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## Seismic Design of Composite Steel Deck and Concrete-filled Diaphragms

**Course Number:** ST-02-680

**PDH:** 4

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## Module 1: Introduction

### Learning Objectives

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

- **Identify** the primary governing codes and standards for composite and steel deck diaphragm design.
- **Evaluate** the scope of technical coverage and specific exclusions within this design guidance.
- **Select** the appropriate calculation methodology based on material selection and jurisdiction requirements.

*Executive Summary:* Diaphragms are the critical first segment of a building's lateral load path, spanning horizontally between vertical elements to resist inertial forces and prevent collapse during seismic events.

### Design Fundamentals

Building structures are integrated systems of horizontal spanning elements, vertical elements, and foundations that resist vertical and lateral loads. **Seismic design** focuses on controlling displacements by providing resistance to the inertial forces generated by the acceleration of the building mass.

The **diaphragm system** acts as a horizontal beam, transferring these loads from floor and roof systems to vertical lateral force-resisting elements like braced frames, moment frames, or walls.

### Scope of Coverage

This course focuses on diaphragms composed of **steel beams** and **steel deck with concrete fill**. While some issues regarding non-composite (bare) steel deck are addressed, they are not the primary focus.

The following categories and conditions are covered:


- **Seismic Design Categories:** B through F.
- **Modeling Conditions:** Integrated treatment of **semirigid** and **flexible** diaphragms.
- **Applicability:** While Category A is exempt from seismic requirements, these methods apply to **wind force** resistance and structural integrity.

### Exclusions and Limitations

Several specific issues are not addressed in this document:

- **Formed concrete diaphragms** on steel members.
- **Out-of-plane wall support** and sub-diaphragm design.
- **Open-web joists** acting as chords or collectors.
- **Parking garage ramps** and discontinuities like saw-tooth roofs.
- **Detailed treatment** of bare steel-deck only systems.
- **Strut-and-tie** analysis and seismic separation joints.




 **Design Tip:** Sidebars are utilized throughout this course to provide additional guidance on engineering judgment, good practices, and open issues in analysis and construction.

### Governing Codes and Standards


Engineers must navigate multiple standards to ensure compliance. The following documents comprise the core requirements for composite and steel deck diaphragms:

Component/Requirement	Primary Standard	Notes
Design Forces & Analysis	ASCE/SEI 7-10	Adopted by IBC 2012 with no modifications for composite deck.
Steel & Composite Strength	ANSI/AISC 360	Used for determining component strengths.
Seismic Provisions	ANSI/AISC 341	Provides additional limitations and quality requirements.
Concrete Evaluation	ACI 318	Used if the steel deck presence is ignored in strength calculations.
Steel Deck Shear	SDI DDM	Recognized by the IBC for calculating in-plane shear strength.

 **Safety Constraint:** While these documents are developed to work together, ambiguities exist. **Engineering judgment** is required for consistent application, as this course represents the authors' professional opinions on matters not explicitly defined by codes.

### Shear Strength Determination

The in-plane shear strength of steel deck (filled or unfilled) is typically determined via calculation or testing and subsequent development of an **evaluation report**.

 **Calculation Note:** Historically, TI 809-04 (the Tri-Services Manual) was used for shear calculations, but it has been superseded. Current IBC regulations recognize the **SDI DDM** for these calculations.



### *Checkpoint Quiz*

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- 1. A designer is working on a building assigned to Seismic Design Category A. According to the text, how should seismic diaphragm requirements be applied?**
- a) Full compliance with ASCE 7-10 seismic provisions is mandatory.
  - b) Seismic design is not required, but diaphragm analysis methods can be used for wind resistance.
  - c) The building is completely exempt from all lateral load analysis.
  - d) Only AISC 360 gravity provisions apply.

**Answer:** (b). Seismic Design Category A is exempt from seismic design, but the methods described in the course are still applicable for resisting wind forces and providing structural integrity.

- 2. Which standard should be used to evaluate the in-plane strength of concrete if a designer chooses to ignore the steel deck in a filled system?**
- a) AISC 341
  - b) SDI DDM03
  - c) ACI 318
  - d) ASCE 7-10

**Answer:** (c). In cases where the designer chooses to ignore the steel deck in concrete-filled systems, ACI 318 is used to evaluate the in-plane strength of the concrete above the deck.

## Module 2: The Roles of Diaphragms

### Learning Objectives

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

- **Evaluate** the primary and specialized structural roles diaphragms perform in resisting gravity and lateral forces.
- **Identify** horizontal structural irregularities, such as reentrant corners and discontinuities, that impact diaphragm response.
- **Analyze** the load paths required for horizontal cantilevered diaphragms and unbraced collector members.

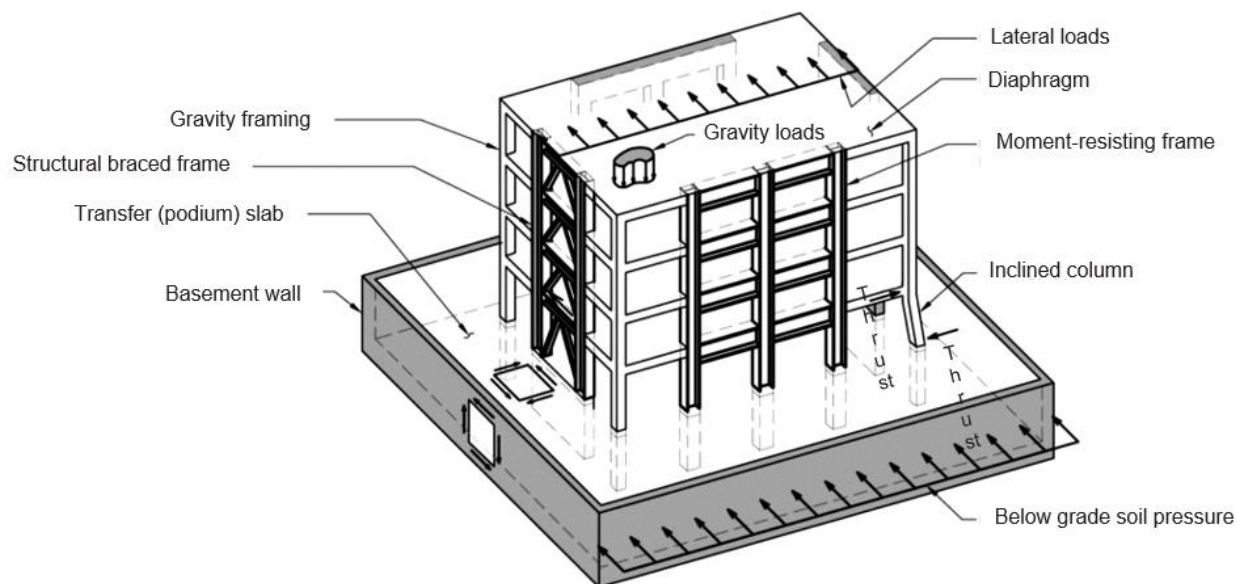
*Executive Summary:* Diaphragms serve multiple critical roles, primarily acting as horizontal spanning elements that transfer lateral inertial forces to vertical resisting elements while maintaining building stability and providing displacement compatibility.

### Typical Conditions

Diaphragms are multi-functional components essential for both gravity and lateral force resistance.

### Primary Structural Roles

- **Transfer Lateral Inertial Forces:** Floor systems commonly comprise most of the building mass, generating significant inertial forces that the diaphragm must transfer to vertical elements of the seismic force-resisting system.
- **Resist Vertical Loads:** As part of the floor and roof framing, diaphragms support gravity loads and help distribute inertial loads from vertical earthquake responses.
- **Provide Lateral Support:** Diaphragms connect to vertical elements at each level to resist buckling and second-order forces associated with lateral displacements.
- **Resist Out-of-Plane Forces:** Diaphragm-to-wall connections provide resistance to out-of-plane forces developed by wind pressure or lateral inertial forces on exterior walls and cladding.
- **Transfer Forces Through Discontinuities:** Large transfer forces often occur at podium slabs or offsets where shear must be transferred from one vertical element to another.
- **Support Soil Loads:** In subterranean levels, diaphragms act as supports for basement walls resisting out-of-plane soil pressure.



**Figure 2-1** – Roles of diaphragms.

### Additional Functions

Beyond basic load path requirements, diaphragms perform specialized functions dictated by architectural and structural configurations.

### Specialized Requirements

- **Load Redistribution Around Openings:** Diaphragms redistribute lateral forces around stairs, elevators, and mechanical shafts back to the lateral force-resisting elements.
- **Torsional Redistribution:** If provided with sufficient strength and stiffness, diaphragms can distribute forces generated by torsional response.
- **Resistance to Column Thrust:** Diaphragms must be designed to resist horizontal thrusts from inclined or offset columns, which can act in tension or compression.

**💡 Design Tip:** Relatively flexible diaphragms generally do not facilitate the distribution of lateral forces due to torsion; ensure the diaphragm classification aligns with the intended structural behavior.

### Cantilevered Diaphragms and Irregularities

ASCE 7 identifies several horizontal irregularities, such as reentrant corners and diaphragm discontinuities, that require specific consideration. For diaphragms that cantilever horizontally:

- **Aspect Ratios:** Cantilevers with aspect ratios (length-to-depth) greater than 1.5 to 2 may require dedicated chords to handle flexural tension.
- **Elastic Behavior:** Chords should be designed to maintain elastic behavior under significant earthquakes to preserve the load path.



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