Why are Buildings with Shear Walls preferred in Seismic Regions?

What is a Shear Wall Building

Reinforced concrete (RC) buildings often have *vertical plate-like* RC walls called *Shear Walls* (Figure 1) in addition to slabs, beams and columns. These walls generally start at foundation level and are continuous throughout the building height. Their thickness can be as low as 150mm, or as high as 400mm in high rise buildings. Shear walls are usually provided along *both* length and width of buildings (Figure 1). Shear walls are like *vertically-oriented* wide *beams* that carry earthquake loads downwards to the foundation.

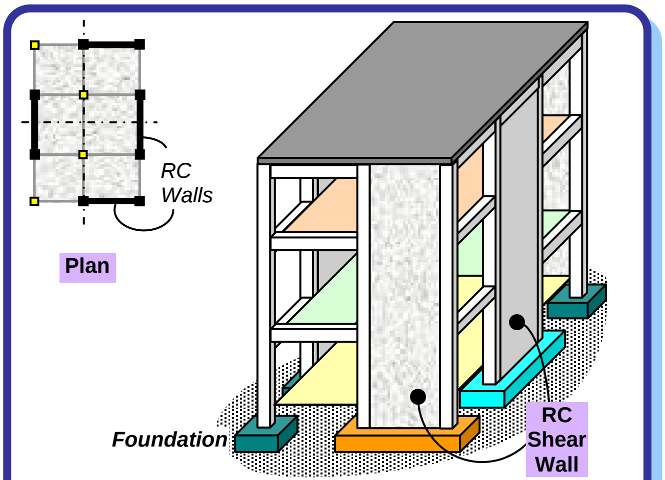

Figure 1: Reinforced concrete shear walls in buildings – *an excellent structural system for earthquake resistance.*

Advantages of Shear Walls in RC Buildings

Properly designed and detailed buildings with shear walls have shown *very good* performance in past earthquakes. The overwhelming success of buildings with shear walls in resisting strong earthquakes is summarised in the quote:

> *"We cannot afford to build concrete buildings meant to resist severe earthquakes without shear walls."*
> :: Mark Fintel, a noted consulting engineer in USA

Shear walls in high seismic regions require special detailing. However, in past earthquakes, even buildings with sufficient amount of walls that were not specially detailed for seismic performance (but had enough well-distributed reinforcement) were saved from collapse. Shear wall buildings are a popular choice in many earthquake prone countries, like Chile, New Zealand and USA. Shear walls are easy to construct, because reinforcement detailing of walls is relatively straight-forward and therefore easily implemented at site. Shear walls are efficient, both in terms of construction cost and effectiveness in minimizing earthquake damage in structural and non-structural elements (like glass windows and building contents).

Architectural Aspects of Shear Walls

Most RC buildings with shear walls also have columns; these columns primarily carry *gravity* loads (*i.e.,* those due to self-weight and contents of building). Shear walls provide large strength and stiffness to buildings in the direction of their orientation, which significantly reduces lateral sway of the building and thereby reduces damage to structure and its contents. Since shear walls carry *large* horizontal earthquake forces, the overturning effects on them are large. Thus, design of their foundations requires special attention. Shear walls should be provided along preferably *both* length and width. However, if they are provided along only one direction, a proper grid of beams and columns in the vertical plane (called a *moment-resistant frame*) must be provided along the other direction to resist strong earthquake effects.

Door or window openings can be provided in shear walls, but their size must be small to ensure least interruption to force flow through walls. Moreover, openings should be symmetrically located. Special design checks are required to ensure that the net cross-sectional area of a wall at an opening is sufficient to carry the horizontal earthquake force.

Shear walls in buildings must be symmetrically located in plan to reduce ill-effects of twist in buildings (Figure 2). They could be placed symmetrically along one or both directions in plan. Shear walls are more effective when located along exterior perimeter of the building – such a layout increases resistance of the building to twisting.

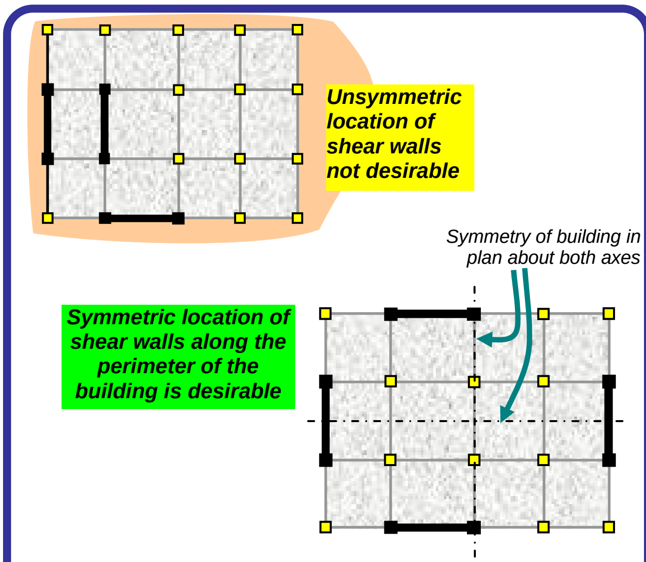

Figure 2: Shear walls must be symmetric in plan layout – *twist in buildings can be avoided*.

Ductile Design of Shear Walls

Just like reinforced concrete (RC) beams and columns, RC shear walls also perform much better if designed to be ductile. Overall geometric proportions of the wall, types and amount of reinforcement, and connection with remaining elements in the building help in improving the ductility of walls. The Indian Standard *Ductile Detailing Code* for RC members (IS:13920-1993) provides special design guidelines for ductile detailing of shear walls.

Overall Geometry of Walls: Shear walls are oblong in cross-section, *i.e.*, one dimension of the cross-section is much larger than the other. While rectangular cross-section is common, L- and U-shaped sections are also used (Figure 3). Thin-walled hollow RC shafts around the elevator core of buildings also act as shear walls, and should be taken advantage of to resist earthquake forces.

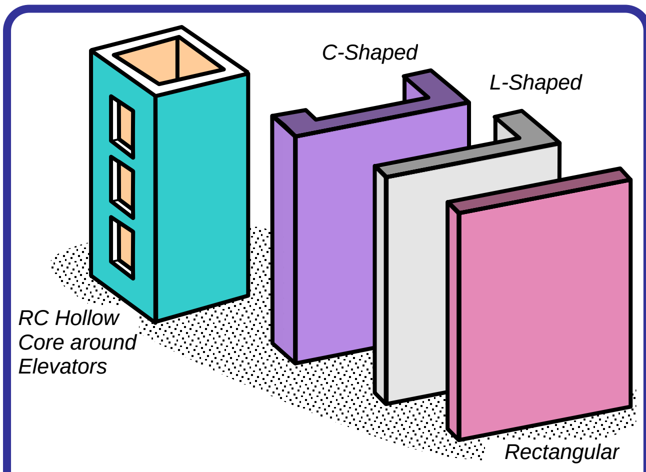

Figure 3: Shear walls in RC Buildings – *different geometries are possible*.

Reinforcement Bars in RC Walls: Steel reinforcing bars are to be provided in walls in regularly spaced *vertical* and *horizontal* grids (Figure 4a). The vertical and horizontal reinforcement in the wall can be placed in one or two parallel layers called *curtains*. Horizontal reinforcement needs to be anchored at the ends of walls. The minimum area of reinforcing steel to be provided is *0.0025* times the cross-sectional area, along *each* of the horizontal and vertical directions. This vertical reinforcement should be distributed uniformly across the wall cross-section.

Boundary Elements: Under the large overturning effects caused by horizontal earthquake forces, edges of shear walls experience high compressive and tensile stresses. To ensure that shear walls behave in a ductile way, concrete in the wall end regions must be reinforced in a special manner to sustain these load reversals without loosing strength (Figure 4b). End regions of a wall with increased confinement are called *boundary elements*. This special confining transverse reinforcement in boundary elements is similar to that provided in columns of RC frames (See *IITK-BMTPC Earthquake Tip 19*). Sometimes, the thickness of the shear wall in these boundary elements is also increased. RC walls *with boundary elements* have substantially higher bending strength and horizontal shear force carrying capacity, and are therefore less susceptible to earthquake damage than walls *without boundary elements*.

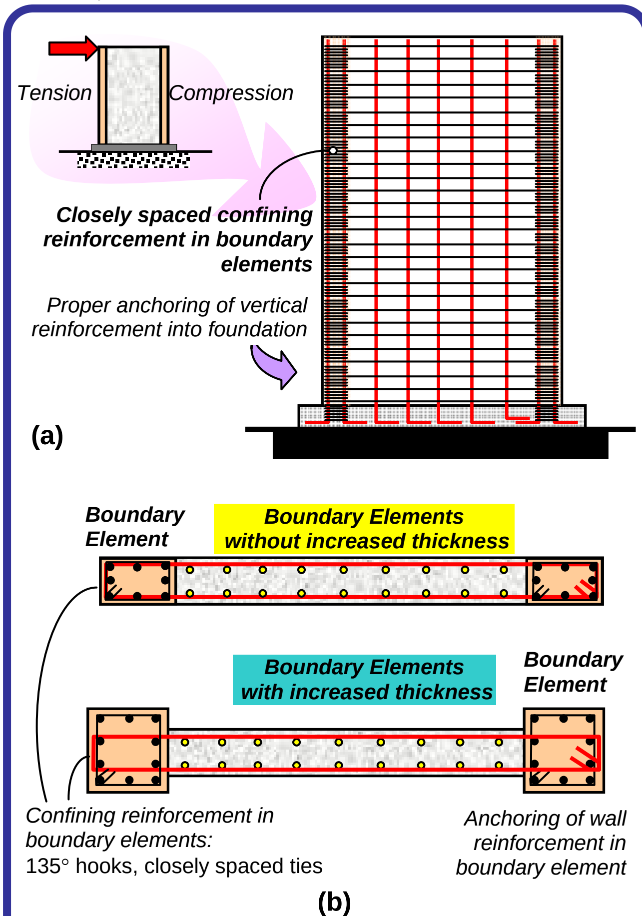

Figure 4: Layout of main reinforcement in shear walls as per IS:13920-1993 – *detailing is the key to good seismic performance*.

Related IITK - BMTPC Earthquake Tip

Tip 6: How Architectural Features Affect Buildings During Earthquakes?

Tip 19: How do Columns in RC Buildings Resist Earthquakes?

Reading 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

Paulay,T., and Priestley,M.J.N., (1992), "*Seismic Design of Reinforced Concrete and Masonry Buildings*," John Wiley & Sons, USA

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