World Housing Encyclopedia

an Encyclopedia of Housing Construction in
Seismically Active Areas of the World

an initiative of
Earthquake Engineering Research Institute (EERI) and
International Association for Earthquake Engineering (IAEE)

HOUSING REPORT
Traditional Naga Type House

Report #	147
Report Date	26-01-2008
Country	INDIA
Housing Type	Timber Building
Housing Sub-Type	Timber Building : Walls with bamboo/reed mesh and post (Wattle and Daub)
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Summary

The housing type is most common throughout the Northeast India which lies in the most severe seismic zone of the country (Zone V - corresponding to MSK IX). Majority of this type of houses are used for residential purposes. Typically these houses are built with light weight locally available material like bamboo, wooden planks, thatch etc. These housing types have traditional system of bamboo/wooden posts. Bamboo posts are inserted into the ground to act

as compression members and are tied with horizontal bamboo/wooden girders with the help of bamboo ropes (cane) to give a proper shape and framing action. However, there is no protection of bamboo/wooden posts against decaying/termites or any other natural cause. The performance of these houses during the past earthquakes is unknown. However, during the discussions with local people about the performance of these houses in the past major earthquakes, it was noted that the majority of houses survived.

1. General Information

Buildings of this construction type can be found in northeastern parts of India covering the states of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura. The different tribes of these states have unique life-styles and habitats. However, their housing type falls within this category with slight changes in their appearance attributed to individual tribal identities. At national level about 11.4% of hosing stock consists of this type of houses (Vulnerability Atlas of India, 2006). In this category of houses the wall material comprises bamboo, thatch and grass etc. with a light weight roof of similar material but also mud, plastic, polythene, GI metal, and asbestos sheet. This type of housing construction is commonly found in both rural and urban areas.

Although more confined to rural areas a significant percentage of this type of housing is also found in towns of the region. However, in the last two decades a decrease of these traditional houses in urban areas of the region has occurred.

This construction type has been in practice for more than 200 years.

Currently, this type of construction is being built. Very limited numbers of houses are in urban areas (towns).

Typical house in this category (click on figures to enlarge)


Typical master room


Loft above the hearth - is used to dry the firewood and to store utensils etc.

Heat from the hearth is used to dry the fire wood.

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat, sloped and hilly terrain. They share common walls with adjacent buildings. When separated from adjacent buildings, the typical distance from a neighboring building is 3-4 (minimum) meters.

2.2 Building Configuration

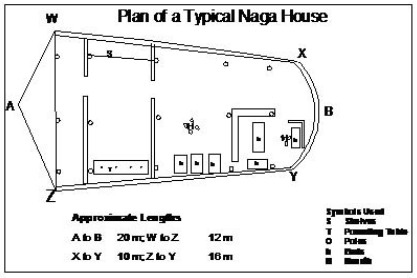
Most of these buildings are rectangular in shape. A few tribes build in circular shapes as well. This housing type has very limited openings. There is only one entrance. Some of the tribes have a rear or side exit as well in their houses. Generally, there is no window and there is no provision for ventilation, making the house very dark inside. A typical house has about 2-5% openings in the surface area of its walls. The kitchen of the house is in one of the inner rooms.

2.3 Functional Planning

The main function of this building typology is single-family house. At times joint families also live together in these houses. In a typical building of this type, there are no elevators and no fire-protected exit staircases. These single storey houses have just one door. Some times a door in the rear or sidewall is also provided, however, escaping during an earthquake or fire does not seem to be a problem.

2.4 Modification to Building

In recent times some changes are taking place in term of 1. Provision of back courtyards 2. Roofing material changing from thatch to corrugated galvanized Iron (CGI) sheets.



Plan of typical Naga House

3. Structural Details

3.1 Structural System

Material	Type of Load-Bearing Structure	#	Subtypes	Most appropriate type
	Stone Masonry Walls	1	Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof)	☐
		2	Dressed stone masonry (in lime/cement mortar)	☐
	Adobe/ Earthen Walls	3	Mud walls	☐
		4	Mud walls with horizontal wood elements	☐
		5	Adobe block walls	☐
		6	Rammed earth/Pise construction	☐

Masonry	Unreinforced masonry walls	7	Brick masonry in mud/lime mortar	☐
		8	Brick masonry in mud/lime mortar with vertical posts	☐
		9	Brick masonry in lime/cement mortar	☐
		10	Concrete block masonry in cement mortar	☐
	Confined masonry	11	Clay brick/tile masonry, with wooden posts and beams	☐
		12	Clay brick masonry, with concrete posts/tie columns and beams	☐
		13	Concrete blocks, tie columns and beams	☐
	Reinforced masonry	14	Stone masonry in cement mortar	☐
		15	Clay brick masonry in cement mortar	☐
		16	Concrete block masonry in cement mortar	☐
Structural concrete	Moment resisting frame	17	Flat slab structure	☐
		18	Designed for gravity loads only, with URM infill walls	☐
		19	Designed for seismic effects, with URM infill walls	☐
		20	Designed for seismic effects, with structural infill walls	☐
		21	Dual system – Frame with shear wall	☐
	Structural wall	22	Moment frame with in-situ shear walls	☐
		23	Moment frame with precast shear walls	☐
	Precast concrete	24	Moment frame	☐
		25	Prestressed moment frame with shear walls	☐
		26	Large panel precast walls	☐
		27	Shear wall structure with walls cast-in-situ	☐
		28	Shear wall structure with precast wall panel structure	☐
Steel	Moment-resisting frame	29	With brick masonry partitions	☐
		30	With cast in-situ concrete walls	☐
		31	With lightweight partitions	☐
	Braced frame	32	Concentric connections in all panels	☐
		33	Eccentric connections in a few panels	☐
	Structural wall	34	Bolted plate	☐
		35	Welded plate	☐
Timber	Load-bearing timber frame	36	Thatch	☐
		37	Walls with bamboo/reed mesh and post (Wattle and Daub)	☑
		38	Masonry with horizontal beams/planks at intermediate levels	☐
		39	Post and beam frame (no special connections)	☐
		40	Wood frame (with special connections)	☐

		41	Stud-wall frame with plywood/gypsum board sheathing	☐
		42	Wooden panel walls	☐
Other	Seismic protection systems	43	Building protected with base-isolation systems	☐
		44	Building protected with seismic dampers	☐
	Hybrid systems	45	other (described below)	☐

Generally these are very light weight structures.

3.2 Gravity Load-Resisting System

The vertical load-resisting system is timber frame. Structure provides a continuous load path. Load is transferred through wooden/bamboo beams and columns/ posts embedded into the ground.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is timber frame. Roof truss/bracing; long wooden pieces / bamboo are used as beams and compression members. They are tied well with the help of bamboo rope/cane. Lateral forces are resisted by cantilever action of the embedded posts and the bracing effect of diagonal bracing members where they are provided.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 10 and 15 meters, and widths between 4 and 5 meters. The building is 1 storey high. The typical span of the roofing/flooring system is 4-5 meters. The typical storey height in such buildings is 3-4 meters. The typical structural wall density is none. Bracing is not achieved by walls but by the timber posts and diagonal timber bracing where provided.

3.5 Floor and Roof System

Material	Description of floor/roof system	Most appropriate floor	Most appropriate roof
Masonry	Vaulted	☐	☐
	Composite system of concrete joists and masonry panels	☐	☐
Structural concrete	Solid slabs (cast-in-place)	☐	☐
	Waffle slabs (cast-in-place)	☐	☐
	Flat slabs (cast-in-place)	☐	☐
	Precast joist system	☐	☐
	Hollow core slab (precast)	☐	☐
	Solid slabs (precast)	☐	☐
	Beams and planks (precast) with concrete topping (cast-in-situ)	☐	☐
	Slabs (post-tensioned)	☐	☐
Steel	Composite steel deck with concrete slab (cast-in-situ)	☐	☐
Timber	Rammed earth with ballast and concrete or plaster finishing	☐	☐
	Wood planks or beams with ballast and concrete or plaster finishing	☐	☐
	Thatched roof supported on wood purlins	☐	☑
	Wood shingle roof	☐	☐
	Wood planks or beams that support clay tiles	☐	☐
	Wood planks or beams supporting natural stones slates	☐	☑
	Wood planks or beams that support slate,		

	metal, asbestos-cement or plastic corrugated sheets or tiles	☐	☑
	Wood plank, plywood or manufactured wood panels on joists supported by beams or walls	☐	☐
Other	Described below	☑	☑

There is no suspended flooring. Ground floor is simple earthen floor with mud plaster in some cases. At times the floor of the house is raised slightly. This safeguards against flooding and dampness during the rainy season. Bamboo matting is used to cover the mud floors.

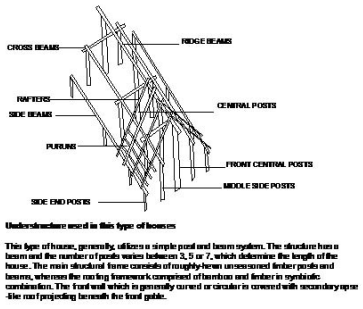
3.6 Foundation

Type	Description	Most appropriate type
Shallow foundation	Wall or column embedded in soil, without footing	☑
	Rubble stone, fieldstone isolated footing	☐
	Rubble stone, fieldstone strip footing	☐
	Reinforced-concrete isolated footing	☐
	Reinforced-concrete strip footing	☐
	Mat foundation	☐
	No foundation	☑
Deep foundation	Reinforced-concrete bearing piles	☐
	Reinforced-concrete skin friction piles	☐
	Steel bearing piles	☐
	Steel skin friction piles	☐
	Wood piles	☐
	Cast-in-place concrete piers	☐
	Caissons	☐
Other	Described below	☐

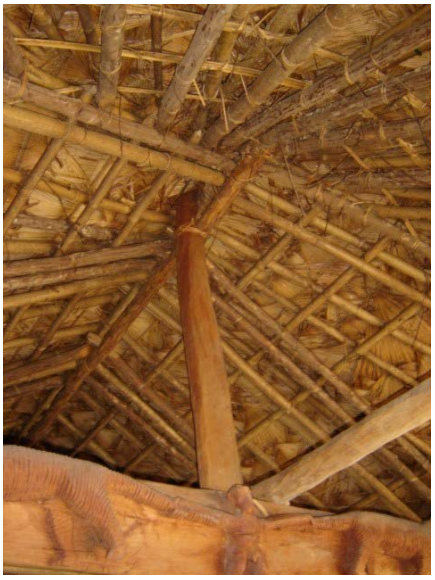
Bamboo posts are inserted into the ground. Generally, the depth is 1 meter.

Timber posts are embedded directly into the ground (Click on figures to enlarge)

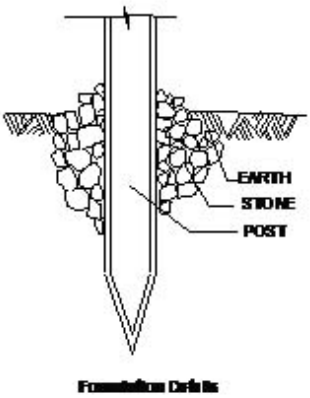
Flooring system used in the housing type



Understructure used in this type of house



Connection details in the roof understructure



Flooring System Used

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 1 housing unit(s). The number of inhabitants in a building during the day or business hours is less than 5. The number of inhabitants during the evening and night is 5-10.

4.2 Patterns of Occupancy

Most of the family members go to work during daytime. Those that stay back at home finish household chores outside the house in the sun. Adult children in every family sleep (at night) at a community hostel/ dormitory made for this purpose.

4.3 Economic Level of Inhabitants

Income class	Most appropriate type
a) very low-income class (very poor)	☑
b) low-income class (poor)	☐
c) middle-income class	☐
d) high-income class (rich)	☐

A middle-income family in the village earns in the range of about Rs. 30,000 to 40,000 annually. However, it is very difficult to calculate the actual income of a household. Every household possesses other means of income with cattle, harvesting of paddy etc.

Ratio of housing unit price to annual income	Most appropriate type
5:1 or worse	☐
4:1	☐
3:1	☐
1:1 or better	☑

What is a typical source of financing for buildings of this type?	Most appropriate type
Owner financed	☑
Personal savings	☑
Informal network: friends and relatives	☐
Small lending institutions / micro-finance institutions	☐
Commercial banks/mortgages	☐
Employers	☐
Investment pools	☐
Government-owned housing	☐
Combination (explain below)	☐
other (explain below)	☐

It is community-based house construction. Construction materials like bamboo, thatch etc. are collected by the individual from relatives and friends and from the jungle. The construction of the house involves community participation. In each housing unit, there are no bathroom(s) without toilet(s), no toilet(s) only and no bathroom(s) induding toilet(s).

Very few people have in-house toilets and bathrooms. .

4.4 Ownership

The type of ownership or occupancy is outright ownership.

Type of ownership or occupancy?	Most appropriate type
Renting	☐
outright ownership	☑
Ownership with debt (mortgage or other)	☐
Individual ownership	☐
Ownership by a group or pool of persons	☐
Long-term lease	☐
other (explain below)	☐

Land for construction of house belongs to the village/community. Entire land is divided into community and individual spaces, where individuals can build/construct their house.

5. Seismic Vulnerability

5.1 Structural and Architectural Features

Structural/ Architectural Feature	Statement	Most appropriate type		
		Yes	No	N/A
Lateral load path	The structure contains a complete load path for seismic force effects from any horizontal direction that serves to transfer inertial forces from the building to the foundation.	☑	☐	☐
Building Configuration	The building is regular with regards to both the plan and the elevation.	☑	☐	☐

Roof construction	The roof diaphragm is considered to be rigid and it is expected that the roof structure will maintain its integrity, i.e. shape and form, during an earthquake of intensity expected in this area.	☑	☐	☐
Floor construction	The floor diaphragm(s) are considered to be rigid and it is expected that the floor structure(s) will maintain its integrity during an earthquake of intensity expected in this area.	☐	☐	☑
Foundation performance	There is no evidence of excessive foundation movement (e.g. settlement) that would affect the integrity or performance of the structure in an earthquake.	☐	☐	☑
Wall and frame structures-redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.	☐	☐	☑
Wall proportions	Height-to-thickness ratio of the shear walls at each floor level is: Less than 25 (concrete walls); Less than 30 (reinforced masonry walls); Less than 13 (unreinforced masonry walls);	☐	☐	☑
Foundation-wall connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation.	☐	☑	☐
Wall-roof connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps	☐	☑	☐
Wall openings	The total width of door and window openings in a wall is: For brick masonry construction in cement mortar : less than ½ of the distance between the adjacent cross walls; For adobe masonry, stone masonry and brick masonry in mud mortar: less than 1/3 of the distance between the adjacent cross walls; For precast concrete wall structures: less than 3/4 of the length of a perimeter wall.	☐	☐	☑
Quality of building materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate).	☐	☐	☑
Quality of workmanship	Quality of workmanship (based on visual inspection of few typical buildings) is considered to be good (per local construction standards).	☐	☐	☑
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber)	☐	☑	☐
Additional Comments	?Roofing framing is tied together with bamboo ropes (cane). ?There is not much maintenance done to these houses. Average life of a house is 10-15 years, after which the old house is abandoned due to deterioration of the material used. However, during the life span of houses, walling and roofing material (thatch) is replaced 3-4 times.			

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake Resilient Features	Earthquake Damage Patterns
Wall		Very light material - bamboo mat covered with mud plaster	
Frame (columns, beams)	No foundation for columns Rope used for the connections between timber members may fail	Proper load transfer path available where there are diagonal bracing members within the wall framing. Joints made of rope (cane)	No serious damage is reported in such houses in the recent past

Roof and floors	Light weight material is used to cover the roof framing No suspended flooring	Proper frame when bracing elements are provided to resist lateral forces	
Other	Wooden platforms which may hang from the roof frame is undesirable The house is not fire-resistant		

- The tradition in the region is to have a kitchen, with a hearth, in the middle of the master room of the house. This room is always pitch dark due to accumulation of smoke. Over the hearth, a bamboo/wooden platform is suspended for drying and storage of meat, vegetables, grains, fire wood, tools etc. The lowest portion of the loft is used for storing firewood for immediate use; the middle portion is used to store meat and grains to be dried and seasoned, while the top portion is used for storing other daily-use items. The hearth is a prominent feature of the living space/ house as it provides necessary light and heat to the inhabitants. The hearth remains lit continuously. - A local tradition is to hang different items like meat, grains, dried vegetables etc. from the roof frame. - The hanging platform and other items put additional weight on the roof. During an earthquake this may lead to collapse of the house. - Traditionally, wooden poles with notches are used to provide necessary support. In the case of bamboo, appropriate slits are made to provide sufficient support.

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is D: MEDIUM-LOW VULNERABILITY (i.e., good seismic performance), the lower bound (i.e., the worst possible) is B: MEDIUM-HIGH VULNERABILITY (i.e., poor seismic performance), and the upper bound (i.e., the best possible) is E: LOW VULNERABILITY (i.e., very good seismic performance).

Vulnerability	high	medium-high	medium	medium-low	low	very low
	very poor	poor	moderate	good	very good	excellent
Vulnerability Class	A	B	C	D	E	F
	☐	☑	☐	☐	☑	☐

5.4 History of Past Earthquakes

Date	Epicenter, region	Magnitude	Max. Intensity

The entire northeastern region of India is highly prone to earthquakes. This region lies under zone V, corresponding to MSK IX+, according to the seismic hazard map of India (IS:1893-2002). A large number of earthquakes have taken place in the region, induding the two M8+ earthquakes in 1950 &1897. During the discussions with the local people it was learned that there was no damage to this type of structure during past earthquakes.

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Bamboo, Wooden logs, bamboo mat		NA	Bamboo wall matting is mud-plastered for durability
Foundation				No foundation. Poles are just embedded in the ground.
Frames (beams & columns)	Wooden logs/bamboo		NA	
	Bamboo roof framing with			

Roof and floor(s)	thatch		NA	No suspended floor

6.2 Builder

Yes.

6.3 Construction Process, Problems and Phasing

Construction of this type of house generally takes place in the dry season / winters. Sourcing of construction materials like thatch/timber/bamboo are collected during winters only. Bamboo/wooden posts are erected and then beams/logs are connected and rafters placed and tied up. The wider community participates in the construction of this type of house. Indigenous/traditional tools are used in the construction. Generally nails or other steel materials are not used for making connections between various members. The construction of this type of housing takes place in a single phase. Typically, the building is originally not designed for its final constructed size.

6.4 Design and Construction Expertise

The entire construction takes place under the master builder who has slightly more expertise in comparison to others in the village. This man has expertise in erecting wooden frames/trusses. He develops his expertise by assisting in the construction of a large number of houses. Over a period of time, due to his experience, he starts working as a master builder. No role is played by professionals such as architects/engineers.

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the country. National Building Code of India Other codes are referred to in the National Building Code of India Part 6 (Structural Design; Section 3) Timber and Bamboo; 3B Bamboo are as following: IS 6874:1973 -Methods of test of round bamboo IS 8242:1976 - Methods of test of split bamboo IS 9096:1979 - Code of practice for preservation of bamboo for structural purposes IS 13958:1994 - Specification for bamboo mat board for general purposes.

There is no strict enforcement of building codes in the construction of this house type.

6.6 Building Permits and Development Control Rules

This type of construction is a non-engineered, and authorized as per development control rules. Building permits are not required to build this housing type.

6.7 Building Maintenance

Typically, the building of this housing type is maintained by Owner(s). The maintenance of this type of house is done in phases in terms of replacing the thin layered mud plaster on the walls every 2-3 years, replacing of walling mat every 4-5 years and replacing the roofing thatch every 5-6 years. Roof and wall material are generally replaced 3-4 times during the life span of the structure. The floor mud plastering is done every week.

6.8 Construction Economics

The unit cost varies from owner to owner. Usually it ranges between Rs. 600-700 (US$ 15-20) per square meter. During the construction of the house, 20-25 people from the village/community come and help the owner in the construction process. Usually, they finish the task by the evening. If some work is leftover, few of them return the next day and finish it. The owner of the house serves food to the members of the community. There is no system of paying the wages for the labour.

7. Insurance

Earthquake insurance for this construction type is typically unavailable. For seismically strengthened existing buildings or new buildings incorporating seismically resilient features, an insurance premium discount or more complete coverage is unavailable. NA.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

Strengthening of Existing Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used
Insufficient wall bracing	Corner stiffening through diagonal bamboo bracing members
Hanging storage loft	Instead convert it into a self-supported platform
Hanging items for storage purposes	Provide storage on a wooden platform supported by its own posts
Fire Resistance	Use fire retardents and increase general awareness

Strengthening of New Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used
Insufficient wall bracing	Corner stiffening through bamboo bracing
Foundation	Embed posts into a proper concrete foundation
Post earthquake Fire	Improve fire resistance of the materials/ use of cgi sheets for roofing purpose
Use of cane for joints	Use nails to achieve stronger joints
Hanging storage loft	Provision of a proper platform that is braced over the hearth
Decaying of bamboo at ground level	Proper treatment against rodents and moisture

8.2 Seismic Strengthening Adopted

Has seismic strengthening described in the above table been performed in design and construction practice, and if so, to what extent?

No.

Was the work done as a mitigation effort on an undamaged building, or as repair following an earthquake?

No.

8.3 Construction and Performance of Seismic Strengthening

Was the construction inspected in the same manner as the new construction?

NA.

Who performed the construction seismic retrofit measures: a contractor, or owner/user? Was an architect or engineer involved?

No.

What was the performance of retrofitted buildings of this type in subsequent earthquakes?

NA.

Reference(s)

1. Vulnerability Atlas of India
   A.S. Arya et. al.
   BMTPC 2006

2. National Building Code of India
   BIS,
   Bureau of Indian Standard 2005

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