IMPROVEMENT OF THE STABILITY OF AFFORDABLE VILLAGE HOUSES

Md Abdur Rouf, K N Ashfaque, Anwar Zahid & Alok Sutradhar, BUET, Bangladesh

Introduction

Bangladesh is a developing country with a very dense population, about 70% of which lives in rural villages. With most of this population living below the poverty line, the demand for affordable housing is increasing. In almost every year, Bangladesh is hit by natural calamities such as floods, cyclone and tidal waves that sweep away the unstable houses of people of low income. There is a great need for stable and durable housing which can be built at a lower cost than at present. The search for an innovative design and construction method is important to obtain the most economic solution as well as a structurally stable one.

A recent study (Ashfaque, 1997) reviews some of the low cost houses being constructed in Bangladesh and finds out the structural deficiencies in them. Also the structural performance of bamboo has been evaluated in laboratory to prove its efficacy in low cost house to resist hazards. Finally a properly designed and stable low cost house using bracing and footing to prevent uplift has been proposed.

Some existing low-cost houses

In Bangladesh, many different Non-Government Organisations (NGO) like Grameen Bank, Association of Social Advancement (ASA) etc. have low-cost housing projects as a part of their development programs.

The low-cost housing project by ASA provides a plan size of 15'-0" x 10'-0" having one room, using C.I. sheet as roofing material, bamboo as column and terza as wall material. Their estimated cost is about Tk. 13,650 per house.

The low-cost housing project by Grameen Bank provided a plan size of 19'-0" x 11'-6" having one room, using C.I. sheet as roofing material, R.C.C post and bamboo as column and terza as wall material. Their estimated cost is about Tk. 12,300 per house. To extend the study, the authors have also collected information on two more private projects (named as P1 and P2) conducted privately by an engineer working in the Grameen Bank.The low-cost housing project P1 provides a plan size of 20'-0" x 9'-3" having two rooms. A 1" R.C. slab with clay tiles is used as its roofing material, R.C.C. hollow post as column and clay tiles as wall material. Their estimated cost is about Tk. 10,700 per house. The low-cost housing project P2 provides a plan size of 20'-6" x 10'-0" divided into two rooms. In this case the

roof is made from 1" folded ferrocement plate and the walls are of terza supported by R.C.C. posts as column and terza as wall material. Their estimated cost is about Tk. 20,000 per house.

The authors also visited Gazipur on several occasions and collected information on a couple of typical low-cost houses (named as V1 and V2) through direct interaction with the local people. The low-cost housing project V1 provides a plan size of 10'-0" x 20'-0" having one room with C.I. sheet as roofing material and mud as wall material. The estimated cost is about Tk. 20,000 per house. The low-cost housing project V2 provides a single room with a plan size of 10'-0" x 10'-0". They use C.I. sheet as roofing material, bamboo as column and jute stick (with a coating of mud and cowdung) as wall material. Their estimated cost is about Tk. 6,000 per house.

Structural stability of low-cost house

In the Grameen Bank project the precast R.C.C. columns are simply rested on two layers of bricks at a depth of 2.5' below the earth surface. In other five projects the R.C.C. or bamboo columns are inserted about 1' to 3' below the ground surface. Therefore, in all six cases, although some designs include horizontal bracings, the frame can be idealized as hinged at both ends (Fig.1).

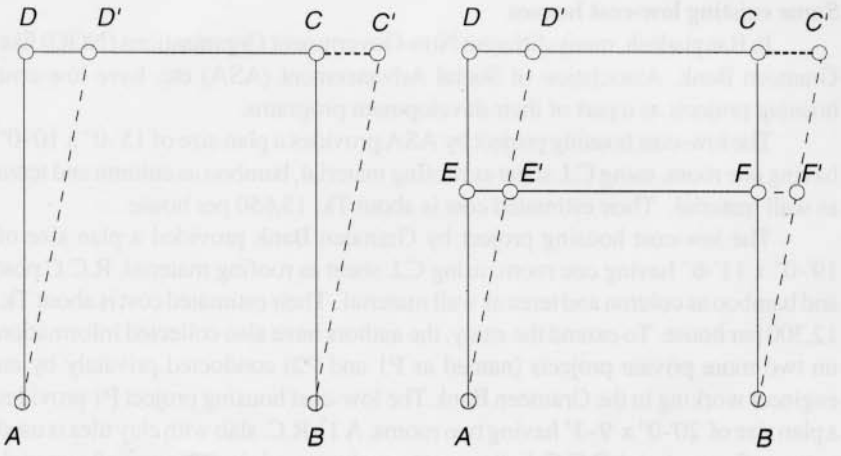

Fig.1 : Unstable Frames

To improve the lateral stability of frames, cross-bracing or knee braces can be utilized. The use of knee brace is less costly and hence included in the proposed house in this study.

Structural materials for affordable village houses

Bangladesh is a developing country and hence indigenous materials available locally must be exploited to the full. Bamboo is used extensively for village houses because of its good characteristics as a structural material. Bamboo is cheap, readily available and grows widely in Bangladesh.

The mechanical properties of bamboo for structural purpose were tested in a laboratory at moderate humidity and room temperature. A series of tests were carried out with different type of locally available bamboo. One immediate problem arose because there is at present no agreed standard method for testing with bamboo. The modulus of rupture of bamboo obtained from static bending test varied between a range of 4000 psi (pounds per square inch) to 8000 psi for several species, while in direct compression (parallel to grain) the range of ultimate compressive strength was 3500 to 8000 psi.

Ferrocement technology provides cost-effective, lightweight and durable structural elements that can be successfully used in low cost housing. Even so, it is not particularly suited for our prevailing socio-economic condition because the construction technology is still not within the economic reach of people in villages.

Proposed plan of stable and affordable village house

The main objective of the study was to develop a stable and affordable house for the mass population. A typical plan size of 10'-0" x 20'-0" (having two grids of 10'-0" x 10'-0" comprising the main frames) and an extension of 4' for kitchen, toilet and veranda have been chosen (Fig.2).

Structural analysis has been conducted considering the critical mid-frame with both end hinged. Column height has been considered to be 10' and knee-braces have been introduced as shown in Fig.3.

Two extreme cases of maximum and minimum dead load have been considered to determine the critical foundation pressure and uplift pressure.

Case (a) : Considering ferrocement shell as roofing element and 6" x 8" R.C.C. beam.

Case (b): Considering C.I. Sheet as roofing element and bamboo as beam element.

The frame has been analyzed for three different wind speeds of 50, 70 and 100 mph to calculate forces in beams, columns and knee-braces. The forces obtained for dead and wind loads were combined to find the design forces. The design forces

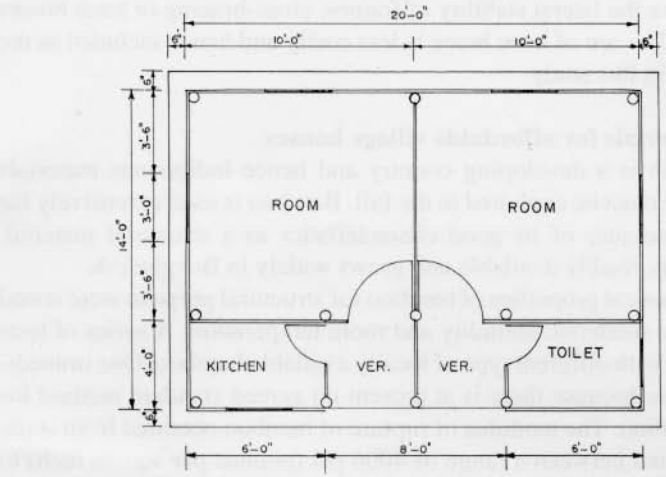

Fig. 2 : Plan of Proposed Low Cost House

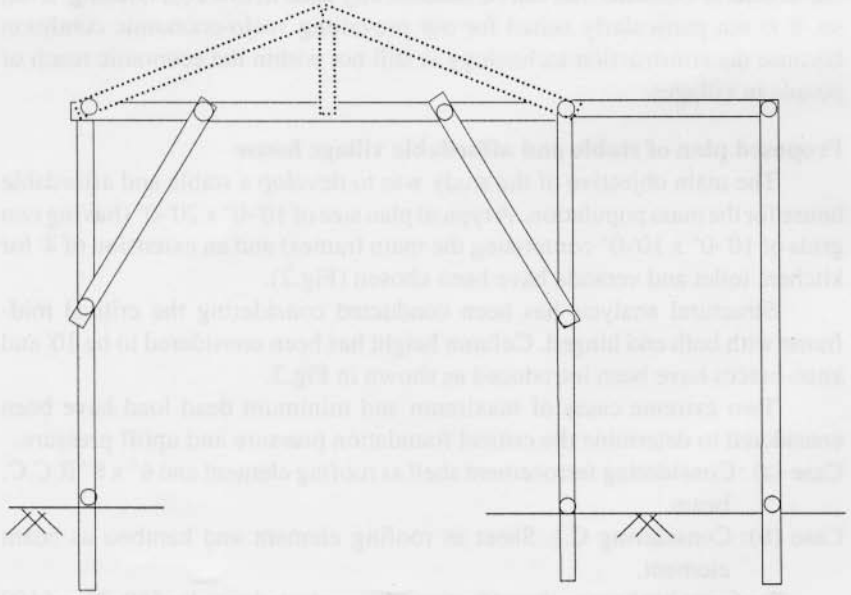

Fig. 3 : A Typical Frame

were then compared with the evaluated strengths of bamboo and R.C.C. columns and beams to be used for the proposed village house. The results of the study can be summarized as follows :

Beam:

Bamboo can be used effectively up to a wind speed of 30 mph, while R.C.C. beams of 5"x 6" and 6"x 8" can be used effectively up to wind speeds of 60 and 100 mph, respectively.

Column:

Bamboo columns can be used effectively up to a wind speed of around 30 mph while R.C.C. columns of 4.5" x 4.5" and 7" x 7" have been found to sustain wind velocities of 58 and 107 mph, respectively.

Footing:

The design of footing has been done for the heavier option i.e. 1" thick ferrocement shell roof, R.C.C. tie beam (6" x 8") and R.C.C. column (7" x 7"). The critical foundation pressure has been found to be 4.0 kip. To satisfy this, an R.C.C. or a brick footing may be used. Dimensions of 20" x 20" and 15" x 15" would give bearing pressures of 0.64 tsf and 1.14 tsf, respectively. Where the soil condition is poor, an appropriate footing must be designed to meet the condition actually encountered.

Uplift Pressure:

The design uplift pressure is based on considering the minimum load that comes by using the lighter option (that is, C.I. sheet roof, bamboo tie beam and bamboo column). The use of a single 5/8" dia bolt has been found to be sufficient for resisting the uplift force at the upper portion of the bamboo column and also at the bottom end of the column.

Knee Brace:

From the structural analysis it has been found that maximum tensile force acting on the knee brace is 2.6 kips and maximum compressive force is 10.0 kips. Based on the test results, bamboo can be considered as a suitable knee bracing material. Bolts required to connect the knee braces are subjected to a maximum force of 10 kips in simple shear, to resist which a single 7/8" dia bolt has been found to be adequate. Knee braces were set in different positions on the columns and it has been found that mid height of the column is the optimum position to resist bending of the column.

Construction cost

Using different combination of roof, beam, column elements construction cost of the proposed house may range from Tk. 10800 (the cheapest) to Tk. 71050 (the costliest). The cheapest price comes from using straw as roof cover, bamboo as beams and columns and terza as wall. The costliest price is for using ferrocement folded plate roof cover, R.C.C. beams and columns, ferrocement walls with R.C.C. foundation. Selection of C.I. sheet roofing with wooden beams, R.C.C. columns, terza wall with R.C. foundation would make the total cost to arround Tk. 22970.

Conclusion

The main drawback in different low cost houses is the lack of stability. This study has shown how stability can be improved through the introduction of knee brace. It has also been proposed to provide kitchen space and safe sanitation facilities in the proposed low-cost village house to keep the total cost comparable to those houses provided by NGO's and others.

Reference :

Ashfaque, K N et al. (1997), A Study on Low-cost Housing, B.Sc. Engg (Civil) thesis, BUET, Dhaka, Bangladesh.