Multi-Story Building Systems and Selection Criteria

AIA Continuing Education Provider

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Purpose and Learning Objectives

Purpose:

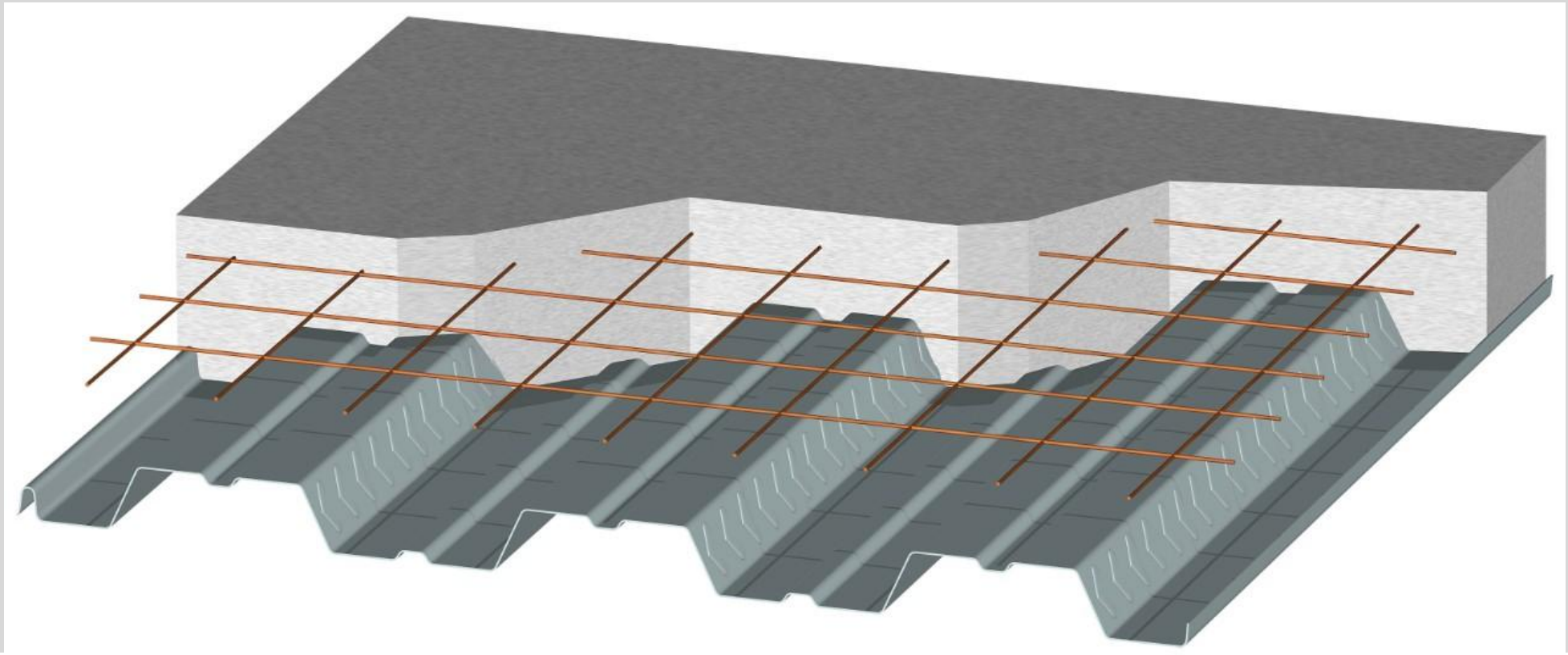
This course outlines the attributes, functions, benefits, limits and acoustic qualities of composite deck-slabs. It reviews the three primary types of composite systems that represent the full range of long-span composite floor systems and examines the criteria for their selection, design, and engineering. In addition, it provides a comprehensive range of industry standards and resources that a designer could consult to ensure, at a minimum, compliance with all building regulations and industry standards.

Learning Objectives:

At the end of this program, participants will be able to:

- optimize the characteristics of the 3 composite system options in order to create efficient, cost effective structures
- meet or exceed all fire safety requirements for composite floor slabs in a cost-effective manner
- utilize basic engineering design principles to create durable and economical composite floor systems, and
- incorporate acoustic control into composite structures to create healthy and comfortable conditions for building occupants.

Contents



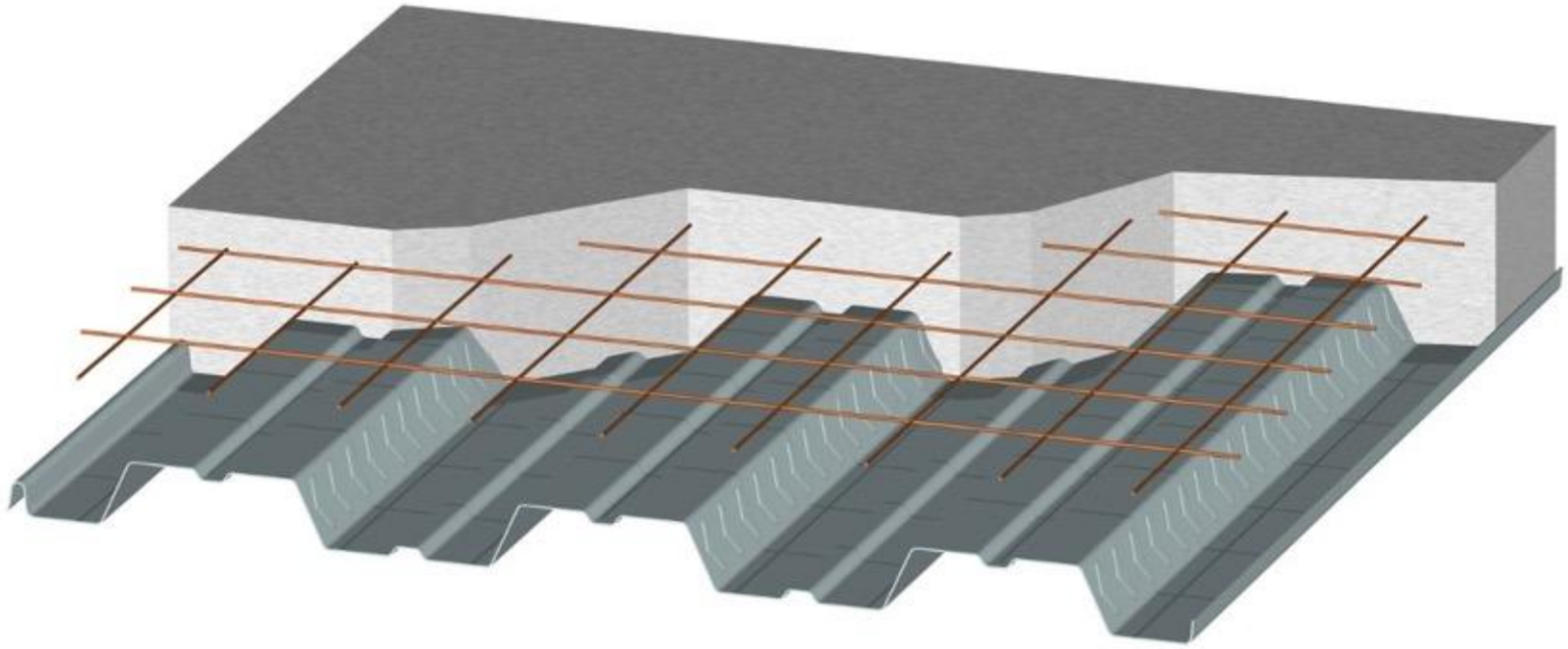
Introduction to Composite Steel Deck Systems

Introduction to Composite Steel Deck Systems

This section will discuss:

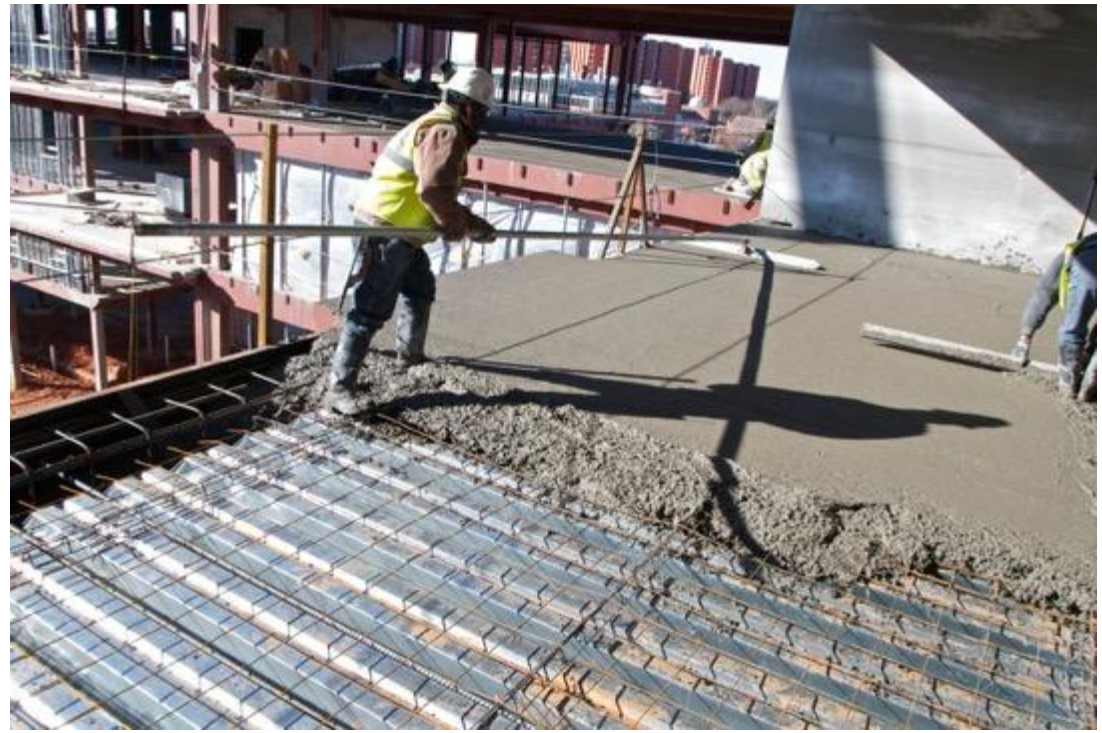
- the definition of a composite slab
- the main functions of composite steel decks
- composite action
- composite deck profiles, and
- guidelines.

Definition of a Composite Steel Deck Slab



A composite steel deck slab is a structural concrete slab formed on corrugated steel deck that acts as a slab with external positive bending reinforcement after the concrete has gained strength. A composite slab generally consists of composite steel deck, structural concrete, and temperature and shrinkage reinforcement, which may be in the form of welded wire fabric, steel fibers, or synthetic fibers. Steel reinforcing bars are often added when design conditions dictate.

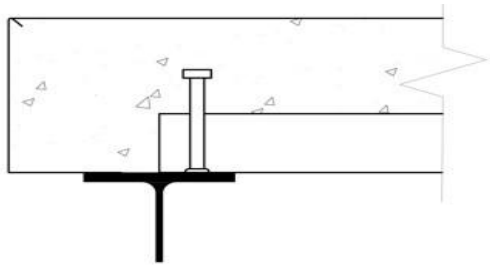
Composite Steel Deck Slabs



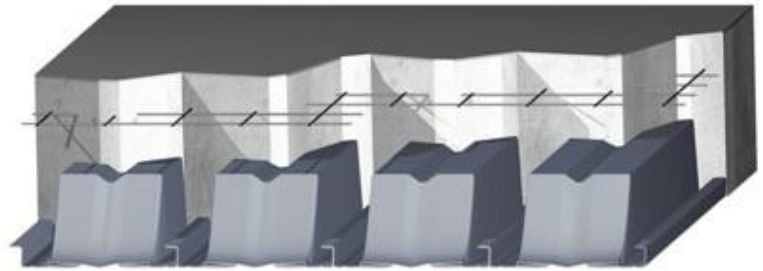
Steel deck plays a central role in composite slab formation. In addition to serving as a working platform (left image),it is also a concrete form (right image). The strength of the deck as a form supports its own weight as well as the weight of fluid concrete in addition to supporting all of the live loads that occur during construction.

Composite Steel Deck Slabs

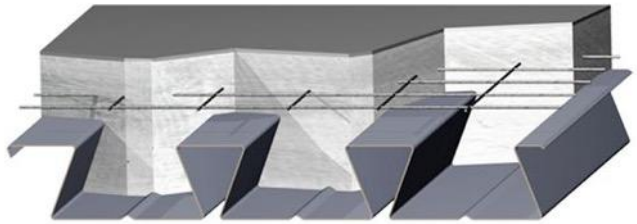
Composite Action



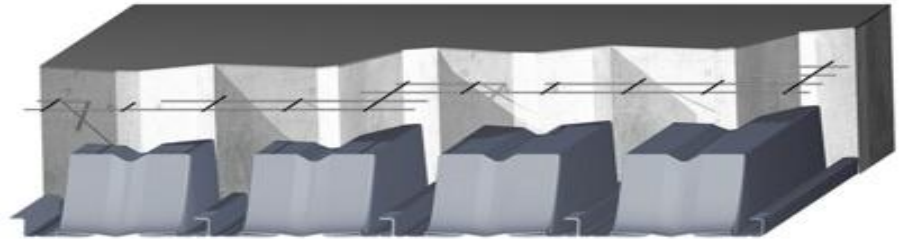
Shear Studs



Deck Embossments/Indentations



Dovetail Shape



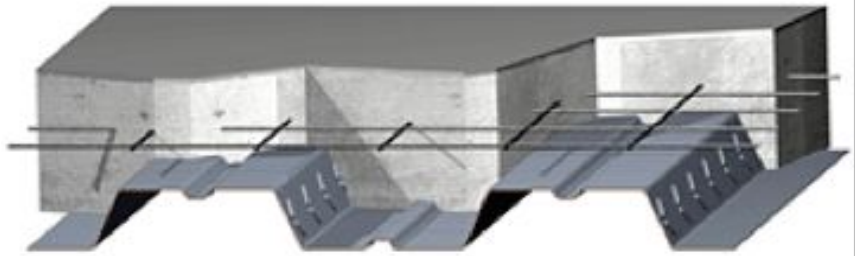
Side Laps

For all composite slab formations, a composite action or bond must be established between the steel deck and the concrete. The composite action is usually achieved by mechanical interlock. This can be achieved with embossments or indentations rolled into the deck profile or by friction interlock in the re-entrant or dovetail profiles. Shear stud connectors which are screwed or welded through the deck to the supports can also contribute to the composite action.

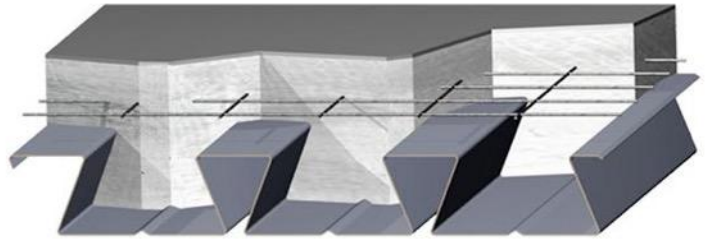
Composite Steel Deck Slabs

Composite Deck Profiles

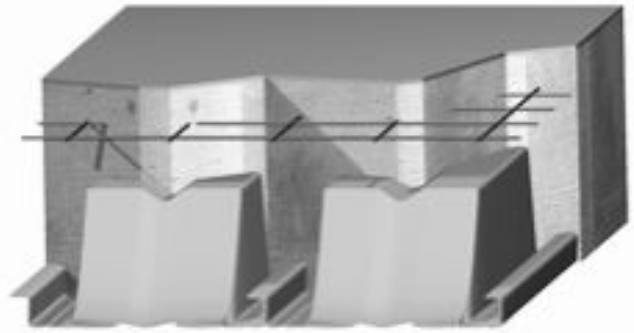
Several profiles of composite steel decks are available for use in composite decks. The shallower, conventional trapezoidal profiles are commonly used for relatively short floor spans ***without*** temporary shoring. The trapezoidal profiles are typically 1.5”, 2” & 3” (38, 50 or 76mm.) in depth. The use of dovetail composite and deep-ribbed composite deck shoring is optional, contingent on span and loading conditions. The dovetail-shaped or re-entrant deck profiles come in depths of 2” and 3.5” (50 and 88 mm.) and they are usually used over longer floor spans ***with*** temporary shoring. The deep-ribbed decks are typically available in 4.5”, 6” and 7.5” (114, 127, and 190 mm.) deep profiles. The deep-ribbed deck has the ability to span longer distances than the other two profiles, ***without*** shoring on single or clear spans up to 22’-0” (6.7M).



Trapezoidal



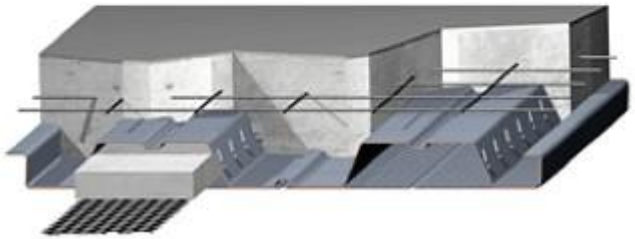
Dovetail



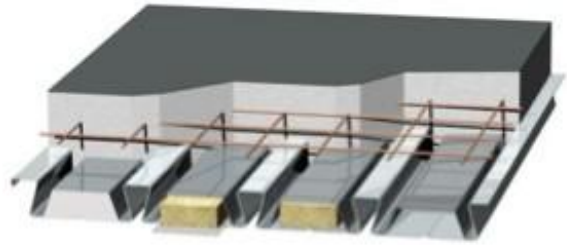
Deep ribbed

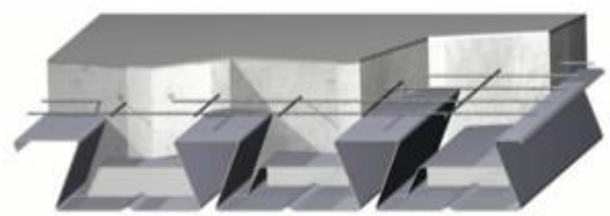
Composite Steel Deck Slabs

Composite Deck Profiles

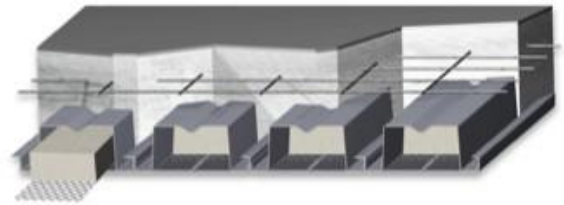


Cellular and Cellular
Acoustical Trapezoidal Decks





Acoustical
Dovetail Decks



Cellular and Cellular
Acoustical Deep Decks

Most of the three basic composite deck profiles can be manufactured to improve acoustical conditions. For the traditional trapezoidal deck and the deep-ribbed deck profile, a perforated liner panel can be welded or riveted to the underside of the deck and then filled with acoustical batts. The dovetail deck profiles can also be fitted with acoustical batts on top of perforated bottom flutes. The batts are protected from the wet concrete using non-structural caps.

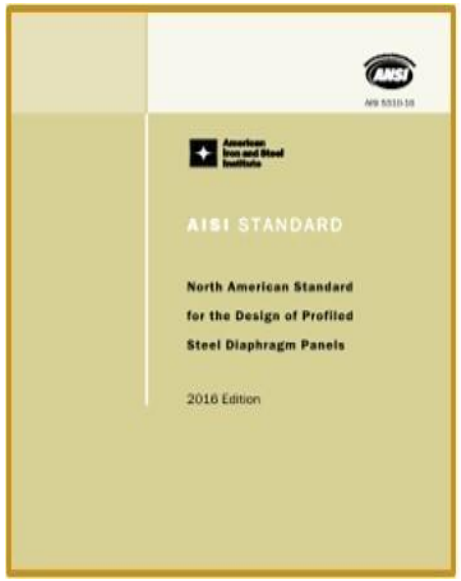
Composite Steel Deck Slabs

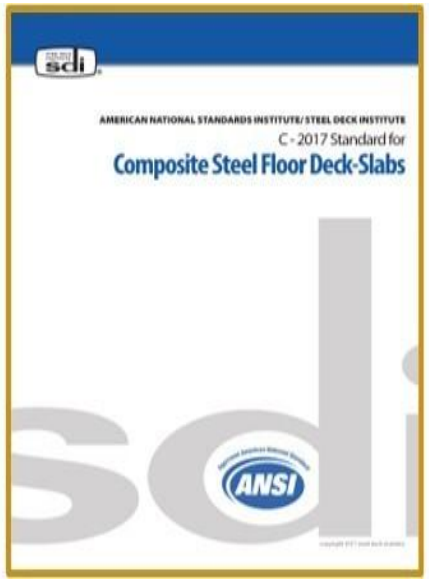
Composite Deck Profiles

Note how, in the photo on the left, the ceiling uses cellular acoustical composite steel deck to support the floor above. In the project photo on the right we can see a green roof supported by a deep-deck composite acoustical roof. This approach can be used in multi-story rec centers, schools, offices or any type of building project where acoustics are a concern and where there is a desire to incorporate an acoustical finished ceiling into a composite floor deck above.

Composite Steel Deck Slabs

The next section of this course will discuss the criteria for composite steel deck system selection. It is important, when reviewing these criteria to understand that all composite deck systems have been proven in the field and well established in the multi-story marketplace. There is also a comprehensive number of guidelines (see images below) which can inform the specification and engineering of composite slabs. These guidelines will be reviewed later in this course. Guidelines can be extremely useful in designing and selecting the most appropriate system.



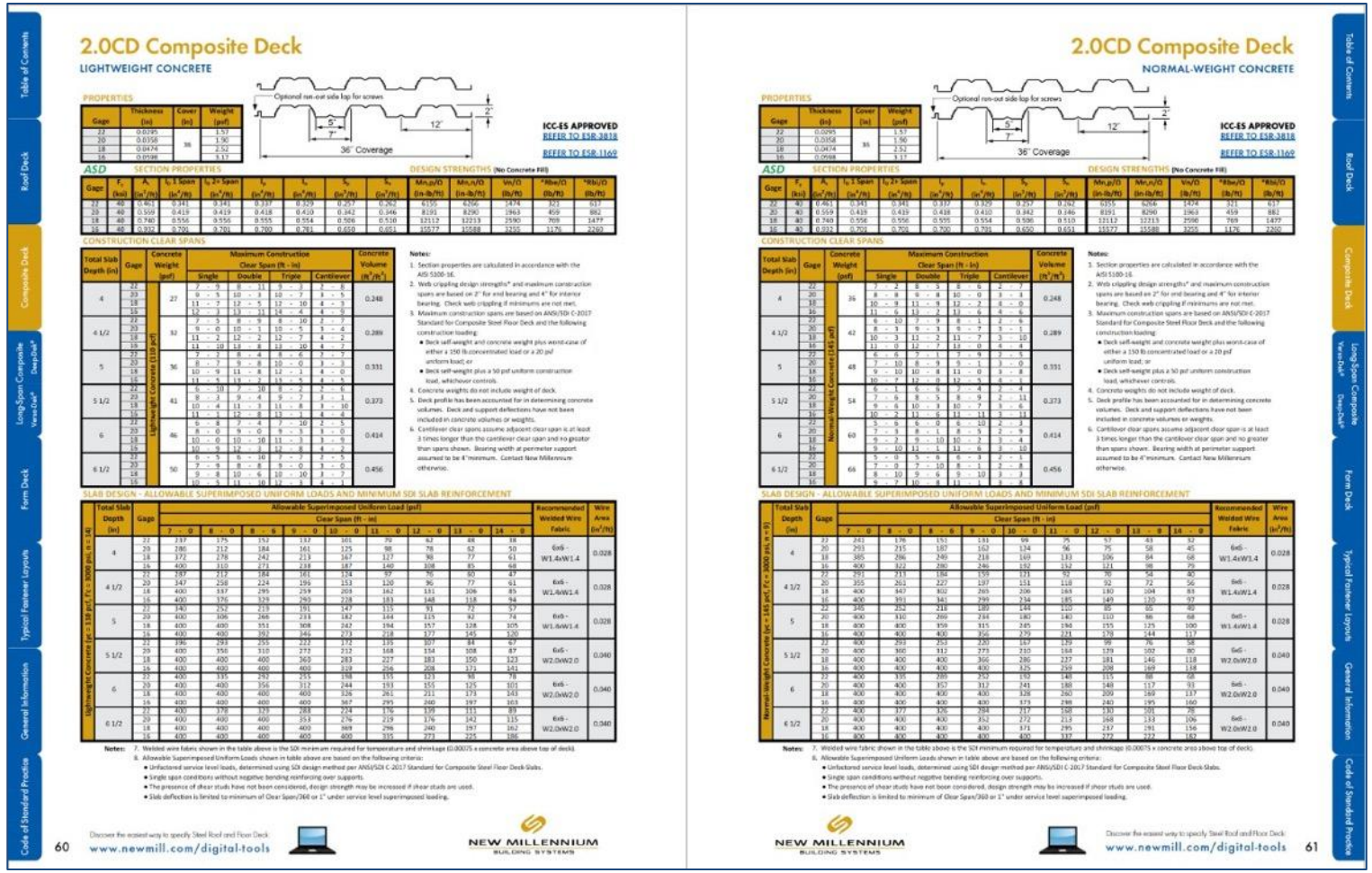


Composite Steel Deck Slabs

Manufacturer's Guidelines

To further assist the specifying professional, steel deck manufacturers publish load tables, diaphragm tables, and design guidelines with design examples to demonstrate the usage of these guidelines and standards.

Because of their extensive field experience and years of product development deck manufacturers that offer these systems can also assist in making the correct system selection. Often, this early level of collaboration between suppliers and team consultants is key to efficient project delivery.



Types of Long Span Composite Floor Systems

Types of Long Span Composite Floor Systems

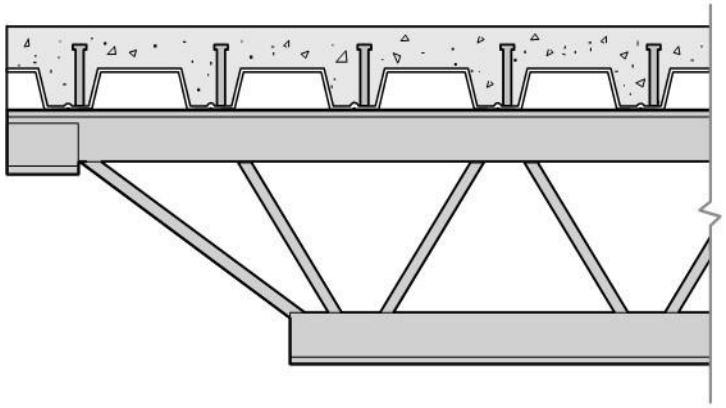
Before the full engineering of a composite floor system can be undertaken, there is an up front decision as to which type of system best meets the design objectives of the project which has to be made. For multi-story building design and construction, there are three distinct system options to consider.

The three systems which this section of the course will discuss are:

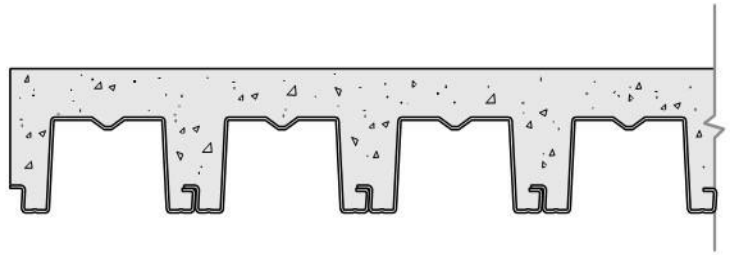
- composite joists
- deep ribbed composite, and
- dove tail composite.

Types of Long Span Composite Floor Systems

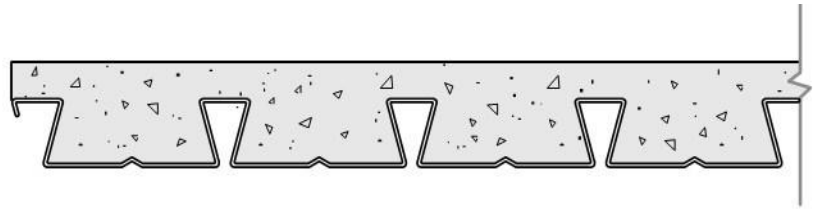
Three Distinct Profiles



1. Composite Joist



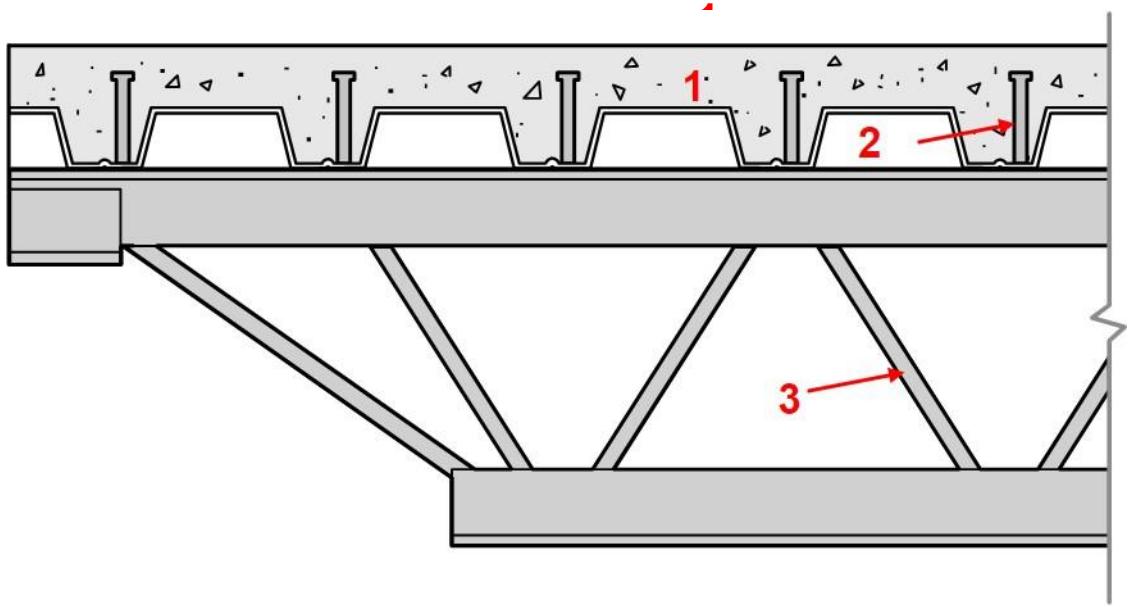
2. Deep Ribbed Composite



3. Dovetail Composite

A distinguishing feature of each and every long-span composite slab system is the structural depth. These are the three systems that represent the long-span composite floor category: image 1, a composite joist with a standard composite concrete floor deck, image 2, a deep ribbed composite profile, and image 3, a dovetail composite profile. Other composite profiles will approximate these configurations, by using structural steel and precast concrete to establish a thin floor structure.

Types of Long Span Composite Floor Systems



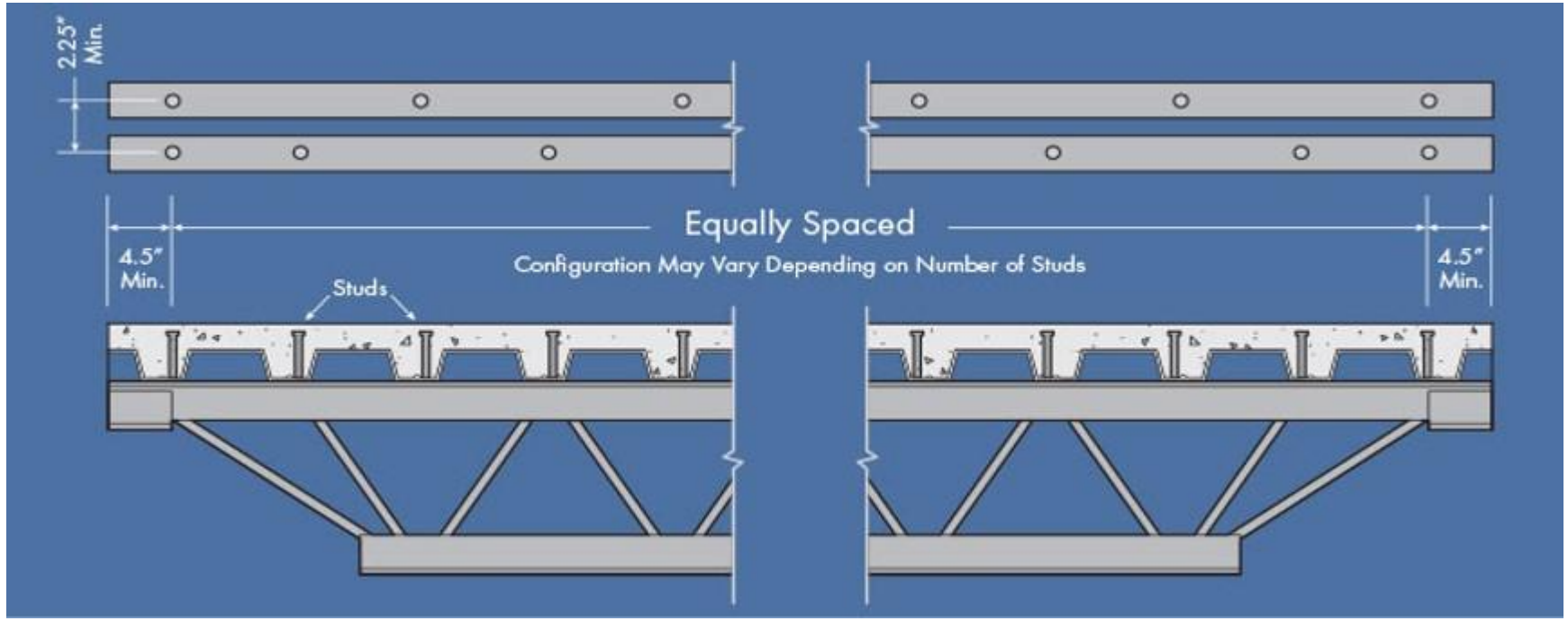
Composite Joists

Composite steel joists integrate steel joists and composite deck using shear studs that are attached through the composite steel deck to the joist top chord. Concrete is then poured on top of the decking, and the shear studs become embedded in the cured concrete, forming a unified load bearing system that deflects as a single unit.

This system then is composed of three key elements:

1. composite deck and concrete topping
2. shear studs, and
3. open web steel joists.

Types of Long Span Composite Floor Systems



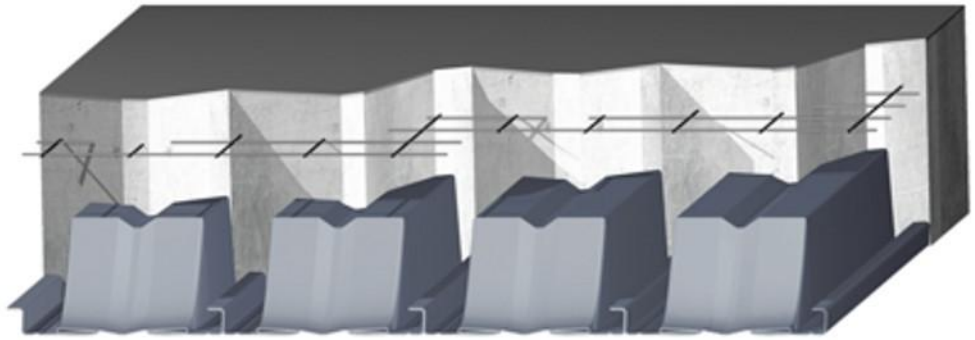
The composite joist system, which can be as shallow as 11″ (274 mm.) in depth, is lighter than wide-flange beams. A lighter structure contributes to a reduced footing and foundation system. There is an overall reduction in steel and less steel means lower costs due to reductions in material and manufacturing, shipping, on-site staging, and joist erection. The system can also be more readily integrated with and/or support the mechanical, electrical and plumbing (MEP) systems. The combined time saved at every stage can often lead to earlier building occupancy.

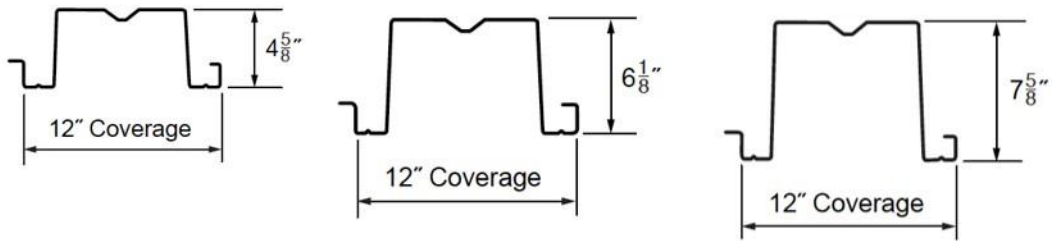
Types of Long Span Composite Floor Systems

Composite joists are the longest spanning composite floor systems on the market. For multi-story projects they can typically span from 20 ft. to 60 ft. (6M. to 18M.) or even more. Instead of a solid wide flange steel beam or a solid concrete beam, the open webbing of the joists allows the MEP integration. In addition, these joists also create large open spaces with expanded column spacing which in turn increases the rental value as well as the flexibility of the space.

For this auto dealership, a 50 ft.(15M.) span requirement pointed immediately to a composite joist floor system. The system supports over 292,000 lbs. (132.4 kg.) of moveable live loads, and this choice of system also eliminated temporary shoring of the floor during construction.

Types of Long Span Composite Floor Systems





Deep Ribbed Composite

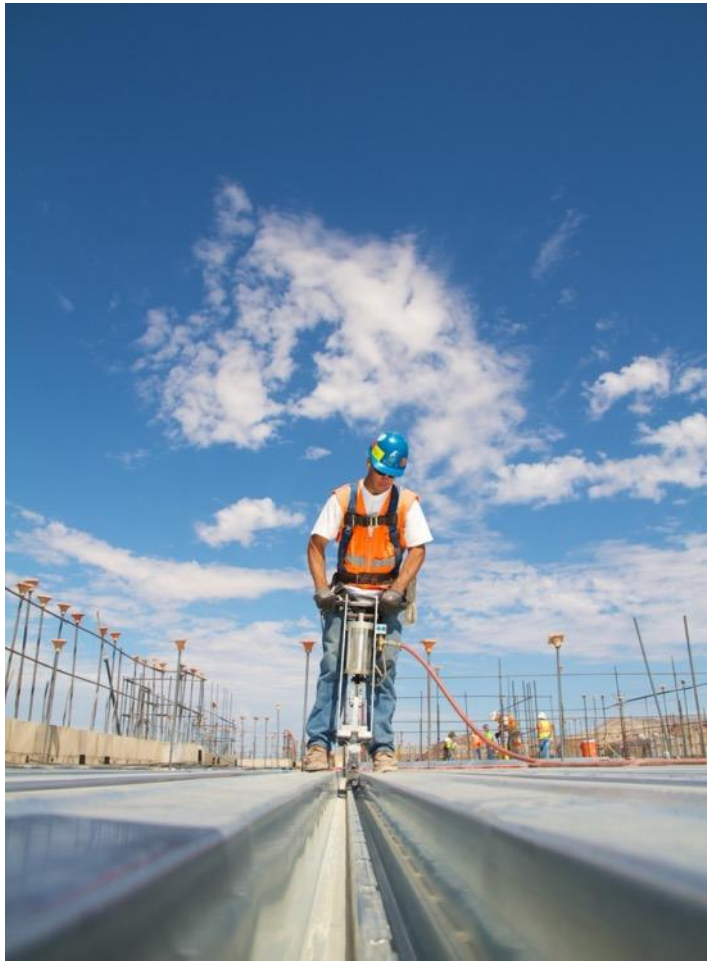
The second type of second long span composite floor system which is available uses a deep ribbed deck profile.

This system can span up to 36 feet (11M.), with unshored concrete pours of up to 22 feet (6.7 M.).

As shown in the adjacent images there are three progressively deeper profiles that are typical of these systems. Another variable in this system is the density of the concrete which can be 4,000, 5,000 or even 6,000 pounds per square inch (psi). (27579, 34473, or 41368 kilopascals (kPa))

Note that the deck coverage does not vary with the depth of the deck profile.

Types of Long Span Composite Floor Systems



Deep Ribbed Composite

Deep ribbed composite deck systems also feature side lap connections which are created with the use of a fastening tool on site (image). This creates a self aligning assembly.

The connections are essential to the installed system's composite bond and strength.

These deep deck systems have the added advantage of ground level assembly in sections that can be panelized and lifted into place. Ground level assembly improves assembly time as well as worker safety.

We will discuss this feature later on in this course in the context of construction efficiency.

Types of Long Span Composite Floor Systems

Deep Ribbed Composite

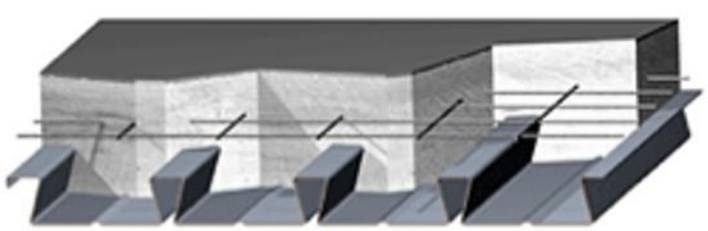
For this university health sciences building, a deep ribbed composite floor system was specified to provide spans of 24.5 ft. (7.5M.) between 80 ft. (24.4M.) girders. The deck had sufficient strength during installation to support construction loads which included the workers, equipment, and wet concrete. Factory closed deck ends allow the concrete to flow over the supports in a monolithic pour thus eliminating the need for additional closure accessories. The 5″ (12.7 cm.) concrete cover provided the desired 2-hour fire endurance rating. The use of an acoustical composite deck, with a noise reduction coefficient (NRC) of 1.00, eliminated the added cost and complexity of a suspended acoustical ceiling. The deck supplier also coordinated early with the engineering team on the detailing of slab penetrations, embedded electrical boxes, conduit, and the integration of concrete anchors for suspended MEP components.

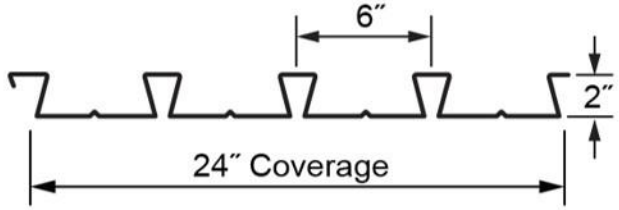
Types of Long Span Composite Floor Systems

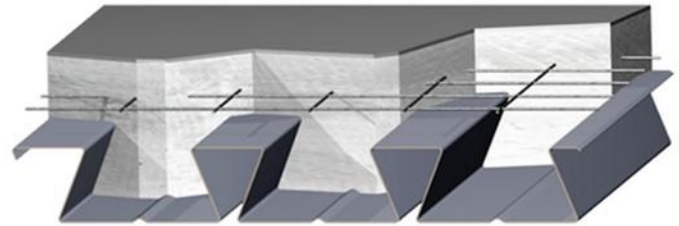
Dovetail Composite

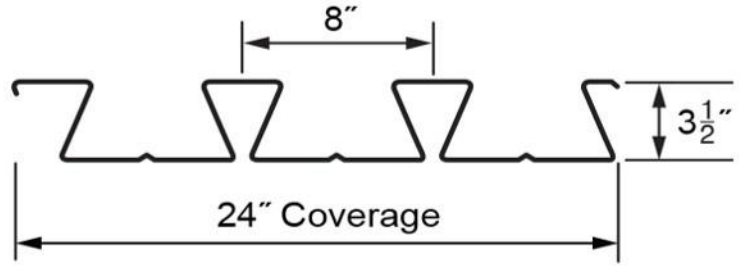
The third long span composite floor system which is available for consideration is characterized by a dovetail deck profile. A distinct advantage of the dovetail profile is that more concrete is placed in the bottom of the deck, so total slab thicknesses can be as thin as 4″(100mm.).

The decks are typically 2″ or 3.5″ (50mm. or 88mm.) deep. They can span up to 28ft. (8.5M.) and they offer the lowest deck profile as well as an attractive exposed plank like aesthetic.









Types of Long Span Composite Floor Systems

Dovetail Composite

The plan for a recent 20 story hotel project called for open spans of 28 ft. (8.5M.) and the maximization of the floor to ceiling height. The initial design also called for one row of shoring, with acoustical and vibration testing. These early design parameters removed composite joists from consideration, mainly due to the alternative higher span/depth efficiencies that can be achieved at the specified 28 ft. span. The design decision then boiled down to which of the other two long-span composite systems would be the most optimal; deep-ribbed composite or dovetail deck composite.

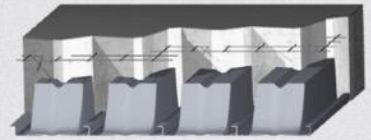
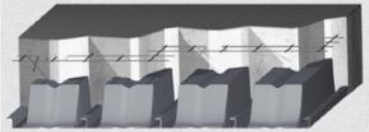
Based on preliminary studies, the joist and deck supplier presented three options: dovetail composite 3.5” (89 mm.) and deep-ribbed composite 4.5” or 6.0” (114 or 150mm.). All of the recommended options accounted for the prevention of long-term deflection. Variations among these options included depth of profile, total slab depth, load bearing strategies, shoring, and side lap attachments.

Types of Long Span Composite Floor Systems

Dovetail Composite

The decision to use a 3.5” dovetail composite deck on this project came down to a particularly distinguishing factor: while meeting other requirements, the dovetail composite floor presented a significantly thinner overall slab depth.

Engineering noted that the achievement of this narrower slab depth was offset by a slightly higher concrete volume, a cost variable to the total project that was considered nominal. The comparative accumulation gains in floor-to-floor height over the 20 floors became the prevailing factor for specification writers and project administrators.

PRELIMINARY DESIGN Normal-weight concrete floor slab Span conditions: 26’-1 – 23’-0 Design loads: SDL=20 psf LL=100 psf (corridor)			
PRODUCT DESCRIPTION	**6” DEEP-RIBBED DECK**	**4.5” DEEP-RIBBED DECK**	**3.5” DOVETAIL DECK**
Deck Height:	6.125”	4.625”	3.5”
Deck Gauge / Weight (psf):	20GA / 3.44	18GA / 4.09	18GA / 4.40
Deck Yield Strength, Fy (KSI):	50 / A653 Grade 50	50 / A653 Grade 50	40 / A653 Grade 40
Closed Ends:	Yes	Yes	No
DESIGN AND INSTALLATION			
Slab Design:	Simple Slab Design	Continuous Slab Design	Continuous Slab Design
Deck Installation:	Single Span	Single Span	Single Span
Shoring Required:	2 Rows @ Third Points	1 Row at Midspan	1 Row at Midspan
CONCRETE SUMMARY			
Overall Slab Depth:	**11.125”**	**10”**	**8”**
Volume (Cyd./100SFt.):	2.16	2.13	2.2
Density (PCF) / Strength (PSI):	145 / 4,000	145 / 4,000	145 / 4,000
Weight / Plus Deck (PSI):	84.6 / 88	83.5 / 87.6	86.1 / 90.5
SERVICEABILITY			
Restrained Fire Rating:	2 Hr. / UL D951 (Unprotected)	2 Hr. / UL D951 (Unprotected)	2 Hr. / UL D947 (Unprotected)

Types of Long Span Composite Floor Systems

Dovetail Composite

When left exposed as in the image, dovetail composite decks can provide a clean, linear, plank-like aesthetic that is appealing to many designers and occupants and suitable for many interior applications. Concealed fasteners contribute to the sleek look.

Optionally, the deck can be an acoustic control element to address goals related to both sound control and aesthetics.

The exposed deck is available with factory applied color for protection of the deck in corrosive environments.

Types of Long Span Composite Floor Systems

Other Variants

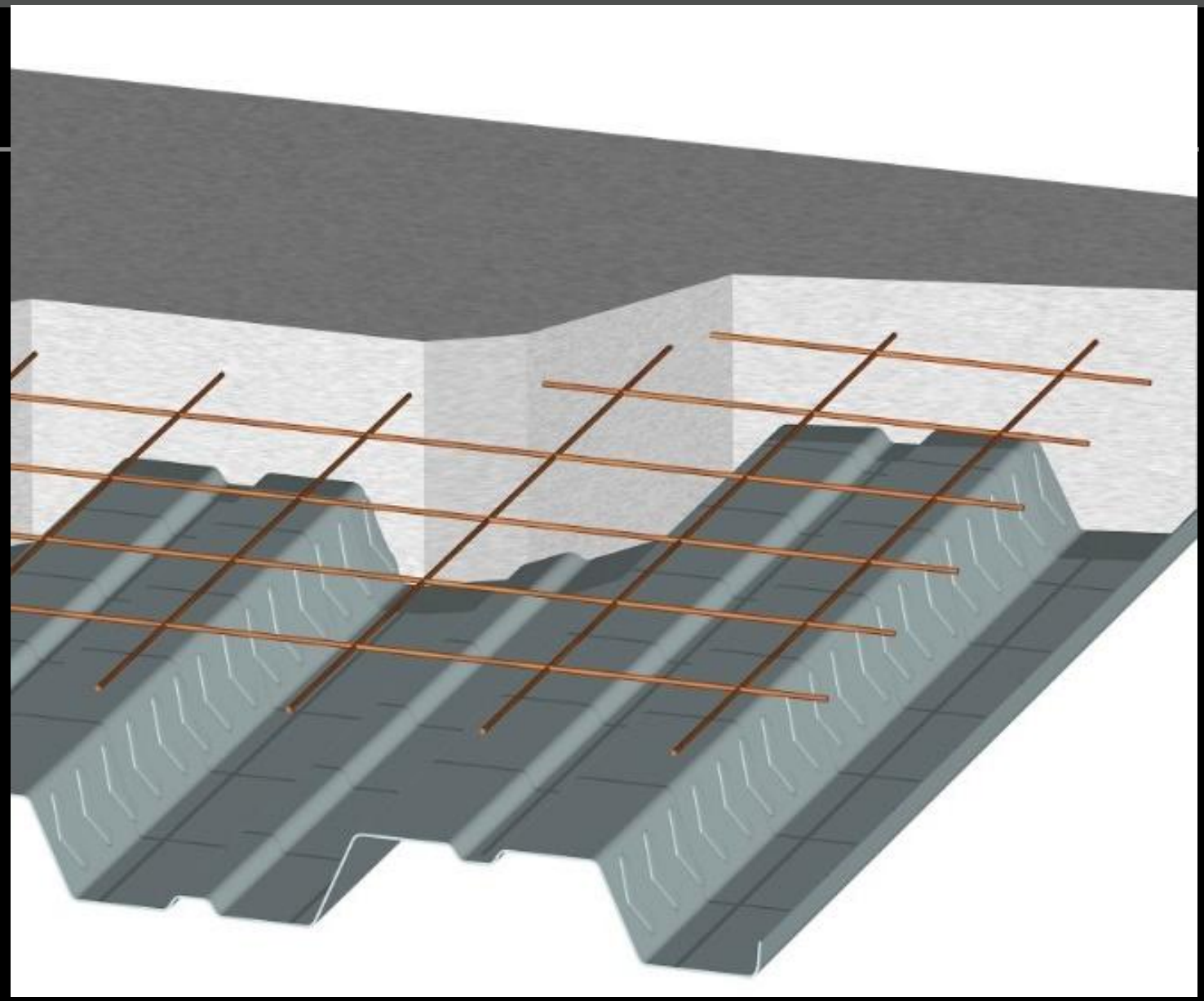
Prestressed Concrete Slabs

Hollow Core Concrete Slabs

Composite Beam

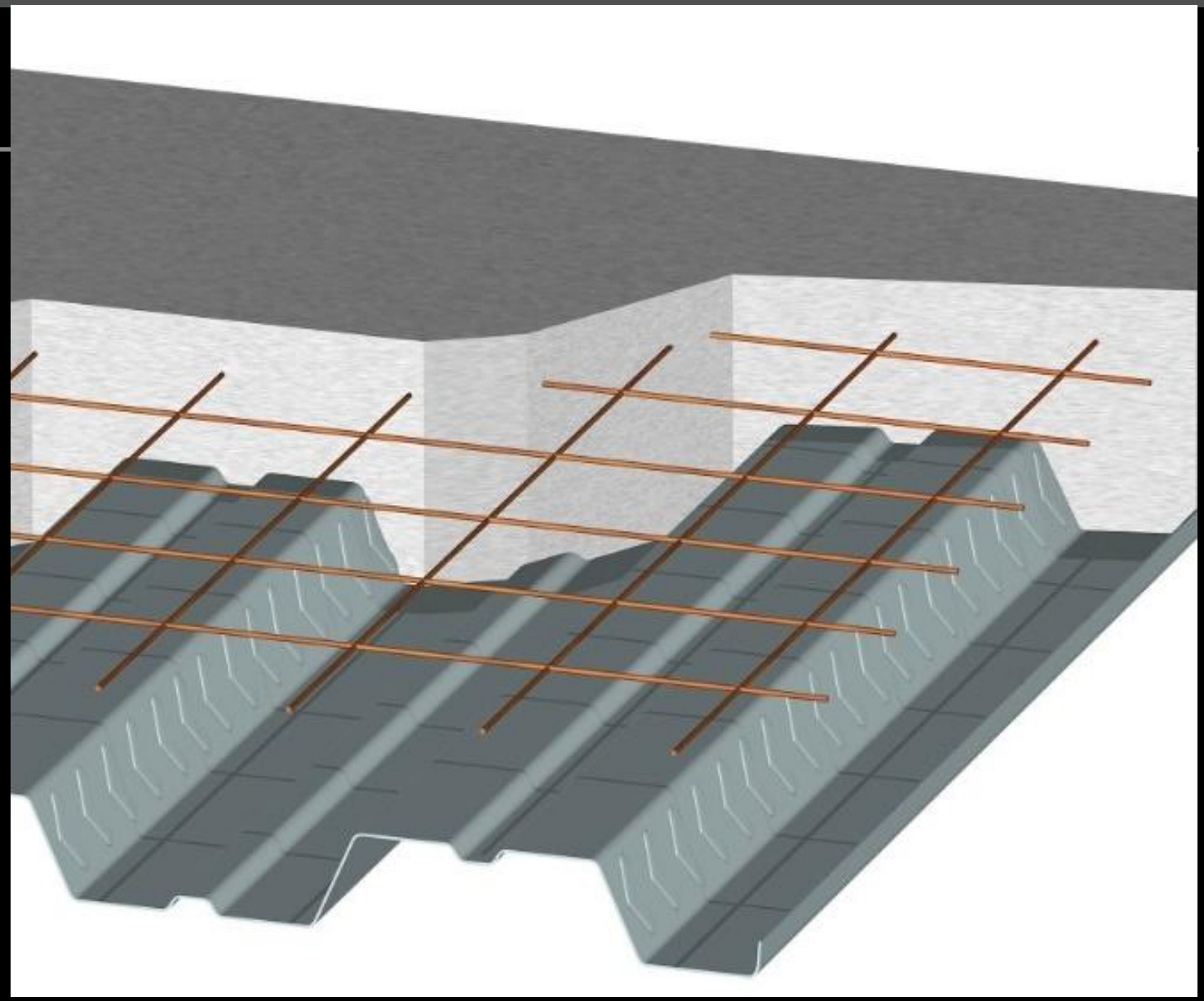
Review Question

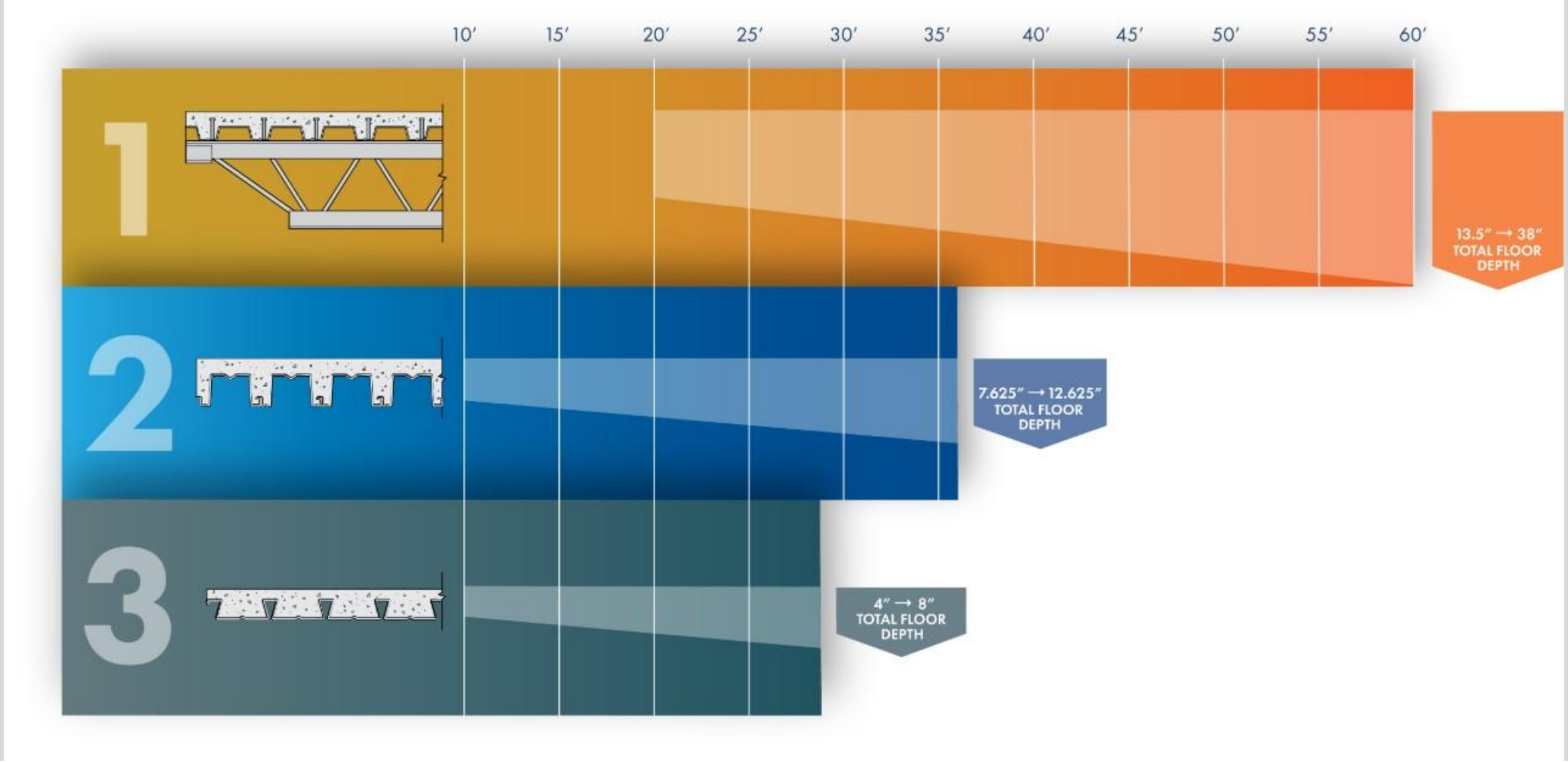
What does a composite deck slab generally consist of?



Answer

A composite slab generally consists of composite steel deck, structural concrete, and temperature and shrinkage reinforcement, which may be in the form of welded wire fabric, steel fibers, or synthetic fibers. Steel reinforcing bars are often added when design conditions dictate.





System Selection Criteria

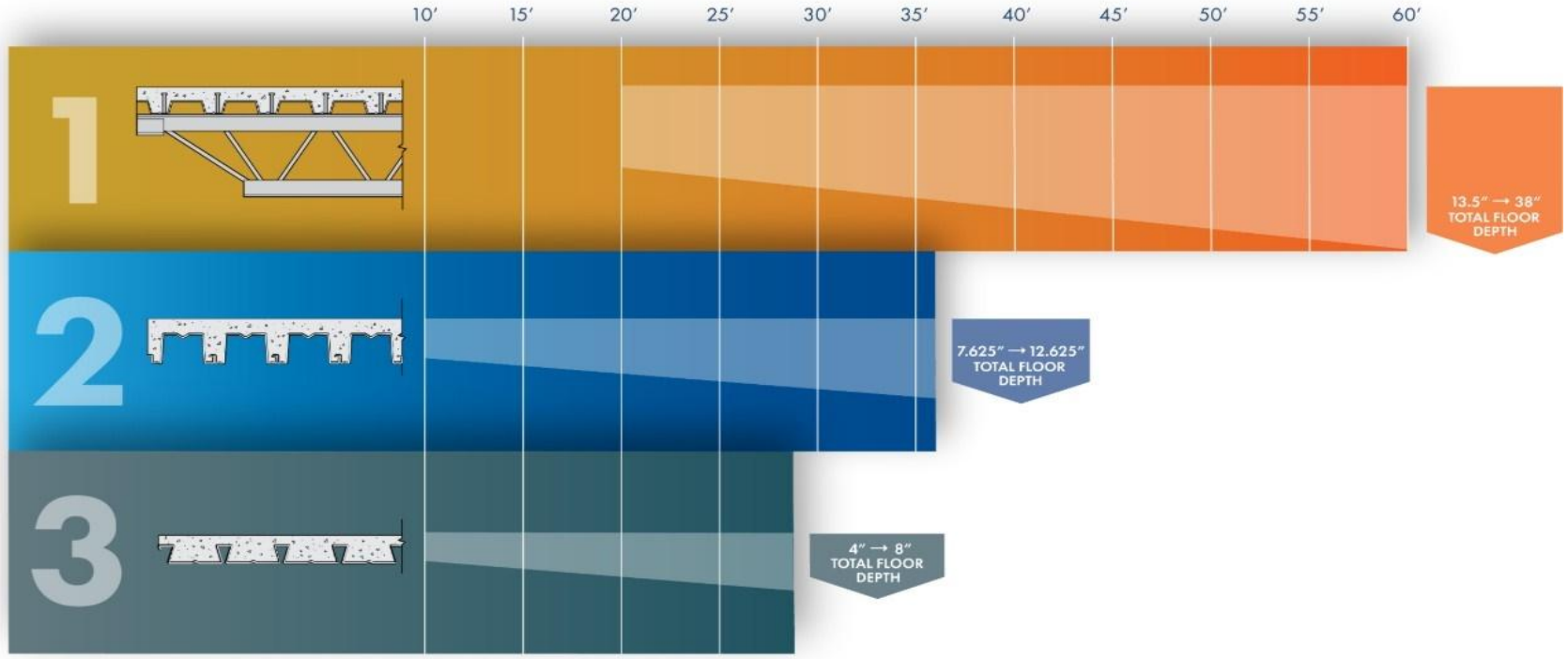
System Selection Criteria

As the previous slides have demonstrated there are many advantages to using long-span composite floor systems in multi-story construction and many things to consider when choosing the best system. In this section, we will explore the selection criteria for these systems. These criteria categories include:

1. floor span and depth
2. sound control
3. MEP Integration
4. UL Fire Protection
5. vibration control
6. constructability, and
7. aesthetics.

System Selection Criteria

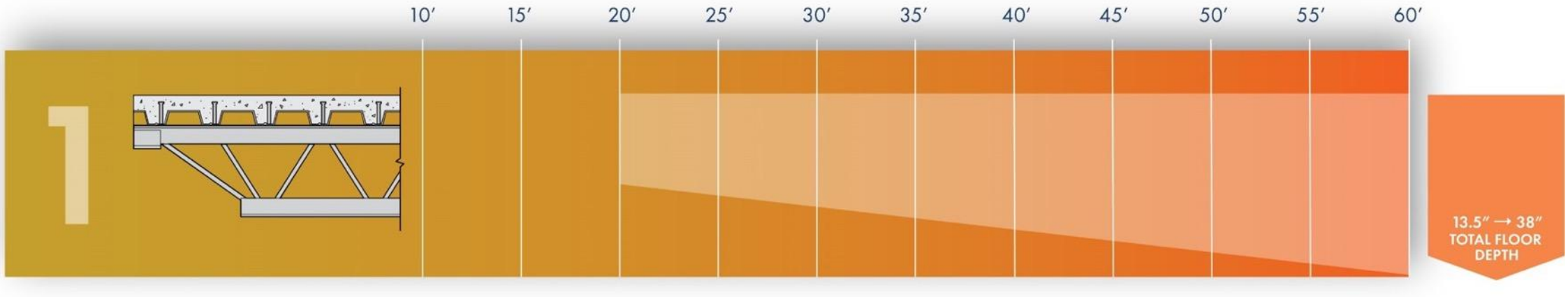
1. Floor Span and Depth



Long span composite floor systems blend the speed and versatility of steel with the performance and durability of concrete. These structural advantages often relate to floor span and depth. Span and depth comparisons for the three system options are illustrated in the diagram above and discussed further in this section.

System Selection Criteria

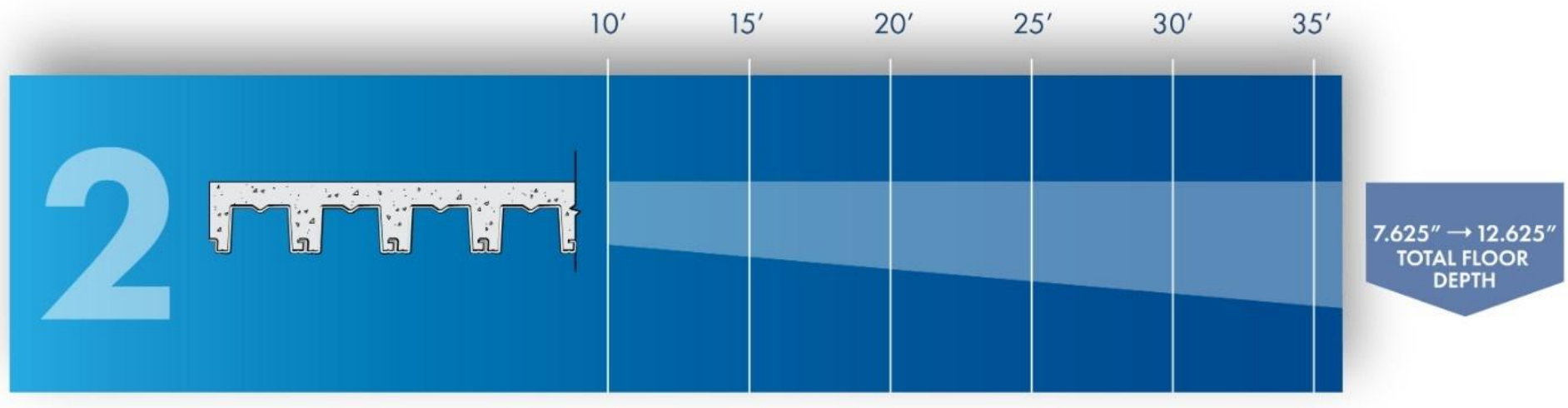
1. Floor Span and Depth : Composite Joists for Spans up to 60 ft. + (18M.+)



Composite joists allow for the longest clear spans -- up to 60 ft. (18M.) and more.
Note also how the total floor depth can be as low as 13.5″ (340 mm.) for a 20 ft. span with this system.

System Selection Criteria

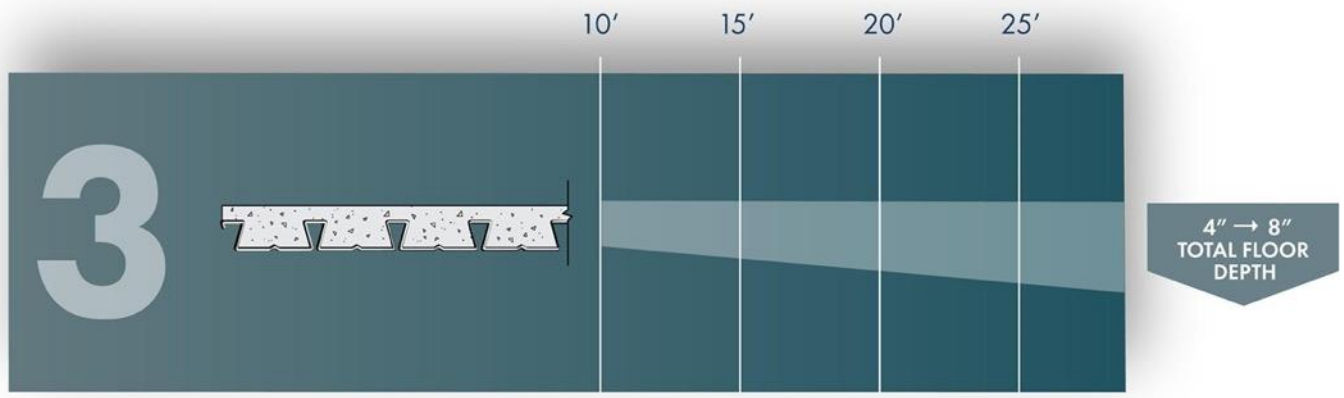
2. Floor Span and Depth: Deep-Ribbed Composite for Mid-range Spans up to 36 ft. (11M.)



If the project calls for an open, column-free floor expanse that is more mid-range, the deep-ribbed composite floor system will often be the optimal choice. This system establishes the shallow, thin slab floor concept without the added structural depth you see with the composite joist system. So, for example, this system can create a 36 ft. (11M.) open-span floor having a total floor depth under 13″ (330 mm.).

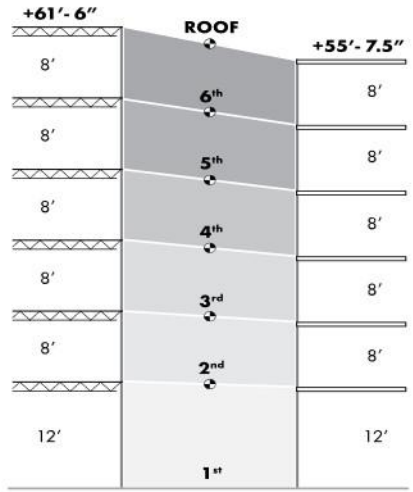
System Selection Criteria

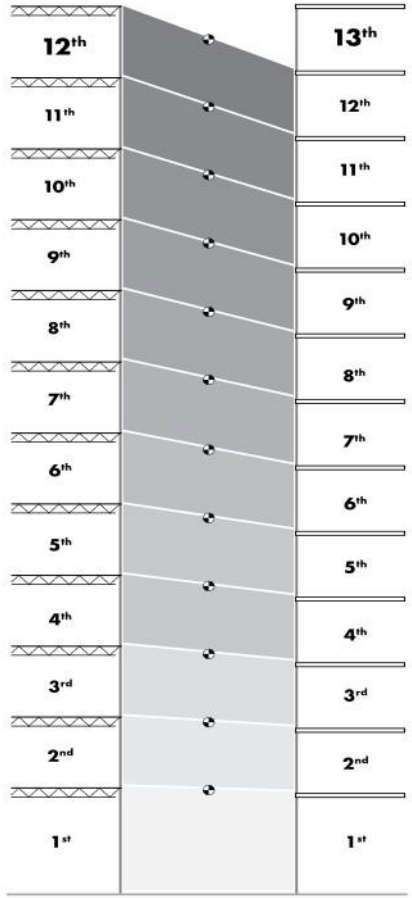
3. Floor Span and Depth: Dovetail Composite for Spans up to 28 ft. (8.5M.).



For lower-ranging floor spans, the dovetail composite floor will provide open spans up to 28 ft. (8.5M.). Here we also have an elegant, thin-slab floor; the thinnest possible. For many multi-story projects, the dovetail composite floor system is optimally based on floor span and depth. For example, this system can create a 28 ft. open span floor having a total floor depth of only 8″ (200mm.).

System Selection Criteria





A distinct advantage of a dovetail “thin slab” composite floor system is an increase in floor-to-ceiling heights, or, conversely, a reduction in floor to floor heights which can lead to an overall reduction in total building height.

The system is, therefore, ideal for buildings needing to meet height restrictions. For taller buildings, the degree of space optimization can sometimes translate into the addition of another floor within the originally planned building height.

A further advantage is that the weight of this system is 40% less than that of cast in place concrete (CIP) and this weight reduction translates into a reduced substructure.

The overall reductions in building height and substructure translate into reduced costs.

System Selection Criteria

2. Sound Control

Normally the building structure is not considered as part of any acoustic control system or solution but very often the design of a long span composite floor system is impacted by decisions related to sound control. Before discussing how this can occur it is useful here to review the relevant terminology that applies to sound control.

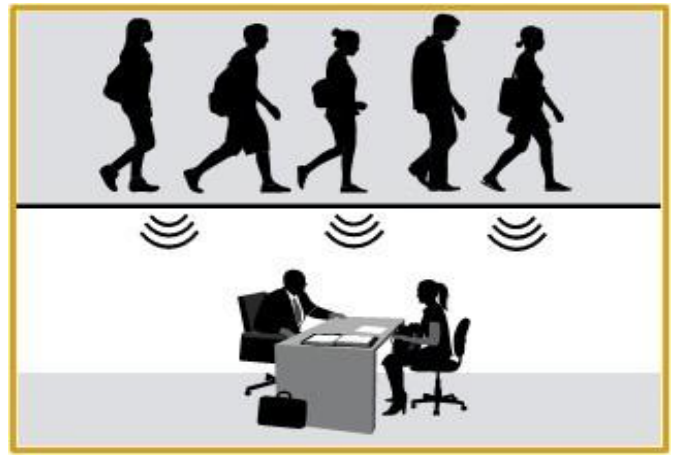
- **NRC** (Noise Reduction Coefficient) is a measure of airborne sound ***absorption*** by a wall, ceiling, floor, or material. NRC is measured between 0 and 1. An NRC rating of 0 indicates perfect reflection, meaning a material bounces 100% of the sound back into the room. An NRC rating of 1 indicates perfect absorption, meaning a material soaks up 100% of the ambient sound. **NRC** sound measures are typically of special interest in the design of multi-story **commercial** ambient sound spaces such as open office design, for example.
- **STC (**Sound Transmission Class) is a measure of airborne sound ***transmission*** and thus the ability of a wall, ceiling, floor or material to ***block*** sound from passing from one side to the other. The higher the STC rating, the better a material's ability to block sound. An STC rating of 50 during lab testing is the standard in many North American building codes.
- **IIC** (Impact Insulation Class) is specific to floor assemblies and measures a floor's ability to ***absorb impact sound,*** especially footsteps. An IIC rating is expressed as whole number. A larger number means more impact sound is being absorbed. A bare 6″ (150mm.) concrete floor will have an IIC score of about 25. Many building codes require a minimum IIC of 50. **STC** and **IIC** sound measures are criticalyl important in the design of **residential and hotel units**.

System Selection Criteria

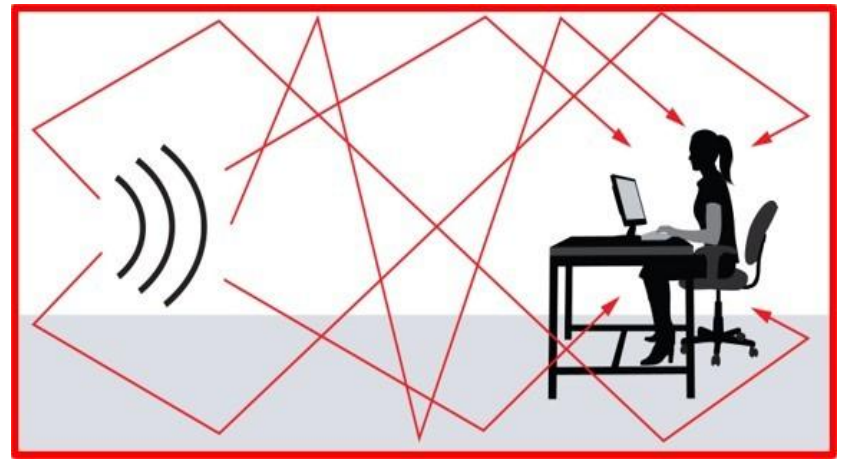
2. Sound Control: STC, IIC, NRC

IBC (International Building Code) code minimums are STC 50/ IIC 50

STC measures the blocking of airborne sounds



IIC measures the absorption of impact sounds

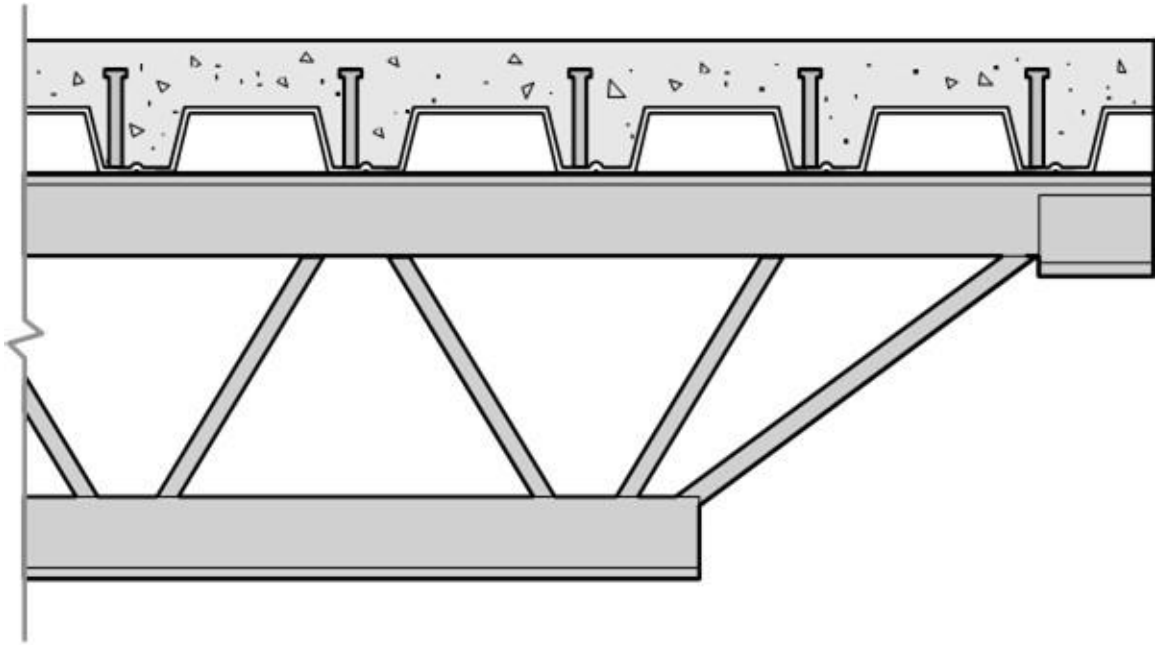


NRC measures the absorption of airborne sounds

The relevance of these different sound ratings become clear when specifying a long-span composite floor system. The relationship between floor and ceiling acoustical performance are integral. The ability to block airborne sound (STC), to absorb impact sound and block its transmission (IIC), and the ability to absorb airborne sound are all important when considering the comfort, health, and productivity of the people occupying the spaces created within these structures.

System Selection Criteria

2. Sound Control: Composite Joists



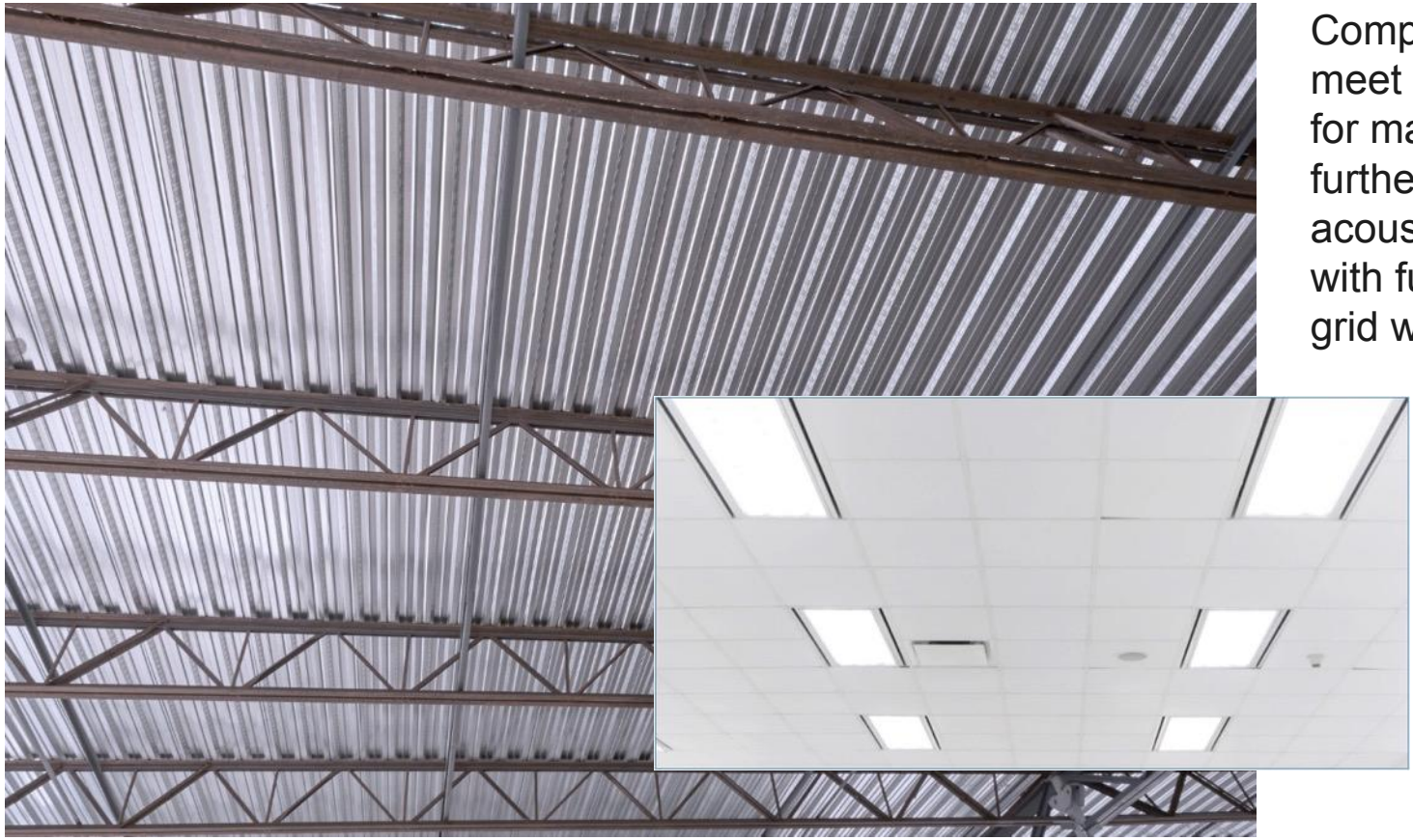
The acoustical performance of a composite joist system is partly determined by the acoustical properties of the composite decking that is fastened to the top of the joists.

The thickness and type of concrete, whether lightweight or normal weight, 4,000, 5,000, or 6,000 psi, (27579, 34473 or 41368.5437 kPa), and the deck profile establishes the base STC and IIC values for this system.

If the base value does not meet the overall acoustic requirements there are further measures which can be taken. These are discussed a bit later on.

System Selection Criteria

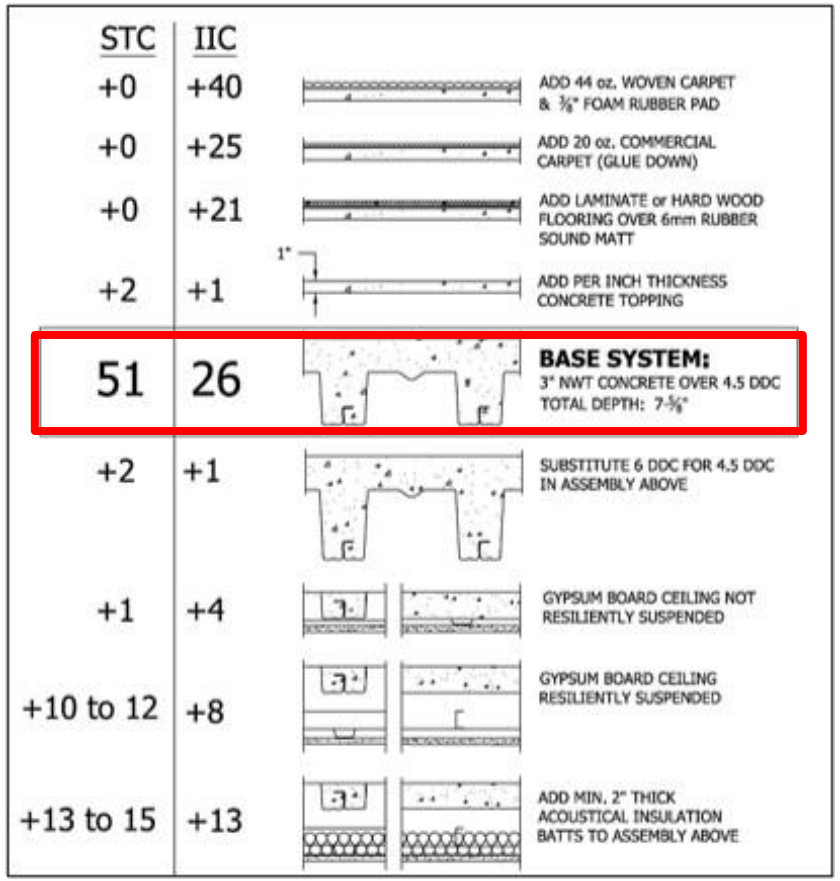
2. Sound Control: Composite Joists



Composite steel joist floor systems generally meet the IBC standard for sound control. But for many multi-story projects, sound can be further managed with the addition of an acoustical ceiling. The ceiling can be created with furring channels and drywall or a ceiling grid with lay in acoustical tiles (image).

System Selection Criteria

2. Sound Control: Deep-Ribbed Composite STC / IIC chart

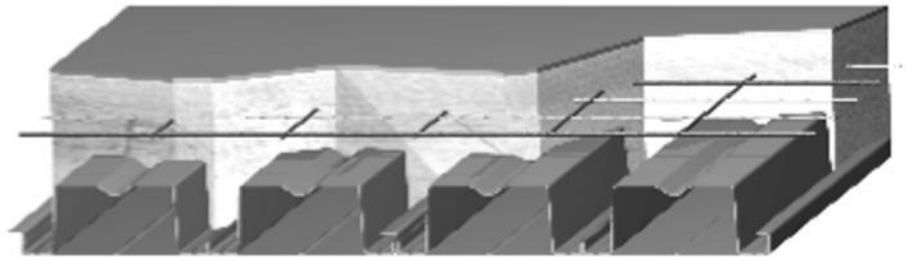


For the deep ribbed long span composite floor system, sound control starts with the floor's base system which in this case is composed of the steel deck and the hardened concrete. In the adjacent example the base construction provides an STC rating of 51 and an IIC rating of 26.

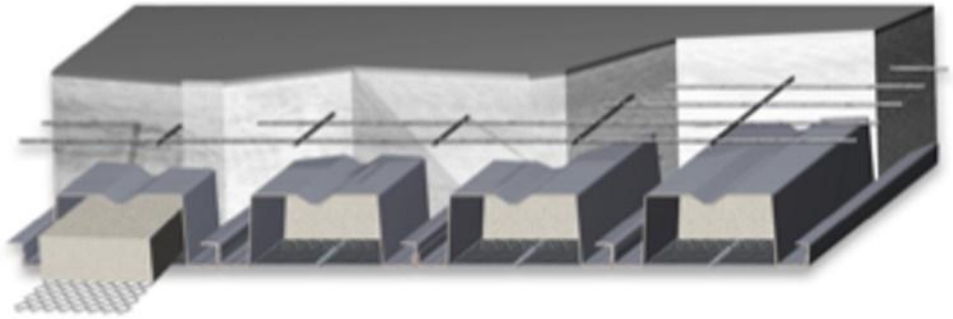
IIC can be increased by adding flooring or ceiling materials -- the most common of which are shown in this chart. These include resiliently suspended gypsum board ceilings, carpet, and acoustical insulation.

System Selection Criteria

2. Sound Control -- Deep Ribbed



Deep Ribbed Cellular Deck



Deep Ribbed Cellular Deck with Batting

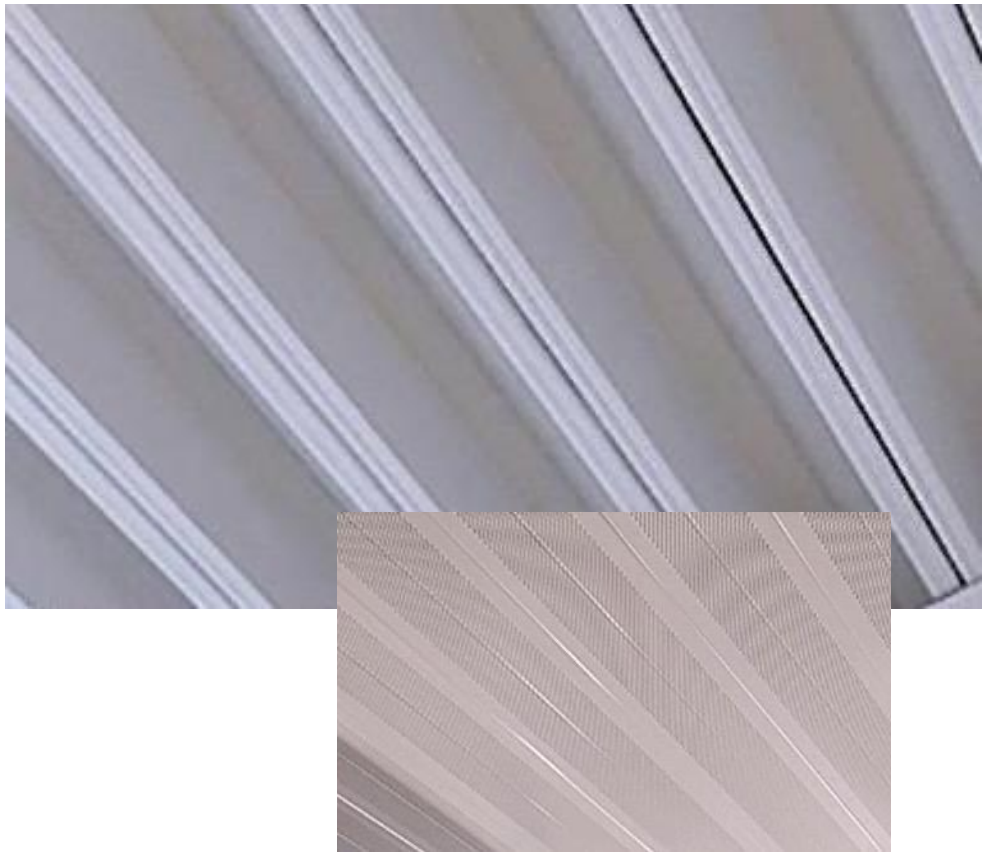
Liner panels are an option on all deep-fluted deck for projects wanting further spanning capability or to address ambient noise.

The flat liner panel is shop-welded to the deck hats and adds to the structural capacity of the profile in cellular or cellular acoustical options.

Cellular acoustical deck features an acoustical batting element in the deck cavity and yields exceptional NRC values.

System Selection Criteria

2. Sound Control



These images illustrate the correlation between sound control and ceiling aesthetics. By adding the cellular structure to the underside of the deep ribbed decking, the acoustical performance of the system increases, and the ceiling takes on a clean, smooth, linear plank appearance (lower left image).

The underside of the deck can be painted on site to match any color palette.

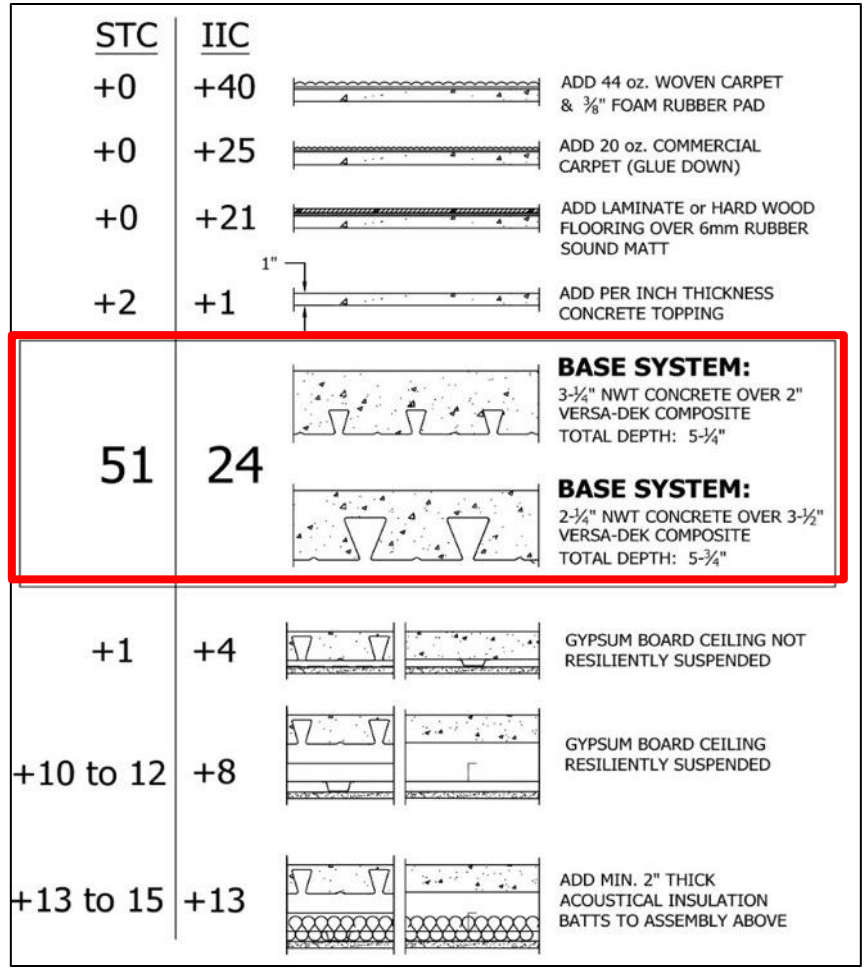
To prevent the clogging of the perforated acoustical deck, plastic lath is installed between the deck and the acoustical batting at the factory.

System Selection Criteria

2. Sound Control: Dovetail Composite STC/IIC Chart

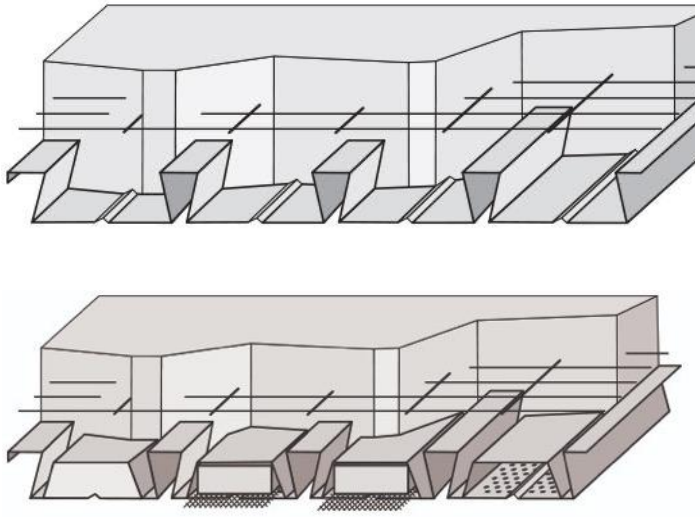
With the dovetail long-span composite floor system, sound control also starts with the floor's base system, which is also composed of the steel deck and the hardened concrete.

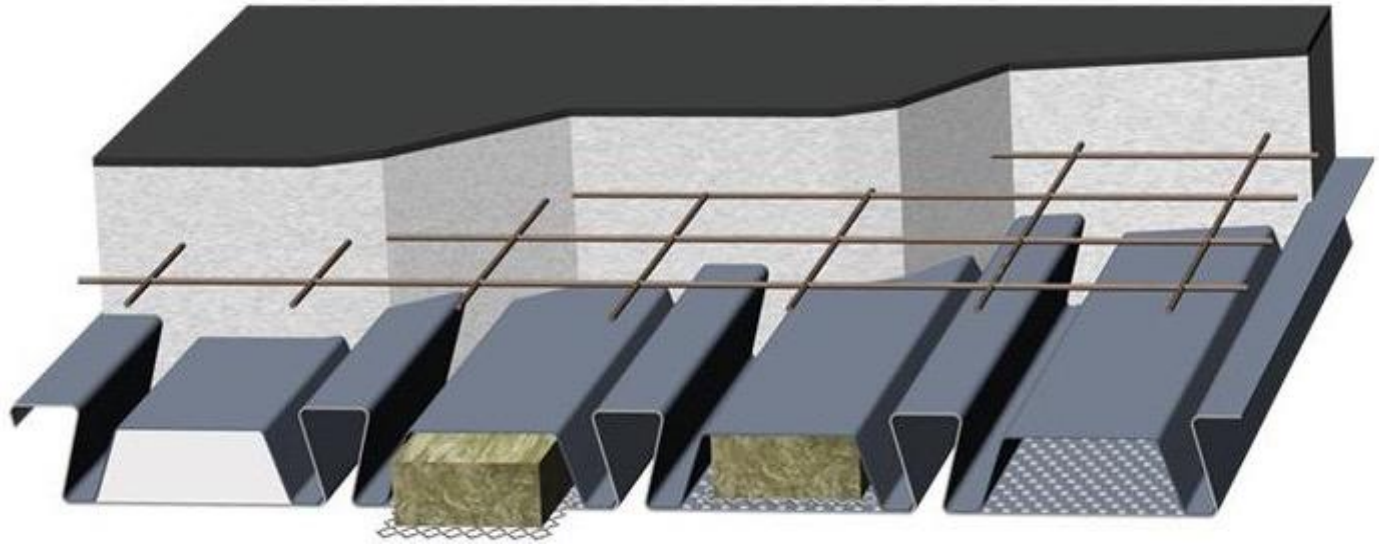
Here the base system already has an STC rating of 51 and an IIC rating of 24. IIC can be increased by adding flooring or ceiling materials -- the most common of which are shown in this chart and which are similar to the options for deep ribbed composite.



System Selection Criteria

2. Sound Control: Dovetail Composite Acoustical Deck with acoustical elements





To improve sound control further with this system, the steel deck can have an acoustical variation as well. In this dovetail profile, the acoustical elements are sealed off from the poured concrete using non-structural caps. The exposed bottom of the deck is perforated to absorb sound.

System Selection Criteria

2.0 Sound Control

Composite floor systems provide considerable flexibility in regard to sound control. Any one of these systems can be configured to deliver a desired sound control level. One option is to suspend a secondary ceiling using any number of materials, such as acoustical ceiling tile. Another option is to expose the composite acoustical floor deck as shown above.

System Selection Criteria

3.0 MEP Integration: Composite Joists

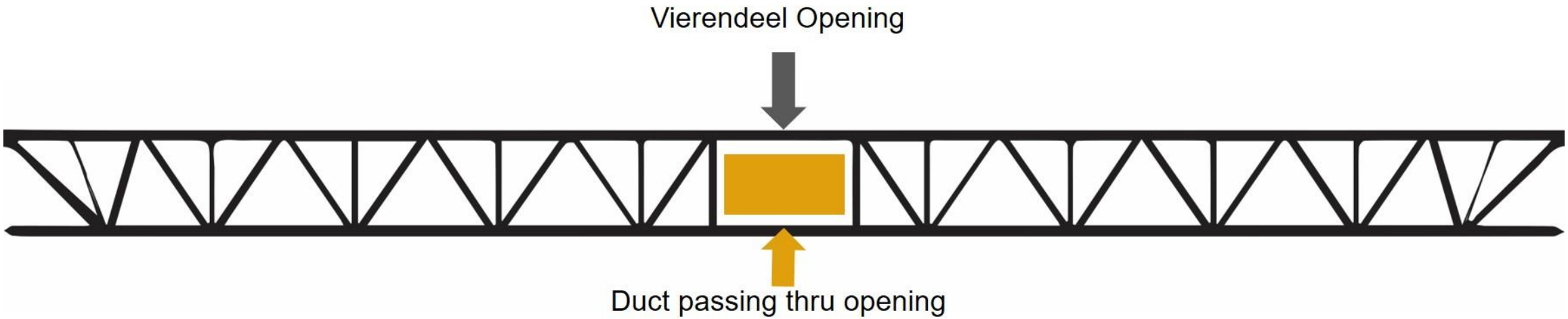
Composite joist systems can integrate MEP runs through the open webbing of the steel joists instead of under them as would be the case with wide flange steel beams or concrete T-beams.

A further benefit is that the MEP systems are still readily accessible after construction and in fact, for the life of the building.

Exposed systems can be readily accessed for inspection, repair, or replacement without damaging other building elements and this easy access represents cost savings.

System Selection Criteria

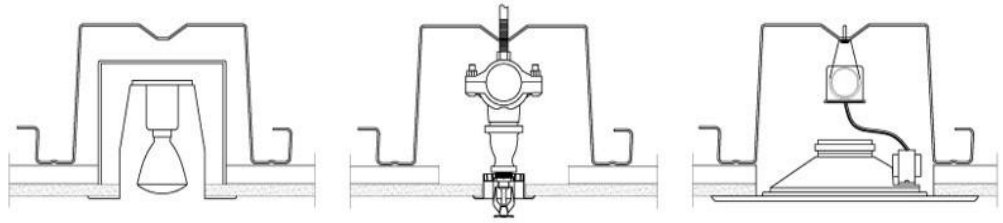
3.0 MEP Integration: Composite Joists

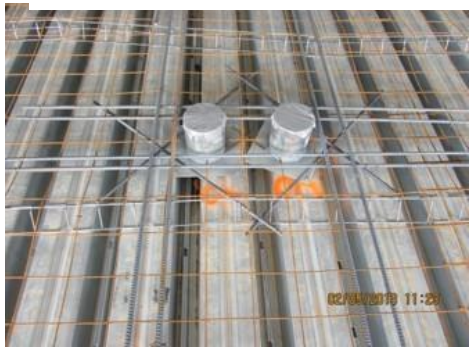


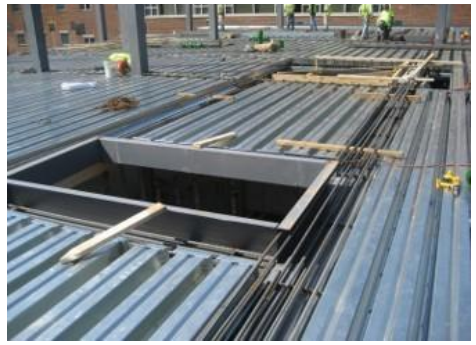
On some composite joist projects, larger MEP runs are addressed using what the trade calls “Vierendeel openings”. Arthur Vierendeel was a 19th century Belgian engineer who first determined that a rectangular framed opening is the most mathematically efficient way to create large open spaces within a truss. According to the Steel Joist Institute (SJI), locating the Vierendeel opening near the mid-span of a uniformly loaded composite joist will provide the most economical joist design. Differential shear across the joist chords will be at a minimum as one approaches the joist mid-span.

System Selection Criteria

3.0 MEP Integration: Deep Ribbed Composite Systems







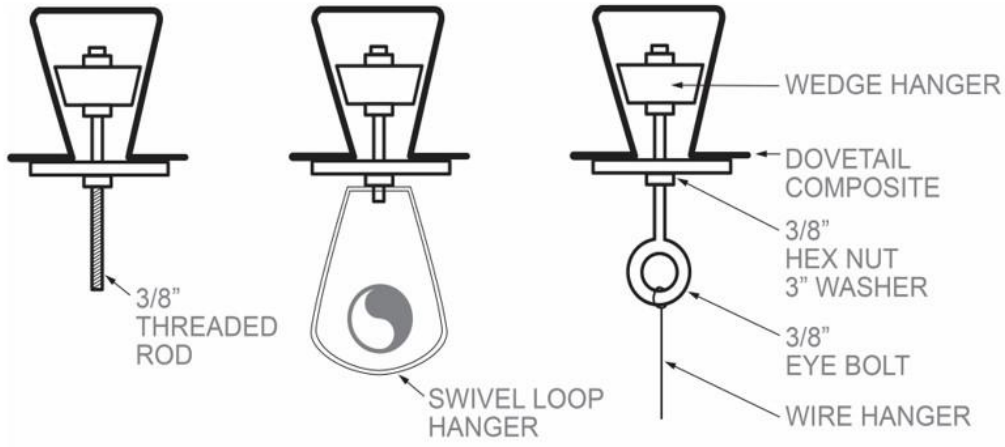
For deep ribbed composite floor systems, MEP integration methods are similar to those used by most composite deck. Unique to the deep ribbed profile is the ability to often place pipe sleeves, junction boxes and engineered openings within the deck profile itself. Deck inserts and drilled-in hangers can also be used to suspend services below the floor. MEP integration requires careful coordination for lighting, fire suppression, and electrical with the possibility of designing for access panels.

System Selection Criteria

3.0 MEP Integration: Dovetail Composite

There are hanging devices specific to the dovetail profile and which are designed to take advantage of the dovetail shape (see adjacent image). They are typically used to suspend lighting, plumbing, and ductwork.

The wedge-shape hangers are adjustable and can be relocated at any time if desired. This is more popular in exposed roof deck applications, as it avoids the need to permanently puncture the deck for any permanent or temporary hanging items such as signage.



System Selection Criteria

3.0 MEP Integration: Dovetail Composite

Preset pipe sleeves help streamline MEP service installations, while wedge shaped deck inserts and drilled in threaded rod hangers are used to suspend services below the floor. The engineered penetration of vent or sewage stacks is readily achievable.

System Selection Criteria

4.0 UL (Underwriters Laboratory) Fire Protection: Composite Joists

FLOOR – CEILING ASSEMBLIES WITH MEMBRANE PROTECTION

Restrained Assembly Rating	Protection Material	Minimum Joist Size[1]	Concrete		Unrestrained Beam Rating	UL Design Number[3]
			Minimum Thickness[2] (in.)	Type		
1 Hr.	Exposed Grid System	N736	2.5	LW, NW	1, 1½, 2, 3 Hr.	D216
						D219
1 1/2 Hr.	Exposed Grid System	N736	2.5	LW, NW	1, 1½, 2, 3 Hr.	D216
						D219
	Gypsum Board	N825		NW	1½, 2 Hr.	D502
2 Hr.	Exposed Grid System	N736	2.5	LW, NW	1, 1½, 2, 3 Hr.	D216
						D219
	Gypsum Board	N825		NW	1½, 2 Hr.	D502
	Gypsum Board	N736		NW	2, 3 Hr.	G547
3 Hr.	Exposed Grid System	N736	3.25	LW, NW	1, 1½, 2, 3 Hr.	D216
						D219
	Gypsum Board	N736	3.0	NW	2, 3 Hr.	G547

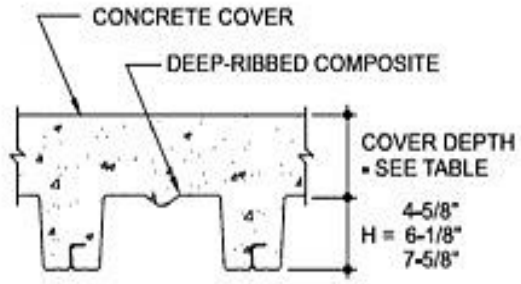
The Steel Joist Institute (SJI) refers to composite joists as “CJ-Series” composite joists. SJI reports that fire testing for CJ-Series composite joists has been completed by UL who conducted a full-scale fire endurance test of these joists and found them to meet the requirements of ASTM E119.

Per ASTM E119, CJ-Series composite joists specifically meet the fire test response standard applicable to assemblies of masonry units and to composite assemblies of structural materials for buildings, including bearing and other walls and partitions, columns, girders, beams, slabs, and composite slab and beam assemblies for floors and roofs.

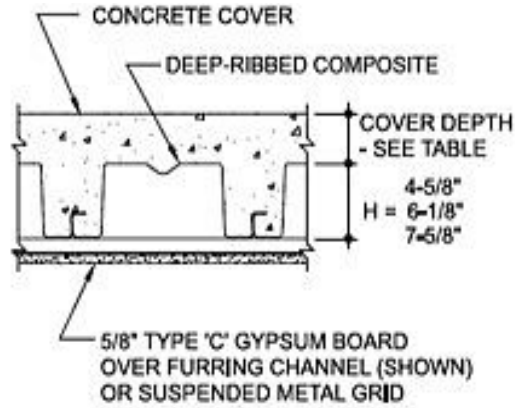
Chart courtesy of the Steel Joist Institute

System Selection Criteria

4.0 UL Fire Protection: Composite Joists



DESIGN NO.	Restrained Assembly Rating	Concrete Cover Depth[1, 2]	
		LWT	NWT
UL D960 UL D951 ULc F914	1-Hr.	4.25" [108 mm]	4.25" [108 mm]
	2-Hr.	5" [127 mm]	5" [127 mm]



DESIGN NO.	Restrained Assembly Rating	Concrete Cover Depth[1, 2]
		LWT
UL D501/ULc D501 UL D505	2-Hr.	2" [51 mm]

UL fire ratings can be met in various ways with this system which can have various profile depths, lightweight or normal weight concrete for the cover, a gypsum layer to protect the slab, or it can be unprotected. The thinnest version is fire-rated for one hour. A two-hour rating can be achieved using only a 2″ (50 mm.) lightweight concrete cover with a gypsum ceiling.

System Selection Criteria

4.0 UL Fire Protection: Dovetail Composite

Dovetail composite floor systems can meet UL fire ratings with the thinnest floor available. A 4″(100mm.) slab depth can provide a one-hour UL fire rating. A 6″(150mm.) slab can provide a 3-hour UL fire rating. The engineer of record (EOR)/ structural engineer is ultimately responsible for determining whether the composite deck is a restrained or unrestrained assembly. A dovetail composite floor system may be restrained within the internal structural bays of a building, but unrestrained outside of the bays or at the end bays. The slab can be made thicker on the exterior bays to then become a restrained assembly.

DOVETAIL COMPOSITE

Dovetail 2″ Composite		
Restrained Assembly Rating	Concrete Type	Total Slab Depth
1	NW	4"
1	LW	4"
1-1/2	NW	4-3/4"
2	NW	5-1/4"
2	SLW	5"
2	LW	4-1/2"
3	NW	6-3/4"
3	LW	5-1/4"
3	SLW	6"

UL Designs – D904, D917, D928, D961

Dovetail 3.5″ Composite		
Restrained Assembly Rating	Concrete Type	Total Slab Depth
1-1/2	NW	5-1/2"
1-1/2	LW	5-1/2"
2	NW	5-3/4"
2	LW	5-1/2"
3	NW	7-1/4"
3	LW	5-3/4"

UL Designs – D947, D964

Concrete Type and Density
NW–Normal-Weight 147pcf **SLW**–Semi-Lightweight 130 pcf **LW**–Lightweight 112 pcf

System Selection Criteria

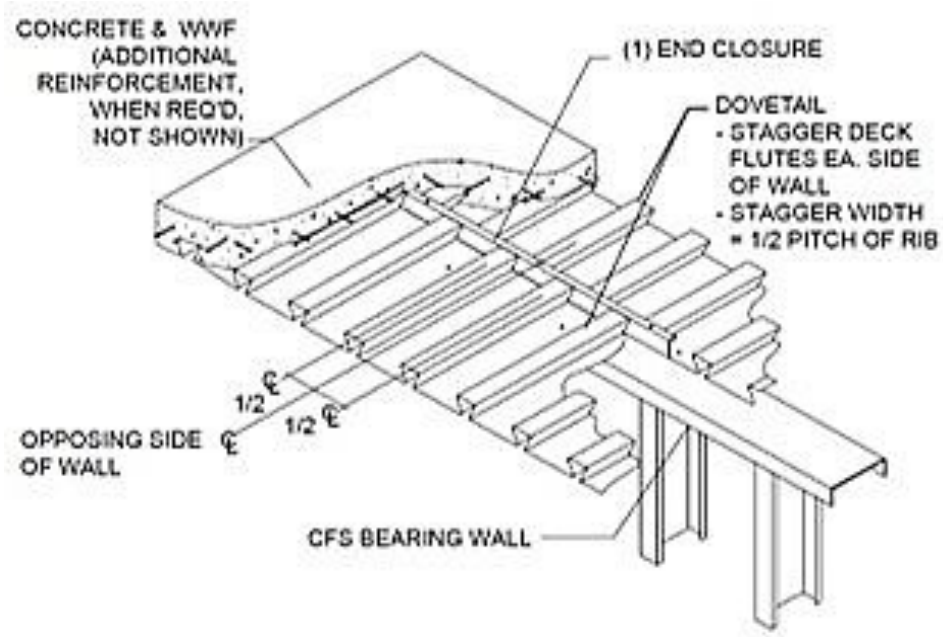
4.0 UL Fire Protection: Dovetail Composite

Dovetail 2″ Composite		
Restrained Assembly Rating	Concrete Type	Total Slab Depth
1 & 2	NW or LW	4-1/2"

UL Designs – HW-S-0062, HW-S-0127

Dovetail 3.5″ Composite		
Restrained Assembly Rating	Concrete Type	Total Slab Depth
1 & 2	NW or LW	5-1/2"

UL Designs – HW-S-0127



HEAD OF WALL FIRE-SOUND BREAK

There are also additional fire control advantages using a dovetail composite floor system. The dovetail pattern allows the staggering of the fluted sections to create a head-of-wall barrier to fire, smoke, and sound. Fire, smoke, and sound cannot pass from unit-to-unit, because they are sealed off. This eliminates expensive fire sealants in the deck flutes when set over cold-formed steel (CFS) bearing walls, at the head-of-wall .

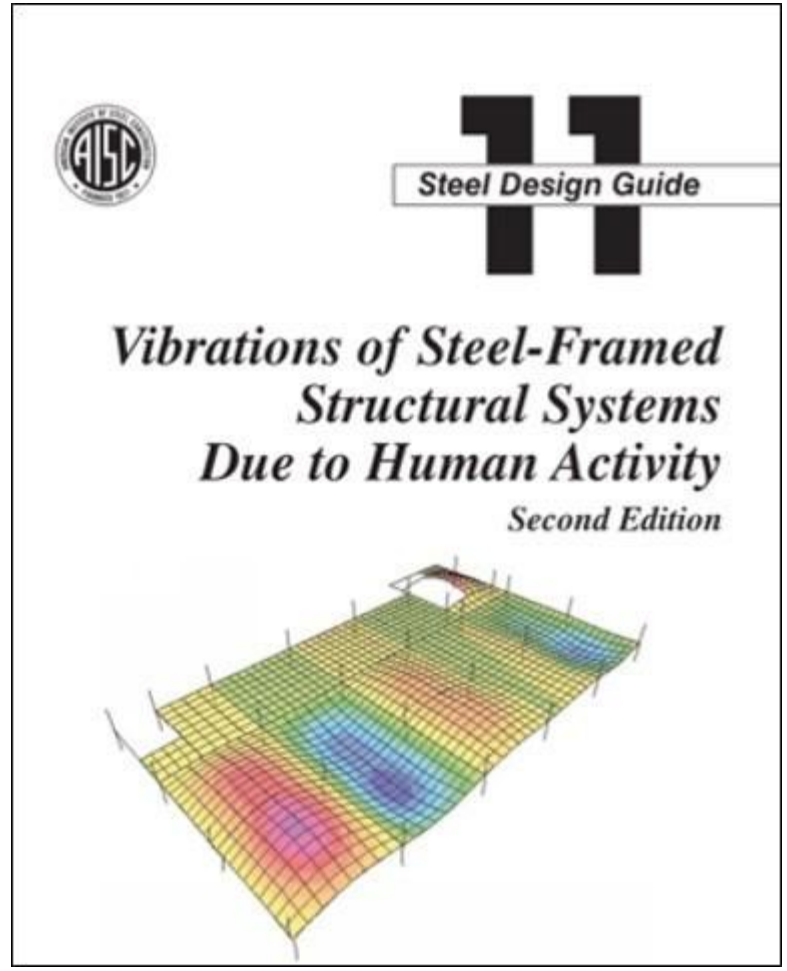
System Selection Criteria

5. Vibration Control

Floor vibration is a frequent and irritating and even damaging issue for building occupants, and also a clear concern among building owners. The concern extends to a range of residential and non-residential applications, such as the surgical wing of a hospital, laboratories, the sensitive electronic equipment warehoused in multi-story data centers, and the satisfaction and comfort of hotel occupants.

For almost any given long-span composite floor system, vibration is mainly controlled by slab thickness and weight, the span of the floor, the framing, partitioning and floor fit out. The specifying engineer can be guided by the vibration control design guide 11 published by the American Institute of Steel Construction (AISC) (adjacent image).

The criterion for vibration tolerances is based on occupancy type.



System Selection Criteria

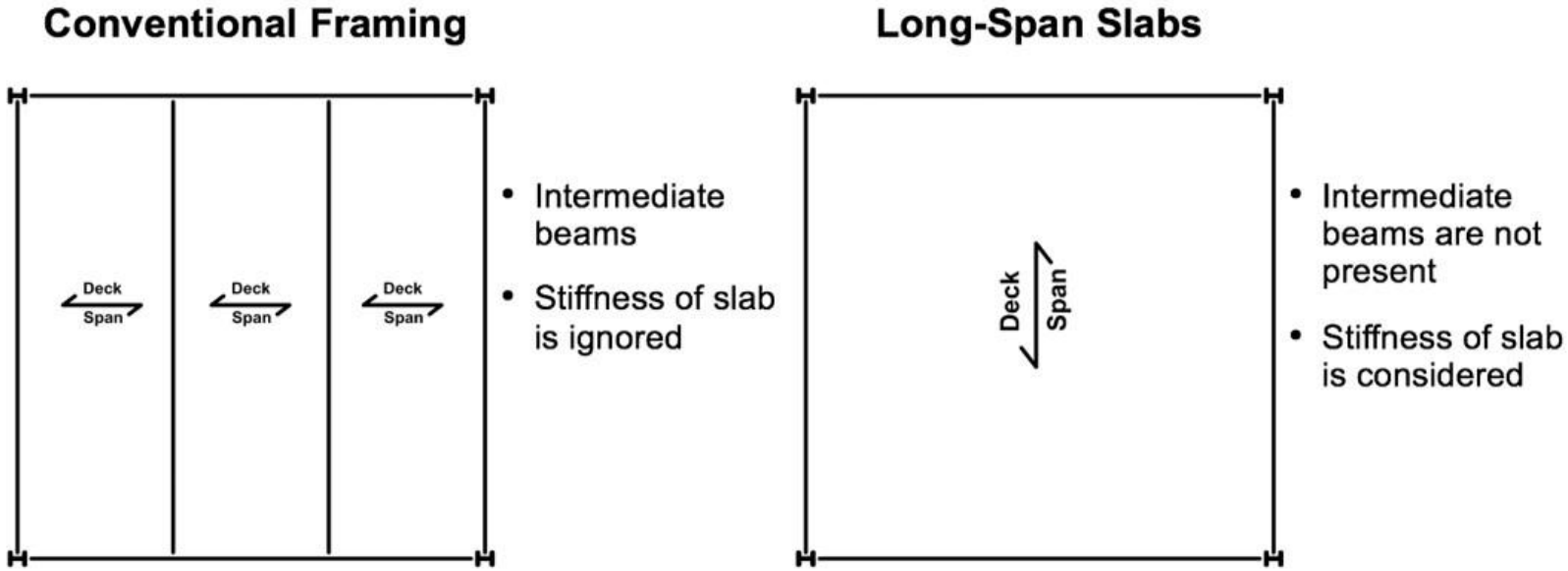
5. Vibration Control: Composite Joist System

A distinguishing feature of the composite joist system is the joist itself. According to the SJI, floors with joist spacings of 4 ft. to 10 ft. (1.2M. to 3.0M.) tend to have increased total concrete slab depths and greater mass to resist floor vibration. The calculation of vibration properties for these CJ–Series joists can readily be determined using floor vibration testing software developed by Structural Engineers Inc. (SEI).

The use of this software is explained within SJI's Technical Digest 5. The digest can be very helpful to even the most experienced steel joist specifier. However, the design professional who is not very familiar with steel joist specification may find that for a particular joist depth, a range of steel joist chord sizes are available. The right choice will not only answer the need for vibration control but will address related considerations including total project cost. For this reason, it is often more expedient to collaborate early with the steel joist manufacturer's engineering team.

System Selection Criteria

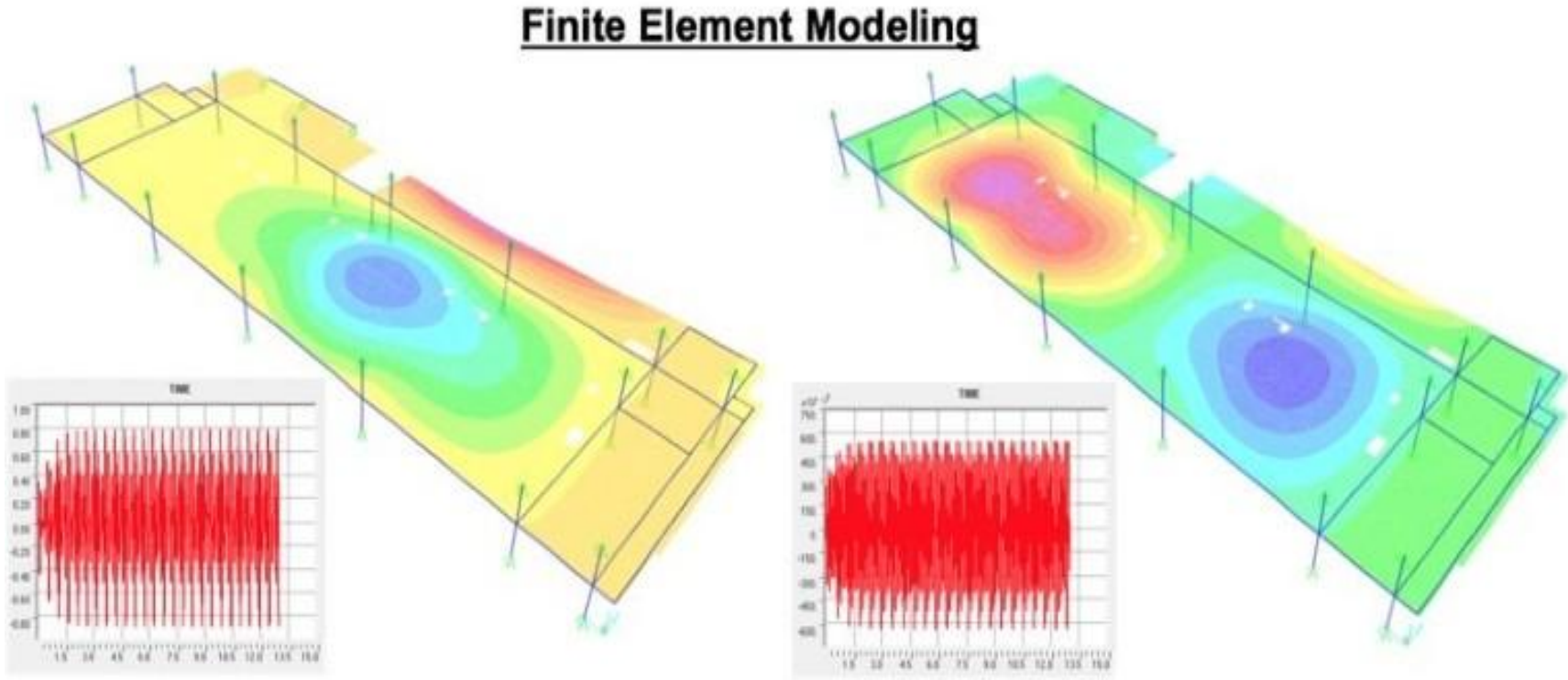
5. Vibration Control



The principles of the vibration analysis method described in AISC Design Guide 11 can be applied to the simplified analysis of floors with long span composite slabs when slab framing layout is regular as shown on this slide. The simplified method of Design Guide 11 cannot be used directly for long span composite slabs because it is based on consideration of flexural stiffness of intermediate beams. The long span slabs are typically used without intermediate beams so the flexural stiffness of the slab should be accounted for in the vibration analysis of long span slab floor instead of the stiffness of the intermediate beams.

System Selection Criteria

5. Vibration Control



When the floor framing is irregular with considerably unequal spans and/or with slab and beam cantilevers, finite element analysis of walking-induced floor vibrations is the only available reliable method. Here again, the specifying professional is encouraged to collaborate with the system supplier’s engineering team.

System Selection Criteria

6. Constructability: Framing Options

Long span composite floor systems contribute to construction efficiency in various ways, owing to their structural differences. All three types of long span composite floor systems can integrate with a range of framing options. A composite joist floor system is typically supported by wide flange beams or concrete walls. The deep ribbed and dovetail type floor systems can integrate with additional framing options as shown below; left to right: upset wide flange beams, steel plate systems, and steel channel beams.

Steel Channel

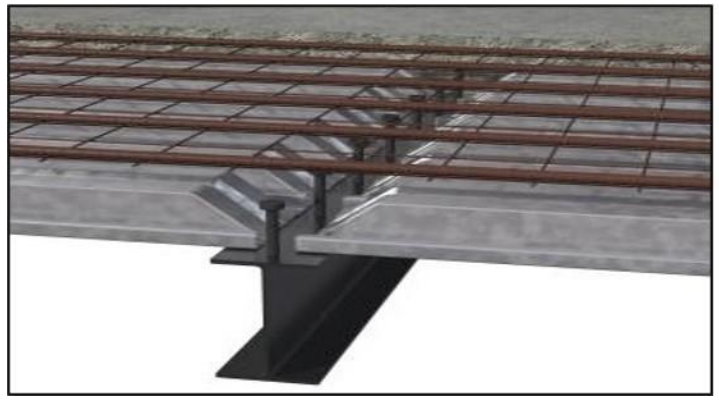
Steel Plate Beam

Upset Wide Flange Beam

System Selection Criteria

6. Constructability: Framing Options

Further framing options that can be used with the dovetail system are shown below.



Wide Flange Beam

Concrete Walls

Existing Structure

System Selection Criteria

6. Constructability: Cold Formed Steel

Cold formed steel (CFS) framing is light weight, extremely strong, noncombustible, and relatively easy to install. This method of framing is used for many kinds of multi-family residential: student dormitories, assisted living facilities, and hotels. CFS framing is now being used for projects exceeding 10 stories. CFS framing can be panelized off-site and delivered sequentially with the steel decking. The range of steel deck options includes dovetail composite and deep deck composite, for lighter weight, rapid construction. The space saving attributes of CFS stack especially well with the “thin slab” dovetail composite and deep deck composite floor profiles.

System Selection Criteria

6. Constructability: Temporary Shoring

The required use of temporary shoring during construction to support the weight of the poured concrete floor is an important engineering consideration.

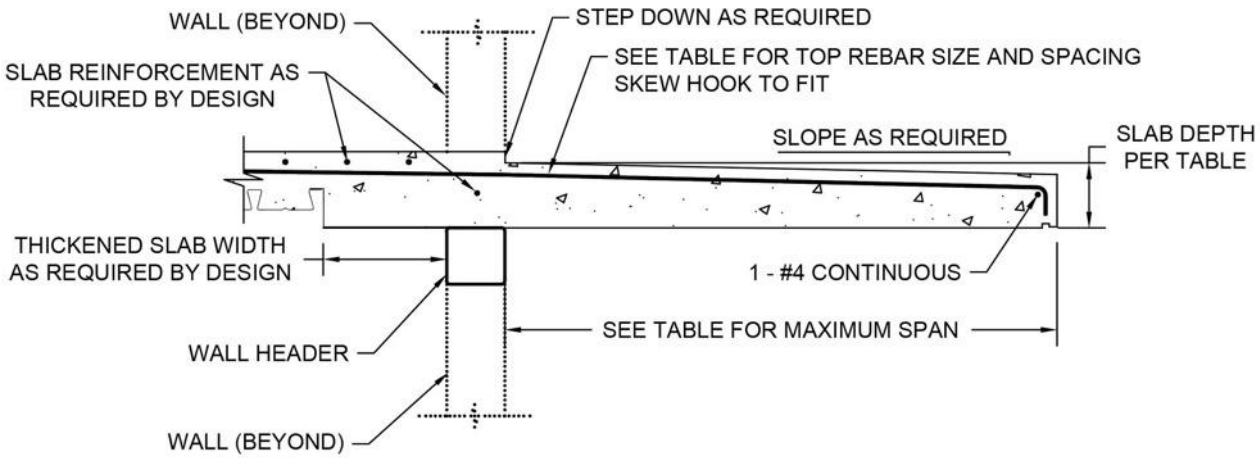
Shoring requirements will, of course, vary with the type of long-span composite floor system being considered.

Shoring requirements are the responsibility of the shoring engineer.

As noted earlier, careful system choice can even eliminate the need for temporary shoring.

System Selection Criteria

Constructability: Balconies



FORMED CONCRETE BALCONY SLAB

Balconies present a unique set of design factors, including their cantilevered structural integration, load considerations, required sloping, and aesthetic appearance. The specification of these structures is guided by the American Concrete Institute's (ACI) standard 318-14 -- *Building Code Requirements for Structural Concrete and Commentary.* Dovetail composite and deep ribbed composite floor systems can be engineered to elegantly address these requirements.

System Selection Criteria

6. Constructability: Panelizing

Deep ribbed composite deck sections can be panelized or assembled on grade and then lifted into place.

Often referred to as a panelized delivery method, erection time can be accelerated.

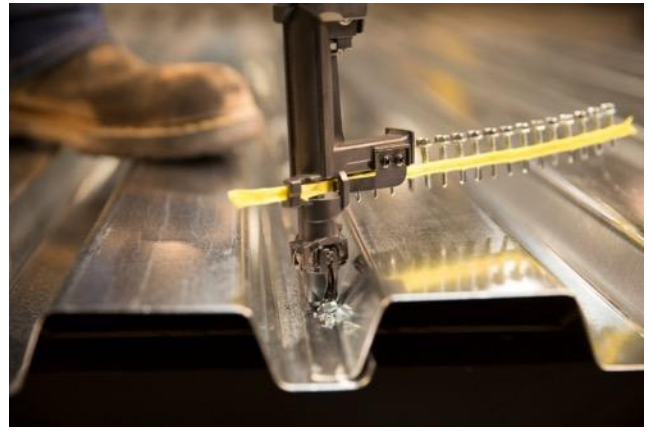
An added bonus is that the installed decking then serves as a much safer platform for workers as compared to the steel framing.

System Selection Criteria

6. Constructability: Deck Fastening

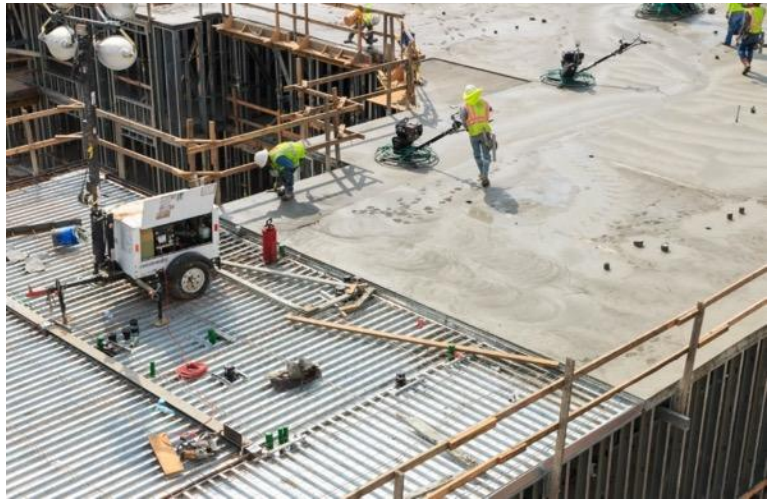
Traditional deck fastening: Deck is traditionally attached to the building frame with arc spot welds, also referred to as “puddle welds”, or by using self-drilling screws or powder or pneumatically driven pins. Sheet-to-sheet fastening is traditionally done with screws, button punching (crimping), clinching or welds.

Automated deck fastening: The use of automated steel deck tools can accelerate deck installation and reduce costs to the project. Deck fastening tools on the market today can perform both side lap stitching and support fastening. Deep ribbed composite deck floors can especially be installed more efficiently using this method, at a rate of up to 25 linear ft. (7.6M) per minute.



System Selection Criteria

6. Constructability: Loads During Construction

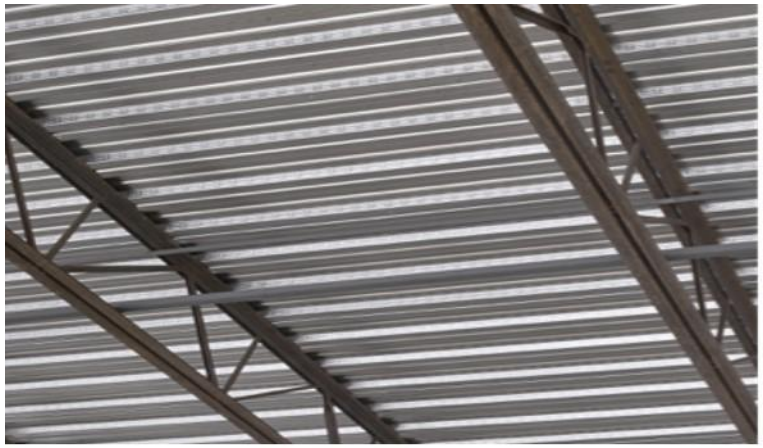


Operational Class	Uniform Load (psf)
Very light duty: sparsely populated with personnel; hand tools; very small amounts of construction materials	20
Light duty: sparsely populated with personnel; hand operated equipment; staging of materials for lightweight construction	25
Medium duty: concentration of personnel; staging of materials for average construction	50
Heavy duty: material placement by motorized buggies; staging of materials for heavy construction	75

Motorized concrete finishers can be used on the deck if an appropriate construction live load was used in the design of the deck as a form. ANSI/SDI C-2017 specifies the minimum uniform construction live load of 20 psf.(.95 kPa) in addition to the weight of fluid concrete, which should be used in the design unless heavier loads are specified in the contract documents. If special heavier construction live loads were not specified in the contract documents, which is often the case, the deck manufacturer will assume the minimum construction live load given in the SDI standard. ASCE 37 lists motorized concrete finishers under Medium Duty Operational Class, which requires the deck to be designed using the construction live load of 50 psf. (2.39 kPa) or even greater.

System Selection Criteria

7. Aesthetics



Composite Joists

Dovetail Composite

Deep Ribbed Composite

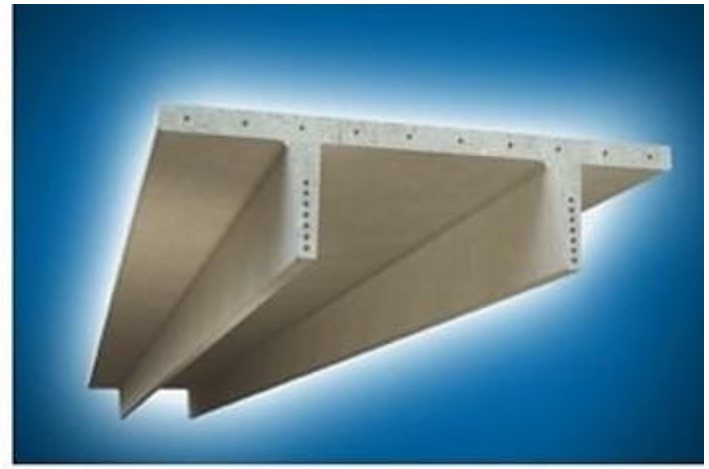
The final criteria, and of particular interest to the architect, will be the range of aesthetic options afforded by long span composite floor systems.
These images show how the aesthetics of a long span composite floor system will vary based on the structural profile. For the longest floor spans, the composite joist floor system has an industrial aesthetic when left exposed. For mid range floor spans, the underside of the deep ribbed composite floor is characterized by a distinct linear shadow pattern and for the lower range of floor spans, the underside of the dovetail composite floor offers a variety of linear plank aesthetics.

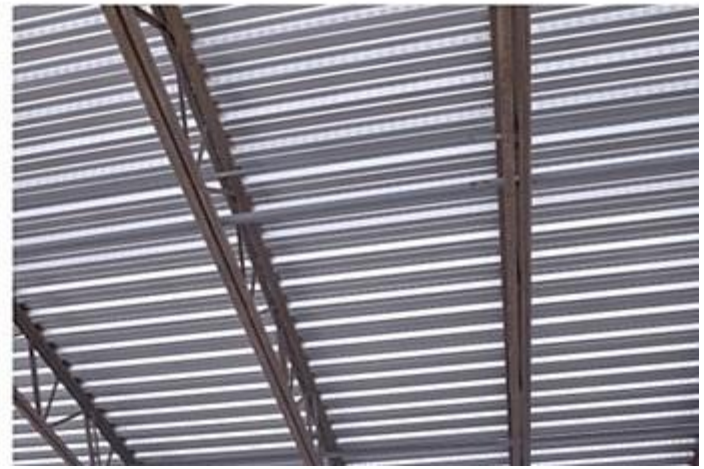
System Selection Criteria

7. Aesthetics: Composite Joists

Composite joist floor systems are generally lighter and less bulky than other concrete integrated floor systems, such as precast concrete, conventional reinforced concrete, and post-tensioned concretes because the beams supporting the slab are typically solid structures, such as wide flange steel beams.

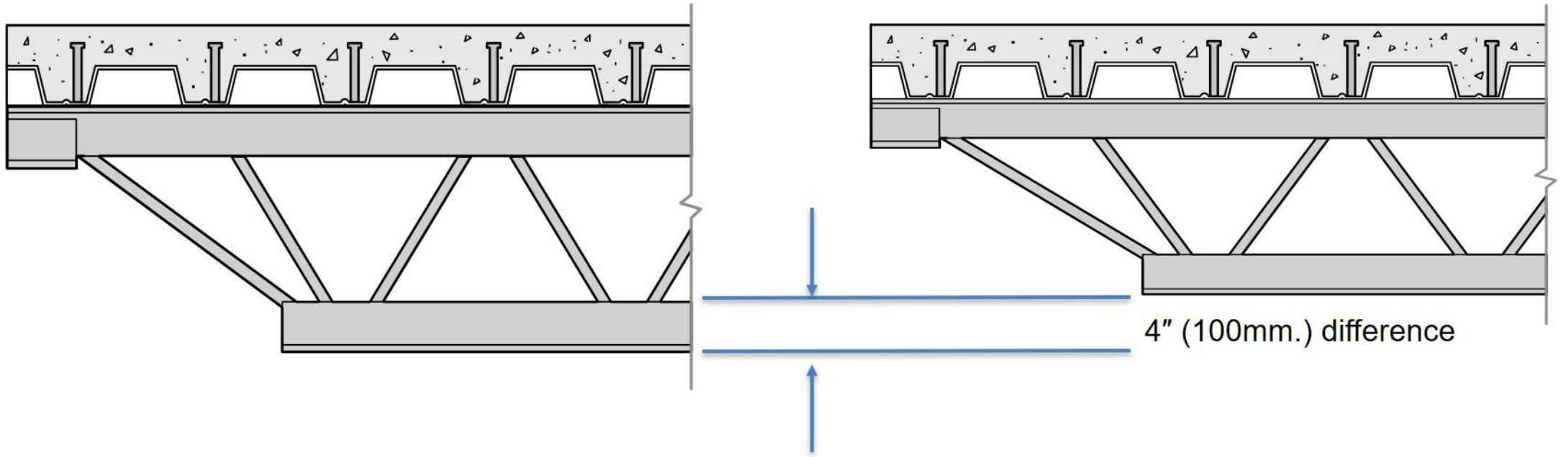
Traditional steel joists can, of course, be used to support the concrete slab, but a traditional steel joist floor system will typically be heavier and deeper than a composite steel joist floor system.





System Selection Criteria

7. Aesthetics: Standard Joists vs Composite Joists.



To illustrate this difference, we can compare a 48ft. (14M.) concrete span using a standard joist with a depth of 24″ (609 mm.). If this were a composite joist system, the same 48 ft. (14M.) span could be engineered using a composite joist system, where the joists would have a depth of only 20″. (500 mm.) thus establishing a 4″ (100mm.) shallower depth. For multiple floor structures this can be a significant saving. i.e. a 20 story structure would be reduced by 6.5 ft.(1.9M.)

System Selection Criteria

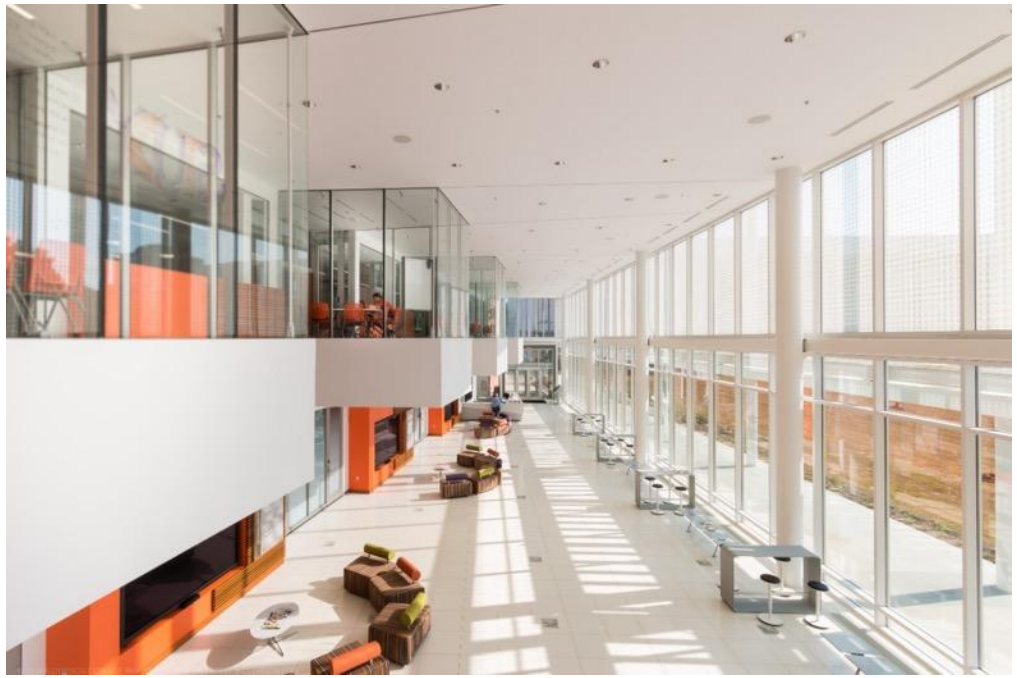
7. Aesthetics

It has been noted previously that when a composite joist floor system is left exposed, it presents a ceiling aesthetic that is industrial and minimalistic.

For this auto dealership, the system was left exposed to aesthetically support the edginess of the brand name. Meanwhile, the system structurally supports the actual cars on the second-floor showroom.

System Selection Criteria

7. Aesthetics

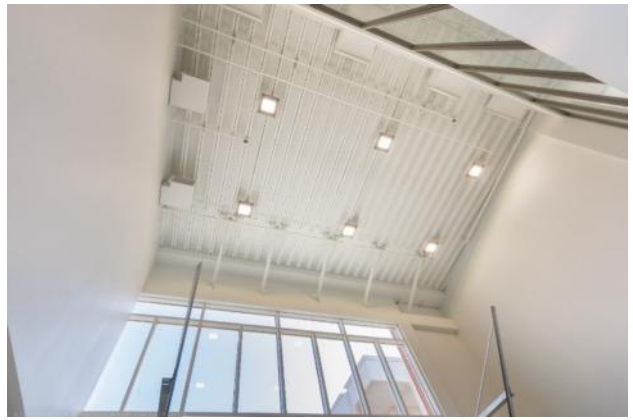


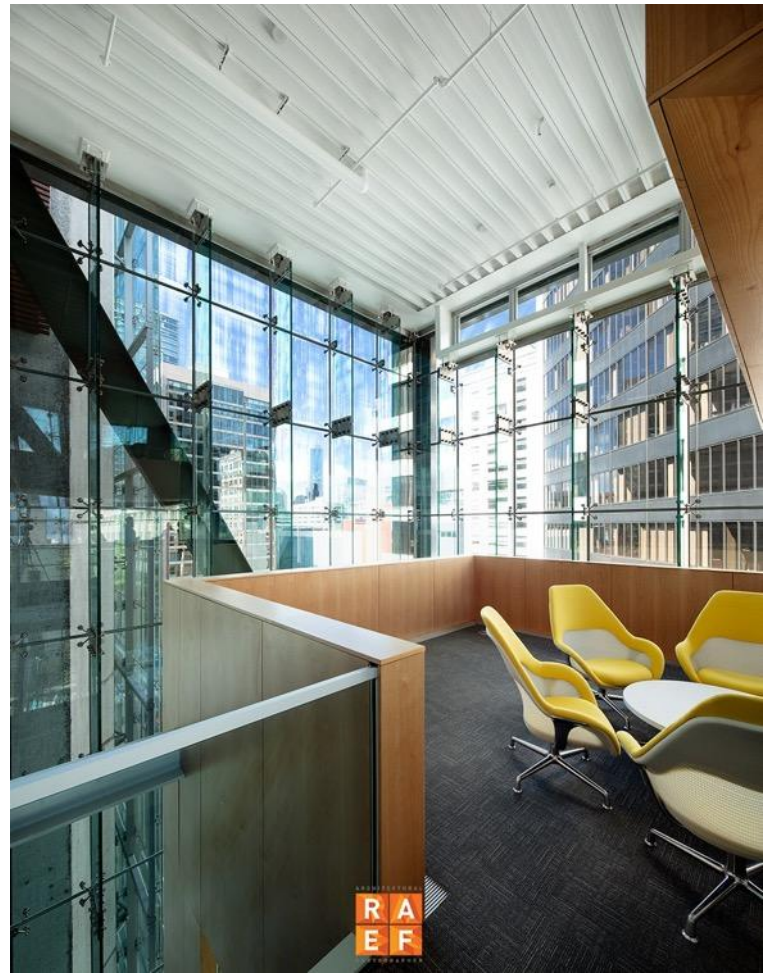
For a composite joist system, the addition of a dropped ceiling to add additional sound control will significantly alter the ceiling aesthetics.This opens up a range of drop ceiling based aesthetic options. Alternatively, gypsum board ceilings can be affixed to improve fire safety, and to add painted options.

System Selection Criteria

7. Aesthetics: Deep Ribbed Composite

The deep ribbed long-span composite floor system offers a very different ceiling aesthetic. The look can be enhanced by a wide range of colors using field applied coatings.





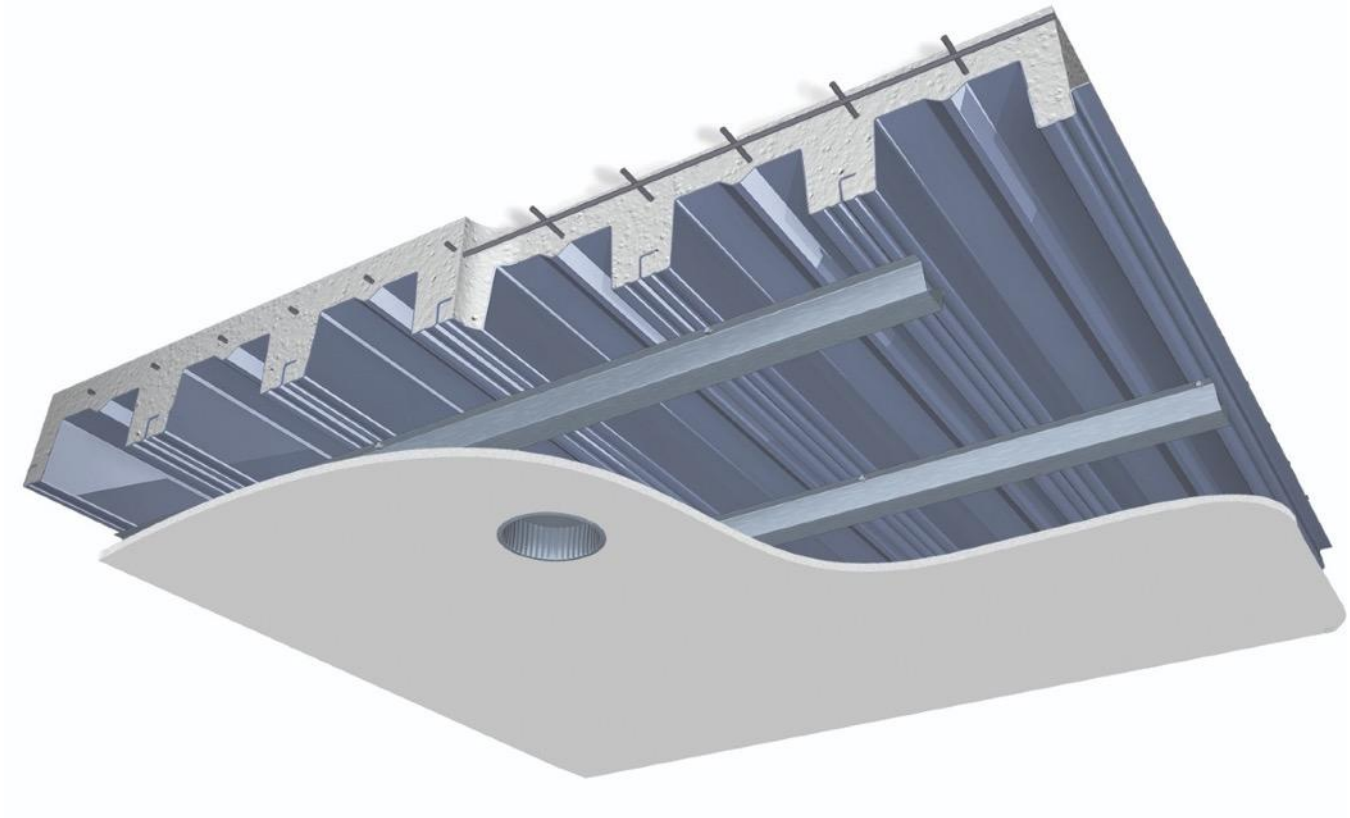
System Selection Criteria

7. Aesthetics: Deep Ribbed Composite Finished Ceiling Options

There are various options for finished ceilings with this system.

They include:

- exposed galvanized deck
- factory primed ready-to-paint surface
- field finished painted surfaces
- furred gypsum board
- suspended ceilings, and
- diverse ceiling aesthetics.



System Selection Criteria

7. Aesthetics: Deep Ribbed Composite

Above are more examples of the aesthetics offered by deep ribbed composite. In addition to the linear shadows of exposed deck, a smooth linear underside appearance can be achieved by specifying cellular deep ribbed deck. The use of cellular brings the additional option to address acoustics. A cellular, acoustical deep ribbed deck may be the optimal solution for a lobby or commercial spaces wanting to reduce ambient noise. The addition of gypsum board is another option, perhaps in the context of also simultaneously increasing the fire protection rating of the floor.

System Selection Criteria

7. Aesthetics: Dovetail Composite

As noted previously the dovetail composite floor system presents a clean, linear plank aesthetic.

The look of the deck can be varied by a range of colors.

For the dovetail system, the deck can be painted at the factory or in the field.
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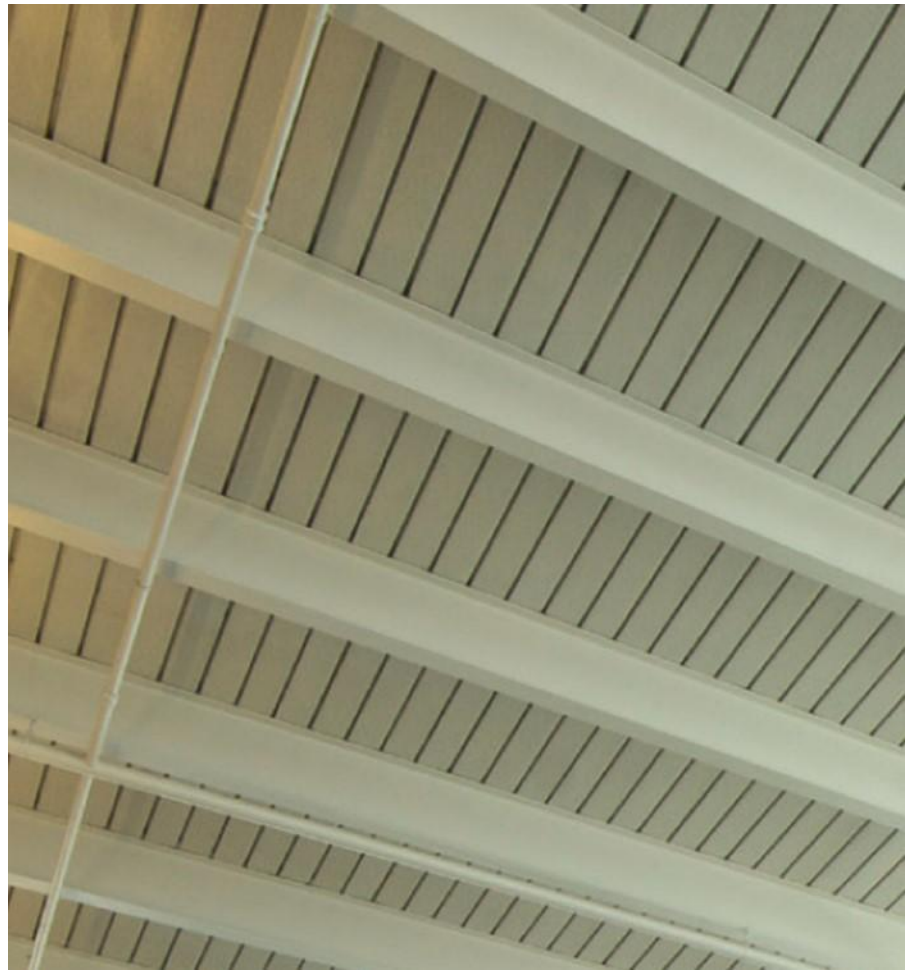
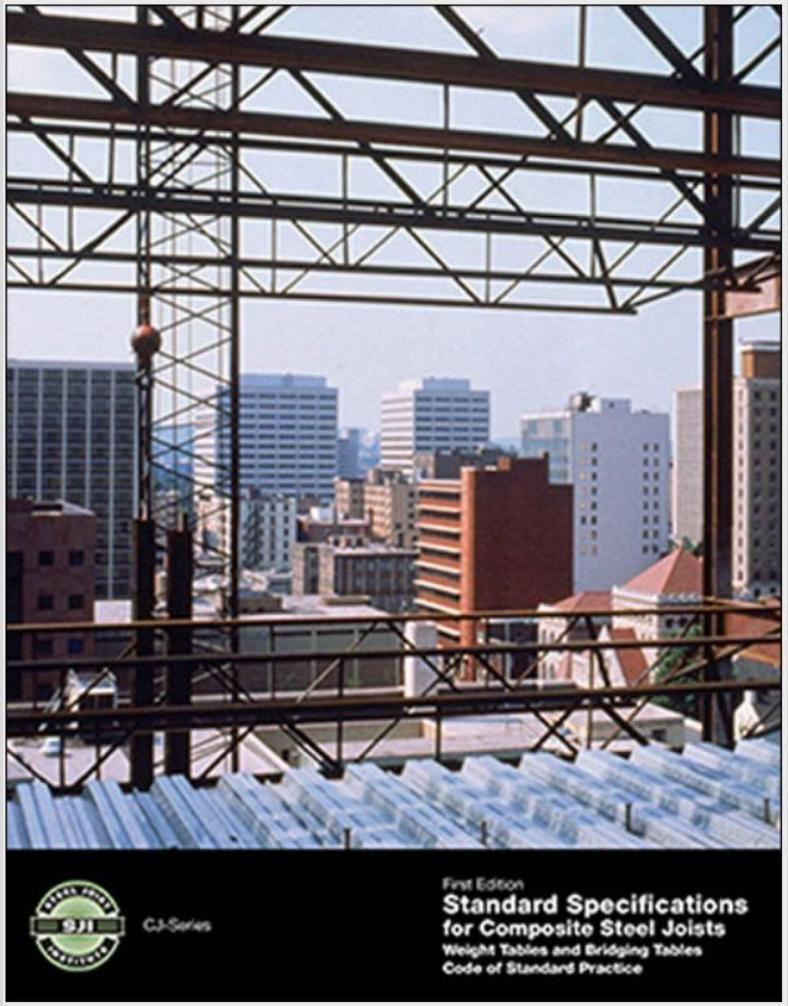
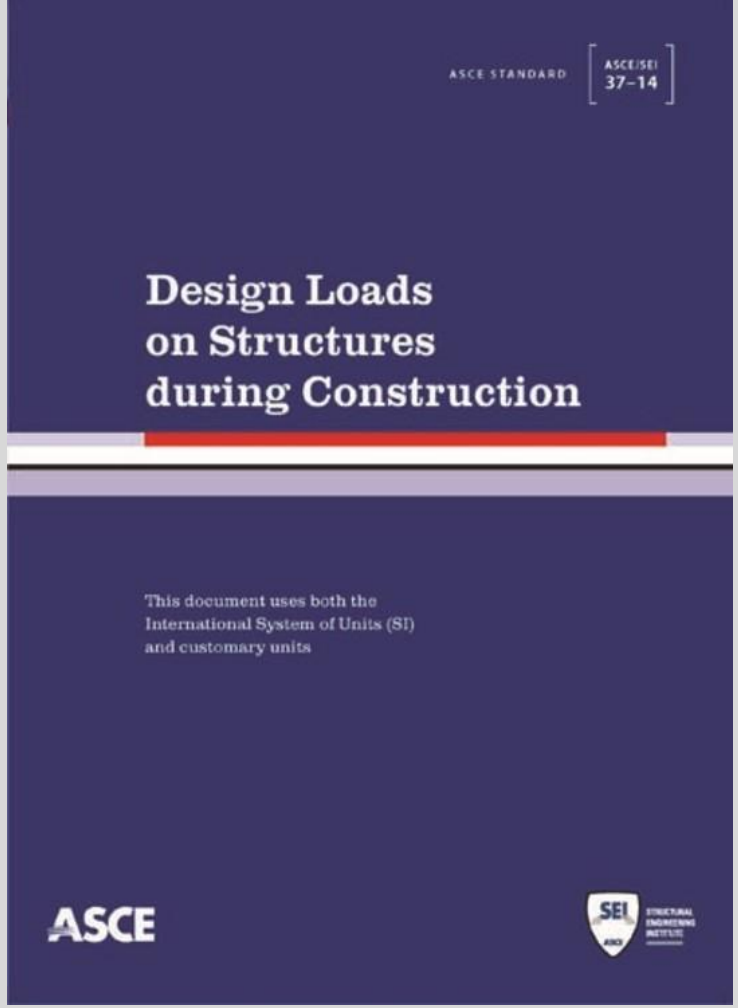
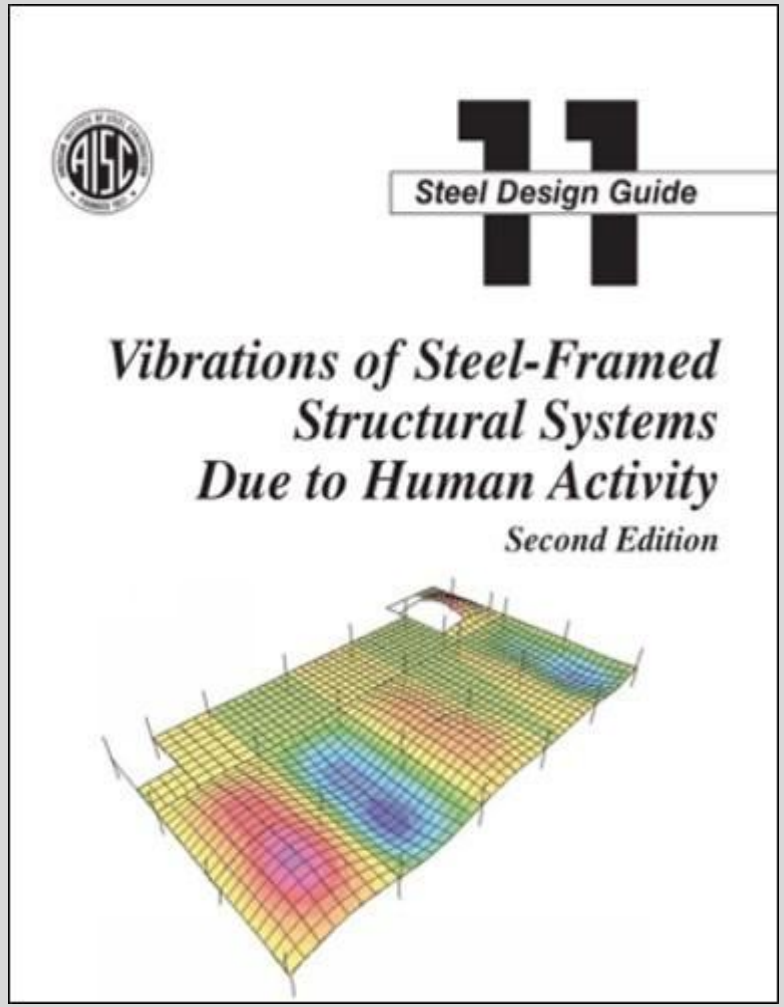








Standards and Resources

Standards and Resources

- Composite Joists
- Composite Deck
- STC and IIC Testing
- Floor Vibration Calculation
- UL Fire Designs
- Steel Deck Fastening
- Loads During Construction
- Shoring
- CFS Wall Panels
- Supplier Guides

The standards and guides listed in this section of the course for the topics listed on this slide are not necessarily all-inclusive. The specifier is advised to further investigate the documents identified here and to maintain contact with the associations that publish and update these documents.

Designers and specifiers should contact the engineering staff at their local steel joist and deck manufacturer/supplier for guidance on the selection of the right long-span composite floor system, based on project demands.

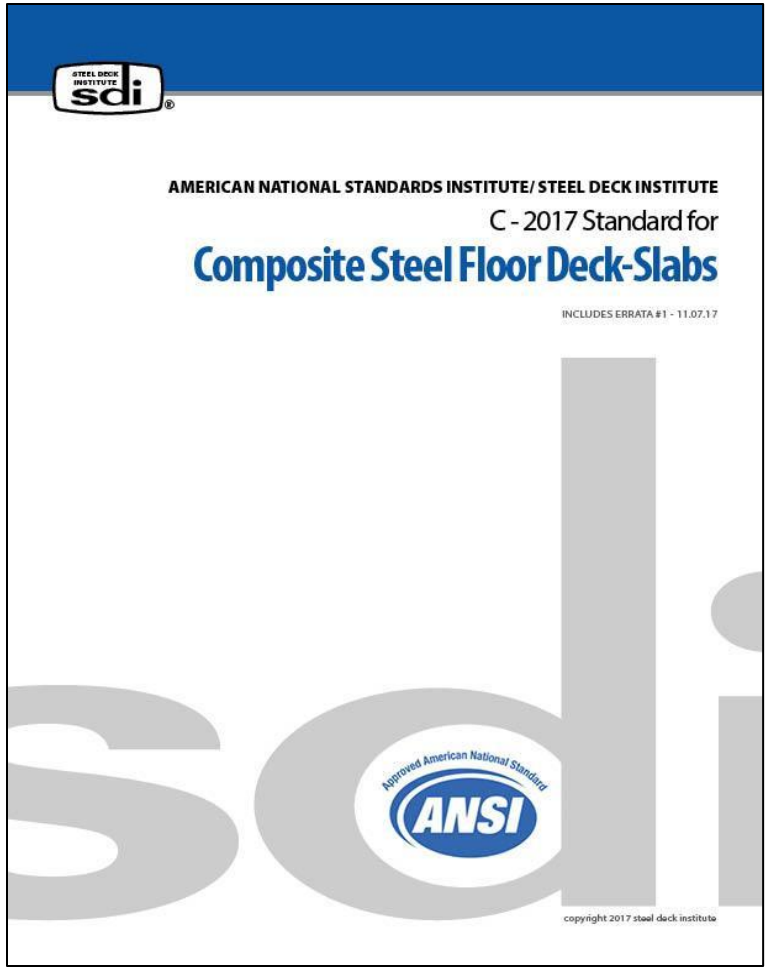
In all cases, the EOR is responsible for all final design decisions.

Standards and Resources

For Composite Joists

- SJI 1st Edition Standard Specifications for Composite Steel Joist

Standards and Resources



For Composite Decks

- AISI S310-16 - North American Standard for the Design of Profiled Steel Diaphragm Panels
- ANSI/SDI C-2017 - Composite Steel Floor Deck-Slabs
- SDI Floor Deck Design Manual, 1st Ed., 2014
- SDI Diaphragm Design Manual, 4th Ed., 2015
- SDI Code of Standard Practice 2017

AISI website: www.steel.org

SDI website: http://www.sdi.org/

Standards and Resources

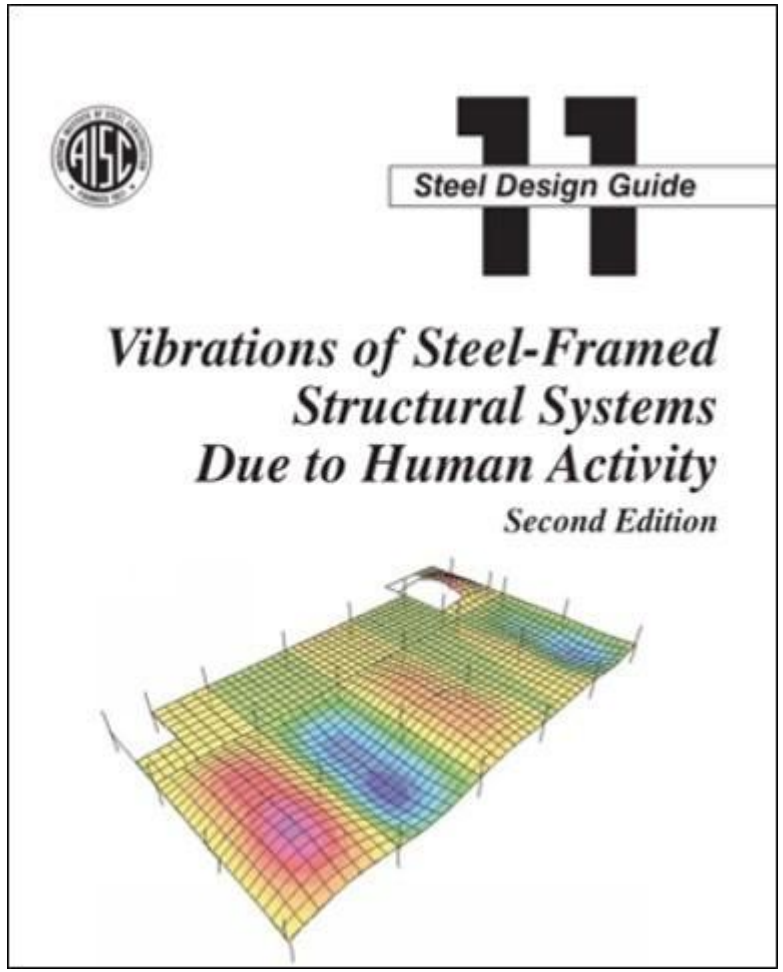
- ACI (American Concrete Institute) ACI 318-14, 2014 “Building Code Requirements for Structural Concrete and Commentary.”
- ASTM (American Society for Testing and Materials) ASTM E90 – 09, 2009
- “Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements.”
- ASTM, 2012 “Standard Classification for Determination of Impact Insulation Class (IIC).”
- ASTM E989 – 12, 2016a “Standard Test Method for Laboratory Measurement of Impact Sound Transmission Through Floor-Ceiling Assemblies Using the Tapping Machine.”
- ASTM E492 – 16 and ASTM E413 – 16, 2016 “Classification for Rating Sound Insulation.”
- CRSI (Concrete Reinforcing Steel Institute), 2014 "Design Guide for Vibrations of Reinforced Concrete Floor Systems"

For IIC and STC testing

The American Society for Testing and Materials (ASTM) publishes many of the standards listed in the adjacent list.

These and other documents can be downloaded at: https://www.astm.org/

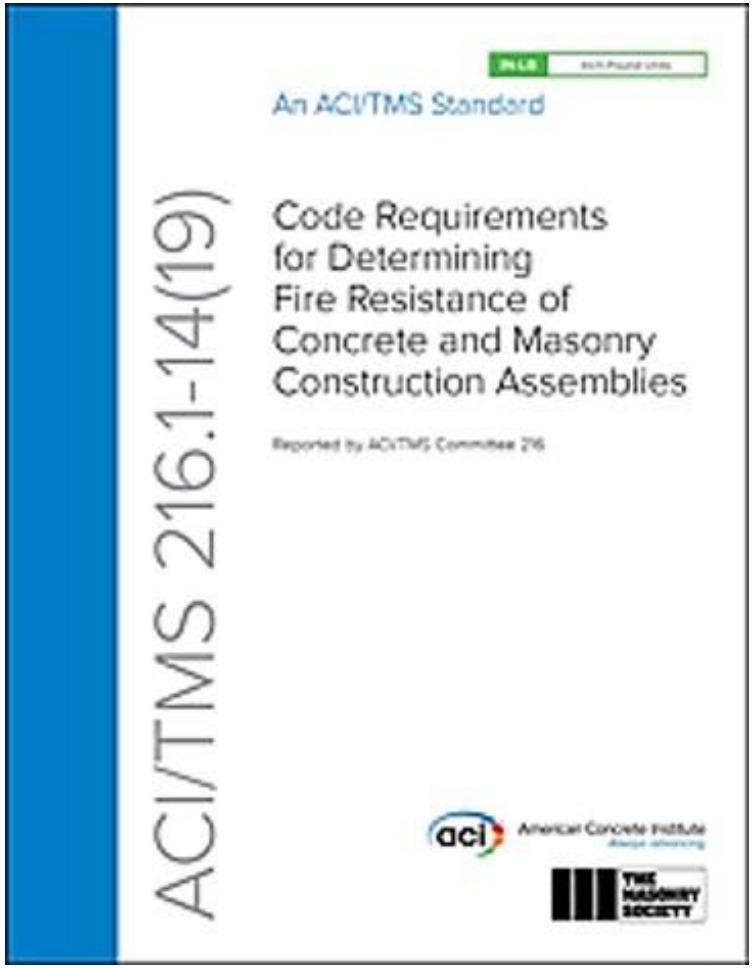
Standards and Resources



For Floor Vibration Calculation

- AISC Steel Design Guide 11 (American Institute of Steel Construction)
- Vibrations of Steel-Framed Structural Systems Due to Human Activity - 2nd Edition

Standards and Resources



For UL Fire Designs

- ASTM E119, Table X3.1 (American Society for Testing and Materials)
- Standard Test Methods for Fire Tests of Building Construction and Materials
- UL Design D982, UL Fire Resistance Directory
- IBC Rational Analysis, Section 909.4 (International Building Code)
- ACI 216.1 (American Concrete Institute)
- Code Requirements for Determining Fire Resistance of Concrete and Masonry Construction Assemblies
- ANSI/AISC 360-10 (American Institute of Steel Construction)
- Specification for Structural Steel Buildings

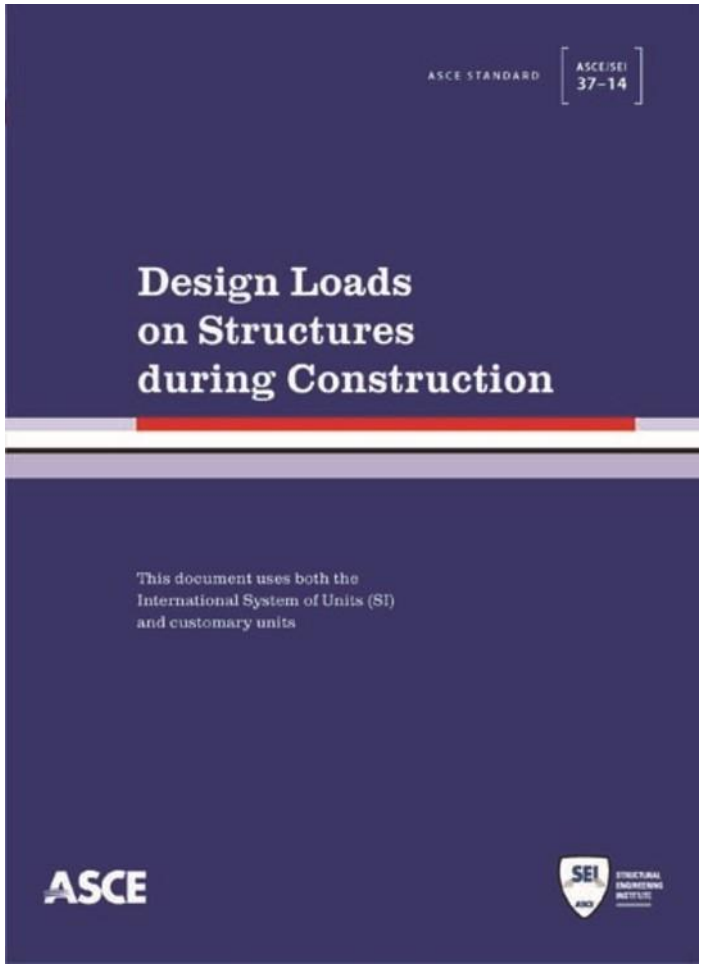
Standards and Resources

For Deck Fastening

- ANSI/SDI QA/QC-2011 Standard for Quality Control and Quality Assurance for Installation of Steel Deck
- Chapter 17 of the 2015 International Building Code

The standards listed here address the use of traditional manual methods of steel deck fastening, as well as the use of more automated methods.

Standards and Resources

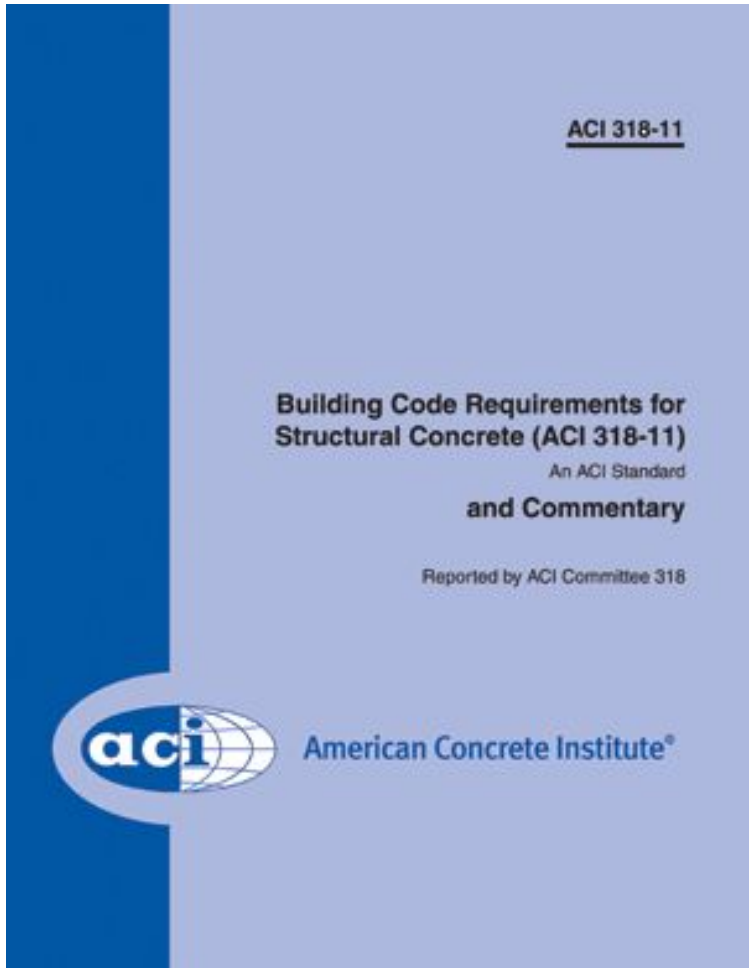


For Design Loads During Construction

- OSHA Regulation 29 CFR Section 1926.754(e)(2)(2003)
- ASCE/SEI 37-14 (R2019) - Design Loads on Structures during Construction

The American Society of Civil Engineers (ASC) ASCE 37 lists motorized concrete finishers under Medium Duty Operational Class, which requires the deck to be designed using the construction live load of 50 psf.(2.4 kPa) or greater.

Standards and Resources



For Shoring

- ACI 318-11
- Building Code Requirements for Structural Concrete
- ACI 347.2R-17
- Guide for Shoring/Reshoring of Concrete Multistory Buildings
- SDI COSP-2017
- COSP / Design Standard for Composite Steel Floor Deck-Slabs

Standards and Resources

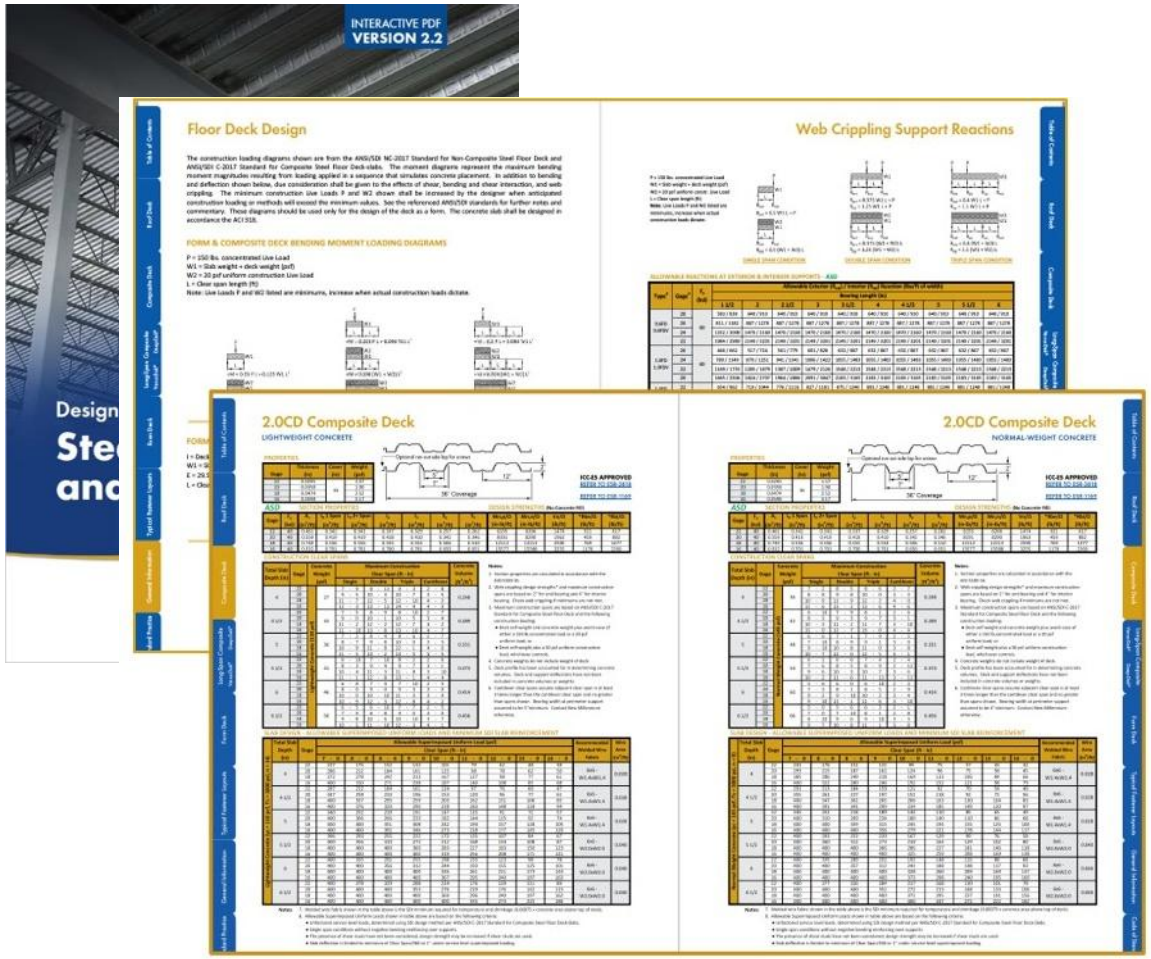
For CFS wall Panels

- CFS Framing Design Manual, 1st Ed., 2017 (Steel Deck Institute)
- Steel Deck on Cold-Formed Steel Framing
- AISI 2015-2019 CFS Series Framing Standards Bundle

The American Society of Civil Engineers (ASC) ASCE 37 lists motorized concrete finishers under Medium Duty Operational Class, which requires the deck to be designed using the construction live load of 50 psf or greater.

Cold-Formed Steel Engineers Institute (CFSEI) website: www.cfsei.org

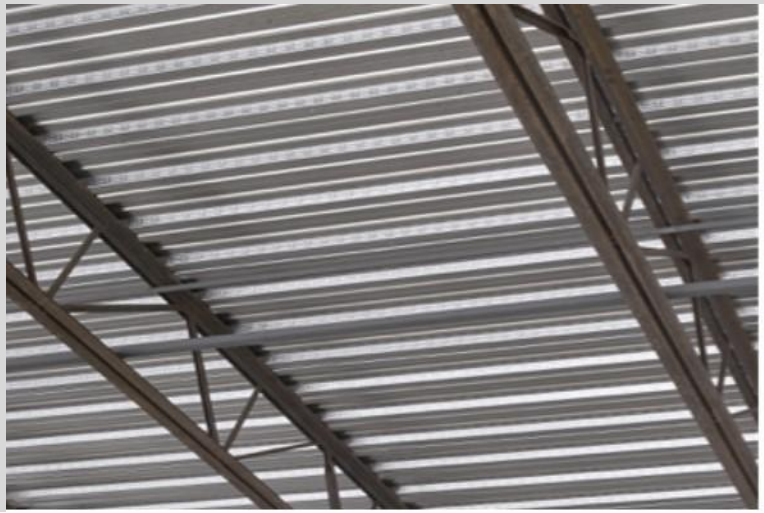
Standards and Resources



Supplier Guides: Steel joist and deck manufacturers produce many helpful resources for the specification and design of composite deck slabs, such as load tables, diaphragm tables, design guidelines, and design examples. This information can be reviewed and downloaded from the supplier websites.

To guide the EOR on system selection and specification, long span composite floor system manufacturers have performed many upfront calculations. They publish the results of these calculations to assist the EOR with many engineering considerations, including the determination of maximum unshored clear spans for the different deck types, deck gauges, slab depths, and concrete densities.

In all cases, the EOR is responsible for all final design decisions.



Summary

Summary

Long-span composite floor systems provide numerous advantages for multi-story construction, and when the designer and specifier are fluent with the attributes of each system, it becomes possible to identify and specify the system which provides the most benefits in each situation during the design process.

The engineering of a long span composite floor is a team effort. Selection of the right system can be guided by early collaboration with suppliers and manufacturers who are familiar with all three types of long-span composite systems (composite joists, deep ribbed composites, and dovetail composites) and the specification and selection criteria such as that which has been outlined in this course.

System selection and engineering can also be informed by numerous standards and guidelines published by the industry, various associations, and testing authorities. These standards should be treated as much as guiding information as rules and regulation.

The potential benefits of composite systems include an overall weight reduction to the structure with the associated cost reductions attributable to that reduction, simplified erection and construction sequencing, reduced floor to floor heights and a reduction to the overall building height or possibly an additional story within a specific height limit, improved acoustic performance of the structure itself, enhanced MEP integration and improved aesthetics.

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