# CAUSES OF STRUCTURAL DAMAGE DUE TO EARTHQUAKES

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# In-Class Activities

- P/A Quiz
- Design philosophy for seismic resistant design
- Needs for strength, ductility and stiffness
- Causes of damage
- Concept quiz

# P/A Quiz

**Which one of the followings makes sense?**

a) The magnitude of earthquakes can be precisely predicted

b) The return period of a certain magnitude earthquake can be precisely predicted

c) The locality of the future earthquakes can precisely be predicted

d) None of the above

# P/A Quiz

**What is earthquake resistant design?**

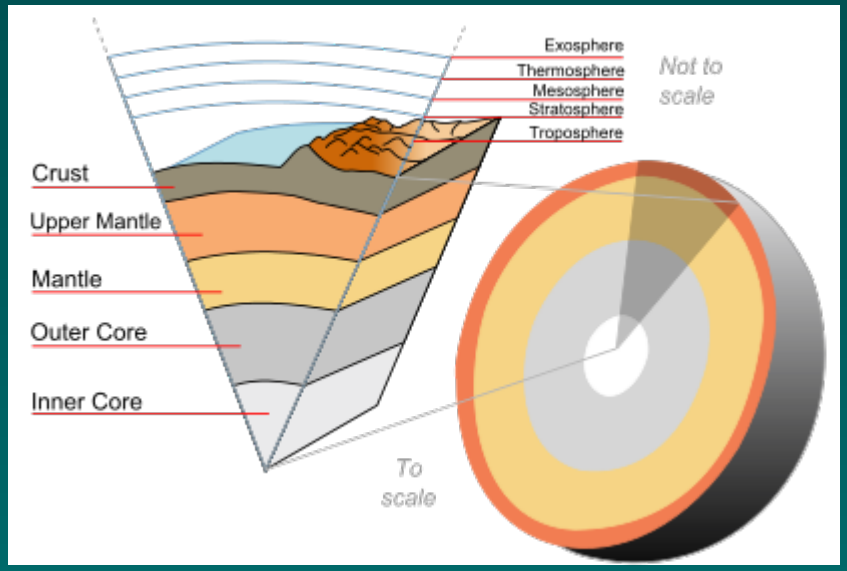
a) No damage in any earthquake

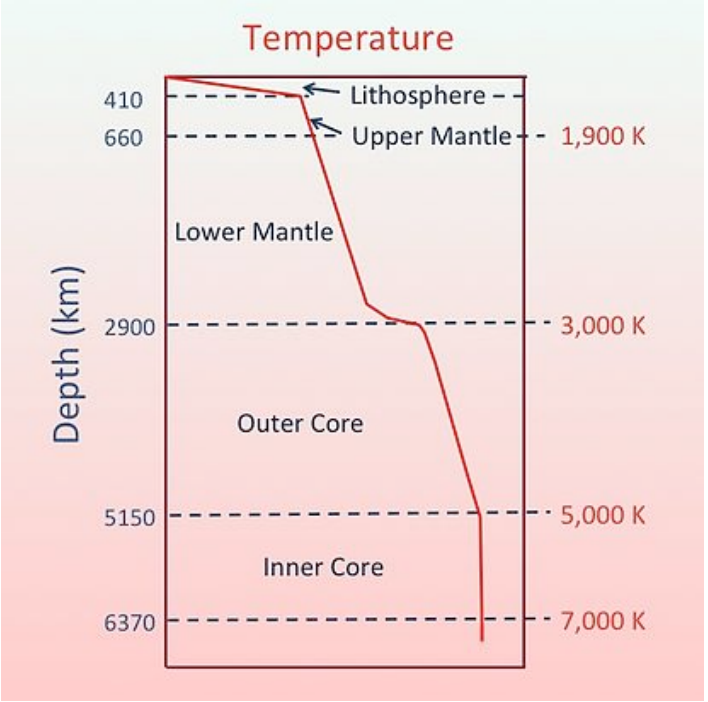
b) No damage in strong earthquakes

c) No damage and no collapse in strong earthquakes

d) Considerable damage, no collapse in strong earthquakes

# EARTHQUAKES



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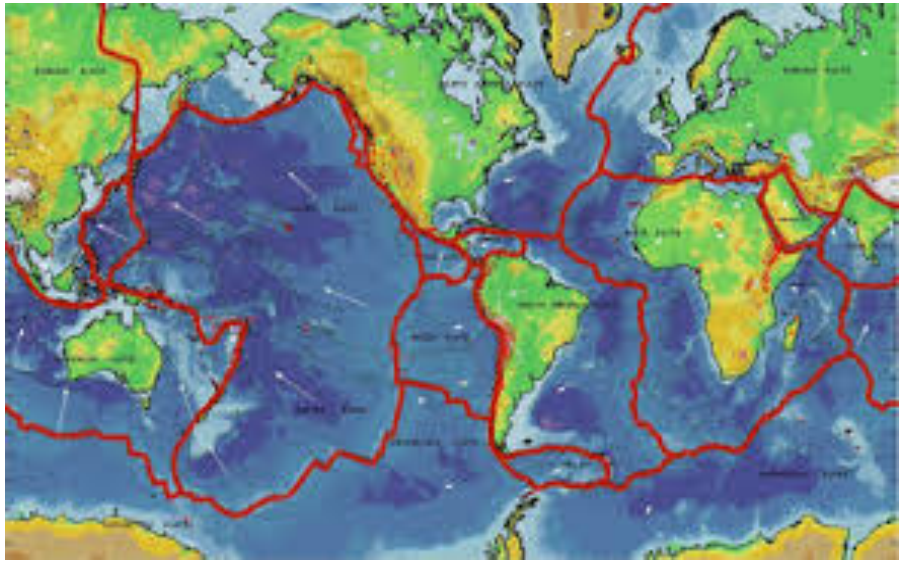

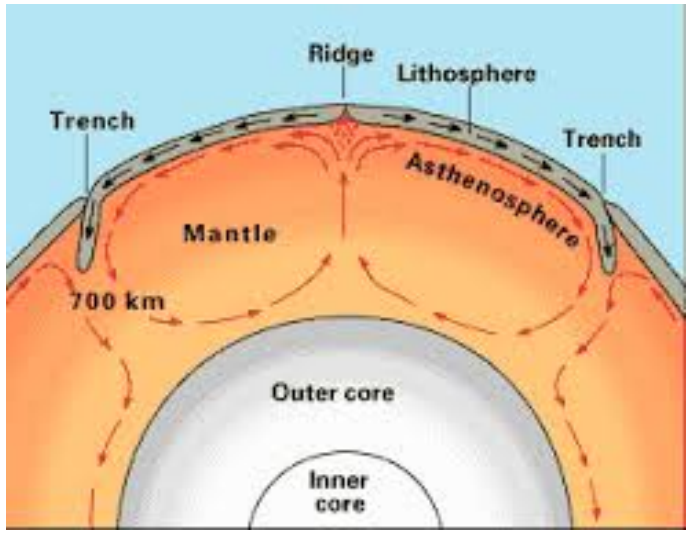

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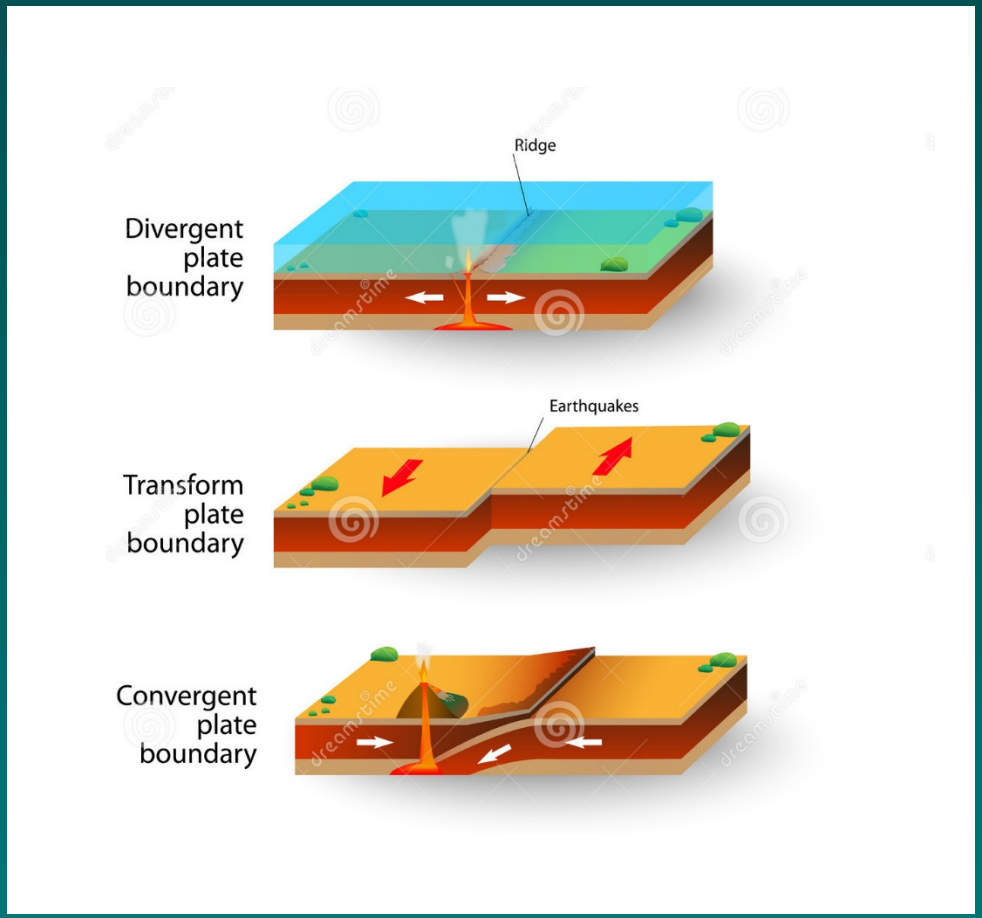

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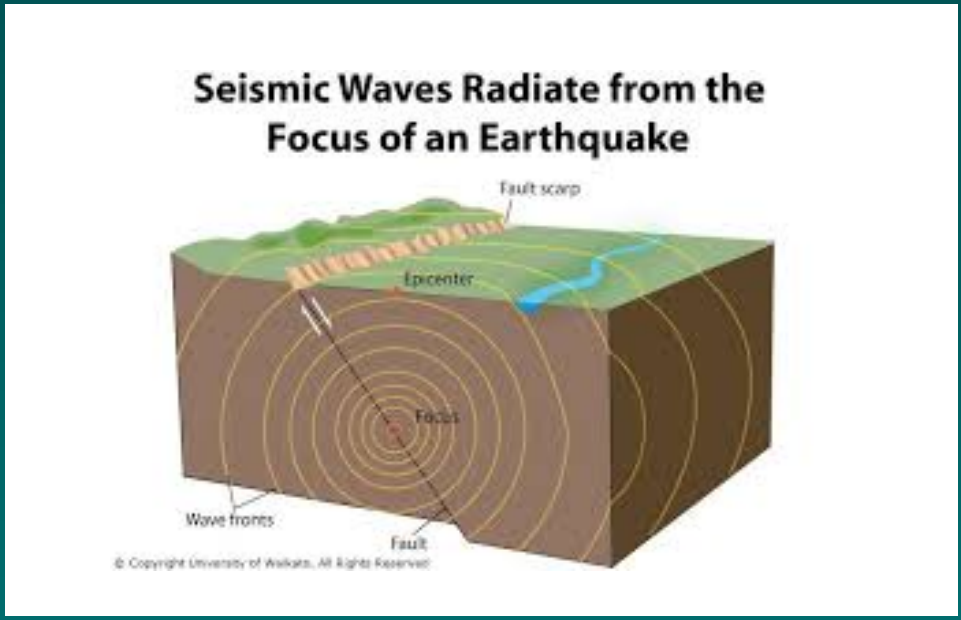
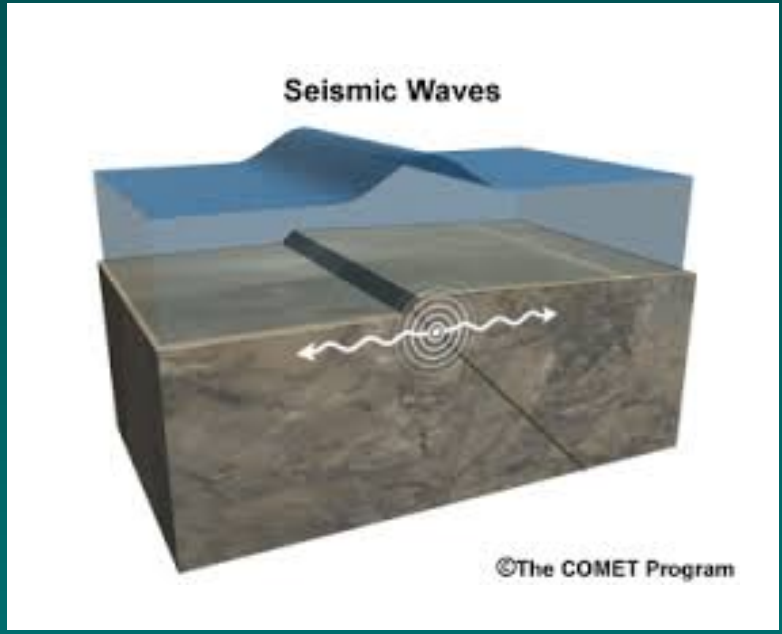


# DESIGN PHILOSOPHY FOR SEISMIC RESISTANT BUILDINGS

- **In case of minor earthquakes:**
  **No damage or distress to occur in load-bearing or non-load-bearing structural elements**

- **In case of moderate earthquakes:**
  **Only repairable damage may occur in load-bearing or non-load-bearing structural elements.**

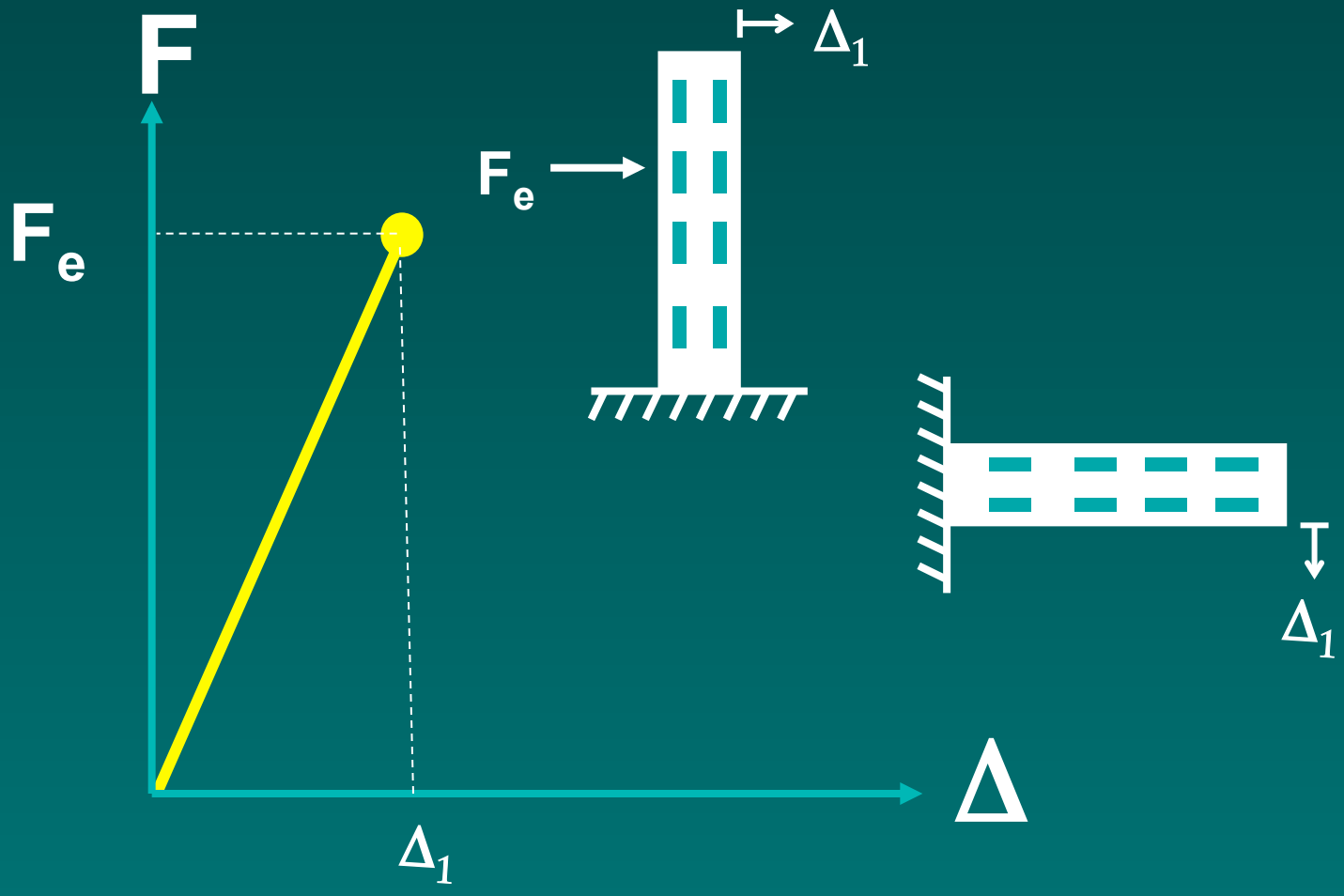
- **In case of a severe earthquake:**
  **The building may become unusable, but collapse has to be prevented.**

# SEISMIC SAFETY IN REINFORCED CONCRETE BUILDINGS

- **Adequate strength**
- **Adequate ductility**
- **Adequate stiffness**

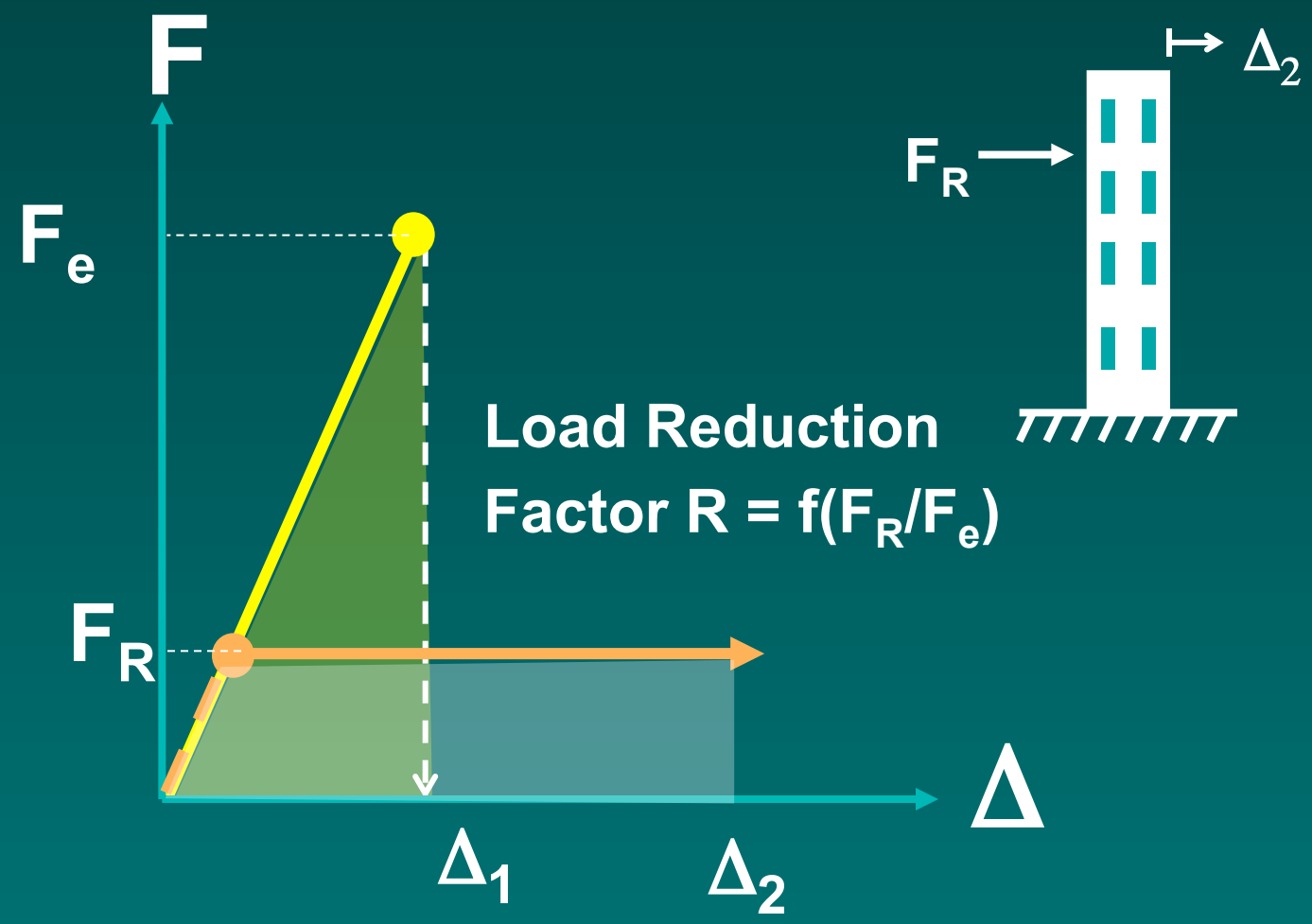
***It is the function of earthquake codes to ensure that the above principles are applied and satisfied.***

# STRENGTH and DUCTILITY



# STRENGTH and DUCTILITY

Lower strength results in smaller force on structure. The structure can survive the earth excitation if it possesses ductility.



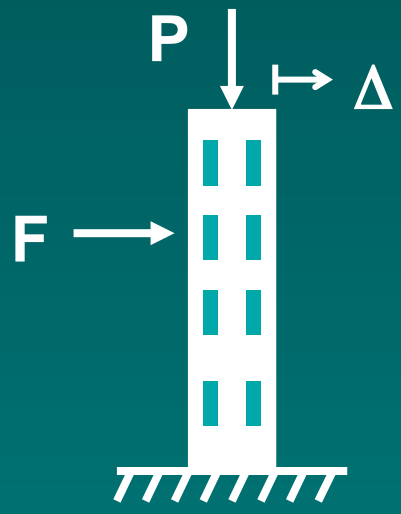
# REASONS FOR STIFFNESS REQUIREMENT

- To reduce second-order moments as much as possible.

As stiffness ↑

Δ ↓

P-Δ ↓



# REASONS FOR STIFFNESS REQUIREMENT

**To minimize non-structural damage.**

# TYPES OF DAMAGE

- Damage due to soil conditions
- Damage resulting from errors made during design and the construction processes.

# DAMAGE DUE TO SOIL CONDITIONS

- Liquefaction
- Rupture or fissure
- Excessive soil deformation

# DAMAGE FROM ERRORS DURING DESIGN & CONSTRUCTION

- **Architectural mistakes and/or mistakes in the selection of structural load-bearing system**
- **Design and detailing mistakes resulting from bad engineering practice.**
- **Construction mistakes**

**These mistakes are known to comprise the largest cause of damage and failure when the structure is subjected to earthquake load !!**

# SYSTEM ERRORS

- Asymmetry in plan and elevation
- Insufficient lateral stiffness
- Over the structure height
  - Sudden changes in strength leading to week storeys
  - Sudden changes in stiffness leading to soft storeys
  - Sudden change in floor plan area leading to set backs

Sudden changes in stiffness and strength over the height of a building result in the creation of a soft storey causing increase in interstory drift.

In these systems damage will occur in the weak floor columns, and if these columns do not possess adequate ductility, failure is inevitable

**Abrupt changes in member sections cause stress concentrations as well as loss of stiffness and strength in these regions.**

# SYSTEM ERRORS

- Discontinuity in frame elements
- Weak column/strong beam connection
- Formation of short columns
- Making buildings with large wing portions
- Houses in terraced rows (insufficient construction joint)

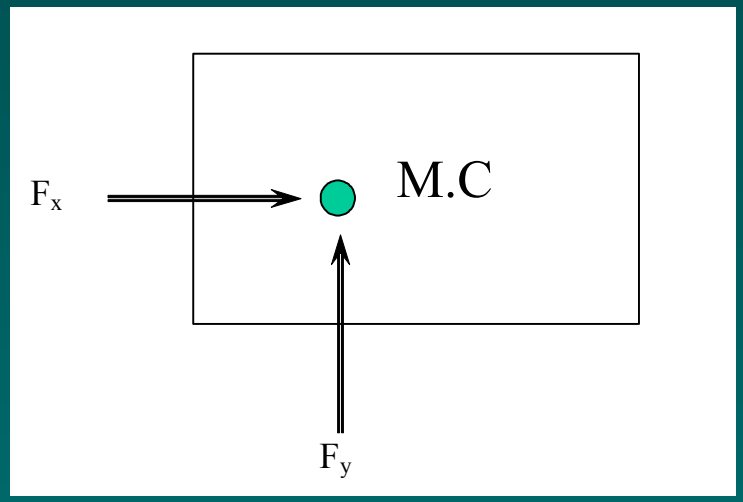
Leaving a row of windows within infill walls or shear walls results in short columns.

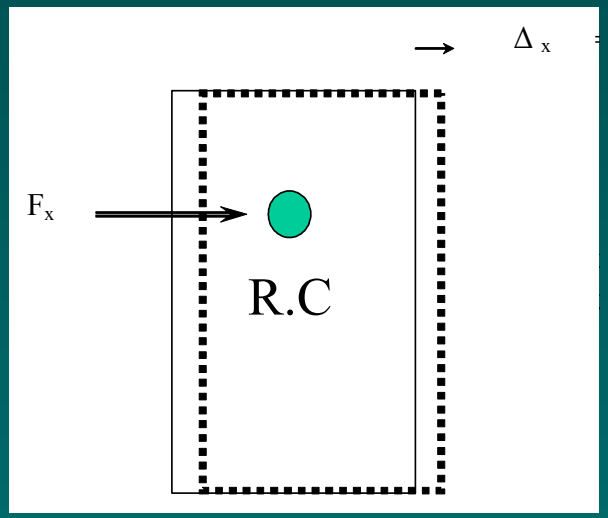
Because short columns are not taken into account in the structural design, the resulting high shear forces cause in shear failures of the columns.

Structural elements of adjacent buildings may undergo severe damage due to hammering effects

Local as well as total collapse may also result…

# UNSYMMETRIC DISTRIBUTION OF VERTICAL ELEMENTS



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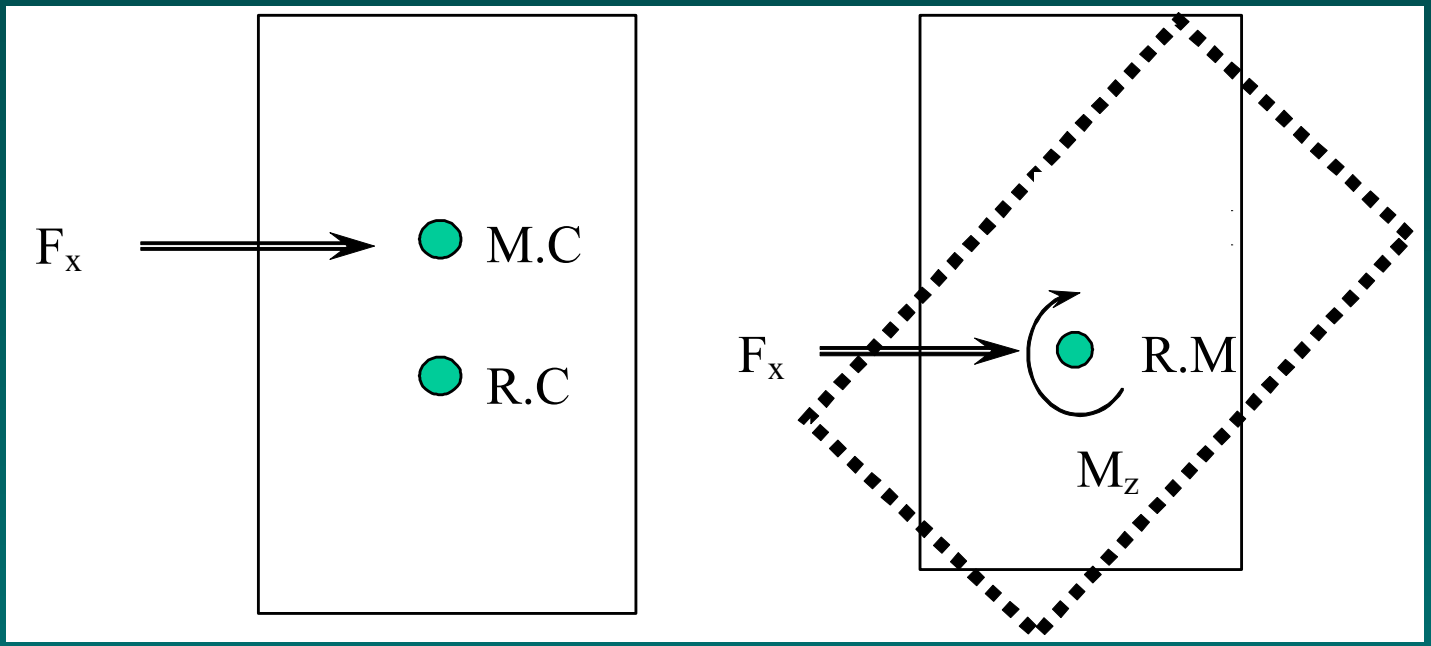

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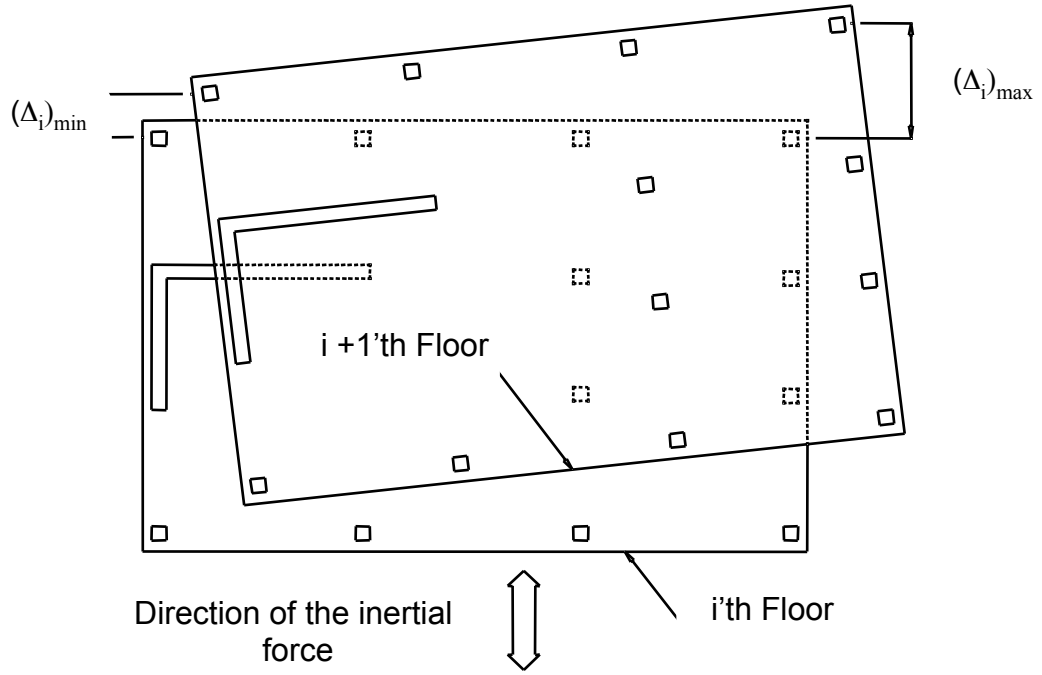


**This is known as floor torsion.**

**The earthquake causes large horizontal forces acting on buildings in both principal directions. Frames can carry these forces if and only if the building has sufficient ductility.**

# IMPORTANT REMINDER

- The buildings that satisfactorily perform during an earthquake dissipate sufficient energy.
- Energy absorption and dissipation depends on ductility, which itself is highly dependent on confinement.
- This ability can only be provided by PROPER DETAILING of R/C members. This is the prime responsibility of the engineers.

# DETAILING ERRORS

- **Detailing errors usually result from a lack of knowledge of structural behaviour**
  - **Bad & wrong engineering practice**

***Negligence of proper detailing of ties and/or confinement reinforcement in plastic hinge regions lead to heavy structural damage in the case of an earthquake!***

# CONSTRUCTION ERRORS

- Poor concrete quality
- Variations in the member dimensions from the design values
- Reinforcement not placed in accordance with project requirements
- At site alterations on the design drawings during construction

# SUGGESTIONS: CHOICE OF SYSTEM

- A regular and symmetric plan should be chosen;
- shear walls should be incorporated into the system to provide sufficient lateral stiffness;
- Sudden changes of stiffness and strength over the building height should be prevented;
- Hammering of neighbouring buildings should be prevented;
- Soft storys, short columns, weak column-strong beam connections should be avoided.

**When symmetrically placed in plan in both directions and continuous over the building height, shear walls contributed very positively to the seismic behaviour of the buildings shown after the 1999 earthquake.**

# SUGGESTIONS: DETAILING

- The dimensions of vertical load carrying members should be satisfactory
- Pay attention to the amount and design details of the reinforcing bars.

# SUGGESTIONS: DETAILING

- The ends of columns and beams should be properly confined
- At all joints (especially in corner columns) ties must definitely be provided.

# SUGGESTIONS: CONSTRUCTION

**Construction requires care, effective supervision and professional application.**

**IT MUST NOT BE FORGOTTEN THAT THE BUILDING WHICH WILL SUFFER THE EARTHQUAKE IS NOT THE ONE FOR WHICH THE CALCULATIONS AND DRAWINGS HAVE BEEN DONE ON PAPER BUT THE ONE THAT IS CONSTRUCTED AT THE SITE.**

# SUGGESTIONS: CONSTRUCTION

**Construction requires care, effective supervision and professional application.**

**IF REINFORCEMENT IS INADEQUATE AND WRONGLY PLACED AND THE CONCRETE QUALITY IS POOR, EVEN THE BEST DESIGN CANNOT SAVE THE STRUCTURE FROM DAMAGE OR COLLAPSE.**

# ALL in ALL

- Engineers and architects must know the reinforced concrete behavior in full details, understand the importance of EQ design codes and obey the code requirements.
- Construction must be supervised thoroughly.
- Legislative bodies must take all necessay actions and enforce all the laws designed for this purpose.

# LESSONS FROM THE PAST EQs

# Concept Quiz

**Earthquake resistant design is:**

a. Architects business
b. Engineers business
c. Constructors business
d. A political will
e. All of the above