IV–44. Single-Brick-Thick-Load-Bearing Walls for Multistoreyed Residential Buildings

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ABSTRACT

Bricks are the mainstay of construction in India where good quality bricks have been produced since olden times and used extensively for construction work of different types.

For residential buildings, the use of bricks is most common. With the accent on reduction in the cost of construction and for ensuring economical use of bricks, adoption of single-brick-thick-load-bearing walls for 4 to 5 storeyed residential buildings is being advocated in India.

The National Buildings Organisation (NBO), Ministry of Works and Housing, Government of India, which is also United Nations Regional Housing Centre for ESCAP has done pioneering work in this field. It had sponsored investigations for ascertaining the strength of bricks, mortars and brick masonry in different parts of the country. In many parts of India, resistance of load-bearing brick structures against seismic forces is one of the important design criteria on which considerable research work has been undertaken.

To ascertain the performance of single-brick-thick-load-bearing walls up to 4 to 5 storeyed residential buildings, experimental/demonstrational housing projects had been undertaken by the N. B. O. On the basis of practical experience gained, criteria for design of load-bearing brick masonry structures were evolved and standards and codes of construction practices have been formulated.

The paper outlines the aforesaid research and development work for promoting economical use of bricks.

STATUS OF BRICK INDUSTRY

Burnt clay bricks are the main stay of construction in India. Bricks of good quality have been produced in different parts of the country especially in the Indo-gangetic planes where good soils for brick making are abundantly available. Simple methods of manufacturing bricks employing manual labour are employed and production of bricks is undertaken in country clamps as well as kilns of various sizes depending upon the quality and quantity of bricks to be produced. It is roughly estimated that over 70,000 million bricks are produced annually in over 25,000 production units scattered all over the country including 9 mechanised brick plants. Fire-wood and agricultural wastes are generally used in country clamps for burning the bricks whereas coal is used for burning bricks in Bulls-trench kilns, which operate seasonally in the vicinity of places of concentrated construction activities.

Brick industry is one of the largest building materials industry providing employment to over two million workers in the country. The production and use of burnt clay bricks has been in vogue since olden times as has been revealed from the excavation of Mohanjodaro/Indus Valley Civilization, which date back to over five thousand years. Bricks of various sizes are produced. However, bricks of 9 x 4½ x 3 in. are common. Modular bricks of 19 x 9 x 9 cm. are also being made to limited extent. On account of their local availability at reasonably cheap cost and good performance characteristics, burnt clay bricks continue to be the basic material for construction and used extensively for construction of buildings and houses. With the increasing tempo of construction activities in the wake of successive Five Year Plan programmes of national development, the demand for good quality bricks has been increasing considerably. In many places shortage of bricks is being experienced and their prices have gone up considerably. The main bottleneck in setting up more brick production units for augmenting production is the inadequate supply of coal of required quality in different parts of the country. Although large resources of coal are avilable in the country at certain locations, the problem of transportation of coal to far off distance places by rail is presenting difficulties.

BUILDING WITH BRICKS

Bricks have been used in a variety of ways for the construction of residential buildings. The use of bricks is most commonly made for construction of load-bearing as well as non-load-bearing walls. In olden times, brick arch roof and brick vaults and domes were very common. Reinforced brick work for roofing and flooring is adopted in many parts of India. Bricks are used for paving of floors, construction of drains, sewers, etc. Brick bats are used for concrete work in places where stone aggregate are not available. Surkhi prepared by crushing burnt clay bricks is used as pozzolana for the preparation of lime mortars.

Buildings and houses constructed with bricks provide adequate thermal comforts which is a matter of great importance in predominantly tropical climates as exist in India. Brick constructions harmonise with the surroundings and present aesthetic appearance. The simple and inexpensive technology of production of bricks in small scale units and skillful use of bricks in construction by masons is considered to be a technology which is appropriate as it suits the socioeconomic conditions prevailing in the country. Generally, for one or two storeyed residential buildings single-brick-thick-load-bearing walls are built. For more than two storeys thicker load-bearing walls are adopted. In many cities and towns in India, it is

becoming increasingly necessary to build more than two storeyed residential buildings in order to economise in the use of land and also the cost of construction.

To wipe out the acute shortage of housing, in India a massive programme of housing construction in the country using indigenous building materials and technology to the extent possible for building houses at an economical cost, is required to be undertaken on long-term basis. This will be evident from the fact that at the beginning of 1979, it was estimated by the National Buildings Organisation (NBO) that there was a shortage of 19.7 million dwelling units—4.9 million units in urban areas and 14.8 million units in rural areas. There is great need to develop the brick industry on modern scientific lines to meet the challenge of construction programme.

DESIGN OF BRICK MASONRY

In order to make optimum use of the strength of bricks for construction of buildings and houses at a low cost investigations were sponsored by the NBO to determine the strength of bricks, strength of mortars and strength of brick work and to suggest economical design criteria. As a result of investigations undertaken by the research laboratories like Central Building Research Institute, Roorkee, adoption of calculated design of brick masonry is being advocated by NBO for construction of single-brick-thick-load-bearing walls for 4 to 5 storeyed residential buildings (without lift) in areas where bricks of good quality having minimum crushing strength of 70 Kg./cm^2 are available.

Apart from the fact that the structure has to be necessarily a low cost one, it has also been designed to resist earthquake forces as two-thirds of the Indian Sub-continent lies in the seismic zone of moderate to severe intensity. The Indian Standards Institution has classified the Indian sub-continent into five zones depending upon the intensity of seismic forces. As per this for example, Delhi and Calcutta regions fall in the seismic zones IV and III respectively. The magnitude on Ritcher's scale of the earthquake corresponding to seismic zone IV varies from 6.5 to 7.0 whereas the magnitude for zone III is 6 to 6.5 respectively. The school of Research and Training in Earthquake Engineering, University of Roorkee (India), which was established in 1960, have undertaken pioneering research and investigations work in seismic design and construction of structures of varied types including brick masonry structures for low cost housing. The School has recommended suitable strengthening measures to be adopted for single brick thick load bearing wall structures for four to five storeyed residential buildings.

TRENDS IN BRICK MASONRY CONSTRUCTION

In these seismic regions, so far it has been the practice to construct thick load bearing brick masonry walls restricted to three storeys. However, based on experiments and analytical observations taking into consideration seismic forces, the Indian Standards Code now permits construction of structures up to four storeys with load bearing walls restricting the total height to 15 metres only provided seismic considerations are taken into account in planning, design and construction.

Under the Experimental Housing Scheme of National Buildings Organisation construction of single-brick-thick-load-bearing brick walls for up to 5 storeyed residential buildings with a total height of 15 metres has been taken up at Calcutta and Delhi with adequate measures to account for earthquake forces. Diagramatic representation of the development in construction of brick masonry structures is given in figure 1.

Four Storeyed Single Brick Wall Construction

In the first instance construction of 16 four storeyed blocks having 96 dwelling units were taken up for construction at Delhi. The project was undertaken by Central Public Works Department under Experimental Housing Scheme of NBO. The main features of construction are:

a) Adoption of 23 cm. (9 in.) thick load bearing brick masonry wall in all the floors with conventional R. C. C. slab roofing and floors.
b) Planning of structures on concept of cross wall construction.
c) Ceiling height has been reduced to 3.55 metres.
d) Using hard moulded bricks of crushing strength of 105 kg/cm^2 in ground floor with cement mortar 1:3 and bricks of 70 kg/cm^2 strength in upper floors.
e) Strengthening the structure against seismic forces which include provision of R. C. C lintel bands, corner reinforcement in masonry, reinforcement at junction of walls, openings of doors and windows, etc.

As compared to conventional type of load bearing brick masonry wall employing 46 cm. (18 in.) wall in Ground Floor, 34.5cm. (13½ in.) in First Floor and 23 cm. (9 in.) in Second Floor and Third Floors, this type of experimental construction with 23 cm. (9 in.) wall in all the floors, resulted in an economy of 13.4% large on account of saving in consumption of bricks and mortar and providing more floor area due to reduced thickness of wall. This construction was put in 1960. (Fig. 1).

The confidence of the engineers and builders about its behaviour and safety is apparent from the fact it has almost become a universal practice that wherever good quality bricks are available in different parts of the country, 23 cm. (9 in.) thick brick walls up to four storeys are adopted. By now over 40,000 houses have been constructed in different parts of the country by using this type of structure.

Five Storeyed Single-Brick-Thick-Load-Bearing Residential Buildings with Precast Roofing (without lifts).

In order to provide more built up accommodation in a given piece of land, construction of five storeyed residential buildings employing single-brick-thick-walls in all the five floors has also been taken up by the National Buildings Organisation on experimental basis. A five storeyed residential building having 24 dwelling units was com-

pleted by Calcutta Metropolitan Planning Organisation in Calcutta in 1974. The main characteristic features of the building are (Fig. 2).

a) Adoption of 25 cm. (10 in.) thick load bearing brick walls in all the five floors. (Calcutta bricks are 10 in. size whereas bricks in Delhi are of 9 in.).
b) Planning of structure on concept of cross wall construction.
c) Precast R. C. channel type roofing and flooring evolved by Central Building Research Institute, Roorkee.
d) Strengthening the structure against seismic forces which include provision of R. C. C. lintel bands, corner reinforcement in masonry.
e) Ceiling height has been reduced to 2.75 metres in all the floors.

The total height of the building does not exceed 15 metres. The performance of the structure is being observed. Meanwhile construction of some 500 dwelling units on the basis of five storeyed residential blocks have also been completed employing above techniques of construction by the Calcutta Metropolitan Planning Organisation.

Five Storeyed Single-Brick-Thick Wall Construction with R. C. C. Roofing

In Delhi, which in terms of seismic intensity is more severe than Calcutta, the construction of five storeyed residential buildings has been taken up by the CPWD under the NBO. Experimental Housing Scheme. The construction work of the building was commenced in early 1977. The main features of this experimental project are—

a) Adoption of 23 cm. load bearing brick wall construction in all the floors.
b) Planning of structures on concept of cross wall construction.
c) The ceiling height reduced to 2.75 metres, the total height of the building being 15 metres.
d) Strengthening measures to resist the earthquake have been incorporated which include provision of sil RCC bands, corner reinforcement.

The strengthening measures which have been adopted in the design and construction of the building have been recommended by the School of Research & Training in Earthquake Engineering, who carried out a detailed analysis of the structure. For this analysis first and top storeys have been checked which are the critical parts of the structure. Advantage is also taken of the symmetry of the structure while carrying out the analysis. The analysis leads to following observations.

Shear stress is within safe limits for brick masonry if it is done in a cement sand mortar not leaner than 1:6. However, in several building elements, the compressive and tensile stresses exceed the safe limit of stresses permissible in the walls. Since maximum stresses are computed at the ends of wall piers, no reduction in permissible stress is allowed due to buckling effects which are present only in the centre of such walls. Hence strengthening measures are required. Based on the above, the following measures are adopted:

a) For all brick work, bricks used shall have a crushing strength of more than 70 kg/cm^2.
b) All 4½ in. walls of all the storeys shall be constructed in cement sand mortar 1:3 or equivalent.
c) The brick work in the first storey shall be in cement sand mortar not leaner than 1:3 or its equivalent. In the rest of the storeys it shall not be leaner than 1:6 or its equivalent.
d) Since all doors and windows except in bath and W. C. have their top flushed with bottom of the slab lintel bend cannot be provided. However, suitable horizontal dowel reinforcements at corners and junctions may be provided, at one course below window sill level and at about mid height above this level to the roof to ensure integral action. The windows in bath and W. C. should be encased.
e) Vertical steel at corners and junctions of walls and also around the openings shall be provided as follows:

Storeys	Top	Fourth	Third	Second	Bottom
Dia. of single bar in mm.	12	12	12	16	16

Provision of vertical reinforcements and its encasement at the corners, junctions and jambs of openings are also made.

f) Slabs shall be given full bearing on the wall to act as roof bands.

School of Research and Training in Earthquake Engineering has recommended that in case precast channel units developed by CBRI or similar precast elements are used for roofing and intermediate floors, following additional strengthening measures may be adopted against earthquake forces:

a) 4 cm (1½ in.) cement concrete 1:2:4 topping with reinforcement consisting of 6 mm. dia bars 23 cm. cement concrete both ways may be provided.
b) Ends or sides of channel units, which are resting on all walls should have reinforcement (12 mm bars) projecting out in the form of loops or hooks. These projecting loops or hooks should be tied together with a runner bar of 12 mm dia passed through them and the gap concreted with 1:2:4 cement concrete.

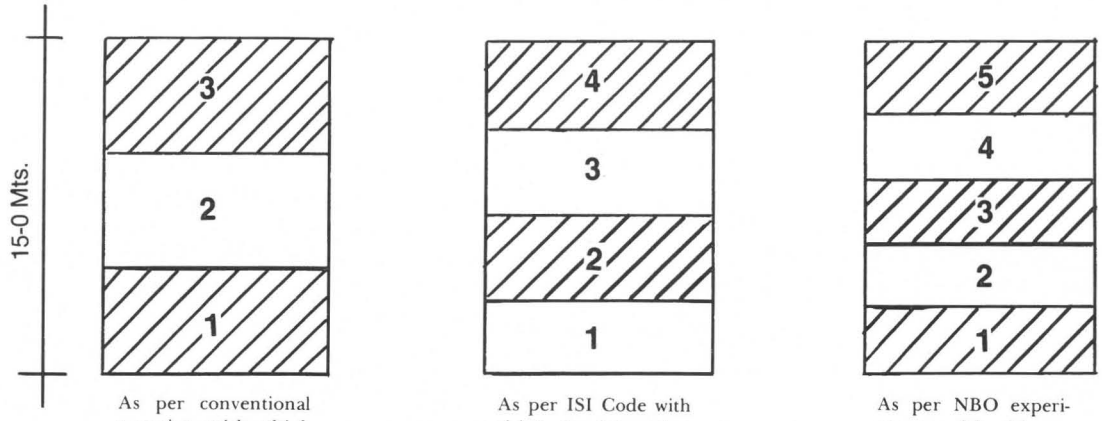
EVALUATION

The performance of buildings put up under the NBO Experimental Housing Schemes employing single-brick-thick-load-bearing walls for up to four to five storeyed structures (walk-up) is being observed scientifically over a period of time to provide feed back information to improve the design with a view to ensuring safety and economy in the cost of construction.

Appropriate Technology

It would thus be observed that the main objective of undertaking experimental construction under the NBO. Experimental Housing Scheme is to promote evolution and adoption of appropriate technology of construction suited to local conditions. This would be obvious from the fact that in India particularly in Indo-Gangetic plains burnt clay brick is one of the predominantly used basic construction material. In Delhi very good bricks are being manufactured which should be used to optimum advantage by constructing multi-storeyed residential buildings. The adoption of single-brick-thick-load-bearing walls up to five storeyed residential buildings avoids the necessity for putting up RCC frame structure and thus saves scarce materials like cement and steel. In hot and arid climatic conditions brick wall having 23 cm. thickness provides adequate thermal comforts as compared to other types of walling material like concrete construction.

Both the manufacture and use of bricks is labour-intensive and provides employment to a large number of skilled and unskilled workers who are available at cheap rates. Saving up to 15 percent in the cost of construction can be achieved by using brick load bearing walls up to five storeyed construction as compared to other forms of construction.



As per conventional practice with thick load-bearing brick walls.

As per ISI Code with thick load-bearing brick walls.

As per NBO experiments with thinner load-bearing brick walls.

Figure 1.

Figure 2. Four storeyed residential buildings in Delhi put up by Central Public Works Department under NBO Experimental Housing Scheme. Single-brick-thick-load-bearing walls have been adopted in all the four floors resulting in about 15 percent economy in cost of construction and also consumption of bricks.

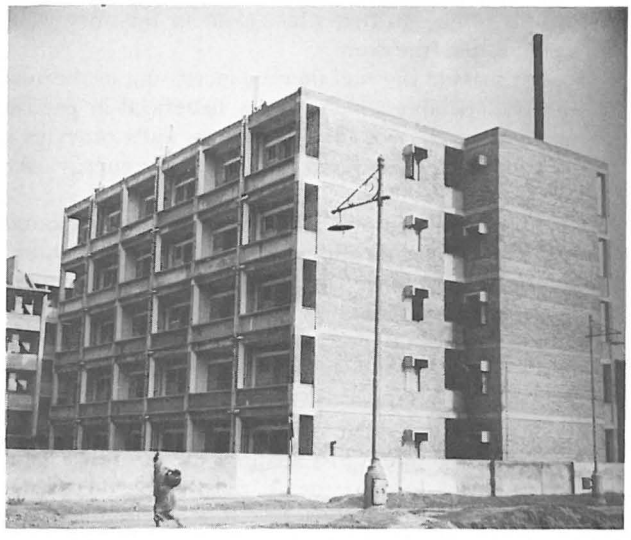


Figure 3. Five storeyed residential buildings in Calcutta put up by Calcutta Metropolitan Planning Organisation under the NBO Experimental Housing Scheme.