IITK - bmtpc
Earthquake Tip 22
Learning Earthquake Design and Construction

Why are Short Columns more Damaged During Earthquakes?

Which Columns are short?

During past earthquakes, reinforced concrete (RC) frame buildings that have columns of different heights within one storey, suffered more damage in the shorter columns as compared to taller columns in the same storey. Two examples of buildings with short columns are shown in Figure 1 – buildings on a sloping ground and buildings with a mezzanine floor.

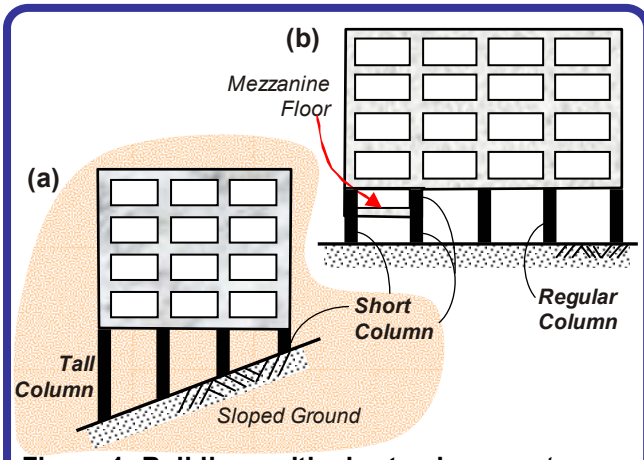

Figure 1: Buildings with short columns – *two explicit examples of common occurrences.*

Poor behaviour of short columns is due to the fact that in an earthquake, a tall column and a short column of same cross-section move horizontally by same amount Δ (Figure 2). However, the short column is stiffer as compared to the tall column, and it attracts larger earthquake force. Stiffness of a column means resistance to deformation – the larger is the stiffness, larger is the force required to deform it. If a short column is not adequately designed for such a large force, it can suffer significant damage during an earthquake. This behaviour is called *Short Column Effect*. The damage in these short columns is often in the form of X-shaped cracking – this type of damage of columns is due to *shear failure* (see *IITK-BMTPC Earthquake Tip 19*).

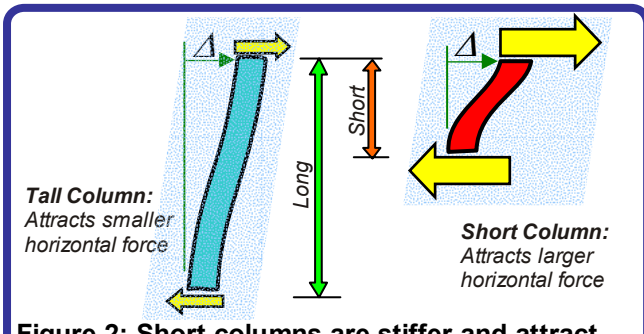

Figure 2: Short columns are stiffer and attract larger forces during earthquakes – *this must be accounted for in design.*

The Short Column Behaviour

Many situations with short column effect arise in buildings. When a building is rested on sloped ground (Figure 1a), during earthquake shaking all columns move horizontally by the same amount along with the floor slab at a particular level (this is called *rigid floor diaphragm action*; see *IITK-BMTPC Earthquake Tip 17*). If short and tall columns exist within the same storey level, then the short columns attract several times larger earthquake force and suffer more damage as compared to taller ones.

The short column effect also occurs in columns that support mezzanine floors or loft slabs that are added in between two regular floors (Figures 1b).

There is another special situation in buildings when short-column effect occurs. Consider a wall (*masonry* or *RC*) of partial height built to fit a window over the remaining height. The adjacent columns behave as short columns due to presence of these walls. In many cases, other columns in the same storey are of regular height, as there are no walls adjoining them. When the floor slab moves horizontally during an earthquake, the upper ends of these columns undergo the same displacement (Figure 3). However, the stiff walls restrict horizontal movement of the lower portion of a short column, and it deforms by the full amount over *the short height* adjacent to the window opening. On the other hand, regular columns deform over the *full height*. Since the effective height over which a short column can freely bend is small, it offers more resistance to horizontal motion and thereby attracts a larger force as compared to the regular column. As a result, short column sustains more damage. Figure 4 shows X-cracking in a column adjacent to the walls of partial height.

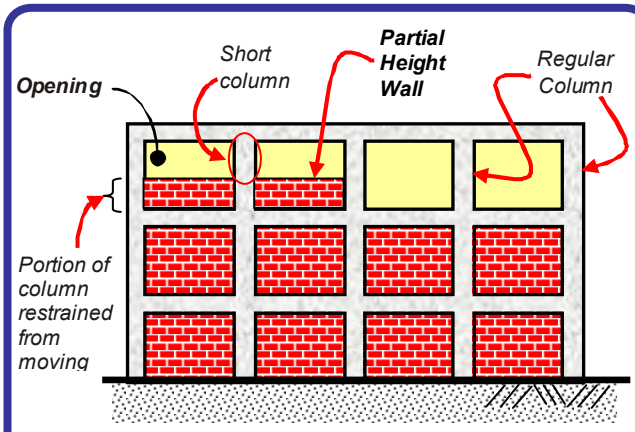

Figure 3: *Short columns effect* in RC buildings when partial height walls adjoin columns – *the effect is implicit here because infill walls are often treated as non-structural elements.*

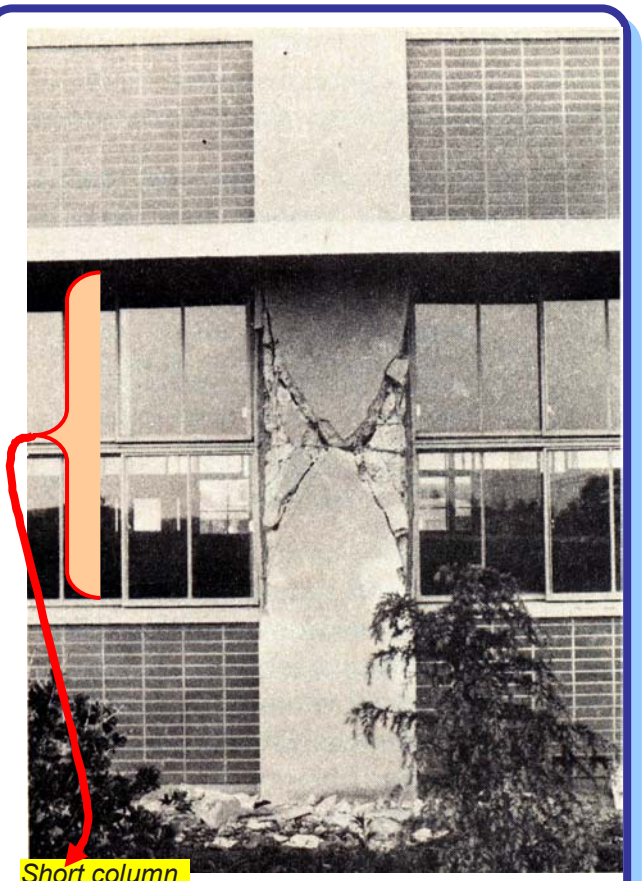

Figure 4: Effective height of column over which it can bend is restricted by adjacent walls – *this short-column effect is most severe when opening height is small.*

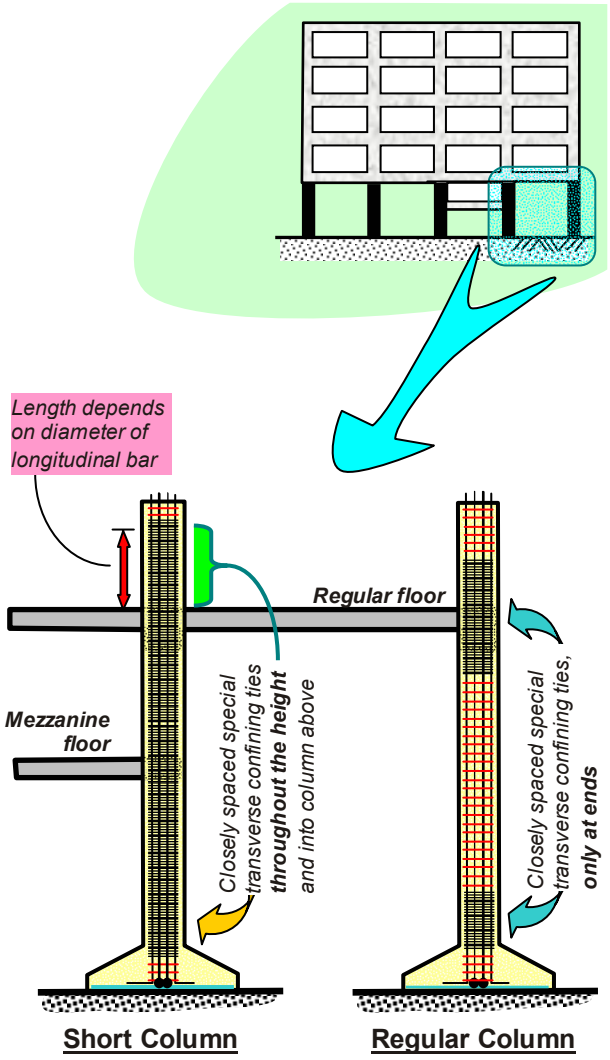

Figure 5: Details of reinforcement in a building with short column effect in some columns – *additional special requirements are given in IS:13920-1993 for the short columns.*

The Solution

In new buildings, *short column effect* should be avoided to the extent possible during *architectural design* stage itself. When it is not possible to avoid short columns, this effect must be addressed in structural design. The Indian Standard IS:13920-1993 for ductile detailing of RC structures requires special confining reinforcement to be provided over the *full height* of columns that are likely to sustain short column effect. The special confining reinforcement (*i.e.*, closely spaced closed ties) must extend beyond the short column into the columns vertically above and below by a certain distance as shown in Figure 5. See *IITK-BMTPC Earthquake Tip 19* for details of the special confinement reinforcement.

In existing buildings with short columns, different retrofit solutions can be employed to avoid damage in future earthquakes. Where walls of partial height are present, the simplest solution is to close the openings by building a wall of full height – this will eliminate the short column effect. If that is not possible, short columns need to be strengthened using one of the well established retrofit techniques. The retrofit solution should be designed by a qualified structural engineer with requisite background.

Related IITK - BMTPC Earthquake Tip

Tip 6: How Architectural Features Affect Buildings During Earthquakes?
Tip 17: How do Earthquakes Affect Reinforced Concrete Buildings?
Tip 19: How do Columns in RC Buildings Resist Earthquakes?

Resource Material

IS 13920, (1993), *Indian Standard Code of Practice for Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces*, Bureau of Indian Standards, New Delhi.

Next Upcoming Tip

Why are buildings with shear walls preferred in seismic regions?

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