Building Science Details for Architectural Precast Concrete Sandwich Panels

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ABSTRACT

An exterior wall must address a number of performance requirements in order to achieve its function of separating the controlled indoor environment from the uncontrolled outdoor environment. These requirements range from structural and fire performance, through building science (heat, air, and moisture control), to durability, economics, and aesthetics. Architectural precast concrete sandwich panels offer the opportunity to provide all performance requirements within one assembly. The complete wall can be constructed by one manufacturer, it can be fabricated in a controlled environment, and the building can be closed in quickly. In order to provide effective performance, the design of architectural precast sandwich panel systems must incorporate building science principles. It is relatively easy to provide the requirements in the field of the panel because concrete can handle many of the requirements on its own (e.g., fire resistance, air permeance, structural sufficiency). However, the requirements at the joints between the panels and junctions with other components must be addressed. This paper presents building science details for architectural precast concrete sandwich panels and analyzes the details to illustrate the principles involved.

INTRODUCTION

Architectural precast concrete panels traditionally have consisted of a single wythe of factory-manufactured precast concrete that was installed on a building to provide the architectural finish and cladding for a building. Architectural precast concrete *sandwich* panels are a more recent innovation. They consist of two wythes of factory-manufactured precast concrete, which are fabricated with a layer of insulation "sandwiched" between them. As with traditional architectural precast, the exterior wythe provides the architectural finish and weather-resistant cladding. The combination of exterior wythe, insulation, and interior wythe in architectural precast concrete sandwich panels offers the opportunity to provide all performance requirements of an exterior wall within one assembly.

In order to provide effective performance, both the sandwich panels and the system in which they are assembled must incorporate building science principles in their design. It is relatively easy to provide the requirements of an exterior wall in the field of the panel because concrete can handle many of the requirements on its own (e.g., fire resistance, air permeance, structural sufficiency). However, the requirements at the joints between the panels and at junctions with other components must be addressed to complete the design. This paper presents building science details for architectural precast concrete sandwich panels and analyzes the details to illustrate the principles involved.

ASSEMBLIES

Design and Fabrication

The architectural team must define the exterior finish appearance and be knowledgeable about precast mold limitations and casting materials. Design details must provide strong conceptual approaches for exterior water management and heat, air, and moisture control across the panel, through the joints, and at junctions with adjacent systems.

Structural requirements and loads should be specified by the building design team or broad code compliance requirements included in the tender documents. The structural design of architectural precast sandwich panels and the shop draw-

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ings are normally produced by the panel manufacturer. Other issues that must be considered include location and tolerance for panel anchors, interface tolerances, and connection details with elements such as windows. The accuracy and completeness of the shop drawings and the coordinated review of these drawings contributes to ensuring all design concepts are reflected in the final constructed product. Transportation issues such as site access and lifting capacity are reviewed by the general contractor and the panel manufacturer.

In the fabrication of architectural precast sandwich panels, the exterior wythe is cast flat in a mold that contains the architectural profile of the panel. A layer of rigid insulation is laid over the exterior wythe with a drainage layer between the insulation and the concrete. The drainage layer may be achieved with insulation that has vertical grooves on the exterior or with a separate material. In the latter case, the material could be one that will drain or one that can be removed after casting to leave a drainage cavity. The interior wythe, or structural wythe, is then cast on the insulation to complete the sandwich panel. Reinforcing and connecting ties are cast into both wythes to provide the tensile and shear capacity required to keep the panel together during fabrication, erection, and use. Support anchors are cast into the structural wythe to attach the panel to the structure.

Precast panel anchors must provide adequate strength for gravity, wind, and seismic loads and must transfer these loads to the building structure. At the same time, the anchors have to allow horizontal and vertical adjustment to account for construction tolerances and final alignment of the panels during erection. Typically, an individual panel will require two gravity anchors that are normally located at the floor line near columns in multi-level building frames. Seismic design is incorporated into all the gravity anchors and one of the gravity anchors allows for thermal movement. A panel will also have two to four lateral anchors depending on the size and shape of the panel; all lateral anchors allow for structural and thermal movements.

Joints between Panels

The joints between sandwich panels must be designed to maintain continuity of the thermal, air, and moisture control functions in order to provide continuity for the wall. This is achieved with a two-stage joint, in which the air seal is located at the line of the interior wythes and the weather seal is located at the outside face of the exterior wythes. The space between the air seal and the weather seal is vented and drained to the exterior at the intersection of the vertical joints with the horizontal joints and at the base of the wall. The joint seals typically consist of a combination of flexible sealant and backer rod. Air and weather seals have been successfully installed from the exterior in order to avoid interference from floors and columns.

Junctions with Other Components

Sandwich panels must be properly detailed where they intersect with other elements of the building. Details at foundations must be designed to provide drainage of the wall cavity and to direct exterior water that is shed from the wall away from the foundation. The interface with other exterior envelope elements such as windows and doors should be designed to ensure that the thermal, air, and moisture seals are continuous.

The roof to precast detail is one of the most frequent areas of failure in architectural precast concrete applications. The major reason is the failure to accommodate differential movements caused by temperature changes, moisture changes, building frame movement, and wind. Especially important is the live load imposed by snow or retained rainwater. The roof-wall junction represents a critical location in the envelope that must separate interior and exterior moisture and pressure differentials.

Architectural precast panels, like all cladding, require coordination of details to ensure the integrity of the envelope when used in combination with other exterior finish systems and materials. Combinations of sandwich panels with metal-glass curtain wall, masonry, stucco, cut stone, and concrete shear walls are commonly employed in today's building industry. Problems can occur because of different planes of the thermal, air, and moisture barriers and of incompatibility at the joints.

Designers must also understand the different physical characteristics of systems and make provision in the design of the interface to ensure that the wall performance is achieved. Different thermal behavior, volume moisture changes, shrinkage effects, and creep deflection between adjacent systems can create distress at the junctions, which leads to performance problems.

BUILDING SCIENCE PERFORMANCE REQUIREMENTS

Performance requirements for exterior walls include structural performance, building science, fire protection, and durability. Building science performance requirements involve control of heat, air, and moisture flows. The level of control is a function of the loads imposed by the exterior environment, which is determined by climate and building design, and by the interior environment, which is determined by the functional program for the building. Minimum acceptable performance for health and safety is set by the building code that is mandated in the jurisdiction. The performance requirements will influence the selection of precast panel type, and the fabricator and the building designer will work together to develop the required details.

Heat Transfer

Concrete is not a good thermal insulator. Insulation must normally be included in a precast wall assembly when the environmental conditions are such that control of surface temperature (condensation potential) and heat flow (load and energy) is required. The insulation system should be designed to provide continuous coverage and especially to minimize thermal bridges since these can lead to low surface temperature with high condensation potential.

Thermal comfort conditions in the interior space depend on stability of the interior air temperature and on the radiant field temperature, and thermal mass in the interior wythe can have a positive effect on thermal comfort. Lack of thermal comfort can be costly since occupants are typically the single biggest expense in a building operation. Thermal mass can provide a flywheel effect against rapid changes in the radiant temperature of the exterior wall and in the interior air temperature. Note that the flywheel effect also means that sufficient time must be allowed to recover when interior conditions diverge from the normal range as with night or weekend setback or system shutdown. Thermal mass may reduce energy usage, but only when the exterior air temperature varies around the interior temperature and only if the interior air temperature is allowed to vary, a feature that could have a negative impact on thermal comfort.

Air Leakage

Control of air leakage affects many issues including condensation, heating/cooling energy, thermal comfort, rain penetration, smoke movement, and sound transmission. Control of air leakage is achieved with an air barrier system, which is a designed element that has the objective of providing a continuous barrier to the movement of air. An air barrier system should have the following characteristics:

- Airtight materials (the National Building Code of Canada sets an upper limit of 0.02 L(s·m²) at 75 Pa);
- Continuous within the building envelope (across joints within the assembly and across junctions with other components and assemblies);
- Structural sufficiency (resist all loads, including wind, and transfer them to the building structure);
- Durability (provides performance for service life without unscheduled maintenance).

Architectural precast concrete sandwich panels meet most of these requirements in that the interior wythe is airtight, structurally sufficient, and durable. Continuity within the architectural precast panel system is the responsibility of the designer. If it is specified, the fabricator, either solely or jointly with the design team, may take responsibility for continuity across joints between panels and for transferring the loads to the building.

Vapour Diffusion

Control of vapour diffusion is required to minimize condensation in humidified buildings in cold climates or in air-conditioned buildings in hot and humid climates. Control of vapour diffusion is achieved with a vapour barrier, which is an element that is installed with the objective of providing a continuous barrier to the diffusion of vapour. Typically, a vapour barrier is a sheet material with sufficiently low vapour permeance to minimize the rate of water vapour diffusion. In addition, to avoid the accumulation of condensation on the vapour barrier, it is located where, for a majority of the time, it is above the dew-point temperature of the adjacent air. Concrete, while not a sheet material, has sufficiently low vapour permeance in the thickness used for precast panels to function as a vapour barrier.

Precipitation

Precipitation, both rain and snow, is the biggest single source of water that must be managed by the building envelope. Failure to manage precipitation can have consequences that are both immediate, e.g., liquid water in the interior space, and long-term, e.g., reduced service life. Precast concrete has an inherent benefit in precipitation control in that the concrete doesn't absorb a lot of water and the thickness used for precast panels tends to be waterproof. The tops of horizontal surfaces must be designed with a positive slope to ensure runoff of rainwater and snow melt, and the underside should incorporate a drip edge to prevent water from returning to the wall. Two-stage joints between panels and rainscreen junctions with other assemblies are required to complement the performance inherent in the field of the panels.

BUILDING SCIENCE DETAILS

Figures 1 to 7 present details that have been developed to address the performance of architectural precast concrete sandwich panels with respect to the building science requirements discussed above. While the details have been developed primarily from a "cold-climate" perspective, every building has a combination of interior environment, exterior exposure, desired aesthetics, and service life that will have an impact on its design. The design for a particular building requires an analysis of its unique set of conditions.

The details include a selection of joints and junctions that can occur on buildings. While the details do not address all possible situations that can arise, they do present approaches to achieving the design intent, especially continuity of the requirements. One common feature is that a design must be buildable, which means that issues such as the skills of the available trades and the sequence of construction must be considered as part of the design.

The following parameters are common to the details in Figures 1 to 7:

- The panels are non-load-bearing, i.e., they are not supporting the structural load of the building.
- The panels have a rainscreen design with a drainage layer that consists either of an open cavity or of channels grooved into the rigid insulation.
- The panels are assembled with two-stage joints, which consist of a "weather seal" installed between the exterior wythes and an "air seal" installed between the structural wythes.
- The "weather seal" and "air seal" are both installed from the exterior to avoid continuity problems around columns, floors, and anchors.
- The drawings are "exploded" to assist in clarity of the different elements.

Foundation Connection (Figure 1)

General. The precast sandwich panel is bearing on the concrete foundation. A steel anchor plate is cast into the foundation to provide a lateral connection. The neoprene shims are installed to support and true the panel.

Thermal Barrier. The thermal barrier is provided by the rigid insulation in the precast sandwich panel. Note the rigid insulation installed on the exterior of the concrete foundaiton. This would not be necessary for condensation control in buildings located in a warm to hot climate or for buildings with low interior humidity regardless of the climate. It might be necessary for energy conservation.

Air Barrier. The air barrier is provided by the structural wythe in the precast sandwich panel. Air barrier continuity at the joints between panels is provided by the air seal, and continuity at the foundation is provided by the connection of the air seal to the foundation.

Vapour Barrier. The vapour barrier is provided by the structural wythe and by the concrete foundation.

Precipitation. Control of precipitation is provided by the rainscreen design of the precast sandwich panel (grooved rigid insulation) in combination with the two-stage joint between panels. The system drains to the exterior at the base of the panel with the joints draining via the air seal, which is tooled to provide a drainage path. The drip cast into the bottom of the structural wythe prevents run-back of water from the face of the panel.

Other Considerations. Erection of the steel frame (column beyond) is followed by erection of precast panels and installation of windows, doors, and services. This system has additional benefit when the structural wythe can serve as the interior finish.

Soffit Connection (Figure 2)

General. The soffit is designed as unconditioned space. The cladding above the soffit is precast sandwich panel, while the cladding below the soffit is curtain wall. A steel anchor plate is cast into the floor slab to provide a lateral connection to the panel.

Thermal Barrier. The thermal barrier is provided by the rigid insulation in the precast sandwich panel, through the adhered rigid insulation across the bottom of the floor slab, to the head of the curtain wall. A thermal bridge exists in the structural wythe from the base of the panel to the top of the floor slab, but this will not be an issue except is cases of extreme interior or exterior environment.

Air Barrier. The air barrier is provided by the structural wythe, and continuity at the joints between panels is provided by the air seal. The smoke stop provides continuity from the air seal to the floor slab, especially at the joints, while the bituminous membrane provides continuity from the floor slab to the curtain wall.

Vapour Barrier. The vapour barrier is provided by the structural wythe, the smoke stop, the floor slab, and the curtain wall.

Precipitation. Control of precipitation is provided by the rainscreen design of the precast sandwich panels (grooved rigid insulation) in combination with the two-stage joint between panels. The cavity in the joint between the weather seal and air seal is drained to the exterior at the base of the panel, and a drip prevents runback of rainwater at the base of the panel.

Other Considerations. It is important to decide whether the soffit is conditioned or unconditioned space since that decision will determine the location of the thermal, air, and vapour barriers. A precast soffit is rarely used because erecting a precast soffit often requires unusual hoisting or jacking equipment; these problems can be avoided by combining a soffit with a spandrel panel in a single unit. Note that the soffit will likely be conditioned space with a precast spandrel unit.

Floor Connection (Figure 3)

General. The precast sandwich panel is bearing on the steel anchor plate cast in the floor slab, with the slotted anchor plate and neoprene bearing plate providing the connection between panels. This is the simplest connection because it is panel-to-panel and the precast fabricator is responsible for all elements.

Thermal Barrier. The thermal barrier is provided by the rigid insulation in the precast sandwich panel.

Air Barrier. The air barrier is provided by the structural wythe, and continuity at the joints between panels is provided by the air seal. The smoke stop provides continuity from the air seal to the floor slab, especially at the joints.

Vapour Barrier. The vapour barrier is provided by the structural wythe.

Precipitation. Control of precipitation is provided by the rainscreen design of the precast sandwich panels (drainage space) and the two-stage joint between panels. Water that enters past the rainscreen (exterior wythe and weather seal) drains to the horizontal joint, where it is taken laterally to the vertical joints and drained to the exterior through weep holes. Holding the drainage to the vertical joints eliminates the potential for drained water to randomly run over the face of the panels, especially windows. Note the slope on the horizontal joint, which directs water away from the air seal.

Other Considerations. The structural connection is typical of a facade consisting of precast panels with punched windows. A facade consisting of spandrel panels and strip windows would have a similar structural connection and require additional coordination with a glazing contractor.

Junction with Window (Figure 4)

General. This detail presents a window head and sill detail for a punched window. It is a design imperative to maintain continuity of building science performance across the junction between precast sandwich panel and windows. Doors also require similar attention to detail. The performance required of the windows is specified by the building designer.

Thermal Barrier. The thermal barrier is provided by the rigid insulation in the precast sandwich panel. Continuity

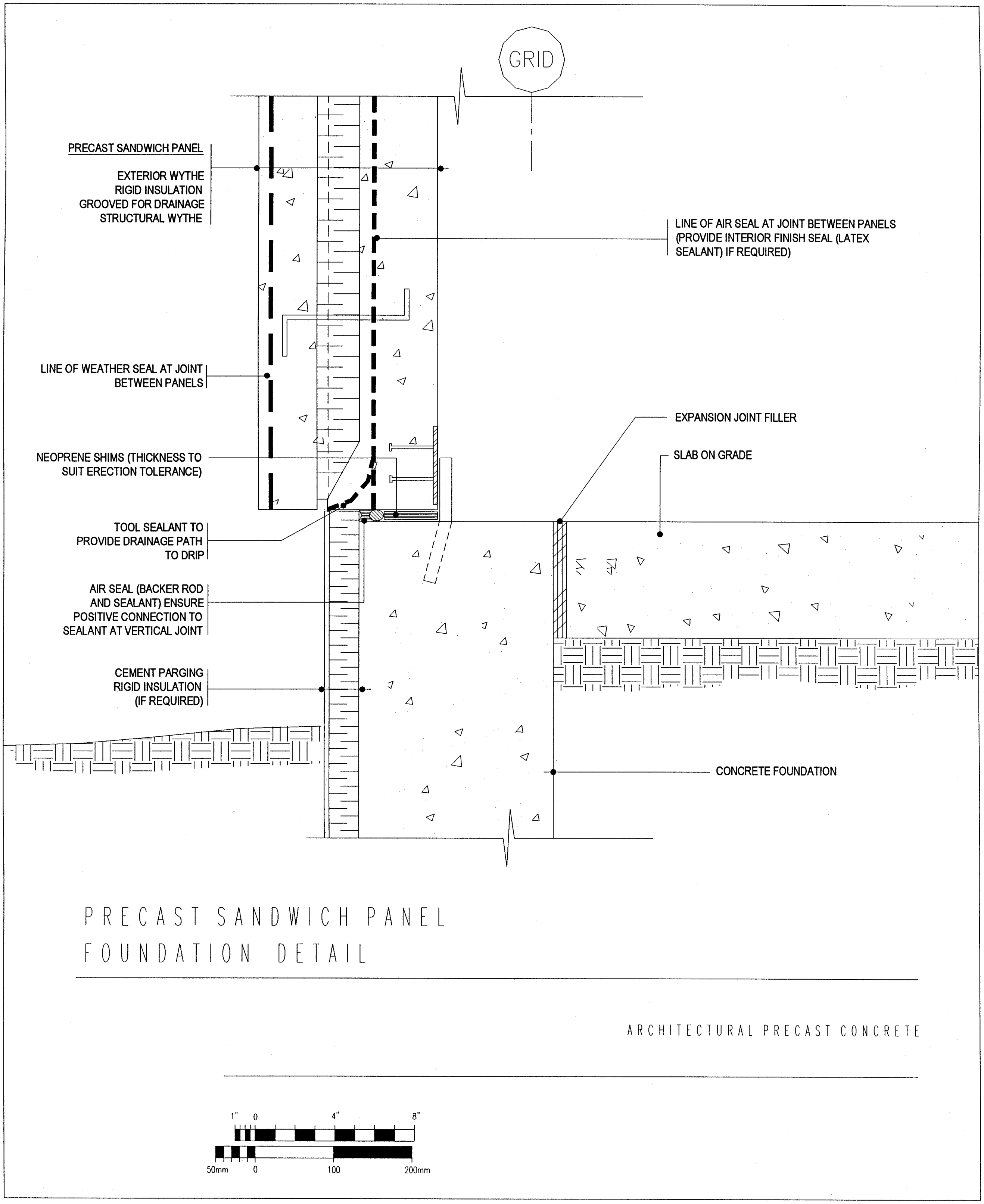

Figure 1 *Foundation connection.*

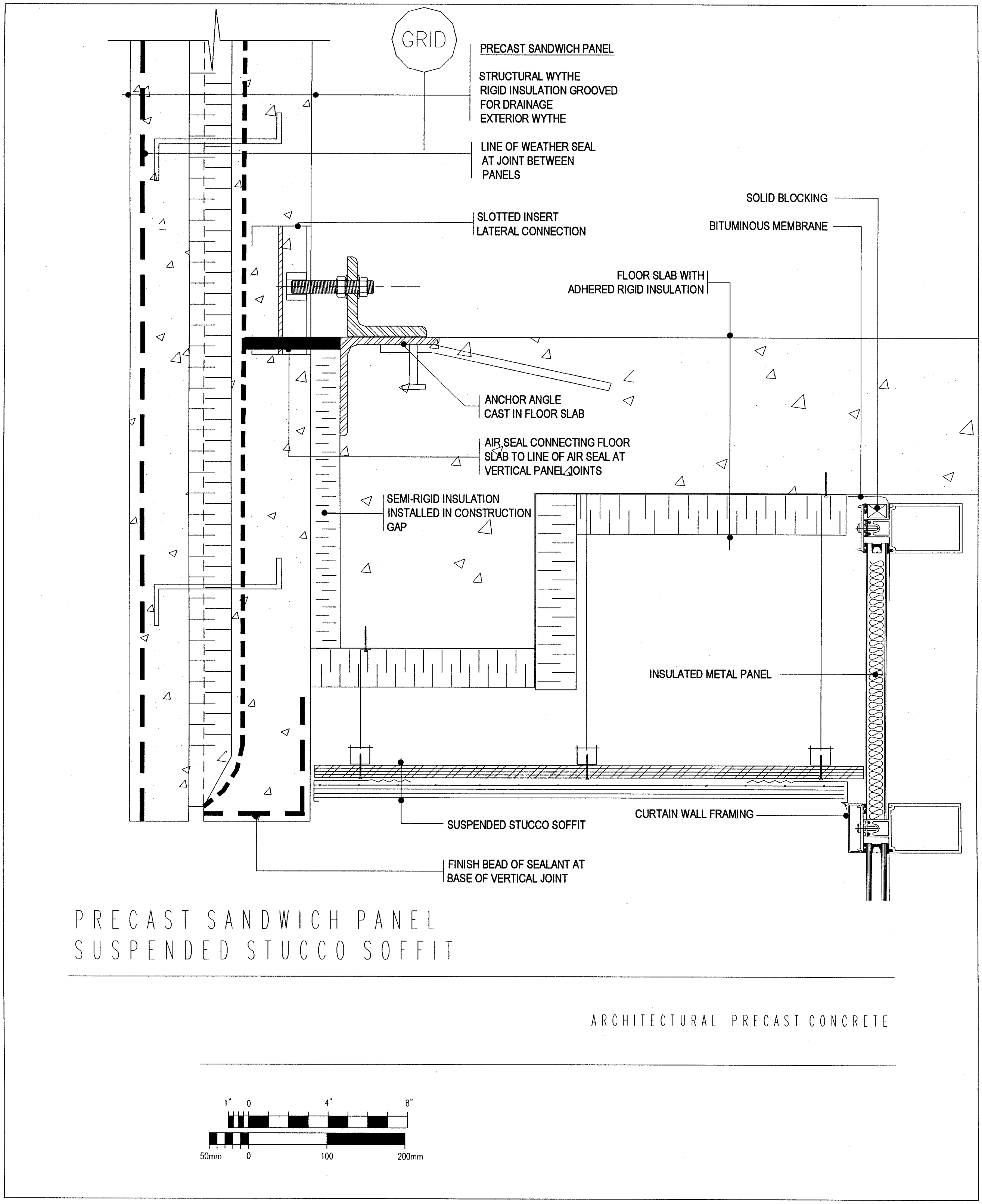

Figure 2 *Soffit connection.*

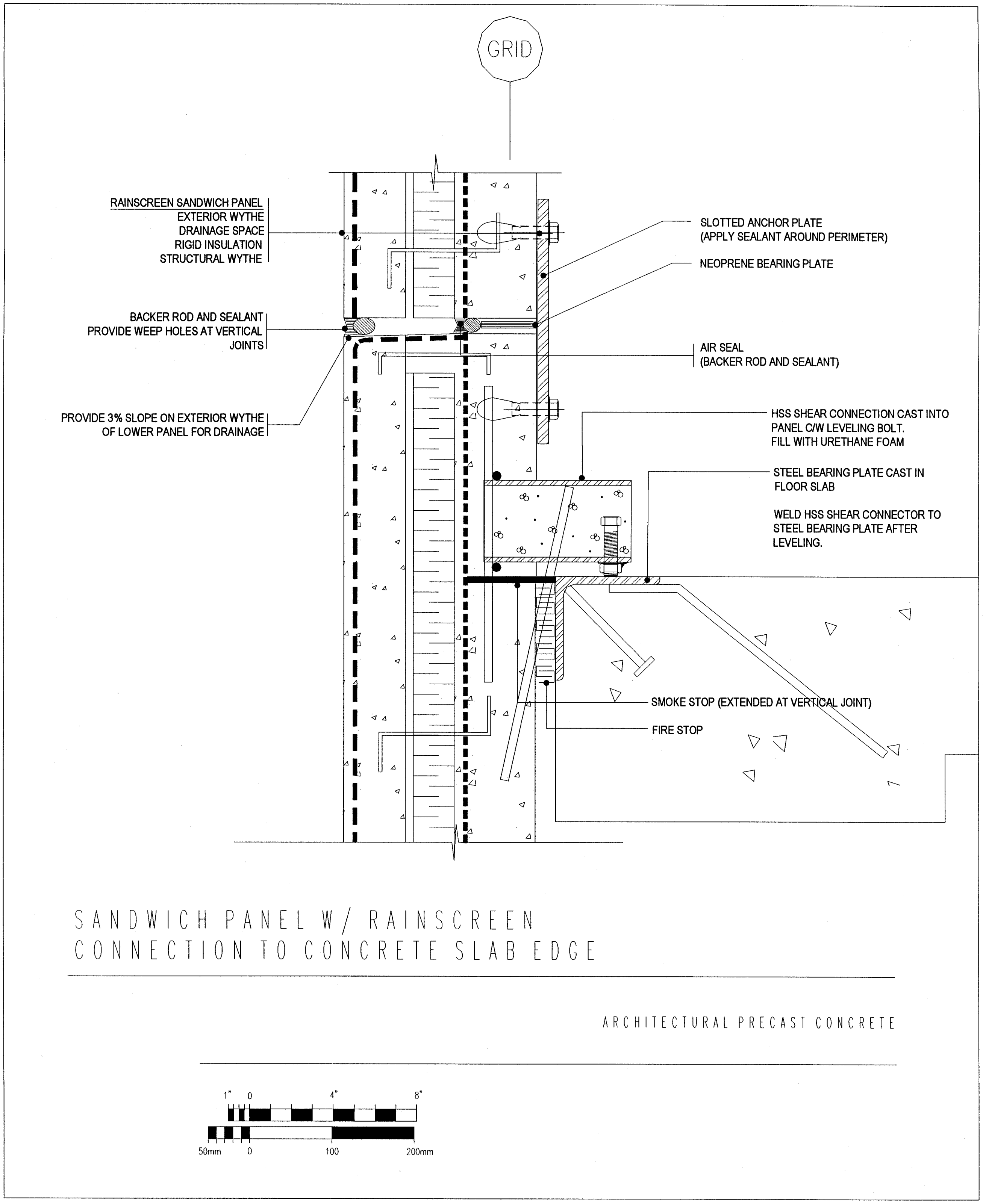

Figure 3 *Floor connection.*

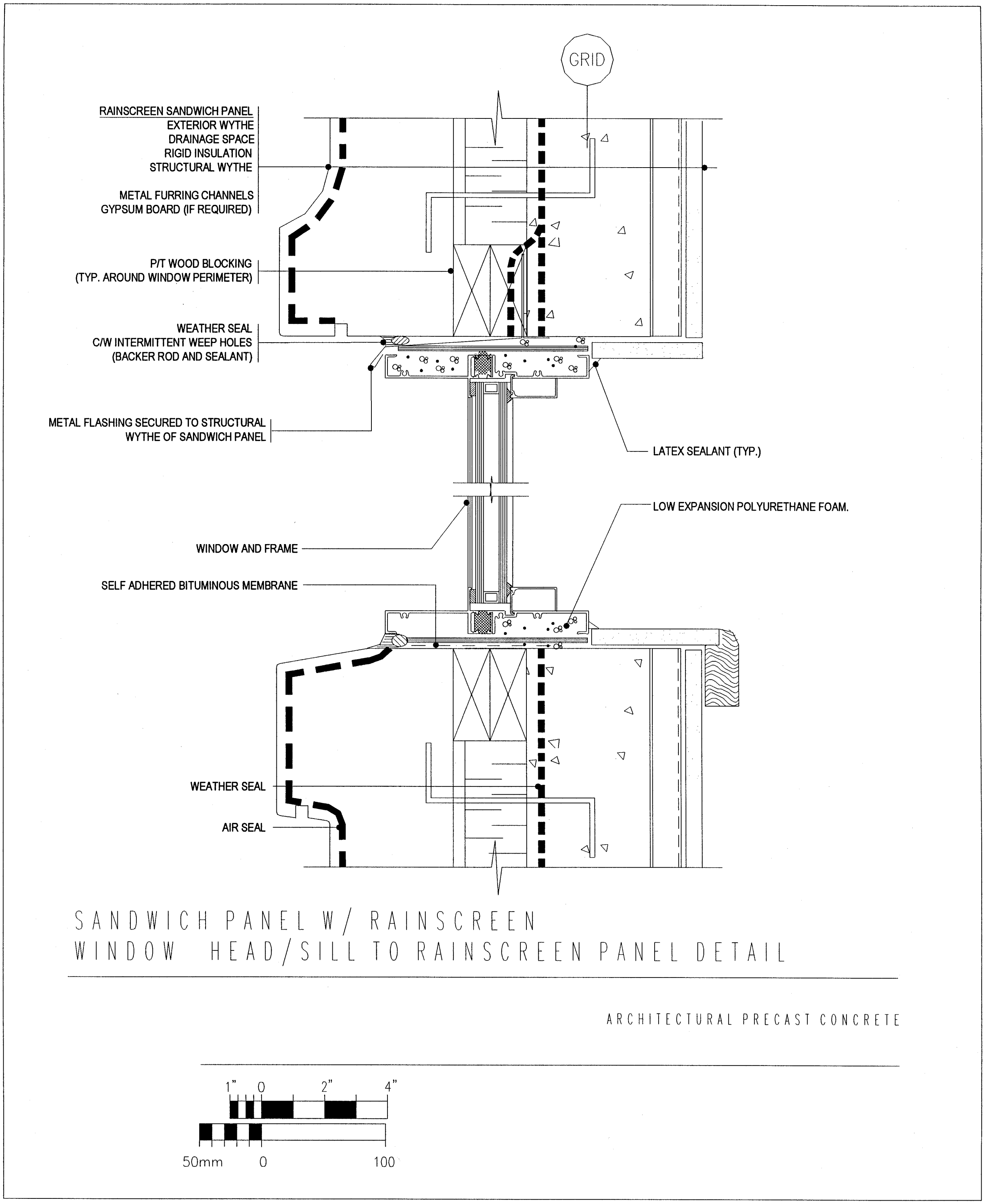

Figure 4 *Junction with window.*

across the junction with the window can be enhanced with spray-in-place polyurethane foam. Note that blind application of foam is not recommended.

Air Barrier. The air barrier is provided by the structural wythe in the precast sandwich panel. Air barrier continuity at the joints between panels is provided by the air seal and across the junction with the window is provided by a low expansion polyurethane foam located between the structural wythe and the window frame. The air barrier design for the window is provided by the window manufacturer.

Vapour Barrier. The vapour barrier is provided by the structural wythe in the precast panel and by the glazing and frame in the window.

Precipitation. Control of precipitation is achieved by the rainscreen design of the precast sandwich panel (drainage space) in combination with the two-stage joint between panels. Water that enters the cavity is eventually directed to drain at the vertical joints (as in Figure 3). The window manufacturer provides the precipitation control design for the window, and the building designer must specify a level of performance that is appropriate to the building requirements.

Other Considerations. Windows can be installed in a number of ways. Punched windows are installed within precast panels, while strip windows are installed on the building as rows (or strips) located between rows of precast spandrel panels. With strip windows, the design must ensure that frame shortening doesn't transfer structural load to the windows and that vertical joints in the panels that intersect the window head/sill are properly addressed.

Junction with Roof (Figure 5)

General. This detail presents a design for a precast wall system on a steel frame building. The precast sandwich panel system is bearing on the foundation (see Figure 1). The critical feature is the deflection under live load of the steel frame relative to the precast sandwich panel and the stress this applies to the building science features at the junction with the roof.

Thermal Barrier. The thermal barrier is provided by the rigid insulation in the precast sandwich panel. Continuity with the rigid insulation on the roof is maintained at the parapet by applying blocking and medium density mineral wool insulation across the top of the parapet and between the wood curb and the structural wythe. In addition, batt insulation is inserted in the wood curb.

Air Barrier. The air barrier is provided by the structural wythe, and continuity at the joints between panels is provided by the air seal. At the parapet, the air seal is carried over to meet a flexible elastomeric air barrier that is fastened to the interior face of the structural wythe with a continuous bar. The elastomeric air barrier in turn connects to the roof membrane.

Vapour Barrier. The vapour barrier is provided by the structural wythe. The structural wythe is connected to the roof vapour barrier via the elastomeric air barrier, which also acts as the vapour barrier in this design.

Precipitation. Control of precipitation is provided by the rainscreen design of the precast sandwich panel (grooved rigid insulation) in combination with the two-stage joint between panels. The sloped flashing over the parapet and fiber can't protect the top of the panels from precipitation.

Other Considerations. The design of the roof/wall parapet shown in Figure 5 allows for deflection of the roof perimeter beam due to snow or other live loads. This is of particular concern in areas of high design snow load or locations where snow can accumulate because of higher adjacent structures. The wood curb can be eliminated and the insulation and flashing applied to the structural wythe when deflection is negligible. The roof membranes and flashing are similar to details in the Canadian Roofing Contractor's Association manual.

Junction with Curtainwall (Figure 6)

General. Both the precast sandwich panel and the curtainwall are designed as rainscreen assemblies. As with windows (Figure 4), it is a design imperative to maintain continuity of building science performance across the junction between precast sandwich panel and curtainwall. The performance required of the curtainwall is specified by the building designer.

Thermal Barrier. The thermal barrier is provided by the rigid insulation in the precast sandwich panel. The thermal break and insulated glass units in the curtainwall are installed in line with the rigid insulation in the precast panel.

Air Barrier. The air barrier is provided by the structural wythe, and continuity at the joints between panels is provided by the air seal. Continuity to the curtainwall is provided by the elastomeric air barrier membrane, which is adhered and clamped to the edge of the structural wythe and clamped to the curtainwall with solid blocking below the pressure plate.

Vapour Barrier. The vapour barrier is provided by the structural wythe. The structural wythe is connected to the curtainwall via the self-adhered bituminous membrane, which also acts as the vapour barrier in this design.

Precipitation. Control of precipitation is achieved by the rainscreen design of the precast sandwich panel (drainage space) in combination with the two-stage joint between panels. The curtainwall manufacturer designs the precipitation control for the curtainwall, and the building designer must specify a level of performance that is appropriate to the building requirements. The glazing deflects most precipitation at the curtainwall, and glazing rabbets drain to the exterior. A weather seal is provided at the junction between the precast panel and curtainwall by backer rod and sealant.

Other Considerations. The precast sandwich panel and curtainwall have a potential advantage in that each system is fabricated by a single manufacturer. However, the junction will not be designed unless someone, e.g., the building designer, takes responsibility for the design.

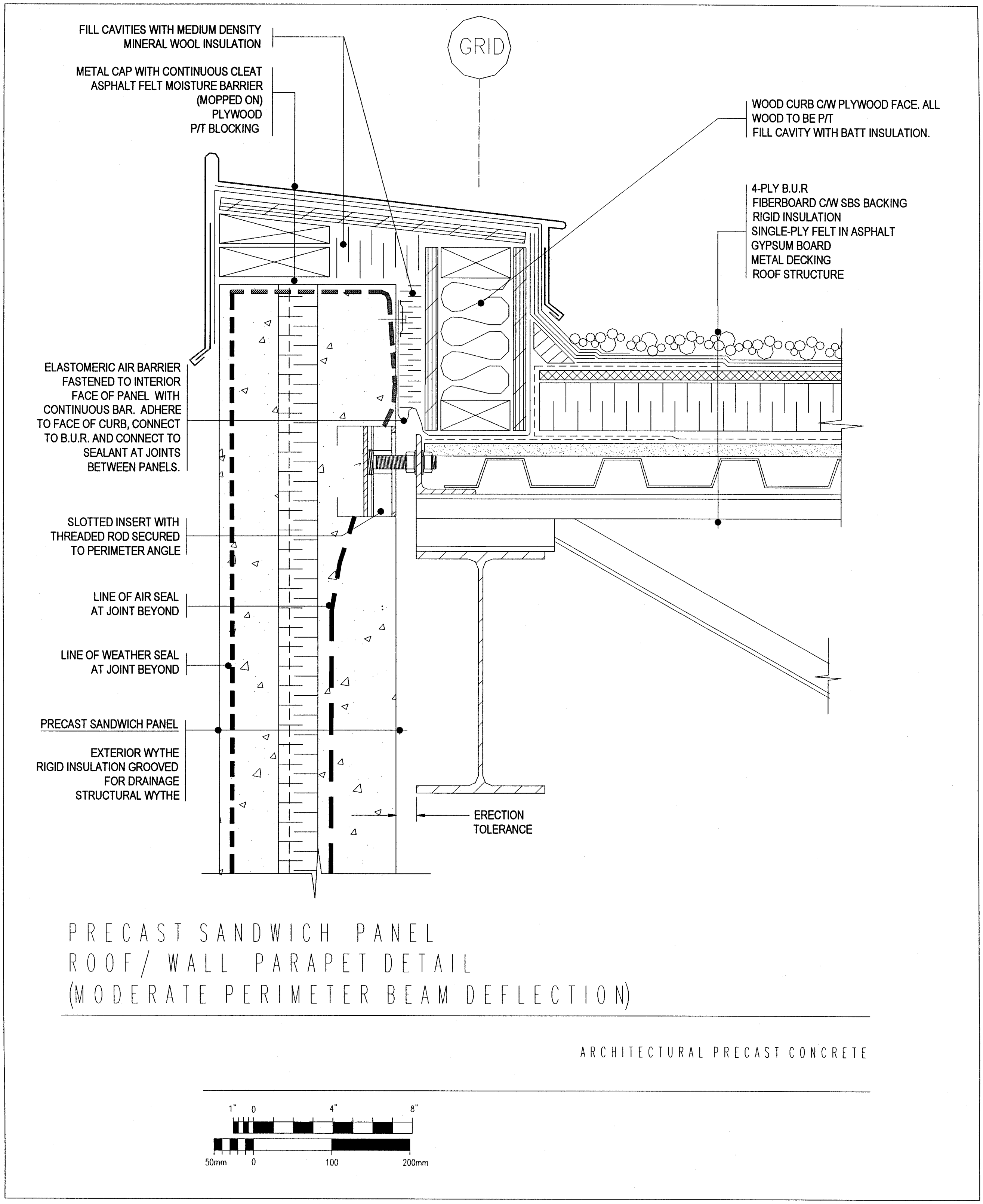

Figure 5 *Junction with roof.*

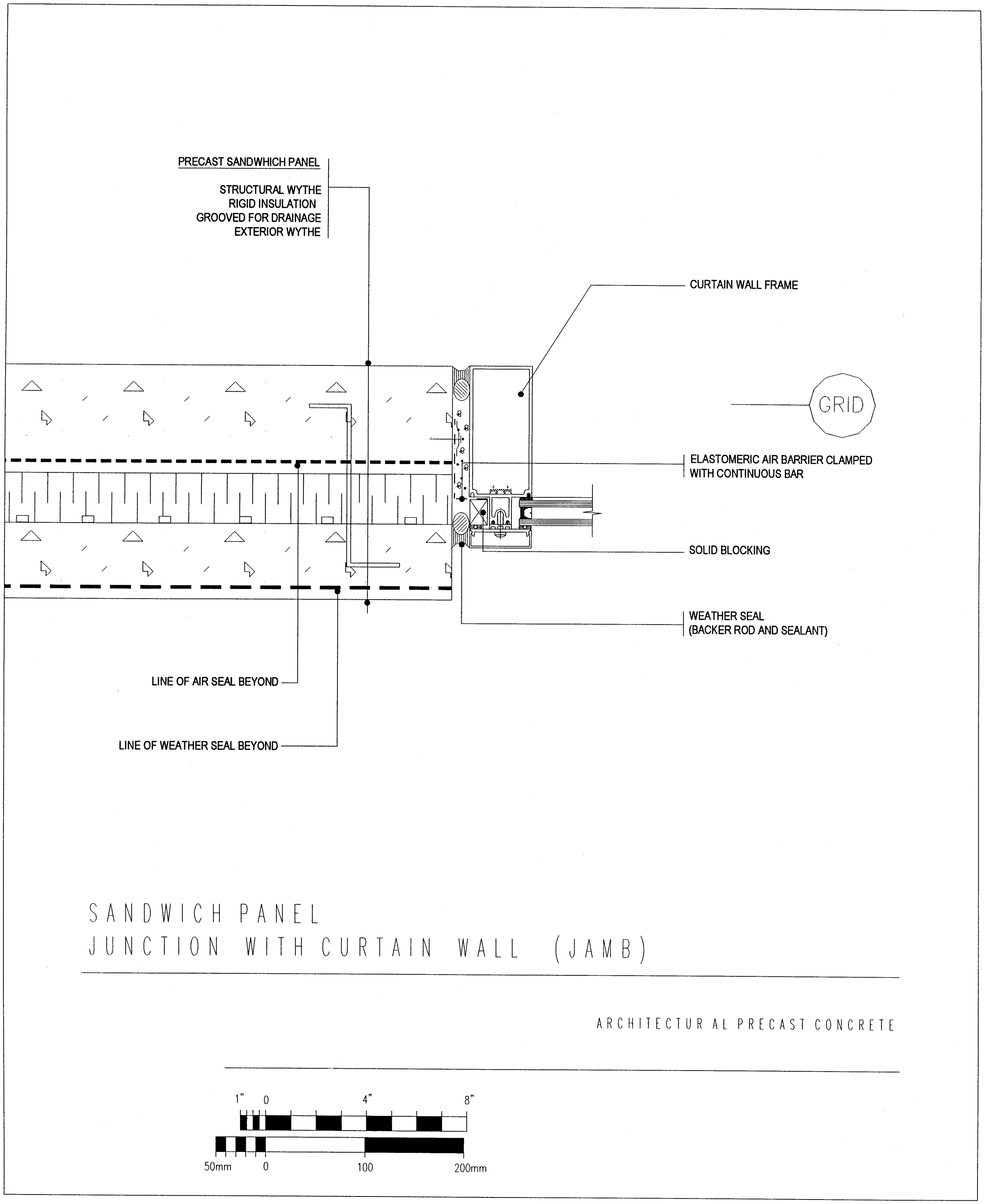

Figure 6 *Junction with curtainwall.*

Junction with Brick Veneer (Figure 7)

General. The insulated precast sandwich panel and brick veneer/steel stud systems are both designed as rainscreen assemblies. The brick veneer/steel stud backup wall is installed after precast erection.

Thermal Barrier. The thermal barrier is provided by the rigid insulation in the precast sandwich panel. The thermal barrier in the brick veneer/steel stud wall is provided by the rigid insulation, which is placed approximately in line with the rigid insulation in the precast panel.

Air Barrier. The air barrier is provided by the structural wythe, and continuity at the joints between panels is provided by the air seal. Continuity to the brick veneer/steel stud wall is provided by the bituminous membrane, which is secured to the edge of the structural wythe and adhered to the column and gypsum sheathing.

Vapour Barrier. The vapour barrier is provided by the structural wythe. The structural wythe is connected to the brick veneer/steel stud wall via the bituminous membrane, which also acts as the vapour barrier in this design.

Precipitation. Control of precipitation is achieved by the rainscreen design of the precast sandwich panel (drainage space) in combination with the two-stage joint between panels. The brick veneer/steel stud wall has a traditional rainscreen design to control precipitation. The clay brick veneer deflects most precipitation, and the air space drains to the exterior. A weather seal of backer rod and sealant is installed at the junction between the precast panel and clay brick veneer.

Other Considerations. The brick veneer/steel stud wall is installed by a number of trades, and coordination with the precast installer is essential. In addition, as with the curtainwall (Figure 6), the junction with the precast sandwich panel will not be designed unless someone, e.g., the building designer, takes responsibility for it.

CONCLUSION

Architectural precast concrete sandwich panels can be designed to provide all the performance requirements of a wall within one assembly. Besides offering a selection of finishes, shapes, colors, and textures to the building designer, they also offer the advantages of construction of the complete wall by one manufacturer, fabrication in a controlled environment, and closing the building in quickly. However, to gain these advantages, the designer has to be aware of the building science issues that must be addressed to achieve effective performance. Seven details of joints and junctions for architectural precast sandwich panels were presented in this paper. These details illustrate approaches to design for performance and can be used to achieve effective building envelope performance, that is, the separation of the controlled indoor environment from the uncontrolled outdoor environment.

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BIBLIOGRAPHY

Architectural Precast Concrete. 1989. Second edition. Precast/Prestressed Concrete Institute.

Brown, W.C., G.A. Chown, G.F. Poirier and M.Z. Rousseau. 1999. *Designing exterior walls according to the rainscreen principle.* Construction Technology Update No. 34, National Research Council of Canada.

Chown, G.A., W.C. Brown, and G.F. Poirier. 1997. *Evolution of wall design for controlling rain penetration.* Construction Technology Update No. 9, National Research Council of Canada.

Design Manual, Precast and Prestressed Concrete. 1996. Third edition. Canadian Precast/Prestressed Concrete Institute.

Garden, G.K. 1963. *Rain penetration and its control.* Canadian Building Digest No. 40. National Research Council of Canada.

Garden, G.K. 1965. *Control of air leakage is important.* Canadian Building Digest No. 72. National Research Council of Canada.

Garden, G.K. 1968. *Look at joint performance*. Canadian Building Digest No. 97. National Research Council of Canada.

Gustaferro, A.H. and M.S. Abrams. 1975. Fire tests of joints between precast wall panels: Effect of various joint treatments. *PCI Journal*, Vol. 20, No. 5.

Handegord, G.O. and K.K. Karpati. 1973. *Joint movement and sealant selection*. Canadian Building Digest No. 155. National Research Council of Canada.

ASHRAE. 1997. *1997 ASHRAE Handbook—Fundamentals*. 1997. American Society of Heating, Refrigerating, and Air-Conditioning Engineers.

Hutcheon, N.B. 1963. *Requirements for exterior walls*. Canadian Building Digest No. 48. National Research Council of Canada.

Latta, J.K. 1967. *Precast concrete walls—Problems with conventional design*. Canadian Building Digest No. 93. National Research Council of Canada.

Latta, J.K. 1967. *Precast concrete walls—A new basis for design*. Canadian Building Digest No. 94. National Research Council of Canada.

National Building Code of Canada. 1995. Canadian Commission on Building and Fire Codes. National Research Council Canada.

Plewes, W.G. 1970. *Cladding problems due to frame movement.* Canadian Building Digest No. 125. National Research Council of Canada.

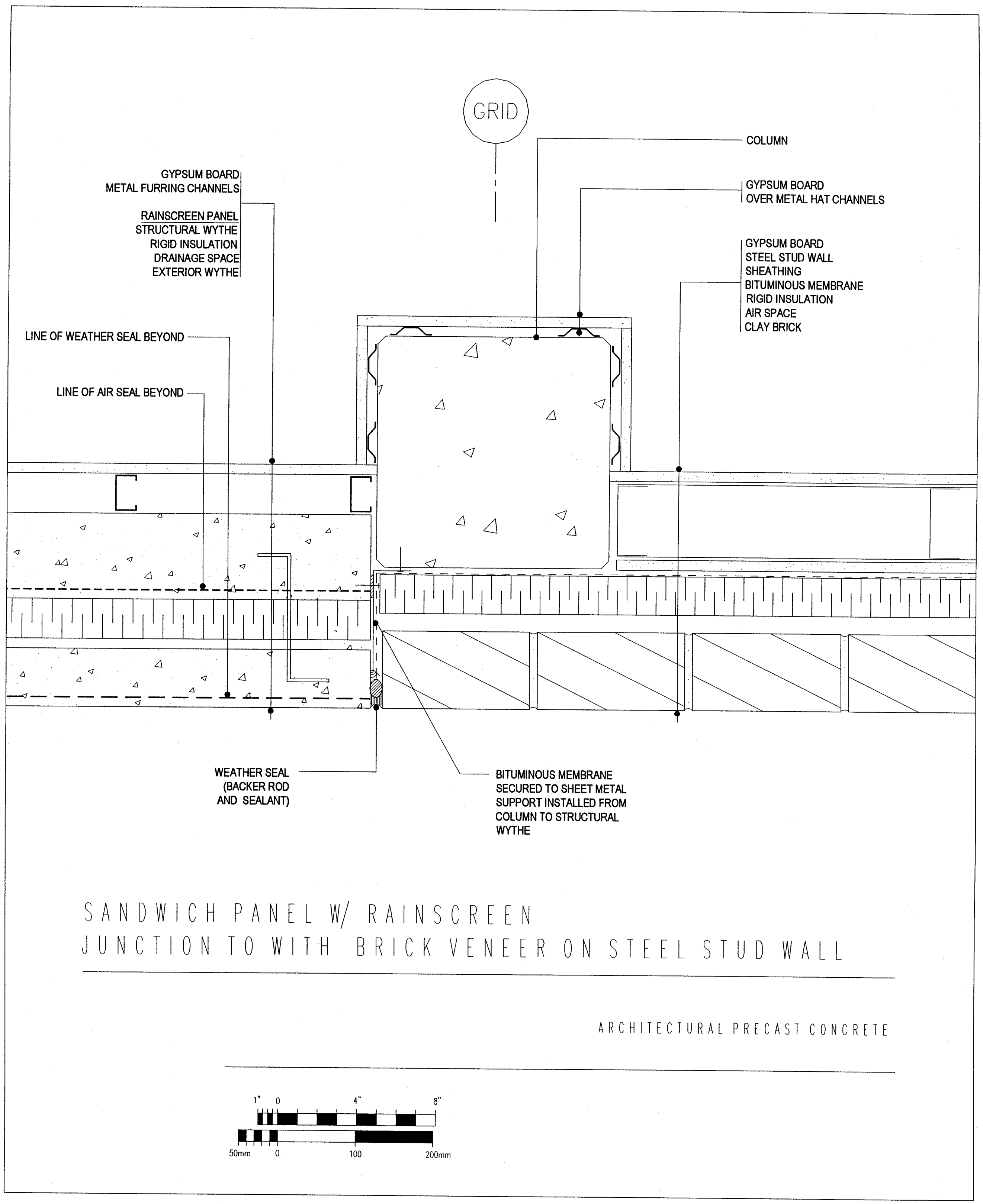

Figure 7 *Junction with brick veneer.*