

## **SKELETON SYSTEM - AN APPROACH FOR CONSTRUCTION OF RURAL BUILDINGS IN EARTHQUAKE PRONE AREAS**

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### **SUMMARY**

Housing and buildings contribute significantly to the fulfilment of social and other day to day needs of human life. In most of the developing countries desired attention is not given to the scientific planning and structural safety of buildings particularly in rural areas resulting in loss of lives and property due to natural calamities. Recent earthquake in India in Uttarkashi (Uttar Pradesh) and Killari (Maharashtra) indicated that tremendous loss of lives and property was due to non-engineered construction of buildings as a result of lack of adequate knowledge and awareness about the measures for planning and designing structures to withstand earthquake in rural areas. A major part of the construction falls under semi-permanent category of construction, usually done with locally available cheaper building materials e.g. mud, unburnt or sundried clay bricks, adobe (Unburnt clay blocks), grass, leaves, reed, bamboo and wood etc. These materials are normally considered as inferior and substandard compared to materials used for construction of buildings in urban areas. The approach for rural constructions need to be cost effective, flexible in choice of building materials, structurally sound and simple in construction with minimum use of non-local materials and skilled labour. Earthquake, although is one of the most hazardous natural calamities but very little attention is paid while designing and constructing dwellings by the people because provisions as per codal requirement make buildings costly which is beyond common man's reach. Keeping in view the limitations and technical feasibility, an approach which consists of a structurally sound skeleton system with wall panelling, flooring etc. in locally available materials and construction practice has been worked out. The approach envisages construction with the aim to prevent loss of lives in the event of an earthquake. It however takes into account the damages to some of the building components that are liable to be repaired at post-earthquake stage without much complications or skills with local materials.

### **INTRODUCTION**

Technically buildings may be broadly classified in two categories, engineered and non-engineered. Engineered buildings are those, which are, constructed with standard methods of construction taking into account the codal requirements with permanent or standard building materials. While non-engineered buildings are constructed with easily and economically available non-standard building materials. Building codes or regulations in most of these cases are not followed as it adds to the cost. Non-engineered buildings are normally self-financed small buildings including residences. In India more than 70% and in world 50 to 60% constructions fall under non-engineered class. Cement, steel, burnt bricks, stone and timber are few construction materials which form the group of standard building materials on which lies the choice of providing major building components e.g. walls, roofs etc. These materials are costly and scarce and are used for construction by well to do class of society. The choice of economically weaker class is left to non-standard materials which are easily and economically available within the reach of the common man. Such materials are grass leaves, reed, wood, mud, unburnt bricks, sundried clay blocks, bamboo, tiles, slate, shingle etc.

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## Building Materials

A critical study of predominant building materials used in the country in walls and roofs reflect that –

- i) Mud, burnt bricks, stone, unburnt bricks, sundried clay blocks, grass, leaves, reed, bamboo and wood covers practically the whole range of walling materials.
- ii) Mud is predominantly used for construction of walls while grass, leaves, reed, wood etc. are used as roofing materials in rural areas as these materials are easily available at door step and suits economically weaker section.

Table below gives the percentage contribution of predominant building materials of walling versus roofing in India.

Predominant building materials of wall	Predominant building materials of roof such as grass, leaves, reed, bamboo, thatch, mud, unburnt bricks or wood	Predominant building materials of roof such as tiles, slate, shingle, corrugated iron or other metal sheets, asbestos cement sheets, brick, lime, stone and RBC/RCC
i) Grass, leaves, reed or bamboo, mud, unburnt bricks, wood	37%	27%
ii) Burnt bricks, G.I. sheets or other metal sheets, stone, cement	8%	28%

## Construction Practices

The building materials, in practice, are deployed for variety of purposes ranging from construction of load bearing walls to frame structures with infill panel wall and roofing with low strength building materials depending upon the availability of materials, financial resources, technical know-how and climatic conditions.

In rural constructions, load bearing walls are generally built with mud, sundried bricks, clay blocks or stone as random rubble masonry in mud mortar. In case of non-load bearing walls, wooden posts are provided to transfer the load and non-load bearing panels are made with split bamboo, reed, grass, leaves etc. These panels are plastered with mud or very seldom with cement mortar as a protective coat. In flat roof, straight branches of trees or ballies are used as joists on which rests a layer of twing, thin bundles of reed or any such material to cover the spaces in between and finally a thick layer of mud thoroughly compacted is laid. Properly sawn joists are occasionally used, in which case flat bricks, slate or wooden planks are laid to cover the spaces between wooden joists. Stone patties are also used spanning wall to wall. Pitched roofs may have only a ridge beam spanning between gable walls or posts and thatch with bamboo to act as rafters lean into the ridge beam from either sides. Trusses and framework for roof are made in variety of ways with ballies, straight branches of trees or bamboo. Any of the local materials e.g. grass, leaves etc. in combination with reed or split bamboo in the form of thatch, slate, country tiles or corrugated sheets is chosen as the roof covering.

## Evaluation

Post earthquake studies indicate that houses, appearing strong, with thick mud or stone walls of the order of 600 to 1000mm thickness and roof with 150 to 450mm thick layer of clay prove most hazardous and transform into heaps of debris resulting significant loss of lives in the event of an earthquake. Fig. 1 shows partial destruction of rubble masonry wall. Fig. 2 shows destruction of rubble masonry while the roof on timber post is almost intact. The principle explains the fact that the damage of structure is a function of its weight. The heavier the weight of structure the severe is the damage.



**Partial destruction of random rubble masonry wall**  
**Fig.1**



**Destruction of rubble masonry and restoration of part skeleton**  
**Fig.2**

Houses made with wooden posts and rafters tied together with roof made of thatch or any such lighter material and panel wall in leaves, grass, reed or split bamboo with or without mud plaster were found resistant to earthquake stresses to a great extent as these structures are light and ductile. Similarly, flat roofs with wooden frame construction in which roof members are securely connected with longitudinal and transverse beams, supported on wooden posts are experienced to be safe to a great extent. In this roof planks are supported on timber frame work rather than masonry walls with proper anchorage to all other building components, viz floor, roof beams and posts to provide desired stability. The roof held up on wooden posts prevents its destruction and inward collapse of the panel walls resulting safety of inhabitants (Fig.3)



**Timber frame work in a residential building**

**Fig. 3**

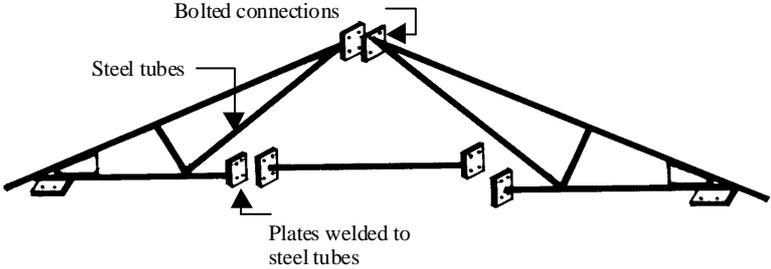
The diminishing forest resources of the country adversely effect free availability of natural building materials. Wood particularly has become a scarce and costly material and is out of common man's reach. Secondly, these materials though are cheaper but suffer from many inherent shortcomings including their short life span. In other words these materials prove to be much costly as compared to permanent building materials if their life cycle cost is considered. As a matter of fact, the user is normally concerned with the initial cost and many a times overlook the cost implications in long run. To keep a balance between the choice of user and long term cost of the materials, there is a need to workout alternate construction systems with structural components in standard materials and other less important components in any other materials as per the choice of the user. In this case too, the local materials must be used after improving their quality by employing treatment or improved techniques which does not require much skills and are cost effective.

It is evident from the above explanation that the best form of structure to withstand earthquake may be a frame structure in which all components are rigidly connected together to behave as a single unit. Keeping in mind the parameters discussed above, a skeleton system has been devised which has a rigid frame structure to bear earthquake stresses and panel walls with a number of options as per user's choice. Such panel walls may be allowed either to get damaged or are made safe enough to bear earthquake stresses with no appreciable damage.

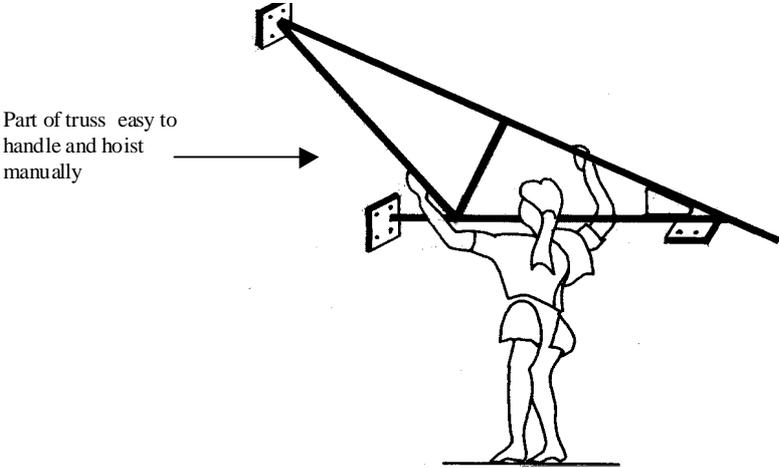
### **Skeleton System**

Skeleton system consists of a steel truss, preferably in tubular sections supported on steel columns positioned by holding down bolts embedded in RCC pedestal or stone/burnt brick masonry. All the members' viz. purlins, trusses and columns are connected together with nuts and bolts assembly to form a single unit. Corrugated galvanised iron (CGI) sheets are used as roof coverings. ACC or any other roof covering e.g. thatch, country tiles etc. may replace CGI sheets if necessary. Trusses are connected together through a runner at the bottom cord when more than one truss is used on a plan. To keep the skeleton rigid and safe against wind, wind bracings are used in end panels of wall as well as roof on both opposite faces in the longitudinal direction. The configuration of the truss has been kept simple and suggested to be fabricated in three parts (Fig. 4) to enable easy

transportation and erection with least manpower. The bigger part of the truss can be lifted and transported by single person as depicted in Fig. 5.

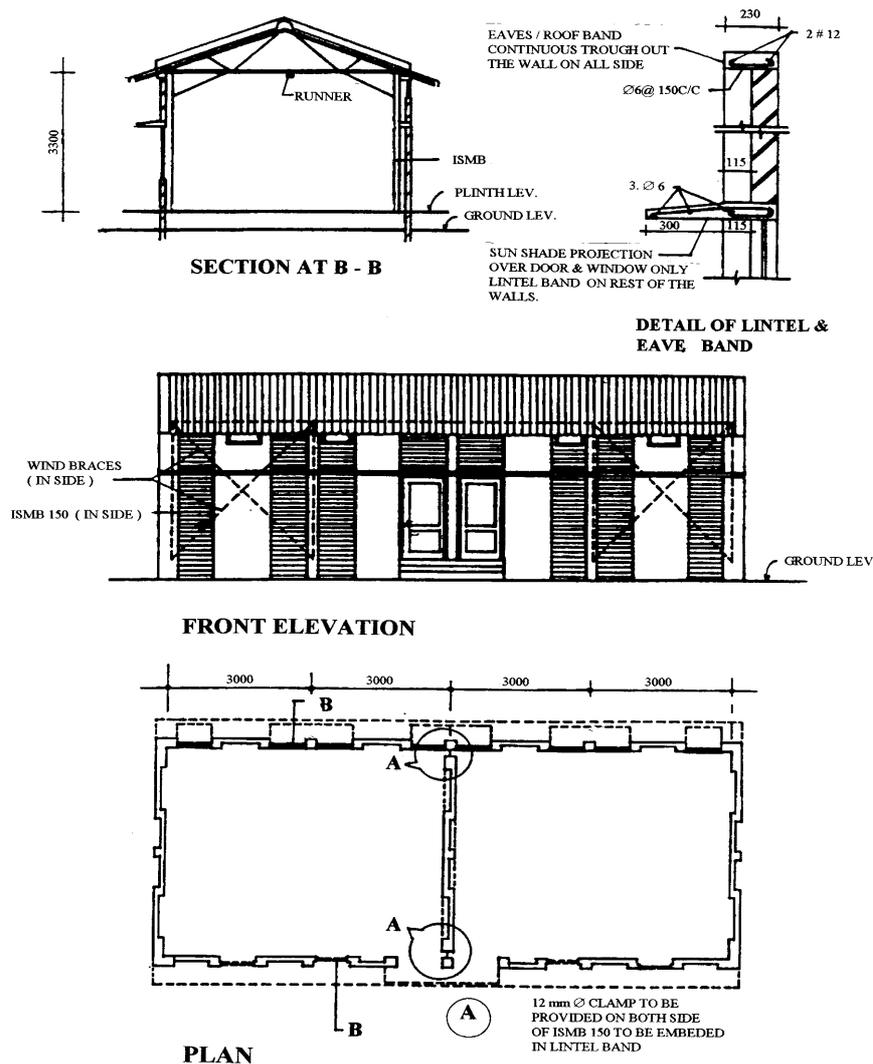


**Steel truss in parts**  
**Fig. 4**



**Manual handling of truss**  
**Fig.5**

Various components of the skeleton e.g. truss, column/post, purlins, bracings etc. may be fabricated at locations where facilities for fabrication exist. The foundation for column may be of precast R.C.C. pedestal to achieve speed in construction. Fig. 6 gives typical plan, elevation and section of skeleton system. Walling and roofing may be done with variety of materials locally available. When the choice is for a better material, burnt brick masonry in cement mortar, with RCC band at lintel and eave level, as shown in the figure, may be adopted. Where stone is available, in abundance, concrete block masonry is advantageous as compared to random rubble masonry in mud, which contribute heavy mass and get crumble on receiving vibrations. Other alternatives of panelling may be mud wall, adobe wall, wall made of reed leaves, bamboo etc. duly plastered, wooden planking or other local material. Roofing in CGI or ACC sheets, country tiles, thatch or slate may be done depending upon the availability of materials. Fig. 7 shows few alternatives of cladding and roofing, fixed to skeleton.

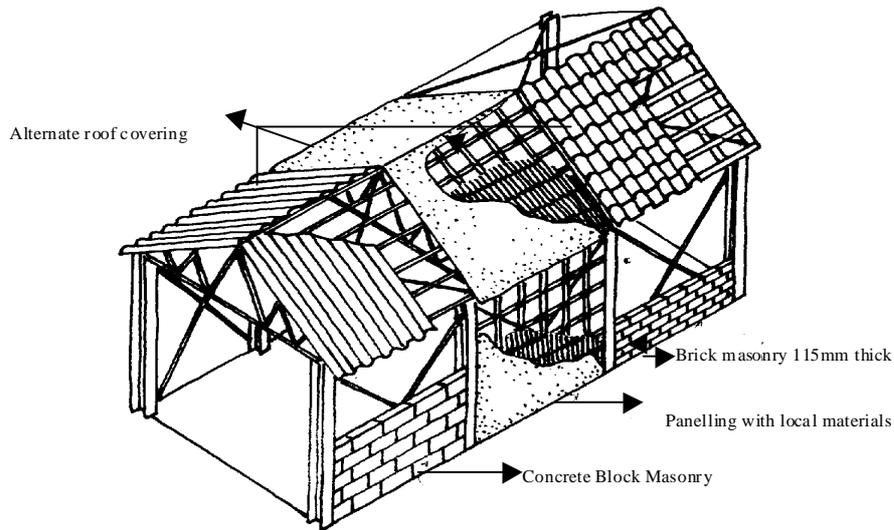


### Skeleton with brick masonry panel

**Fig. 6**

The system has an additional advantage of getting completed in stages as an incremental construction depending upon the financial resources. Once skeleton is erected, it may be used for primary requirement and other building components as panelling, flooring, joinery etc. may be subsequently added in phases.

Building made with walling materials like grass, reed, wood, bamboo etc. used by majority class are good as earthquake friendly buildings being light weight construction but suffer with inherent weaknesses of rapid decay besides being highly combustible due to their organic origin. This results in short life and needs quick replacement of components. Hence, it is important to improve or modify their workability by using them after proper seasoning and preservative treatment for making wall panels and thatch roof. The quality of thatch could be further improved by using a simple technique in which the panel material is pressed between two split bamboo mats and tied with GI wires to gain strength and also to improve fire retardant properties of the panel. Water proofing of panel or thatch may be done with non-erodable mud plaster in which 62.5kg of bitumen cut-back is mixed with one cubic metre of soil-animal dung paste and applied as plaster in usual manner.



**Alternate cladding/roof covering fixed to skeleton**

**Fig. 7**

Mud walls may be improved for earthquake resistant properties by reinforcing with split-bamboo or reed duly seasoned and treated with preservative. Introduction of wooden runners properly jointed at corners around the building adds to the strength. Non-erodable mud plaster for water proofing of walls provides additional advantages to the mud walls.

### **CONCLUSIONS**

Earthquake is the most hazardous natural calamity and needs serious attention by the common man specially for the construction of habitable buildings. Standard codes and regulations are available but their adoption is attributed to either buildings financed by government bodies or affluent class of the society. The common and the poor man normally do not refer to these building codes due to lack of technical knowledge and financial resources. Putting restrictions of fulfilling codal requirements is not practical in context of self financed small rural constructions. An approach that calls for improvements in the materials and practices as suggested above with little extra cost is desirable for making earthquake friendly structures in rural areas. These structures may not be completely earthquake proof but atleast will save life even if a few non structural components give way and get damaged. Such damaged components may be replaced or repaired afterwards without disturbing the skeleton, which will stand safe.

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