In Support of Glazed Curtain Walls

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Curtain wall supports are important to understand because they have a large impact on both crucial architectural dimensions and perimeter transitions. Some architects seem to be of the opinion these connections should somehow resemble the typical window frame attachment. This article's authors have seen designs that simply disregard the issue of supports; the details feature a curtain wall floating on a perimeter 12.7-mm (0.5-in.) wide sealant joint. The architects of such projects are then genuinely surprised when anticipated façade module dimensions, alignments, and proportions are lost in the field.

Images courtesy Halliwell Engineering Associates

Figure 1

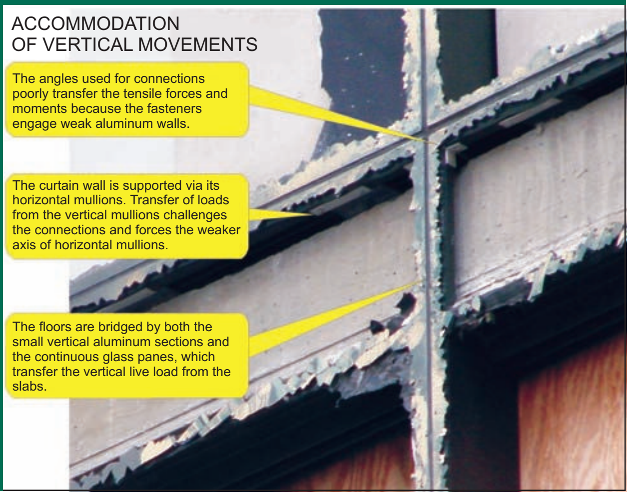
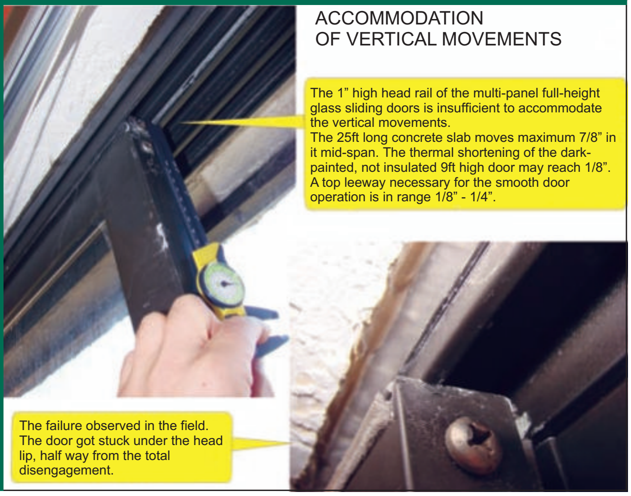


Figure 2



Unfortunately, the designer's confusion is sometimes reflected in the actual construction. Figure 1 shows a spandrel of a multi-story curtain wall in a high-rise building. It is important to observe how the live load is transferred from slabs onto the curtain wall.

In other cases, windows and doors are often used in lieu of regular glazed curtain walls. They also become subject to the same limitations and requirements affecting curtain wall assemblies. Figure 2 illustrates the failure of multi-panel, full-height glass sliding doors, incapable of accommodating the live load slab movement.

Simply put, curtain walls are not designed to carry loads from the slab. Instead, a bulky vertical structure is typically used for that purpose. The supporting elements of curtain walls must be designed to allow the free vertical movement in excess of the calculated movements.

Problems with transitions

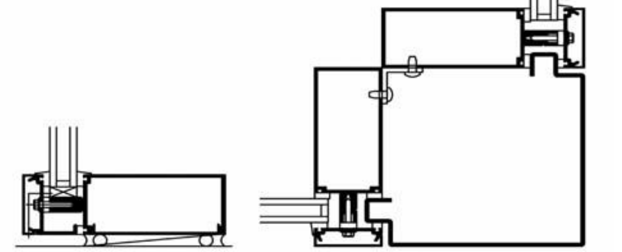
A quick scan of typical warranties shows many curtain wall manufacturers and installers exclude the responsibility for interface details and damage caused by a building's movement. Consequently, it is up to the designer to properly specify and coordinate these systems, while fully understanding their ramifications.

There is an entire 'family' of problems stemming from inappropriate transition details—these often originate in the catalogs of manufacturers, before being propagated by unsuspecting design professionals. Figure 3 illustrates the vertical detail section of a sill and the horizontal detail section of a typical curtain wall's corner. (Similar details are found in many examples of U.S. product literature.)

The accompanying field photograph in Figure 4 shows the resulting corner sill detail. The major problem stems from the fact the details disregard the presence of curtain wall anchors and the possible ramifications of their movement. Further, the

Figure 3

COMMON POOR DETAILS



SILL - VERTICAL SECTION   CORNER - HORIZONTAL SECTOIN

Figure 4

CURTAIN WALL CORNER

sill detail treats the bottom horizontal mullion as if it was continuous.

In the example shown in Figure 4, most major façade layers have been irrevocably interrupted, regardless of any future corrections and modifications the installer undertakes.

The choice of a single-wythe concrete masonry unit (CMU) curb wall for the support apparently proved challenging. The fasteners' minimum edge distances are typically the forgotten limiting factor in the choice of the substrate. Further, the support should never solely rely on gravity, as the plastic shims are prone to dislocation. Figure 5 lists other relevant deficiencies for the sill and corner associated with this detail.

Wind force resistance

Coordination and division of responsibility can become major problems whenever the curtain wall is supported on the work of other trades. A designer must specify the coordination of the flow of information among the design-builders of the adjacent systems. The reaction forces from the curtain wall anchors are very important and must be provided to the interested trades.

Normally, the best solution is to directly support the curtain wall from the building's main structure. Cast-in-place concrete curbs with embedded anchors are a second choice; to achieve success with this strategy, the vertical mullions should be frequently extended beyond the visible portion of the wall (Figure 6, next page). Unfortunately, many manufacturers charge the same rate for the footage of this extension as they do the visible part of the curtain wall, although the difference lies only in the extra length and depth of aluminum extrusions of vertical mullions. (While light-gage metal studwork can be a tempting choice for the budget-conscious designer, it is not necessarily suited for the localized transfer of movement forces and moments.)

Manufacturers have devised myriad

Figure 5

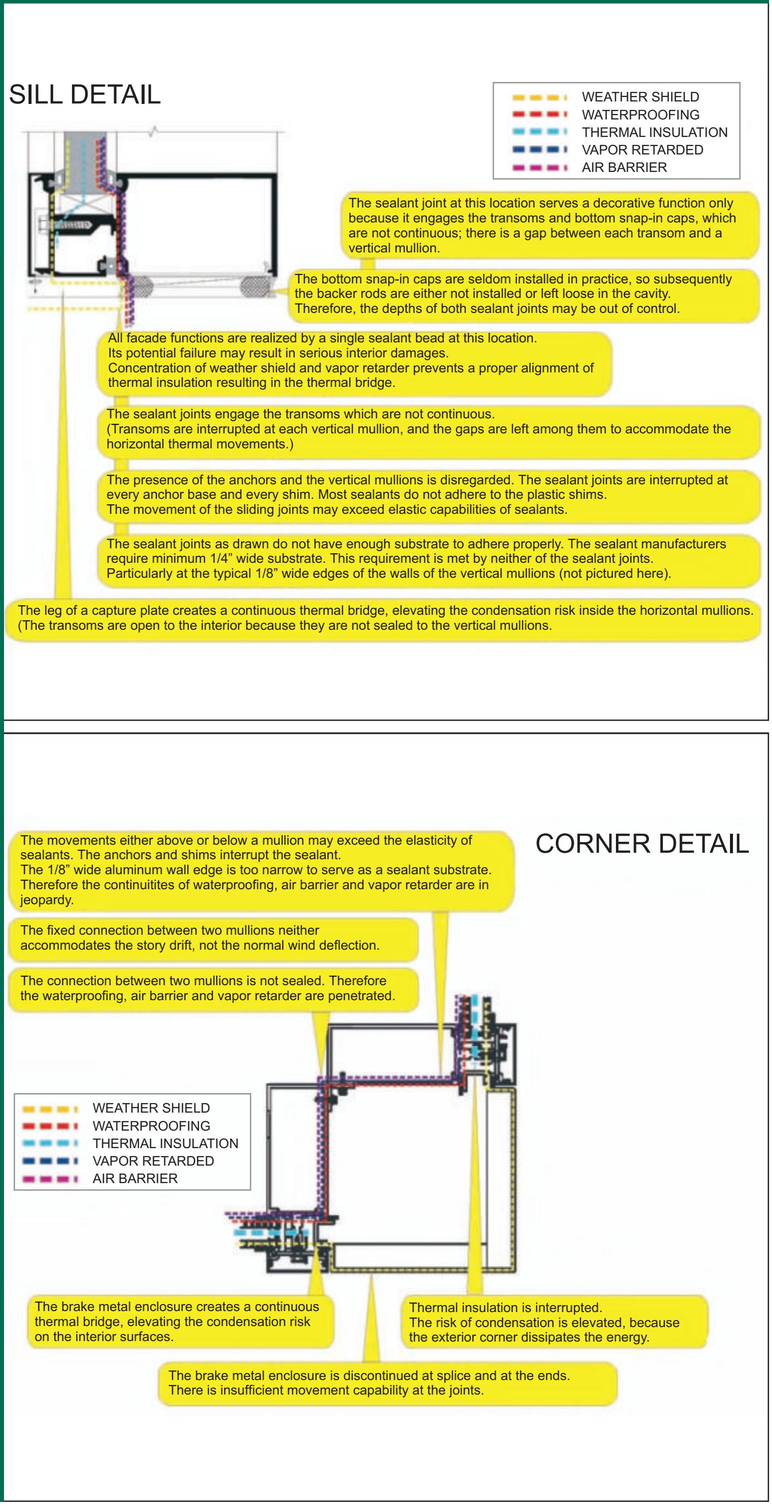


Figure 6

EXTENSION OF VERTICAL MULLION

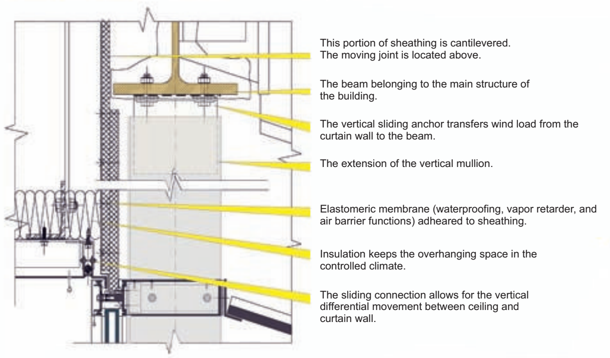
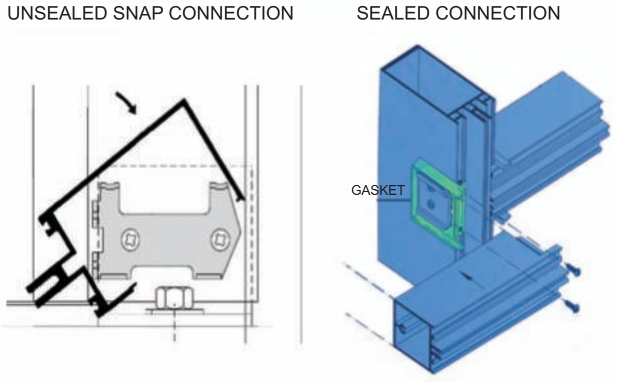


Figure 7



methods for connecting horizontal and vertical mullions. In the authors' experience, these connections are typically not sealed in the United States (Figure 7), even though most designers treat them as though this was the case, apparently relying on their air, water, and water vapor tightness.

In some curtain walls, the sides must remain free to move, allowing for uniform response under load. Locking one side of a moving wall may cause the development of undesired stresses. To avoid interface failures, the vertical mullion depth should be enough to prevent excessive differential movement at the side transitions with adjacent walls. The typical L/175 limit may be sufficient for this purpose. Only if the wall assembly adjacent to the curtain wall responds similarly to the wind load can they be locked together. In a similar fashion, the design of corners and penetrations must accommodate both the story drift and the wind deflection, or provide for transfer of forces.

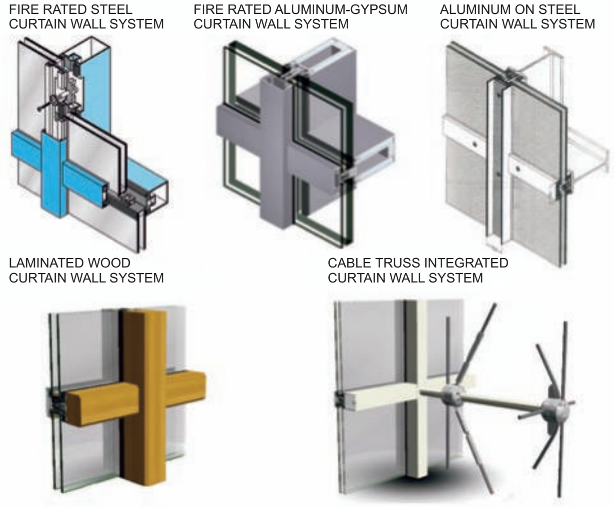
There are many materials used in the curtain wall construction (Figure 8). The authors' personal favorite is laminated word (for aesthetic reasons), but rolled steel, steal trusses, cable trusses, cable nets, epoxy laminate and glass fins are also available. Composite materials can be used to achieve special purposes. For example, gypsum-filled aluminum and steel profiles are used either for sound attenuation or fire resistance, while steel-filled aluminum is specified for wind resistance or protection against burglars or bullets.

A curtain wall can be supported in many ways. Depending on the particular needs ot the project, walls can be standing or hanging. Typically, the former eases the design of waterproof sills, while the latter allow the glass load to be carried more economically. The wall can be further devided into segments, which can be separately supported.

Wind load may be primarily resisted by horizontal or vertical members. (The horizontal members yield more economical profiles in narrow curtain walls.) The dead load, on the other hand, may be transferred separately or together with the wind load. The way a curtain wall is supported may greatly affect the architect's options of façade modulation.

Figure 9 (next page) includes a sketch and diagram of a standing, segmented, vertical mullion belonging to a typical stick-system aluminum curtain wall. This assembly stands on its bottom supports, with the vertical members resisting the wind load and transferring the glass load. The curtain wall has to resist the forces marked with red and accommodate the movements indicated with yellow. The coordinates of adjustment are in blue.

Figure 8



Images courtesy Schiico and Jansen Steel

Figure 9

DIAGRAM OF CONNECTIONS

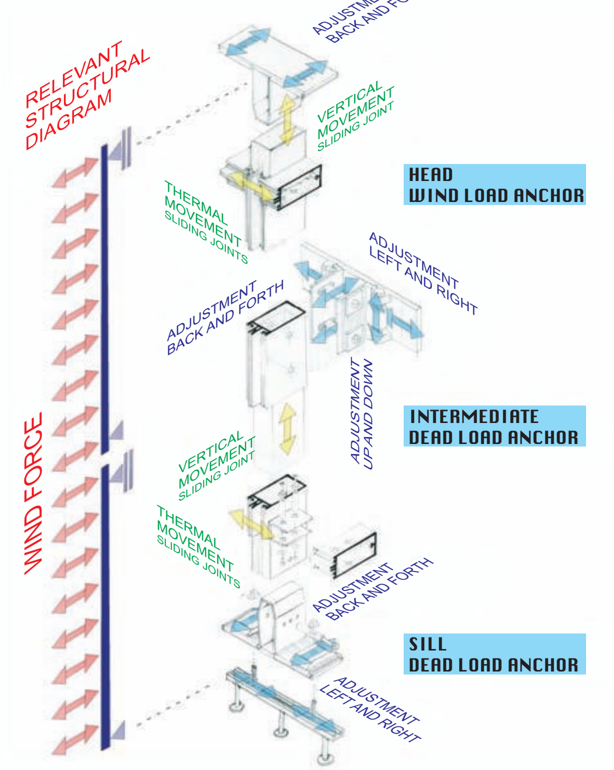
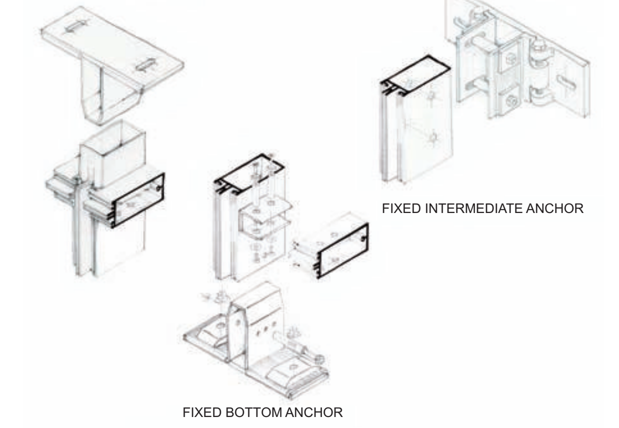


Figure 10



This diagram of a simple curtain wall involves only two types of anchors—fixed and sliding. They support the primary mullions that resist the wind force, typically the vertical ones. Some glass curtain walls may require hinges to prevent the development of undesired stresses.

Figure 10 shows the exploded views of the typical adjustable anchors. Depending on their cost and the level of sophistication of their specifier, anchoring systems may be more or less installation-friendly. Both universal and dedicated adjustable support systems—made of aluminum and stainless steel to avoid corrosion induced by galvanic action—are available. Others are frequently subjected to some random field fabrication and modifications. Figure 11 includes photographs of field-fabricated anchors.

Even relatively sophisticated anchors are subject to errors and omissions. Figure 12 (next page) shows the intermediate anchor of a large custom curtain wall. The adjustment is fixed by tightening the serrated washers against the serrated anchor plate. The inspection revealed many washers were slightly twisted around bolts and did not engage their counterparts' serrations. A strong wind could easily displace this wall. Additionally, the sliding mullion connections were found to be still locked with the temporary installation screw (marked with an arrow).

Dead load resistance

A self-load is an important consideration in the anchorage design. The majority of vertical load carried by a curtain wall comes from its glass, whose 2563 kg/m^3 (160 pcf) density, per American Society of Civil Engineers (ASCE) 7-05, *Minimum Design Loads for Buildings and Other Structures*, translates

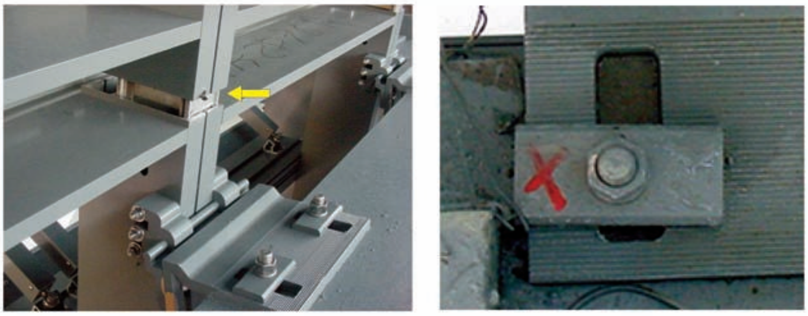
Figure 11

FIELD MODIFICATIONS OF CURTAIN WALL ANCHORS

Figure 12

LOCKED SLIDING JOINT

TWISTED WASHER



into 3kg (6.67 lb) per 0.09 m^2 (1 sf) weight of a 12.7-mm (0.5-in) thick glass pane. This weight is transferred onto a transom by the two setting blocks located at quarters of the transom's span (per the Glass Association of North America's *GANA Glazing Manual)*.

For an architect who tries to develop his or her own curtain wall details or tweak its dimensions, this information conveys two important messages:

1. The further the load is transferred from the centerline of glass units, the more movement the anchor has to sustain.
2. The longer the transom, the higher it has to be to stay within its deflection limit.

Details between continents

Whenever possible, the authors strongly encourage design professionals to study European curtain wall details alongside the usual U.S. product literature. (Figure 13 shows the same curtain wall manufacturer's U.S. and European versions of sill and corner details.) Generally, details from across the Atlantic are not necessarily more correct in addressing a situation, but they often show a deeper designers' understanding than those observed in the U.S. product literature.

In the United States, the authors have observed sealant joints used to soley perform many essential façade functions. It seems this over-reliance on sealants may have helped prevent the transfer or adoption of more advanced curtain wall interface technologies from other countries. The authors hope the sort of details reproduced in Figure 14 will gain acceptance in the design community, as they represent a reasonable compromise between building traditions and proper curtain wall construction.

In this drawing, there is a two-stage sealant joint and the continuation of all major layers provided via the continuous thermally broken profile of glazing pocket filler that can accommodate the movement in-plane. In some cases, a pre-formed gasket can substitute for the second sealant joint, which is difficult to install due to its depth.

These details allow for an uninterrupted, continuous seal around the curtain wall opening. Further, major functions are addressed by respective separate seals that provide redundancy and allow for proper thermal insulation in-between two layers. The support function is also completely

Figure 13

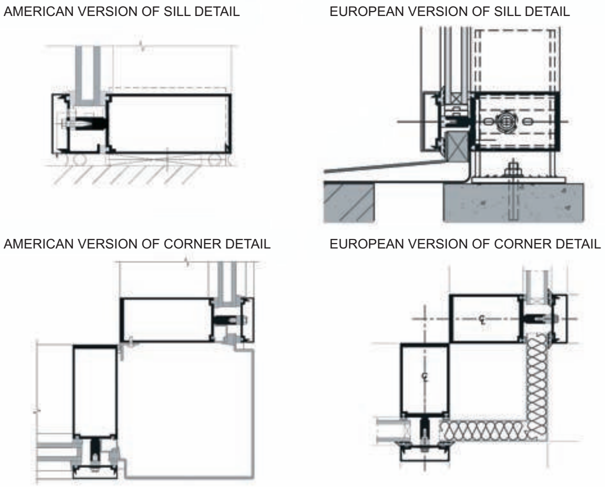
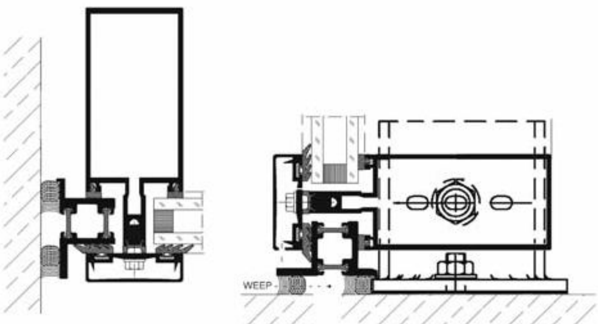


Figure 14

JAMB DETAIL

SILL DETAIL



separated from sealing functions. The depth of a glazing enables an additional 6.4 mm (0.25 in.) of differential movement.

Delivery method

Today, most curtain walls come as design-build products, eventually designed by the contractor's or manufacturer's engineering teams. An architect may draw a curtain wall schematically, but the interfaces among the systems must be thoroughly detailed. A design team of record must provide both the design conditions and requirements to a contractor's engineering team, and understand the limitations of his or her design.

The architect should coordinate the design parameters with engineers. For example, a desired curtain wall supported along an edge beam may have a 9.5-mm (3/8-in.) limit of live-load sag of its support. It may be more economical to provide stiffer structural beams than a custom curtain wall. Similarly, moist mechanical conditions at perimeter rooms (such as a museum's display space) can require a curtain wall with a high condensation resistance factor (CRF). Consequently, a designer may need to consider rearranging the floor layout. Similar coordination may be necessary for other design perimeters, ranging from acoustical to ballistic-resistant needs.

Specifications

The typical requirements begin with the wind pressure. The authors recommend specifying the minimum wind pressure (*e.g.* maximum wind pull as 1915 Pa [40 psf]) in addition to the standard vague disclaimer, "per code having jurisdiction." This is because some contractors may have a tendency to disregard both the specification and governing codes, producing bids that simply cannot be appropriately compred. It also helps to specify the applicable code.

Structural requirements depend on project conditions and may include factors such as:

- seismic criteria;
- snow load;
- rain load;
- maintenance load;
- guardrail load;
- lateral movement accommodation;

In the United States more so than Europe, sealant joints will be used to perform many essential facade functions. This over-reliance on sealants may have prevented the transfer of more advanced curtain wall technologies from abroad.

- slab deflection accommodation;
- expansion joint's movement accommodation;
- range of temperatures for movement accommodation;
- safety factors; and
- glass probability of failure.

Typical structural limitations include the non-residual maximum deflections;

- framing members: parallel to plane of curtain wall;
- framing members: normal to plane of curtain wall;
- framing members: cantilevered parallel to plane of curtain wall (vertical);
- framing members cantilevered normal to plane of curtain wall;
- metal panels or covers: normal to plane of curtain wall; and
- vertical glazing: normal to glass plane.

Structural limitations also include the residual maximum deflections:

- variation in plane;
- flatness; and
- uniform bow.

In addition to non-residual and residual deflections, any other requirements and limitations the designer deems adequate to the situation applies.

Conclusion

Architects and specifiers should collect and coordinate the appropriate information to design the interfaces among wall systems with awareness and understanding of the way they are supported. Movement and adjustment data needs to be analyzed and placed in the construction documentation. Once this information is secured, a curtain wall is given a chance to avoid the “Failures” section of industry magazines.

Recommended Reading

Aside from perusing the catalogs of various European and U.S. curtain wall manufacturers, the authors suggest interested design/construction professionals seek out the following resources:

- Thomas Herzog’s *Façad Construction Manual* (Birkhauser, 2004);
- Schittich et al’s *Glass Construction Manual* (Birkhauser, 1999);
- Alan Brookes’ *Cladding of Buildings* (E&FN Spon, 1998);
- American Architectural Manufacturers Association’s (AAMA’S) *Aluminum Curtain Wall Design Guide* Manual;
- Glass Association of North America’s (GANA’s) *Glazing Manual*;
- Joseph S. Amstock’s *Glass in Construction* (McGraw-Hill, 1997); and
- Rick Quirouette’s *Glass and Aluminum Curtain Wall Systems* (Canada Mortgage and House Corp. [CMHC]).

In the authors’ experience, many curtain wall manufacturers and installers exclude responsibility for interface details and damage caused by a building’s movement. It is up to the designer to properly specify and coordinate these systems.

Additional Information

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Abstract

When it comes to curtain walls, design professionals must collect and coordinate the appropriate information to design interfaces with an awareness and an understanding of the way in which they are supported. The authors examine a variety of tactics and troubles with U.S. assemblies, emphasizing that movement and adjustment data needs to be analyzed and placed in the construction documentation.