



OPENINGS IN COMPOSITE FLOOR DECKS

Introduction

Structural considerations for openings in composite floor decks

- General information on the design of composite floor decks
- Design of the steel deck as a form for construction loads
- Design of the composite deck for superimposed loads
- Openings in composite floor deck

Non-structural considerations for openings (fire stopping)

Creating the openings in composite floor decks

Hilti CFS-CID MD System, an innovative solution for penetrations

Appendix A

References

INTRODUCTION / Section 1

Composite floor deck construction has become very popular, because it combines structural efficiency with speed of construction to offer an economic solution for a wide range of building types including commercial, industrial, health, or residential building sectors.



Figure 1 — Composite floor deck construction

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.

Openings in floor decks are a common part of any building. These openings can range from small holes for pipes and conduits to large size opening for mechanical duct work, storm drain pipes or a group of small holes. These openings will allow contractors to install relevant building systems such as cold and hot water, DWV systems (Drain, Waste, Vent), high and low voltage electrical, HVAC, etc.



Figure 2 — Penetrations in composite floor decks

As observed in numerous projects across the US and Canada, there are various methods to form and create the openings. Each method has its own advantages and disadvantages.

Due to the structural nature of this task, it is important that all slab openings are examined by a professional designer to determine how they influence the structural performance of the slab system and whether reinforcement around the opening is needed to strengthen the edge of the opening¹. Fire protection of the penetrations is also another important topic that needs to be taken into consideration when there is an opening in the floor deck to maintain the fire resistance rating of the deck.

This white paper provides an overview on the various methods of creating small and medium size penetrations, which make up the majority of the total penetrations in composite floor decks, and discusses how the new Hilti CFS-CID MD system can be an integrated, efficient, and productive solution to overcome these problems by having all required elements in one package and provide an innovative installation process.

¹ Per SDI, isolated openings less than 6" do not generally require reinforcement

STRUCTURAL CONSIDERATIONS FOR OPENINGS IN COMPOSITE FLOOR DECKS²

2.1 GENERAL INFORMATION ON THE DESIGN OF COMPOSITE FLOOR DECKS

Composite floor consists of a concrete topping cast onto metal decking (Figure 3). Concrete is usually light weight or normal weight concrete, and the steel deck is a cold formed corrugated steel sheet spanning between steel joists or beams.

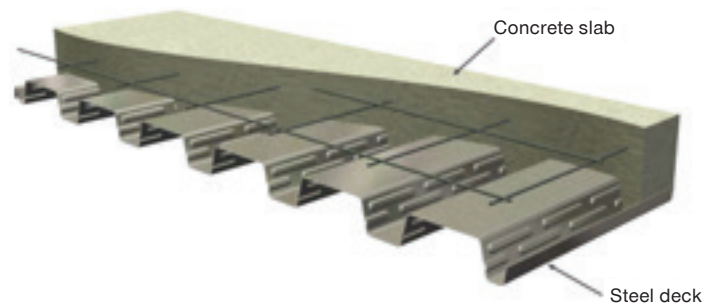
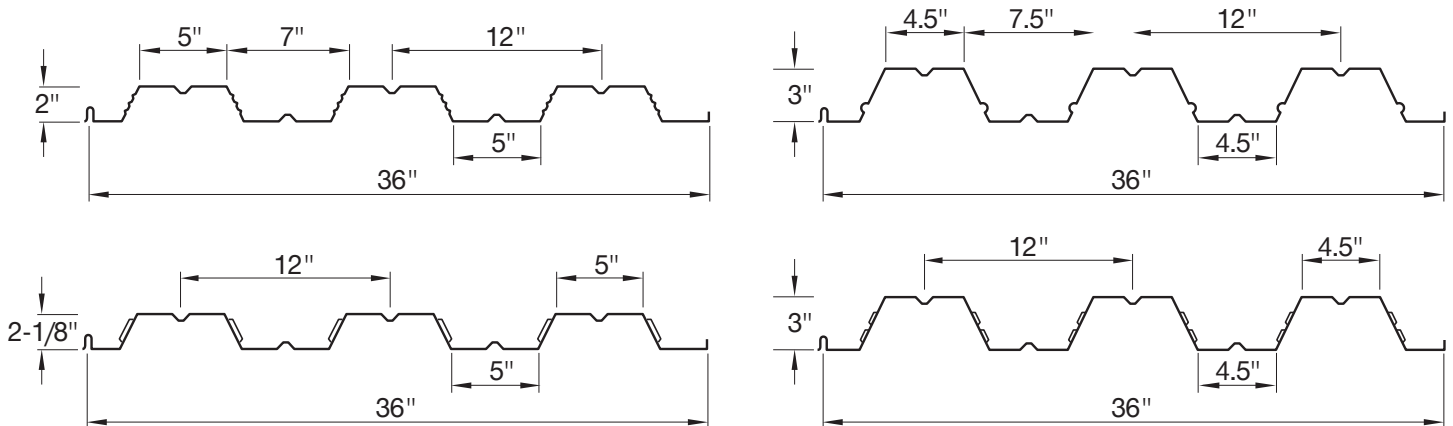


Figure 3 — Composite floor deck configuration

Based on the steel deck profile and loading on the deck, the deck can span 4' up to 16' between beams. Most steel decks are manufactured from steel conforming to ASTM A1008/A1008M, structural sheet for uncoated deck or ASTM A653/A653M, structural sheet for galvanized deck. Structural steel sheets have minimum specified yield strength of 33ksi. The strength and stiffness of the panels are a result of the deck gage, shape of the ribs, and the material properties of the steel. The deck material thickness is specified either by dimensional thickness or by gage. Figure 4 shows a few common steel deck profiles and thickness.

In construction, composite deck serves dual purposes. It serves as a form during the construction phase while the concrete is poured and cures. Then the decking acts compositely with the concrete to support the loads on the floor. Therefore, there are two main structural functions to be considered for the design of the composite decks:

a) design of the steel deck as a form to support construction loads,



Gauge No.	Design Thickness	
	in.	mm.
22	.0295	0.75
20	.0358	0.91
18	.0474	1.20
16	.0598	1.52

Figure 4 — Common steel deck profiles and thickness

b) design of the composite slab for superimposed loads after concrete hardened.

Note that the design of the steel deck to accommodate as a form is usually more critical than the design of the composite floor for superimposed loads since the steel deck profile and thickness shall be chosen such that the un-shored span of the steel deck can support the construction loads.

2.1.1 Design of the steel deck as a form for construction loads:

As a formwork during concreting, the steel deck should be designed to resist the anticipated construction loads applied to the steel deck. A design meeting the minimum design loads specified in the **Standard for Composite Steel Floor Deck-Slabs, ANSI/SDI C-2011** includes evaluation of two separate load combinations: the dead weight of concrete and 20 psf uniform construction live load; and the dead weight of concrete and 150 lbs concentrate load per foot width of deck. The design of deck as a form is a straight forward engineering exercise. Since the deck is no more than a cold-formed steel beam spanning between the support framing, the provision of the **North American Specification for the Design of Cold-Formed Steel Structural members, AISI S100**, is typically used to determine the strength of the deck. The bending moment, web shear, and reactions are determined using engineering mechanics for slender beams. The maximum moment, web shear, and reactions are then checked against the strength of the deck to determine the appropriate deck profile, thickness, and allowable un-shored span for a project. The reactions of the steel deck at supports must also be checked to ensure that the webs of the steel deck do not buckle. The decking is normally intended to be used without temporary propping since propping reduces the speed of construction and therefore affects the construction sequence and economy. The maximum un-shored span of the steel deck is usually provided by the deck manufacturer for each deck type. Therefore, deck thickness and profile is typically selected such that shoring is not required.



Figure 5 — Construction of composite floor deck

The designer also needs to check the deflection of the deck at the construction stage to limit excess deflections which can lead to ‘ponding’ of the concrete, which can cause unintended dead loads on the structure. Deflection limits for the decking are given in **SDI C-2011**. The calculated deflection of the deck as a form is based on the weight of the wet concrete and the self-weight of the steel deck uniformly loaded on all spans and is limited to the lesser of 1/180 of the clear span or 3/4”.

2.1.2 Design of the composite deck for superimposed loads:

After the concrete has cured, the decking acts ‘compositely’ with the concrete to resist the loads on the floor (please see Figure 3). Composite action is obtained by shear bond and mechanical interlock between the concrete and the decking. The design of composite steel deck-slab system 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 rebar.

The bending capacity of the composite steel deck shall 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. There are various methods described in **ANSI/SDI C-2011** to determine the strength of the composite deck-slab such as Prequalified section method, Shear bond method, and Full scale performance testing. Also, while generally not the controlling design factor, deflection of the deck under superimposed loads shall be checked according to the building codes, which typically limit deflection to L/360 during service live.

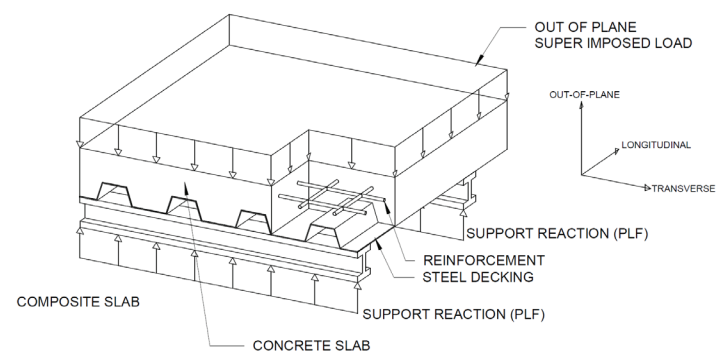


Figure 6 — Out of plane gravity loads on the deck

In addition to providing resistance against out of plane vertical loads, the composite decking is used as a horizontal shear diaphragm to stabilize the building and transferring in-plane shear loads (such as wind and seismic forces) to the buildings main frame (walls and columns). For this purpose, 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

perimeter beams act as the beam flanges. Detailed design guide can be found in the **Steel Deck Institute Diaphragm Design Manual, SDI-DDM**.

2.2 OPENINGS IN COMPOSITE FLOOR DECK

Openings and penetrations in composite slab decks are an unavoidable part of any structure to accommodate the installation of various mechanical and electrical application systems.

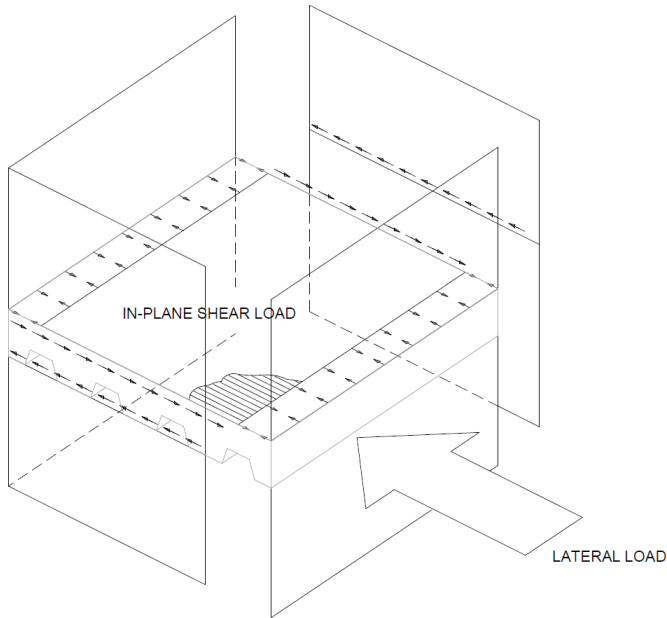


Figure 7 — In-plane shear loads on the deck

Due to the complexity of the design procedure of composite floor decks, the deck manufacturers usually provide tables summarizing design parameters and permissible loads such as section properties, maximum un-shored span, and superimposed loads and diaphragm shear load which are intended to be an easy to use design aid. However, these tables consider the deck as a solid uniform platform with no opening or penetration. Since openings can impact the deck performance, the designer must independently examine the penetrations and their effects on the deflection, bending, and shear strength of the deck to determine if reinforcement for the deck is needed.



Figure 8 — An example of mechanical hot and cold piping systems

Openings in the deck may be categorized by their size as small (openings up to 12"), medium (1' to 4'), and large (over 4') openings. Note that closely-spaced openings may need to be treated as a larger opening. The need for extra reinforcement in the slab depends on various parameters such as the size of the opening, location of the opening within span, orientation of opening within the plane of the metal deck, metal deck type, gauge, concrete depth, as well as loading criteria. Based on SDI recommendation, single small openings up to 6" do not generally need any consideration. Medium openings normally require additional rebar reinforcement to be placed in the slab. For large openings, in addition to rebar reinforcement, additional steel frame may need to be designed.

In addition, one major consideration, which increases the complexity of designing openings, is whether the deck is cut before or after the concrete has cured. Contractors usually cut out the opening through the steel deck before concrete is poured to take advantage of an easier installation process and immediate access to the opening. However, cutting out the steel deck before the concrete is poured causes further challenges during the construction phase while the deck performs as a form.

Cutting the deck before concrete is poured reduces the flexural capacity of the deck and can induce excessive deflection in the deck. This can lead to concrete ponding during construction with an associated increase of the dead load on the deck. Sometimes, additional steel elements or temporary shoring may be needed around a penetration to strengthen the steel

deck to support construction loads. Also, cutting the web of the steel deck before concrete is poured can reduce the steel deck vertical 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. Therefore, steel plates or frames may be needed to strengthen the edges of the opening and redistribute the load around the opening.

SDI provides some design guidance and reinforcement details published in the white paper entitled **'Deck Damage and Penetrations'** to strengthen the steel deck as a form during construction phase when cutting the deck prior to casting is unavoidable. Per SDI's recommendation:

- a) No reinforcement is required if a single opening, smaller than 6"
- b) plates can be welded around the opening if the openings are larger than 8", but smaller than 13", spaced more than 4' apart (Figure 9).

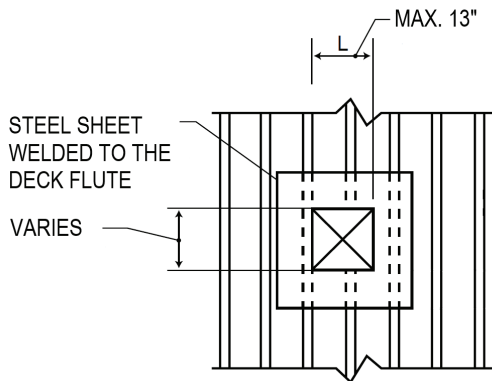


Figure 9 — Strengthening the edges of opening with steel sheets

- c) Steel framing per Figure 10 can be use if the openings are larger than 13", but smaller than 2' perpendicular to deck

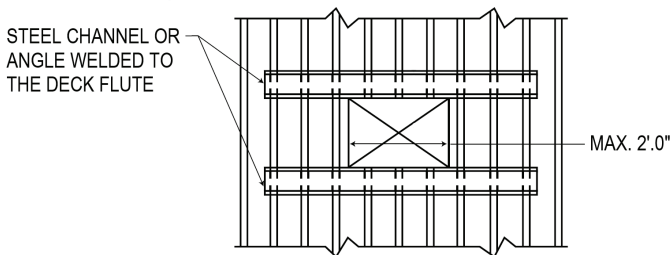


Figure 10 — Strengthening the edges of opening with steel frames

- d) For openings larger than 2', the deck panels can be analyzed as a cantilever slab with its free end terminating at the opening (see Figure 11). SDI's requirements for steel deck design as a cantilever span are as below:

- Allowable bending stress of the steel deck shall not exceed $0.6F_y$ with loading of concrete weight + deck weight + the larger of 20 psf or 150 lb. concentrated load
- Allowable deflection of free edge shall not exceed $1/120 L$ under loading of concrete + deck.
- Web crippling shall be checked with loading of concrete weight + deck weight + 20 psf over cantilever and adjacent span.

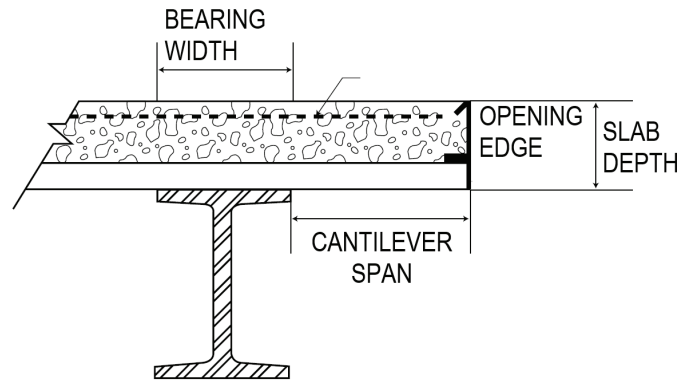


Figure 11 — Design of the steel deck for opening as a cantilever span

Note that the cantilever design would not be applicable if the deck sheets are installed in single span lengths or at openings adjacent to the outside support of an end span condition. This can be a critical condition requiring shoring support prior to concrete pour.

NON-STRUCTURAL CONSIDERATIONS FOR OPENINGS (FIRE STOPPING)

Section 3

Today's building code's primary focus is to safeguard the public health, safety and general welfare of the occupants. As part of this focus building codes require passive fire protection to minimize the spread of fire and smoke during a fire event. As a part of the overall passive fire protection scheme, the building is divided into compartments in order to contain the hot gases and smoke from spreading throughout the building. This allows occupants more time to safely exit the building while helping protect critical assets.

The Architect and design team are involved in the design of the passive fire protection for the building. In their consideration for compartmentation and fire resistance rated assemblies, architects must determine the size of the structure, and the type of occupancy or use of the building including the use of each of its individual spaces. The building code prescribes requirements for separation and types of fire-resistant rated assemblies. Those spaces in the building which are required to be separated by fire-resistive assemblies will have fire resistant rated protection for openings, joints, and penetrations. For penetrations, the building codes prescribe a specific protection method, using through-penetration firestop systems designed for the rating of the assembly and tested in accordance with ASTM and UL fire test standards specific to firestopping.



Figure 12 — An example of through-penetration firestop system

A through-penetration firestop system is an assembly of materials designed to prevent the spread of fire and its byproducts for a prescribed period of time under defined test conditions (usually 1, 2, or 3 hours) through openings which are made in floors or walls. This system comprises of three elements: a fire-resistant rated assembly, i.e. wall or a floor; a penetrating item, i.e. pipe, cable, etc.; and the firestop system. A certified testing agency must independently test all firestop systems to evaluate both functionality and quality. The performance of the firestop system is dependent upon the specific assembly of materials tested including the number, type and size of penetrations and the materials of the floors or walls in which it is installed. Therefore, it is important the firestop system be installed exactly per their listing details and manufacture's instruction, otherwise, it may not perform as designed during a fire event

The prescriptive code recognizes the critical function of the firestopping thus requiring both review and approval of plans prior to installation, and inspection of installed systems from the authority having jurisdiction or in some cases a third-party inspection firm. The inspector may ask the installer for the tested and listed system utilized to help avoid issues during the installation. The jurisdiction-approved plans will attempt to include details for all the proposed systems that could be encountered on the project based on the materials being used and the assemblies being penetrated.

For floor penetrations, the potential solutions for firestop systems might be numerous and complex depending on many variables including the size of the openings, the material of the elements that go through the opening, and the specific requirements of the project design. There are numerous types

of firestop materials used in firestopping systems. Over the past few years the industry has been moving towards the development of preformed firestop devices. These devices allow for easier firestop installations thus minimizing the risk of human error with more traditional methods resulting from the installation being completely dependent on the skill of the installer. Installing these preformed firestop devices allows contractors to have a more productive and accurate installation while helping inspection by minimizing the complexity of the firestopping installation.

For composite decks, however, contractors have been less likely to utilize these preformed devices due to an existing conflict on how to create the openings in the floor without compromising the integrity of the deck, or the added complexity of alternative method to create and firestop the opening.

CREATING THE OPENINGS IN COMPOSITE FLOOR DECKS

Section 4

There are two main methods to create small and medium size openings in composite floor decks: core-drilling the opening after concreting, and sleeving or boxing-out the opening before concrete poured. Each of these methods has its advantages and disadvantages as described below. Note that creating large size opening methods are out of the scope of this section.

CORE-DRILLING OR CUTTING THE SLAB AFTER CONCRETING:



Figure 13 — An example of core-drilling of a concrete floor

Concrete core drilling involves drilling rounded holes in concrete walls or floors. Diamond concrete-core drills are the most commonly used tools for this process. The core drill bit tends to consist of a steel tube impregnated with diamond segments on the drilling end. The concrete coring bit is mounted on the rotating shaft of a concrete core-drilling machine and is secured to the wall or floor. A solid cylindrical concrete core or “slug” is removed from the hole once the drilling is complete.

When post-forming is unavoidable, non-percussive cutting methods such as diamond core drills/saws are the most common method used to keep the disturbance to the mechanical interlock between the decking and the concrete at a minimum.

The main challenge related to core-drilling is the potential impact on the wall or floor in case existing reinforcements would be cut. Cutting reinforcements can compromise the structural integrity of the floor / wall. Therefore, the location of the holes and reinforcement shall be coordinated with the structural engineer before coring; and a scanner such as Ferro scan should be used to make sure that coring is not going to affect any critical reinforcement of the deck. It is common that reinforcements are localized where the opening needs to be made. In such a case, as reinforcements can't be moved, contractors have to find a solution to create the opening in a different place which increases complexity and may require looping back to the architect to adapt the mechanical/electrical systems design.

SLEEVING OR BOXING-OUT BEFORE CONCRETE POURED:

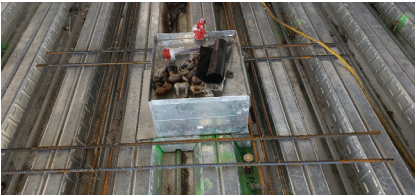


Figure 14 — Configuration of sleeving and boxing-out openings

Another approach to create the opening is to form an opening by setting sheet metal sleeves on the deck and then cut it prior or after concrete pouring. Depending on whether the steel deck is cut before or after concreting, the following are some examples of the typical installation process. However, there might be some variations in the process, depending on the contractor, project and engineering guidelines.

If the steel deck is cut after concrete poured and hardened.

This method is generally preferred because it eliminates the need for construction load reinforcement and sealing, but is more challenging. There are also 2 phases in the installation process. In the first phase, sleeves are set in the deck using a welder or screwing it and then blocked from the top and sealed to eliminate gaps between the deck and the sleeve. Concrete reinforcement for post-cure superimposed loads is added around the openings per designer's guidance and the area is inspected for final changes and actions. During the second phase, contractors remove the material to unblock the sleeve and then cut the deck using cutting tools like a plasma cutter or a torch. Note that this method represents a real challenge to cut the deck inside the concreted sleeve, especially inside sleeves less than 4" diameter. After performing the cut, pipe or conduit will be run through the penetration and finally it will be firestopped.

If the steel deck is cut before concrete is cured.

Cutting out the slab before concrete is cured can compromise the strength of the steel deck as a form in the area around the openings and result in excessive deflection and concrete ponding. Therefore, additional steel deck strengthening elements or even temporary shoring might be required prior to concrete pouring to support the construction loads.

There are also 2 phases in this installation process. During the first phase, which is before concrete pour, contractors cut holes (usually with plasma cutters or torches) and if necessary reinforce the deck with metal strips, angles and / or temporary shoring. As in the previous method, sleeves are set in the deck using a welder or screwing it and then blocked from the top and sealed to eliminate gaps between the deck and the sleeve, and making sure there won't be leaks in the cut holes. Concrete reinforcement for post-cure superimposed loads is added around the openings per designer's guidance and the area is inspected for final changes and actions. During the second phase, which is after the concrete is poured and cured, contractors remove the caps and material used to block the sleeve and run the pipe or conduit through it; and then firestop the penetration.

Sometimes, contractors encounter problems when cutting the deck before the concrete is poured and contact the designer or steel deck manufacturers asking for a reinforcement plan. To provide a practical reinforcement plan, the designer must inspect the building condition and decide how much damage can be tolerated depending on the architectural and structural considerations. For example, if the underside of the deck is going to be exposed to public view, then very little visible damage may be allowed. These processes may delay the job and have some financial consequences. Therefore, any penetration method avoiding cutting the deck before concrete poured would be extremely helpful for both contractors and designers.

HILTI CFS-CID MD SYSTEM, AN INNOVATIVE SOLUTION FOR PENETRATIONS

Hilti has developed a new innovative solution, Hilti CFS-CID MD system, to overcome the above-mentioned problems. Hilti CFS-CID MD system is a cast-in firestop system to be used in composite floor decks for a variety of pipe materials and diameters.

Hilti CFS-CID MD system is composed of a firestop cast-in sleeve, a platform, a metal guide sleeve and a hole saw as shown in figure 16.



Figure 15 — The Hilti CFS-CIS MD fire stop system for composite floor decks



New CFS CID MD 2" P device



New CFS CID MD PLT W3"



New CFS-CID MD HS GUI2"



New CFS-CID MD HS 2"

Figure 16 — Various components of the Hilti CFS-CIS MD firestop system

THE INSTALLATION PROCESS INVOLVES 2 STEPS:

Step one: Prior to concreting

Platforms are set in the deck as shown in Figures 17a and 17b. After determining where CFS-CID MD sleeve must be located, platforms are attached to the deck with screws as shown in the diagram. Then the CFS-CID MD sleeves will be set on the platform. Note that the design allows for multiple platforms installed in any direction of the deck, allowing to address penetrations that are close to each other or spread out in the deck.

Step two: Post concreting

The opening is created by cutting the metal deck through the CFS-CID MD sleeve as shown in Figure 17d through 17e. Note that firestop is included in the CFS-CID MD sleeve, therefore, no additional steps other than running the pipe or conduit through the penetration are needed. Always refer to the proper UL system that will provide the appropriate installation instructions and ratings information.

This new working process provides a high-quality and comprehensive benefits to the engineers and contractors, aiming to create penetrations in composite floor decks for a variety of electrical, plumbing and mechanical systems. As a summary, by using Hilti CFS-CID MD system for penetrations:

- Steel deck reinforcement or additional shoring, as described in Section 2-2, items a) through d), to support the steel deck as a form during the construction phase is not needed since the steel deck is left intact until the concrete is poured and hardened. By using Hilti CFS-CID MD system, reinforcement can be laid out between sleeves. Using this system for penetrations can provide more structural integrity in the composite floor deck compared to boxing-out conditions. Therefore, reinforcing the concrete slab for superimposed loads (for service life of the deck) would be easier and more convenient for the designer. Appendix A provides potential options on the concrete slab reinforcement for superimposed loads.

- The fire resistance rating of the floor is maintained. This system is internationally tested and approved by UL and FM for up to 3 hours fire resistance which is typically beyond the required time for residential and commercial buildings. Always refer to the right UL system that meets the project requirements for the penetration. Firestop installation is performed reliably and early in the process, which allows to preserve the quality and helping to ensure its proper functioning.
- Productivity and efficiency of contractors will increase since the entire installation process from the beginning to the end will be improved and simplified. This system helps to plan layout and sleeve management for penetrations and consequently reduces the required coordination between trades and helps to minimize errors on job site.

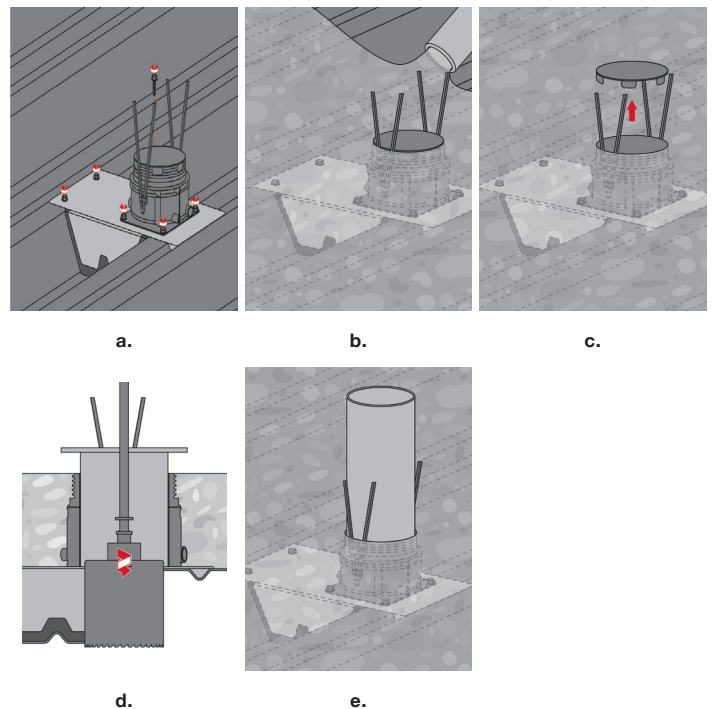


Figure 17 — Steps for the installation of the Hilti CFS-CIS MD system

APPENDIX A / Opening Reinforcement considerations for Superimposed Service Loads

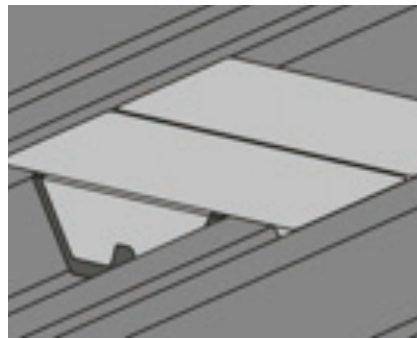
As mentioned in Section 2.2 (page 5) of this paper, there is no independent need to strengthen the steel deck as a form during construction using Hilti CFS-CID MD system since the deck is not cut prior to concrete poured and hardened. However, the professional designer may need to reinforce the floor slab penetrations to accommodate post-cure superimposed loads utilizing standards established by SDI and the American concrete Institute ACI 318. While the EOR must determine reinforcement requirements for their specific project, this appendix provides some reinforcement plans for consideration for small and medium size penetrations which are created by the Hilti

CFS-CID MD system in composite floor decks. Two various platform arrangements are presented as shown in Figure 18:

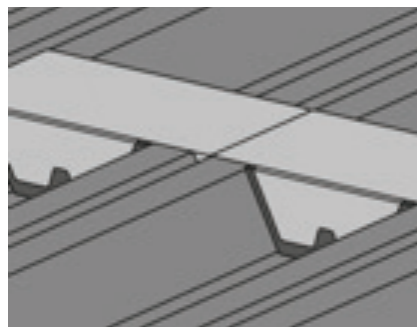
- a) platforms are placed only in one flute of the steel deck
- b) platforms are placed in two or three adjacent flutes

There are also some conditions incorporated into the basis of these details as listed below:

- Only one web of steel deck shall be cut per each sleeve penetration
- Superimposed load does not exceed 50 psf with no concentrated load around the opening.
- The openings are not adjacent to the support beam or girder.



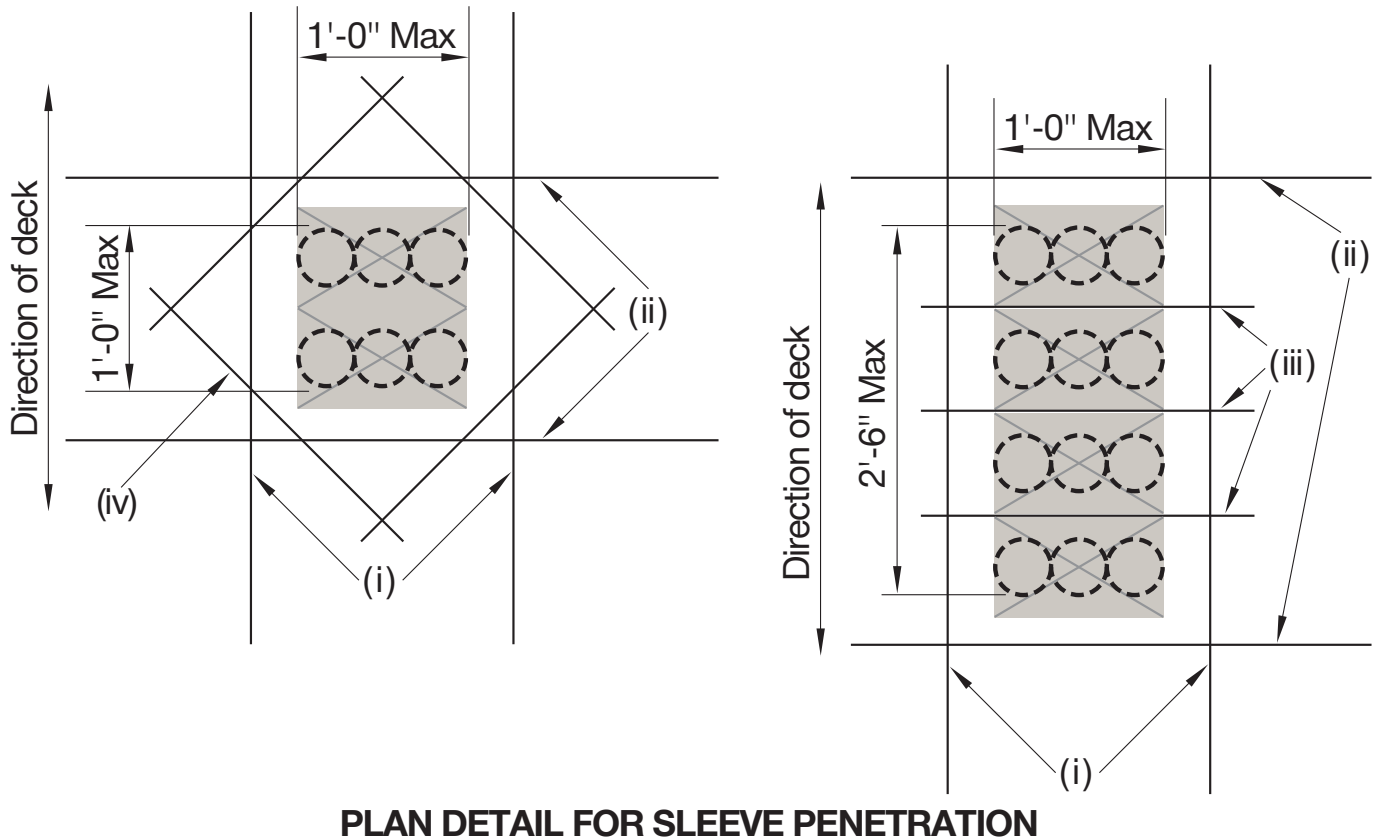
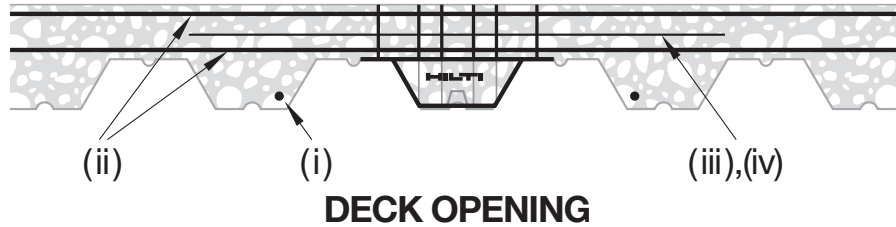
(a)



(b)

Figure 18 — Various configuration of the Hilti CFS-CID MD placement over steel deck

a) Multiple inline platforms, placed in one deck flute:



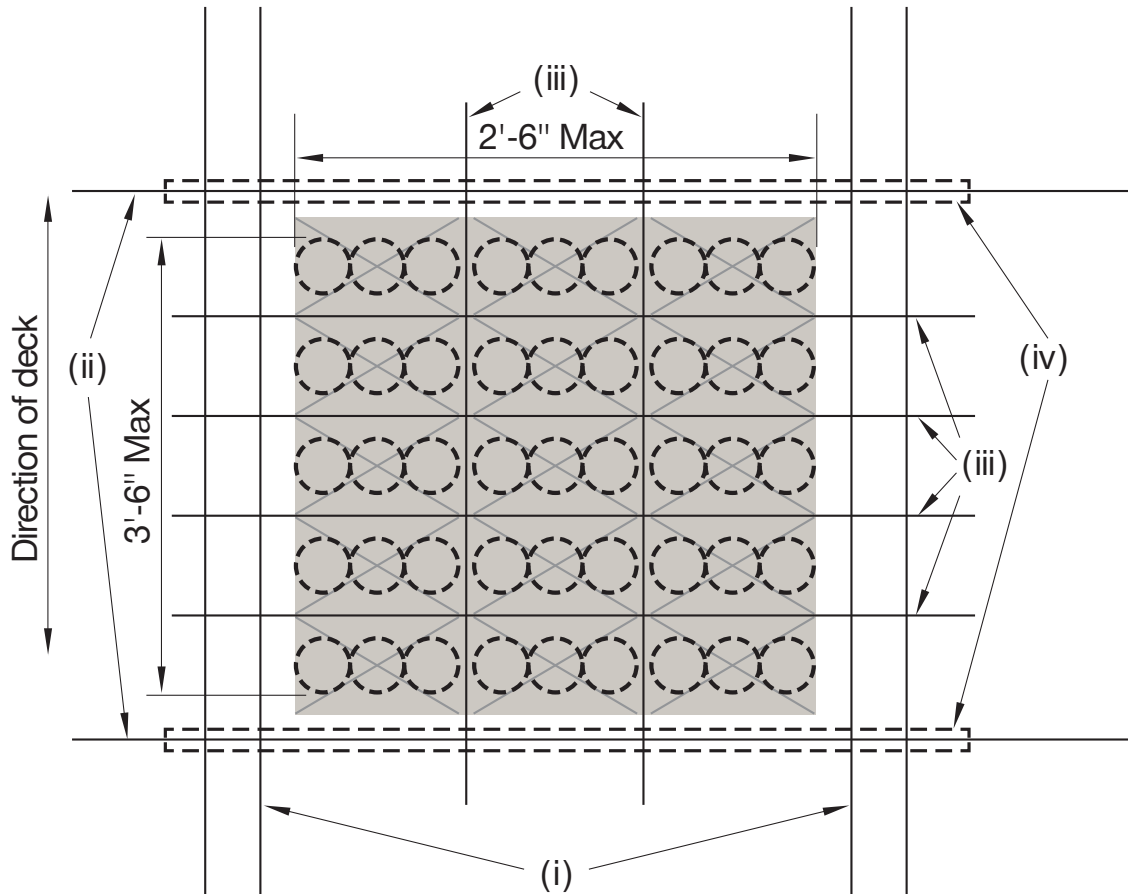
(i) Rebar @ $\frac{3}{4}$ " clear from bottom of the deck flute (size and length of rebar tbd by EOR.)

(ii) Two layers of rebar (size and length of rebar tbd by EOR.)

(iii) Rebar dowels between sleeves. Provide min. 3" Clear space between sleeves (size and length of rebar tbd by EOR.)

(iv) Rebar at 45° type at re-entrant corners (size and length of rebar tbd by EOR.)

b) Multiple platforms, placed in two or three adjacent deck flutes:



PLAN DETAIL FOR SLEEVE PENETRATION

- (i) Rebar at $\frac{3}{4}$ " clear from bottom of the deck flute (size and length of rebar tbd by EOR.)
- (ii) Rebar at $\frac{3}{4}$ " clear from top of deck (size and length of rebar tbd by EOR.)
- (iii) Rebar dowels between sleeves. Provide min. 3" Clear space between sleeves (size and length of rebar tbd by EOR.)
- (iv) Steel angel or channel welded to the top of deck flute (size and length tbd by EOR.)

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