

How Architectural Features affect Buildings during Earthquakes?

Importance of Architectural Features

The behaviour of a building during earthquakes depends critically on its overall shape, size and geometry, in addition to how the earthquake forces are carried to the ground. Hence, at the planning stage itself, architects and structural engineers must work together to ensure that the unfavourable features are avoided and a good building configuration is chosen.

The importance of the configuration of a building was aptly summarised by Late Henry Degenkolb, a noted Earthquake Engineer of USA, as:

"If we have a poor configuration to start with, all the engineer can do is to provide a band-aid - improve a basically poor solution as best as he can. Conversely, if we start-off with a good configuration and reasonable framing system, even a poor engineer cannot harm its ultimate performance too much."

Architectural Features

A desire to create an aesthetic and functionally efficient structure drives architects to conceive wonderful and imaginative structures. Sometimes the *shape* of the building catches the eye of the visitor, sometimes the *structural system* appeals, and in other occasions *both shape and structural system* work together to make the structure a marvel. However, each of these choices of shapes and structure has significant bearing on the performance of the building during strong earthquakes. The wide range of structural damages observed during past earthquakes across the world is very educative in identifying structural configurations that are desirable versus those which must be avoided.

Size of Buildings: In tall buildings with large height-to-base size ratio (Figure 1a), the horizontal movement of the floors during ground shaking is large. In short but very long buildings (Figure 1b), the damaging effects during earthquake shaking are many. And, in buildings with large plan area like warehouses (Figure 1c), the horizontal seismic forces can be excessive to be carried by columns and walls.

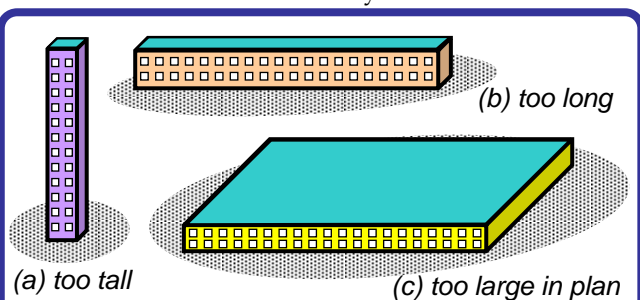
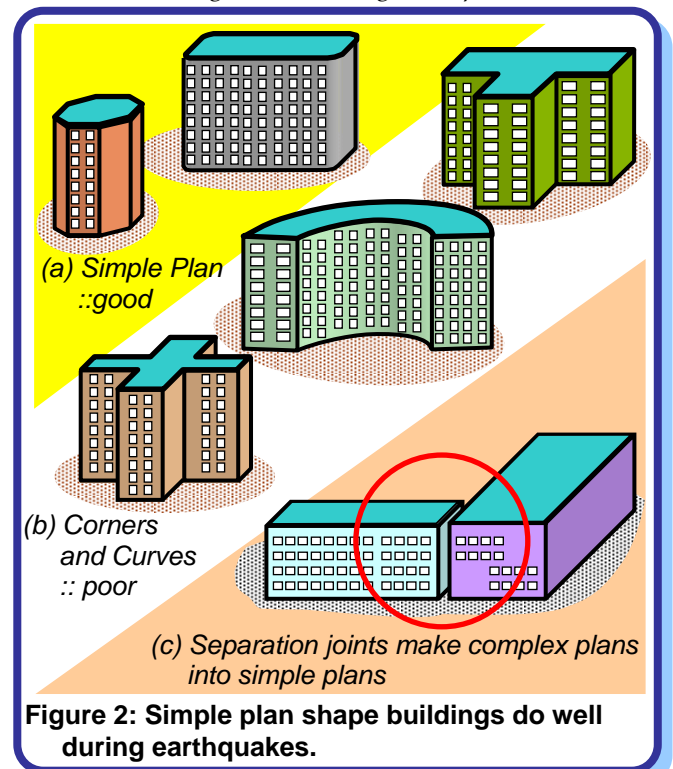


Figure 1: Buildings with one of their overall sizes much larger or much smaller than the other two, do not perform well during earthquakes.

Horizontal Layout of Buildings: In general, buildings with simple geometry in plan (Figure 2a) have performed well during strong earthquakes. Buildings with re-entrant corners, like those U, V, H and + shaped in plan (Figure 2b), have sustained significant damage. Many times, the bad effects of these interior corners in the plan of buildings are avoided by making the buildings in two parts. For example, an L-shaped plan can be broken up into two rectangular plan shapes using a separation joint at the junction (Figure 2c). Often, the plan is simple, but the columns/walls are not equally distributed in plan. Buildings with such features tend to twist during earthquake shaking. A discussion in this aspect will be presented in the upcoming IITK-BMTPC Earthquake Tip 7 on *How Buildings Twist During Earthquakes?*



Vertical Layout of Buildings: The earthquake forces developed at different floor levels in a building need to be brought down along the height to the ground by the shortest path; any deviation or discontinuity in this load transfer path results in poor performance of the building. Buildings with vertical setbacks (like the hotel buildings with a few storeys wider than the rest) cause a sudden jump in earthquake forces at the level of discontinuity (Figure 3a). Buildings that have fewer columns or walls in a particular storey or with unusually tall storey (Figure 3b), tend to damage or collapse which is initiated in

that storey. Many buildings with an open ground storey intended for parking collapsed or were severely damaged in Gujarat during the 2001 Bhuj earthquake.

Buildings on slopy ground have unequal height columns along the slope, which causes ill effects like twisting and damage in shorter columns (Figure 3c). Buildings with columns that hang or float on beams at an intermediate storey and do not go all the way to the foundation, have discontinuities in the load transfer path (Figure 3d). Some buildings have reinforced concrete walls to carry the earthquake loads to the foundation. Buildings, in which these walls do not go all the way to the ground but stop at an upper level, are liable to get severely damaged during earthquakes.

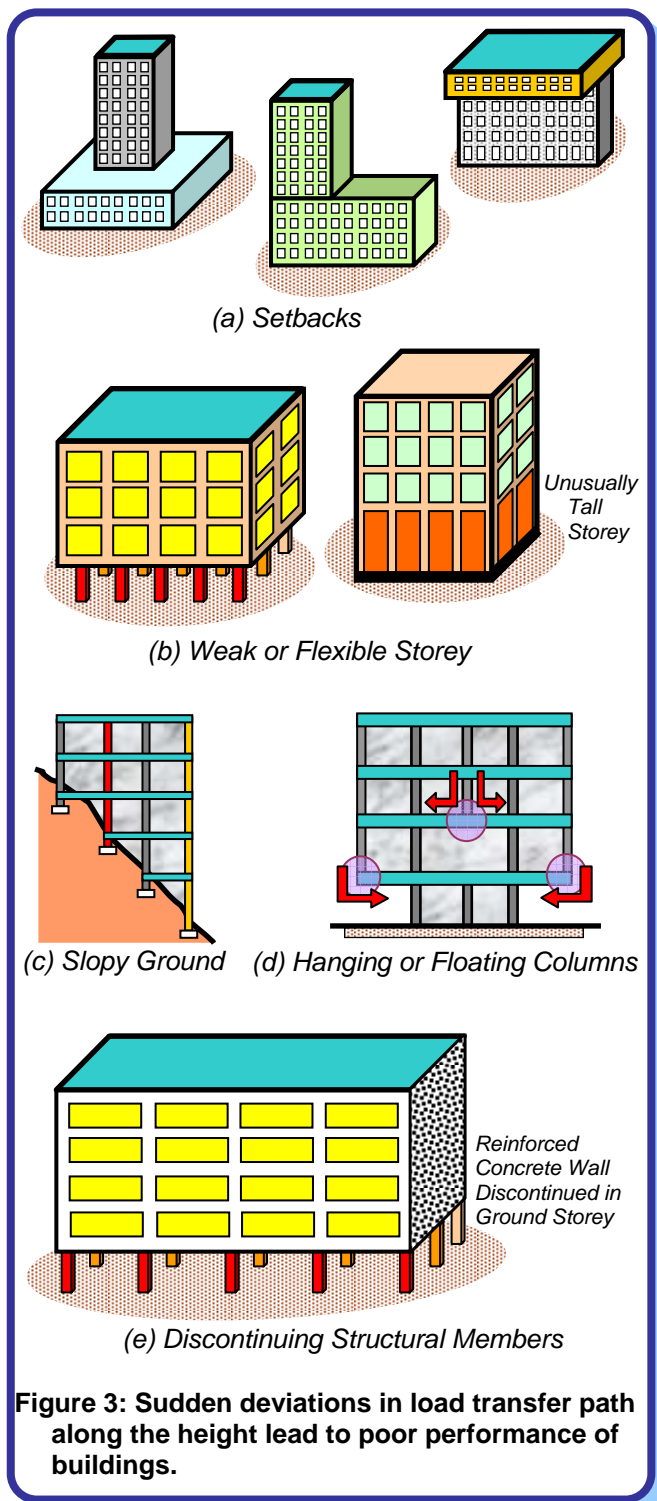


Figure 3: Sudden deviations in load transfer path along the height lead to poor performance of buildings.

Adjacency of Buildings: When two buildings are too close to each other, they may pound on each other during strong shaking. With increase in building height, this collision can be a greater problem. When building heights do not match (Figure 4), the roof of the shorter building may pound at the mid-height of the column of the taller one; this can be very dangerous.

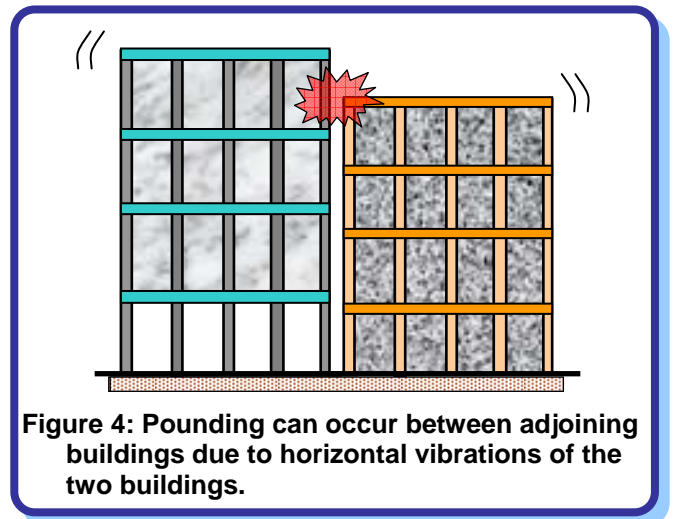


Figure 4: Pounding can occur between adjoining buildings due to horizontal vibrations of the two buildings.

Building Design and Codes...

Looking ahead, of course, one will continue to make buildings interesting rather than monotonous. However, this need not be done at the cost of poor behaviour and earthquake safety of buildings. Architectural features that are detrimental to earthquake response of buildings should be avoided. If not, they must be minimised. When irregular features are included in buildings, a considerably higher level of engineering effort is required in the structural design and yet the building may not be as good as one with simple architectural features.

Decisions made at the planning stage on building configuration are more important, or are known to have made greater difference, than accurate determination of code specified design forces.

Reading Material

Arnold,C., and Reitherman,R., (1982), *Building Configuration and Seismic Design*, John Wiley, USA
 Lagorio,HJ, (1990), *EARTHQUAKES An Architect's Guide to Non-Structural Seismic Hazard*, John Wiley & Sons, Inc., USA

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