DESIGNING WITH STRUCTURAL

STEEL

A GUIDE FOR ARCHITECTS

SECOND EDITION

AMERICAN INSTITUTE OF STEEL CONSTRUCTION
One East Wacker Drive, Suite 3100
Chicago, Illinois 60601-2000
Tel. 312.670.2400
Fax 312.670.5403
www.aisc.org

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INTRODUCTION

This section has been developed to provide conceptual detailing considerations for various building enclosure systems (building skins) and their connections to different types of steel framing systems. The details are intended to identify issues that should be addressed in early phases of the project, as wall sections and interfaces with the structure are developed. Each type of enclosure system includes a commentary that elaborates on detailing considerations. Several references are given at the end of this section.

This section is not intended to be a comprehensive detailing guide. It is intended to identify issues that should be addressed in early phases of a project—when wall sections and enclosure systems are interfaced with the structure. The details are not intended to identify all necessary components of a weather tight enclosure system. Various regions of the country will have other details that are equally appropriate and cost effective.

GENERAL CONSIDERATIONS

Lateral System. The type of lateral system used in a building will have a large impact on where the interior face of the enclosure system is located relative to the column centerlines. If diagonal bracing is used, the enclosure system and the interior wall finish, along with its supports, must clear the bracing members. Usually the bracing members are rods, angles, or structural tubes that are located on the column centerlines. If single angles are used, the vertical leg of the angle is attached to a gusset plate that is located on the column centerline and the horizontal leg is oriented either toward the interior or exterior face of the building. The horizontal leg should be oriented so as to avoid interference with the CMU back up and the interior wall finish supports. It should be noted that if a diagonally braced system is used, bracing is not required in every bay. Depending on the building size and configuration, bracing may only be required in one or two bays in each direction. Diagonally braced bays can sometimes accommodate doors and windows within the bay—provided the opening's frames and supports clear the bracing members.

If rigid moment frames or shear walls are used as the building's lateral system, the lateral system will not dictate the location of the enclosure system or interior wall finish surfaces. There are, however, cost implications and detail considerations that must be addressed if unbraced lateral systems are used. Additional information on lateral systems is given in the Systems Section of this Guide.

Floor System. The floor system shown is a steel floor deck with a concrete topping system. Typical floor system thicknesses range from 4 in. to 7.5 in. The thickness of the floor system is dependent on the floor loads, the distance that the system must span between beams, and the required fire rating. The metal deck can be either a composite steel floor deck, or a non-composite steel floor deck. A composite steel floor deck is a cold-formed steel deck that acts as a permanent form and as the positive bending reinforcement for the structural concrete topping. In other words, it is a steel deck which has dimples pressed in the deck which interlock with the cured cast-in-place concrete to form the tension reinforcing in the bottom of the slab. Non-composite steel floor deck is cold-formed steel deck that acts as permanent formwork for reinforced concrete slabs. It is only a form—the deck does not have dimples, and it does not act compositely with the concrete.

The floor system can be supported on either non-composite beams, or composite beams. Non-composite beams are standard steel beams that support the metal deck and concrete topping. Composite beams are steel beams that have headed studs welded to the top flanges of the beams after the metal deck has been installed. These studs interlock with the cured cast-in-place concrete and act together as a composite unit. The advantage of composite beams is that the steel depths and weights can usually decrease as a result of the composite action. It should be noted, however, that the resulting shallower floor system should be carefully checked for any floor vibration concerns.

Several other types of floor systems including cast-in-place concrete and precast concrete planks can be used with steel framing. Precast planks can economically span 10 to 40 ft between steel girders, depending on the floor load and plank thickness. Be careful, though, as long spans of planks may lead to deeper steel girders.

Fireproofing. Applicable building codes will determine the required fire ratings for various construction classifications. They also determine the required fire ratings for various components and systems within the building. All recognized fire rated systems are tested and passed by appropriate regulation standards agencies such as Underwriters Laboratories, or National Evaluation Service, Incorporated. Many types of fireproofing systems are available. Friable (soft) and cementitious fireproofing systems are generally the most cost effective types of spray-on systems. Intumescent paints may be a desirable solution as a fire-resistant coating for steel that is exposed to view.

Primed or painted surfaces can present potential adhesion problems for spray-on fireproof coatings. If paint is specified for structural steel that will subsequently be protected with spray-on fireproofing, e.g., metal deck, the architect should contact both the paint and fire protection suppliers, in advance, to ensure compatibility of the two products. Otherwise, bonding agents or costly field modifications may be necessary. Generally, as long as the steel surface is free of dirt and oil, the presence of light rust will not adversely affect the adhesion of spray-on fire protection.

DETAILING CONSIDERATIONS FOR MASONRY

Sample plan and section details for masonry are given in Figures 1a, 1b, and 1c. These figures illustrate many of the concepts discussed in the GENERAL CONSIDERATIONS Section, as well as those discussed in this section.

Enclosure System. For the purpose of this Guide, the enclosure system is defined as the weather tight wall system that encloses the building. It is essential that the location of the enclosure system be determined relative to the column centerlines at an early stage of the project. Proper position of the enclosure system is critical because it can increase the chances for economical solutions to bracing systems, foundations, and perimeter framing member sizes in the building.

Concrete masonry units (CMU) have been selected as the back-up system for the masonry details. CMU was chosen because it has a long history of successful applications. Another viable back-up system that may be appropriate in various areas of the country is a metal stud back-up system. Consult a cost estimator for economic advantages of both systems in a particular area. A metal stud back-up system has been found to be economical for specific applications, however, it is generally a less forgiving system than CMU, and requires close attention to detailing and assembly of the system.

The following aspects of the enclosure system should be carefully considered:

- **Location of inside face of CMU relative to column centerline**

  When considering the use of a brick and CMU enclosure system, the location of the entire enclosure system relative to the column centerline must be determined. The brick and block enclosure system should completely bypass the floor slab, perimeter beam flanges, as well as the column flanges, or the brick should bypass the slab while each floor slab supports the CMU.

  There are advantages and disadvantages to both alternatives. If the masonry enclosure system bypasses the slab edge, the perimeter steel members do not support the load of the masonry at each floor, and therefore allow the perimeter steel members to be lighter and shallower.

  The disadvantage of the masonry enclosure bypassing the slab edge is that the weight of the entire enclosure system would be supported directly on the perimeter footings or grade beams. This may require a larger and more expensive foundation. Furthermore, since no part of the exterior columns would be buried within the enclosure system, the columns would have a larger projection into the building's usable spaces. It should be noted that the location of the inside face of the masonry enclosure system would be dictated by clearances required for the largest column or widest beam flange at the perimeter of the building.

  It should also be noted that when a building has a high overall ratio of openings to remaining walls, a system where the masonry bypasses the steel frame is a preferred solution.

- **Location of face brick relative to edge of slab**

  There are basically two options for the location of the building's face brick relative to the floor slab edge. It can either bypass each floor, where the entire weight of the brick is supported on the perimeter foundation wall, or the brick can be supported on shelf angles at various floor levels.

  If the vertical height of the building exceeds approximately 30 ft, it may be necessary to support the brick on shelf angles at periodic horizontal elevations. A structural engineer should be consulted to assist with this determination. However, if shelf angles are not required, it is generally more economical to support the entire weight of the face brick on the foundation wall. Note that some codes may require support at each floor.

- **Location of CMU and face brick for parapet detailing**

  Depending on where the enclosure system is located relative to the column the CMU will either bypass the perimeter steel beam at the roof or it will not. If the CMU bypasses the perimeter centerline the CMU may extend above the roof as a cantilever and provide lateral support for the roof parapet. A structural engineer should be consulted to determine the maximum height where the CMU can support the parapet.

  If the CMU does not bypass the steel framing, the continuity of the CMU will be lost and provisions will need to be made to prevent movement or rotation of the parapet above the roof.

Masonry Anchors. If the masonry walls span vertically between floors, adjustable anchors at a column would be a redundant form of reinforcement. Anchors at columns can also increase the cost of a masonry wall system, since a steel detailer would need to detail each anchor on each column (assuming that this is in the detailer's scope of work). If the anchors are field installed, anchor installation must be coordinated with the fireproofing contractor. It is expensive to remove fireproofing and install anchors to a column after the column has been fireproofed.

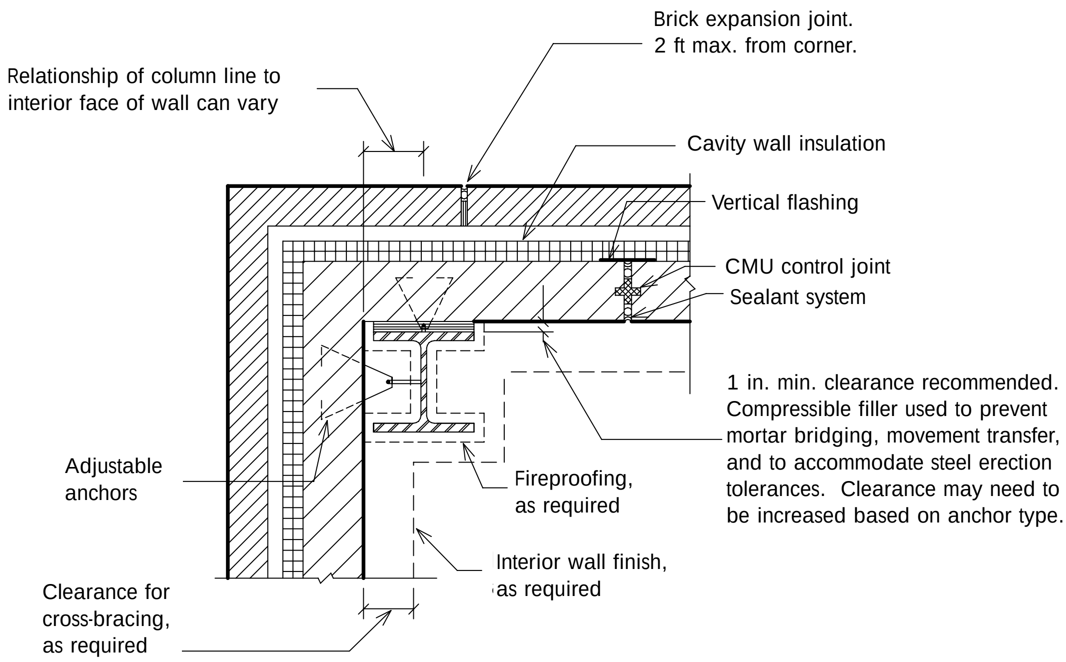

Figure 1a. Detailing Considerations for Masonry (Plan Detail at Masonry Corner)

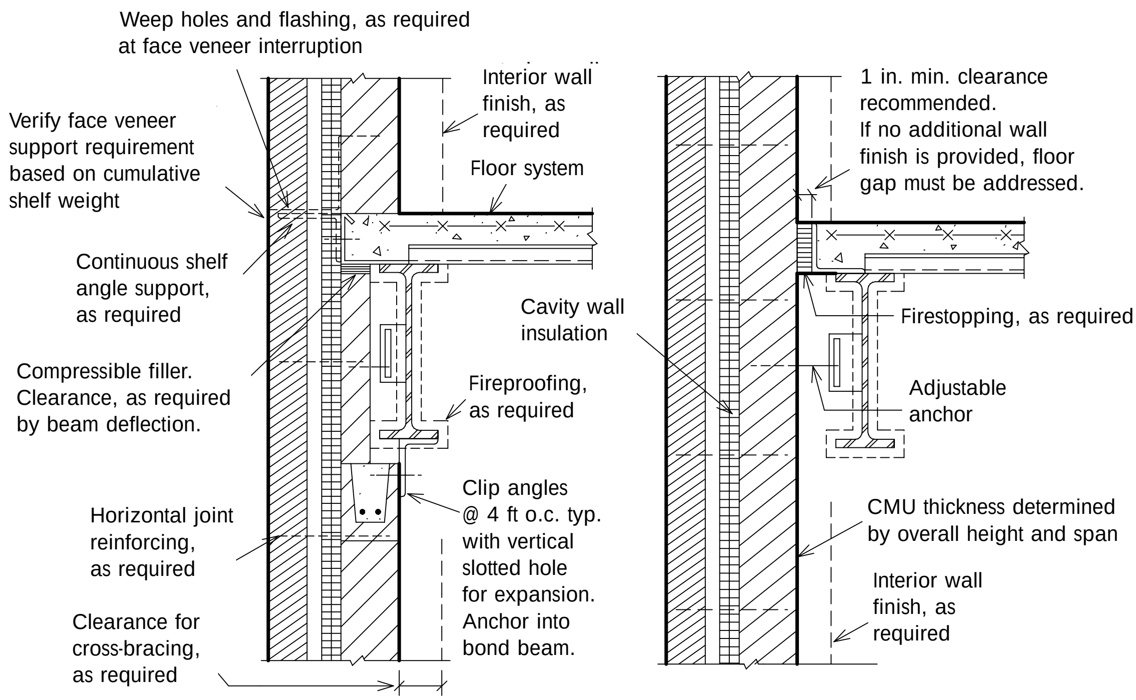

Figure 1b. Detailing Considerations for Masonry (Sample Wall Section Details at Floor)

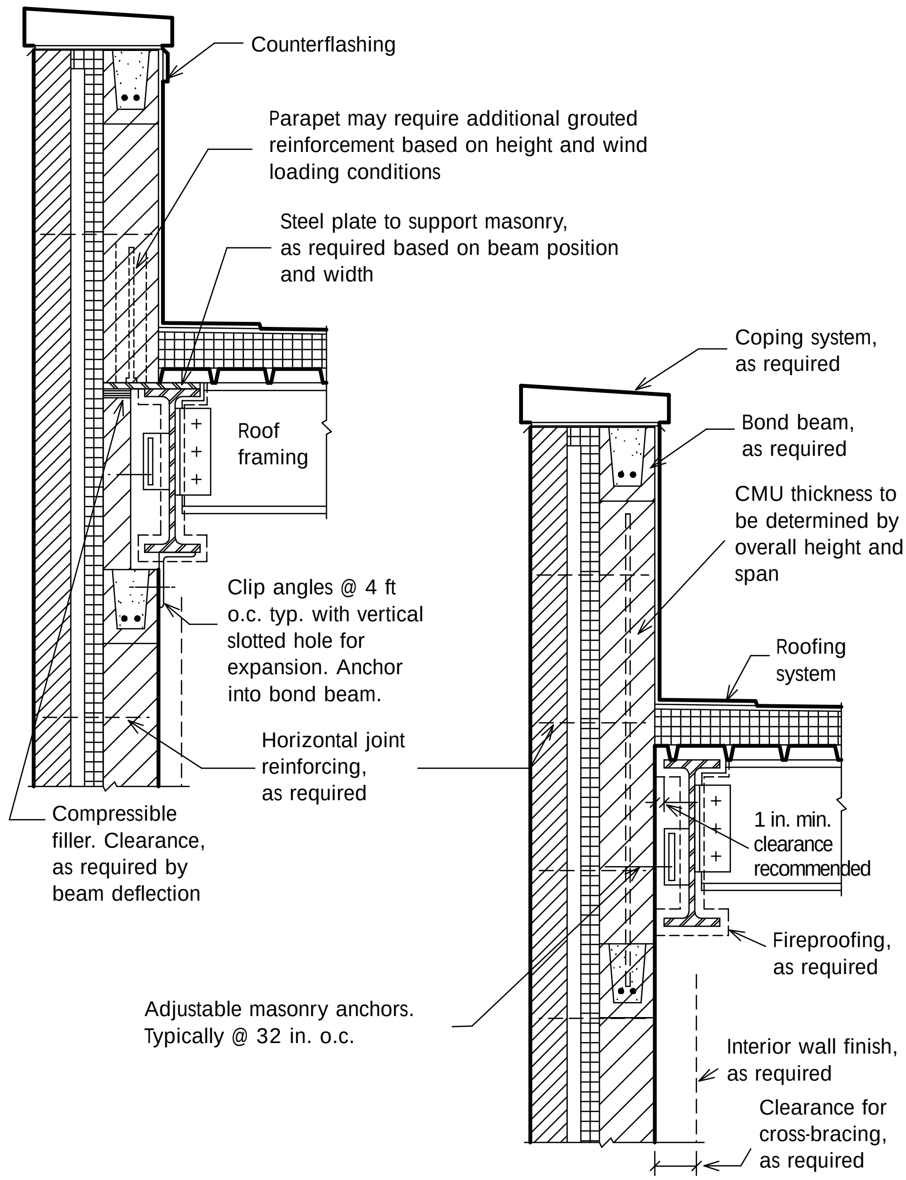

Figure 1c. Detailing Considerations for Masonry (Sample Wall Section Details at Roof)

DETAILING CONSIDERATIONS FOR PRECAST CONCRETE PANELS

Sample plan and section details for precast concrete panels are given in Figures 2a-2f. These figures illustrate many of the concepts discussed in the GENERAL CONSIDERATIONS Section, as well as those discussed in this section.

General Considerations. Precast concrete panels can be an attractive and economical enclosure system for appropriate applications. Precast panel systems are most economical when the panel sizes are 20 ft to 30 ft in length, and the panel width/height is limited to approximately 14 ft.

Gravity Load. Precast concrete panels are generally supported one of three ways. One way to support the panels is to span the panels horizontally between columns. The panels may also be supported at each floor level by the perimeter beams. Otherwise the panels may be stacked on each other and supported by the building's foundation. Obviously, a large building height may limit the feasibility of stacking the precast panels. The panel profile and structural bay size will determine the most economical panel support system.

Wind Load. Precast concrete panels can be designed to span either vertically or horizontally for the applied wind load. If the panels are designed to span vertically, they are generally laterally supported at each floor level or by a secondary lateral support system that transfers the lateral load to the primary structure. If the panels are designed to span horizontally, they are laterally supported at the columns as well as intermittent lateral supports at the floor levels. Precast concrete panels are usually designed as part of the enclosure system only, and not designed to be incorporated as part of the building's lateral system.

Construction Tolerances. All enclosure systems must have tolerances for deviations in materials and the construction process. Connections of precast panels to a steel frame must provide flexibility in all directions for field installation of the connection. Generally, it is not the architect's responsibility to design the connection, but the architect should recognize flexibility for field tolerances.

Connections. There are numerous ways to connect precast concrete exterior wall panels to the supporting steel frame. The precast panel manufacturer will generally determine the final details of the connection. It is, however, the architect's responsibility to make adequate provisions for proper support and construction tolerance of the panels. Some precast manufacturers prefer to bear the panels on recessed pockets within the panels that are supported directly on seated connections or haunches from beams or columns. The seated connections or haunches minimize the eccentricity of the panel self-weight on the support connection. Other support options include such assemblies as structural angles or channels attached to the columns or beams which would support embedded angles located on the back of the precast panels.

Inside Corners. One of the most overlooked conditions when detailing precast panel systems is the inside corner condition. This is a particularly important condition when using panels that span horizontally. The reason that inside corners must be carefully considered is because, unless carefully detailed, the panel may not have adequate support. Due to the column location at the corner configuration, the panels cannot be supported directly from the column. Instead, the panels are supported directly on the spandrel members or on the concrete slab above the spandrel members.

There are typically three methods to support precast panel ends at inside corners. The first method is to have each spandrel member act as the sole support for the panels near the column. This method can be successful if the spandrel is properly designed. Since the panels will have a tendency to roll or rotate, the spandrels must be designed for the torsional forces induced by the eccentricity of the precast panel. This method usually results in heavier spandrel members, but it does eliminate the need for stiffeners and braces. The second method is similar to the first method except that the spandrel members alone do not resist the torsional forces in the spandrel. A steel member is placed perpendicular to the spandrel at the point where the panel is supported. This solution will decrease the size of the spandrel members, but the additional perpendicular steel may be undesirable, or conflict with other building systems. The third method is to provide stiffener plates and kickers to resist the torsional effects on the spandrel beams. This has been a successful solution, but the stiffeners will increase the steel fabrication costs.

Supporting the horizontal spanning panels directly from the columns at an inside corner is not a suggested detail. To support directly from the column, the panels would have to be supported on steel members that cantilever horizontally from the column to the panel. The panel loads would be eccentric to the column, and would increase the bending and torsional stresses on the column. Furthermore, since both of the panels need to be supported from the same column, the cantilevered members would be at different elevations—creating a non-typical bearing support condition of the corner panels.

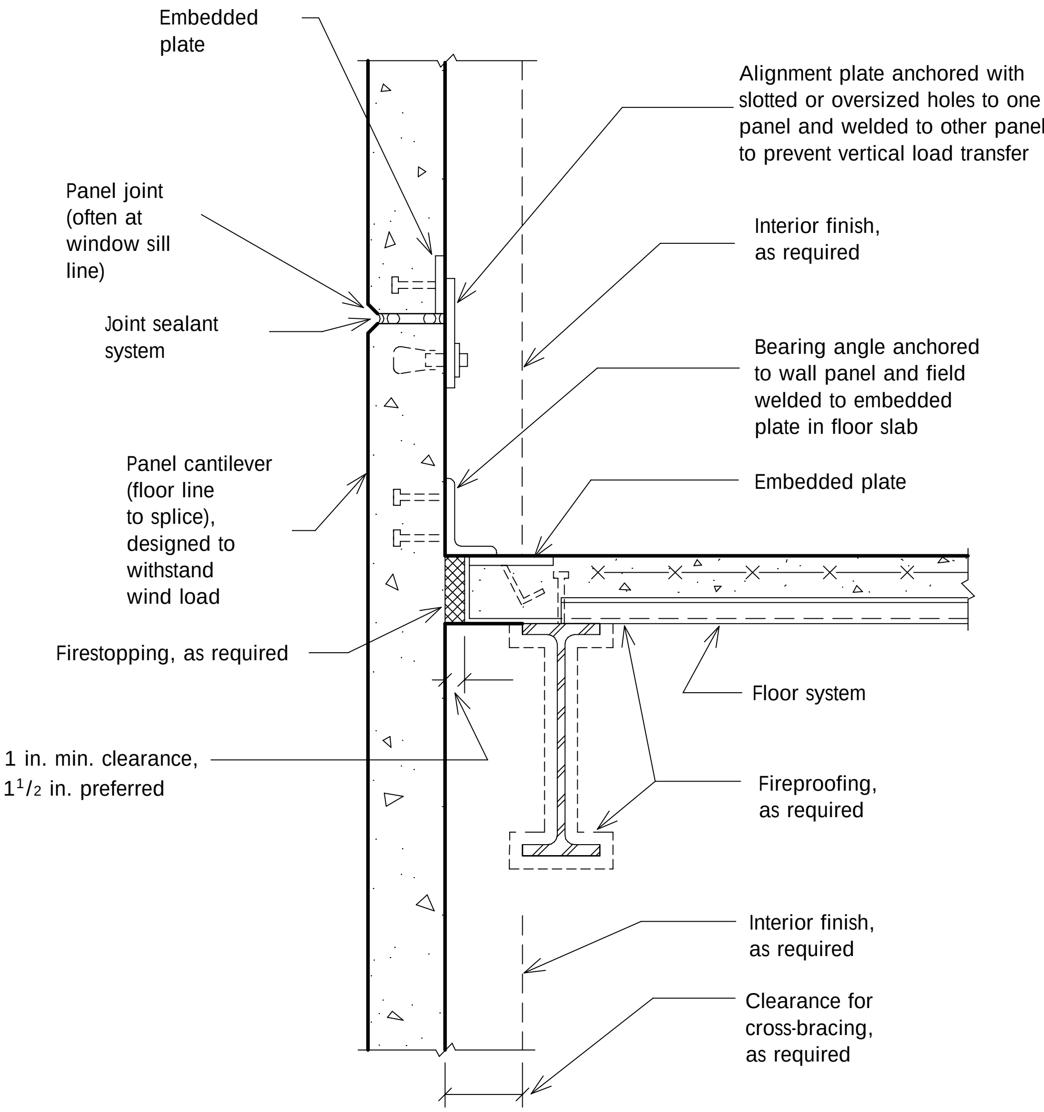

Figure 2a. Detailing Considerations for Precast Concrete Panels (Sample Wall Section Detail at Vertical Span Precast Panels)

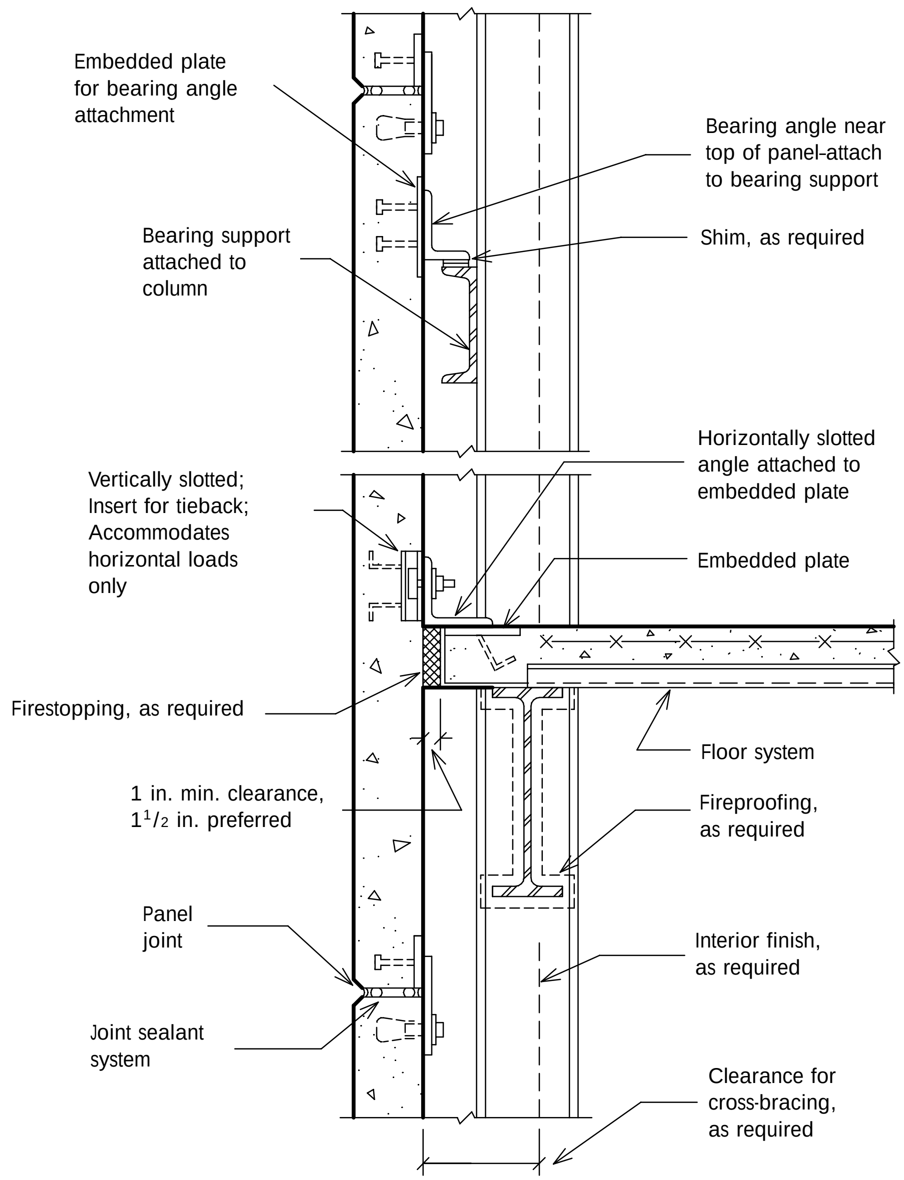

Figure 2b. Detailing Considerations for Precast Concrete Panels (Sample Wall Section Detail at Horizontal Span Precast Panels)

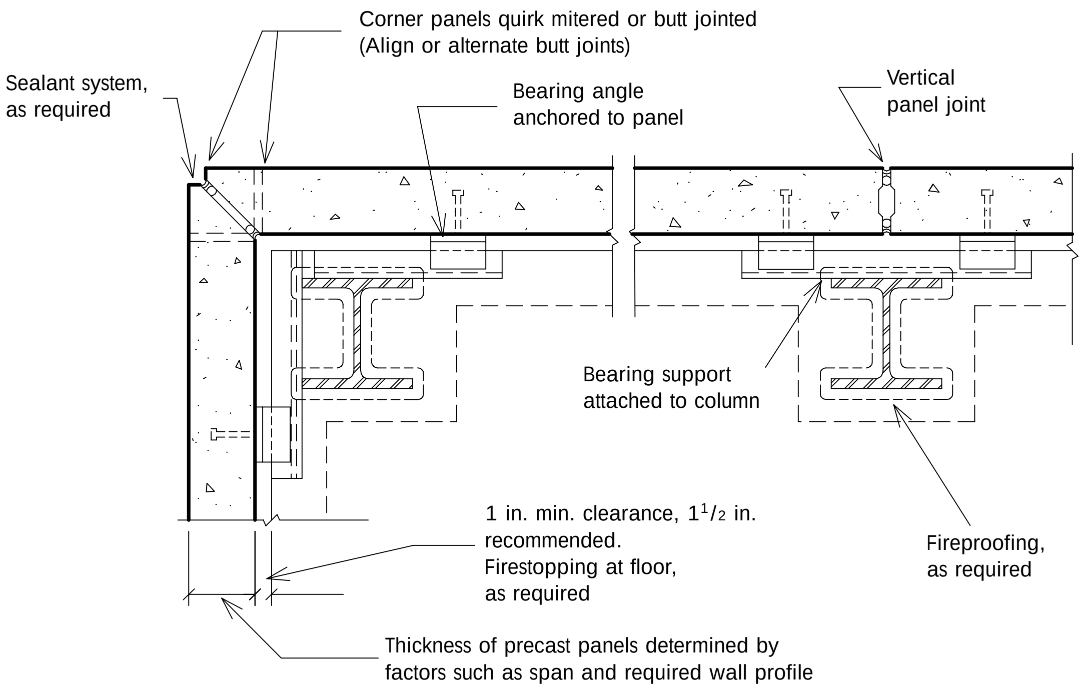

Figure 2c. Detailing Considerations for Precast Concrete Panels (Sample Plan Detail for Horizontal Span Precast Panels)

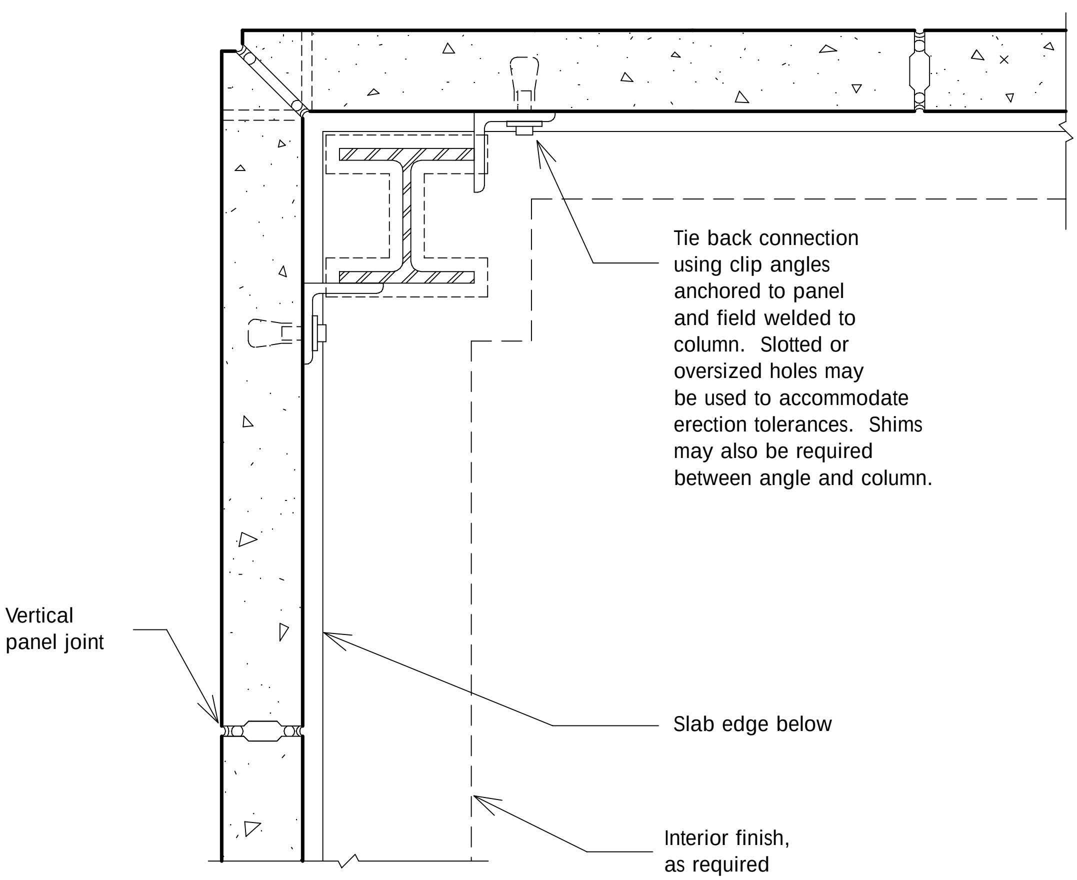

Figure 2d. Detailing Considerations for Precast Concrete Panels (Sample Plan Detail for Vertical Span Precast Panels)

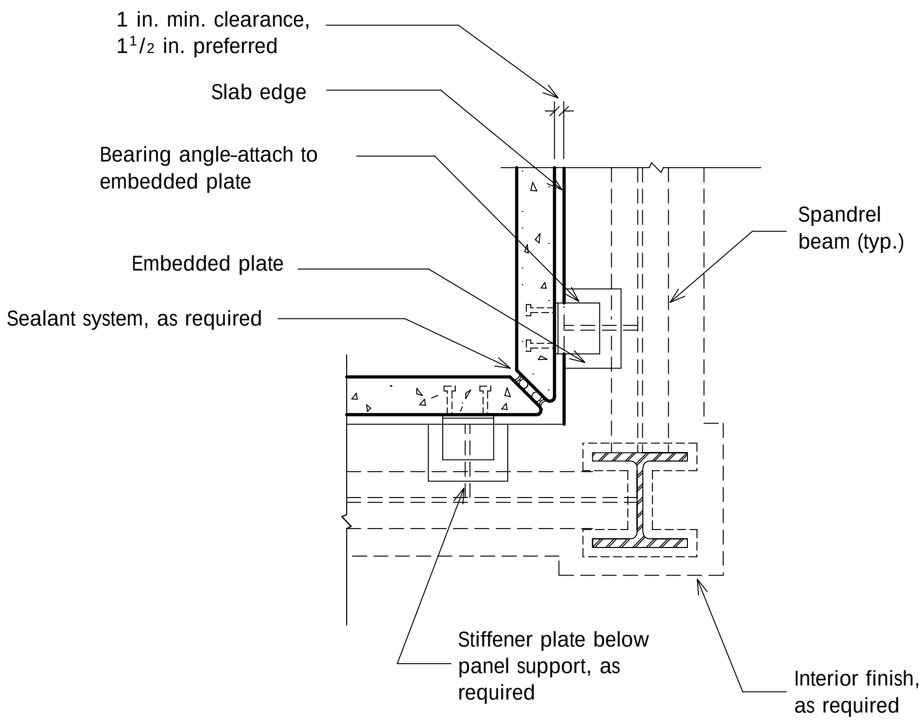

Figure 2e. Detailing Considerations for Precast Concrete Panels
(Sample Plan Detail for Horizontal Span Precast Panels at Inside Corner)

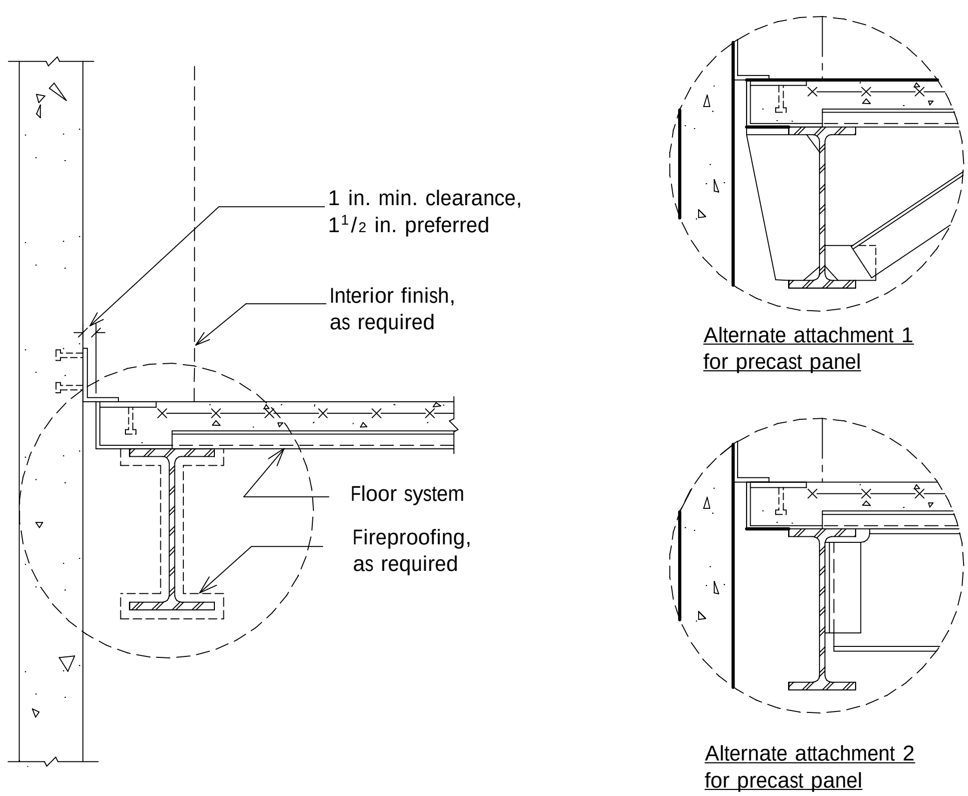

Figure 2f. Detailing Considerations for Precast Concrete Panels
(Sample Wall Section Details for Horizontal Span Precast Panels at Inside Corner)

DETAILING CONSIDERATIONS FOR LIMESTONE PANELS

A sample wall section detail for limestone panels is given in Figure 3. The figure illustrates many of the concepts discussed in the GENERAL CONSIDERATIONS Section, as well as those discussed in this section.

Anchors. The term "anchor" generally refers to straps, rods, or other connections between limestone and the structure. Most anchors are intended to hold limestone panels in their vertical position, as opposed to supporting the weight of the limestone. All anchors embedded in limestone should be a non-corrosive material (stainless steel, brass, bronze). Limestone anchors are typically embedded in the stone with mortar. Therefore, stainless steel or other non-corrosive materials will reduce the chance of staining and spalling problems resulting from corrosion of the anchor steel. Carbon steel of adequate strength may be used for supports that are not embedded in stone. It is recommended that a limestone fabricator be consulted for further detailing information.

Back-up Systems. Panel thickness, panel span, and wind load requirements, will all be variables in determining the proper back-up system for the limestone panels. The back-up system could be any material that is compatible with limestone and is stiff enough to limit the horizontal deflection and maintain the integrity of the panels. Typically, a steel sub-frame system is used as a back-up system, as illustrated in Figure 3. CMU may be considered as a back-up system, but it is usually most appropriate for smaller panel sizes and lighter overall loading conditions.

Supports. Unlike precast concrete panels, limestone panels should always be vertically supported at the bottom of the panel. If the panel bears on the panel directly below it (see Figure 3), non-corrosive anchors should be used to connect the two panels. If the panels are supported on steel angles with "grab rods," the angles may be carbon steel that is galvanized or painted, but the steel rods should be a non-corrosive material.

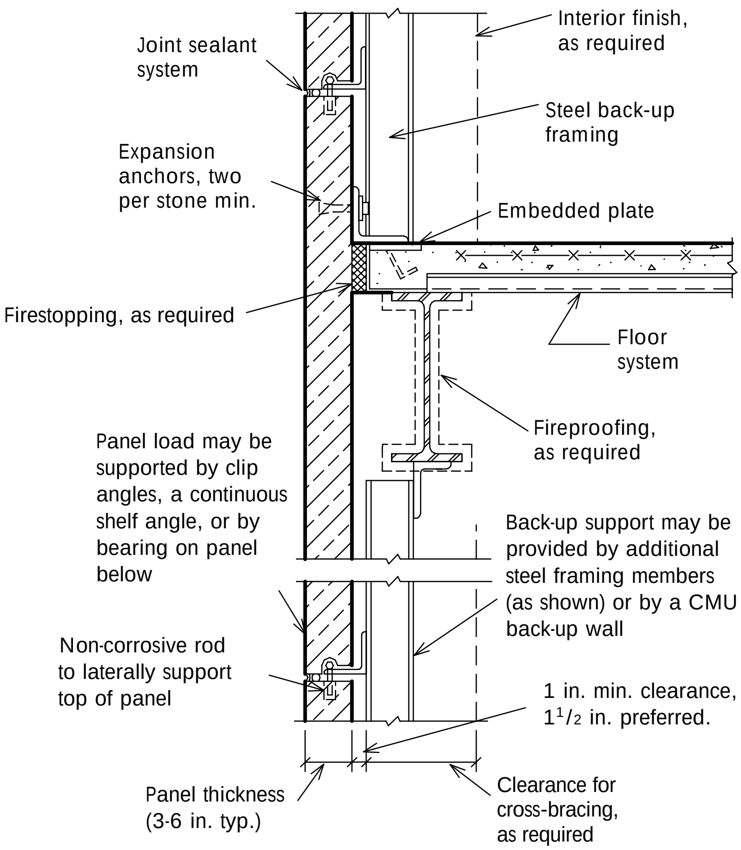

Figure 3. Detailing Considerations for Limestone Panels (Wall Section Detail)

DETAILING CONSIDERATIONS FOR THIN STONE VENEER PANELS

A sample wall section detail for thin stone veneer panels is given in Figure 4. The figure illustrates many of the concepts discussed in the GENERAL CONSIDERATIONS Section, as well as those discussed in this section.

General Design Considerations. Thin stone panels are products of nature. As a result, they have different physical properties—even stones from within the same quarry. For example, the strength characteristics of a granite panel may be as much as 150 percent of another granite panel. When selecting a thin stone veneer system, architects should carefully consider: the physical properties of the stone to be selected, design criteria for the veneer, evaluate the interrelationship of the exterior wall assembly, and determine/clarify the structural engineering responsibilities of the stone veneer and the anchoring system. See Figure 4 for a sample wall section detail.

Back-up System. A grid strut back-up system will be required to laterally and vertically support the thin stone. The back-up system is generally a steel sub-frame system, or a CMU wall. Consult a stone fabricator for detailing information and deflection limitation criteria.

Anchors. Because of the variety of strengths between stones, even between stones from the same quarry, stone panel anchors need to be chosen very carefully. There are hundreds of different anchors that are inserted into a kerf or slot cut into a hole drilled into the sides or rear of the stone panels. Choosing the appropriate anchor, based on the panel size, thickness and back-up system is critical to the success of thin stone veneer panel systems.

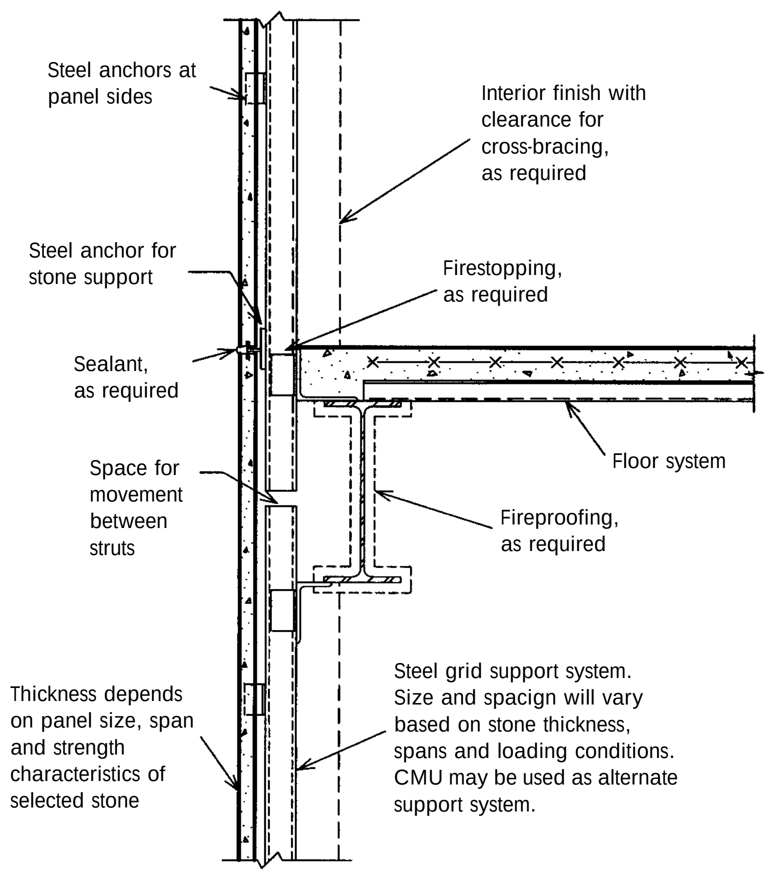

Figure 4. Detailing Considerations for Thin Stone Veneer Panels (Wall Section Detail)

DETAILING CONSIDERATIONS FOR WINDOW WALL ENCLOSURE SYSTEMS

General Considerations. Window wall systems have a lateral load resisting structural system within themselves. The mullions of the window wall system provide support to transfer the exterior wind loads on the glazing to the primary building structure. Generally speaking, the glazing will span in the short direction between mullions. Therefore, depending on the proportions and orientation of the glazing, the structural mullions will span either horizontally or vertically. Consult a window wall manufacturer to determine practical mullion locations and depths. It should be noted that mullions could be reinforced with steel to increase their strength without increasing their depth. See Figure 5 for a sample wall section detail.

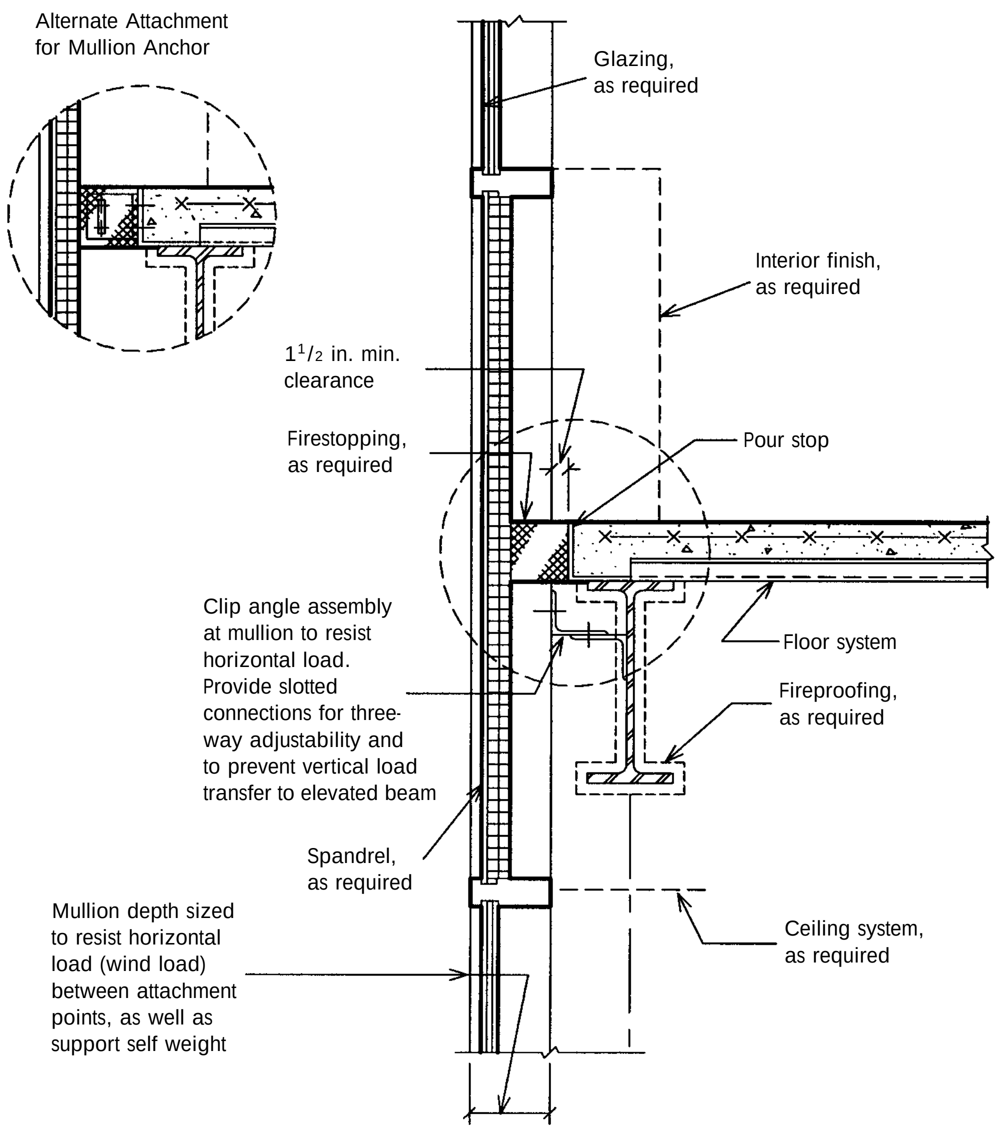

Figure 5. Detailing Considerations for Window Wall Enclosure Systems (Wall Section Detail)

DETAILING CONSIDERATIONS FOR FLOOR/CEILING SANDWICH

A typical floor/ceiling sandwich detail is given in Figure 6.

M.E.P. Space. Evaluating space requirements for mechanical, electrical, and plumbing systems can be difficult to do at an early phase of a project. Unfortunately, that is when types of system decisions need to be made. Probably the most important system decision to be made is to determine the approximate sizes of the mechanical ductwork. Consult a mechanical engineer for this information. Also, general locations of major ductwork or piping crossovers should be identified. Crossovers can be the type of problem area that require lowered ceilings and expensive beam web penetrations if sufficient space is not provided when the ceiling sandwich depth is determined.

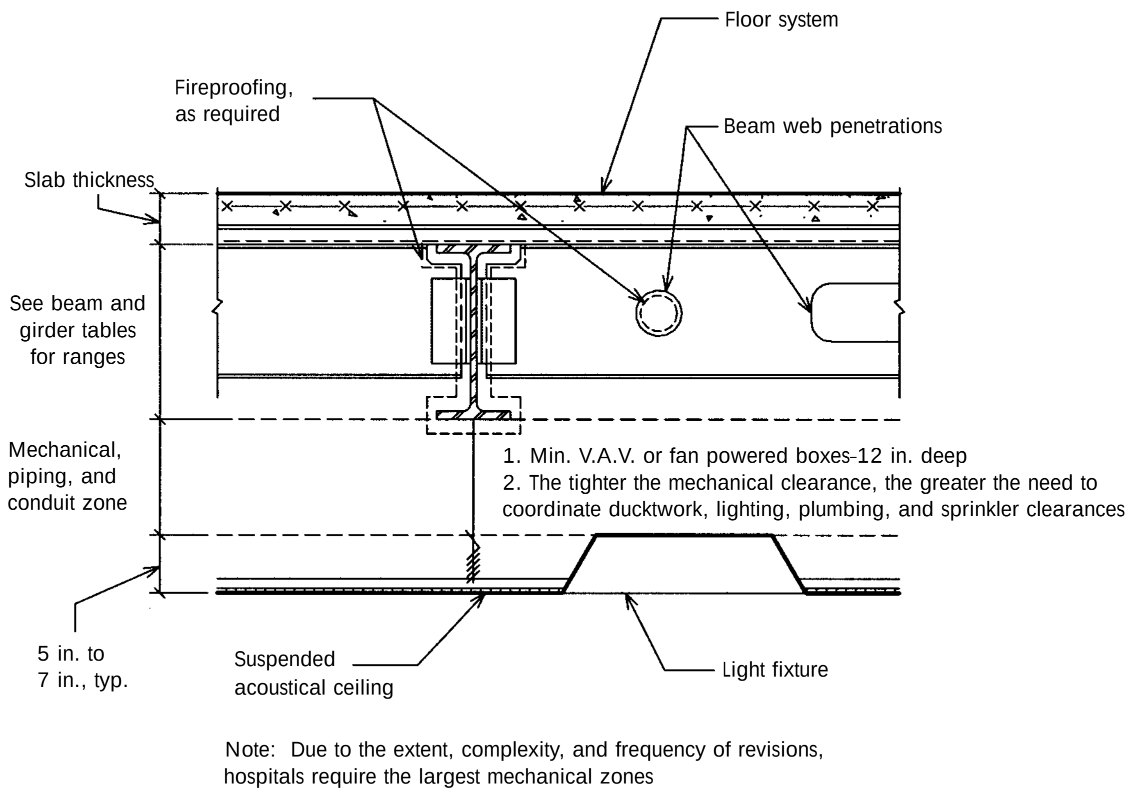

Figure 6. Detailing Considerations for Floor/Ceiling Sandwich

DESIGN CONSIDERATIONS FOR DIAGONAL BRACING DETAILS

A sample diagonal bracing detail is given in Figure 7.

General. Buildings that use diagonal braces for the lateral system can be extremely economical (see the Systems section of this manual). However, the disadvantage of diagonal braces is that the braces may conflict with ideal locations for doors or windows. In order to minimize any sort of conflict between the bracing and the doors/windows, it is important to understand exactly what shape the brace member is, and where it is located.

It is desirable to have the work lines of all of the connecting members intersect at one work point (see Bracing Detail). The work lines run through the centroids of the members. If the member is not symmetrical, the work line is not at the mid-depths of the member, i.e., the centroid of an angle is not at the mid-depths of the angle. This is essential to understand when determining whether or not a window or doorframe will bypass the brace.

Gusset Plates. Gusset plates may be a variety of sizes and shapes. It will be dictated by the force in the diagonal brace and the thickness of the gusset plate. If the gusset plate is hidden within a wall, the size and shape of the gusset plate generally is not an issue. However, if the gusset plate is exposed, there are virtually endless possibilities for its shape. However, the size of the gusset plate may be governed by the amount of area that the diagonal brace must overlap the gusset plate in order to achieve an adequate connection. To minimize the gusset plate sizes, the diagonal brace may actually start below the finished floor surface, as shown in the detail.

Work Lines. The "work line" for the bracing member, located at the centroid of the bracing member, may not necessarily be at the mid-depths of the member. This would be the case for non-symmetrical members such as WT-shapes and angles. Also, the angle of the bracing member at a floor may be at a different angle from a floor above or below it. This would occur if the floors had different floor-to-floor heights.

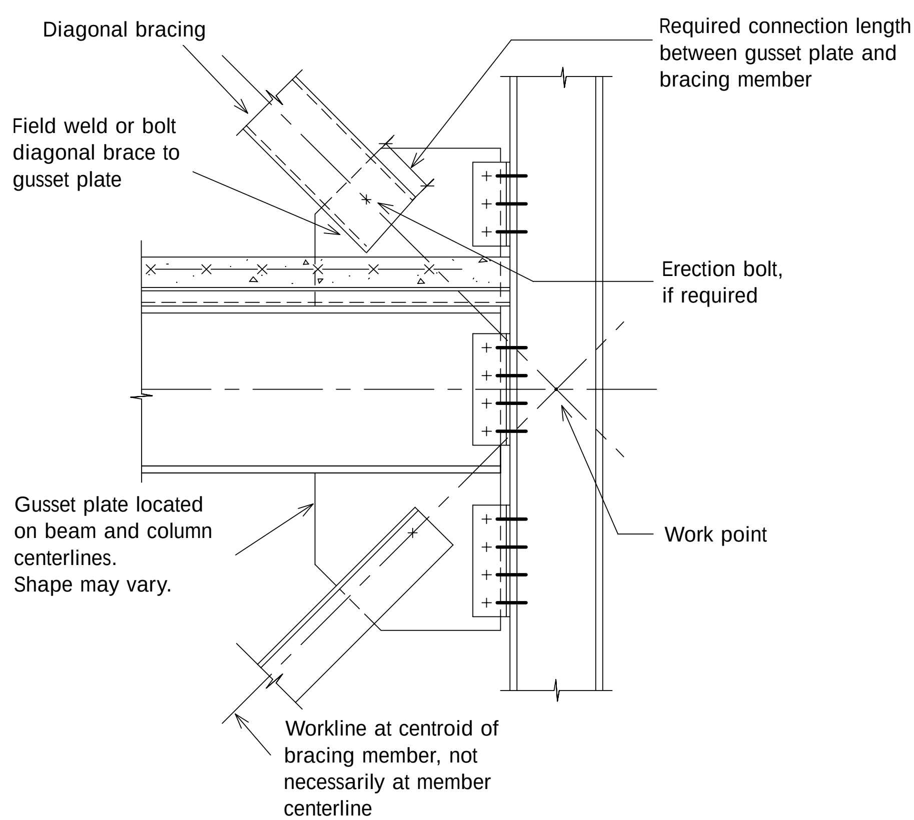

Figure 7. Detailing Considerations for Diagonal Bracing

Bracing Members. Bracing members can consist of virtually any structural shape. Typically, rods, single angles, double angles, WT-shapes, and hollow structural sections are used for diagonal members in tension. Sometimes, wide flange shapes are used if the bracing forces are extremely large.

Work Point. The work point is the intersection point of all of the work lines. It should be noted that it is desirable, but not always necessary, for the work lines to intersect at a work point. If the work lines do not intersect at a work point, the connections must be designed for these eccentricities. As a result, the members may increase in size. Consult a structural engineer if this situation must be investigated.

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