LATERAL LOAD RESISTANT SYSTEM FOR SEISMIC DESIGN

Presented by:
Dr. Mohammadreza Vafaei
(P.Eng., M.ASCE, M.EERI, M.SSA)

Faculty of Civil Engineering, Forensic Engineering Center, Universiti Teknologi Malaysia, Johor Bahru
Lateral Load Resistant Systems

- **Moment-Resisting Frames (MRF)**

  Moment-resisting frames are assemblages of beams and columns, with the beams rigidly connected to the columns. Development of bending moment and shear force in the frame members and joints make them capable of resisting against lateral loads.

A Steel MRF

A Concrete MRF
Lateral Load Resistant Systems

- **Moment-Resisting Frames (MRF)**

**Distribution of Internal Moments under lateral Load in MRFs**

**Location of Zero Moments in MRFs**

Adopted from: A seismic Design Analysis of Buildings, by Kiyoshi Muto; Maruzen Company, Ltd., Tokyo, 1974
Lateral Load Resistant Systems

- **Moment-Resisting Frames (MRF)**

Distribution of Internal Shear Force in Columns under lateral Load

Axial Load in Columns due to lateral loads

Adopted from: A seismic Design Analysis of Buildings, by Kiyoshi Muto; Maruzen Company, Ltd., Tokyo, 1974
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- Moment-Resisting Frames (MRF)

MRF with infill masonry

3-Strut Model for infill walls

\[ w_s = 0.175d \left( \lambda_{\theta_2} \right)^{-0.4} \]

\[ \lambda_{\theta_2} = \left( \frac{(E_w t \sin 2\theta)}{(4E_c I_c h_w)} \right)^{0.25} \]
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• Moment-Resisting Frames (MRF)-Typical Damage Types

Infill wall damage in RC MRF

Strong Beam-Weak Column in RC MRF
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- Moment-Resisting Frames (MRF) - Typical Damage Types

Joint damage in RC MRF

Shear Failure in RC Column
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- Moment-Resisting Frames (MRF)-Typical Damage Types

Failure of Beam-to-Column Connection

Failure of Fishplate
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- **Bracing Systems**

  A **Braced Frame** is a structural system which is composed of members that are designed to work in tension and compression, similar to a truss. Braced frames are almost always composed of steel members.
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- **Bracing Systems**

  - **Conventional**
    - Concentrically Braced
  
  - **Modern**
    - Eccentrically Braced
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• Bracing Systems - (Possible Configurations)

  - Concentrically Braced
  - Eccentrically Braced

Diagrams of possible bracing configurations.
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• **Bracing Systems- (Possible Configurations)**

Acceptable

Not recommended

Not allowed

*What type of brace arrangement along the height is allowed?*
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- Bracing Systems: (Typical Damage Types)

Slender Elements for Bracing

Section Fracture
Lateral Load Resistant Systems

- Bracing Systems: (Typical Damage Types)

  Fracture of link in EBF

  Flange Buckling at Link in EBF
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- Bracing Systems: (Typical Damage Types)
  
  - Pull out of Gusset Plate
  - Bucking of Braces
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- **Walls (Bearing Walls, Shear Walls)**

  Shear wall is a structural system composed of shear panels to counter the effects of lateral load acting on a structure. Shear walls **resist in-plane loads** that are applied along its height. The applied load is generally transferred to the wall by a diaphragm.
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- Walls (Bearing Walls, Shear Walls)

- Precast Walls
- Cast-in-place Shear Walls
- Coupling Walls
- Steel Shear Walls
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- Walls (Bearing Walls, Shear Walls)

Coupling Wall under lateral load
Lateral Load Resistant Systems

- Walls (Bearing Walls, Shear Walls)

Soft-story due to Failure of Concrete wall

Damage to Precast walls (Joint’s Failure)
Lateral Load Resistant Systems

- Walls (Bearing Walls, Shear Walls)

Insufficient transverse reinforcement

Buckling of Longitudinal Reinforcement at Corners
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- Dual Systems (MRF + Wall or Bracing System)

The lateral load-resisting structure comprises of moment frames and shear walls acting together in the same direction. Shear walls interact with the moment frames and resist seismic effects.
Lateral Load Resistant Systems

- Dual Systems (MRF + Wall or Bracing System)
Lateral Load Resistant Systems

- **Comparison on stiffness**

Effectiveness of structural walls and bracings (Sugano, 1989; CEB, 1997)
Lateral Load Resistant Systems (Tall Buildings)

Gravity Load Design
Proportionate to \( \sim H \)

Lateral Load Design
Proportionate to \( \sim H^2 \)

Lateral Deformation
Proportionate to \( \sim H^4 \)

Deformation and Vibration are Critical Matters in Tall Buildings
Lateral Load Resistant Systems (High-rise)

• Comparison among Lateral Load Resisting System (Arrangement In Plan)

**Interior Systems**
Single / dual component planar assemblies

**Exterior Systems**
Systems at building perimeter

source: Architectural Science Review
Lateral Load Resistant Systems (High-rise)

- Evaluation of Lateral Load Resisting System (Dynamic behaviour)
Lateral Load Resistant Systems (Tall Buildings)

Different Configurations of Tube Systems
Lateral Load Resistant Systems (Tall Buildings)

Shear Lag Effects in Framed Tubed
Lateral Load Resistant Systems (Tall Buildings)

Outrigger Truss system

Outrigger Truss system
Lateral Load Resistant Systems

- Seismic Damage to Tall Buildings

Damage to upper levels during earthquake

Soil Liquefaction
Lateral Load Resistant Systems

- **STRUCTURAL SYSTEM IN EUROCODE 8**

  1. **Wall system**
     Structural system in which both vertical and lateral loads are mainly resisted by vertical structural walls, either coupled or uncoupled, whose shear resistance at the building base exceeds 65% of the total shear resistance of the whole structural system.

  2. **Frame system**
     Structural system in which both the vertical and lateral loads are mainly resisted by spatial frames whose shear resistance at the building base exceeds 65% of the total shear resistance of the whole structural system.

  3. **Dual system**
     Structural system in which support for the vertical loads is mainly provided by a spatial frame and resistance to lateral loads is contributed to in part by the frame system and in part by structural walls, coupled or uncoupled.
Lateral Load Resistant Systems

- **STRUCTURAL SYSTEM IN EUROCODE 8**

4. **Frame-equivalent dual system**
   Dual system in which the shear resistance of the frame system at the building base is greater than 50% of the total shear resistance of the whole structural system.

5. **wall-equivalent dual system**
   Dual system in which the shear resistance of the walls at the building base is higher than 50% of the total seismic resistance of the whole structural system.

6. **Torsionally flexible system**
   Dual or wall system not having a minimum torsional rigidity. An example of this is a structural system consisting of *flexible frames combined with walls concentrated near the centre* of the building in plan.
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7. **Inverted pendulum system**
System in which 50% or more of the mass is in the upper third of the height of the structure, or in which the dissipation of energy takes place mainly at the base of a single building element.
THANKS FOR YOUR ATTENTION