DESIGN OF SHEAR WALLS AND DEEP BEAMS

SHEAR WALL

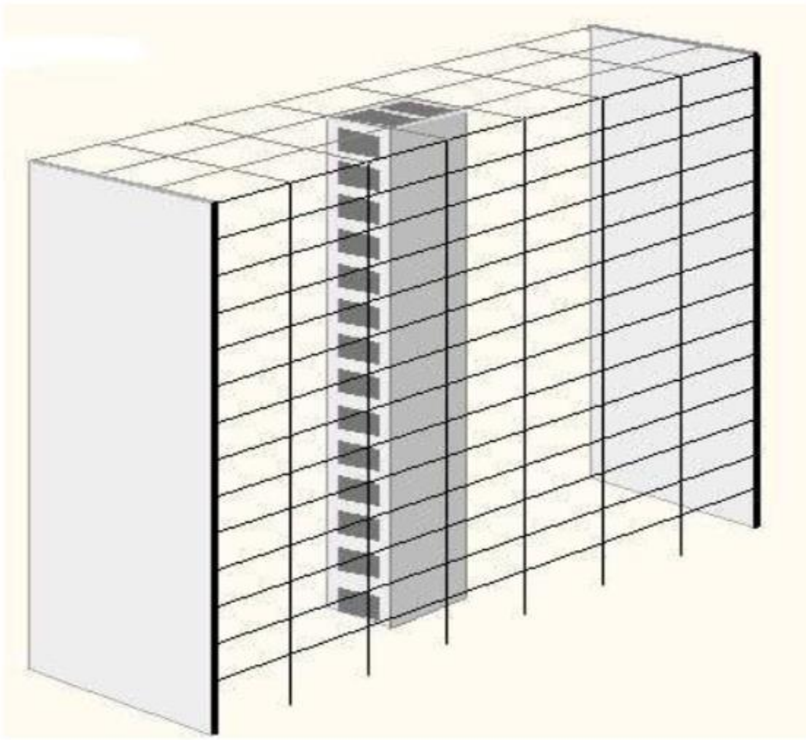
In reinforced concrete framed structures the effects of wind forces increase in significance as the structure increases in height. Codes of practice impose limits on horizontal movement or sway.Limits must be imposed on lateral deflection to prevent:

- Limitations on the use of building,
- Adverse effects on the behavior of non-load bearing elements,
- Degradation in the appearance of the building,
- Discomfort for the occupants.

Generally, the relative lateral deflection in any one storey should not exceed the **storey height divided by 500.** The figure below shows the deflected profiles for a shear wall and a rigid frame.

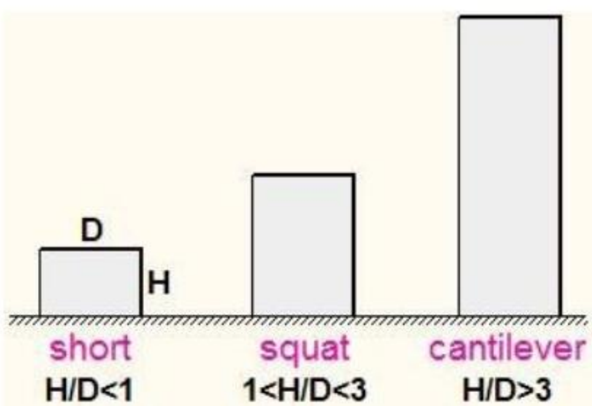
One way to limit the sway of buildings and provide stability is to increase the section sizes of the members to create a rigid, moment-resisting frame. However, this method increases storey heights, thus increasing the building cost. It is rarely used for more than 7 or 8 storeys.

Another way is to provide stiff, shear resisting walls liked to a flexible frame. These can be external walls or internal walls around lift shafts and stair wells (a core) or sometimes both are provided.

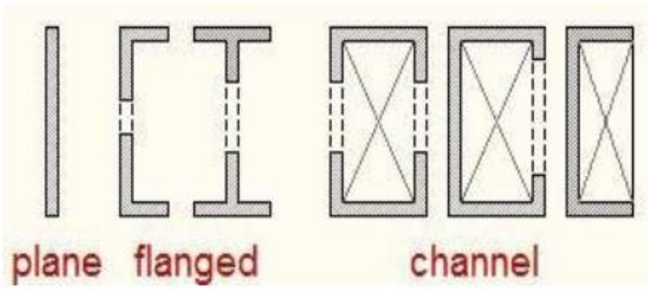


STRUCTURAL FORMS OF SHEAR WALLS

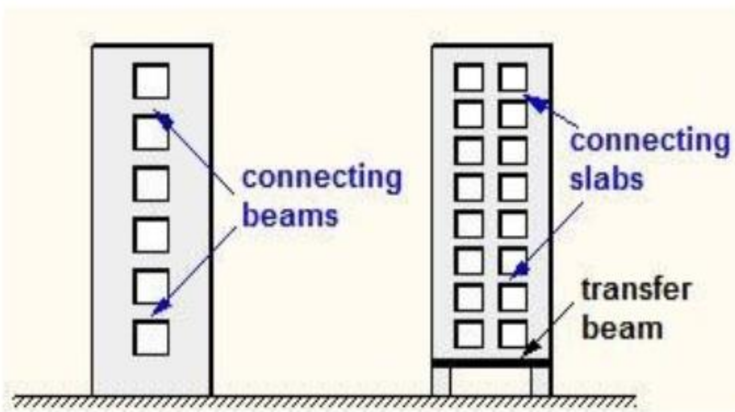
Monolithic shear walls are classified as short, squat or cantilever according to their height to depth ratio.



Generally shear walls are either plane or flanged in section, while core walls consist of channel sections.



In many cases, the wall is pierced by openings. These are called coupled shear walls because they behave as individual continuous wall sections coupled by the connecting beams or slabs.



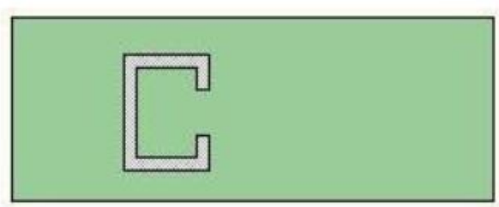
Normally the walls are connected directly to the foundations. However, in a few cases where the lateral loads are relatively small and there no appreciable dynamic effects, then they can be supported on columns connected by a transfer beam to provide clear space.

POSITIONING OF SHEAR WALLS

The shape and plan position of the shear wall influences the behavior of the structure considerably. Structurally, the best position for the shear walls is in the centre of each half of the building. This is rarely practical, however, since it dictates the utilization of the space, so they are positioned at the ends.

This shape and position of the walls give good flexural stiffness in the short direction, but relies on the stiffness of the frame in the other direction.

This arrangement provides good flexural stiffness in both directions, but may cause problems from restraint or shrinkage. As does this arrangement with a single core, but which does not have the problem from restraint of shrinkage.



However, this arrangement lacks the good torsional stiffness of the previous arrangements due to the eccentricity of the core.

If the core remains in this position then it must be designed explicitly for the torsion. It is far preferable to adopt a symmetrical arrangement to avoid this.

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. 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 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.

Reinforcement Bars in RC Walls

Steel reinforcing bars are to be provided in walls in regularly spaced vertical and horizontal grids .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. 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. 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.

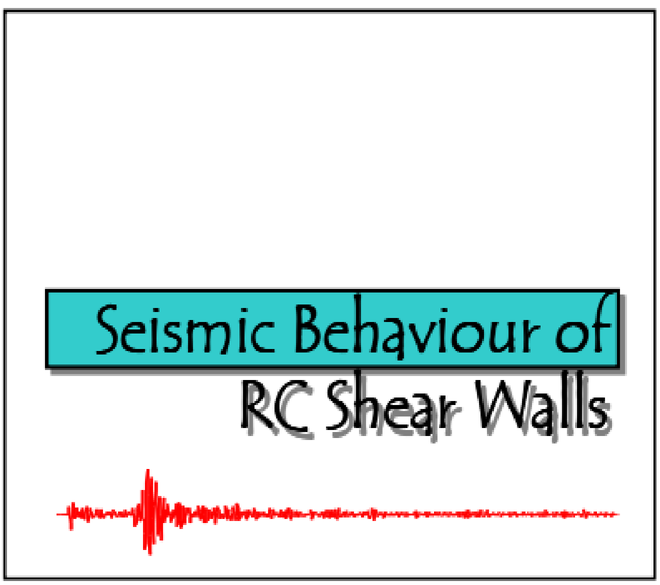
DEEP BEAMS

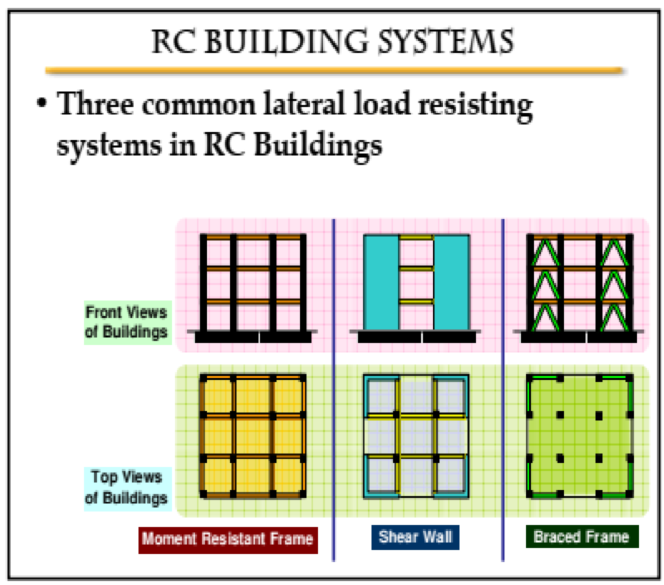
INTRODUCTION

The traditional principles of stress analysis are neither suitable nor adequate to determine the strength of reinforced concrete deep beams. In deep beams, the bending stress distribution across any transverse section deviates appreciably from straight line distribution assumed in the elementary beam theory.

BEHAVIOUR OF DEEP BEAMS

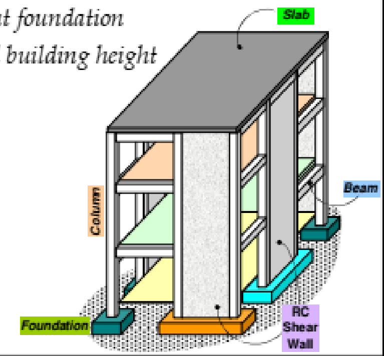
The behaviour of a deep beam depends also on how they are loaded & special considerations should be given to this aspect in design. Here cracking will occur at one-third to one-half of the ultimate load.In the single span beam supporting a concentrated load at mid span, the compressive stresses act roughly parallel to the lines joining the load and the supports and the tensile stresses act parallel to the bottom of the beam. The flexural stresses at the bottom is constant over much of the span. The figure shows the crack pattern and the truss analogy of the same.





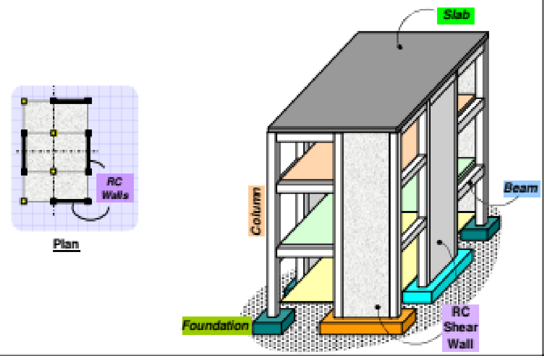
SHEAR WALL

- **What is a Shear Wall?**
  - *Vertical plate-like RC Walls*
  - *Generally starts at foundation*
  - *Goes through full building height*



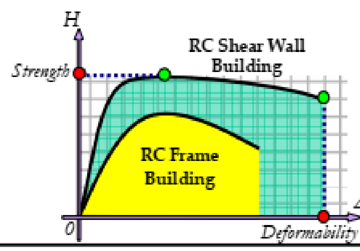
SHEAR WALLS...

- **RC Shear Wall Building**
  - *Shear Walls also called* **Structural Walls**



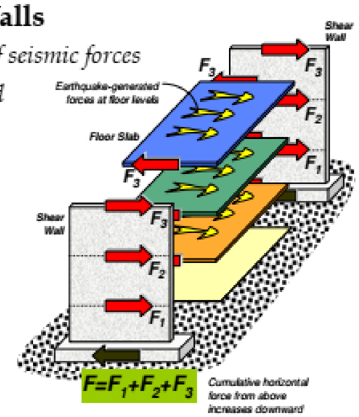
SHEAR WALLS...

- **Principal attributes**
  - *Large Strength*
  - *High Stiffness*
  - *Ductility*
    - **Shear wall can be detailed to have large ductility**



SHEAR WALLS...

- **Role of Shear Walls**
  - *Smooth transfer of seismic forces*
  - *Vertically oriented wide beams*



SHEAR WALLS...

- **Advantages of Shear Walls**
  - *Very good earthquake performance, if properly designed*
  - *In past earthquakes*
    - **Large number of RC frame buildings damaged or collapsed**
    - **Shear wall buildings performed very well**

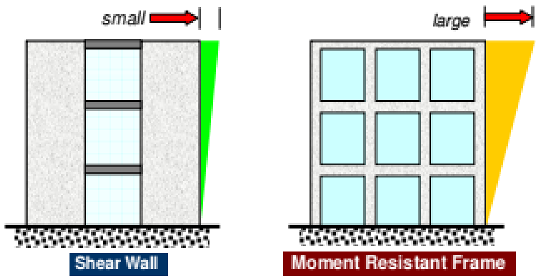
> **"We cannot afford to build concrete buildings meant to resist severe earthquakes without shear walls"**
> *:: Mark Fintel, a noted earthquake engineer in USA*

SHEAR WALLS...

- **Advantages of Shear Walls...**
  - *Easy to construct*
    - **Straight-forward reinforcement detailing**
      - ❑ *Easily implemented at site*
  - *Effective in*
    - **Reducing construction cost**
    - **Minimising earthquake damage to**
      - ❑ *Structural elements*
      - ❑ *Non-Structural elements*
        - ✓ *E.g.,* Glass Windows, Building Contents

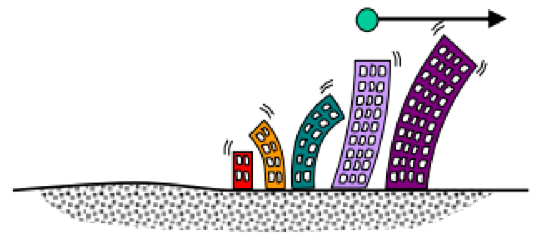
SHEAR WALLS...

- **Advantages of Shear Walls...**
  - *Lesser lateral displacement than frames*
  - *Lesser Damage to structural and non-structural elements*



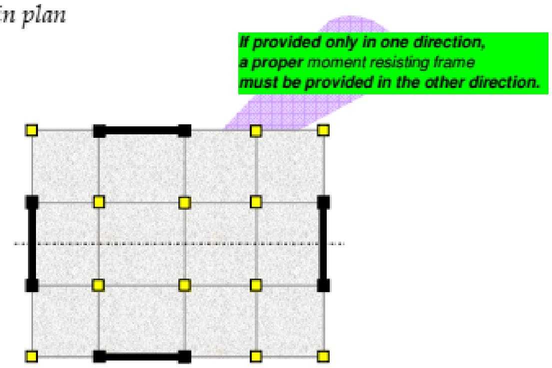
SHEAR WALLS...

- **Current Use of Shear Walls**
  - *Popular choice in many earthquake prone countries*
    - Chile, Canada, USA and New Zealand
  - *In general, used in medium and high rise buildings*
    - 10 storeys and higher



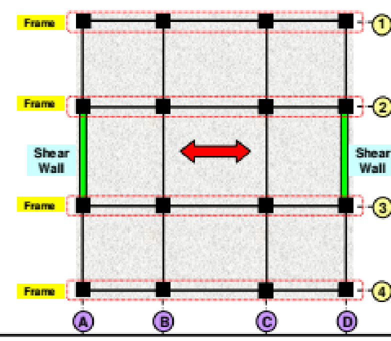
ARCHITECTURAL ASPECTS

- **Walls must be preferably in both directions**
  - *in plan*



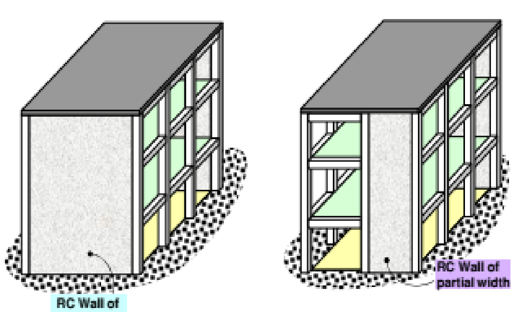
ARCHITECTURAL ASPECTS...

- **If provided only in one direction, a proper moment resisting frame must be provided in the other direction.**



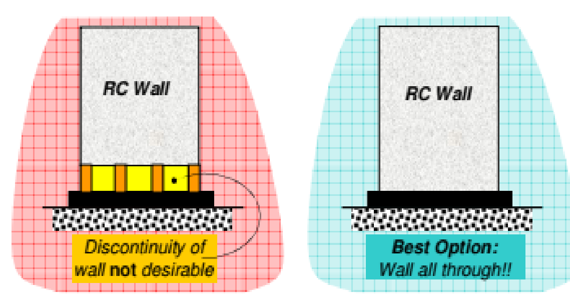
ARCHITECTURAL ASPECTS...

- **Shear wall can extend over the full width of building, or even over partial width**



ARCHITECTURAL ASPECTS...

- **Walls should be throughout the height**
  - *Cannot be interrupted in lower levels*



ARCHITECTURAL ASPECTS…

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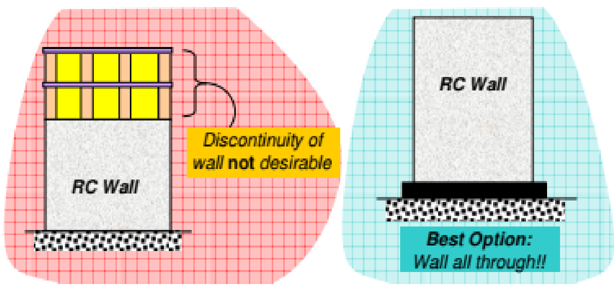
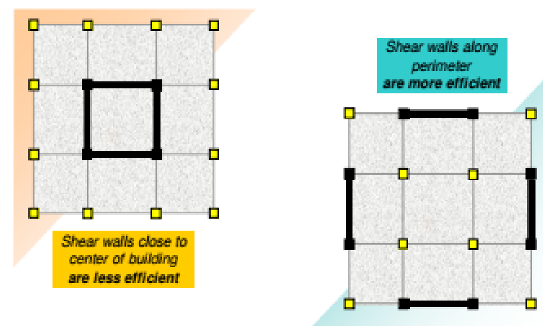


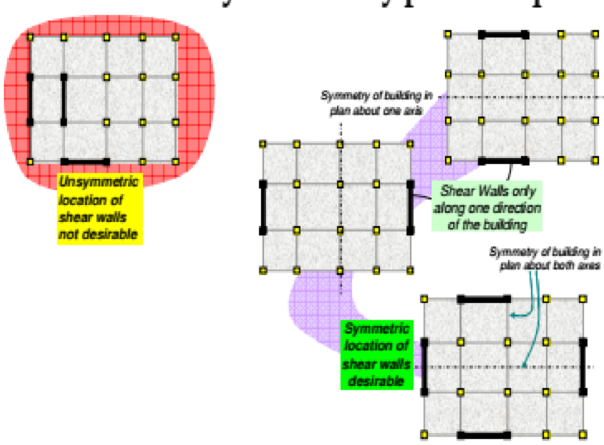
ARCHITECTURAL ASPECTS…

- **Walls should be along perimeter of building**
  - *Improves resistance to twist*



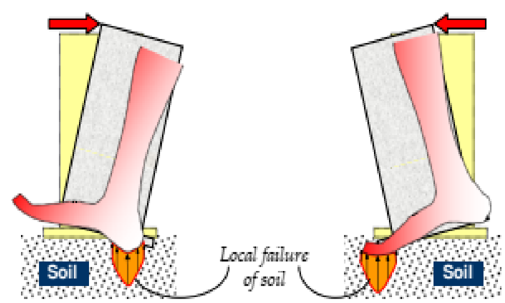
ARCHITECTURAL ASPECTS…

- **Walls must be symmetrically placed in plan**



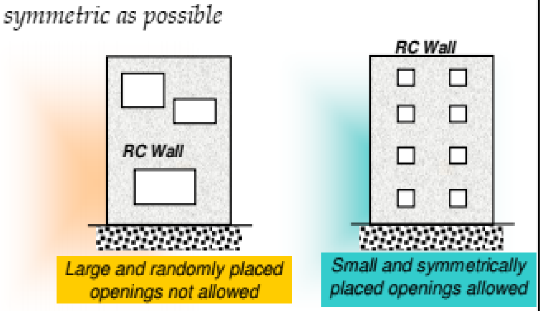
ARCHITECTURAL ASPECTS…

- **Shear wall building should not be narrow**
  - *Earthquakes cause significant overturning effects*
  - *Special care is required in design of their foundations*



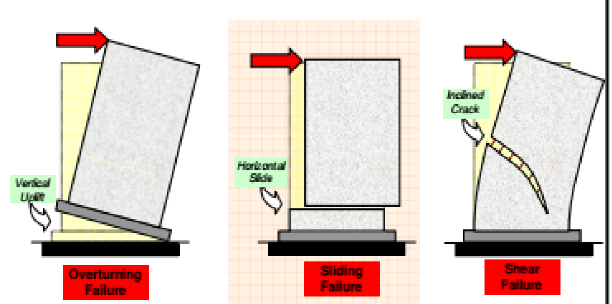
ARCHITECTURAL ASPECTS…

- **Openings in walls must be**
  - *As few as possible*
  - *As small as possible*
  - *As symmetric as possible*



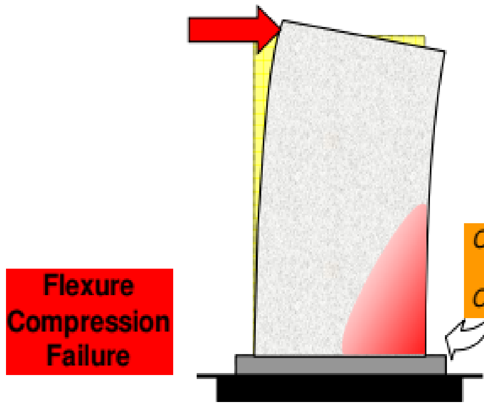
SEISMIC BEHAVIOUR

- **Undesirable Modes of Failure**



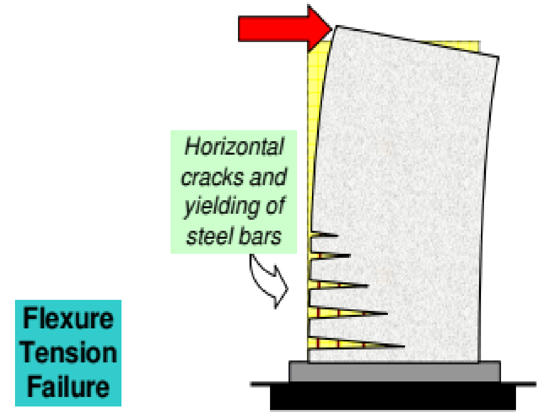
SEISMIC BEHAVIOUR…

- Undesirable Mode of Failure



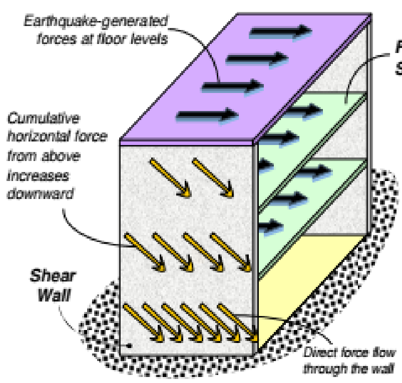
SEISMIC BEHAVIOUR…

- Desirable Mode of Failure



SEISMIC BEHAVIOUR…

- Shear demand is more in lower storeys



SEISMIC BEHAVIOUR…

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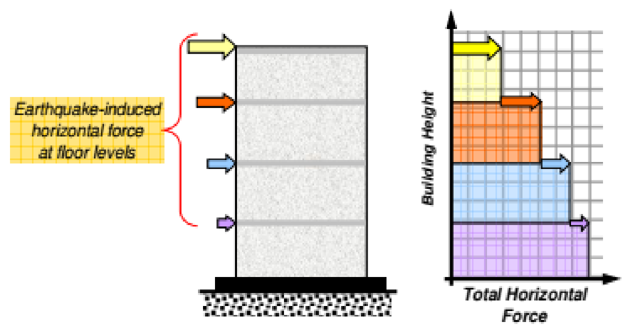
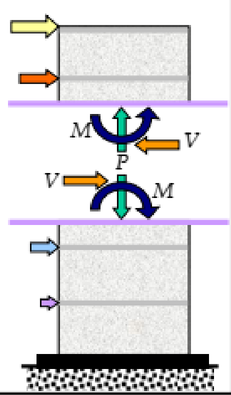


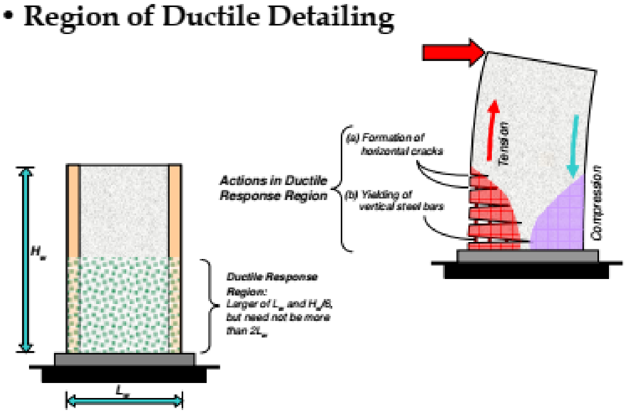
SEISMIC BEHAVIOUR…

- At each section along the height, shear wall carries
  - Axial Force P
  - Shear Force V
  - Bending Moment M



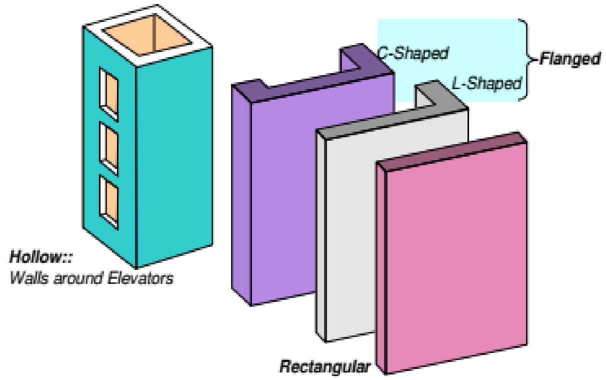
SEISMIC DESIGN OF RC WALLS…

- Region of Ductile Detailing



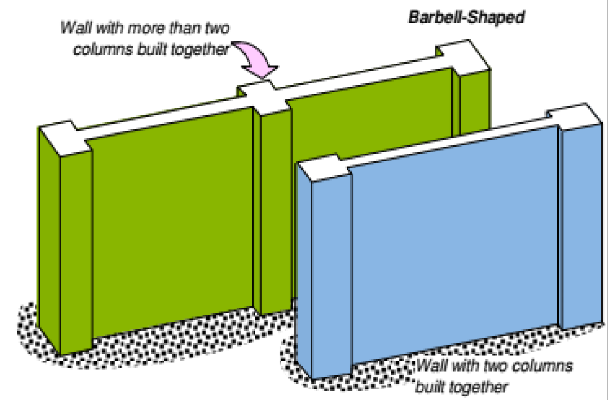
SEISMIC DESIGN OF RC WALLS…

• Possible Geometry of Walls



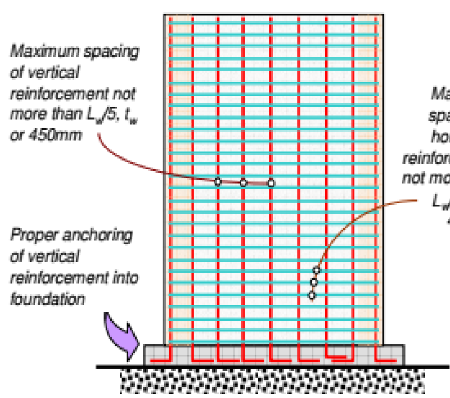
SEISMIC DESIGN OF RC WALLS…

• Possible Geometry of Walls…



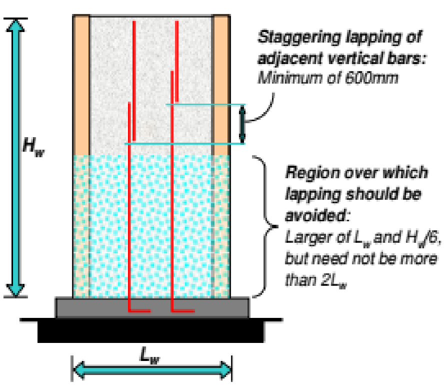
SEISMIC DESIGN OF RC WALLS…

• Primary Reinforcement in Walls



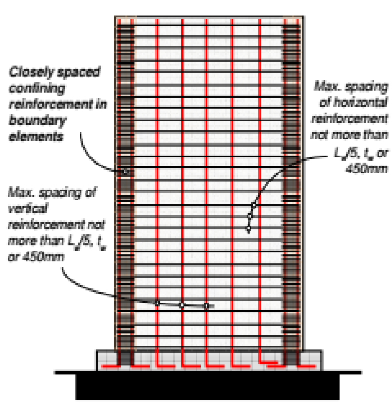
SEISMIC DESIGN OF RC WALLS…

• Lapping of Vertical Reinforcement Bars



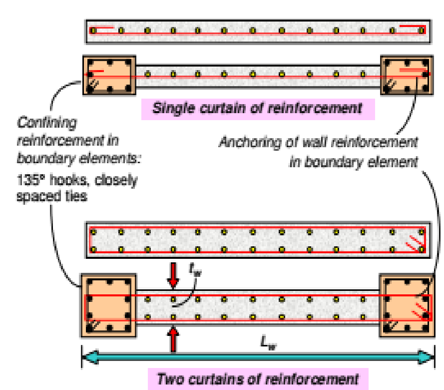
SEISMIC DESIGN OF RC WALLS…

• Detailing of Vertical and Horizontal Bars



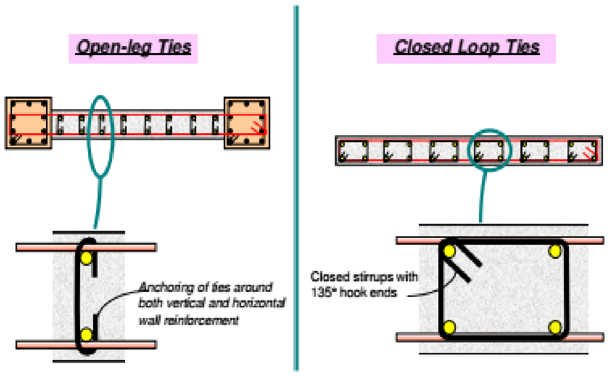
SEISMIC DESIGN OF RC WALLS…

• Confining Steel in Boundary Elements



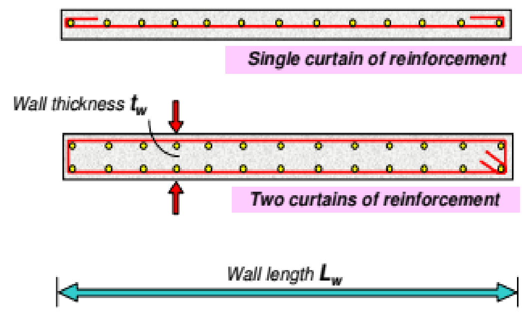
SEISMIC DESIGN OF RC WALLS…

- **Confining Wall Concrete**



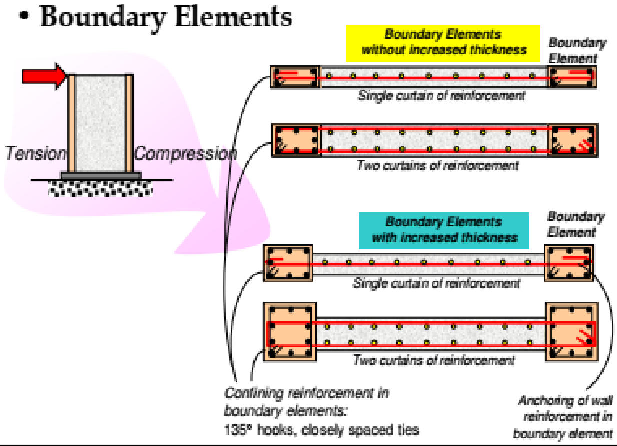
SEISMIC DESIGN OF RC WALLS…

- **Curtains of Reinforcement**
  - *One*
  - *Two*



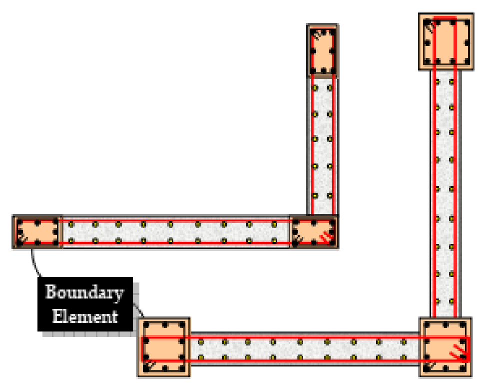
SEISMIC DESIGN OF RC WALLS…

- **Boundary Elements**



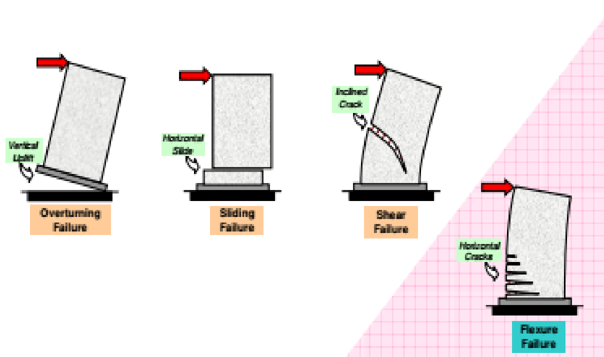
SEISMIC DESIGN OF RC WALLS…

- **Boundary Elements…**



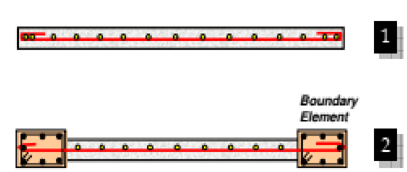
SEISMIC DESIGN OF RC WALLS…

- **Seismic behaviour is controllable through design**



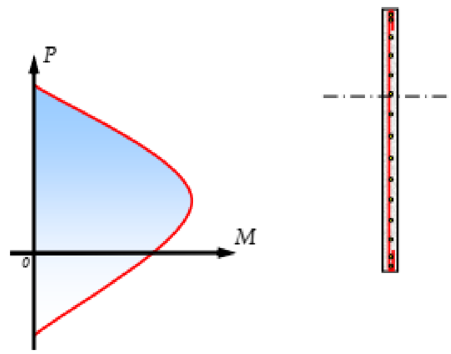
SLENDER AND SQUAT WALLS…

- **Influence of Boundary Elements on Strength**
  - *For same amount of concrete and steel*
    - Strength of Section 2 > Strength of Section 1



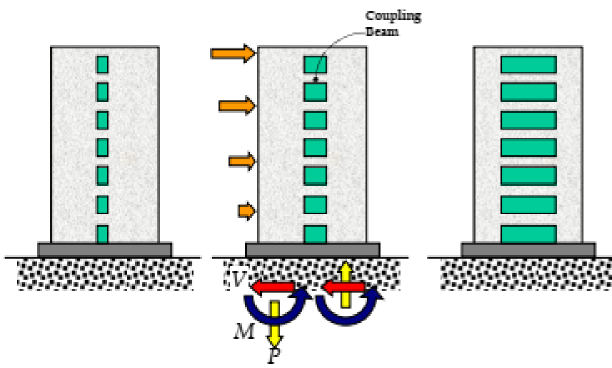
SLENDER AND SQUAT WALLS…

- **Effect of Axial Load on flexural strength**
  - *Just as in columns*



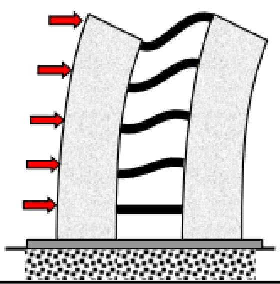
COUPLED SHEAR WALLS

- **Size of opening**



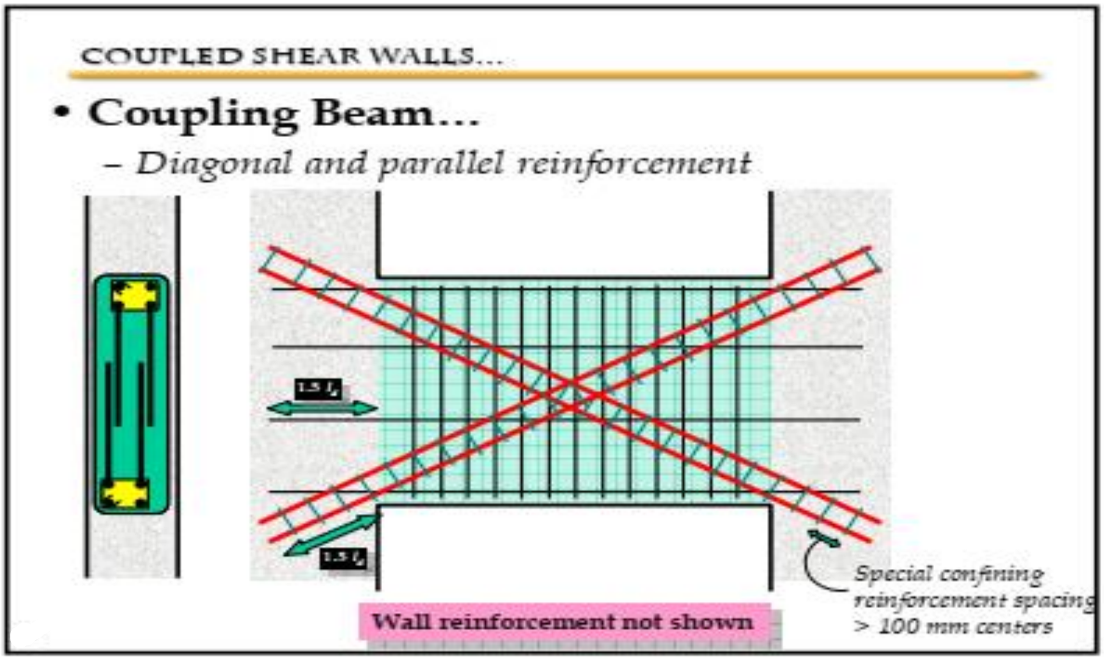
COUPLED SHEAR WALLS…

- **Coupling Beam**
  - *Span-to-depth ratio is small*
    - **Shear deformations are significant**
  - *Ends have large rotational and vertical displacement*
    - **Require very high ductility**



COUPLED SHEAR WALLS…

- **Coupling Beam…**
  - *Shear failure should not precede flexural yielding*
  - *Diagonal reinforcement more effective*
  - *Provide confinement throughout the beam*
  - *Good anchorage of main bars into walls on either side*


COUPLED SHEAR WALLS…
• Coupling Beam…
– Diagonal and parallel reinforcement
Wall reinforcement not shown
Special confining reinforcement spacing
> 100 mm centers