECTIONS & OVERHANGS				●	STRENGTH OF MORTAR
●				DOOR/WINDOW LOCATIONS		●			QUALITY OF WORKMANSHIP

RECOMMENDATIONS FOR IMPROVEMENTS	DET. REF. NO.	% CONST. COST	MAN-DAYS
Use cement mortar in foundations	-	15	6
Anchor sill plates to foundation	-	1	1
Use spikes to secure logs to one another	-	15	4
Use adequate lashing at wall-to-roof connections and rafter/purlin connections	5	5	2
Reduce the size of the rafter plate in walls	-	-	-
Use post-and-beam construction technique (common in some newer houses) with wood sheathing	-	100	-
Add X bracing to roof framing	1	8	2
Add diagonal corner braces in plane of roof	2	4	1.5

AVERAGE TOTAL COST OF HOUSE Rs 2-3,000



HOUSE TYPE: Wood

LOCATION: Kalimpong

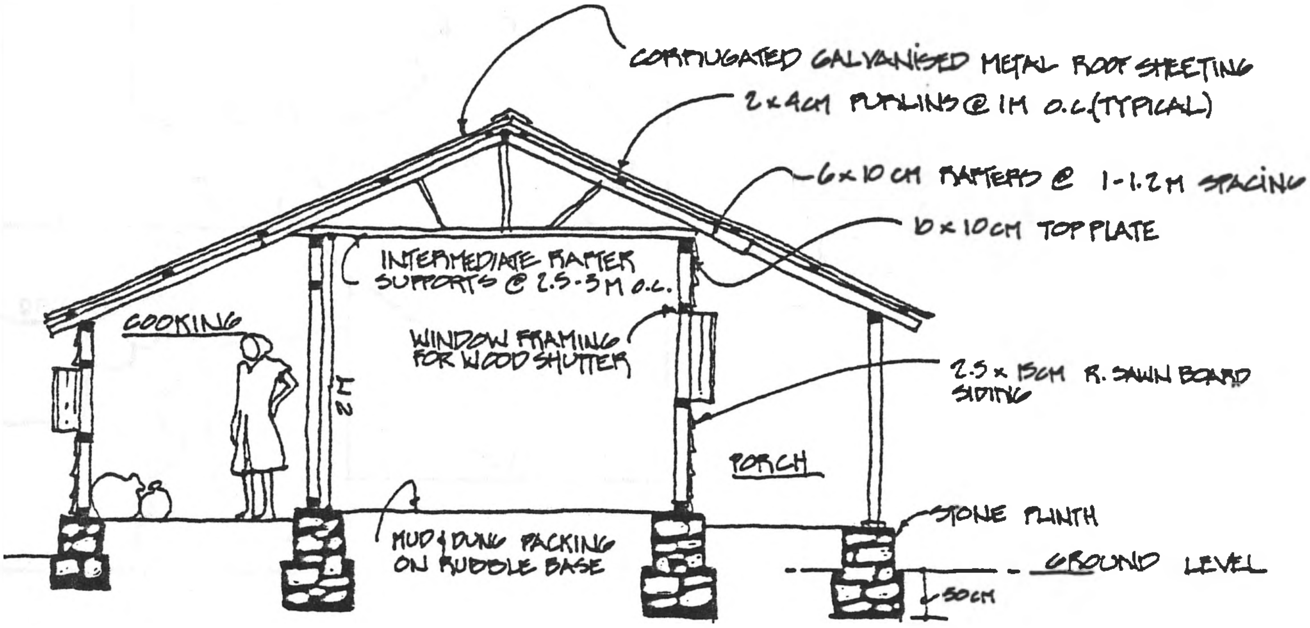
FOUNDATION: The foundation is constructed of random stone with mud or cement/sand mortar, usually 60 cm. wide x 50 cm. deep below ground level and 45 cm. wide x 45-50 cm. height above ground, forming a plinth filled with rubble and packed earth.

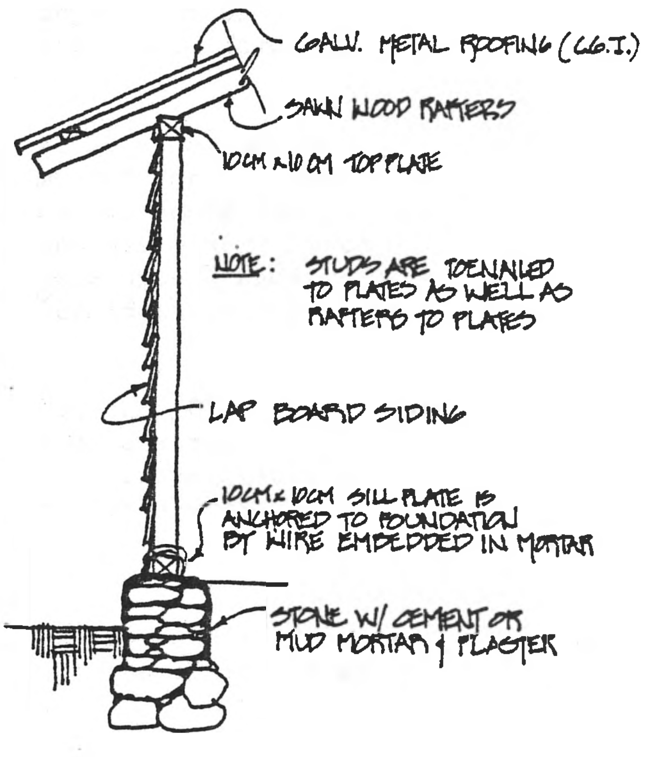
WALLS: Walls consist of sawn wood framing, 5 x 10 cm., with studs at 1.2 - 1.5 m. on center and 10 cm. square top and bottom plates. Bottom plates are often tied to the stone plinth by wrapping a light-gauge wire around the plate and embedding it in the foundation wall. Lapped, rough sawn board siding is attached. The corners have short 45° braces at the bottom plates.

ROOFS: Roofs are predominantly gable-type using 6 x 10 cm. wood rafters at 1 - 1.2 m. spacing and 2 x 4 cm. purlins at 1 m. on center supporting galvanized metal roof sheets. The roof pitch is usually 2:12 or 3:12. Intermediate rafter supports are usually employed at 2.5 - 3 m. on center.

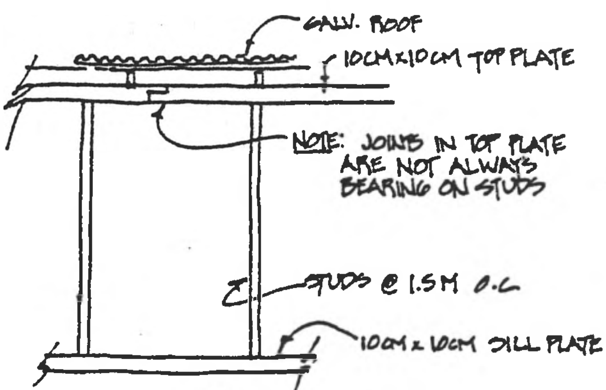
BEHAVIOR IN EARTHQUAKES: Timber houses have performed very well in earthquakes due to the high tensile strength of the materials and the ductility of the structure.

BUILDING SECTION

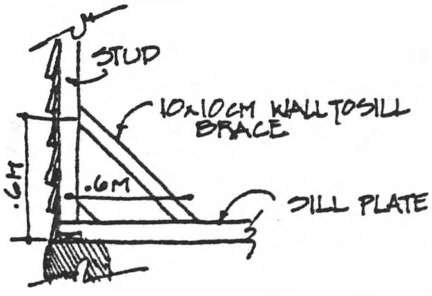




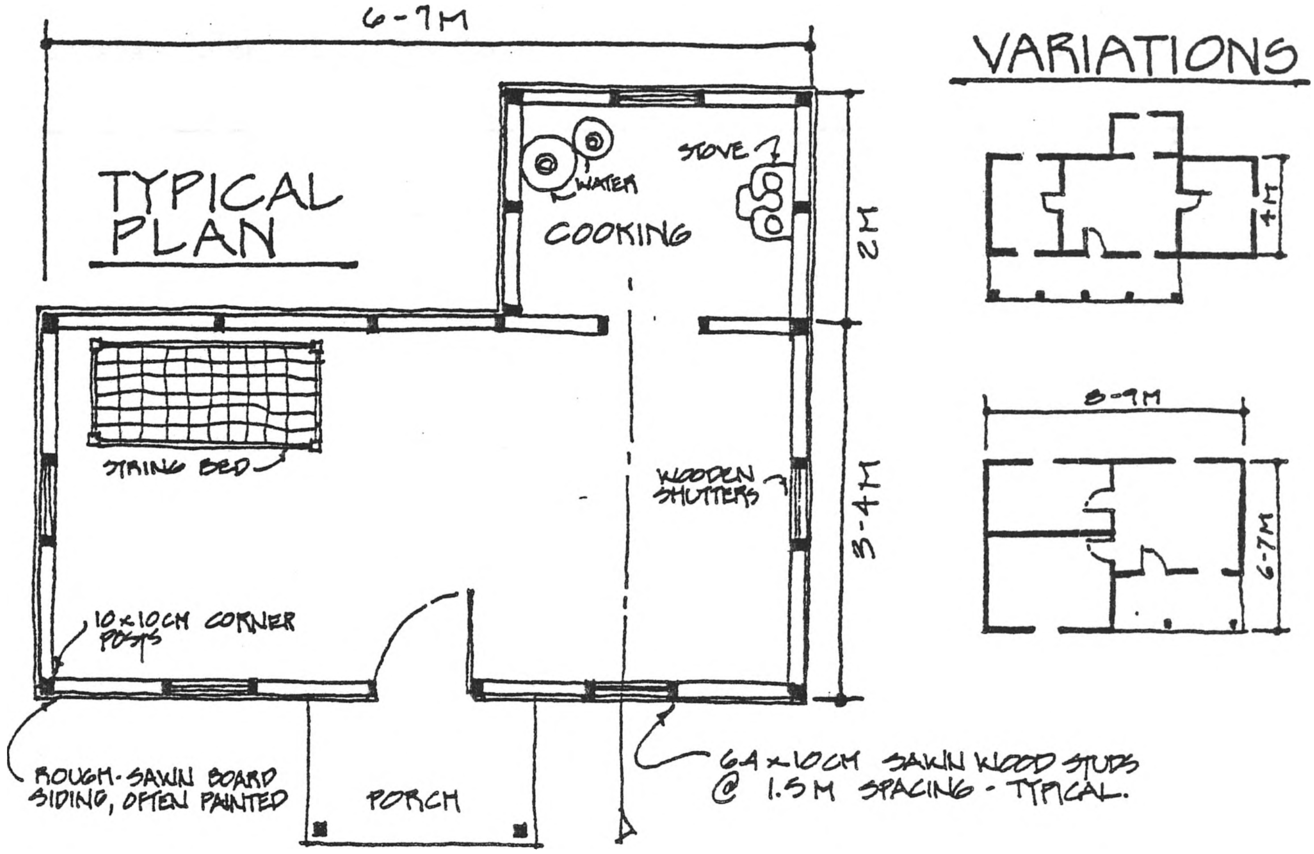
TYPICAL WALL SECTION



DETAIL OF WOOD FRAMING



DETAIL OF CORNER BRACING

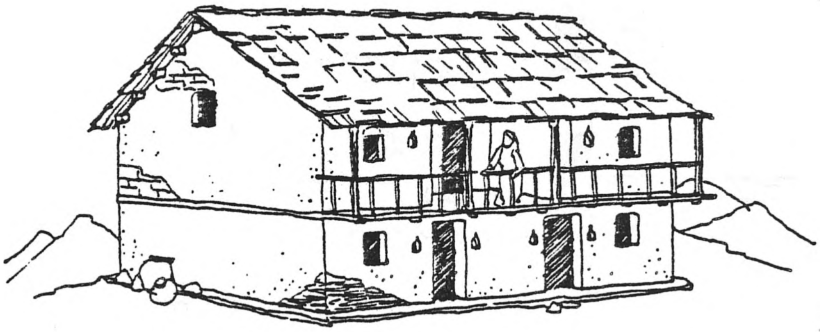


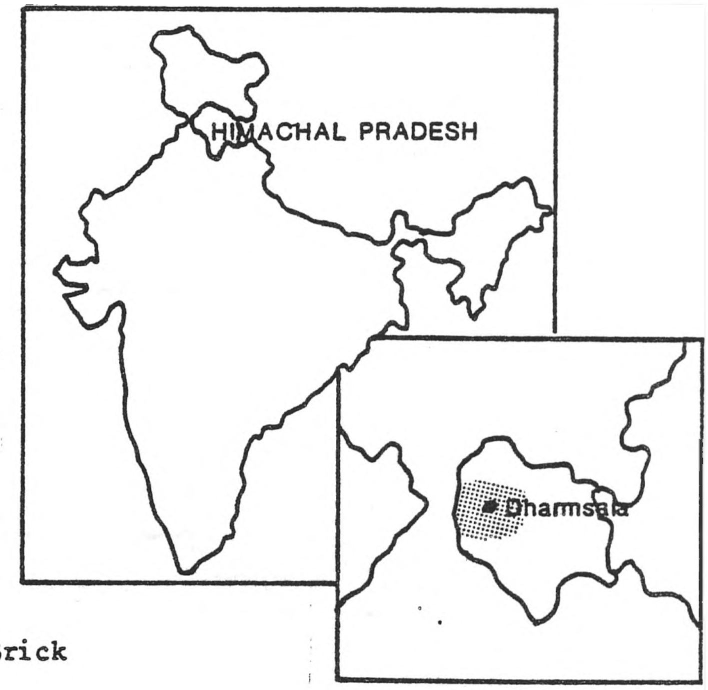
Seismic Resistance Evaluation

GOOD	FAIR	POOR	N/A		GOOD	FAIR	POOR	N/A	
	●			SITING	●				DOOR/WINDOW AREAS
●				SEPARATION BETWEEN BLDGS.	●				FOUNDATION-WALL CONNECTION
	●			FOUNDATION DESIGN	●				WALL-WALL CONNECTION
●				BALANCE OF STRUCTURE	●				WALL-ROOF CONNECTION
	●			SHAPE OF PLAN	●				LIGHT WEIGHT WALLS
●				CENTER OF GRAVITY	●				LIGHT WEIGHT ROOF
●				RIGID WALLS	●				RING BEAM
●				ROOF DESIGN	●				STRENGTH OF BLDG. MATERIALS
●				PROJECTIONS & OVERHANGS				●	STRENGTH OF MORTAR
●				DOOR/WINDOW LOCATIONS	●				QUALITY OF WORKMANSHIP

RECOMMENDATIONS FOR IMPROVEMENTS	DET. REF. NO.	% CONST. COST	MAN-DAYS
Use cement mortar in the foundation	-	8	3
Anchor sill plate to foundation	-	1	.5
Iimprove bracing and use more nails in walls and roof construction	-	5	6
Use roof truss design	-	2	2

AVERAGE TOTAL COST OF HOUSE Rs 10-12,000





HOUSE TYPE: Slate and Sun Dried Brick

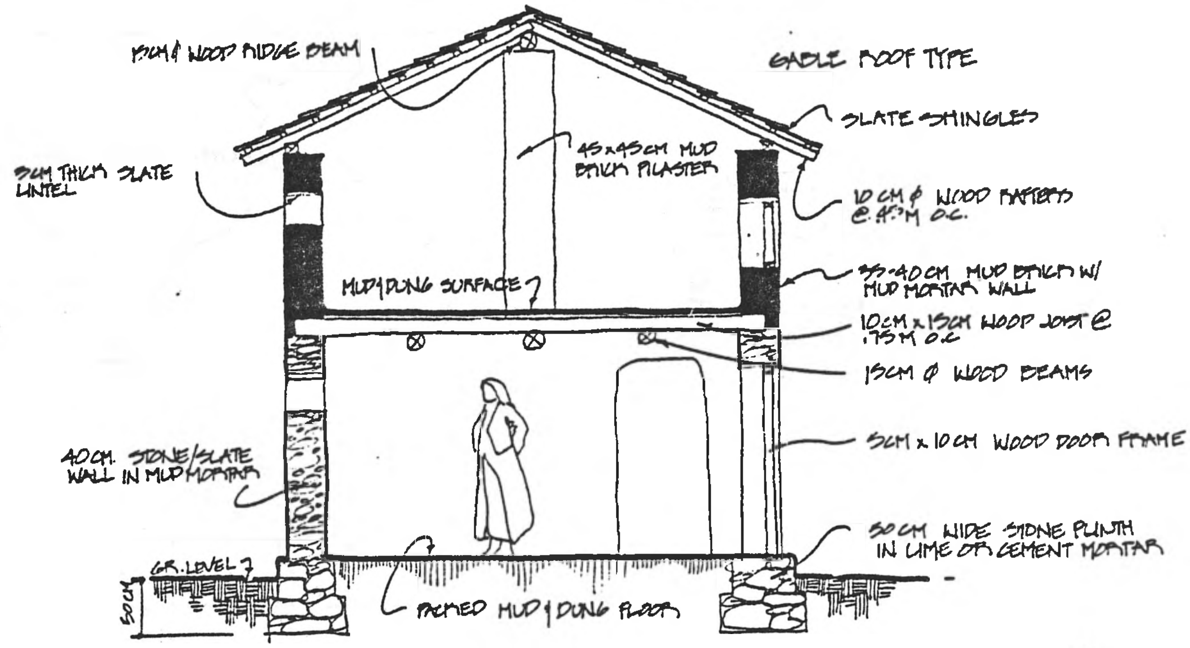
LOCATION: Dharmsala, H.P.

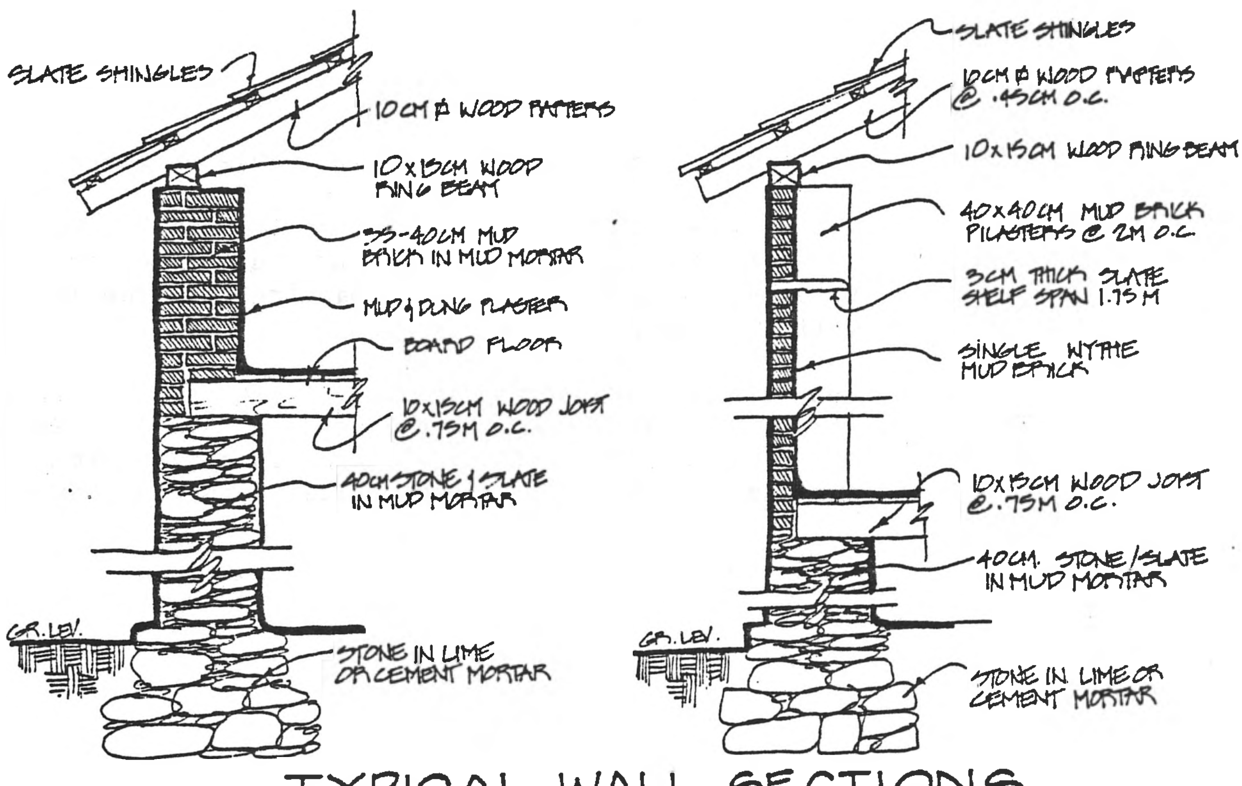
FOUNDATION: The foundation is made of random rubble or slate.

WALLS: Walls are of slate, 40 cm. wide and up to 1.3 m. in height, becoming 2 wythes of sun dried brick. Floor framing is sawn wood joists spanning from the longitudinal wall to a central beam.

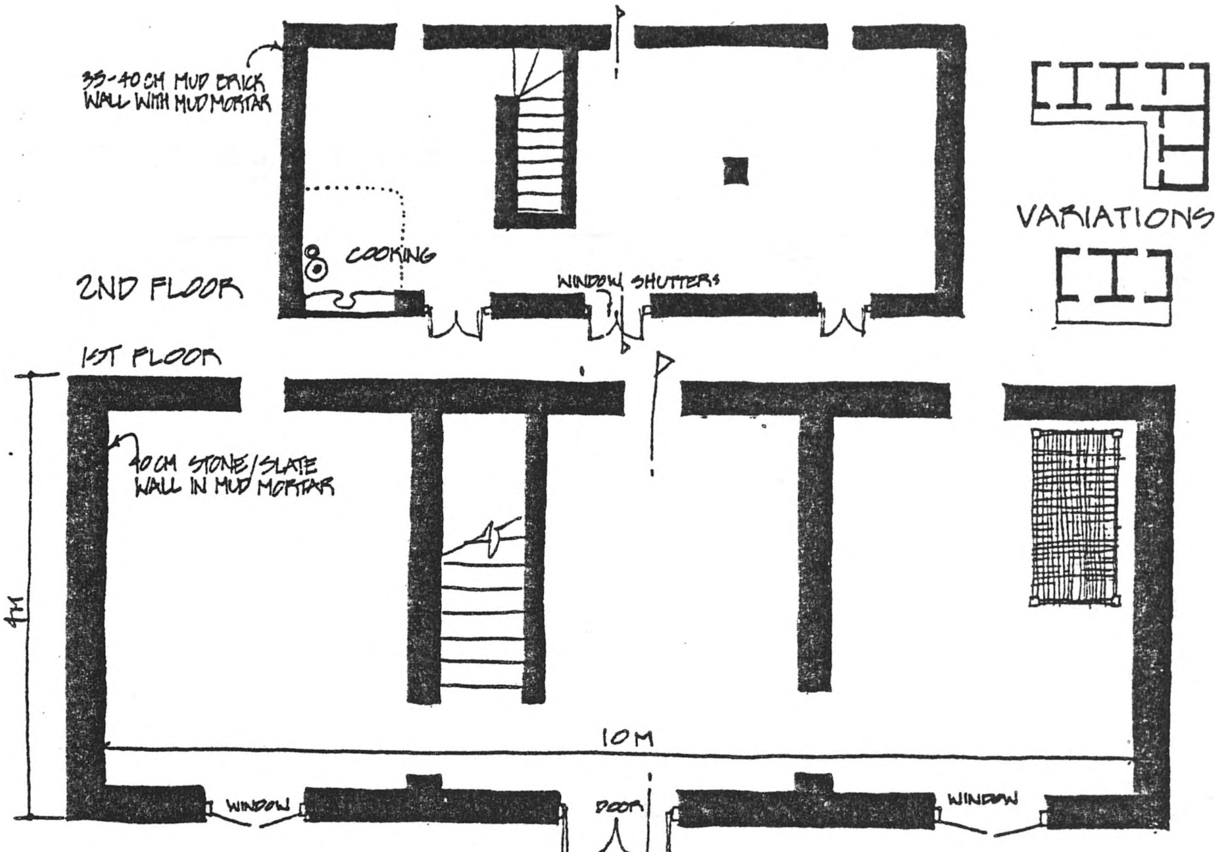
ROOF: The gable roof structure is covered with slate shingles. The ridge pole bears on the gable end walls. Rafters are of sawn wood at about 90 cm. on center with 2 x 7 cm. purlins. Cross ties are at quarter points of the roof.

BUILDING SECTION





TYPICAL WALL SECTIONS

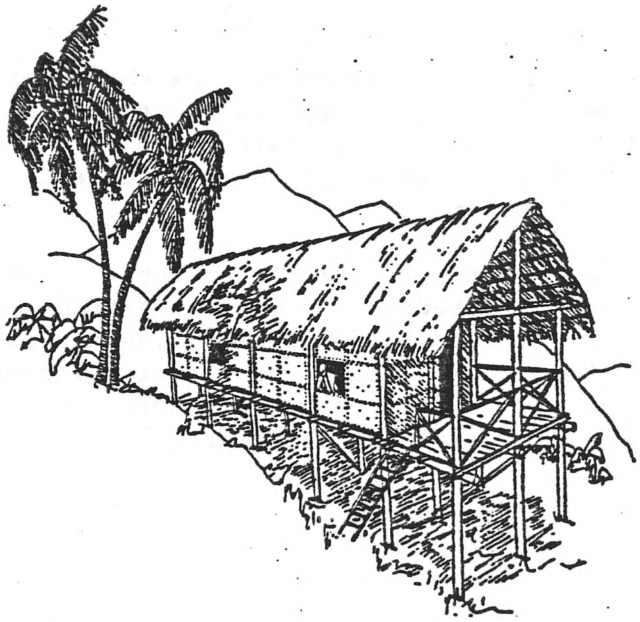


TYPICAL PLAN

Seismic Resistance Evaluation									
GOOD	FAIR	POOR	N/A		GOOD	FAIR	POOR	N/A	
●				SITING		●			DOOR/WINDOW AREAS
		●		SEPARATION BETWEEN BLDGS.		●			FOUNDATION-WALL CONNECTION
		●		FOUNDATION DESIGN			●		WALL-WALL CONNECTION
	●			BALANCE OF STRUCTURE			●		WALL-ROOF CONNECTION
	●			SHAPE OF PLAN			●		LIGHT WEIGHT WALLS
		●		CENTER OF GRAVITY			●		LIGHT WEIGHT ROOF
		●		RIGID WALLS			●		RING BEAM
	●			ROOF DESIGN			●		STRENGTH OF BLDG. MATERIALS
		●		PROJECTIONS & OVERHANGS			●		STRENGTH OF MORTAR
	●			DOOR/WINDOW LOCATIONS		●			QUALITY OF WORKMANSHIP

RECOMMENDATIONS FOR IMPROVEMENTS	DET. REF. NO.	% CONST. COST	MAN-DAYS
Utilize balanced structure and shape of plan design principles	-	-	-
Build stepped stone foundation	-	3	4
Eliminate use of slate at lower wall	-	-	-
Construct one story structures	-	-	-
Use ring beam	-	2	.5
Use fired brick masonry with cement mortar	-	100	-
Improve roof truss design	1	5	2

AVERAGE TOTAL COST OF HOUSE Rs 18,000



HOUSE TYPE: Ikra-Plaster

LOCATION: Assam

FOUNDATION: Typically 15-25 cm. diameter wood posts are driven into the ground to a depth of 65-90 cm. below ground level. Posts are continuous up to the roof level. Variations include stone plinths in mud or lime mortar, 40 cm. in width and 50 cm. below ground level. Wooden posts used as the columns supporting the roof are driven into the plinth. 40 cm. square stone piers at 1.0 - 1.5 m. high and 2 m. on center are also used as a foundation support system. The superstructure rests on these piers and depends on the weight of the structure for secure bearing.

WALLS: Walls are composed of 15-25 cm. diameter wood posts at 1.5 - 2.0 m. apart. These are continuous from ground or plinth level to the roof level. A 15 cm. diameter wood beam supporting the roof is lashed to the posts. A framework of bamboo with "ikra" reed panels lashed to the frame forms the walls. The ikra is normally plastered with mud or sometimes a lime mixture inside and out. These panels are about 5 cm. thick. Variations include sawn timber structural frames with 15 cm. square posts at 1 meter on center and 10 cm. horizontal wood members at 1 m. on center nailed to the posts. The voids are infilled with plastered ikra reed or split bamboo panels.

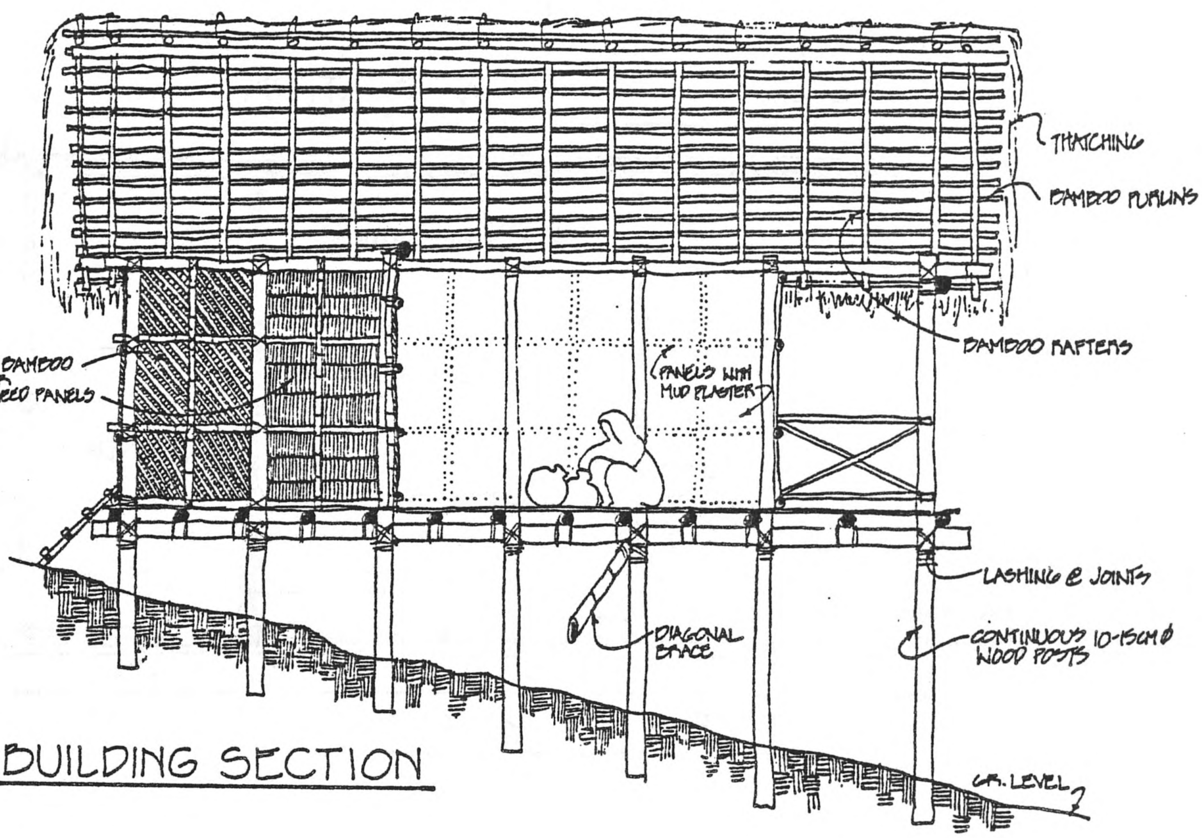
ROOF: Gable type roofs are constructed of 7-8 cm. diameter rafters spaced 60-70 cm. apart lashed to the walls and a 10-13 cm. diameter ridge beam. Bamboo purlins spaced 30 cm. apart support a thatch roof. Sawn wood purlins are used with C.G.I. roof sheets.

BEHAVIOR IN EARTHQUAKES

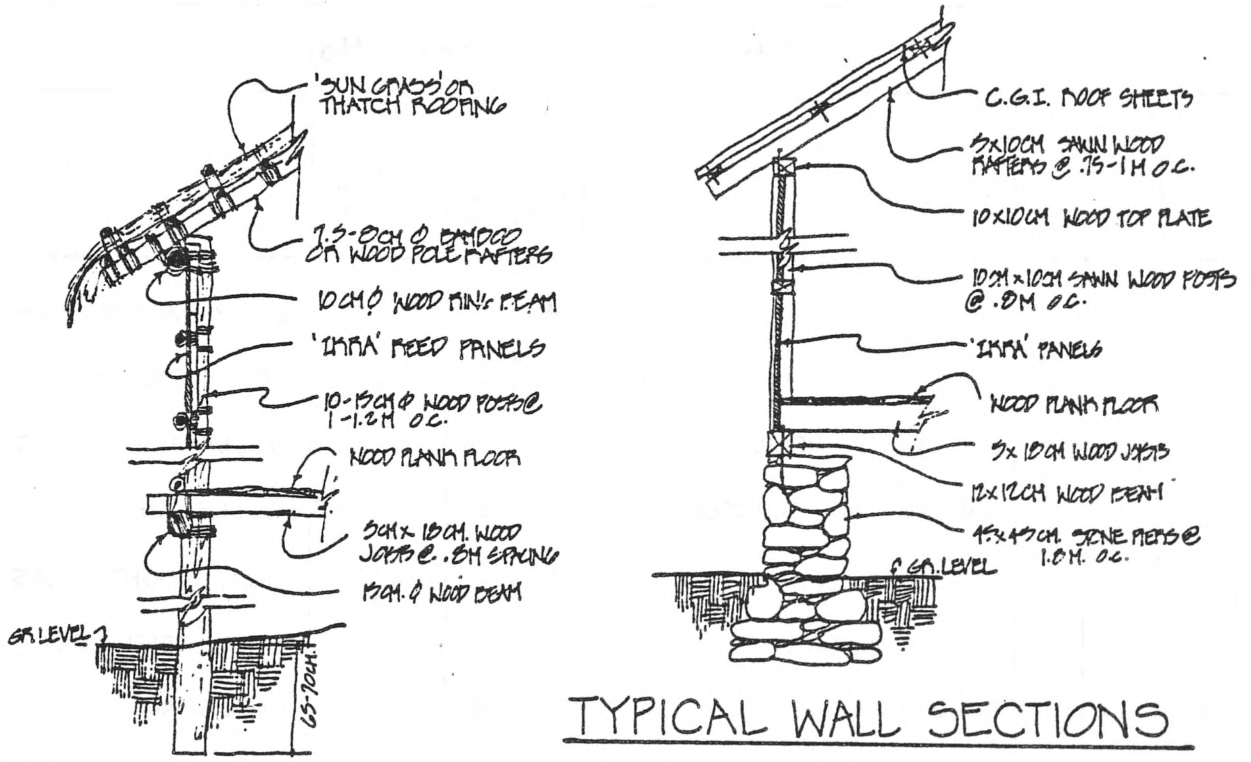
For houses built in the hilly regions where posts are driven into the ground for support, the structures were damaged due to the sinking of posts up to 30 cm. deeper into the earth. Various parts of the structure tended to tear apart from each other.

Houses using the stone piers remained largely intact as the superstructure vibrated as a whole, independent of the stone piers. It should be noted regarding the observed performance of these houses after the Dhubri Earthquake of 1930 that it was not of sufficient intensity to displace the superstructure entirely from the piers.

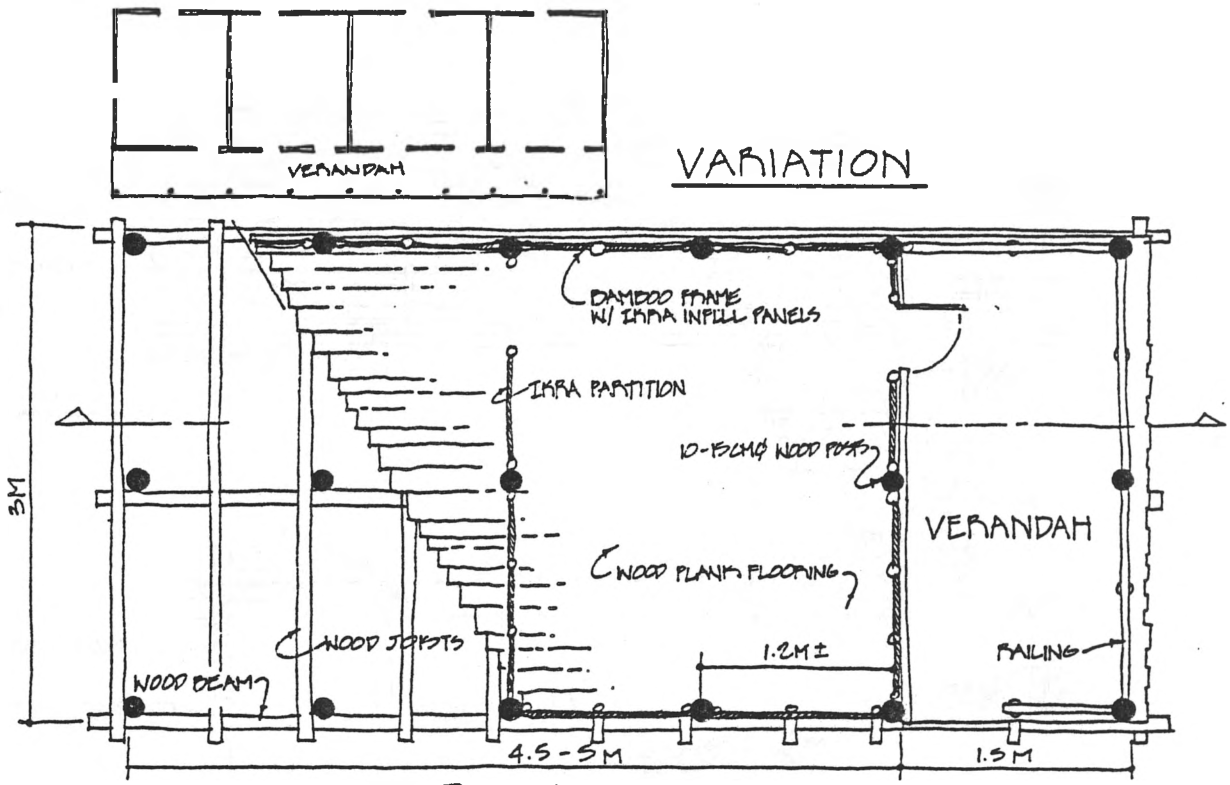
[The source for this monograph is an article entitled "Building Practices in Seismic Zones of N. Bihar, N. Bengal and Assam", written by N. Gosain. The INTERTECT team members did not visit the Assam region.]



BUILDING SECTION



TYPICAL WALL SECTIONS



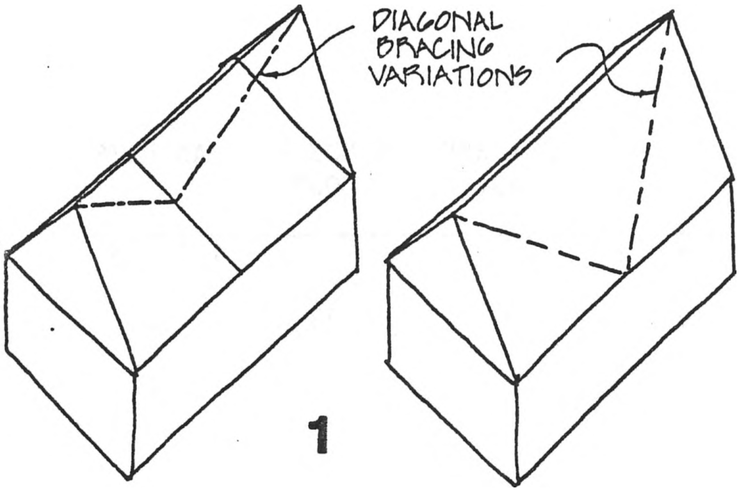
TYPICAL PLAN

Seismic Resistance Evaluation

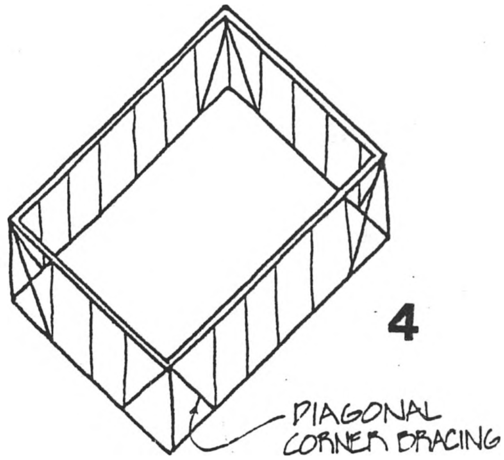
GOOD	FAIR	POOR	N/A		GOOD	FAIR	POOR	N/A	
			●	SITING	●				DOOR/WINDOW AREAS
●				SEPARATION BETWEEN BLDGS.		●			FOUNDATION-WALL CONNECTION
			●	FOUNDATION DESIGN	●				WALL-WALL CONNECTION
●				BALANCE OF STRUCTURE		●			WALL-ROOF CONNECTION
●				SHAPE OF PLAN	●				LIGHT WEIGHT WALLS
●				CENTER OF GRAVITY	●				LIGHT WEIGHT ROOF
	●			RIGID WALLS		●			RING BEAM
	●			ROOF DESIGN	●				STRENGTH OF BLDG. MATERIALS
●				PROJECTIONS & OVERHANGS				●	STRENGTH OF MORTAR
●				DOOR/WINDOW LOCATIONS					QUALITY OF WORKMANSHIP

RECOMMENDATIONS FOR IMPROVEMENTS	DET. REF. NO.	% CONST. COST	MAN-DAYS
Use stepped foundation where applicable		3	1.0-1.5
Embed wood posts in concrete spread footings		33	6
Use diagonal bracing between structural posts		-	2
Use diagonal bracing at corners and in walls		-	1
Use diagonal bracing in the roof structure		-	1
Notch rafters to seat securely on the wall plates and lash or nail properly		-	1
Use continuous ring beam		-	2
Use hip roof design		6	3

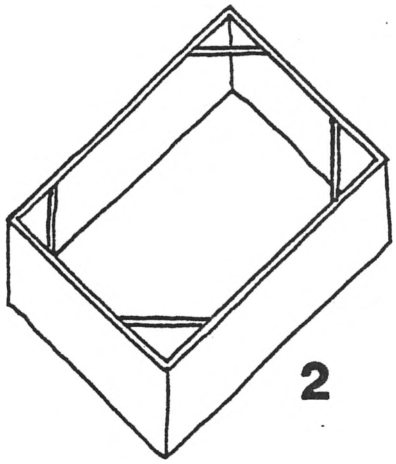
AVERAGE TOTAL COST OF HOUSE Rs 3-6,000 90% self-help


DIAGONAL
BRACING
VARIATIONS

1


DIAGONAL
CORNER BRACING

4



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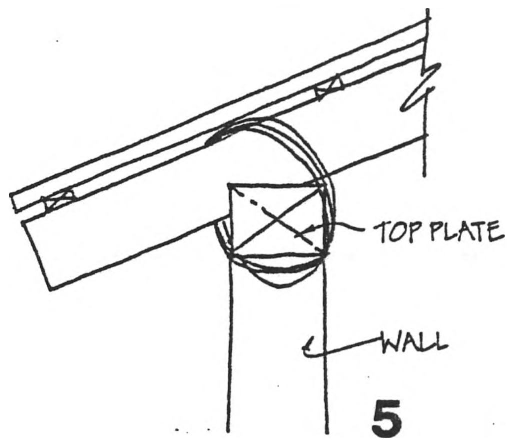
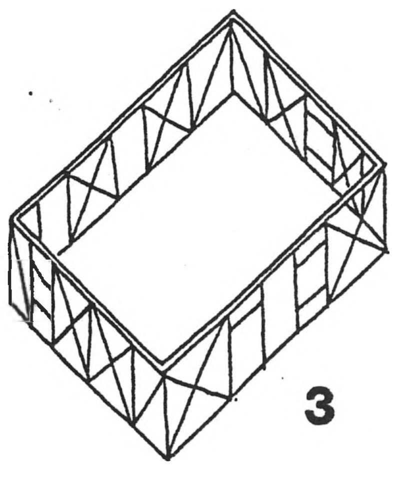

TOP PLATE
WALL

5



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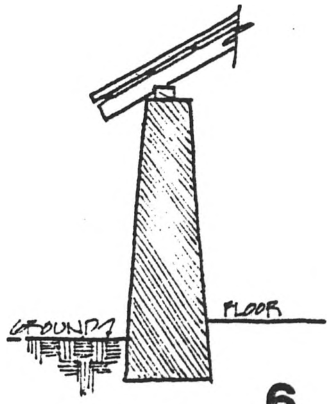
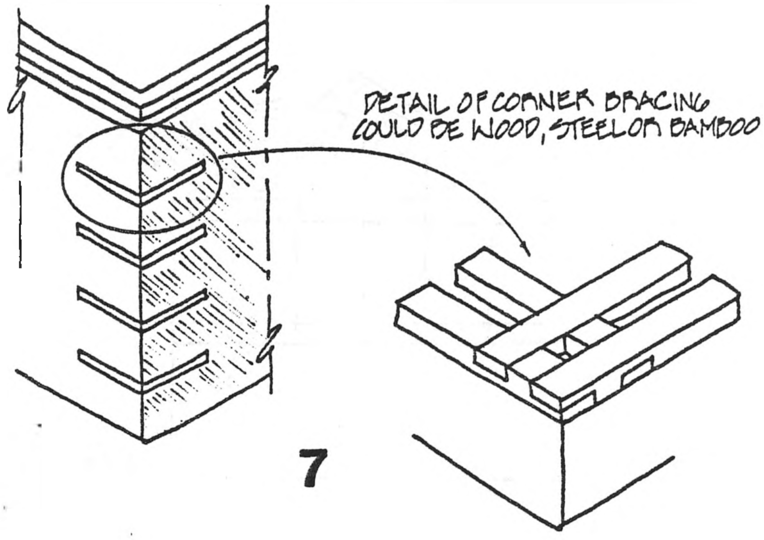
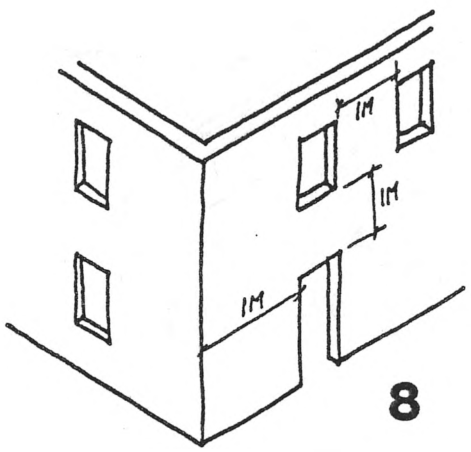

GROUND
FLOOR

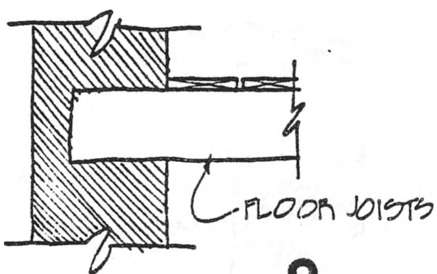
6


DETAIL OF CORNER BRACING
COULD BE WOOD, STEEL OR BAMBOO

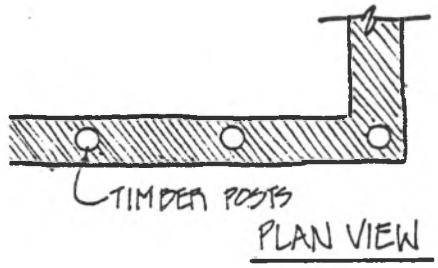
7


1M
1M
1M

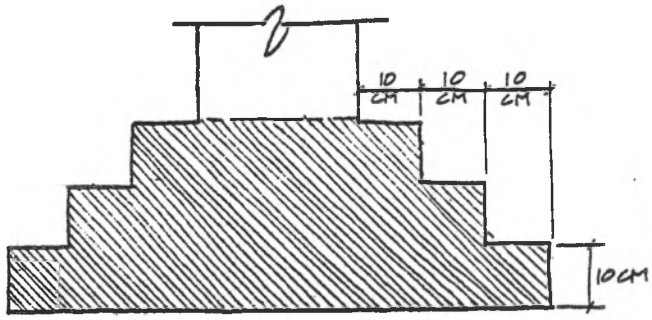
8


FLOOR JOISTS

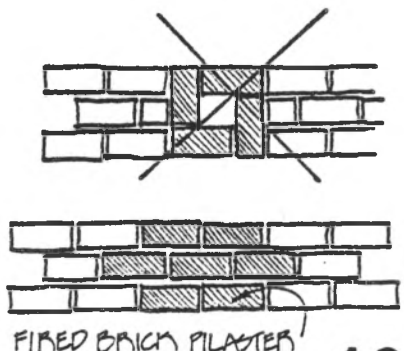
9


TIMBER POSTS
PLAN VIEW

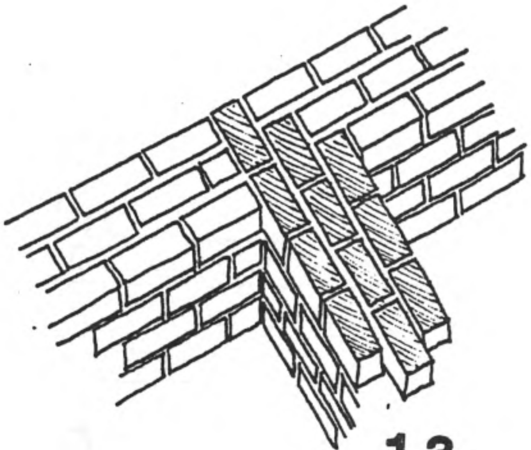
10


10 CM
10 CM
10 CM
10CM

11


FIRED BRICK PILASTER

12



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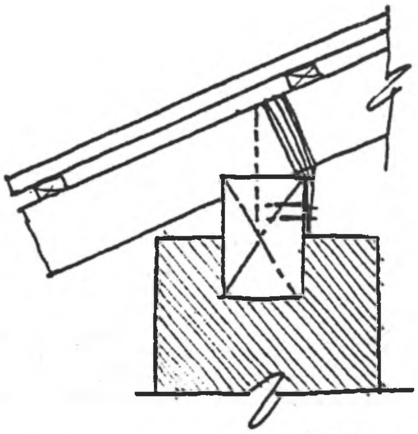

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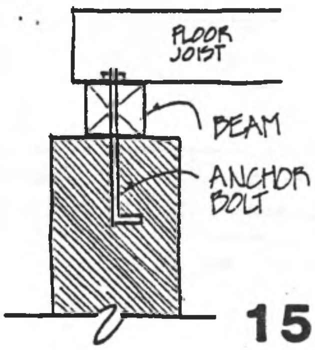

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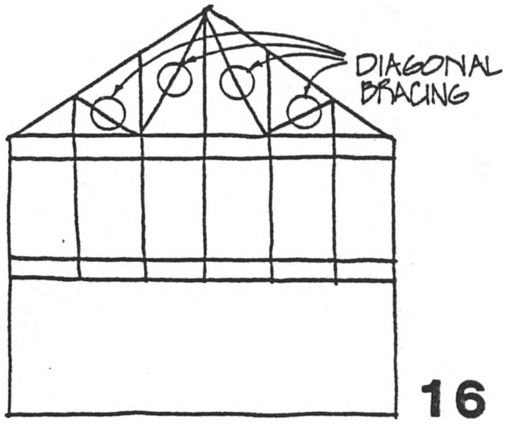

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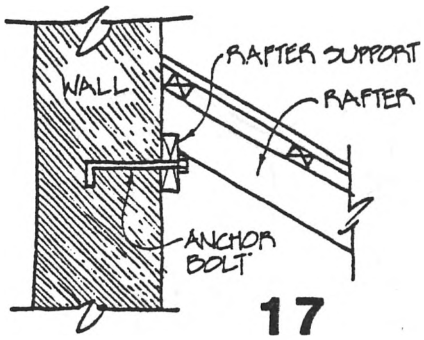

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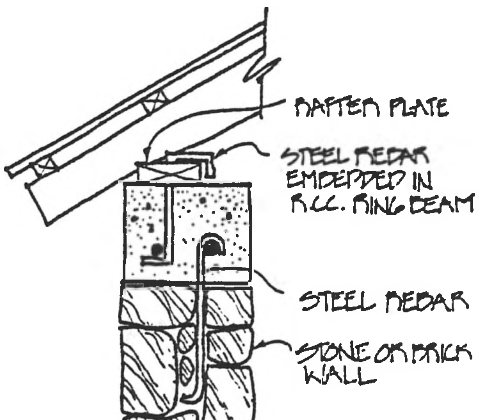

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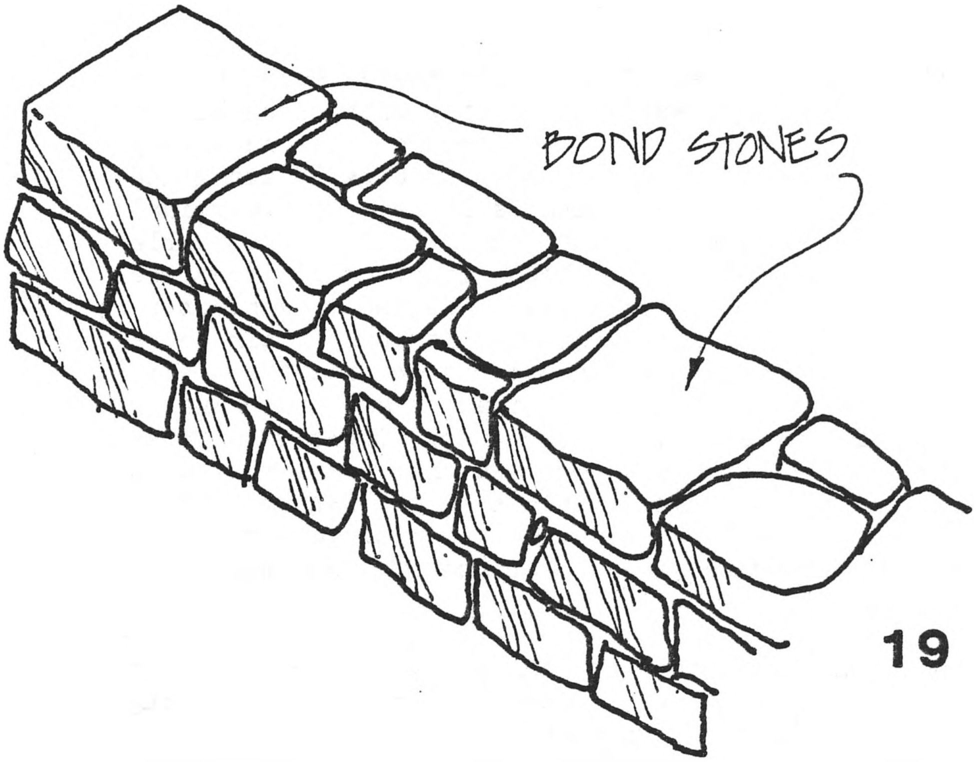

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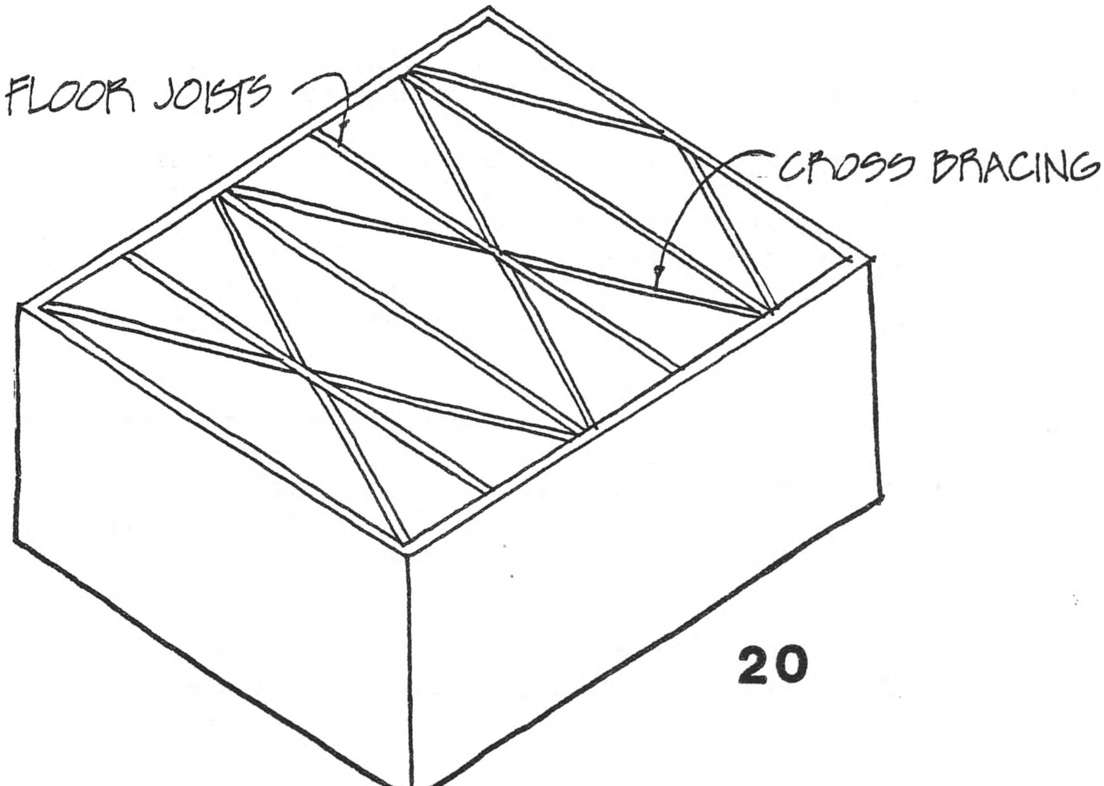


20

IV. HOUSING PROCESS

PROCESS

For most families the process of building their house in the rural regions of India spans many years. It begins with accumulation of savings to purchase land and then to acquire the necessary materials and labor to construct the basic house. Usually among the lower-income population in rural areas, land is leased and a marginal structure using the least expensive and most readily available materials is constructed. This initial house might be built by the owner and his family, if possible. This was evidenced in Maharastra where a typical family with a marginal income had built their house using a locally available reed woven into a mat and plastered with mud. The roof was constructed of bamboo framing and thatching or flattened-out metal from old cans and food tins. These structures are perceived as the first step in a process that sometimes takes many years, depending on the economic situation of the family. Since these initial houses are usually constructed on unowned or leased land, the owners may not improve them because of the lack of a formal and legal tenure.

The struggle for land ownership by the poorer segments of the rural population is a critical issue throughout India and is being addressed to some extent by land reform measures in many states. The housing process is directly influenced by land tenure status since upgrading and investment in permanent housing is usually attempted only on secure sites.

Employment opportunities, which fuel the migrations of landless people, have significant impact on the potential for the growth of permanent settlements. If long-term employment potentials are not available in an area, many landless or jobless families are compelled to maintain migratory living conditions, building makeshift or temporary shelter until some form of security is realized.

This type of temporary housing - constructed of minimum materials and depending largely on unskilled labor - deteriorates rapidly and presents a safety hazard to the occupants. Housing of this sort requires the most maintenance and repair. Transitional housing, that is, housing that evolves through a series of rebuilding and modification over time, begins as the prospects for stability improve.

If land tenure is achieved to a satisfactory level, the next step in the housing process is to completely rebuild another more permanent house on the secured site using the highest quality materials affordable to the family. This aspect of the housing process is important to recognize in order to understand how and why housing is improved.

The house may be constructed in several phases, depending on the financial situation of the owner. Initially he may not have adequate funds to complete the house, only enough to build the walls, floor and roof. Construction of window shutters and doors may be contracted later when additional capital is available to pay for the work.

Normally the owner and his family will participate by preparing the site, gathering materials and assisting a paid tradesman to construct the building. There are usually skilled masons and/or carpenters in every village who provide the services. Materials are purchased from local vendors who either produce or refine materials such as brick, wood, or some clay tiles. Or they sell imported materials such as cement, metal roof sheets or factory made clay tiles. Sometimes the owner must also pay to have materials transported to his building site. Once the materials are on the site, the homeowner will hire a mason or carpenter to build the house. Occasionally rural families will obtain loans from a wealthy family in the village using their land as collateral.

Often a house is constructed for the extended family such as two brothers and their families, a common practice in Gujarat and Himachal Pradesh. Construction costs are then shared between the two families.

The housing process in Kashmir is unique where a house is often constructed for a large extended family. The funds for building may be pooled among 4 or 5 wage earners often engaged in farming a shared plot of land. The construction process is similar to that of other seismic areas of India where skilled tradesmen are contracted to build the house with assistance from the families.

The common denominator among the various housing processes is the key role of tradesmen. If housing vulnerability reduction efforts are to be implemented, such programs should focus primarily on improving the skills of local tradesmen as they play a vital role in determining the form and construction detailing in the housing process.

One of the most serious problems facing the homeowner is the depletion of timber resources for use in housing construction. Wood is already extremely scarce and is relatively expensive. It is anticipated that the shortage will become so critical that wood for rural housing construction will be largely unavailable in the near future and will require the homeowner to purchase more expensive alternatives such as steel or lower-quality substitutes such as bamboo. At present, it is evident that many people reduce the size and number of wood components required for safe construction either because of high costs or unavailability.

SOCIO-ECONOMIC COMPLEXITIES

The social fabric of India is extremely diverse and complex. Language, food, customs, religion and housing vary from state to state and often within a state. India is the embodiment of a traditional society, particularly in the rural areas where change is slow and actions along with perceptions follow rigid traditional lines. It is important to understand these elements when considering the introduction of new housing construction techniques or house forms. The orientation and layout of the house is often dictated by religious guidelines that have been followed since time immemorial. For example, in ancient Hindu guidelines the precise dimensions and orientation as well as the process for constructing a proper house are set forth in explicit instructions. The social implications associated with changes in housing design or construction techniques must be recognized if housing improvement programs are to succeed.

There is a strong desire among the rural populations surveyed to construct permanent housing using higher quality materials. The obstacles that prevent more housing improvement are primarily the high cost of materials, land tenure, and material availability. Wood resources are critically scarce, resulting from years of uncontrolled deforestation. This shortage not only limits a rural family's access to supplies, but also inflates the cost of good quality-timber, making it largely unaffordable to the rural population.

When expensive resources such as wood are used, the sizes and quantity needed to build a safe roof, wall or floor system are usually compromised to save money. Many such shortcuts reduce the structural integrity of the house, resulting in unsafe conditions made all the more critical because of its location in regions of high seismic risk.

Given the long-term situation of timber shortages, other materials such as bamboo will be used with greater frequency by the rural poor. Although bamboo has a long history of use as a primary building material and is readily available throughout most regions of India, its use has limitations without proper treatment against insect attack and ground contact.

Widespread use of lightweight roofing materials such as thatch or metal sheeting is considered by many earthquake engineers to be the single most important factor in saving lives during a serious earthquake. Light-weight materials require much less structure for support than the traditional claddings such as clay tile and slate, and their use reduces or eliminates the threat of heavy roofs collapsing and killing the occupants during ground shaking.

The shift to lightweight roofing may seem to be both a logical and achievable goal that could have great potential for saving lives. However, the social and economic complexities intrinsic in such a transition require thorough investigation. Many zones of high seismic activity (such as the Kutch region of Gujarat, the Koyna Dam area of Maharashtra, Kashmir, Himachal Pradesh, and North Bengal) all have well-entrenched industries employing many thousands of rural people in the production of indigenous roofing materials, such as slate shingles and clay tiles. The production of clay tiles represents perhaps the largest industrial employment in the Kutch region of Gujarat. Also the production of slate roof tiles supports a myriad of cottage industries along India's northern Himalayan border. These industries and their related networks contribute significantly to the economic support of rural communities. A shift away from usage of these materials would necessitate development of an alternate use or retraining for production of other products.

At the present time corrugated galvanized iron roof sheeting (CGI) costs approximately 1.5 to 2 times the cost of slate shingles depending on the location, and its cost is about 15 to 20% higher than factory produced clay tiles.

Social Preference

Another important consideration influencing the acceptance of alternative materials is social preference. Such preferences coupled with economic feasibility can determine the success or failure of vulnerability reduction efforts. While people may recognize the benefits of using the CGI sheets instead of factory-made clay tiles, the preference may still be for clay tiles because of traditional, or in many cases aspirational bias. It was evident in both Maharashtra and Gujarat that both the CGI sheeting and clay tiles were available; however, the clay tiles were overwhelmingly the preferred material among local people.

Thatch roofing is also considered by many to be a suitable roof material because of its traditional use among rural people, low initial cost and light weight. However, this material is considered to be inferior and carries with it a stigma of poverty. Those families engaged in building upgraded permanent housing would not be easily persuaded to use thatching in lieu of other more popular materials that represent a higher value and enhanced social status.

It was evident in our surveys throughout the rural seismic regions that people generally aspired to build a "pukka" house, one of fired brick construction. This was perceived as the most durable and most valuable form of house representing economic and social status. This overwhelmingly evident aspiration and perception is contradicted by the reality of economic feasibility for most people. The housing process often will evolve into the construction of a pukka house over time if the economic situation of the family improves to the level where such a house is affordable.

This aspiration and perception does not seem to preclude the construction of permanent housing using less expensive and/or less desirable materials. Generally rural families seem to have a realistic perception of their ability to afford an appropriate housing form and building materials. This was illustrated in an interview with a man in Himachal Pradesh who was building a 2 story house for his family and using a rammed earth technique that he described as an "old way" of building. It was obvious that the house was to become the family's permanent home and that the family had saved many years to afford such a house. When asked what sort of house would he build if he could afford to build any house he wanted, his reply was "pukka".

This brings up a significant point in the provision of housing assistance and housing improvements to rural areas by outside agencies such as the government or a voluntary agency. While a family might accept the idea of improvement to construction techniques for a mud brick house they are building themselves, they may demand a much more sophisticated house built of higher quality materials, such as fired brick, if an outside agency is providing housing units for people.

It was evident throughout most of the seismic regions surveyed, particularly Maharashtra and Gujarat, that government assistance in housing usually takes the form of providing demonstration units constructed for people using an improved mud brick construction technique or fired clay brick walls with reinforced concrete lintels and beams. There was no indication of programs designed to assist the homeowner in making improvements to existing housing or channeling funding directly to the homeowner for credit assistance in new construction.

BUILDING SKILLS

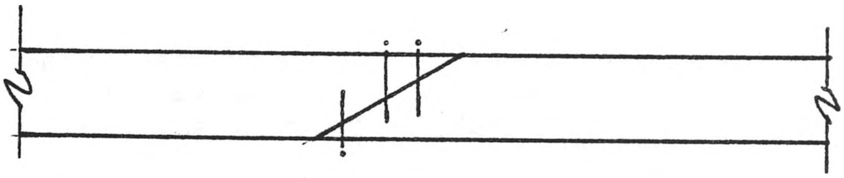
The structural integrity of buildings during earthquake activity depends greatly on the quality of workmanship and detailing when the building is constructed. In studying the skills of local tradesmen responsible for the construction of vernacular housing throughout the seismic regions, a number of problems affecting the vulnerability of the houses were evident.

A. Carpentry Skills:

1. Joints: A consistent problem in wooden and bamboo structures is the inadequacy of joints in design, execution and fastening. Particularly evident were the ineffective methods of constructing roof framing systems. Often no shaping or jointing of round wood rafters was utilized to make a good connection to ring beams or wall plates. The connections often depended on inadequate nailing for strength. Also, inappropriate joint conditions were common where structurally important members were nailed in tension rather than shear.

Lashed joints often did not use adequate lashing to maintain the integrity of the connection. This was particularly apparent in houses using bamboo or round wood posts, beams and rafters.

2. Splicing: The splicing techniques used in the seismic regions surveyed were for the most part very weak, depending on nailing for strength. ie:



This is a serious problem, compounded by the fact that the nailing was inadequate even when the splicing condition was properly executed.

3. Bracing: It was evident in many areas that bracing of both roofs and walls was either not practiced or was not correctly executed. The areas of concern were:

a. No diagonal bracing in the gabled ends.

b. Placement of support posts that do not distribute loads evenly and no lateral bracing of posts.

c. Use of bracing in tension that tends to separate with movement.

d. Construction of wall bracing at angles which are insufficient to provide adequate rigidity.

4. Material Use and Selection: Common to many of the regions surveyed were problems associated with improper use and sizing of structural components. Many houses could be significantly improved by modifying selection and use of the same materials. Examples of problems include:

a. Many of the roof trusses were framed incorrectly using heavy, oversized members and inadequate framing of web supports to form a true truss configuration, making the entire system structurally unsound while using expensive, oversized and unnecessary wood components.

It is important that particular attention be given to the construction of roof systems in general. Earthquake engineers at the University of Roorkee consider the problem of inadequate roofing systems as a primary target for potential improvement that would save many lives in the event of a severe earthquake. Improving the quality and techniques of construction would be essential in achieving the required strength.

b. Wood and bamboo lintels were used over door and window openings in walls of mud, brick, rammed earth, fired brick, and stone. The lintels were not thick enough to support the weight of the wall and roof loads, thus making the door and window openings unsafe. This is especially critical when the building is subjected to earthquake forces because the walls fail at these openings and many people are killed as they try to get out of the houses.

c. In two-story houses, wood floor joists were not adequately tied into the wall structure and will collapse under the forces of ground shaking during an earthquake.

d. Often improper wood species were selected as primary structural components, which deteriorate rapidly due to insect attack. Bamboo is especially susceptible to such attack.

B. Masonry Skills:

For a masonry wall to have adequate strength, care must be taken to align the wall both vertically and horizontally, use good mortar and strong bricks or stone. A number of problems have been documented, including:

1. Insufficient or Improper Foundations: Often the footing may utilize fired clay bricks but the mortar is mud and the width of the footing is not sufficient to prevent uneven settlement. Many houses have no foundations.

2. Poor Mortar is one of the most common problems in masonry construction. When mud bricks are used as a bearing wall, unstabilized mud mortar is often used. Also when fired clay brick is used, mud mortar may also be used. The use of mud mortar is certainly a result of the increased cost of cement or lime needed to make a better quality mortar; nevertheless, it is one of the most critical elements affecting the structural integrity of the wall.

3. Poor Craftsmanship in wall constuction is also a major factor contributing to structurally unsound walls. Plumb lines are not used and horizontal alignment is poor. Also brick bonding patterns are insufficient to achieve adequate wall strength. Often successive veneers of brick are constructed in an effort to increase the strength of a weak wall. These veneers eventually peel away, adding nothing to the original wall structure.

4. Poor Quality Bricks are often used to cut costs, which eventually deteriorate and create weak sections in the wall.

5. Additions to houses are not properly tied into the existing house and also create asymmetrical configuations that adversely affect the reaction of the structure when subjected to the ground shaking during an earthquake.

'oncrete Mixing is evident where used for lintel

ed bricks and mud bricks in the same wall is a
chnique in some areas. This practice reduces the
.ural performance of the wall significantly.

V. HOUSING IMPROVEMENT

PUBLIC AWARENESS

In most areas surveyed the level of earthquake awareness among local residents was very low. This presents an obstacle to vulnerablilty reduction efforts by outside agencies because the importance of the issue is not perceived by homeowners. In essence it is not a priority. There are many more pressing issues in the daily lives of rural families and, unless the area has been struck recently by an earthquake causing substantial damage, people may not feel the need to make safety-related improvements. It is essential that public awareness programs be conducted in a way that will reach rural populations and be effective in communicating the issues.

As stated in the previous section, local tradesmen are perhaps the most important target group for public awareness efforts. Since they are responsible for the construction techniques, it is essential that appropriate information, as well as intensive training programs reach this segment of the rural population.

A major problem in implementing public awareness programs is the diversity of local languages, customs, and building practices. Programs must be developed for the specific regions targeted incorporating appropriate language and relevant construction techniques. G.C. Mathur, the current director of the National Buildings Organisation, describes the social and economic restraints that must be taken into consideration in any large scale vulnerability reduction program as follows:

"In any large scale program of improvement of houses particularly to improve the earthquake resistance of mud houses, which are existing or are being put up in large number, it is important to identify social and economic constraints which come in the way of modifications evolved as a result of research and development of science and technology. The social constraints include:

> (a) Lack of Awareness: A vast majority of population, particularly in the low income groups, is oblivious of the potential hazards to houses and buildings in the event of earthquakes. It is necessary to bring home to them the implications of earthquake disasters and the difficulties and costs involved in undertaking large scale reconstruction work. Information about past case histories of incidence of earthquake damages can be an eye opener in creating in them an awareness for effecting improvements to their existing houses and for building more earthquake resistant houses.
>
> (b) Attitudinal Change: The mass of population is largely tradition bound and offers resistance to change due to several inhibiting factors. Through dissemination of

information, personal contacts and community action, attitudinal changes have to be brought about so that the people become responsive to modification required to make buildings and houses more earthquake resistant to earthquake forces.

(c) Illiteracy: Large populations in developing countries are not literate. As such they are unable to appreciate scientific and technological developments and the advantages accruing thereof. (This) can be substantially eliminated through a program of literacy. Emphasis would have to be laid on nonformal methods of education and greater importance would have to be given to audio-visual media in imparting education and presenting information regarding prevention of damage and destruction to earthen houses and buildings most commonly built by them.

(d) Lack of Motivation: Unless the people particularly in the low income groups, see for themselves benefits accruing from proposed modifications to the existing houses or in the construction of new houses to improve their performance in the event of earthquake they do not come forward to adopt improvements. It is therefore necessary to motivate them so that they themselves are willing to adopt improvements and this calls for a program of motivation through several means.

(e) Lack of Community Action: It is often seen that individuals may not come foreward to accept modifications to safety of houses in the event of an earthquake. However, community action can be taken advantage of to bring about desired improvements. For this the local community organizations would have to be advised and the local leadership appropriately oriented. This will greatly promote the program of housing improvement through mutual help and cooperation.

The important economic constraints to modification include:

(i) Acute Poverty: In most developing countries a vast majority of the population lives below the poverty line and their consumption level is below subsistence level. They have per force to stay in improvised shelters made practically at no cost using locally available materials. Poverty is the predominant inhibiting factor which makes them adverse to any modifications to improve their houses.

(ii) Poor Occupational Base: There are several factors which contribute to poverty and important among them is the poor occupational base on account of which the poor have no option to increase their level of income, without which it is difficult to undertake any effective program for improvement of existing houses to withstand earthquake forces.

(iii) Lack of Credit Worthiness: As poor people and those in the low income groups have hardly any assets or very low assets in the form of land and houses, they are not in a position to borrow any money from credit institutions like Banks, Cooperatives, Etc. for improving the earthquake resistance of their houses. Unless they are able to procure some finances at low interest rates, they will not be able to adopt appropriate modifications.

(iv) Non-availability of Materials: Often improved construction techniques involve use of specific types of materials, products and techniques. Non-availability of such resources as well as appropriate skills prevents adoption of modifications. Even though these may be available obviously, some extra cost may be involved in their adoption which the poor people are not in a position to afford.

Although research and development work to some extent has been undertaken to tackle technological problems of improving the resistance of mud houses to earthquakes, not much research and investigations have been undertaken. To eliminate or reduce the impact of the social and economic constraints to modifications as mentioned above, there is great need to undertake studies to investigate and establish the relevance of technology in terms of social and economic change." (1)

Mathur goes on to outline a series of coordinated actions he sees as essential if housing improvement efforts are to succeed:

i) Providing Incentives: Motivate the rural people in improving their mud houses for which greater awareness regarding the drawbacks of dilapidated mud houses and structural deficiencies of such constructions and possible damage to these in the event of heavy rainfall, earthquakes etc. should be brought to their notice.

ii) Provision of Financial Assistance: Financial assistance to the villagers for improving their houses could be in the form of subsidy or loan on easy terms. Instead of this required building materials could also be supplied to them if possible free of cost or at low cost.

iii) Technical Guidance: Technical guidance in adopting improved mud construction techniques by dissemination of information, demonstrations, exhibitions etc.

1. Social and Economic Constraints to Modification and Obstacles to Technology transfer for making Mud Houses Resistant To Seismic Forces, G.C. Mathur, Director National Buildings Organisation, New Delhi, India, 1982.

iv) Demonstration Projects: Demonstration rural housing projects should be taken up to create an impact of improved mud construction techniques so that the villagers can appreciate the proposed improvements.

v) On-the-job Training: On-the-job training should be imparted to unskilled and skilled villagers in the techniques of improved mud construction.

vi) Organising Communication: A proper system of communication between research and development organisations and the village community should be established to bring to them the potentialities of new construction techniques for improving mud houses.

vii) Institutional Support: Institutional arrangements should be made to organise, support and propogate improvements in mud construction and for channelising necessary finanical and technical assistance.

viii) Undertaking Research and Development: Research and development work should be undertaken in tackling local problems that are involved in effecting improvements in mud construction in different regions.(2)

PROGRAM RESPONSIBILITY

India has many levels of administration and substantial overlap of responsibilities, particularly in the area of housing. The government organizations most evident in providing local program support are the National Buildings Organization (NBO), which is a division of the Ministry of Works and Housing, and the Central Building Research Institute (CBRI) which operates a variety of demonstration and training programs throughout India. The Housing and Urban Development Corporation (HUDCO) provides funding to the rural and urban housing boards and also provides support for building materials industries such as lime plants and brick factories.

NBO, CBRI and HUDCO are national organizations that must interface with state agencies that are also responsible for housing, such as the State Rural Housing Board, and locally with the Block Development Officers who are responsible for overseeing local projects. There is also a parallel system of development administration active on the village, district and state level known as the Panchayat Service which has varied responsibilities.

Depending on the region of operation, the specific roles and responsibilities of these organizations are not always distinct as illustrated in this description of duties as stated in a monograph on rural housing for the state of Gujarat:

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2. Ibid.

"Gujarat State Rural Housing Board is looking after the activities of housing in rural areas of the State and the Slum Clearance Board is also looking after the activities of slum dwellers. Other schemes such as housing for landless labourers and subsidized industrial housing, low income group and middle income group housing schemes are being looked after by Gujarat State Housing Board with the help of the State Govt. The Panchayat Authorities are looking after the housing schemes in rural areas and also they look after housing schemes for selected categories such as scheduled castes and scheduled tribe people."(3)

The efforts of private voluntary agencies active in housing improvement and village development in seismic areas are not evident, although there are several such agencies active in this field, predominately operative in the southern and eastern regions of India.

The National Buildings Organisation (NBO) and the Central Building Research Institute (CBRI) are the most successful and most active advocates for the provision of housing and the transfer of construction technology. The NBO maintains 12 Rural Extension Wings that service the regions of high seismic risk with the exception of Assam and the Adaman and Nicobar Islands. These Wings are usually administered by faculty members attached to the state engineering colleges. Activities are somewhat limited due to the part-time responsibilities of the Rural Housing Wing directors and relatively low budgets for staff and project implementation.

The NBO's functions are described as follows:

The National Building Organisation was set up as an important activity connected with housing. The Organisation was established in early 1954 by the Govt. of India under the Ministry of Works & Housing with the following objectives:

* To act as interface between

a. All incoming technological findings, and

b. Their application in the field towards low-cost housing construction and improved building quality in India.

* To augment/improve the production of traditional building materials and promote the establishment of new building materials industries;

* To launch and partially finance experimental construction schemes to implement research results;

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3. Monograph on Rural Housing and Village Planning for the State of Gujarat, 1981, National Buildings Organisation, India, 1981.

* To promote rural housing through research, training and demonstration;

* To collect, document and disseminate information on the latest advances in building techniques and housing;

* To develop housing and building statistics and conduct studies relating to social, economic, financial and investment aspects of housing.

The Organisation was entrusted the role of the UN Regional Housing Centre for ESCAP in 1956. The Organisation is expected to achieve its objectives and functions through building a close liaison with research organizations in India and abroad, and construction agencies (both Government and private, including the individual builders), to ensure that the findings of the research investigations reach the users and requirements of the users are brought to the notice of such organizations. This helps to bridge the communications gap between research and workers and users. This is achieved through (a) building a repository of knowledge in the form of a well-stocked and documented library of technical literature and films; (b) organizing a series of seminars, get-togethers, conferences and training courses; and (c) bringing out technical publications. This also helps to locate the gaps in knowledge, on which it sponsors research projects through established research institutions. It does not conduct any laboratory investigations or carry out any field studies/surveys. The NBO conducts only desk research.(4)

The NBO works closely with CBRI in sponsoring exhibitions and demonstrations of research and development conducted on building materials and building systems. CBRI also maintains extension wings throughout the country responsible for research and dissemination of information. The School of Research and Training in Earthquake Engineering at the University of Roorkee is an active agent in research and testing of various types and structural details of rural housing as it pertains to performance under seismic forces. The function of the University is essentially to generate the hard data that must then be analyzed as to its relevance in the actual practice of conducting a comprehensive vulnerability reduction program.

A collaboration between the University of Roorkee, CBRI and NBO with NBO as the lead agency would be an effective coalition to implement comprehensive training and housing improvement activities. This would capitalize on the existing network of NBO Rural Housing Wings as a structure for administering program activities.

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4. Monograph on Rural Housing and Village Planning for the State of Maharashtra, Rural Housing Wing, NBO, India 1983.

TRAINING AND COMPREHENSION

During the course of the field surveys, comprehension tests were conducted with local residents, predominately skilled tradesmen. The test booklet is attached as Appendix III. The purpose of the testing was to determine the types of graphic aids that could be easily understood by local tradesmen in the various seismic zones surveyed. This information could then be utilized in developing appropriate training aids for use in public awareness programs and building skills training efforts.

Experience has shown that often critical information is not adequately communicated to the people it is intended to assist because of inappropriate drawings and/or text. In rural areas where the population is not exposed to a great deal of graphic images and may be largely illiterate, training aids may be often used that do not communicate clearly the concepts intended. What works in one region may not work in another. This may require a variety of methods to communicate the information such as demonstration of techniques, film clips, three dimensional modeling, or simple line drawings.

There are many effective approaches to the development of training aids; however, these concepts must be field-tested to determine their effectiveness.

It was evident from field tests conducted during this survey that the majority of people tested were able to comprehend sequential story lines that illustrated particular tasks. Construction details out of context were not recognized, nor were significant scale changes understood such as the enlargement of detail, illustrated in the comprehension tests. Also, two dimensional flat images were better understood than perspective drawings. The delineation of characters, housing types and materials should reflect regional characteristics. The drawings should be self-explanatory because of the high degree of illiteracy.

Local residents were generally very aware of the building process and use of building materials indicating good potential for receptivity to public awareness efforts.

Without question, the most effective form of public communication is the film industry of India. It is the overwhelmingly preferred form of entertainment and reaches into remote rural areas. Many government agencies, such as family planning, use this technique for public awareness efforts. The NBO has developed a film entitled "When the Earth Shakes" that graphically depicts the scenario that follows an earthquake. This film was distributed throughout India and shown before feature films.

As a follow-up to the comprehension tests of training aids conducted during field work in India, the Central Building Research Institute requested that INTERTECT develop a working model for training aids to be used in their ongoing program. The following documents were produced for CBRI and have been field tested:

* Developing Public Awareness Materials
* How to Build a Plinth Guard
* How to Make a Non-Erodable Mud Plaster
* Comprehension Test Booklet

These documents are included as appendices to this report to illustrate the types of educational material that may be prepared for a housing improvement program in the seismic areas.

APPENDIX I

TYPICAL BUILDING COSTS*

The following is a list of construction costs that represent an averaging across the seismic zones surveyed.

A. Materials

1.	Mud brick	Rs. .10/brick
2.	Fired Clay Brick (10.2w x 22.81 x 7.6thk)	Rs. 400/thousand
3.	Cement	Rs. 75/sack
4.	Mangalore Roof Tiles	Rs. 1.9/tile
5.	Asbestos Roof Sheet	Rs. 52/sq. m.
6.	Lumber:	
	unsawn poles	Rs. .5/ln.ft.
	sawn lumber	Rs. 9/bd.ft.
7.	Bamboo, 10 ft. length	Rs. 2 each
8.	Slate, 9" x 20"	Rs. 3.5 each
9.	Uncut stone	Rs. 40/truck load
10.	Reinforcing steel	Rs. 5500/ton
	1/2" x 8 ft. long	Rs. 24

B. Labor

1.	Mason	Rs. 20-30/day
2.	Carpenter	Rs. 25-40/day
3.	Laborer	Rs. 6-15/day

* All costs in Indian Rupees: Rs. 1 = +/- $0.10 U.S. (April 1984)

APPENDIX II

DEVELOPING PUBLIC AWARENESS MATERIALS

Effective communication of building modification techniques to village craftsmen and homebuilders is essential to reduce housing vulnerability. Although the technology may well be known by those involved in housing development, it has been found that little or no literature exists which communicates in a simple, easily understandable manner with the ultimate audience -- the uneducated villager.

According to the Indian census of 1971, literacy levels within regions most vulnerable to earthquake risk are fairly low. The highest literacy levels, around 30-40%, are concentrated around urban areas, while rural villages generally rank lowest. This, along with language barriers and various socio-economic constraints, requires educational methods specifically suited to the needs of each particular community.

One of the major constraints found in the areas visited was a lack of imperative for change. In most regions, little or no awareness of earthquake risk exists; thus, attempts to introduce new building practices could encounter difficulties. Those people who had experienced earthquakes often felt the threat was too remote to warrant change. Most villagers were aware of seismic activity but, because tremors in recent memory failed to drastically affect structures, they felt their houses were strong enough to withstand shock. This then leads to the question of priorities. To a family whose existence is of subsistence standards, little time or money remains for the sake of a potential threat. The realities of their daily existence are far more immediate. Any effective modification to a structure might require a small expense; yet without the desire (or often the ability) to save, such modifications receive little attention. Thus, any educational program for housing improvement should raise the awareness of the threat and emphasize the real danger to lives and property. Other prevalent attitudes must also be overcome in effecting a desire to change. A sense of fatalism is fairly common, deeply rooted in the cultural and religious consciousness. And too, building practices handed down from generation to generation are not easily altered unless a desire to change these practices has been created. These, combined with the economic constraints, necessitate the use of incentives, community and youth group activities, materials subsidies or other types of compensation to encourage housing improvements.

Both private and public sectors must be involved on a long-term basis in order to affect any strategy for housing improvement and vulnerability reduction. Incentive programs should be primarily geared to the private sector, as it is within this group that the largest percentage of housing will be constructed and financed. So long as the majority of housing is financed through personal savings, little, if any, control over building practices can be exercised. Construction habits will be dictated by tradition, popular trends, availability and cost of labor and materials. This implies that the development of public awareness programs should be the immediate goal. Concurrently, efforts to enact legislation against erratic building habits in villages should also be encouraged.

The following section covers specific means of communicating new information to villagers. The first part of the section deals with information on villagers' abilities to comprehend and interpret various types of drawings. This information is based on individual responses to pictures in a test booklet used throughout rural areas in seismically active zones.

A sample of the test booklet is included in this report. If further testing is desired, drawings can be modified according to regional differences, e.g., houses and construction details, clothing styles and facial types should relate closely to those who will be using the finished training booklets.

Similar tests have been conducted in other parts of the world as a means of determining how technical information can be relayed successfully to uneducated villagers. In all cases, this testing procedure has led to the development of training aids that do not require reading skills or any particular building knowledge. Hence, the training aids can be used not only by tradesmen, but also by village youth, women and even children as a means of stimulating interest to promote change.

The second series of drawings included in the report is an example of the type of training booklet designed for the villagers. This format is based upon responses to the tests conducted in villages in West Bengal, Rajasthan, Bihar, Himachal Pradesh, Uttar Pradesh, Gujarat, Maharashtra, and Jammu & Kashmir. Even in regions with the lowest literacy levels and little exposure to other forms of communication -- television, advertising, magazines, etc. — it was found that villagers could comprehend the drawings and understand the message. Similar test booklets and training aids can easily be created along these guidelines for other areas of rural development: nutrition, sanitation, hygiene, water purification, health, etc.

Preparation of Test Booklet and Training Booklets:

The test booklet used in the villages determines how and what the people can understand in pictures. It cannot be assumed that what an educated person sees in an illustration is also understood by an uneducated person. For example, a house shown in perspective may be interpreted as a building with walls that become smaller near the corners. Or a detail out of context may be seen as a totally unrelated object. Abstract symbols, such as arrows or directional lines, might be viewed as objects of religious significance or telephone wires. The artistic rendering of detail can also be misinterpreted: what is illustrated as a thatched roof may be seen as wood or C.G.I. sheeting. Hence, it is essential that any pictures used in charts, booklets or films be developed in accordance with the following guidelines:

(a) Size of Drawing: If too large, the drawing cannot be seen as a whole. If too small, it cannot be interpreted at all. Illustrations should be scaled to a comfortable reading size, keeping in mind the distance from which the pictures will be viewed.

(b) Perspective: 2-dimensional drawings are often more easily understood than 3-dimensional. Drawings should show perspective according to what a person normally sees. For example, the drawing of a village as seen from a nearby hill may be correctly interpreted, whereas an aerial perspective of structures would be misleading and should be used only when necessary.

(c) Shading and Coloring: Certain colors have traditional significance that will distract from the message of the visual. Colors should be selected within the appropriate cultural context or, better yet, extension agents/instructors from the local population might be encouraged to "color" teaching aids themselves. Whenever used, color should not distract from the main message of the drawing.

Shading can help to identify an object or person as a solid form, thus clarifying lines that might otherwise be confusing. Skin tone is important in helping local viewers to identify persons depicted in drawings as belonging to their own racial/ethnic group.

Care must be taken that shaded or colored areas are not interpreted as whole objects, rather than merely the enhancement of an object.

(d) Symbols: For example, arrows, dotted lines, wind lines, X's, check marks and directional indicators often are misunderstood or are interpreted as religious symbols, telephone poles, appendages of the illustration in point, or as other unrelated objects. These are best avoided unless dealing with a more educated community.

(e) Details: Details out of context are often totally misinterpreted. For example, a drawing depicting the enlargement of a foundation footing may be seen as a multi-story building, a train, etc., or may not be comprehended at all. If possible, details should be shown within the context of the larger picture or as whole objects. For example, a person with part of the head cropped off will be distracting to a villager; a disembodied hand may be difficult to identify.

(f) Background: Backgrounds should be eliminated or simplified as much as possible. Drawings and photographs should include only such background details which would encourage recognition of the subjects depicted or which would place the subjects in the appropriate cultural context.

(g) Sequencing of Images: People unaccustomed to reading often have difficulty making the mental connection from one image to another. For example, if attempting to show what happens to a house during an earthquake, it is best to show the destruction of the house in stages. A picture of the house immediately followed by a picture of the collapsed structure is often seen as two totally unrelated structures and the message is lost.

(h) Style: Clarity of drawing style is important. Too many details tend to confuse, while too few details create ambiguities. It has been found that simple line drawings which carry only the essential information are most effective. For example, if showing the plastering of a wall, emphasis should be placed on the activity of plastering and on the plaster, rather than on the wall details or other components.

(i) Story Line: Creation of a story line is extremely effective, especially when developing training booklets. A simple chronology of events can show the steps to be followed for modifing a house or for constructing a totally new house. People respond very well to information conveyed through stories and generally retain the information longer when presented in this format. This implies the use of a character or characters throughout the booklet who, through their actions, show how to modify or build a house.

(j) Text: If desired, a simple text in the local dialect can be added to enhance the story for those who do read, yet all necessary information should be conveyed by the drawings alone. The text should focus on essentials only. It should reinforce the key message contained in the drawings or photos. Bold, upper-case lettering is more easily comprehended than small, typed texts.

(k) Cultural Conformity: Drawings are generally viewed fairly literally. Hence, if a housing style or detail does not conform to the conventions of a particular region, villagers may respond with, "We don't have that kind of house here" or "We don't do that here", and the message will be lost. For example, a drawing which depicted a structural framing technique in Andhra Pradesh was seen as a rest house in the northern tea estate areas of West Bengal. It is recommended that, whenever possible, training aids be prepared with attention to regional building practices and cultural differences.

Understandably, in a country where language and literacy levels vary from region to region, the most effective means of communication is through on-site demonstrations, dialogue and visual aids. Radio, television and film can augment a program if the means and economics exist. It is imperative that these be prepared with a sensitivity to local customs, level of skill and language.

Teachers' Instructional Booklet:

This should be created as a supplement to the cartoon booklet, providing technical background for teachers or extension workers. A more cost-effective means would be to print the explanation or technical information for teachers below the drawings or on the facing pages.

Films:

Films are an extremely popular form of entertainment in India and can be used very successfully to stimulate interest in vulnerability reduction. Because of the general lack of awareness of earthquake risk, it is recommended that a film be prepared which describes an earthquake and its impact on housing. Through animation or dramatization, a short 10-15 minute film would serve as a popular means of introduction to a village. The film could be used for both public information activities and in instructional programs for extension workers. In many villages, this might be the only form of entertainment for the week, so attempts should be made to schedule the film at a time when daily chores are completed and just before or during the building season. Discussions should be encouraged afterwards with special attention paid to reactions and attitudes concerning the film's message. An inexpensive flyer illustrating what an earthquake is and how it can damage a house should be distributed to those watching the film. This will reinforce the film's message by helping to maintain a level of awareness. If a demonstration project is scheduled, the time and place might also be noted on this sheet as a reminder.

Demonstration Projects:

Demonstrations of ways to build or retrofit a house for vulnerability reduction should be planned for as many villages as possible. This can be arranged through the local Panchayat or Tehshildars, Block Development Officers, or other influential community leaders. A demonstration on a house undergoing construction would provide the builders and villagers with an opportunity to actively participate. Evening classes might be scheduled after the day's work to make as many villagers as possible aware of the modifications. With this stimulation of awareness, villagers would then be more demanding of tradesmen to include modifications when given the opportunity to build for themselves.

During this class, active audience participation should be encouraged. Training booklets could be distributed and explained to those involved in housing construction and/or to heads of households. Various incentives might be created within the village to encourage use of the building practices outlined in the booklet.

Audio Cassettes for Radio Programs:

Radio can be used very effectively to educate the public about potential earthquake danger. Initially, short messages or dramatizations (about 1 minute in length) could be created to emphasize (a) the risk (potential for damage to lives and property) and (b) the need to take action, with information given on to whom the listeners should talk for help or guidance if building a new house.

These short messages can be interjected between radio programs, music, etc., several times during the day. Repetition of the message is important, as is timing. Radio messages should be aired according to the listening habits of the target audience.

These short announcements could be augmented through longer, more in-depth programs which would reinforce the shorter messages and introduce new information.

Audio cassettes for distribution to radio stations could describe earthquake risk and outline methods for improving buildings. A discussion with the Panchayat, village leader or extension worker could be aired afterwards in which information about pilot programs, demonstrations and specific activities could be announced.

Posters:

Posters or flyers displayed in public places in the village can stimulate interest in a program. A popular film actor or cartoon hero could be utilized to describe housing modifications. These should be prepared using guidelines suggested in the section on testing booklets. Posters should also indicate where interested parties can obtain more information.

Mobile Teaching Units:

These could be used to bring the film and other information to villagers. Based on the "village theatre" form of entertainment, the mobile unit could serve as an entertaining and effective means of creating awareness and distributing materials in rural areas.

Exhibitions and Trade Fairs:

These are also very popular with villagers and present an opportunity to reach a wide audience, as these events are well attended. Films can be shown, booklets or flyers distributed and information on earthquake and vulnerability reduction provided. Charts and diagrams showing how an earthquake affects housing, and information on various modifications, should be prepared using the same guidelines explained in the section on training booklets.

When preparing an exhibition, it is important to remember that the majority of viewers cannot read and that the effectiveness of the display will closely related to the degree in which it communicates through pictures or, better yet, realistic models.

Community Participation:

As much emphasis as possible should be placed on community involvement in the implementation program. This can be encouraged by involving villagers in the extension of the program. For example, youth leaders or carpenters selected by the villagers could be assigned the role of encouraging building modifications, or of inspecting houses in which modifications have been completed. Involvement of women and children in the program should not be overlooked, as they are often helpers in housing construction and can be very influential. Materials such as booklets, posters, etc., should be readily available to villagers; copies can be given to village leaders, teachers, carpenters and masons, and should be available in schools, churches and libraries.

Throughout the training and implementation process, materials and programs should be evaluated for their effectiveness. Villagers should be questioned for responses to films, radio announcements and posters, and levels of acceptance should be considered. It is understandable that a program of this scale will take years before its impact is felt. However, if these recommendations are followed, public awareness of earthquake risk should be heightened and hopefully the necessary steps for reducing that risk will result. Co-operation between technical and research organizations, state governments, voluntary agencies and local leaders will have a major impact on the program's effectiveness. Through concerted efforts, acceptance of new building techniques by builders and villagers will gradually become part of the building tradition.

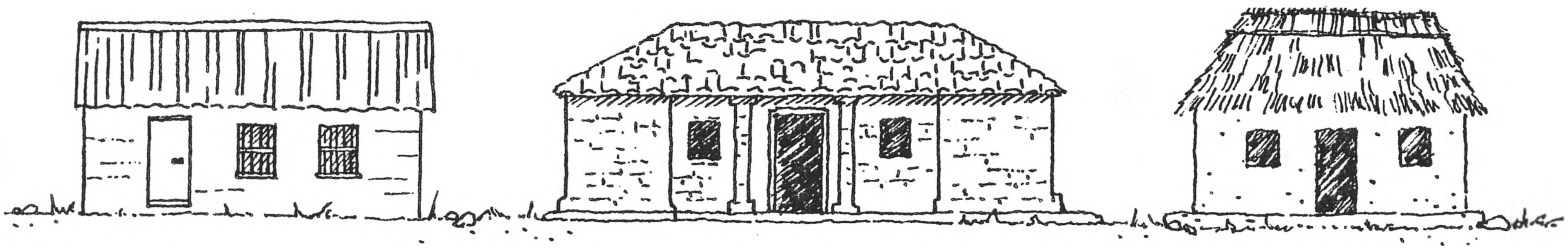
APPENDIX III

Comprehension Test Booklet

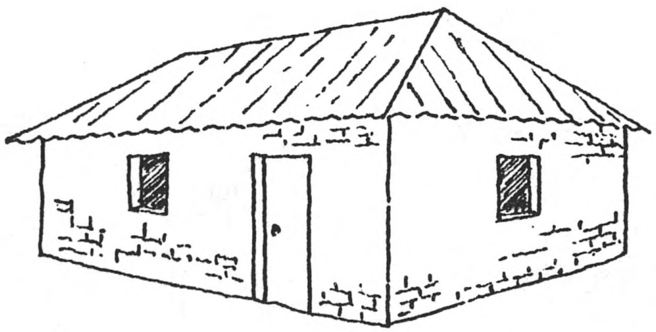
COMPREHENSION TEST BOOKLET

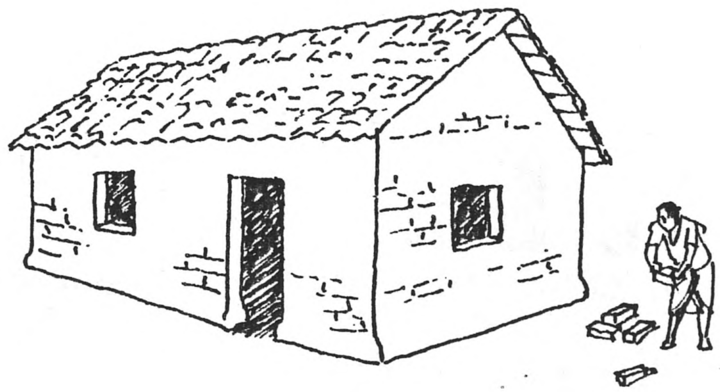
Note: The questions suggested on each page are to aid the instructor in determining what a villager sees in the drawings. These will simply begin a dialogue which the instructor should further encourage through questions of his own.

Manual prepared by Juliana Marek, INTERTECT, under contract to the University of New Mexico, with funding provided by the Office of U.S. Foreign Disaster Assistance, Agency for International Development

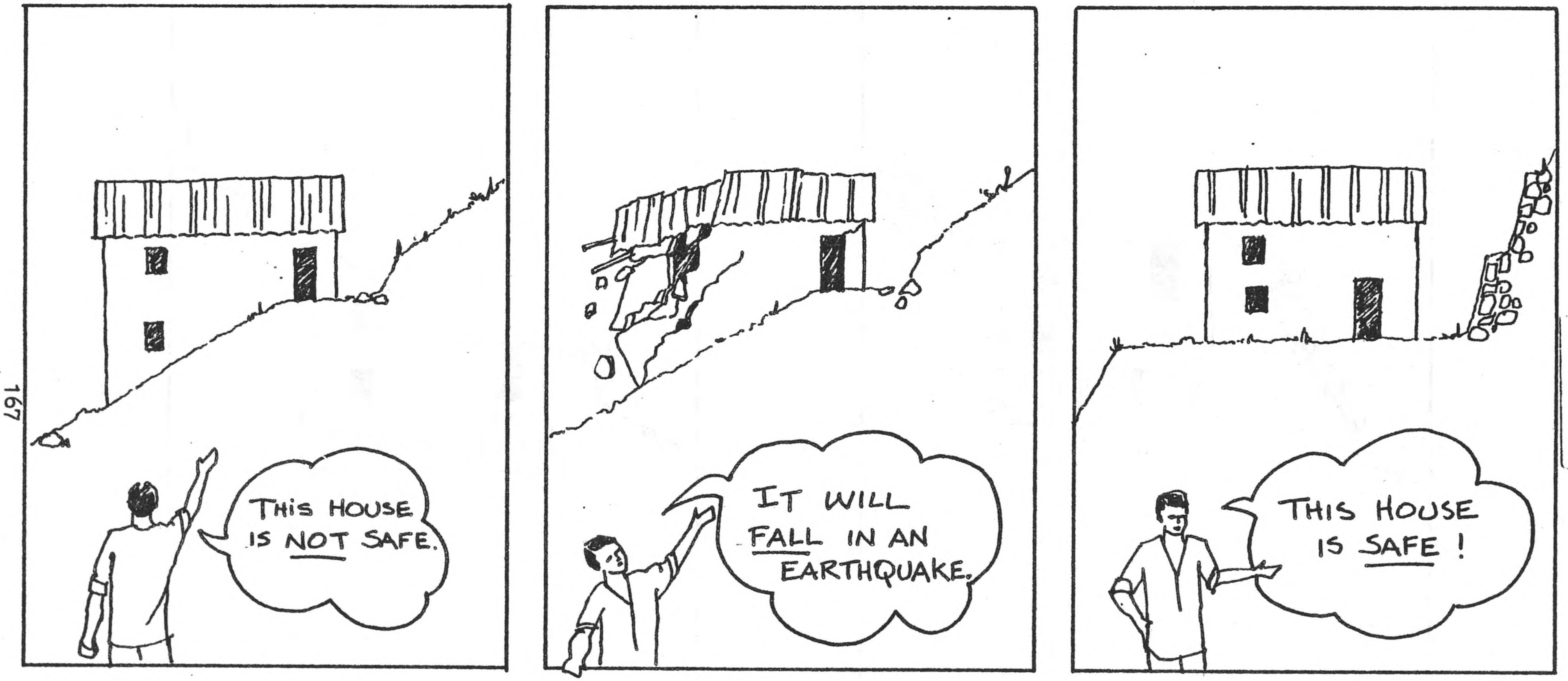


Ask villagers what they see on this page. Have them describe materials used on each roof.

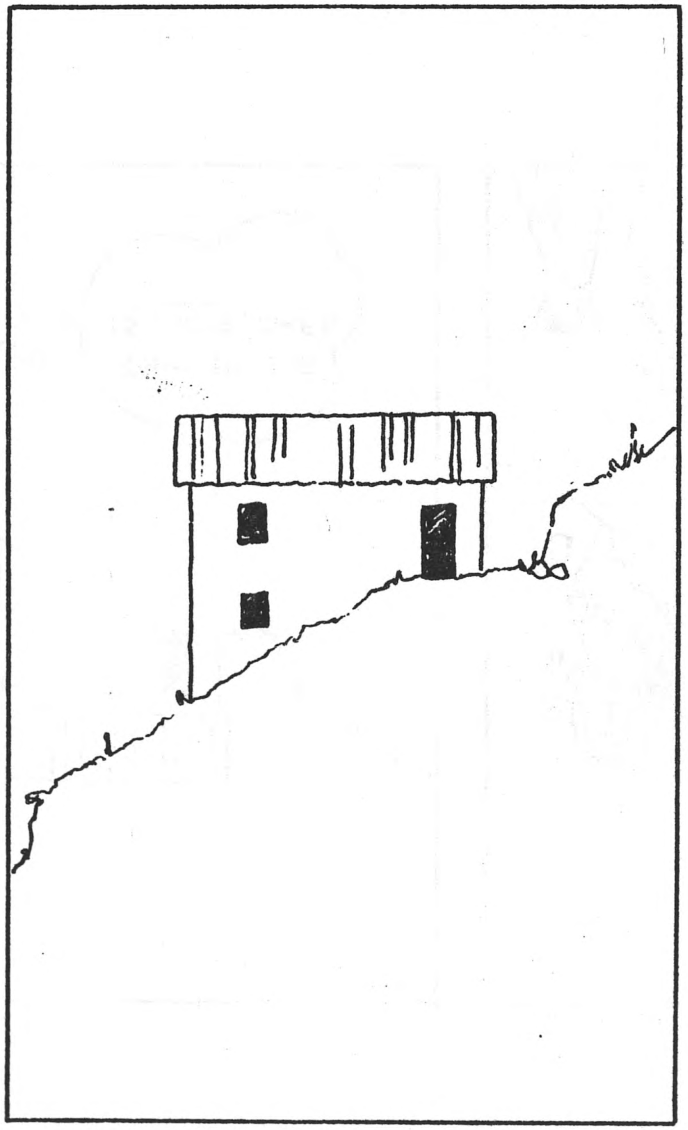


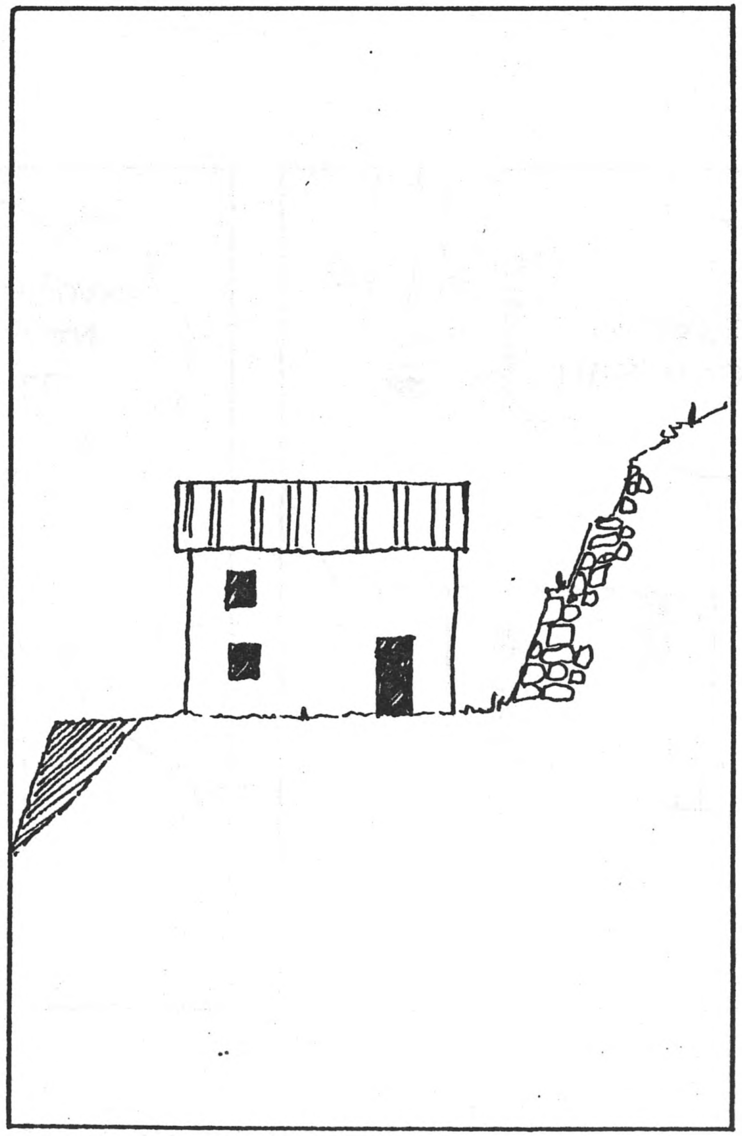


Ask how many walls can be seen on each house.

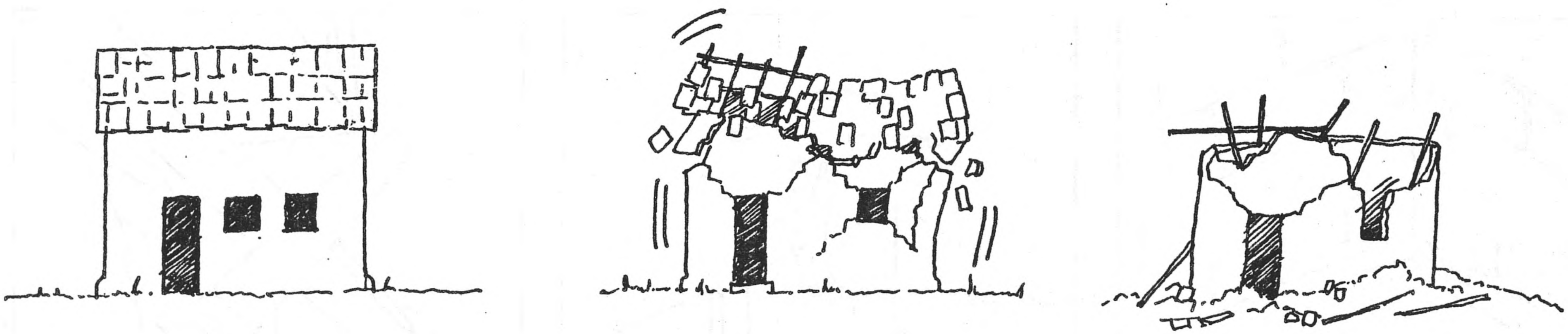


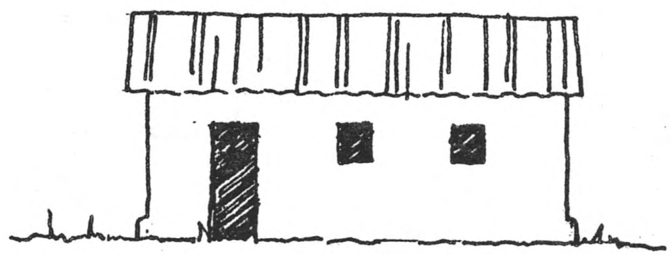
Read captions. Ask someone to tell why the house in the last box is safer. Ask which house is the safest in an earthquake.



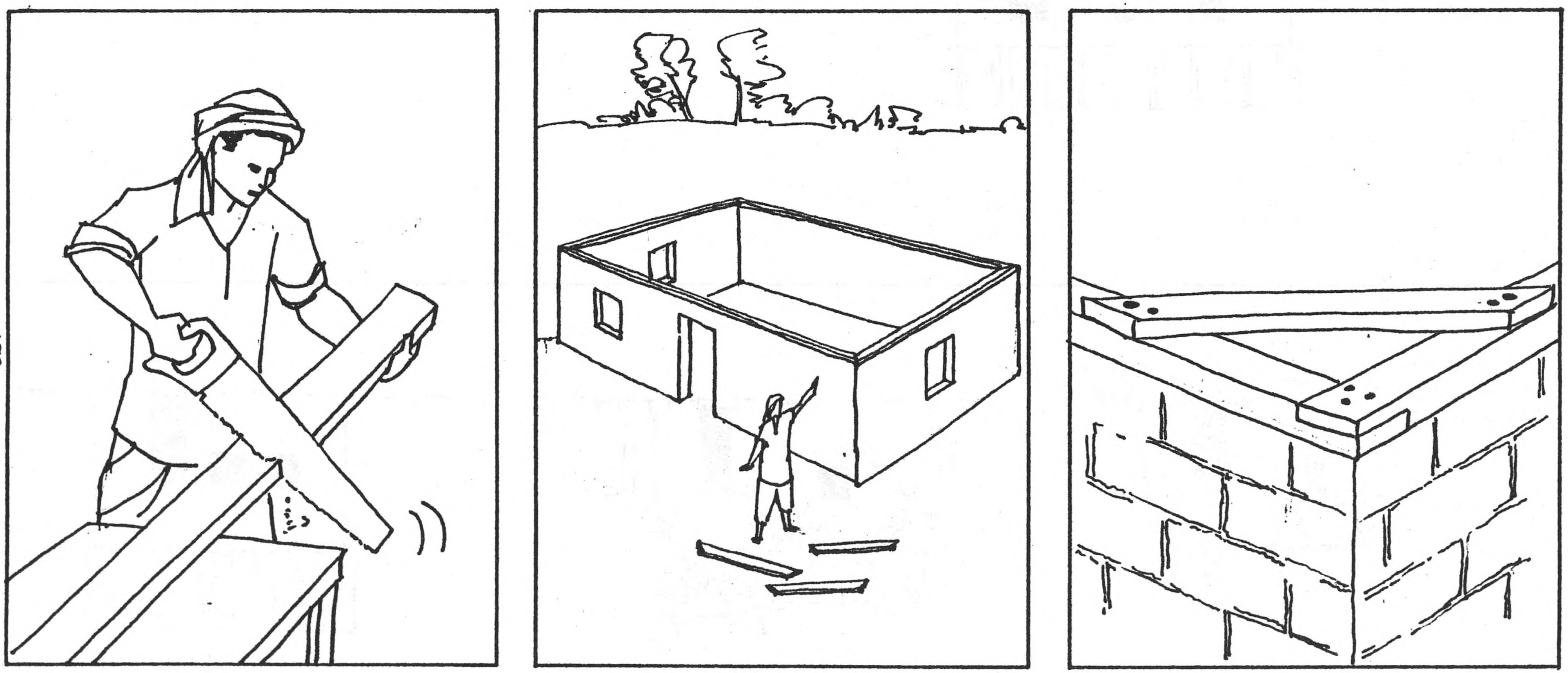


If the previous drawings were understood, villagers should see that the second house is safest and will explain why.

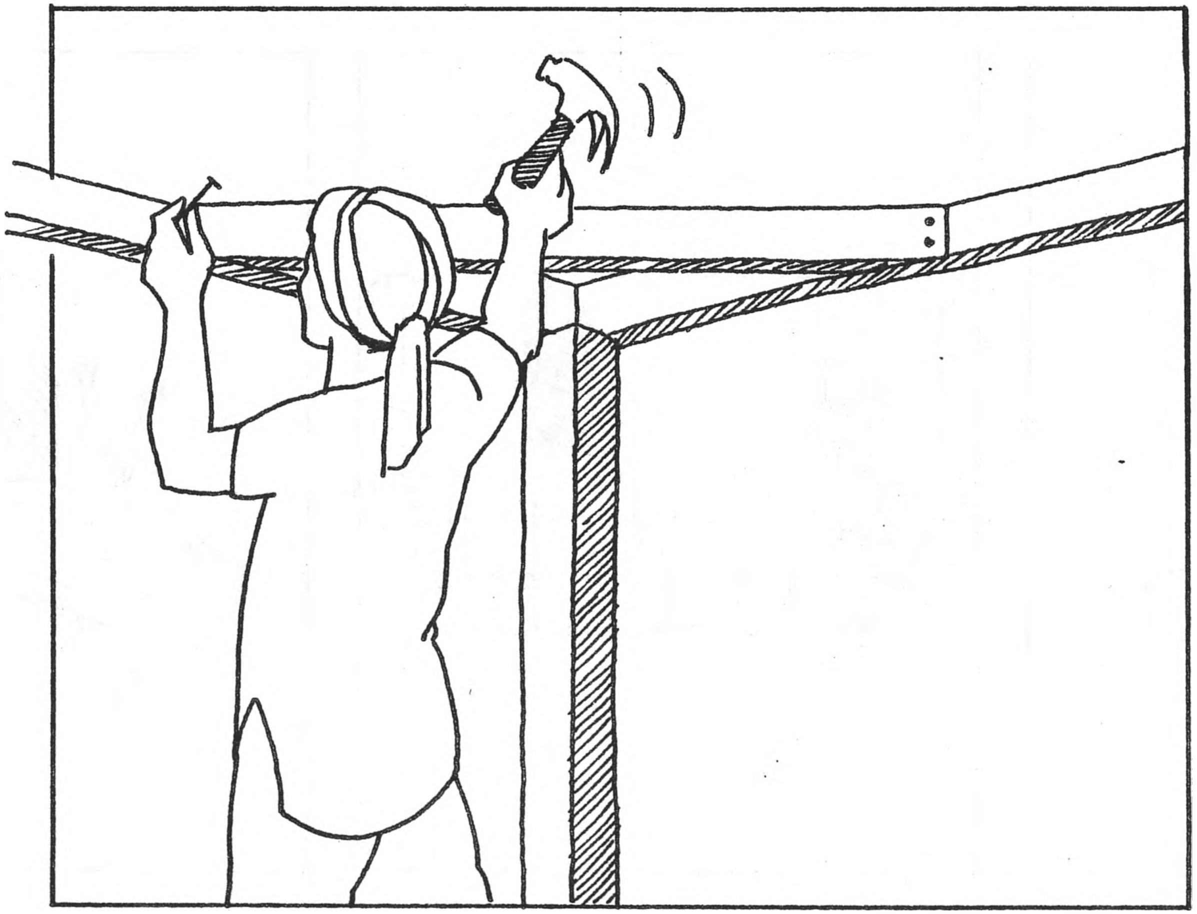




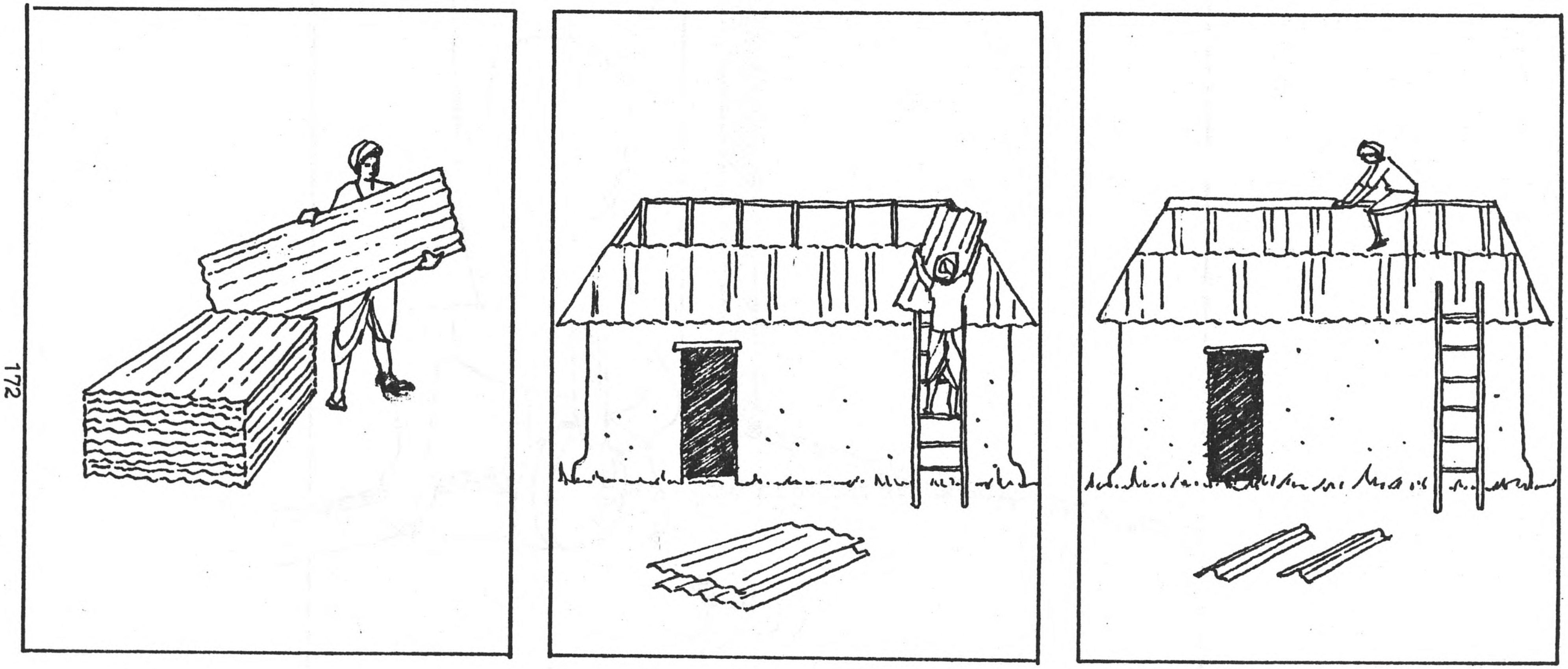
Ask someone to describe what is happening to the house on top. Explain that the bottom house is safer during an earthquake. See if villager can see the difference between lower house and upper house.



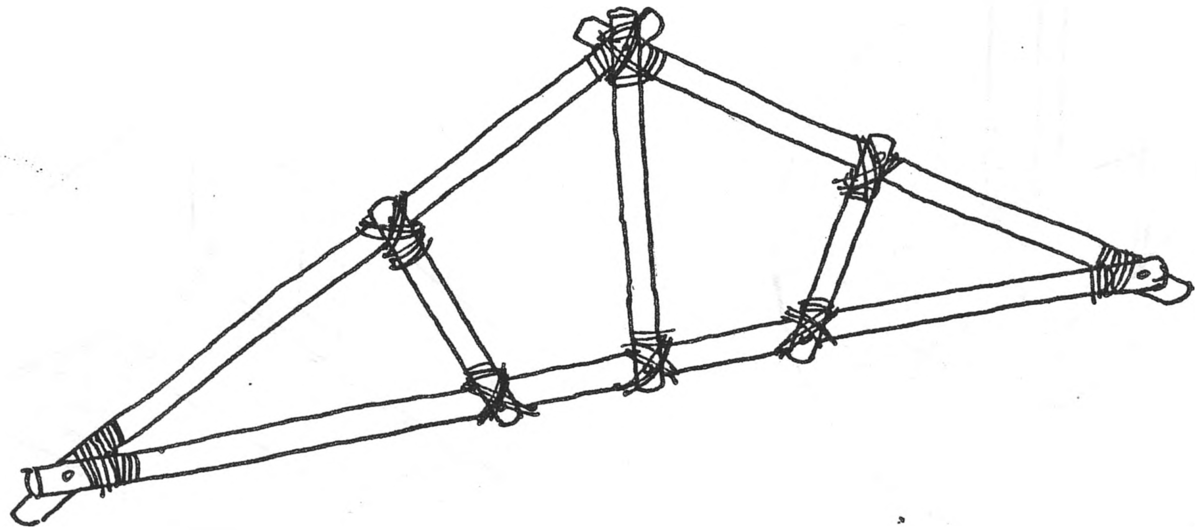
Ask someone to describe what is happening in this sequence. Ask what part of the house is being braced and what material is being used.



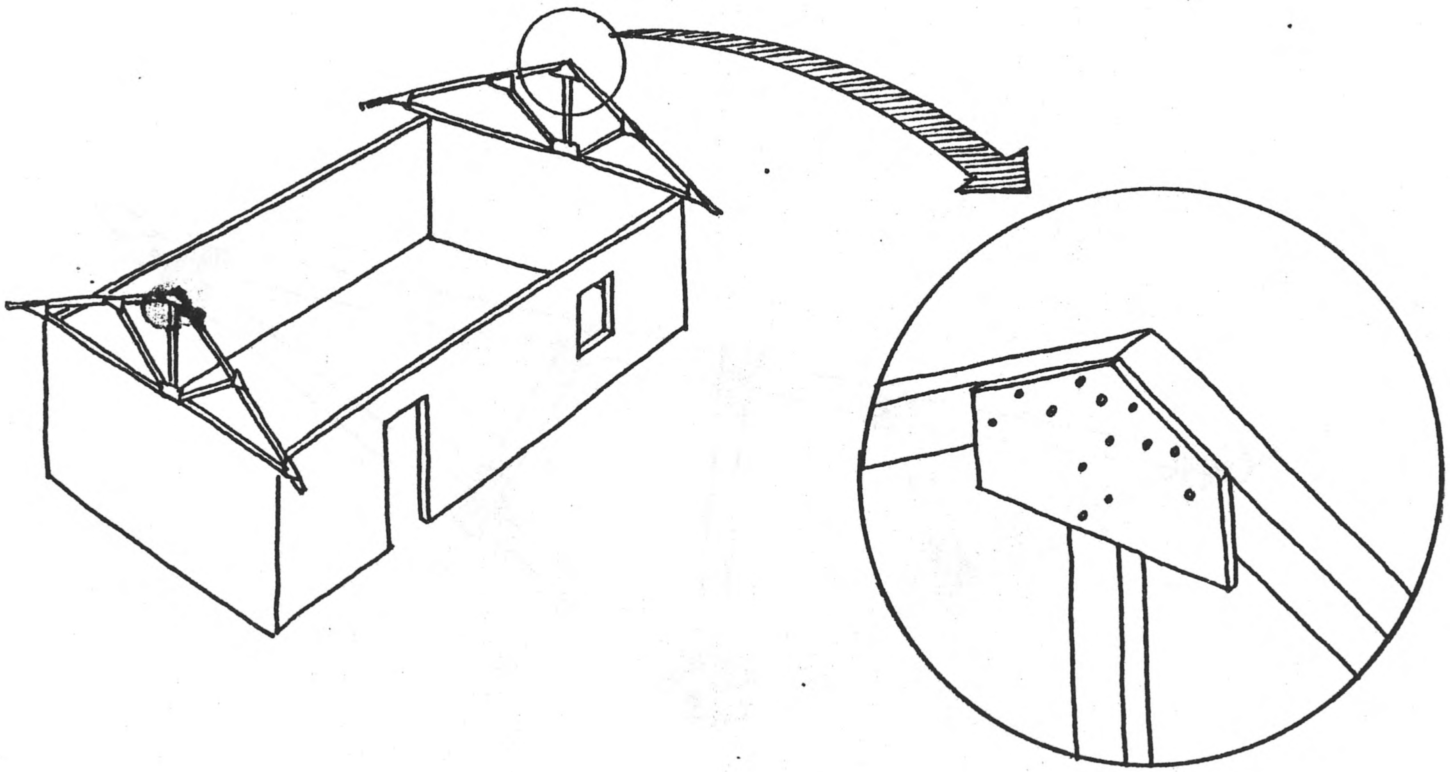
Ask villager to describe what the man is doing. Ask which part of the house is shown e.g. corner, center post, etc.



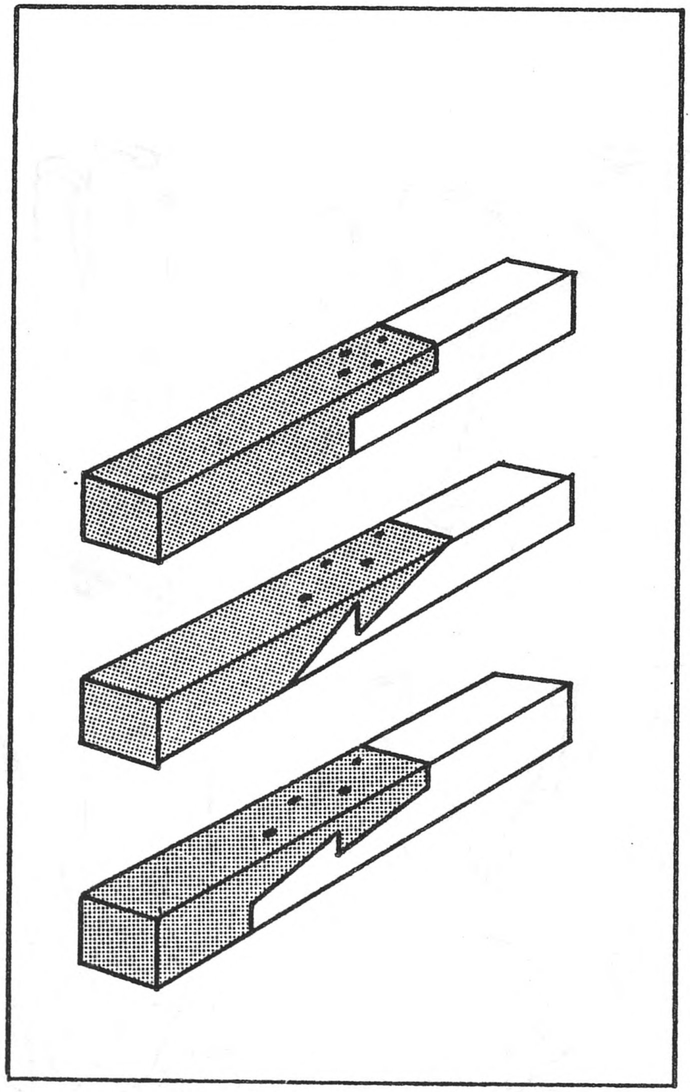
Ask someone to describe what is happening in the sequence. Ask what material is being used on the roof.

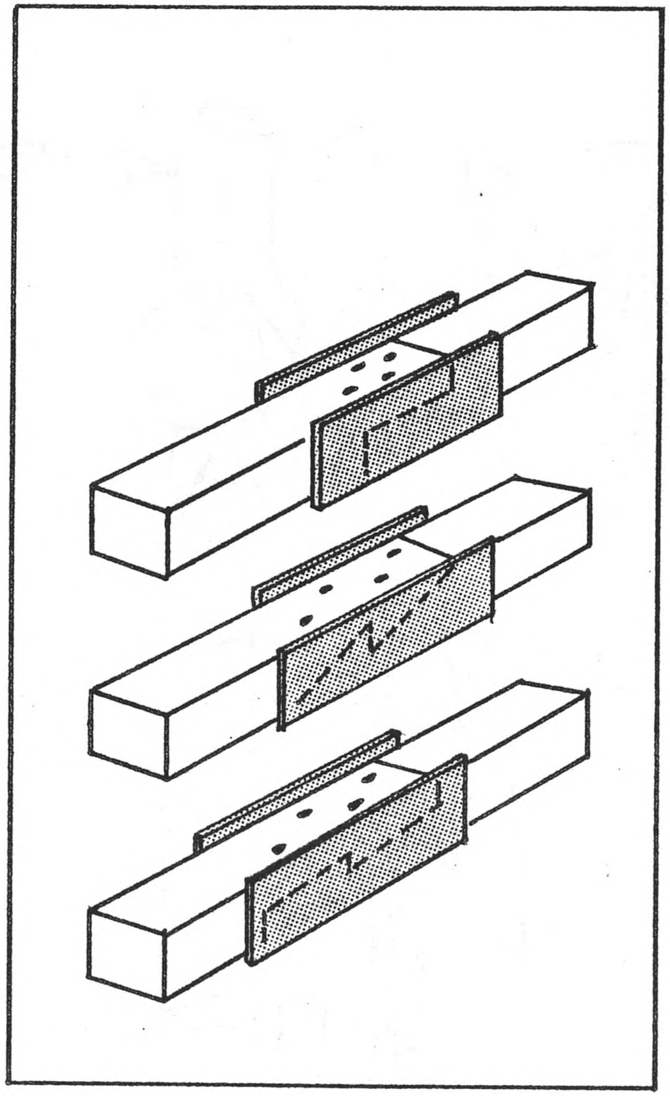


Have someone show you which part of the house this is. Ask what materials are used.

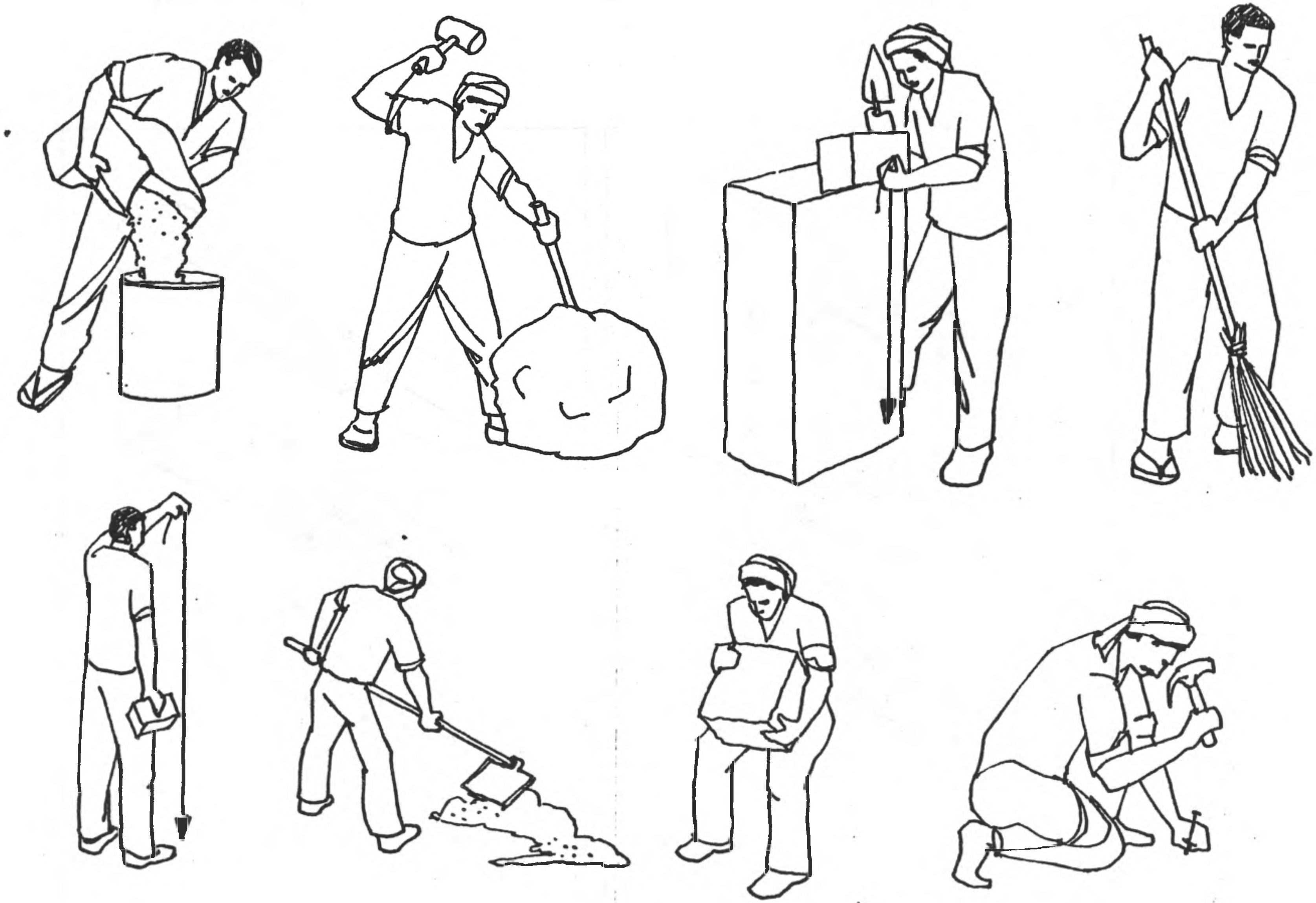


Have someone point to the part of the house shown in the circle.



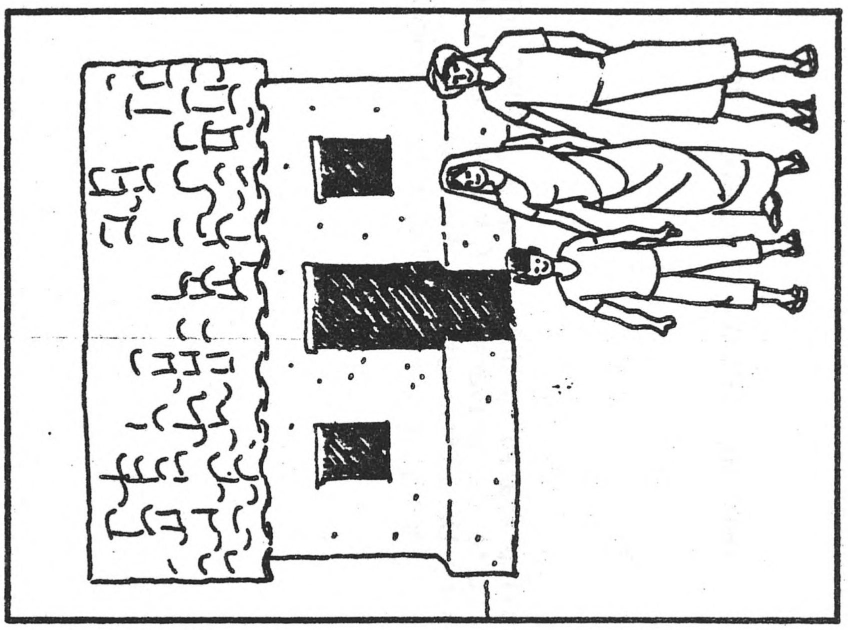


Ask what these are. If recognized as wood joints, ask which is the strongest and which is the weakest.



Have someone describe the activities shown.

APPENDIX IV



How To Build A Plinth Guard

HOW TO BUILD A PLINTH GUARD

Manual prepared by Juliana Marek, INTERTECT, under
contract to the University of New Mexico, with funding
provided by the Office of U.S. Foreign Disaster Assistance,
Agency for International Development

PLINTH GUARD (Suggested Text)

1. When it rains, this house is damaged by water. Water causes the foundation to deteriorate. To protect the foundation make a PLINTH GUARD.

2. First, dig a trench all around the house. It is ____ inches deep.

3. Line the trench with bricks. Put mortar between the bricks. Lay the bricks all around the house.

4. Mix the mortar. Build a brick plinth guard against the wall of the house. Make the guard _____ inches high and 1 brick wide.

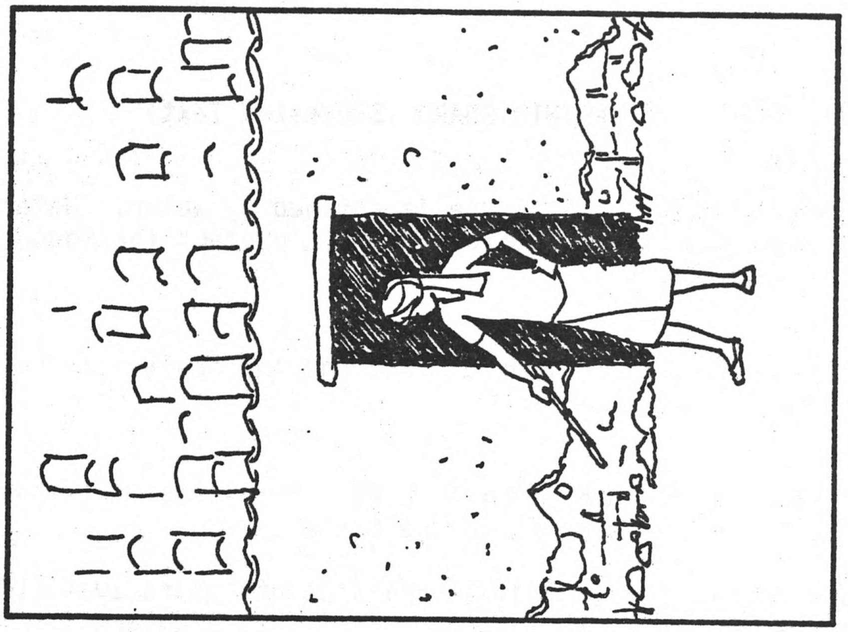
5. Cut a groove into the wall of the house just above the brick plinth guard. Cut this all around the house.

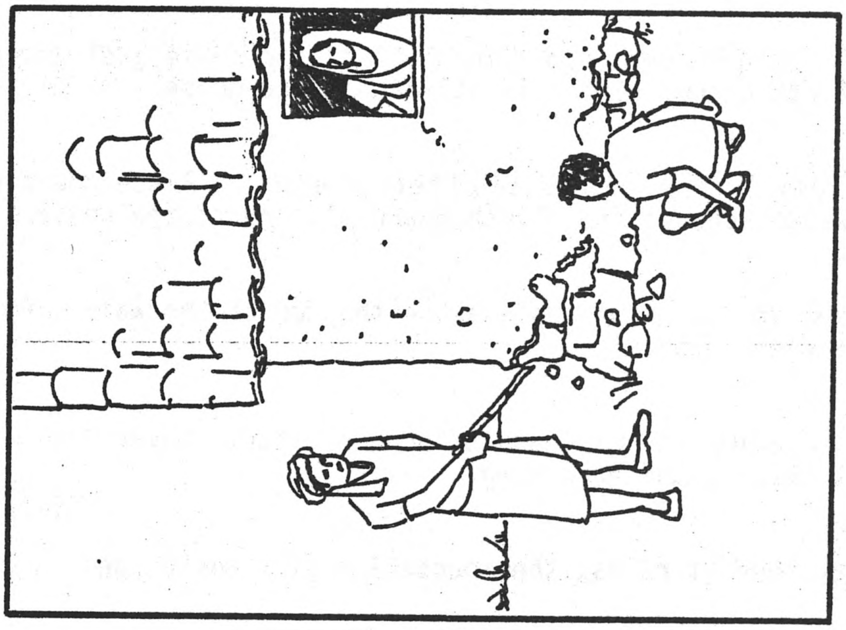
6. Break bricks into smaller pieces. Place the pieces on the inside edge of the plinth guard all around the house.

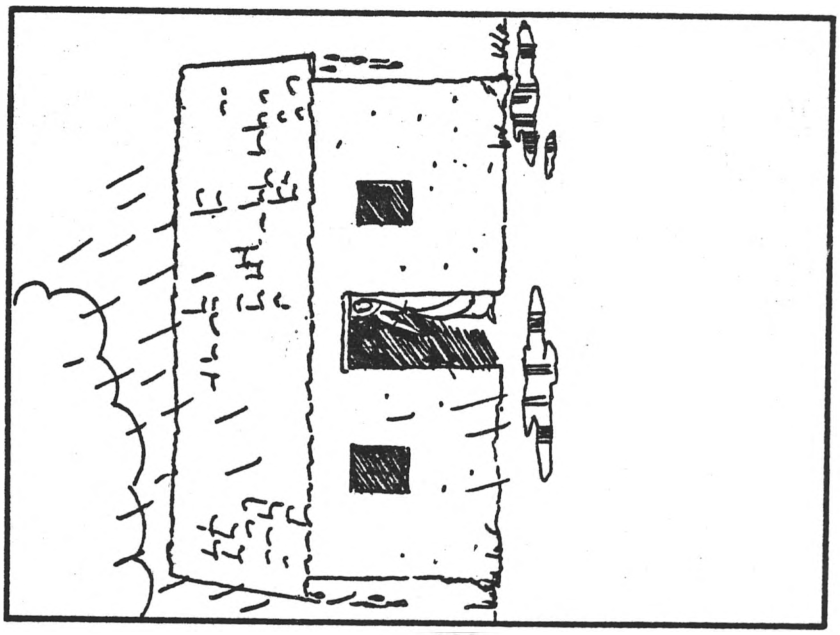
7. Lay bricks at an angle along the top of the wall. Put mortar in between each brick.

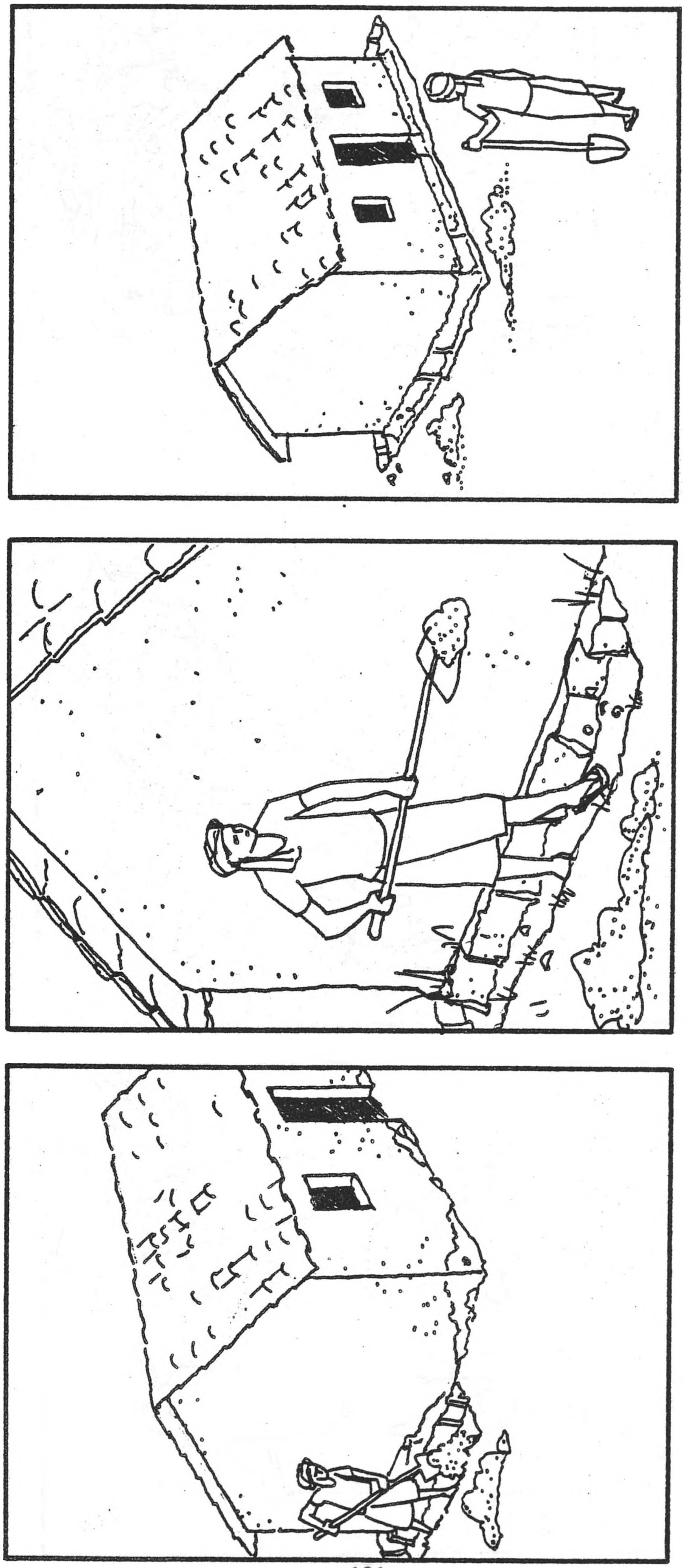
8. Mix a dung, mud, and bitumen plaster. Cover the walls. Start at the top and work down.

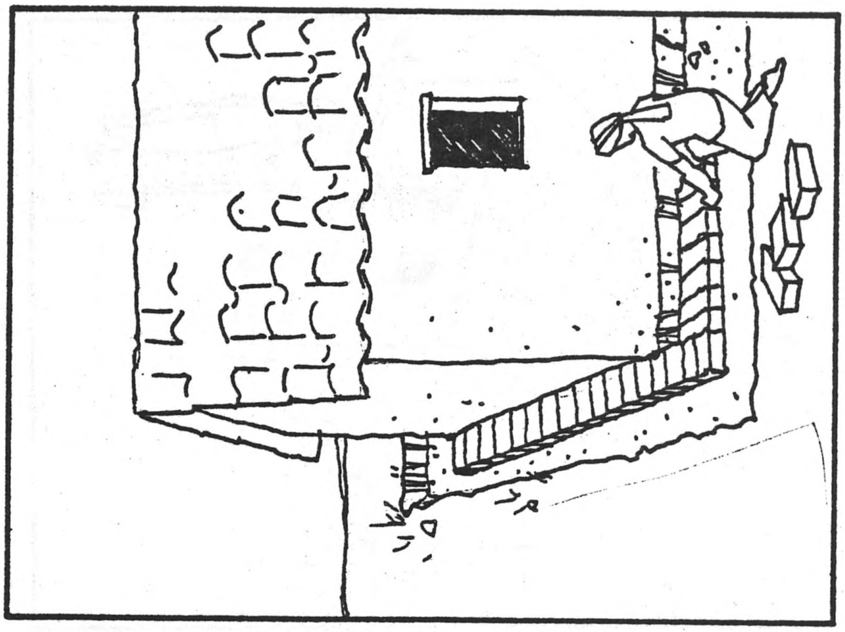
9. Now when it rains, the foundation will not erode.

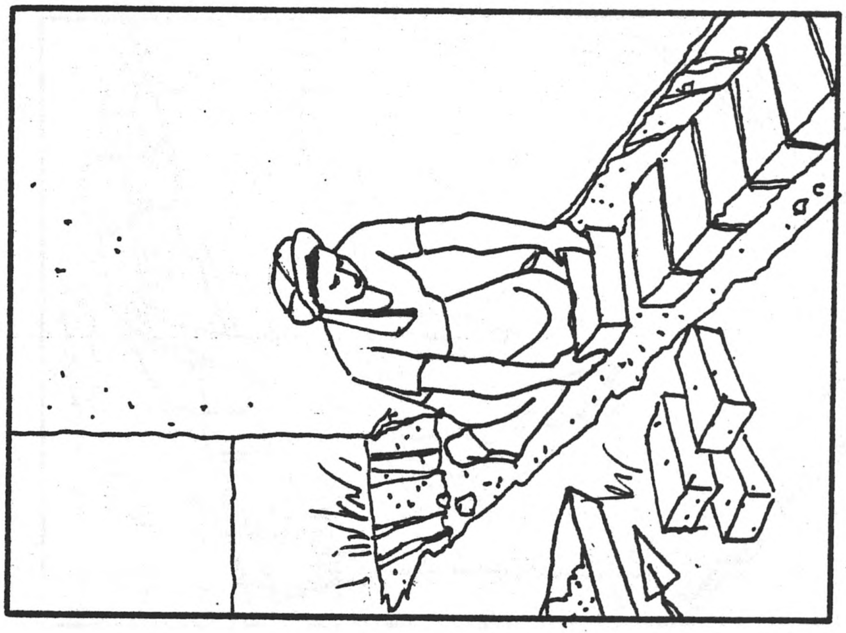


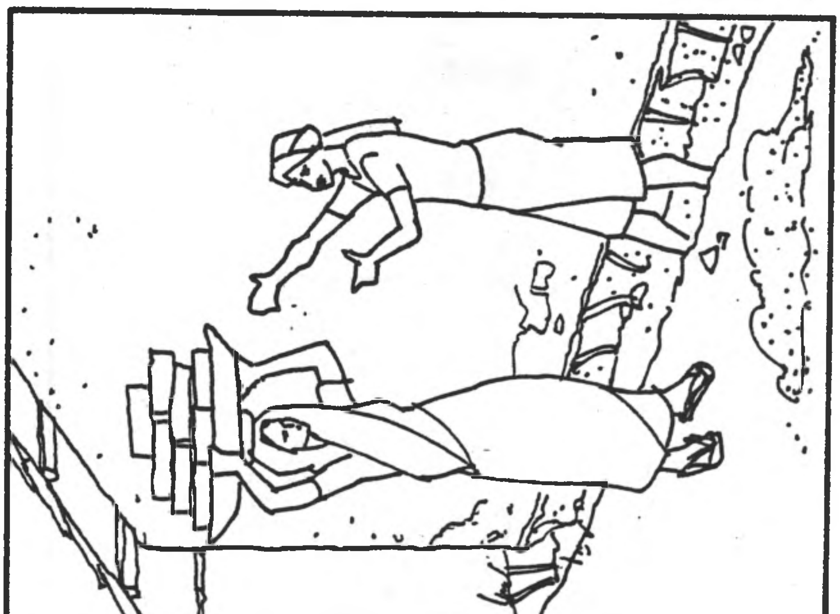


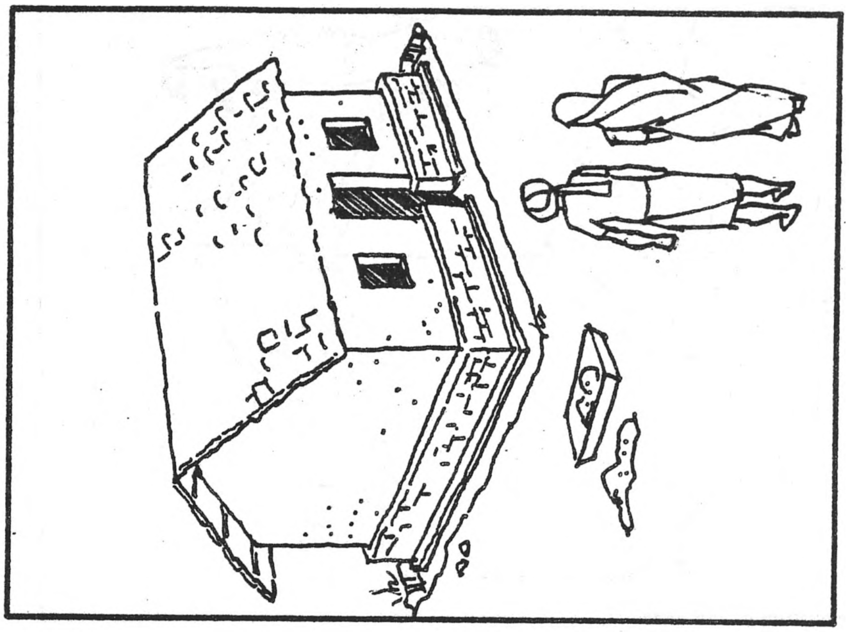


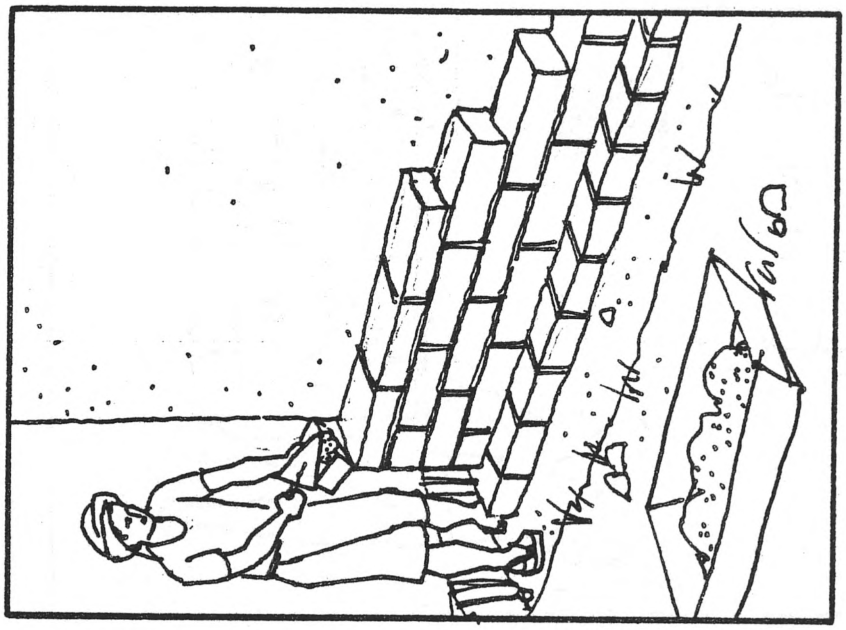


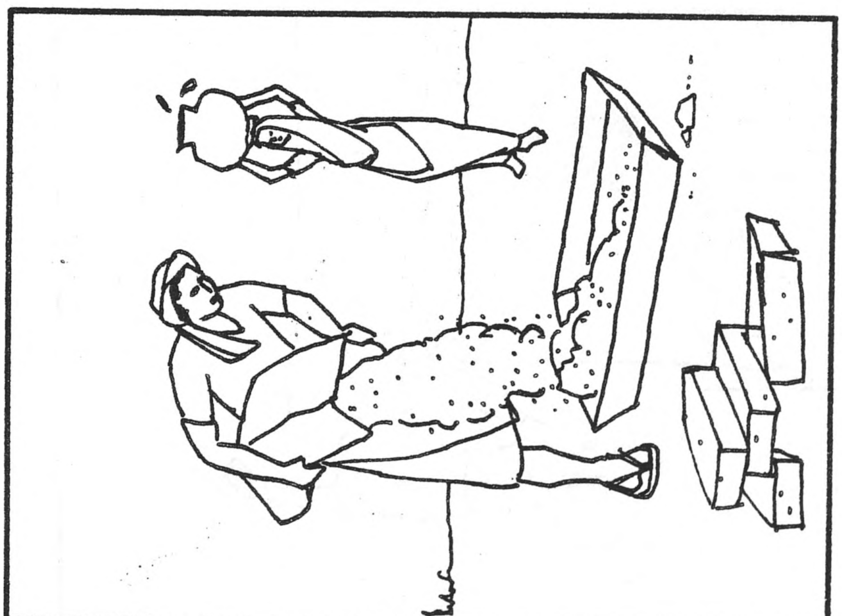


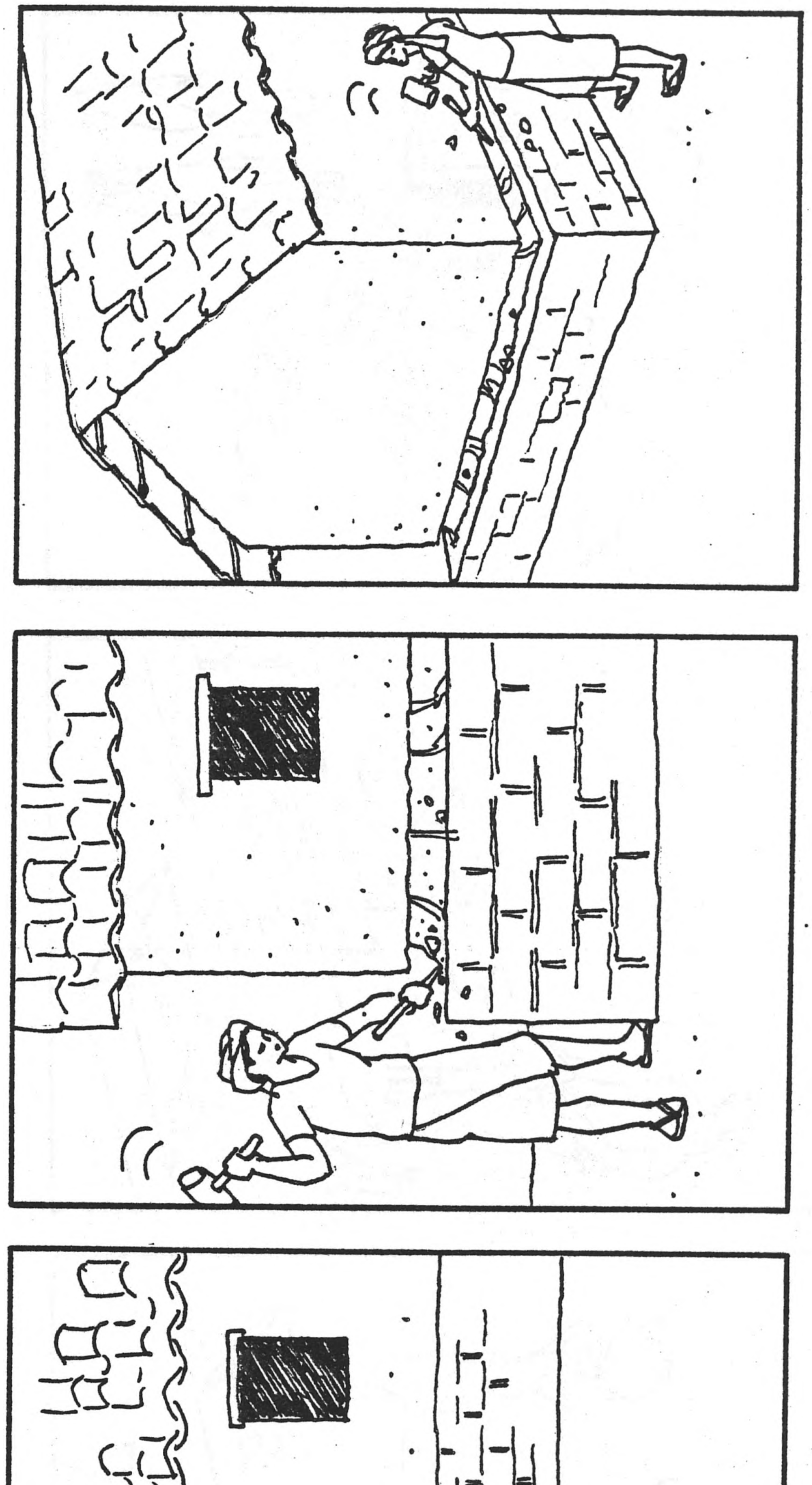


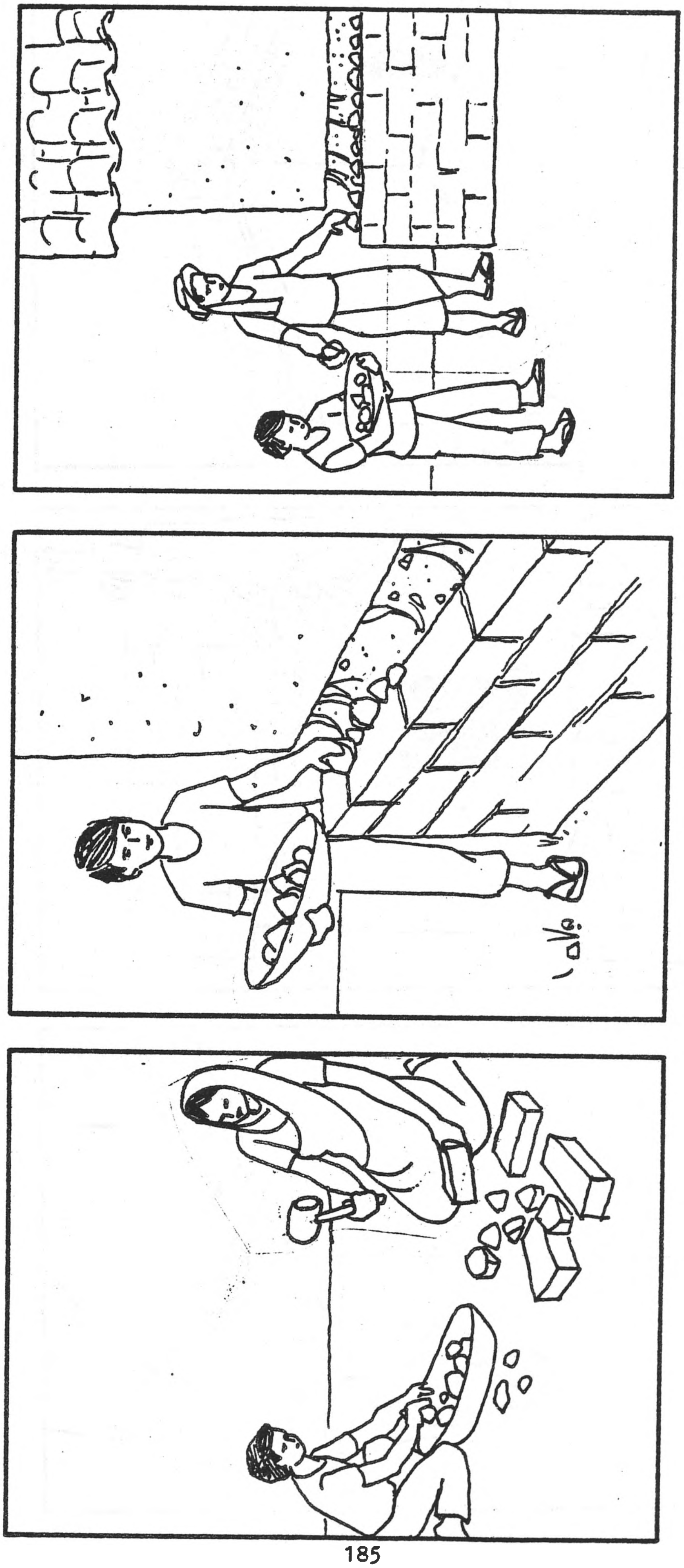


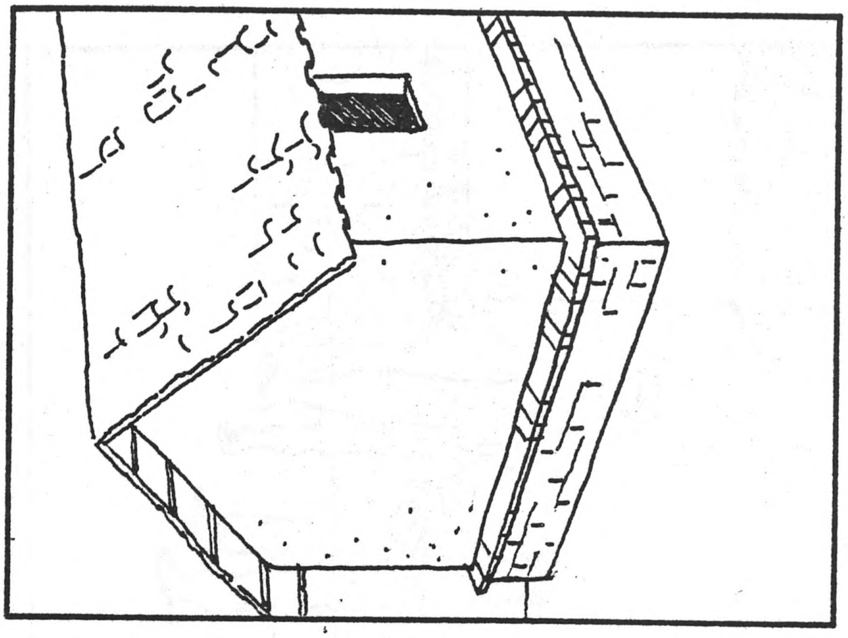


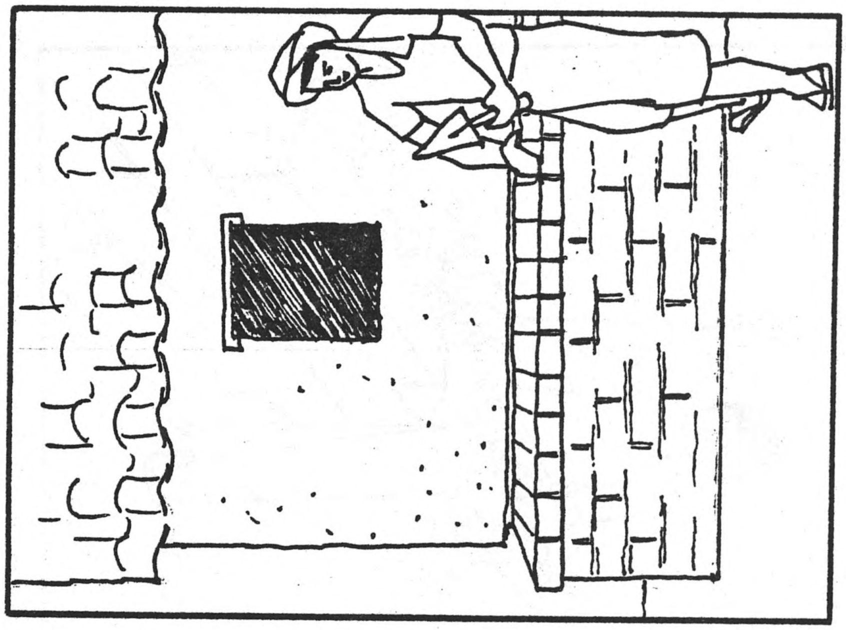


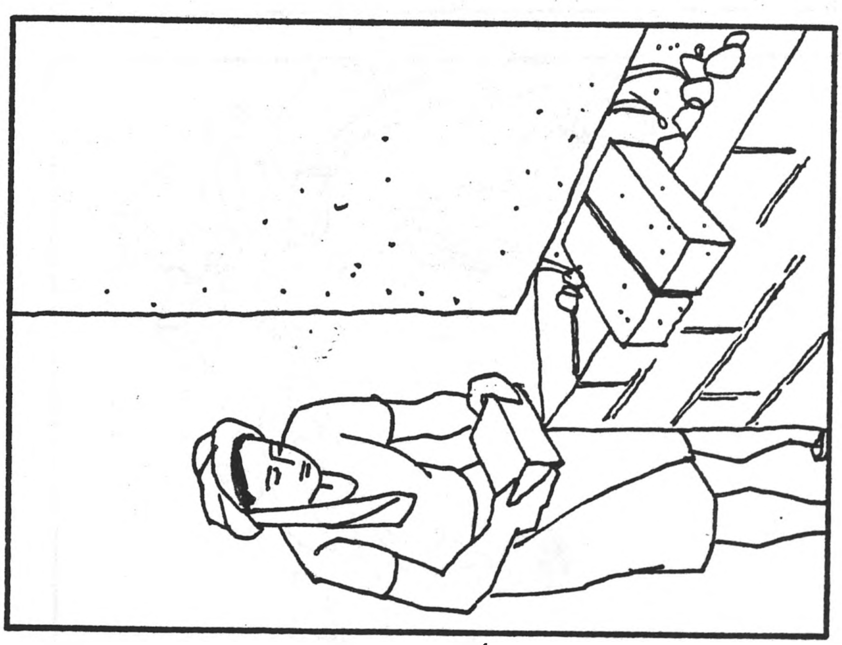


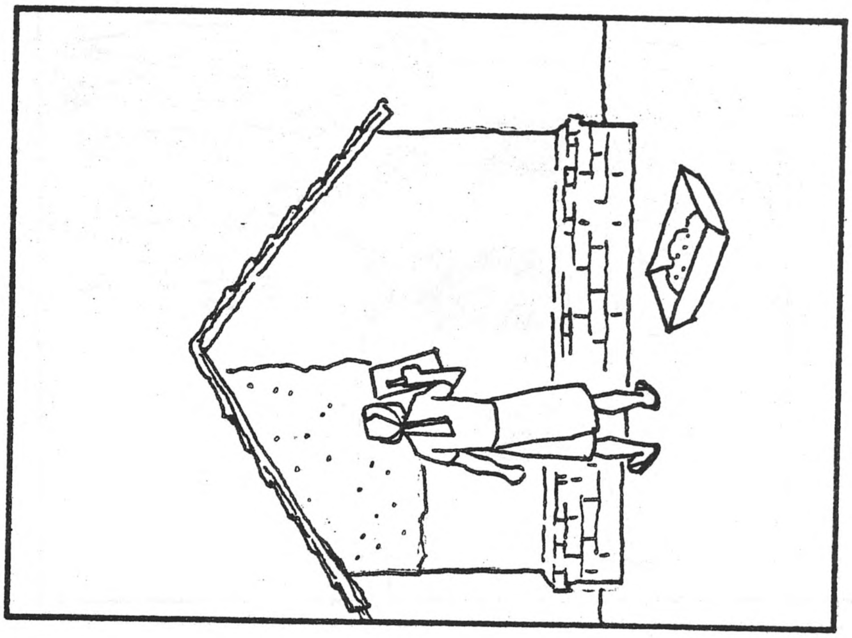


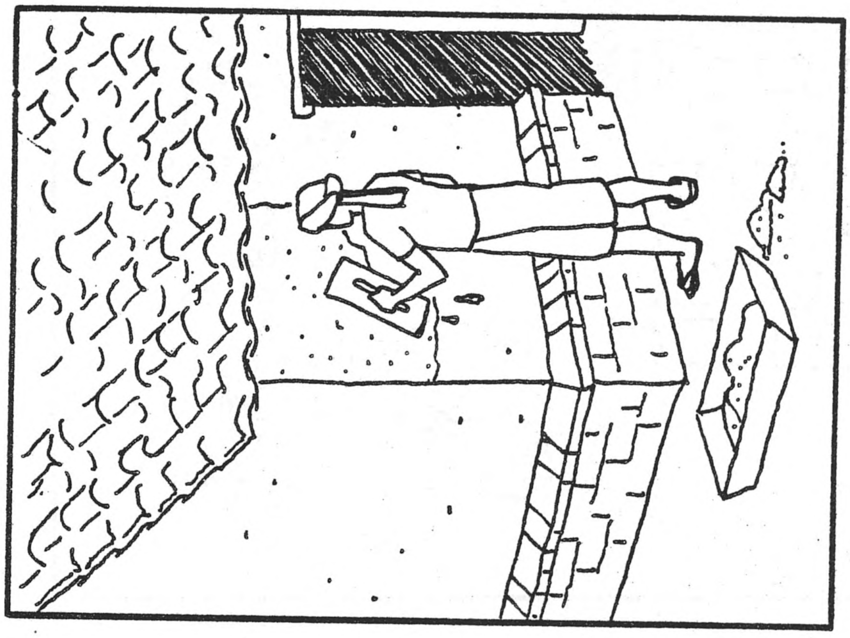


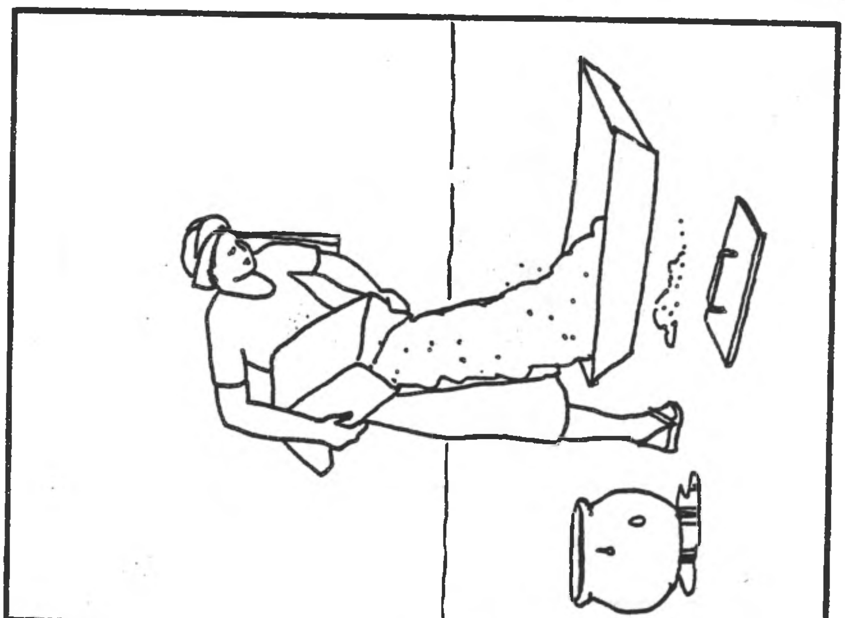


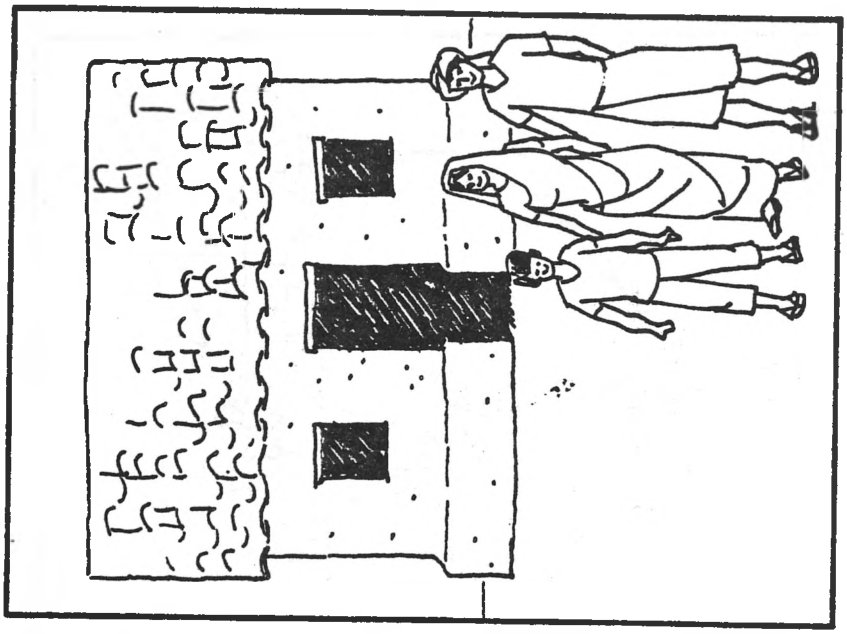


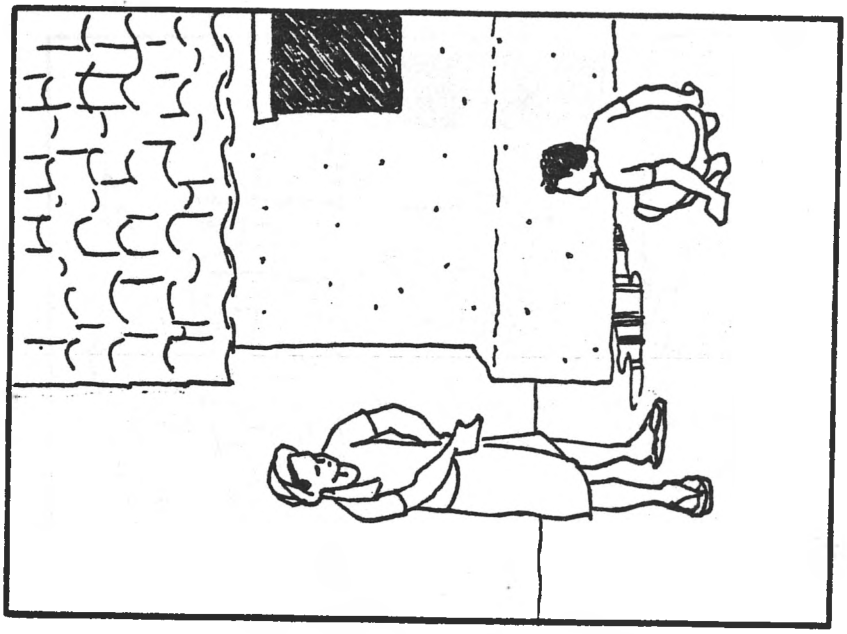


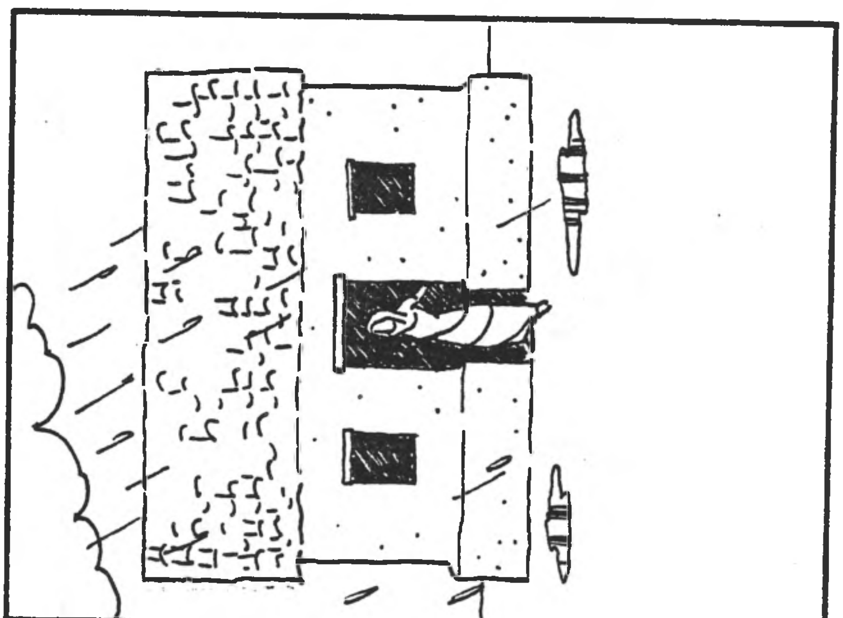




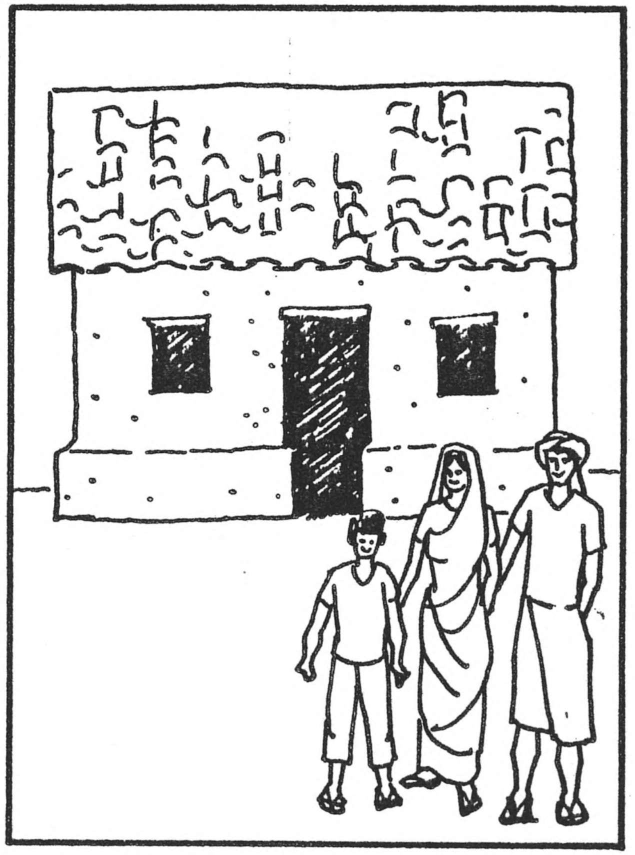








APPENDIX V



How To Make A Non-Erodable Mud Plaster

HOW TO MAKE A NON-ERODABLE MUD PLASTER

Manual prepared by Juliana Marek, INTERTECT, under
contract to the University of New Mexico, with funding
provided by the Office of U.S. Foreign Disaster Assistance,
Agency for International Development

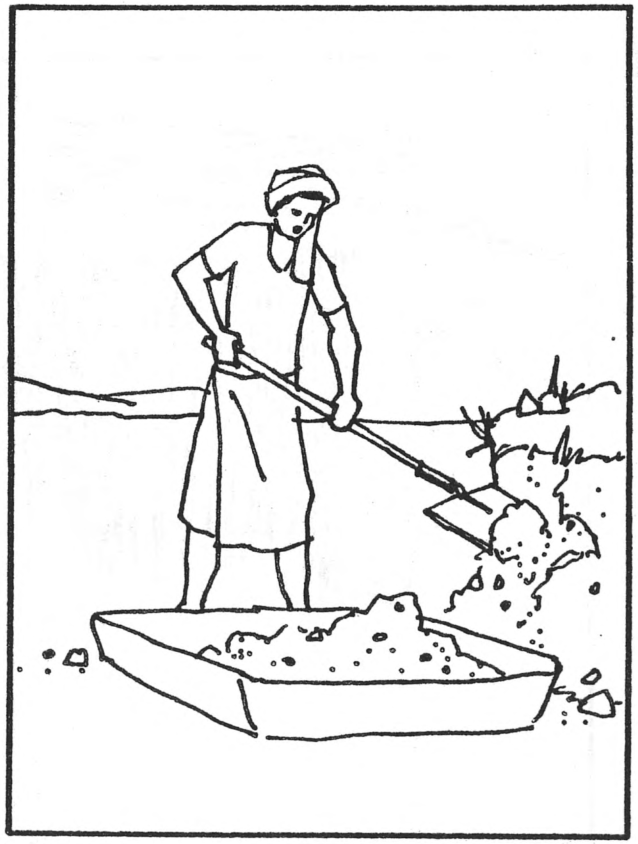
SUGGESTED TEXT:

Every time it rains, this house is damaged a little by the water.

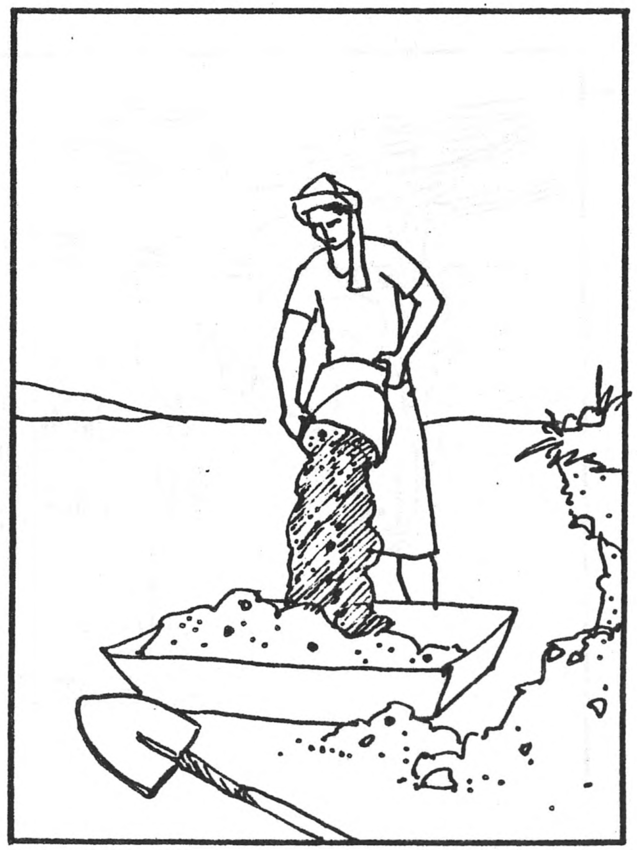
The house will not last long if the walls erode.

To protect this house, cover it with NON-ERODABLE MUD PLASTER.

First, collect mud from the bottom of the village pond.



Mix this with local soil.

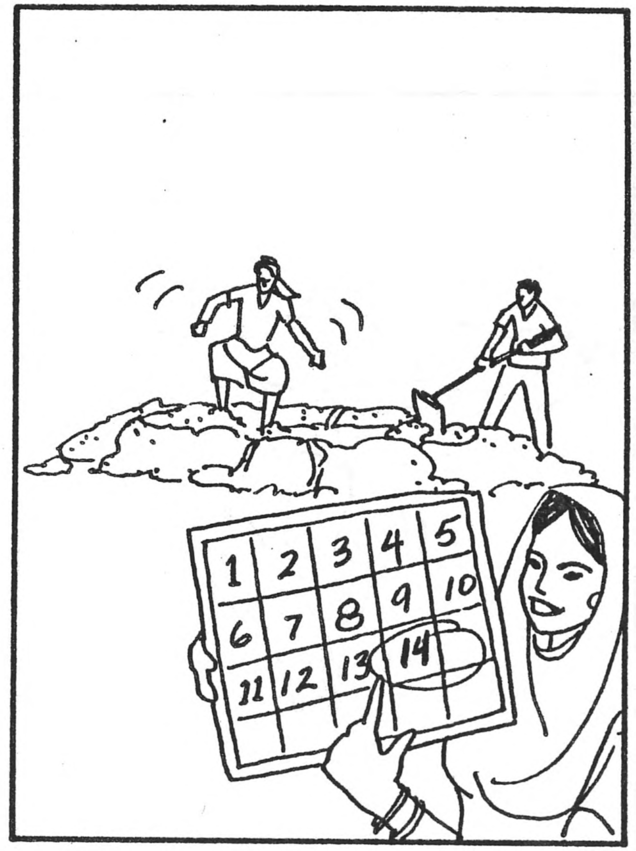


Keep the mud and soil mixture wet.
He kneads it with his feet every day.

His wife cuts bhusa to add to the mud.

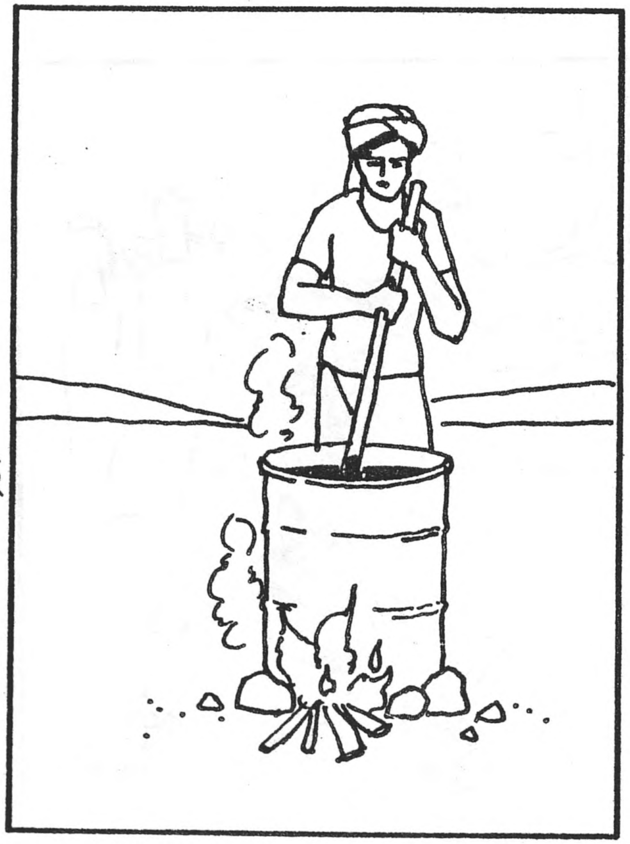
He chops the bhusa into small pieces.

Add bhusa to the soil and mud.

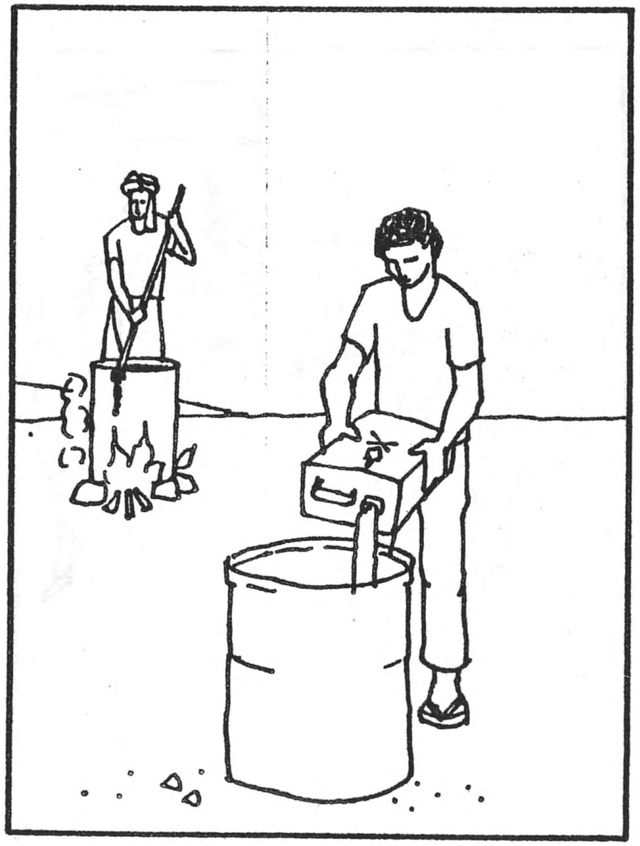


Knead it for 10 to 14 days.

Knead the mixture every day until the bhusa becomes soft and disintegrates.



Heat bitumen until it melts.



Mix this with kerosene oil.
Use 1 part kerosene to 5 parts bitumen.

Add the hot bitumen to the kerosene oil very slowly. Stir the mixture until all the bitumen is added.

Add the bitumen and kerosene mixture to the mud mortar.

Spread this evenly over the mud mortar and mix thoroughly with a spade.

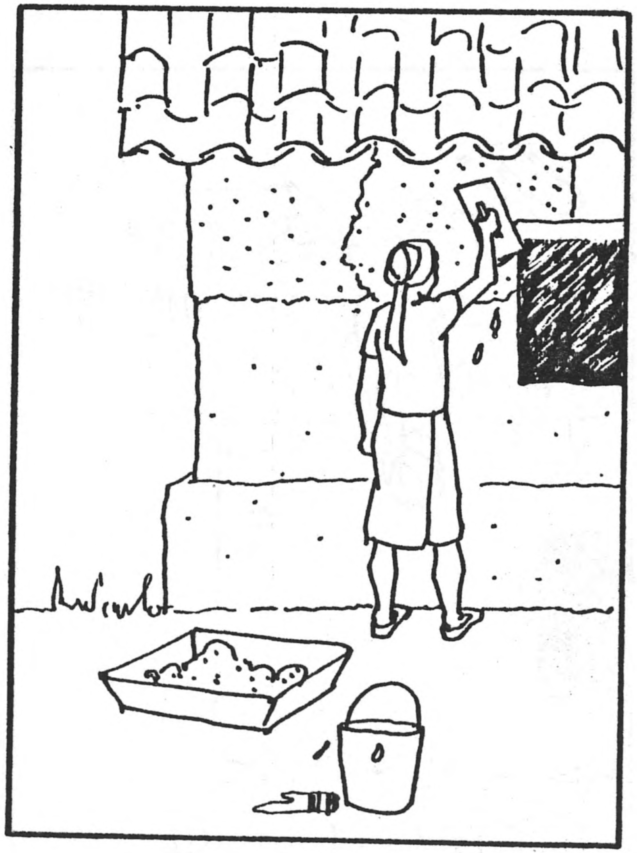
When the plaster is ready, it will have a smooth, workable texture.

Before applying the plaster, scrape the wall to make the surface smooth.

Fill cracks with a mud slurry.

Sprinkle the wall with water to create a stronger bind.

Cover the wall with the plaster.

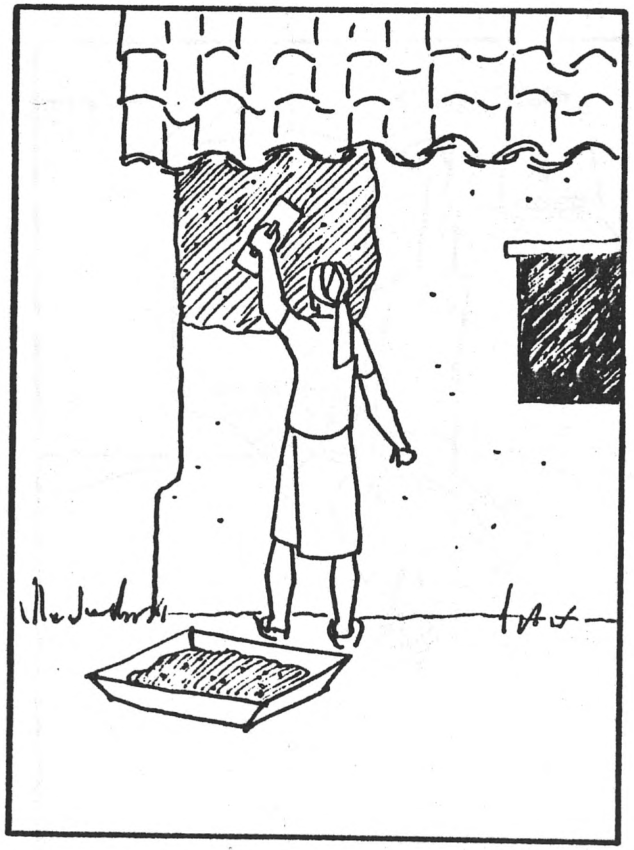


Start at the top of the house and work down.

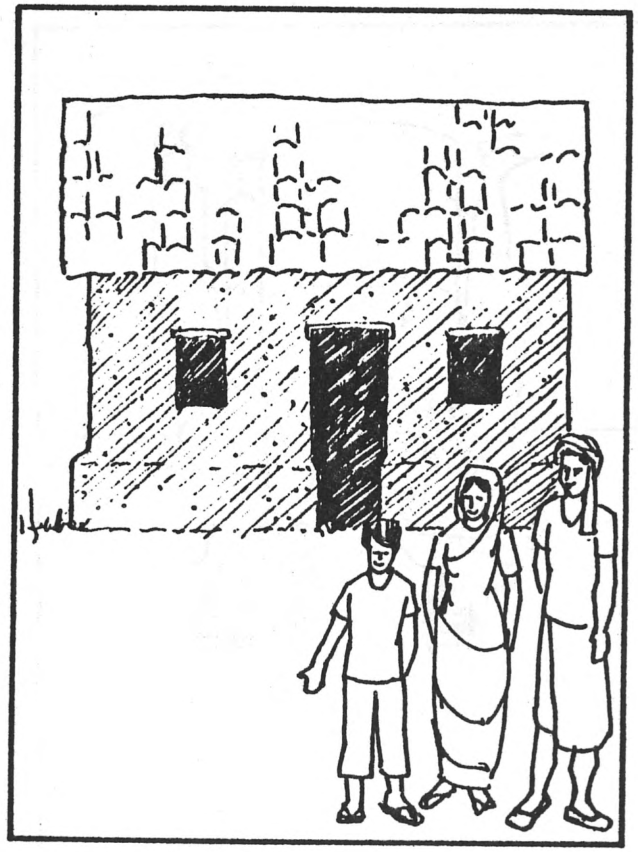
Sprinkle the surface with water to prevent cracks.

When plaster is partially dry, cover the surface with gobri.
Mix 1 part cow dung, 1 part soil, and water to form a thick paste.

Add the bitumen mixture to the gobri.



Apply this from the top of the house to the bottom.



Now the house is finished. It should last 8 to 10 years longer!

APPENDIX VI

MODIFIED MERCALLI INTENSITY SCALE OF 1931

I Not felt except by a very few under especially favorable circumstances.

II Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.

III Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing of truck. Duration estimated.

IV During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed, walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.

V Felt by nearly everyone, many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.

VI Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.

VII Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars.

VIII Damage slight in specially designed structures; considerable in ordinary substantial buildings, with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motor cars disturbed.

IX Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.

X Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.

XI Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.

XII Damage total. Practically all works of construction are damaged greatly or destroyed. Waves seen on ground surface. Lines of sight and level are distorted. Objects are thrown upward into the air.

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