Starting from August 2004, *Resonance* is publishing in the Classroom section, a series of short articles, 'Earthquake Tips', related to earthquakes, their effects on civil structures, and design and construction of earthquake resistant buildings. The concepts are clearly explained with sketches and analogies. We hope the *Resonance* readers will benefit from this series of articles.

Earthquake Tips have been brought out by the Department of Civil Engineering, IIT Kanpur, and sponsored by Building Materials and Technology Promotion Council, New Delhi, India. These articles are reproduced here with permission from IIT Kanpur and BMTPC, New Delhi.

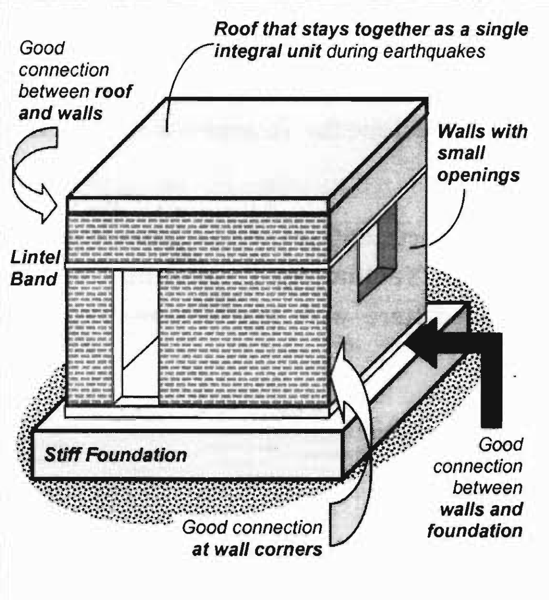
C V R Murty
Indian Institute of Technology
Kanpur, Kanpur 208 016, India
Email:eqtips@iitk.ac.in

Learning Earthquake Design and Construction 13. Why Should Masonry Buildings have Simple Structural Configuration?

Box Action in Masonry Buildings

Brick masonry buildings have large mass and hence attract large horizontal forces during earthquake shaking. They develop numerous cracks under both compressive and tensile forces caused by earthquake shaking. The focus of *earthquake resistant* masonry building construction is to ensure that these effects are sustained without major damage or collapse. Appropriate choice of structural configuration can help achieve this. The structural configuration of masonry buildings includes aspects like (a) overall shape and size of the building, and (b) distribution of mass and (horizontal) lateral load resisting elements across the building. Large, tall, long and unsymmetric buildings perform poorly during earthquakes (*IITK-BMTPC Earthquake Tip* 6). A strategy used in making them earthquake-resistant is developing good *box action* between all the elements of the building, *i.e.*, between roof, walls and foundation (*Figure* 1). Loosely connected roof or unduly slender walls are threats to good seismic behaviour. For example, a horizontal band introduced at the lintel level ties the walls together and helps to make them behave as a single unit.

Keywords
Earthquake, masonry buildings.



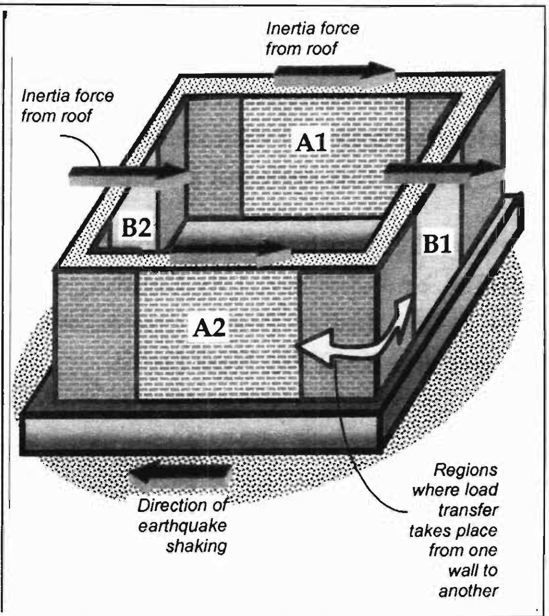


Figure 1 (left). Essential requirements to ensure box action in a masonry building.

Figure 2 (right). Regions of force transfer from weak walls to strong walls in a masonry building – wall B1 pulls walls A1 and A2, while wall B2 **pushes walls A1 and A2.**

Influence of Openings

Openings are functional necessities in buildings. However, location and size of openings in walls assume significance in deciding the performance of masonry buildings in earthquakes. To understand this, consider a four-wall system of a single storey masonry building (*Figure* 2). During earthquake shaking, inertia forces act in the strong direction of some walls and in the weak direction of others (See *IITK-BMTPC Earthquake Tip 12*). Walls shaken in the weak direction seek support from the other walls, *i.e.*, walls B1 and B2 seek support from walls A1 and A2 for shaking in the direction shown in *Figure* 2. To be more specific, wall B1 pulls walls A1 and A2, while wall B2 pushes against them. At the next instance, the direction of shaking could change to the horizontal direction perpendicular to that shown in *Figure* 2. Then, walls A and B change their roles; Walls B1 and B2 become the strong ones and A1 and A2 weak.

Thus, walls transfer loads to each other at their junctions (and through the lintel bands and roof). Hence, the masonry courses from the walls meeting at corners must have good interlocking. For this reason, openings near the wall corners are detrimental to good seismic performance. Openings too close to wall corners hamper the flow of forces from one wall to another (*Figure* 3). Further, large openings weaken walls from carrying the inertia forces in their own plane. Thus, it is best to keep all openings as small as possible and as far away from the corners as possible.

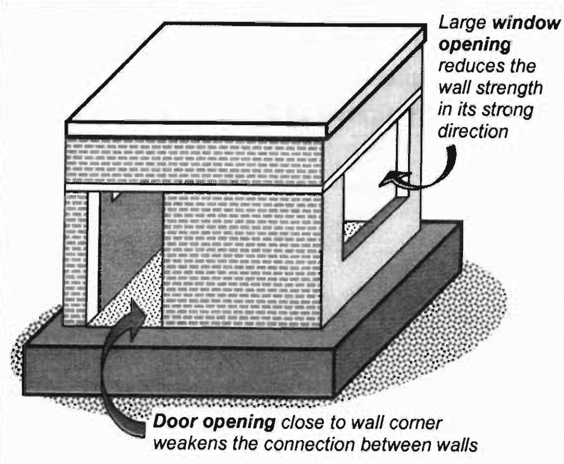


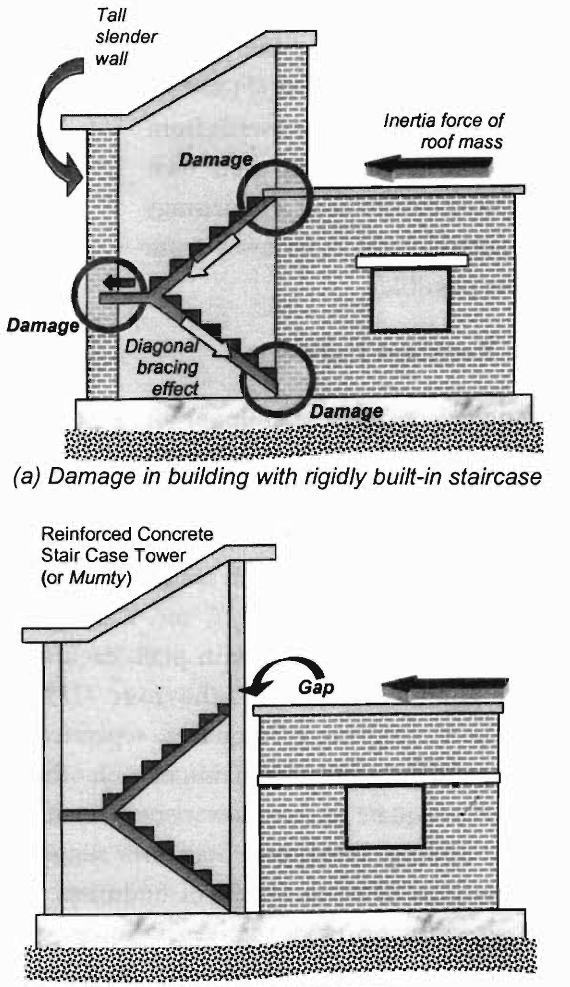
Figure 3. Openings weaken walls in a masonry building – a single closed horizontal band must be provided above all of them.

Earthquake-Resistant Features

Indian Standards suggest a number of earthquake-resistant measures to develop good *box-type* action in masonry buildings and improve their seismic performance. For instance, it is suggested that a building having horizontal projections when seen from the top, *e.g.*, like a building with plan shapes L, T, E and Y, be separated into (*almost*) simple rectangular blocks in plan, each of which has simple and good earthquake behaviour (*IITK-BMTPC Earthquake Tip* 6). During earthquakes, separated blocks can oscillate independently and even hammer each other if they are too close. Thus, adequate gap is necessary between these different blocks of the building. The Indian Standards suggest minimum seismic separations between blocks of buildings. However, it may not be necessary to provide such separations between blocks, if horizontal projections in buildings are small, say up to ~15-20% of the length of building in that direction.

Inclined staircase slabs in masonry buildings offer another concern. An integrally connected staircase slab acts like a cross-brace between floors and transfers large horizontal forces at the roof and lower levels (*Figure* 4a). These are areas of potential damage in masonry buildings, if not accounted for in staircase design and construction. To overcome this, sometimes, staircases are completely separated (*Figure* 4b) and built on a separate reinforced concrete structure. Adequate gap is provided between the staircase tower and the masonry building to ensure that they do not pound each other during strong earthquake shaking.

Figure 4. Earthquake-resistant detailing of staircase in masonry building – must be carefully designed and constructed.



(a) Damage in building with rigidly built-in staircase

(b) Building with separated staircase

Suggested Reading

[1] IS 1905, *Indian Standard Code of Practice for Structural Use of Unreinforced Masonry*, Bureau of Indian Standards, New Delhi, 1987.

[2] IS 42326, *Indian Standard Code of Practice for Earthquake Resistant Design and Construction of Buildings*, Bureau of Indian Standards, New Delhi, 1993.

[3] IS 13828, *Indian Standard Guidelines for Improving Earthquake Resistance of Low-strength Masonry Buildings*, Bureau of Indian Standards, New Delhi, 1993.

[4] M Tomazevic, Earthquake Resistant Design of Masonry Buildings, Imperial College Press, London, UK, 1999.

Suggestions/comments may be sent to: eqtips@iitk.ac.in.