IITK - bmtpc
Earthquake Tip 26
Learning Earthquake Design and Construction

What Harms Load Paths in Buildings?

Buildings with Moment Resisting Frames

Smooth transfer of inertia forces in a *Moment Resisting Frame* (MRF) building is critically dependant on the geometry of the frame grid. Some desirable features of a frame grid include:

(a) *Several distinct planar, regular MRFs placed parallel to each other, in each of the two perpendicular plan directions* of the building;

(b) *Columns running run through full height and beams through full width* of the building;

(c) *Uniform spacing between parallel planar MRFs in each plan direction*; and

(d) *Beams within each planar frame slender enough to deform in flexure*: Concrete beams of very short span may damage in shear, which is undesirable.

Poor Frame Grid -

For smooth load transfer in an MRF, it is necessarily for beams and columns to intersect and to form a *well-defined grid*. Of the two MRF buildings shown in plan in Figure 1, the first one has regular frames in both plan directions (Figure 1a), while the second has irregular beam and column layout consisting of a small MRF in the X-direction and limited frame action in the Y-direction (Figure 1b); this is NOT an acceptable earthquake-resistant solution.

Large detours in load paths result in stress concentration in the frame and in poor performance. This can happen, if frame lines are discontinuous (*i.e.*, beam lines jog out-of-plane), and if beams frame into each other instead of into columns.

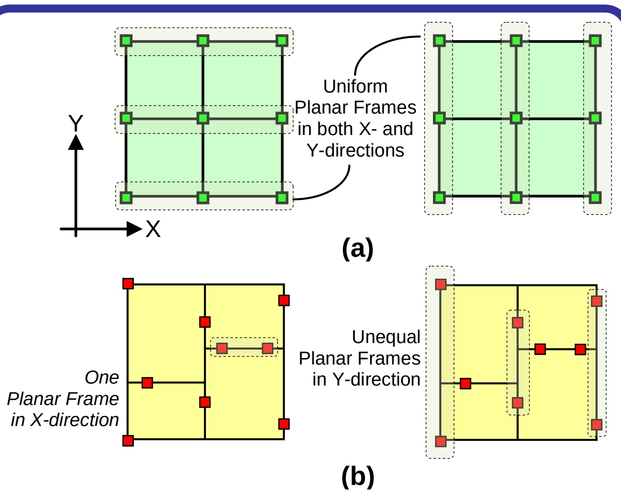

Figure 1: Structural framing in RC buildings in plan – *(a) good, and (b) poor.*

Discontinuity in Vertical Elements: Floating Columns and Setback Columns -

Discontinuing a load carrying member along its length or height is *harmful* to earthquake performance of the building. It is not desirable to discontinue a column in the lower storey of a building (Figure 2a); such columns are called *floating columns*. When a column is pushed out of the vertical line in a lower storey, the forces carried by the upper portion of the column have to bend at the setback location to continue towards the foundation (Figure 2b); such columns are called *setback columns*. Presence of a setback column also leads to poor building performance in an earthquake; brittle damage is expected in beam-column joints and beams adjoining the setback location.

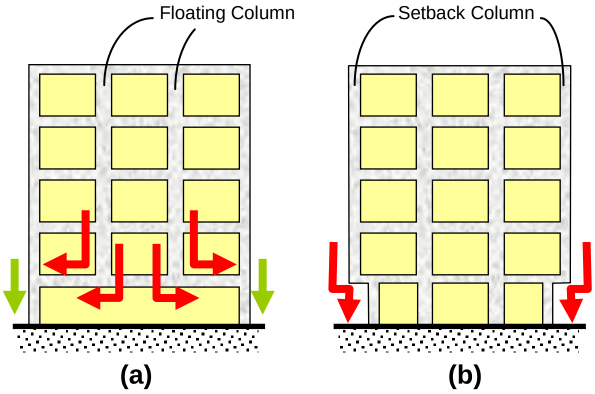

Figure 2: Discontinuing columns in MRFs detrimental to earthquake safety of buildings – *(a) floating column: the column is discontinued at a lower level, and (b) set-back column: the column is moved out of plumb*

Buildings with Structural Walls

Structural walls (SWs; also called *Shear Walls*) have *large lateral stiffness* and *lateral strength* in the length direction and provide very good load paths. Buildings with SWs have *performed well* during past earthquakes. Some desirable features of buildings with SWs include:

(a) Continuous SWs running through full building height generally offer direct load paths for inertia forces collected from diaphragms at different floor levels to be carried down to the foundation;

(b) Uniformly distributed SWs in both plan directions; and

(c) Sufficient wall density, *i.e.*, total cross-section area of structural walls in plan as a percentage of plan area of building.

Situations arise when departure occurs from good earthquake behaviour. These include:

(a) Large and/or irregular openings

SWs with smaller and uniform openings behave better (Figure 3a). In SWs with large and random openings, there are multiple load paths and each of those has long detours. As a result, the load paths become long and convoluted instead of being short and direct (Figure 3b). This creates undesirable interrupted load transfer along the SW height. Design codes require special attention in the design and detailing of walls between openings, to reduce negative effects of openings and ensure desirable ductile behaviour of buildings with SWs.

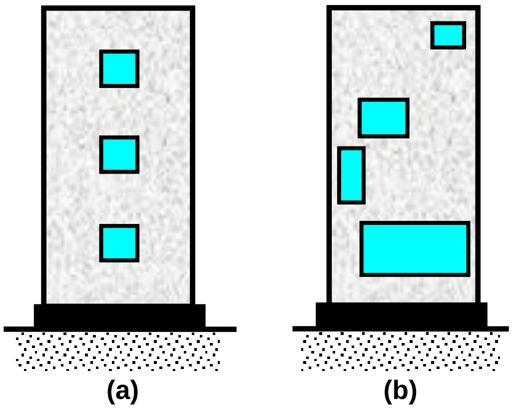

Figure 3: Openings in walls of buildings – *(a) uniform size and location, and (b) random size and location*

(b) Discontinuity, out-of-plane offsets and in-plane offsets in SWs in lower elevations

Sometimes, in the lower storeys of buildings, SWs are discontinued completely (Figures 4a and 5a), discontinued but moved *in-plane* (Figures 4b and 5b), or discontinued and moved *out-of-plane* (Figures 4c and 5c). This leads to abrupt changes in load path. Buildings with such wall configurations perform poorly in earthquakes. Such options should be avoided in earthquake-resistant buildings.

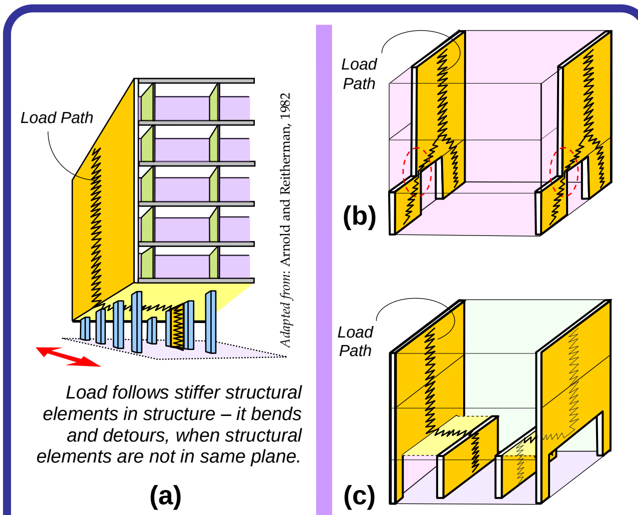

Figure 4: Undesirable shifts and splits in Load Paths, when structural elements are moved: *(a),(c) out-of-plane, (b) in-plane*

(c) Truncating structural walls in upper elevations

When SWs are discontinued at upper elevations over a part of their width (Figure 6a), or over the full width at a certain height (Figure 6b), abrupt changes occur in stiffness and strength of the building within a vertical plane. These practices should be avoided in earthquake-resistant buildings.

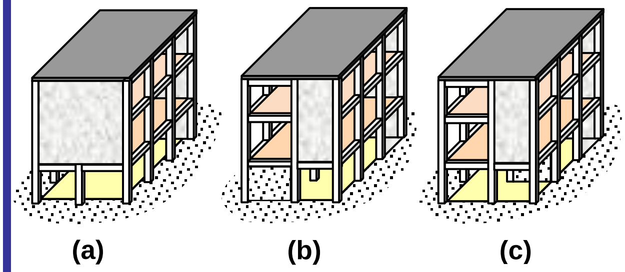

Figure 5: Poor configurations of walls in Buildings – *(a) discontinuing walls in lower storeys, (b) moving wall in same plane, but to adjacent bay, and (c) moving wall out-of-plane to inside, but same bay.*

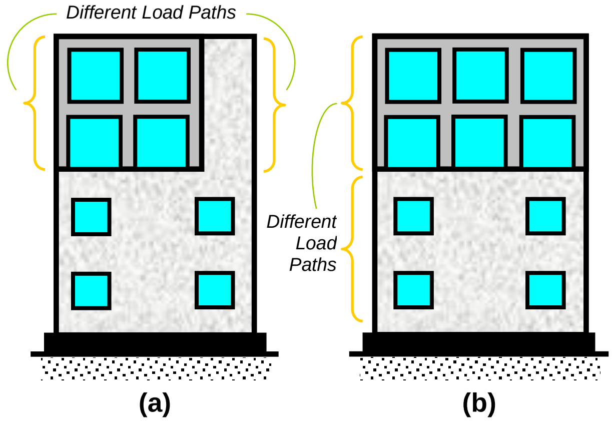

Figure 6: Hybrid load paths in structural walls (SWs) – *(a) SW truncated in part, and (b) SW truncated fully*

Related IITK - BMTPC Earthquake Tip

Tip 7: How buildings twist during earthquakes?
Tip 18: How do beams in RC buildings resist earthquake effects?
Tip 20: How do beam-column joints in RC buildings resist earthquakes?
Tip 21: Why are open ground storey buildings vulnerable in earthquakes?
Tip 23: Why are buildings with shear walls preferred in seismic regions?

Resource Material

Arnold,C., and Reitherman,R., (1982), *Building Configuration and Seismic Design*, John Wiley, USA
Ambrose,J., and Vergun,D., (1999), *Design for Earthquakes*, John Wiley & Sons, Inc., USA

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