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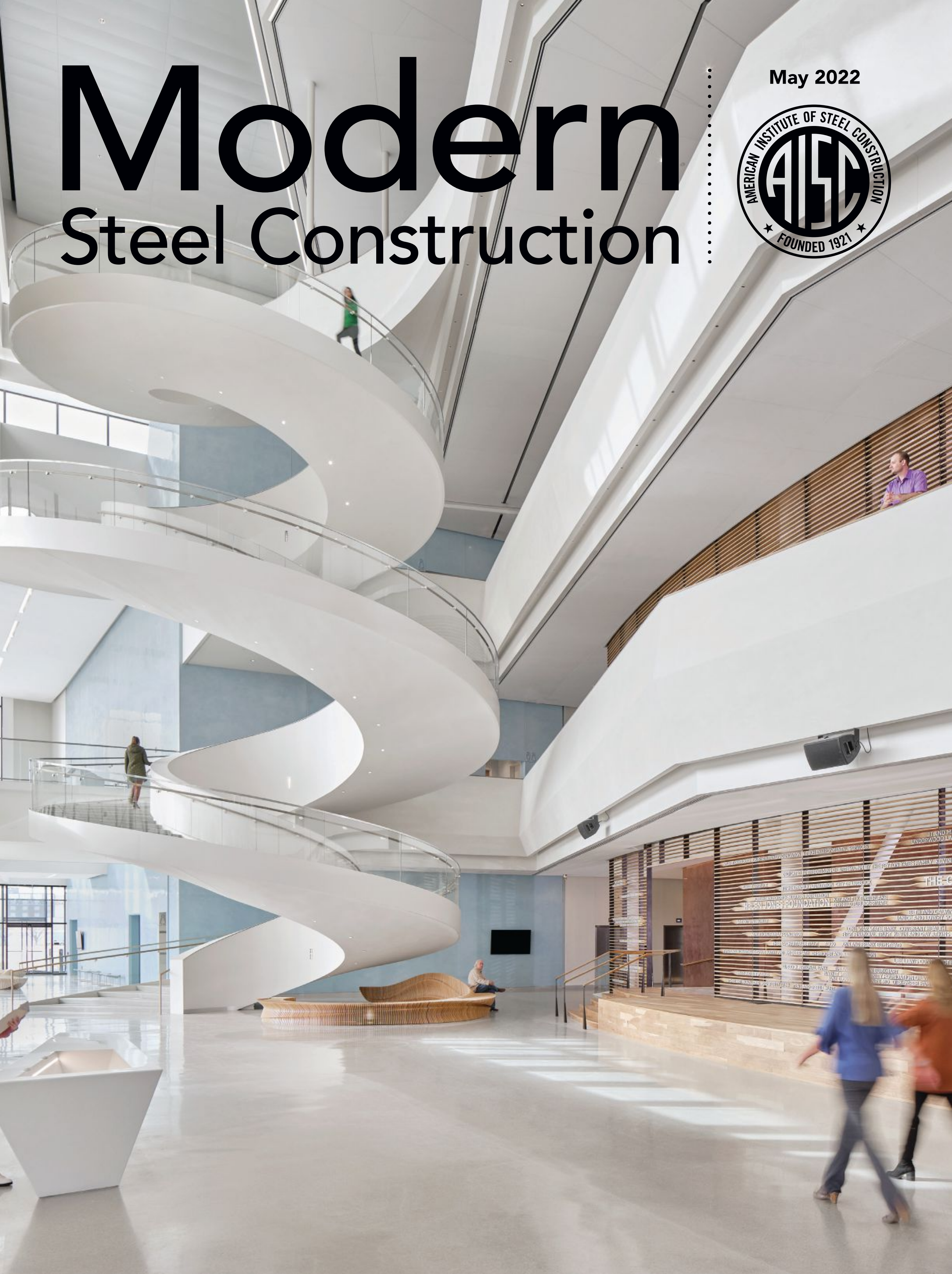

Practical Point Load Determination

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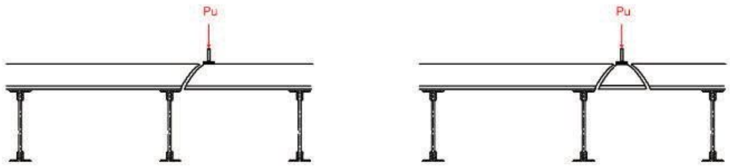
Tips for more efficiently determining point loads for composite elevated deck slabs.

Ubani Obinna

Fig. 1. Schematics of a composite steel floor slab.



a. One-way shear failure

b. Punching shear failure

c. Positive flexural failure

d. Negative flexural failure

e. Weak-axis flexural failure

Fig. 2. Composite deck limit states.

CONCRETE OVER METAL DECK is a very common construction method for elevated slabs for a wide range of building types, including steel-framed commercial and industrial buildings. The composite action between profiled steel decking and concrete slab provides a solid design solution for supporting both lateral and gravity loads.

When it comes to industrial buildings, concrete and metal deck must often support platforms or heavy equipment that potentially impose large, concentrated loads. Adding wide-flange steel beams below the deck is a typical solution. However, it's not always preferable as it can increase cost and schedule, as well as requires prior coordination.

In situations where the wide-flange option isn't feasible, relying on the composite deck itself to support the large point loads becomes essential and inevitable. The Steel Deck Institute (SDI) publishes a design manual for floor deck that provides tables for composite deck shear and moment capacity, though it's not always easy to quickly determine point load capacity using these tables. Here, we've proposed a quicker method for looking up composite slab point load capacity for a variety of deck profiles and design variables is presented.

General Design Considerations

When a concentrated load is acting on the composite slab, there are five ultimate limit states (LS) that need to be considered: one-way shear, punching shear, positive bending, negative bending, and weak-axis bending, as shown in Figure 2. (Note that for industrial buildings, weak-axis bending of the slab typically does not govern.)

To investigate how each limit state governs the ultimate point capacity of the composite floor slab, consider the common industrial building composite floor construction type shown in Figure 3. In this configuration, the gravity beams are equally spaced 6 ft on center and the composite slab is composed of inverted 1.5-in.

metal deck topped with 3.5-in. normal-weight concrete. Welded wire reinforcement (WWR) is placed over the metal deck to control the cracks induced by shrinkage and temperature. Structurally, it also serves as flexural reinforcement that enables the deck to resist negative bending. As such, the composite deck subjected to concentrated load can be considered the point load acting on a continuous beam. For this example, three continuous spans are considered in the analysis, and the point load is located at the middle span.

Here, the main design variables include span, the base plate dimensions where the point load is being applied (wplate), concrete strength, and the thickness of the concrete slab over metal deck. The dimension of the base plate is a very important variable as it directly determines the size of the critical perimeter for punching shear and thereby dictates the two-way shear capacity. To investigate the effect of each variable on the point load capacity, each parameter varies, per Table 1.

Table 1. Design variable range

Design Variable Variation	
Span Length	6 ft to 8 ft
Base Plate Dimension	8 in. to 16 in.
Concrete Strength	3,500 psi to 4,500 psi
Concrete Thickness	2.5 in. to 4.5 in.

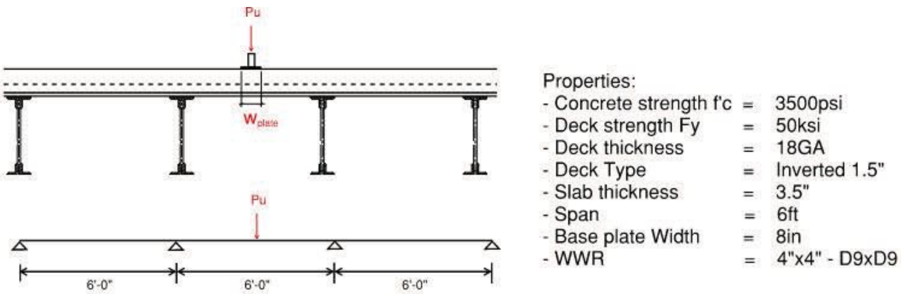


Fig. 3. Schematics of a point load on concrete slab over metal deck.

Figure 4 presents the impact of each limit state on the point load capacity with respect to each design variable. As span increases, the point load capacity is always governed by a negative bending limit state. The same trend is observed as the base plate dimension and concrete strength vary. However, as the slab thickness over the metal deck flute increases, the governing limit state changes from negative bending to one-way shear. This can be understood by considering that increasing the concrete thickness can greatly increase the one-way shear capacity of the composite slab but not as much as the flexural capacity. In addition, the figure indicates that varying the base plate dimension and slab thickness can have a significant impact on the ultimate capacity.

Deck Point Load Charts

Based on the methodology presented above, easily determining the point load capacity given the design information, without the need to look deeply into each limit state individually, is a worthwhile goal. Designing composite floor deck slabs involves a number of design parameters, and previous sensitivity analyses indicate that the variables that have the most significant effect on point load capacity are base plate dimension and slab thickness. Additionally, different metal deck profiles will produce different capacities. Here, three types of profiled metal deck are considered: inverted 1.5-in. deck, 2-in. metal deck, and 3-in. metal deck. Three concrete thicknesses over the deck flute are considered: 2.5-in., 3.5-in., and 4.5-in.

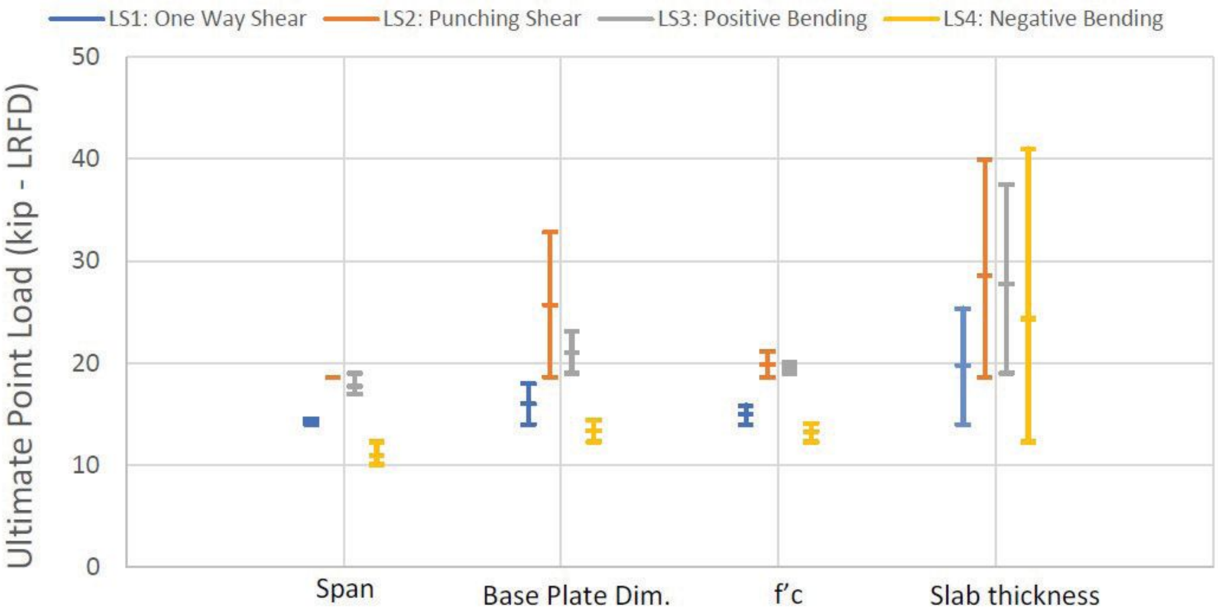


Fig. 4. Sensitivity of design variable and limit states on deck point load.

Base plate widths vary from 6 in. to 24 in. with every 2-in. increment. Other design variables, including concrete strength, WWR ratio, metal deck thickness, and span, are assumed constant and follow the information shown in Figure 3.

We developed a worksheet to determine the point load capacity considering all limit states, and a cluster of point load capacity results was obtained considering all possible combinations of the main design variables for each deck profile. Subsequently, second-order regression analysis was performed to create a large amount of data where contour lines with constant point loads are then generated. Figure 5 presents the ultimate point load capacity (LRFD) contour line for three different types of metal deck with 5 kip of point load increment (for clarity, the simplified structural analysis model appears at the top of the chart). In this chart, horizontal axis is the dimension (width) of the base plate that supports the load, and vertical axis is the slab thickness over the metal deck flute. In the figure, solid lines, dash lines, and dotted lines represent the contour plot of composite floor using inverted 1.5-in. deck, 2-in. deck, and 3-in. deck, respectively. Linear interpolation can be applied if the result lies in between, and the superposition method can be applied if multiple point loads are imposed within the same middle span. From this chart, you can quickly estimate the deck point load capacity instead of going through a complete design check process.

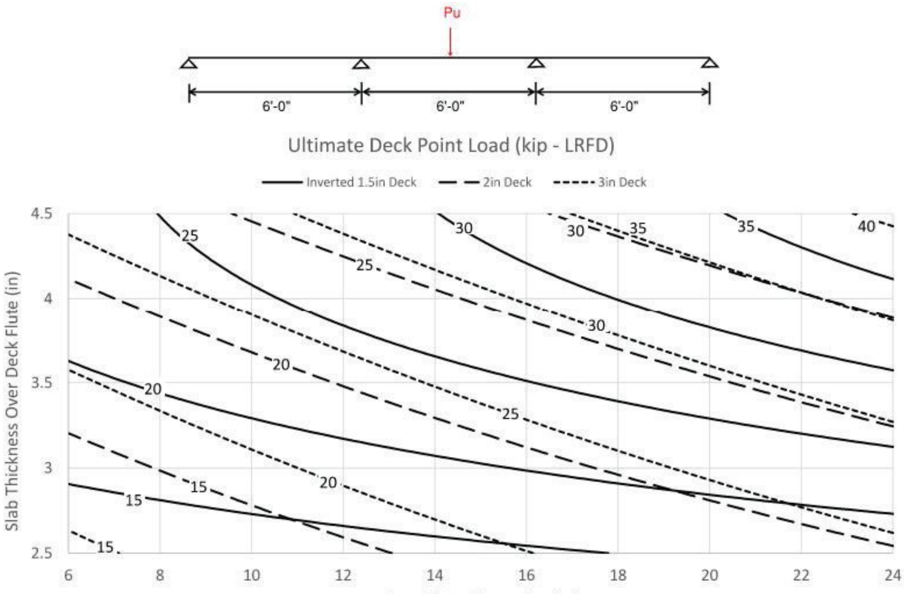


Fig. 5. Ultimate composite floor point load capacity (equal span).

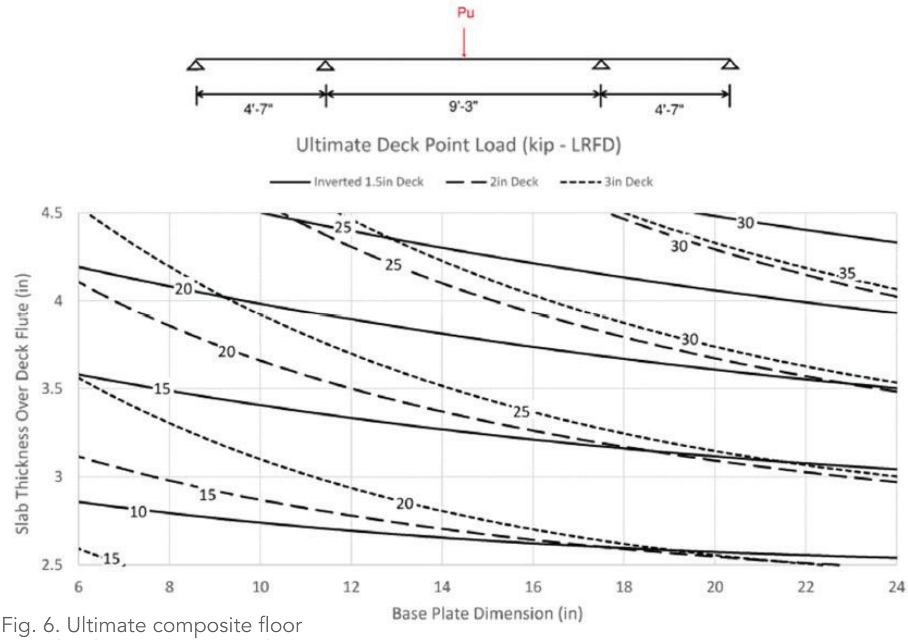


Fig. 6. Ultimate composite floor point load capacity (unequal span).

Due to floor openings, beam members might not be equally spaced. In this case, the force required for the deck to carry is distributed differently compared to an equal span scenario. We considered an unequal span configuration where edge spans are 4-ft, 7-in. long and the middle span is 9 ft, 3 in. Figure 6 presents the point load capacity with unequal spans.

Adjustment Table

The two previous charts assumed that several other parameters would remain the same, including concrete compressive strength (f'c), span length, WWR rebar ratio, the location of the point load (edge span vs. middle span), and the number of spans considered. In practice, variations of these parameters would occur and affect the final capacity. To address this, we performed additional analysis, and Table 2 summarizes the effect of each variation by introducing an adjustment factor. This factor is a ratio of the point load capacity from a "varied" scenario to that of the baseline case indicated in Figure 5. As seen in the table, an increase of concrete strength by another 500 psi would increase the capacity by about 5% to 10%. If the span is 7 ft (1 ft longer than 6' ft), then the final capacity would be reduced to 0.85 to 0.9 of the baseline case. This can be understood by considering that bending moments can be increased and thereby limit the point load carried. With regard to WWR rebar area, it can increase the capacity by up to 5%. If the concrete slab is not thick, negative bending is a governing limit state, as indicated in Figure 4. Therefore, increasing the rebar area would help increase the capacity. Once concrete thickness increases so that one-way shear becomes the controlling limit state, increasing the rebar will not contribute to any increase in capacity. Also, placing the point load to the edge span

Table 2. Correction Table

Design Variable	Variation	Modification Factor
f'c	+500 psi	1.05 – 1.10
Span	+1ft	0.85 – 0.90
Rebar	+20%	1.00 – 1.05
Location	end span	0.80 – 1.00
Number of span	+1 span	1.00 – 1.02

will potentially decrease the capacity. This is because maximum positive and negative moment is greater when the point load is at the edge span, as there is only one adjacent span that provides rigidity to resist the load. However, once the one-way shear limit state governs, placing the load in the edge span or middle span would not make any difference. Additionally, the capacity is slightly increased if an additional span is considered in the analysis.

Determining the point load on a composite floor deck is important for industrial buildings. By creating a systematic calculation worksheet and performing regression analysis, we've attempted to simplify the process by creating two ready-to-use lookup charts for point load capacity considering different deck profiles and span information, as well as an adjustment table to address variation in other important design variables. ■

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Design Examples

To test the resources mentioned in this article, we've provided three design examples.

Example 1. A composite deck made of 2-in. metal deck topped with 4-in. concrete was designed to support equipment with a weight of 10 kip on a single 10-in. by 10-in. base plate. The relevant gravity framing and composite deck information are shown in Figure 3. Would the deck be considered adequate?

As indicated in Figure 7, the ultimate point load capacity is around 22 kips by interpolation, which is greater than 1.6×10 kip = 16 kip. Therefore, DCR=16/22=0.73, so the answer is yes.

Example 2. A composite deck made of inverted 1.5-in. deck topped with 3.5 in. of concrete was designed to support an ultimate load of 15 kip (gravity beams are spaced unequally as shown in Figure 6 and the rest of the information following Figure 3). What would be the minimum required base plate size?

Looking at Figure 6, inverted 1.5-in. deck with an 8-in. base plate would have an ultimate point load of 15 kip. Therefore, the base plate must be a minimum of 8 in. wide.

Example 3. For the platform system and loads shown in Example 1, if the span is 7 ft instead and the post is located at the end span, would the deck be considered adequate?

According to Table 1, two adjustment factors need to be considered—namely 0.8 for the end span and 0.85 for the longer span. Therefore, the current ultimate capacity is 0.8×085×22=14.96 kip and DCR = 1.6×10/14.96 = 1.07. Therefore, the current design is not adequate.

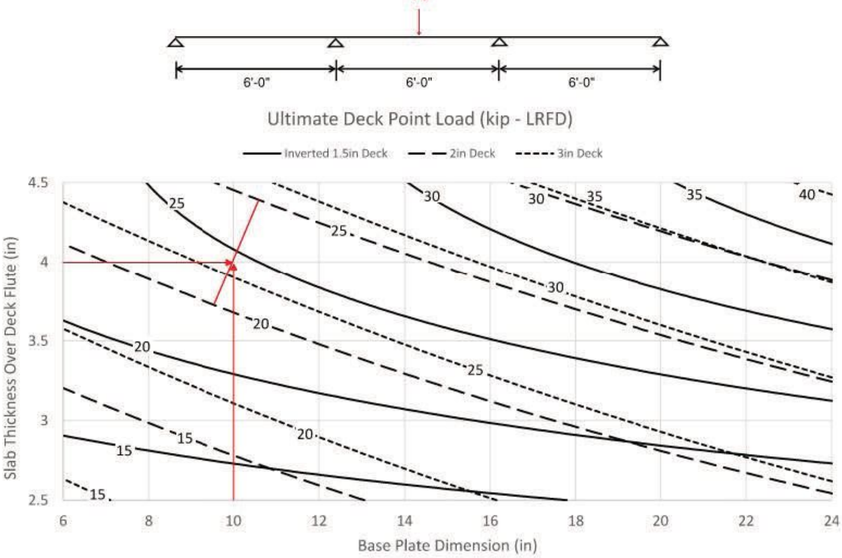

Fig. 7. Ultimate deck capacity lookup for Example 1.