# Composite Steel and Concrete Diaphragm Seismic Design

**Course Number:** CE-04-356

**PDH:** 4

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# Module 1: Design Fundamentals

## Learning Objectives

By the end of this section, you will be able to:

- **Identify** the critical role of diaphragms within a continuous lateral load path.
- **Select** the appropriate building codes and standards for analyzing composite steel deck diaphragms.
- **Evaluate** the scope and limitations of current design guidance for steel-framed building systems.

*Executive Summary:* Diaphragms are essential horizontal spanning elements that complete the three-dimensional framework of a building. They transfer inertial forces from the floor and roof mass to the vertical lateral force-resisting system, ensuring structural stability and preventing collapse during seismic events.

## Instructional Approach

**Sidebars in the Course** Sidebars are used in this course to **illustrate key points** and to provide **additional guidance** on good practices and open issues in analysis, design, and construction.

## Scope of Guidance

This course focuses on the design of diaphragms composed of **steel beams** and **steel deck with concrete fill**. While reinforced concrete diaphragms are addressed in other technical briefs, this material specifically integrates conditions for **semirigid and flexible diaphragms**.

**Items not covered in this document** A number of important issues related to diaphragm design are not addressed in this document; these include:

- **Formed concrete diaphragms** on steel members.
- **Out-of-plane wall support** and design of sub-diaphragms.
- Design of **open-web joists** as chords or collectors.
- **Ramp issues** in parking garages.
- **Saw-tooth roofs** and similar discontinuities.
- Detailed treatment of **steel-deck only** systems.
- **Strut-and-tie** analysis methods.
- **Expansion joints** and seismic separation issues.

## The Lateral Load Path

Building systems resist loads through an integral network of horizontal elements (decks/beams), vertical elements (walls/columns), and foundations. Seismic design focuses on controlling building displacements by resisting **inertial forces** generated by the building's mass.

- **Horizontal Span:** The diaphragm system acts as the first segment of the lateral load path.
- **Force Distribution:** It spans horizontally between vertical elements (walls, braced frames, or moment frames).
- **Critical Component:** Without a properly designed diaphragm, there is no resistance to the movement of distributed building mass, which can lead to **collapse**.

## Regulatory Framework and Standards

The following documents comprise the primary requirements for composite and steel deck diaphragms:

- **ASCE/SEI 7-10:** Contains the main **design forces** and **analysis requirements**.
- **ANSI/AISC 360:** Used to determine **component strengths** for steel and composite members.
- **ANSI/AISC 341:** Provides **seismic provisions**, including limitations and quality requirements.
- **ACI 318:** Used if the designer chooses to ignore the steel deck and evaluate only the **concrete in-plane strength**.
- **SDI DDM:** The Steel Deck Institute Diaphragm Design Manual is recognized by the IBC for calculating **in-plane shear strength**.

⚠️ **Safety Constraint:** Seismic design is mandatory for all buildings assigned to **Seismic Design Category B through F**. Category A is exempt from seismic design, though these methods are often applied to resist **wind forces** in those structures.

💡 **Design Tip:** While codes work together, **engineering judgment** is required to resolve ambiguities in their application, especially regarding semirigid modeling and transfer forces.

## Course Roadmap

The modules following this introduction are structured to lead you through the complete design process:

1. **Roles and Components:** Sections 2 and 3.
2. **Behavior and Forces:** Sections 4 and 5.
3. **Diaphragm Analysis:** Section 6.
4. **Component Design:** Section 7.
5. **Construction:** Section 9.

*Checkpoint Quiz*

1. **Which standard is the primary source for determining diaphragm design forces (Fpx)?**
   a) AISC 360
   b) ACI 318
   c) ASCE 7-10
   d) SDI DDM03

**Answer:** (c). This standard contains the analysis requirements and load equations (Fpx) for diaphragms.

2. **Why is the diaphragm considered a "critical" segment of the lateral load path?**
   a) It supports the majority of the building's vertical gravity loads.
   b) It provides the only connection between the roof and the foundation.
   c) It collects and delivers inertial forces to the vertical lateral force-resisting elements.
   d) It is the primary source of inelastic deformation in a structure.

**Answer:** (c). Without the diaphragm, there is no continuous path to transfer the building's mass acceleration to the lateral resisting system.

3. **In which scenario would a designer primarily consult ACI 318 for diaphragm strength?**
   a) When designing a bare steel deck roof system.
   b) When ignoring the contribution of the steel deck in a concrete-filled system.
   c) When calculating the strength of steel headed-stud anchors.
   d) When modeling a semirigid diaphragm in Seismic Design Category B.

**Answer:** (b). ACI 318 is used to evaluate the concrete portion above the deck flanges.

# Module 2: The Roles of Diaphragms

## Learning Objectives

By the end of this section, you will be able to:

- **Evaluate** the primary structural roles diaphragms play in resisting gravity and lateral loads.
- **Identify** specialized diaphragm functions, including load redistribution and resistance to column thrust.
- **Calculate** design considerations for horizontal structural irregularities and unbraced components.

*Executive Summary:* Diaphragms are multi-functional components that act as the primary horizontal delivery system for building loads. They transfer inertial forces to the lateral force-resisting system, support vertical gravity loads, and provide essential lateral bracing to vertical elements to ensure global stability.

## Typical Conditions

In standard building configurations—including those with podium levels at grade and below-grade levels—diaphragms fulfill several critical structural roles:

- **Lateral Force Transfer:** Floor systems typically comprise the majority of a building's mass. Diaphragms transfer the resulting inertial forces to vertical elements like walls and columns during seismic events.
- **Vertical Load Resistance:** As part of the floor and roof framing, diaphragms directly support gravity loads.
- **Lateral Support of Vertical Elements:** By connecting to vertical elements at every floor, diaphragms resist buckling and second-order P – Delta forces. They complete the three-dimensional framework necessary to resist lateral loads.
- **Out-of-Plane Force Resistance:** Diaphragm-to-wall connections provide the necessary resistance against wind pressure and out-of-plane seismic forces acting on exterior cladding.
- **Internal Force Transfer:** Lateral shears often must be transferred between different vertical elements, especially at discontinuities like podium slabs where shear transfers from above-grade elements to basement walls.
- **Below-Grade Soil Support:** For subterranean levels, diaphragms provide the reactions for basement walls spanning against lateral soil pressure.

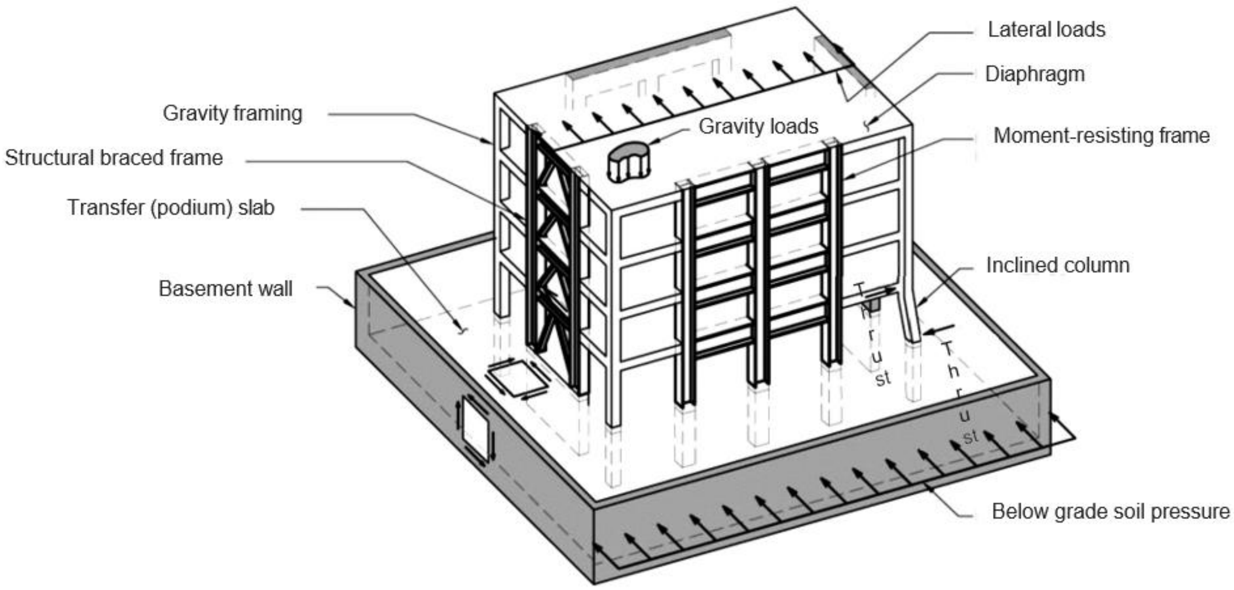


**Figure 2-1** – Roles of diaphragms.

### Additional Functions

Architectural and structural complexities require diaphragms to perform specialized functions:

- **Redistribution Around Openings:** Diaphragms must redirect lateral forces around stairway openings, mechanical shafts, and atria.
- **Torsional Redistribution:** Diaphragms with sufficient stiffness distribute forces resulting from building torsion to the lateral force-resisting elements.
- **Resistance to Column Thrust:** Inclined or offset columns generate large horizontal thrusts within the plane of the diaphragm due to gravity and overturning. Diaphragms must be designed to resist these thrusts in either tension or compression.

## Horizontal Structural Irregularities

Per ASCE 7 Chapter 12, designers must consider irregularities such as reentrant corners, discontinuities, and cantilevers.

- **Cantilevered Diaphragms:** Portions extending far from the main body need careful evaluation.
- **Flexural Behavior:** Aspect ratios greater than 1.5 to 2 may require chords to develop the tension component of flexural demand.

💡 **Design Tip:** To maintain an integral load path and ensure elastic behavior under significant seismic events, consider amplifying chord design forces by the system overstrength factor Omega 0.