structural **DESIGN**

Structural Considerations for Openings in Composite Floor Decks

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O omposite floor deck construction has become very popular. It combines structural efficiency with a speed of construction that offers an economical solution for a wide range of building types, including commercial, industrial, or residential buildings. Composite slabs consist of profiled steel decking with an in-situ reinforced concrete topping. The decking not only acts as a permanent formwork to the concrete but also provides sufficient shear bond with the concrete so that, when the concrete has cured, the two materials act together compositely to resist the loads on the deck.



Figure 1. An example of core-drilling of a concrete floor.

Openings in composite floor decks are a common part of any building. These openings can range from small holes for pipes and conduits to larger openings for mechanical ductwork, storm drain pipes, or a group of small holes. These openings allow contractors to install relevant building systems such as heating, ventilation, and plumbing.

Openings can have a significant impact on the structural performance of decks. It is essential that all openings are examined by a professional engineer to determine their influence on the deck and whether reinforcement around the opening is needed.

This article provides an overview of the various methods of creating small and medium-sized penetrations and their impact on the structural performance of composite decks.

Creating Openings

There are two main methods to create small and medium openings in composite floor decks: core-drilling holes and sleeving or boxing-out openings.

Concrete core drilling involves drilling rounded holes in concrete walls or floors (*Figure 1*). Diamond concrete-core drills are the most commonly used tools for this process. The core drill bit tends to consist of a steel tube with a matrix impregnated with diamond segments welded to the drilling end. The concrete coring bit is mounted on a rotating shaft of a concrete core-drilling machine and

is secured to the wall or floor. A solid cylindrical concrete core or "slug" and metal deck under the cured concrete are removed from the hole once the drilling is complete. Due to the possible close spacing of existing floor slab reinforcement, reinforcement could likely be unintentionally cut during this process. Therefore, the location of the holes and the reinforcement should be coordinated with the structural engineer before coring. A scanner can be used to help locate the existing reinforcement steel to assist in avoiding it during the coring operation.

Sleeving or boxing-out is another approach to creating an opening. In this method, the opening is formed by setting sheet metal sleeves in the deck (*Figure 2*). Alternatively, there are some cast-in firestop systems, including firestop cast-in sleeves, that can improve and simplify the entire installation process and increase the productivity and efficiency of contractors. Check with your local regulations and project requirements on whether it is permissible to cut the deck. The Steel Deck Institute (SDI), *Manual of Construction with Steel Deck* (SDI-MOC3), provides some examples of decked over floor opening closures, as illustrated in *Figure 3*.

It is highly recommended to leave the steel deck intact until the concrete has cured. However, contractors may cut the opening through the steel deck before the concrete is poured; they see this as a more straightforward installation with less labor, allowing immediate access to the openings before the concrete is poured. However, cutting out the slab before the concrete is cured can prevent the deck from properly



Figure 2. Schematic configuration of sleeving and boxing-out openings.

acting as a form. The steel deck must be examined by a professional engineer to determine if additional steel elements or temporary shoring are needed.

General Design Information

Composite floors consist of a concrete topping cast onto a metal deck. The topping can be light-weight or normal-weight concrete. The steel deck is a cold-formed corrugated steel sheet that spans between steel joists or beams and serves a dual purpose. It serves as a form during the construction phase while the concrete is poured and cured and serves as reinforcement to act compositely with the concrete to support the floor loads. Therefore, there are two main structural functions to be considered for the design of composite decks; (a) design the steel deck as a form to support construction loads, and (b) design the composite slab for superimposed floor loads after the concrete hardens. However, the design of the steel deck to serve as a form is usually more critical than the design of the composite floor to support superimposed floor loads. The steel deck profile and thickness need to be chosen such that the unshored

span of the steel deck can support the construction loads. As a formwork during concreting, the steel deck should be designed to resist anticipated construction loads. This design must meet the minimum design loads specified in the American National Standards Institute's and the Steel Deck Institute's *Standard for*

Composite Steel Floor Deck-Slabs, ANSI/ SDI C-2017. It also must evaluate three separate load combinations: (a) the dead weight of concrete and steel deck plus a 20 pound per square foot (psf) uniform construction live load, (b) the dead weight of concrete and steel deck plus a 150 pounds (lb.) concentrated load per foot width of the deck, and (c) the dead weight of steel deck plus not less than 50 pounds per square foot (psf) uniform construction live load. The engineer should also check the deflection of the deck at the construction stage to limit excessive deflections, which can lead to ponding of the concrete. Ponding can cause unintended dead load on the structure.

After the concrete is poured and cured, the deck acts compositely with the concrete to resist superimposed loads. Composite action is obtained by the shear bond between the concrete and the deck. The design of composite steel





(FIELD CUT TO CONTOUR OF DECK, OR USE

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Figure 4. Out of plane gravity loads on the deck.

form platform with no openings or penetrations. Since openings can impact the deck performance, the engineer must independently examine the penetrations and their effects on deflection, bending, and shear strength of the deck to determine if reinforcement for the deck is needed.

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deck-slab systems reflects the engineering concepts used to design reinforced concrete beams. The concrete acts as the compression material and the steel deck bonded to the bottom of the concrete acts as the tension reinforcing steel. The bending capacity of the composite steel deck must be sufficient to resist out of plane gravity loads on the deck, which are typically superimposed dead and live loads in addition to the concrete and deck self-weight (*Figure 4*).

Composite decking is also used as a horizontal shear diaphragm to stabilize the building and to transfer in-plane shear loads (such as wind and seismic forces) to the building's main frame lateral resistance system (Figure 5, page 10). For this purpose, the composite deck shear diaphragm is modeled as a horizontal beam with interconnected floor deck units that act as the beam web. Intermediate joists or beams function as web stiffeners, and the perimeter beams act as the beam flanges. A detailed design guide can be found in the Steel Deck Institute's (SDI) Diaphragm Design Manual, Edition 4 (SDI-DDM04). Due to the complexity of the design procedures of composite floor decks, deck manufacturers usually provide tables summarizing permissible loads, section properties, maximum unshored spans, superimposed loads, and diaphragm shear loads. However, these tables consider the deck as a solid uni-



Figure 6. Unsupported opening model for small or medium openings. Courtesy of SDI-FDDM.

Structural Considerations

The size of openings in the deck may be categorized as small openings (up to 12 inches), medium openings (1 foot to 4 feet), and large openings (over 4 feet). Per the SDI *Floor Deck Design Manual* (FDDM), large openings should be designed to have all deck bearing edges supported by structural framing. Openings that are of medium or small size may be accommodated without structural frames. It is highly recommended that the deck not be removed from the opening before the concrete is cured. Additionally, non-compliance could lead to potential safety issues.

Check with your local regulations and project requirements on whether it is permissible to cut the deck. Cutting the deck before the concrete is poured and cured reduces the flexural capacity of the deck and can induce excessive deflection. This can lead to concrete ponding during construction. An associated increase of the dead load on the deck may result from additional concrete poured to provide a level floor elevation. Also, cutting the web of the steel deck before the concrete is poured can reduce the steel deck's vertical end reaction from this shallow beam must be supported as a point load on the composite deck-slab adjacent to the opening.

Note that closely-spaced openings may need to be treated as a medium or large opening. When the group of small or medium openings runs perpendicular to the span of the deck, the width of the hole should be considered to be the overall length along the string unless there is adequate deck remaining between the holes. However, when the groups of openings run parallel to the bearing direction of the deck, the width of the opening can be considered as the width of a single hole (*Figure 7*).







Summary

Openings and penetrations in composite slab decks are an unavoidable part of any structure to accommodate the installation of various mechanical, electrical, and plumbing systems. Typically, openings are created by core-drilling the concrete floor or setting sleeves to create an opening before concreting. Due to the potential safety issues in cutting the deck, check with your local regulations and project requirements before proceeding. Openings can reduce the structural capacity of the composite deck. To main-

tain the deck's structural stability and strength during its service life, a qualified structural engineer should evaluate the openings and their impact on the structural performance of the slab/deck system and provide a reinforcement plan as required.

Per SDI-FDDM, large openings should be designed to have all deck bearing edges supported by structural framing. Small or medium penetrations may be accommodated without structural frames. Note that, for the design of small or medium openings, location and spacing of the openings should also be considered. A close grouping of penetrations transverse to the span direction of the decking should be treated as a single large opening.

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of people or equipment on the deck during construction. SDI-FDDM provides a method for the design of the small or medium openings in composite steal decks. In this systemed at

medium openings in composite steel decks. In this method, the concrete above the top of the deck along the opening's edges, perpendicular to the ribs, is assumed to act as a shallow beam, as illustrated in *Figure 6*. This beam can be designed as a reinforced beam or as a structural plain concrete beam to carry the sum of the dead weight of the deck-slab plus the superimposed design loads. The

shear capacity locally around the opening and may result in deck web crippling under concentrated loads such as the weight of people or equipment on the deck during construction