Aluminum Cladding On Multistory Steel Frames

Loads, cladding movement, construction tolerances and clearances and anchorage to a building must all be considered

By Kevin C. Cole, P.E.

Aluminum and glass cladding is one of the most common exteriors for multistory steel-framed buildings. Whether its a stick, unitized, mullion or some other system and whether its infilled with glass, metal, stone or some other material, the structural engineer faces many of the same issues.

Development and determination of the exact cladding system for a particular building often will occur well after the completion of the Structural Drawings and Specifications. The cladding engineer finds most of the performance criteria for an aluminum curtainwall system in Section 8900 (Curtainwall, General) of the Structural Specification. Other relevant sections include: Division 3 (Concrete); Division 4 (Masonry, Stone); Division 5 (Metals); and Division 7 (Thermal and Moisture Protection).

Building and Cladding Loads

The cladding loads will be different than those loads for which the steel building frame was designed; however, they will come from the same source.

Wind loads can be determined by utilizing one or more of the following sources:

- Local Building Codes
- State Building Codes
- Model Building Codes
- National Standards
- Wind Tunnel Studies

The Structural Drawings and Specifications should clearly indicate the code and the edition of the code. Specific criteria that are particular to the individual building should be stated, especially if the criteria are not apparent in the code. Such criteria could be: exposure; importance factor; wind speed; mean building height; or areas of discontinuity.

Since the cladding engineer usually has limited knowledge of all the design conditions or the terrain surrounding the building, exposure cannot usually be appropriately estimated. Therefore, the structural engineer should list the exposure.

Model building codes address seismic loading, awareness of which has been heightened in the years following Loma Prieta and Northridge. The National Earthquake Hazard Reduction Program (NEHRP) is administered by the Federal Emergency Management Agency (FEMA) and through the Building Seismic Safety Council (BSSC) has provided Recommended Provisions for Seismic Regulations for New Buildings. These provisions have resulted in building designs that are more flexible. While this added flexibility may be good for the building frame, it places additional demands on the cladding system. As cladding systems need to respond to increased movement, it becomes even more critical that seismic requirements be clearly documented in the

Structural Drawings and Specifications.

Live loads are another consideration in designing cladding, especially if the cladding system includes a sunshade, canopy, cornice or other horizontal projection. This load could be snow or occupancy load. Again, these loads should be included in the Structural Notes or in the Specification.

Other loads that should be included include Window Washing tiebacks, concentrated loads on sills, panic loads at entrances and other loads that are not typical to the building occupancy but may affect the performance of the cladding system.

Building and Cladding Movement

The typical multistory steel-framed building built today is much more flexible than its predecessor. In the design of cladding systems, many building and cladding movements must be considered. These movements can be accommodated with a splice joint in a stick system or a stack joint in a unitized system (see Figure 1).

The accumulation of these tolerances and movements add up very quickly. The project's architect is typically interested in the smallest sight lines possible. To minimize these sight lines, care and accuracy are necessary in determining the magnitude of tolerances and movements. Some of these movements can only be determined by the project's structural engineer and should be clearly identified in the Structural Drawings or Specifications.

Movements and tolerances that should be considered by the cladding engineer include: thermal movements; live load deflection; interstory differential movement (seismic); column shortening; shop fabrication; field installation; lateral story-to-story movement due to wind or seismic drift; and seismic lifting.

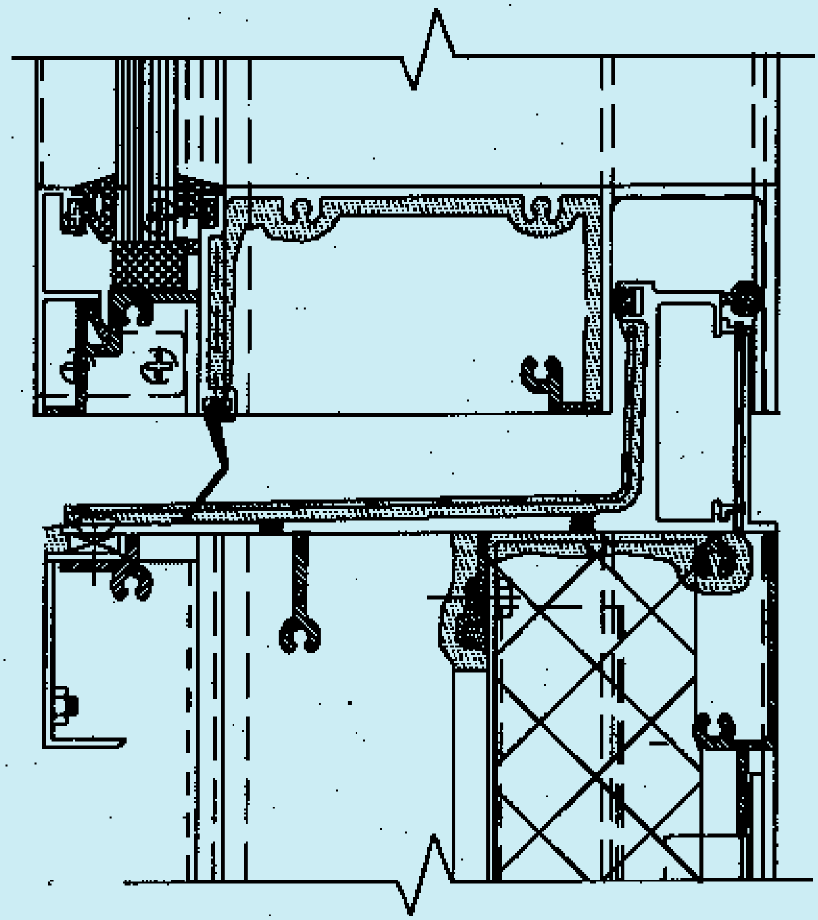


Figure 1: Typical stack joint detail

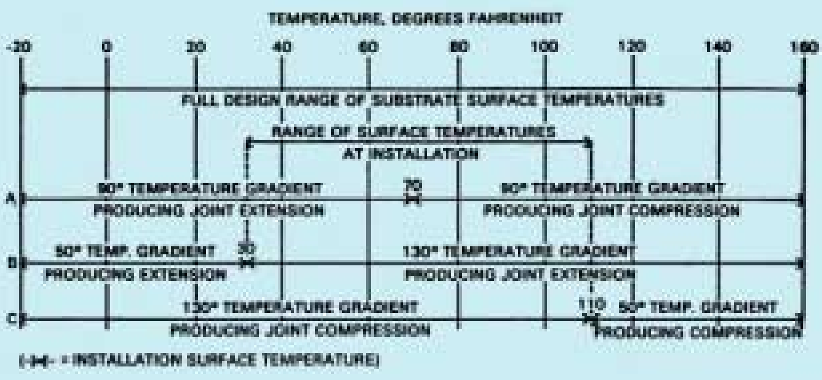


Figure 2: Affect of installation surface temperature on joint size

• **Thermal Movements.** Typically, the specification will list the expected temperature limits that the cladding system will experience. Unfortunately, these numbers do not provide all the information required to design for thermal movement. For example, performance requirements may state: "Design fabricate and install curtain wall system to provide for expansion and contraction over an ambient temperature differential of 120 degrees F and a metal surface temperature of +180 degrees F

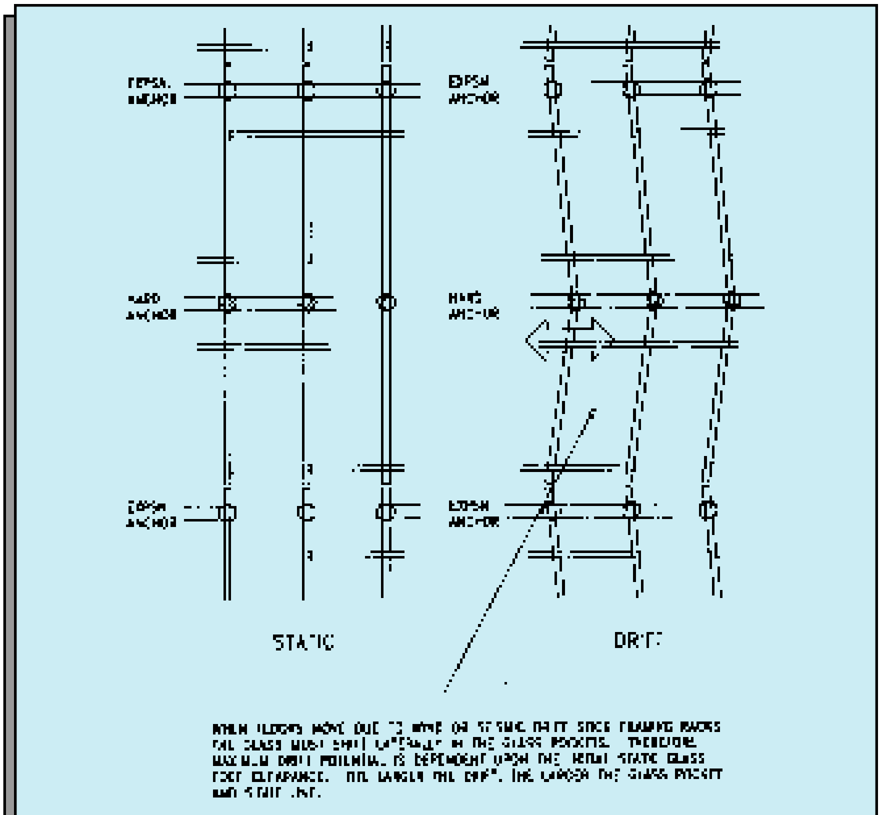


Figure 3: Stick system with drift

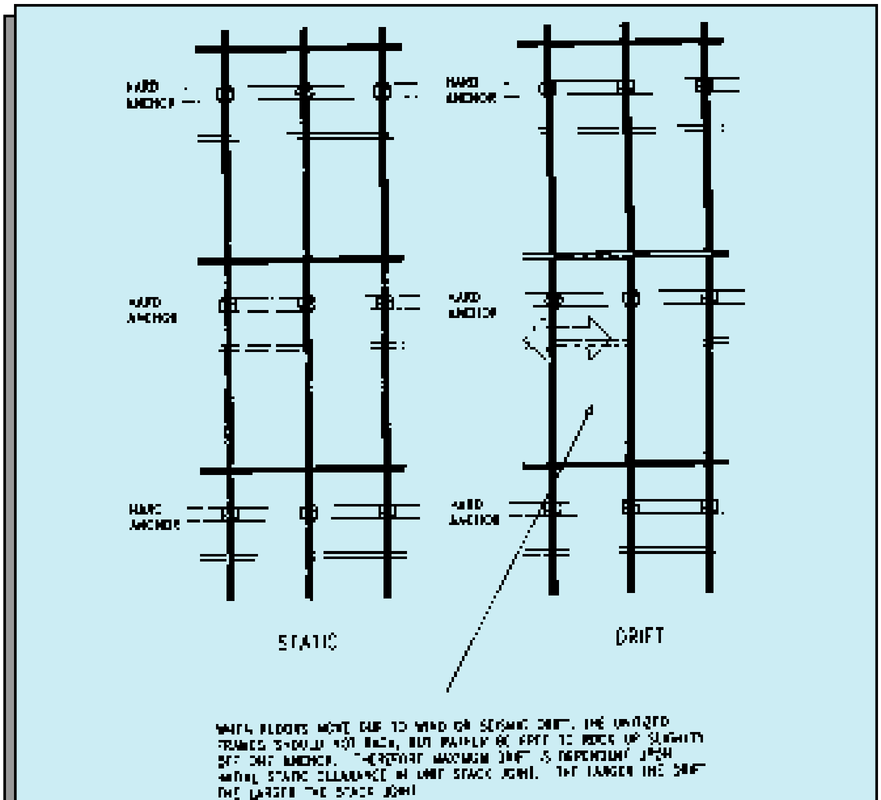


Figure 4: Unitized system with drift

without bucking, sealed joint failure, glass breakage, undue stress on member or anchors and other detrimental effects. Dimensions shown on drawings are based on an assumed design/fabrication temperature of 70 degrees F. Fabrication and erection procedures shall take into account the ambient temperature range at the time of the respective operations. However, figure 2 depicts a graph showing the possible temperature ranges that the material will experience. This graph indicates that the real temperature range the material will experience is 130 degrees F and not 180 degrees F. This provides for a difference in movement for a 13' story-to-story height of approximately ⅛". While this number may appear small, added to other conservative estimates for other movements it can greatly affect the size of a movement joint.

• **Live Load Deflection.** The live load deflection of the spandrel beam supporting the cladding system should be determined and documented by the project's structural engineer. The magnitude of this number has a large impact on the movement joint size. If the structural engineer is to only consider code issues related to deflection, a 30'-long spandrel beam could have a live load deflection of up to 1". This high a deflection would cause the movement joint and the stack mullion to be very large. Typically, if the live load deflection of the spandrel beam can be held to ⅜" or less, a system that is cost effective and acceptable to the architect can be achieved. Live load reductions and care in framing can help keep the live load deflection of the spandrel beam lower. This deflection should be determined and documented by the project's structural engineer.

• **Interstory Differential Movement (Seismic).** This movement occurs when the slabs between floors move vertically during a seismic event. If the spandrel beam is designed to resist live load deflection to a limit of ⅜" or less, then the vertical movement also will be affected. These movements when applicable should be determined and noted by the project's structural engineer.

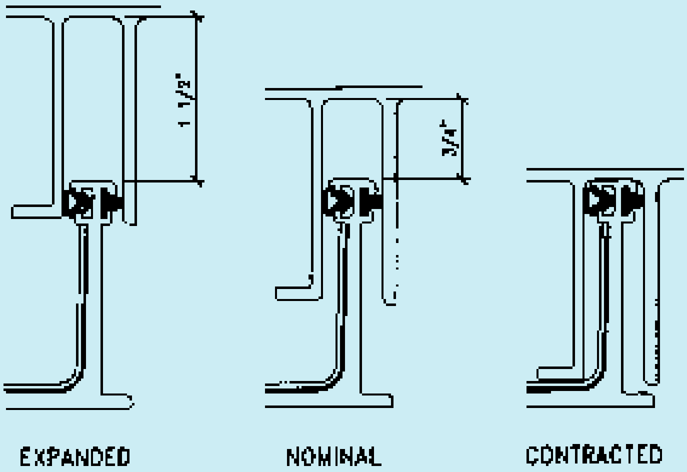
• **Column Shortening.** For low-rise and mid-rise buildings, this movement is of little concern. For high-rise buildings, the shortening related to the structure's dead load often has taken place before the cladding system is installed. Any shortening due to cladding loads and floor live loads should be determined and documented. Consideration should also be given to the timing of the application. If column shortening is a design consideration, it should be determined and documented by the building's structural engineer.

• **Shop Fabrication Tolerances.** The joint must allow for as much as 1⁄16" movement due to shop fabrication tolerances.

• **Field Installation Tolerances.** The joint must allow for as much as 1⁄16" movement due to shop fabrication tolerances.

• **Lateral Story-to-Story Movement Due to Wind or Seismic Drift.** Depending on the cladding system, lateral movements will have an impact on the horizontal movement of the cladding system and could have an impact on the vertical movements of units. Figure 3 shows how a stick curtainwall system responds to lateral story-to-story movement due to wind or seismic drift, while figure 4 shows how a unitized system responds. The new Seismic Provisions also have an impact. Many of the terms we have become accustomed to are changing. The cladding engineer needs to know two things regarding seismic movements. First, are the anticipated movements. And second is to know what is expected of the cladding system from a performance standpoint.

• **Seismic Lifting.** The horizontal movement described



Thermal Contraction / Expansion	+/-	0.209"
Live Load Deflection	+/-	0.375"
Shop Fabrication Tolerance	+/-	0.062"
Field Erection Tolerance	+/-	0.062"
Lifting from Horizontal Drift	+/-	0.032"
TOTAL	+/-	0.740" USE 3/4"

Figure 5: Sample stack joint design

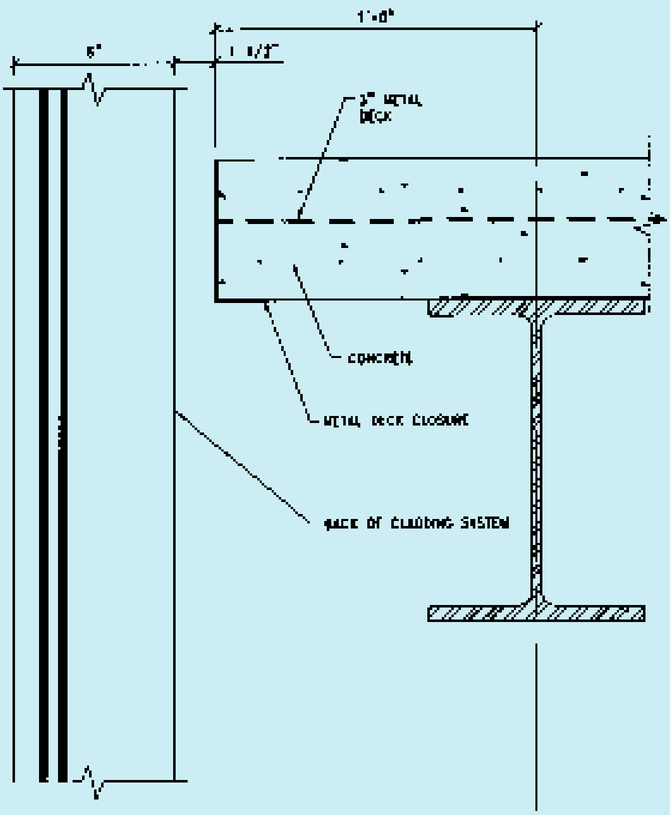


Figure 6: Detail with deck extending to slab edge

above and shown in figure 4 will cause unitized frames to lift slightly. This lift must be included in the vertical movement considerations.

Figure 5 shows the accumulation of movements and tolerances on a sample stack joint. Conservatism in each category will create movement joint that provides a large, costly sight line.

Building Construction Tolerances & Clearance

The terms tolerance and clearance as applied to cladding systems are closely related and often confused. They have distinctly different meanings, however, and this distinction must be clearly understood.

A tolerance is a permissible amount of deviation from a specified or nominal characteristic, such as a dimension, color, shape, composition or other quantity. In cladding system design related to the steel frame, we are only concerned with dimensional tolerances.

A clearance is a space or distance purposely provided between adjacent parts, both to allow for anticipated size variations and to provide working space where needed or perhaps for other reasons.

The in-place tolerance of a cladding system is typically in the range of 1/16". The building construction tolerances are typically much higher than that (the allowed tolerances of a steel-framed building can be found in the AISC Code of Standard Practice.

Upon review of the code, a building slab edge could have more than 1" of tolerance in any direction. For this reason, care must be taken in dimensioning the nominal location of the slab edge. Again, this information is contained in the Code of Standard Practice.

At times the cladding supplier is asked to provide a nominal dimension of less than 1" from the back face of the cladding system to the slab edge.

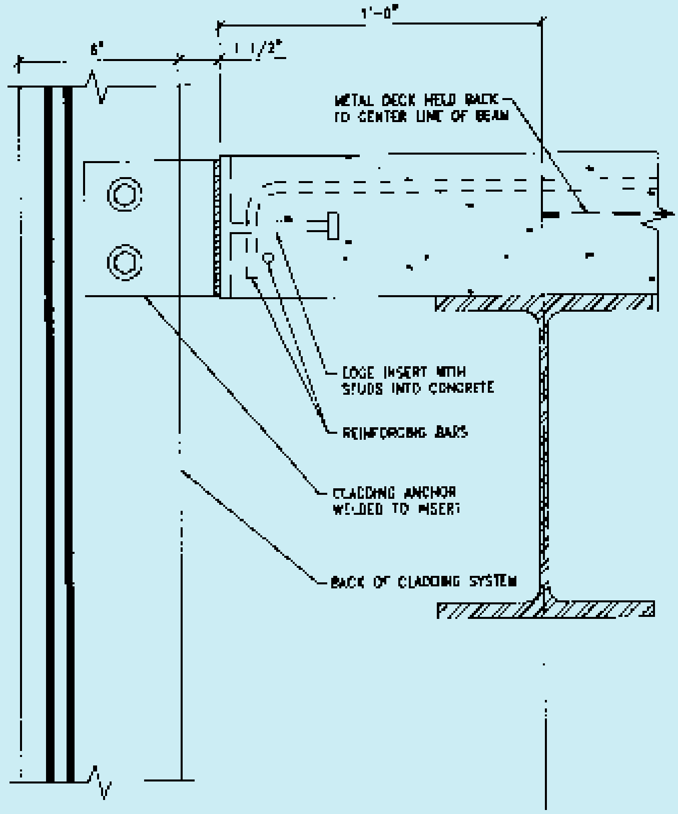


Figure 7: Stick system slab anchor detail

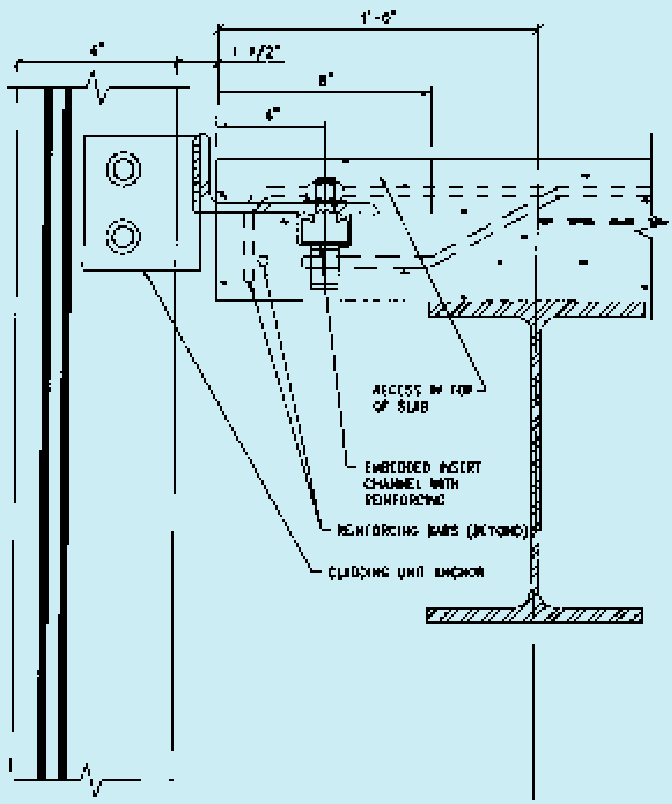


Figure 8: Unitized system slab anchor detail

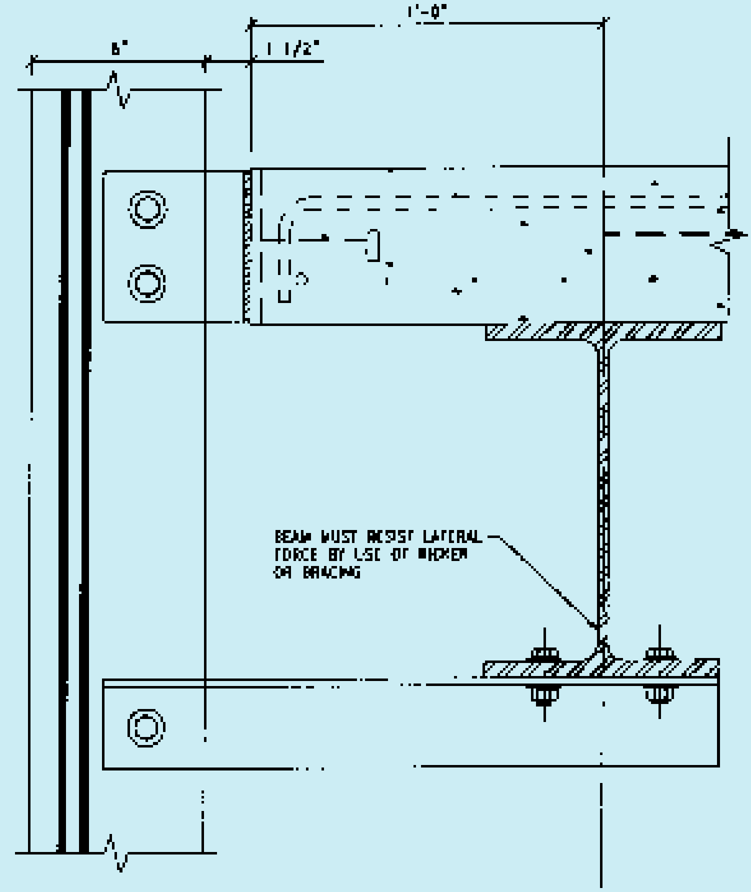


Figure Kicker detail

Dimensional restraints such as these make it impossible to provide tight cladding tolerances without notching the cladding system or the building slab. Either of thse options can be very costly. The nominal dimension from the back face of the cladding system to the slab edge should not be less than 1½". Figures 6-9 show a typical slab edge and the suggested nominal dimensions.

Cladding Anchorage

The way the cladding system is anchored to the building often is problematic. If the building structural engineer does not pay attention to the loads and considerations of the anchorage of the cladding system to the building, major additional costs may be realized. Important considerations include: termination of the metal deck; slab reinforcing at the anchor area; and kickers at the underside of spandrel beams.

• **Termination of the metal deck.** If the metal deck extends all the way out to the face of the edge screed then there is little concrete left to place a cladding system anchor. Figure 6 shows a slab edge detail with this condition. Typically, the cladding engineer needs 8 to 12" to develop the capacity of a cladding anchor. Figure 6 purposely omits the cladding anchor because it would be difficult to design a cladding anchor that could adequately support the loads in that condition. It is the responsibility of the project's structural engineer to design the slab edge not just for the anchor loads into the overall slab but also for the local effects of curtainwall anchor.

Figures 7 and 8 show details that provide adequate concrete to support a stick system or a unitized system. Figure 7 shows a plate with steel stud anchors welded to it. Given the proper concrete cover, this is a very suitable anchor for the standard stick curtainwall system. This anchor can be designed by the building's structural engineer or by the cladding engineer. If it is intended that the cladding supplier furnish the anchor plate and that the cladding engineer design the anchor plate, that intention should be clearly stated in the contract documents.

Another option would be to provide a continuous angle at the screed edge with steel studs spaced to resist the curtainwall live and dead loads. This angle would replace the formed screed edge.

Figure 8 shows an insert embedded into the full-depth concrete at the slab edge. This anchor can be used for unitized curtainwall systems and allows the cladding supplier to install a preassembled curtainwall unit from the inside of the building. This process reduces field labor and risk. Reinforcing bars can be added to the insert in those conditions when seismic loading requires a mechanical attachment of the cladding anchor to the slab system.

• **Slab reinforcing at the anchor area.** If the slab edge does not have any reinforcing as shown in figure 6, there is a danger that the cladding system loads could crack the concrete and cause a failure. The reinforcing shown on figures 7 and 8 will help enclose the failure planes at the embed and insert and will reinforce the top of the cantilevered slab edge. This reinforcing should be designed by the structural engineer and shown on the structural drawings.

• **Kickers at the underside of spandrel beams.** Often the architect's design goal is to provide a curtainwall with sight lines as small as possible. A 5" to

8” deep stick or unitized curtainwall system will work for a low- to mid-rise building with 4’ to 6’ mullion spacing and floor-to-floor heights below 14’. When the design parameters exceed these limits, it is difficult to design a system that meets the depth requirements set by the architect. One option for the cladding engineer is to provide a kicker at the underside of the spandrel beam as shown in figure 9. This kicker may apply loads to the spandrel beam for which it was not designed.

The building’s structural engineer should coordinate the design effort with the architect. If the architect is interested in small sight lines but the floor-to-floor height, mullion spacing or wind loads are excessive, the structural engineer should consider providing either stiffeners, kickers or some other form of lateral support for the bottom flange of the spandrel beam to resist a potential kicker load. If the spandrel beams are not designed for kicker loads, the structural engineer should take care in reviewing the architectural drawings. At times, a set of architectural drawings will show kickers supporting the cladding system even though the structural engineer did not design it.

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