Successful Designs for Curtain Wall Attachment

By John L. Wheaton, P.E.

The Wachovia Building in North Carolina is an example of a successfully detailed curtain wall system.

Successful designs for attaching curtain wall systems to steel structures start with a basic understanding of the design curtain wall system, how it frames and how its anchorage system and loads relate to the primary structure to which it is attaching. While there are many types of exterior cladding systems, this article will focus on attachment issues related to continuous aluminum curtain wall systems anchoring to the building, along with some common problem area applications, as well as how the attachments relate to the structure behind.

Curtain Wall Basics

A curtain wall system is a non-load bearing exterior wall system that clads the building and transmits gravity, wind and seismic loads to the building structure. Curtain wall systems are comprised of any combination of glass, panel or stone veneer supported by aluminum or steel framing members and anchored to the building structure. The curtain wall acts as a major defining element of the outside of a building and is required to give the building its unique expression architecturally, while preventing air and water infiltration within specified limits from entering it. In order for the wall system to do this it must be attached to the primary building structure and thereby transmit the forces caused by wind load and dead load to the perimeter of the structure.

Curtain Wall Forces

Typical reaction forces from a curtain wall anchor are approximately 1.0 k to 1.5 k for dead loads (based upon typical weights of 8.50 to 10.0 psf) for a glass curtain wall and 4.0 k to 6.0 k for wind load depending on the type of system and wind pressures on the building. Some systems are heavier, particularly when stone panels are glazed into the wall system. Wind loads vary widely depending upon many sight and building factors but will usually fall within a 2.0 k to 6.0 k range.

Successful attachment design can start with the engineer of record communicating basic wind-speed, exposure and code information on the structural drawings. Often times the structural drawings do not define or provide sufficient information related to wind criteria for the curtain wall engineer to determine the windloads for components and cladding without submitting requests for information or making addition inquiries with the building design team. Also, the architectural specifications in Sections 8800 and 8900 for glazing and curtain wall systems can be ambiguous and in direct conflict with the structural general notes.

Successful attachment designs start with an understanding of the loads applied to the structure and clear definition of the wind load criteria. This can lead to a rapid preliminary investigation of the approximate loads applied to the edge of slab and how that loading impacts the slab edge and perimeter steel framing.

Typical Curtain Wall Framing

In the design of a typical continuous curtain wall system, the curtain wall vertical mullions are the primary load carrying members, and they frame in single or double span members vertically up the building, spliced every floor (single span mullions) or every other floor (twin span mullions.) The typical anchor from the vertical mullion to the floor slab or perimeter steel will be either a wind load or a dead load anchor. Successful attachment designs will move from an understanding of the loads to the consideration of the type of anchor and its attachment to the edge of the structure. In this gray area where the curtain wall system stops and the primary structure begins, consideration of the curtain wall loads and type of anchorage by the engineer of record can be a great aid to the overall success of the project. This can be accomplished by making sure that the edge of the structure provides adequate strength and dimension for the attachment of the curtain wall anchor.

The edge of the structure can take several forms. Three primary conditions in a steel building with composite deck are a continuous edge angle, a steel embed plate or an insert cast into the slab.

Continuous Edge Angle

Although often ideal for the curtain wall erector, a continuous structural angle that serves as a pour stop and an attachment element is not typically provided. When it is provided, it permits the curtain wall contractor to weld steel anchors to the edge angle at whatever point they are required. Edge angle design needs to be considered by the engineer of record for the building, and successful attachment design would incorporate the curtain wall reactions being placed at any point horizontally along the edge angle with appropriate allowances made for the construction tolerance. Construction tolerance typically accounts for one inch misalignment up, down or side-to-side. First, the angle is checked as a continuous beam with the worst case

Above and below: At 550 West Jackson, a project in Chicago, problems were encountered when an existing slab was being modified. Existing columns interfered with embed locations.

for the angle being a load in the center of deformed bar attachments that anchor the edge angle to the concrete. Local stresses should also be considered. The deformed bar or stud attachments into the concrete would also be checked with the worst case for the attachments if the load was located at the deformed bar. A check of these two items would incorporate the loading from the curtain wall anchor into the edge angle for any application.

A typical design for a continuous edge angle would be a $^3/8''$ thick continuous angle or bent plate welded to the spandrel beam and attached into the concrete with a $^1/2''$ x 18″ or $^1/2''$ x 24″ Nelson D2L bar or equivalent. Bar spacing will vary depending upon the load, angle profile and load frequency. As consultants on PNC Bank in Pittsburgh, we met and coordinated with the engineer of record for the building structure just before the miscellaneous iron contract was released. In meeting with the architects and structural engineer at this important phase of the project, we discovered that the continuous edge angle at the face of slab had not had the curtain wall loads factored into the design. The curtain wall loads were significant and would have caused rotation and overstress of the angle member.

This timely coordination meeting between the writer and the building engineer led to a last minute revision preventing a situation that could have resulted in to an inadequate edge angle. The foresight of the building design team led to a successful design for this application. Although possibly surprising to the engineers reading, my experience is that oftentimes no coordination take place, and it can lead to higher costs on project and less than desirable designs. This transition area requires both the building structural engineer and the curtain wall engineer to cross over into each other's realms.

Embed Plates

More common are composite steel and concrete floor slabs, embed plates are cast into the slab behind a light gage pour stop and are utilized by the curtain wall subcontractor to attach the curtain wall anchors. In this application, the structural engineer needs to acknowledge that point loads from the embed plate will be transmitted into the edge of the concrete slab and that the slab needs to be of adequate thickness to permit the use of a proper anchor. Too often the decking runs past the spandrel beam to the edge of the floor slab and does not permit a universal or expedient embed design. When the embed design and installation has to be incorporated with the flutes of the decking and decking direction, it leads to unnecessary complications in the design and embed layout. There needs to be adequate dimension, edge distance, coverage and bearing to permit an appropriate embed design. For thin slabs (4″ to 5″), the writer prefers a full depth concrete condition where the deck is held back and the concrete is full depth beyond the spandrel beam. If the cantilever is large, outriggers under the flat decking can support the slab. A typical embed plate design would be a 5″ x 12″ x $^3/8''$ (or $^1/2''$) steel plate with Nelson H4L studs or D2L bars embedded into the concrete. These occur at each vertical mullion location.

Channel Inserts

The last major type of attachment component into the structure is channel type insert cast into the edge of the slab. While not directly related to the structural steel, it does permit a desirable and successful design for the attachment of the curtain wall to the structure, regardless of structural systems used. The insert is cast into the floor slab behind the concrete pour stop and is designed to carry a bolted connection from the curtain wall anchor into the insert. There are basically only two products of any use in this application, which are a heavy-duty "Unistrut" type insert or a Halfen Insert. In my opinion, the Halfen insert is by far the best choice because it provides for a large number of design choices and load applications. They easily install on the job. Inserts come with internal toothed nuts or tee bolts that insert and twist 90 degrees to lock in place. Anchors for the curtain wall would be tee shaped or double angles and would bolt into the insert. The insert permits side-to-side motion of the anchor and allows for construction tolerance. This is a successful attachment concept because of the ease of erection and the lack of welding required to attach the anchors.

Non-Typical, but Common Applications

Successful attachment designs will give due consideration to some common non-typical area applications. These applications recur often from job to job, and it is important to make allowances for them. Below are some of these topics.

Roof conditions

A roof condition is typical, but the attachment to the roof level is non-typical as compared to the floor level attachments when it is a built up roof. A properly designed continuous edge support needs to be provided in order to attach the curtain wall anchors at the roof. Commonly, a continuous bent plate or structural angle, the member and the welds to the roof beam should be designed for the curtain wall reactions. Weak axis bending and rotation of the angle should be considered.

Kickers

There are several major reasons why kickers (intermediate level anchors or braces supported to the structure behind) are required for supporting curtain wall systems. Kickers, attached below the floor slab either to the bottom of the slab or to the steel spandrel beam, are required as intermediate supports when the curtain wall system does not have the strength to meet stress or deflection considerations. This can be due to any combination of tall spans, large loaded areas, shallow systems or an inability to internally reinforce due to system or architectural considerations. When kickers are required, the curtain wall contractor usually desires to weld or bolt an outrigger type anchor to the web or flange of the steel spandrel beam. A typical kicker will take the form of two angles (typically on the order of a 4 x 3 x $^1/_4$) or a steel tube with a plate on the end to mimic the edge of slab condition. I believe successful attachment designs, particularly on larger buildings, will incorporate the possibility for kickers at tall floors or high load areas.

Close coordination with a curtain wall consultant or the subcontractor's curtain wall engineer as early as possible is valuable if kickers enter into the design. A kicker can be attached to the web of a spandrel beam towards the top flange to minimize rotation if enough separation exists vertically between the floor anchor and the kicker to make a positive impact. Often the curtain wall engineer wants to anchor the kicker to the bottom flange of the beam in order to spread the anchors far enough apart to minimize load and deflection. This is usually undesirable for the structural engineer because this can cause excessive rotation of the beam (typically a wide flange). Successful designs can include an allowance for struts that will brace the bottom flange of the beam from the point of the kicker attachment to the top of the web of the adjacent beam behind. This transmits the forces through the strut into the floor slab and distributes the load into the structure. Typical kicker loads would be on the order of 1.0 k to 4.0 k in magnitude and would occur at the mullion spacing for a particular area or elevation.

Stair towers

Stair towers usually pose unique challenges because of differing floor elevations to which attach stairs by differing subcontractor and unique architectural features. Projects that provide adequate steel framing completely around the stair enclosure at a constant elevation and recognize the curtain wall attachment requirements offer the best scenario. Primary horizontal steel framing for attaching the curtainwall should be detailed on the structural drawings and called out at a constant elevation. If there is a vertical surface that mimics the same relationship between the back of the mullion and the face of structure, then a typical anchor can be used or one that is similar in concept.

Tall Storefront Spans at Ground Levels

This subject is another entire topic in itself. Often at the base of the building the architect desires features in the wall system that require large spans and open areas. It is not uncommon to have mullion spans approaching 25′ to 30′ at the first floor with a curtain wall system depth that makes it physically impossible to span the distance. When reinforcing is not an option, horizontal steel tubes framed between the columns and provided for curtain wall attachments will limit the coordination problems for the curtain wall subcontractor. These horizontal members can be covered to be made into an architectural feature.

Canopies

Canopies are sometimes detailed in concept on the architectural drawings to support to the curtain wall system. Add a deep canopy in conjunction with the clear span issues at a ground level floor, and you create an impossible situation. Successful designs will incorporate a line of intermediate steel horizontally at the canopy line. The canopy can be supported through the wall to the steel provided. The curtain wall system can be coordinated to work around the penetrations through the wall.

Conclusion

My perspective throughout this article has been primarily concerned with the transition area between the curtain wall anchor system and the structure behind. Proper consideration of how the curtain wall system anchorage requirements relate to the structure is key for a more successful approach in this area of the project. It will make for better shop drawing coordination, fewer potential change orders, more seamless design, less time to engineer the wall system and other added scheduling benefits.

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