steelwise

DETAILS FROM THE EDGE

Considerations for detailing the slab edge and designing façade attachments.

BY JIE ZUO

SLAB EDGE DETAILS WHERE the structural frame of the building meets the architectural skin can be cumbersome and complex. But they don't have to be!

The design and detailing of the structural components around the slab edge to support the façade can have a tremendous impact on the overall cost of the project, as well as the façade's functionality. There are many factors to consider when developing a design strategy to accommodate the façade loads, including the type of façade, its location relative to the structural frame, the length of cantilever of the slab past the spandrel beam, the strength of the slab and metal deck and the orientation of the metal deck and adjacent framing.

AISC *Steel Design Guide 22*, *Façade Attachments to Steel Framed Structures*, available on www.aisc.org/epubs, gives the practicing engineer guidelines to address these issues. This article draws from the design guide to provide tips and considerations on how to detail slab edges for supporting façade loads in an efficient and economical manner.

Loads and Forces

Let's first examine the loads and forces that are involved. The gravity load on the façade generally consists of solely the dead self-weight of the façade panel. Most façades carry no vertical live load, but it's important to recognize when there are flat areas that project from the structure and provide working space for building maintenance and window washers. In these cases, live, rain and/or snow loads must also be considered.

The center of gravity of the façade elements is almost always offset some distance from the centerline of the support locations on the steel frame. This eccentricity between the center of gravity of the façade panel and the support locations on the steel frame produces a moment that usually is resolved with a horizontal force couple from the top and bottom attachments (as shown in Figure 1). The top attachment may be in tension from the gravity loads due to resolving the eccentricity, and often, negative wind pressures combined with this horizontal force couple will be critical in the design of the façade attachment.

Often, the weights of the façade panels are supported on the slab edge. The slab edge details must transmit these forces and moments into the structural frame without exceeding deflection, tolerance and clearance limits. Conceptually, there are two methods to transfer the forces from the slab edge and into the structural frame:

Method 1 – The slab and metal deck act as a cantilever to resist the façade loads. In this approach, the strength and stiffness of the slab and metal deck resist the shear and moment, essentially treating it like a cantilevered beam to support the façade loads. This method is economical when the typical slab and metal deck are adequate or can easily be reinforced to take the additional facade loads. (See Figure 2, p. 18, for free body diagrams of the structural components involved in this method.) If, however, the thickness of the slab must be increased to accommodate the façade loads, this may diminish the cost effectiveness of this method.

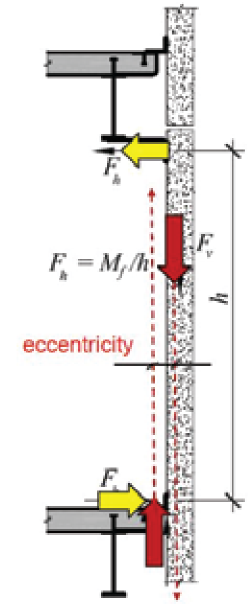
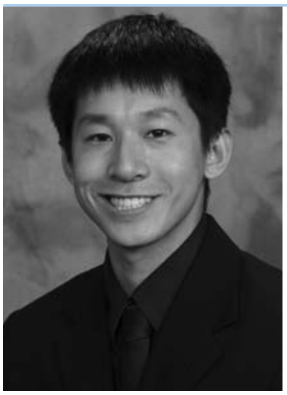


Fig. 1: Horizontal force couple due to eccentricity.

The façade panel loads may be transferred into the slab by direct bearing on the slab or by attachment to steel embedments or bent plates that also serve as pour stops. If a bent plate pour stop is used, a steel headed stud anchor or deformed bar anchor is often welded to the pour stop at the end of the slab, which engages the concrete reinforcement and transfers the forces into the slab. The stud or bar attachment cannot be shop-welded when it projects over the spandrel beam, as this would violate OSHA requirements that prohibit tripping hazards.



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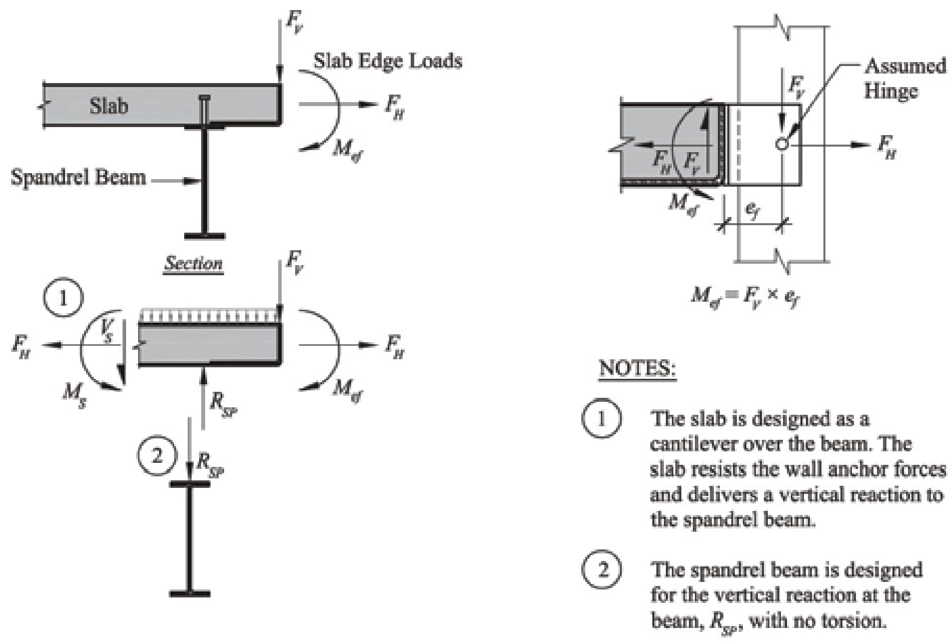


Fig. 2: Design concept of Method 1, where the slab is utilized to resolve eccentricity of façade panel loads.

Resolving the eccentricity of the façade load location and the spandrel beam support with the slab and metal deck as a cantilever eliminates the need to design the spandrel beam for torsion or brace it against twist. However, the façade load induces negative moment in the slab as it passes over the spandrel, which may require additional flexural reinforcement in the top of the slab in that area.

Method 2 – A bent plate or other steel assembly is used as a means to transfer the loads to the spandrel. This approach has a load path that bypasses the slab and metal deck; it relies on the strength and stiffness of an attached bent plate, angle or other structural steel assembly to transfer the loads directly into the spandrel (as seen in Figure 3). This method generally is used in cases where the slab and metal deck are inadequate to resist the façade loads. Examples of such scenarios include a long, overhanging slab that produces a large moment or when there is a slab opening in the back-span that limits its capacity. Due to the eccentricity of the façade load, the spandrel must resist the induced torsion or be braced against it.

Concrete Slab and Metal Deck

The concrete slab cantilever can be designed according to ACI 318 and there exist design tables in AISC *Steel Design Guide 22* for flexural strength and slab geometries. When the slab and metal deck act as a cantilever to support the façade (Method 1), the façade should transfer its loads to the slab through direct bearing. To determine the effective slab width, a conservative approach is to take the effective width equal to the width of the concentrated load plus twice the distance to the line of bending in the slab (as shown in Figure 4, p. 20).

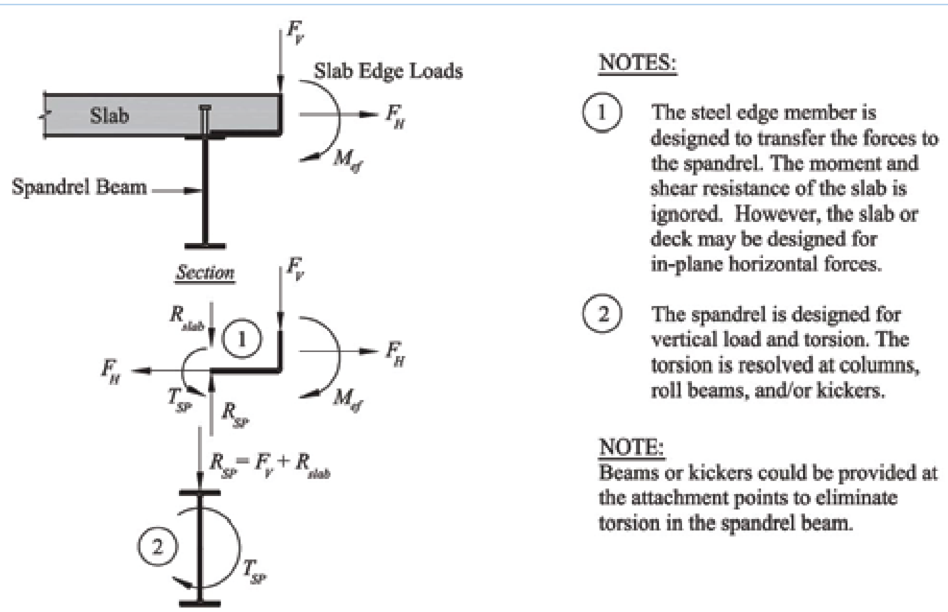
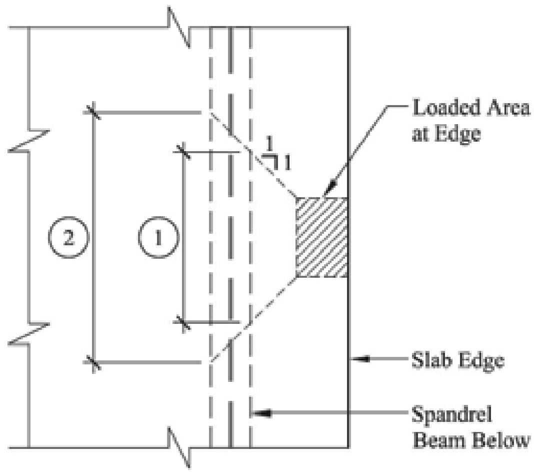


Fig. 3: Design concept of Method 2, where the spandrel is used to resolve eccentricity of façade panel loads.



NOTES:

1. Effective width at tip of flange at slab overhang.
2. Effective width at critical section for slab back span. Note that if the deck is perpendicular to the spandrel, the effective width is reduced by the presence of the flutes in the deck. Use the sum of the rib widths within the effective strip.

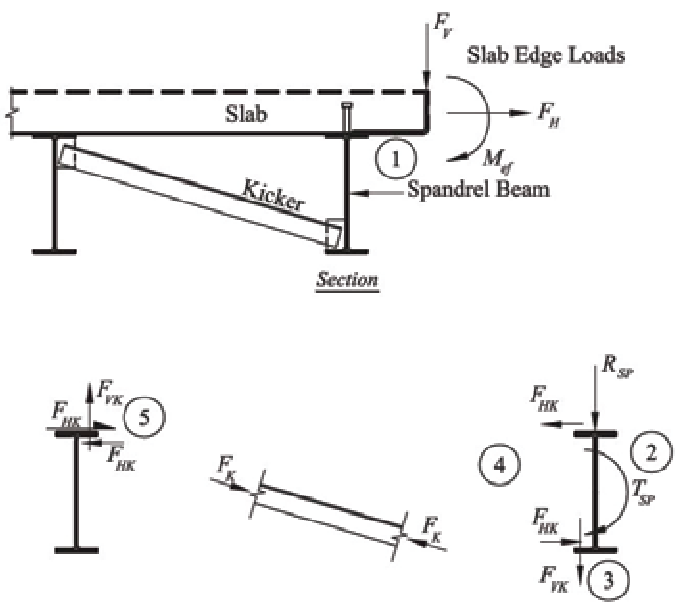
Fig. 4: Effective width for concentrated loads at slab edge.

The orientation of the flutes of the metal deck also may affect the effective width and effective depth of the slab. When the flutes are oriented parallel to the spandrel beam, the effective depth is taken at the location where the depth is reduced at the flute; the effective width is unaffected. If the flutes are oriented perpendicular, the full slab depth is effective but the effective width must be reduced to account for the area of concrete not present in the compression zone. The design guide also addresses other forces that slab and deck must also be able to resist, including forces from kickers or roll (back-up) beams, when used, and the horizontal force couple due to eccentricity.

Spandrel Beam

In the case of Method 2, the eccentricity of the façade load induces torsion on the spandrel beam. Wide flange sections make great flexural members, but offer little torsional resistance and often require bracing against twist. If the spandrel beam is a girder with in-fill beams framing to it, the secondary framing may provide adequate restraint against twist. If there is no secondary framing, however, the spandrel must have sufficient torsional strength and stiffness or additional restraint must be provided.

One common solution is to add intermittent perpendicular kickers or bracing angles between the bottom flange of the spandrel and the top flange of the first interior beam (as shown in Figure 5). It can also be an anchored connection in the slab. Another common solution is to include additional framing perpendicular to the spandrel, referred to as "roll beams" (shown in Figure 6, p. 22). The connections on roll beams must be designed with enough moment resistance to sustain the torsional shear. The presence of a kicker or roll beam results in vertical and horizontal reactions in the spandrel, and the horizontal force couple between the top and bottom flanges resolves the twisting force.



NOTES:

1. The steel edge member is designed to transfer the forces to the spandrel. The slab is neglected.
2. The spandrel beam is designed for the vertical reactions and torsion between the kicker locations.
3. The kicker reaction results in both horizontal and vertical load to the bottom flange of the spandrel.
4. The force-couple at the top and bottom flanges resolves accumulated torsion from the spandrel. The top flange of the spandrel must be restrained by the deck/slab or a supplemental member.
5. The kicker applies vertical and horizontal forces to an interior beam and/or slab.

Fig. 5: A kicker brace can be used to resolve the torsion in the spandrel.

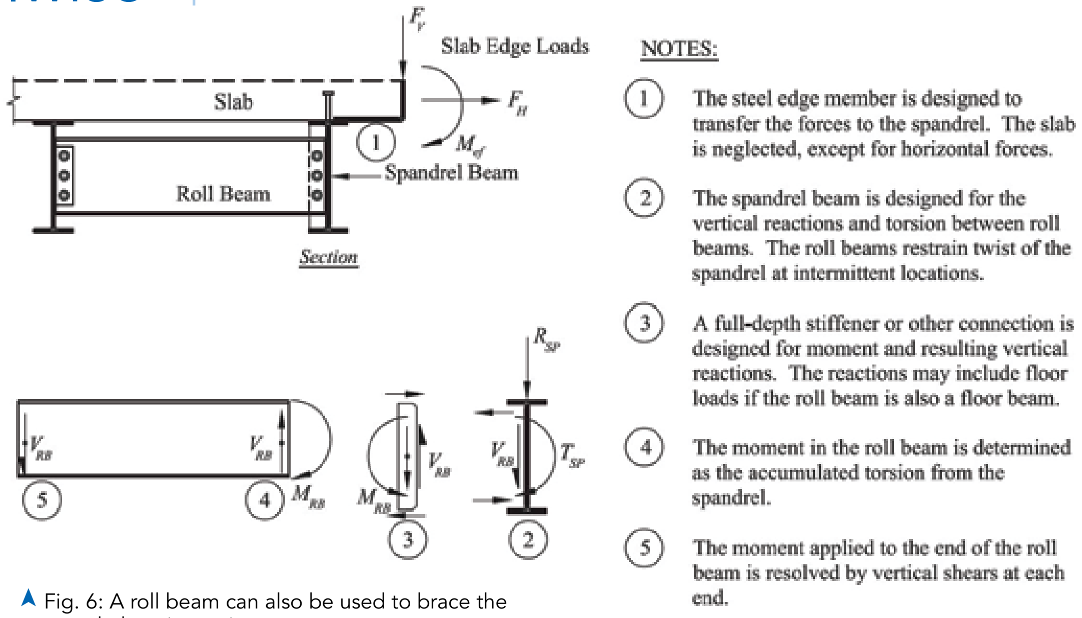


Fig. 6: A roll beam can also be used to brace the spandrel against twist.

Light-Gauge Metal Pour Stop

One economical slab edge detail incorporates a light-gauge metal pour stop. Typically used in Method 1 and made of cold-formed steel of 10- to 20-gauge thickness with a yield strength of 33 ksi, its sole purpose is to form the edge of the slab. It is an item that usually comes with the metal deck procurement package and is welded to the spandrel during erection of the metal deck. The Steel Deck Institute provides a design table for light-gage metal pour stops to support the weight of wet concrete, concrete pore water pressure on the vertical leg and a uniform construction live load of 20 psf; this table is also printed in AISC *Steel Design Guide 22*.

SDI recommends that the designer limit the design flexural stress to 20 ksi for the wet concrete load, temporarily increased by one-third for the construction live load. The table provides designs for an overhang length of up to 12 in. It is also recommended that the horizontal and vertical deflection should be limited to a maximum of ¼ in. for concrete dead load. (The design approach of the light-gauge metal pour stop is detailed in Figure 7.)

These pour stops are generally not strong enough to be expected to carry any of the façade loads. Use of this type of detail is limited to the slab being able to resist all of the superimposed loads, including the façade. Overlap between the spandrel flange and the pour stop is commonly specified as 2 in.

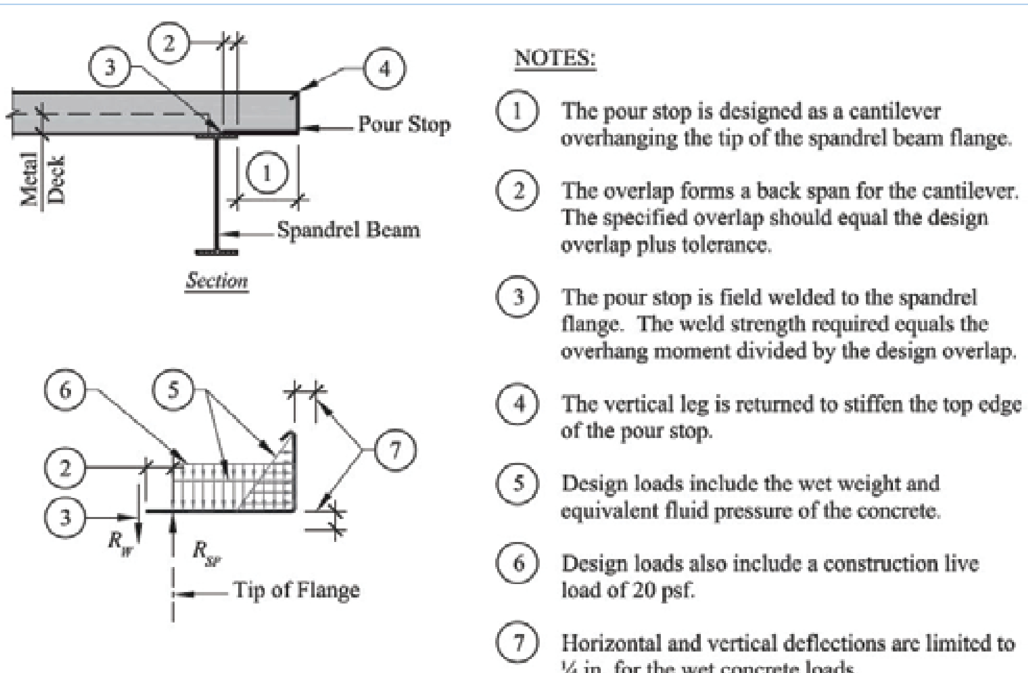


Fig. 7: Design considerations for a light-gauge metal pour stop.

Bent Plate

Instead of a light-gauge metal pour stop, a bent plate, angle or other steel assembly can be used. Bent plates are stronger and have more versatility than light-gauge metal pour stops. A bent plate can be designed to act as a pour stop, and also as a transfer element to provide a load path between the façade attachment and the slab, or between the façade attachment and the spandrel beam.

Designers might choose to use a bent plate in lieu of a light-gauge metal pour stop for several reasons, including:

1. The cantilever slab overhang is too large to be supported by a light-gage metal pour stop.
2. To transmit the façade forces into the slab by attaching it to the façade and welding a headed stud on the vertical leg (Method 1).
3. The slab and metal deck are inadequate in strength or stiffness to support the façade, so the bent plate is used as a means to transfer the forces into the spandrel (Method 2).

Note that as thickness increases, practical lengths of the bent plate get shorter. Hot-rolled angles do not have this length limitation and have tighter tolerances, but required thicknesses and leg sizes are not always readily available. Minimum and maximum thicknesses of bent plates are generally 3⁄16 in. and ½ in., respectively, limited by the bending equipment capacity. They can be shop- or field-welded or bolted, though shop attachment requires that field adjustment must be provided for in another way. AISC *Steel Design Guide 22* contains design tables for bent plates up to an overhang length of 18 in.

Steel Design Guide 22 is a good resource when designing and detailing the slab edge to sufficiently transmit the façade loads into the structural frame. There are many solutions, but the key is to develop one that is economical and efficient. Also, refer to the *MSC* SteelWise column in December 2007, titled "Pushing the Envelope," and AISC's webinar on façade attachments at **www.aisc.org/elearning**. MSC