

# Introduction to Structural Analysis and Design

Introduction to Structural Analysis and Design  
Key concepts, workflow, and fundamental tools for engineers

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## 1. What Is Structural Analysis?

| Aspect          | Description                                                                                                                                                                                                                                    |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Definition      | The process of determining the response of a structure (forces, moments, deflections, stresses) to applied loads.                                                                                                                              |
| Goal            | Verify that the structure will perform safely and serviceably under all expected loading conditions.                                                                                                                                           |
| Typical Outputs | <div>- Internal forces (axial, shear, bending, torsion)</div> <div>? Displacements &amp; rotations</div> <div>? Stresses &amp; strains</div> <div>? Stability indicators (e.g., buckling factors)</div> <div>- Elastic analysis (linear)</div> |
| Common Methods  | <div>? Inelastic analysis (plastic, nonlinear)</div> <div>? Dynamic analysis (modal, time history, response spectrum)</div> <div>? Finite Element Method (FEM)</div>                                                                           |

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## 2. What Is Structural Design?

| Aspect       | Description                                                                                                                                                                                                                                                                                                          |
|--------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Definition   | The synthesis of a structure that satisfies the required performance criteria while meeting code, economic, and constructability constraints.                                                                                                                                                                        |
| Design Cycle | <div>1. Conceptual layout (geometry, support conditions)</div> <div>2. Preliminary analysis (size member sections)</div> <div>3. Detailed analysis (refine forces, check serviceability)</div> <div>4. Member design (size, reinforcement, connections)</div> <div>5. Verification (code checks, optimization)</div> |

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| Aspect  | Description                                       |
|---------|---------------------------------------------------|
| Outputs | - Final member dimensions (cross-section, length) |
|         | ? Reinforcement detailing (for concrete)          |
|         | ? Connection specifications (bolts, welds)        |
|         | ? Construction drawings & specifications          |

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## 3. Fundamental Concepts

### 3.1 Load Types

| Load               | Typical Sources                                        | Representation                          |
|--------------------|--------------------------------------------------------|-----------------------------------------|
| Dead Load (DL)     | Self-weight of structural elements, permanent fixtures | Uniformly distributed or concentrated   |
| Live Load (LL)     | Occupants, furniture, movable equipment                | Variable, often specified by code       |
| Wind Load (WL)     | Atmospheric pressure, gusts                            | Pressure distribution, dynamic factor   |
| Seismic Load (EQ)  | Earthquake ground motion                               | Base accelerations, response spectra    |
| Thermal Load       | Temperature change                                     | Expansion/contraction forces            |
| Snow, Rain, Ice    | Climatic loads                                         | Distributed loads based on climate data |
| Construction Loads | Temporary loads during erection                        | Often staged in analysis                |

### 3.2 Support Conditions

- **Fixed (encastre)** – No translation or rotation.
- **Pinned (hinged)** – No translation, free rotation.
- **Roller / Sliding** – Translation allowed in one direction, no rotation.
- **Elastic support** – Modeled with springs (translational/rotational stiffness).

### 3.3 Internal Force Types

| Force | Effect on Section |
|-------|-------------------|
|-------|-------------------|

# Introduction to Structural Analysis and

## Design

**Axial (N)** Tension or compression; uniform stress  $\sigma = N/A$

**Shear (V)** Causes shear stress  $\tau = V/A$  ( $A$  = shear area)

**Bending (M)** Generates bending stress  $\sigma = M \cdot y/I$

**Torsion (T)** Produces shear stress  $\tau = T \cdot r/J$

### 3.4 Material Behavior

| Material | Typical Model                                   | Key Properties                     |
|----------|-------------------------------------------------|------------------------------------|
| Steel    | Elastic?perfectly plastic (yield stress $F_y$ ) | Young's modulus $E$ , yield stress |