

Pushing the Envelope

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Careful attention to façade attachment details pays off in the long run.

ONE OF THE MOST CHALLENGING DETAILS FACING STRUCTURAL DESIGNERS IS THE SUPPORT OF A BUILDING FAÇADE. The complexity of this attachment is not to be overlooked, and the entire design team should be engaged in developing a strategy for supporting the façade system in order to prevent unplanned changes and problems in the field. The structural designer should then strive to develop slab edge and spandrel beam designs that are consistent with this strategy.

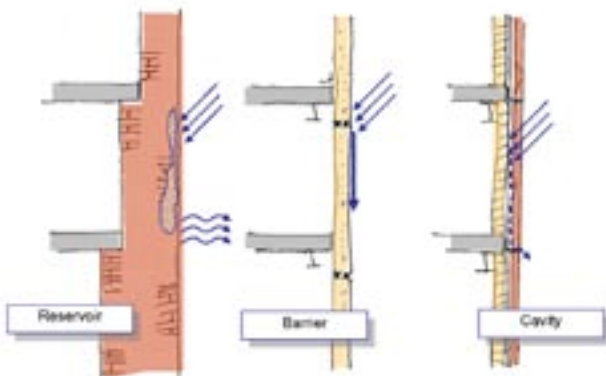
Building Envelope Systems

Before devising a support strategy, it is important to understand the function of the façade system. There are three basic concepts for exterior walls to mitigate water infiltration: reservoir walls, barrier walls, and cavity wall systems. While each system is designed to keep water out of a building, each approaches the problem differently. Understanding the type of system that the structural frame is supporting is important for determining appropriate goals for the structural support.

Older masonry bearing wall buildings employ the reservoir system. In traditional thick stone and brick bearing wall buildings, the walls act as reservoirs and allow a certain amount of water infiltration into the wall. The walls are thick enough to prevent an unacceptable amount of water from entering the interior space, and the water later escapes by weeping and evaporation. Though good in its day, this system is heavy and is no longer considered to be cost-effective.

Most modern commercial walls are constructed as either barrier or cavity systems. Barrier wall systems are just that—barriers designed to keep water out of the wall and to rely on the exterior surface and joint seals to prevent (or mitigate) water infiltration into the building.

Alternatively, cavity walls have a drainage plane and waterproofing barrier behind the exterior cladding and a means to divert water



Exterior wall systems for mitigating water infiltration.

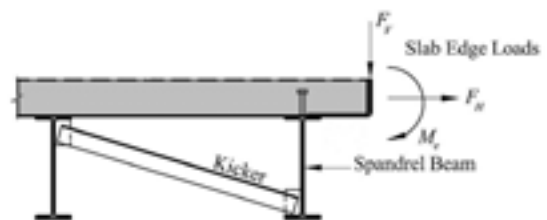
out of the wall. Water that makes it past the cladding runs down the drainage plane and out of the wall through weep holes at the base or at flashing joints. AISC's Design Guide 22 and its seminar on façade attachments to steel frames give attachment strategies to accommodate the challenges of each of these wall systems.

Design of Slab Edge Conditions

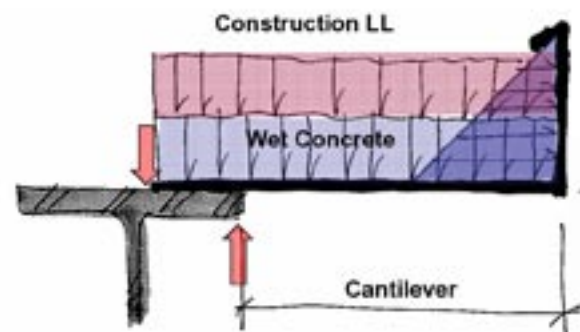
In designing slab edge conditions, there are two fundamental approaches: Either the slab cantilevers over the spandrel beam to carry any loads applied to the overhang, or the designer does not count on the slab as a cantilever, and loads applied to the overhang are carried by a structural steel plate or assembly attached to the spandrel beam. Generally, using the slab to carry the loads as a cantilever will be more economical than relying on the spandrel beam alone, but the slab must have sufficient strength to carry the load without increasing the thickness of the floor slab system. Otherwise, a bent plate or other steel assembly must be designed to transfer façade loads to the spandrel beam. Several examples of these appropriate details are included in the design guide and seminar.

Pour Stops and Bent Plate Edge Details

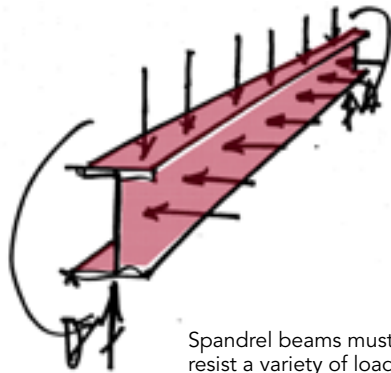
The use of a light-gage metal pour stop as part of the façade support system is generally limited to slabs that have a clear overhang less than 12 in. and slabs that have sufficient strength to sup-



Typical forces at slab edge conditions.



Design loads on light-gage metal pour stops or bent plates.



Spandrel beams must resist a variety of load conditions.

port superimposed loads. Typically, in this type of slab edge, the façade attachment will be made directly into the slab or spandrel beam and will not engage the pour stop. Accommodating such an approach may become difficult at corners and column joints. When used, the light-gage metal pour stop should be designed for the wet weight of concrete, concrete fluid pressure on the vertical leg, and 20 psf of live load. When these conditions are such that a light-gage element can not accommodate the loads, the designer must employ the use of a bent plate at the slab edge. The bent plate may be designed to be a pour stop, a means to attach the façade, and a means to transfer the façade loads to the primary structure.

Design of Spandrel Beams

As one might suspect, spandrels must have sufficient strength and stiffness to resist the applied loads, but must also be designed to accommodate architectural and practical limitations of the system. For strength, the spandrel design must consider:

- superimposed floor loads
- loads arising from weak-axis bending
- torsion on the member and its connections
- offsets between the centerline spandrel and of the column
- eccentric façade loads

For serviceability, the spandrel design must consider:

- deflection due to superimposed dead loads and live loads
- rotation of spandrel beams and façade supports
- long-term creep of composite sections
- relative displacements of the structural frame with respect to the façade
- tolerances of the façade and structural frame

And, for practical reasons, the spandrel design must consider:

- overall depth and flange width
- the interferences with the slab edge and the connections
- interferences with window heads
- interferences with mechanical systems such as ducts and piping
- interferences with shade pockets or other architectural features
- flange interferences with the façade system
- clearances for fireproofing and façade elements
- constructability of the spandrel

Because composite spandrel beam sizes are often controlled by post-composite deflections, cambering composite spandrel beams does not tend to reduce the beam weights for most façade systems. Cambering adds to the tolerances that the design of the façade system must accommodate, and it should typically be avoided for spandrel beams.

Wind and Seismic Loads

For the base building components, the structural engineer of record can often use a simple and conservative design when planning for façade wind and seismic loads without adding undue cost. Negative wind pressures on the wall, combined with gravity load eccentricities, will often control the design of the façade attachment, particularly those attachments made to the bottom flange of the spandrel beam as shown in the below figure. The IBC requires components and cladding to be designed for seismic forces and the attachments to accommodate relative seismic displacements, which can be large. These requirements should not be overlooked and can control wind loading for heavy wall systems.

Kickers and Roll Beams

When façade loads are eccentric to the supporting spandrel beams, significant eccentricity exists on a cantilevered slab. There are a number of strategies that the designer can use to help to resist the torsional moments imposed on the spandrel beam. Commonly, either a roll beam or a kicker is provided to restrain the beam against rotation. Each system has advantages and disadvantages. In addition to their role as a torsional brace, kickers can also be used as an effective solution for resisting façade forces applied between floor levels; however, they require coordi-

nation with the architectural and mechanical systems, which can limit their use. Roll beams ensure a rectangular grid of girders and beams, but designers must be sure to design their connections to the spandrel beams to have some level of moment resistance. Both approaches, however, are effective ways to restrain torsion on spandrel beams and thereby reduce spandrel beam rotations.

Accommodating Tolerances and Adjustments

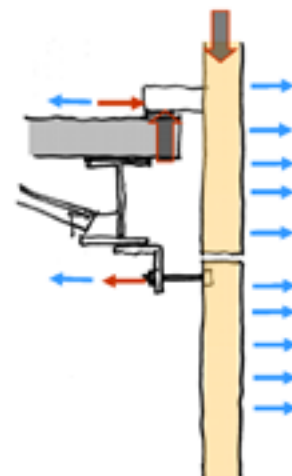
Every façade attachment design must allow for adjustment to accommodate tolerances and deflections. Steel framing tolerances are generally larger than façade tolerances, and the designer must be careful to provide sufficient adjustability in the design to accommodate these tolerances, which may accumulate. A good attachment detail will provide the means to:

- adjust the slab edge in or out relative to the spandrel beam,
- adjust the location of the façade system in or out relative to the slab edge,
- adjust the location of the façade system up or down relative to the slab edge,
- and adjust the location of the attachments both vertically and horizontally.

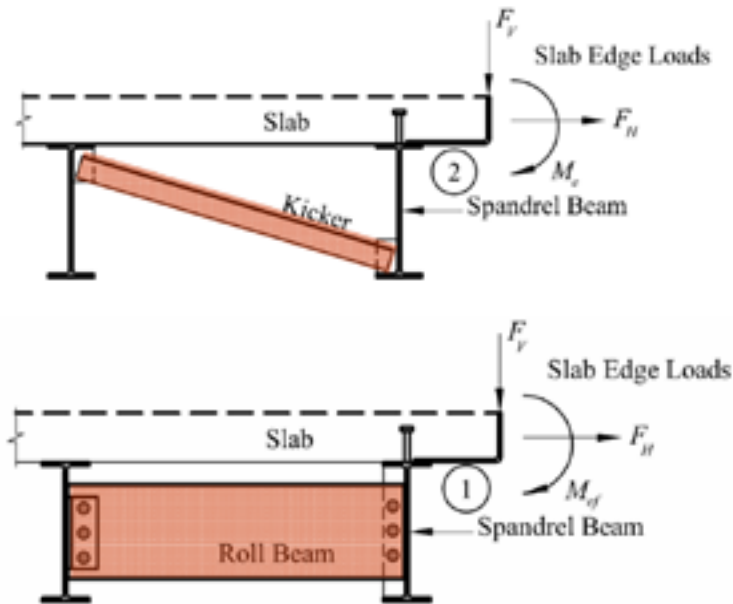
Designers must also provide sufficient clearances between the steel frame and the façade that accommodate tolerances, relative movements and rotations, thermal insulation, fireproofing, and access to install the façade component.

Forces from Restraint

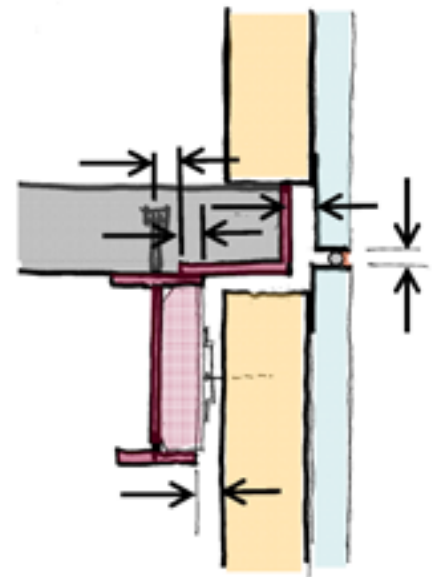
The façade system must be designed to



Façade attachments must be designed to resist lateral and gravity loads.



Eccentric loads on spandrel beams can be resisted by kickers (top) or roll beams (bottom).



Façade systems and related details must account for fabrication and erection tolerances.

accommodate relative movement between stories, and when that movement is restrained the restraining element is highly loaded. When possible, it is best to avoid restraint altogether. When it can not be avoided, restraint forces can be difficult to predict because of cracking, creep, and attachment stiffness. It is also important to be cautious of the potential for inadvertent restraint caused by friction, movement, or other sources, which can have dire consequences when not accounted for.

Conclusions

Designing façade systems can be a challenging effort. The process should be

approached with an earnest understanding of its complexity, and by initiating a dialogue among the structural engineer, architect, façade system designer, and contractor to arrive at the most practical and economical solution for a project. With open communication and the appropriate degree of care, most façade attachment problems can be avoided from the start, making the project successful for the entire construction team. **MSC**

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