

DIRECT ADHERED CERAMIC TILE, STONE AND THIN BRICK FACADES

TECHNICAL DESIGN MANUAL

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Cover Photo: Project-Xerox Building Santa Ana, CA USA, 1988

Description: 12 x 12 x 3/8 inch (300 x 300 x 10 mm) Balmoral red granite over cement plaster, metal lath and steel studs. Architect-Strock & Associates, Irvine, CA, USA

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DIRECT ADHERED CERAMIC TILE, STONE AND THIN BRICK FACADES

TECHNICAL DESIGN MANUAL

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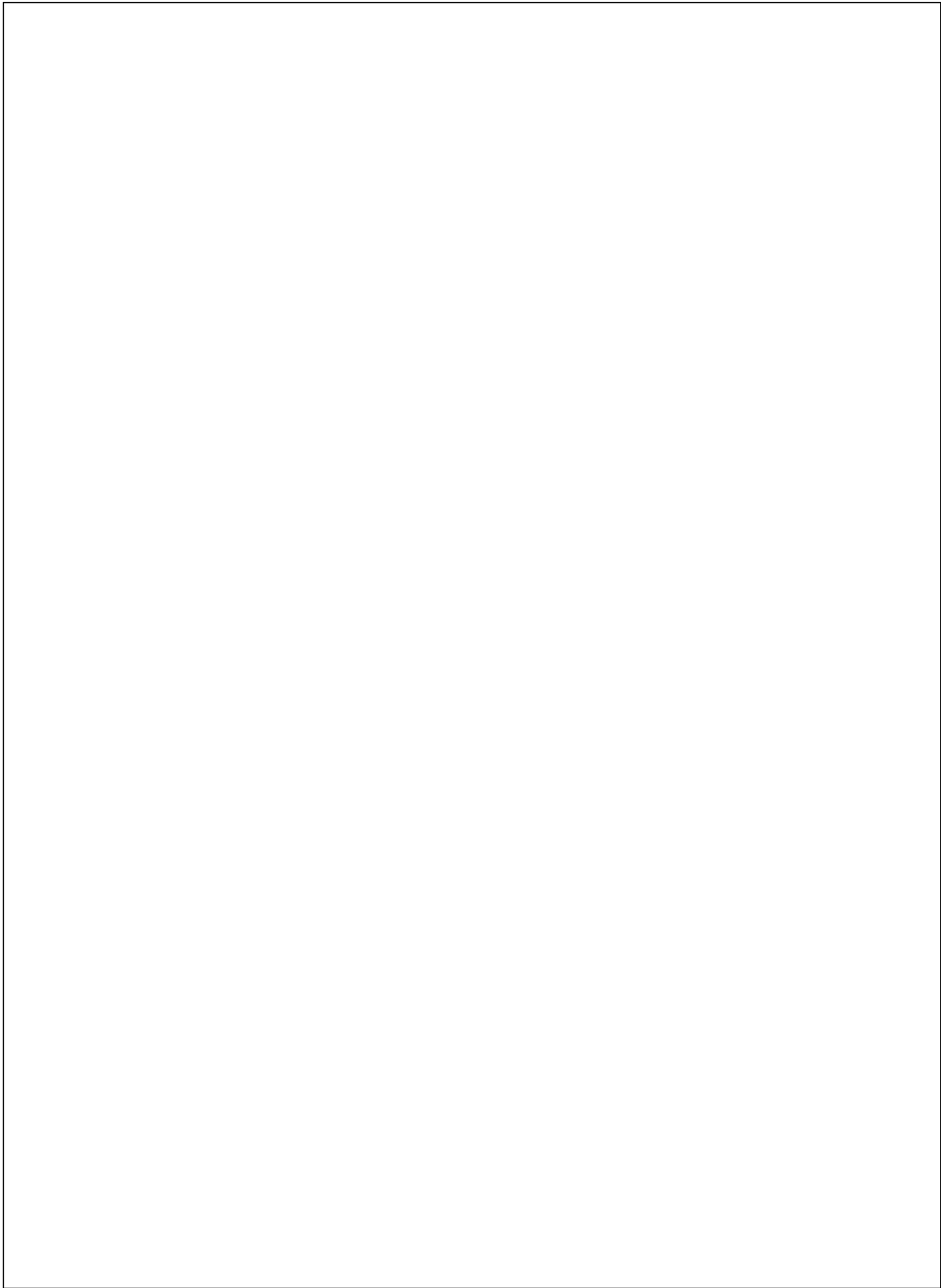
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SECTION 1

INTRODUCTION



SECTION 1

INTRODUCTION

1.1 PREFACE

LATICRETE International, a manufacturer of ceramic tile, stone and brick masonry installation systems, has long recognized the need for a technical manual to provide guidelines and recommendations for the design, specification, and installation of direct adhered ceramic tile, stone, and thin brick cladding for exterior facades. Technical advances in materials, manufacturing, and construction methods have expanded the role of this type application ever since the development of adhesive mortars in the 1950's. In keeping with their position as an industry leader, LATICRETE International is publishing this first edition of the *DIRECT ADHERED CERAMIC TILE, STONE and THIN BRICK FACADES Technical Design Manual* to make state-of-the-art information and technology available to architects, engineers, construction professionals, and manufacturers in the ceramic tile, stone and thin brick industries. It is also the goal of this publication to encourage new ideas, research, and building regulations for the purpose of improving the future of this construction technology and the ceramic tile, stone and brick industries.

1.2 WHAT IS DIRECT ADHERED CLADDING AND WHY USE THIS TYPE OF CONSTRUCTION?

For the purposes of this manual, the terms "direct adhered facade," "direct adhered external cladding" and "direct adhered exterior veneer" are all used interchangeably. By definition, these terms refer to an exterior wall or envelope of a building that is clad or faced on the exterior surface with a weather-resistant, non-combustible cladding material which is directly adhered to a structural backing material with an adhesive. The cladding is adhered in such a manner as to exert common action to the underlying wall

under load or applied forces. While there are numerous materials that could be used as an adhered cladding for a facade, in this manual the term "cladding" refers to the most common materials used in this type of construction; ceramic tile, natural stone and agglomerates, and thin brick masonry.

Why use the direct adhered method of cladding a building facade? There are many advantages. Adhesive technology has opened up an entire new world of aesthetic and technical possibilities for cladding of facades. The direct adhered method offers the architect tremendous design flexibility provided by new materials which would otherwise be, or previously were, unsuitable as a cladding for facades, such as ceramic tile. The building owner benefits from the more efficient and environmentally sensitive use of materials, resulting from reduced weight, cost of material, and more efficient use of natural resources. The building construction process is made more efficient by lightweight, pre-finished materials, or from pre-fabricated wall components, which all reduce construction time, on-site labor costs, and provide better quality assurance.

However, all these advantages of the direct adhered method for cladding facades can only be realized with a new approach to the design and construction of exterior walls. Design and construction techniques must be adapted to the specific requirements and behavior of construction adhesive technology, as well as the unique attributes of ceramic tile, stone, and thin brick cladding materials.

1.3 HISTORY OF CERAMIC TILE STONE AND THIN BRICK FACADES

Ceramic Tile

Ceramic tile has been used for centuries as a decorative and functional cladding for the exterior facades of buildings. Ceramic tile development can be traced to 4000 B.C.

in Egypt. However, use of ceramic tile on walls first appeared around 2700 B.C. when it was used to decorate the graves of pharaohs in Egypt. The earliest surviving example of exterior ceramic (terra cotta) tile cladding is the Dragon of Marduk sculpture from the Ishtar Gate in Mesopotamia dating to 604 B.C. (Figure 1.3-1) It was not until the 13th century when wall tiling for exterior walls was established in the Middle East. All prominent buildings during this period had ceramic tile clad exterior walls. The influence of Islamic architecture gradually spread to Spain and Italy in the 16th century, where ceramic tile was used extensively as an external cladding on public buildings.

Until recently, ceramic tile had been used primarily on walls and building facades because technology did not permit mechanically resistant and affordable products for floors and pavements. It is

ironic, that with the development of new ceramic tile and adhesive technology, the bulk of modern production of ceramic tiles is now used on floors and interior walls, when for centuries ceramic tile was used as a decorative and functional exterior cladding material. The use of ceramic tile on modern building facades has, until recently, been limited primarily as an isolated decorative element, due to inconsistent performance of past installations.

Natural Stone

Stone has been part of our building culture and heritage since the beginning of human existence. Use of natural stone as an exterior cladding has been extensive over the course of human history. This was due to man's ability to fabricate stone in blocks or sections of sufficient size and

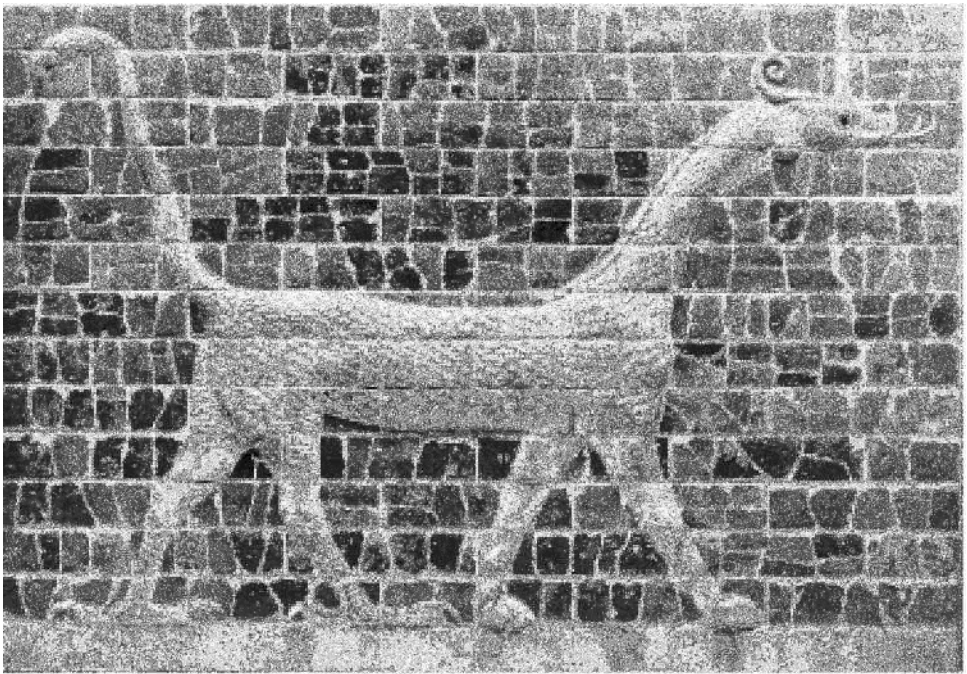


Figure 1.3-1 The Dragon of Marduk, Ishtar Gate, Mesopotamia, 604 B.C. 1

¹Photo: ©Detroit Institute of Arts Founders Society

thickness to support its own weight through stacking, either dry or with mortars.

With the development of lightweight structural skeletons and curtain wall construction in the late 19th century, the very weight and durability that made stone so desirable, also made economical fabrication and handling, difficult which ultimately slowed its development into these new construction methods.

It was not until 1955 that the invention of high quality synthetic diamonds and carbide abrasives at the General Electric Company in the USA revolutionized the fabrication of thin stone to meet the competitive demands of construction economy. The development of modern fabrication methods in the 1960's allowed relatively thin slabs of stone (2–4 inches/ 50–100mm thick) to be “hung” from building exteriors using metal mechanical anchors and curtain wall frames, followed by attachment to facades with adhesive technology. Further stone fabrication advancements now allow thickness as low as 1/4-3/16 inch (6–10mm).

In the 1950's, Henry M. Rothberg, an engineer who later founded the company LATICRETE International, invented a product and a new methodology that would make direct adhesive attachment of ceramic tile, natural stone, and thin brick on exterior building facades physically and economically feasible.² This development revolutionized both the ceramic tile and stone industries and has once again popularized the application of ceramic tile and stone on facades (Figure 1.3-2).

Thin Brick Masonry

While the use of traditional clay brick masonry has an extensive history, the recent introduction of thin brick technology was a direct result of the development of latex cement adhesive mortar and other types of construction adhesive technology in the 1960's.

As we approach the next century, the construction industry is under extreme economic and social pressure to develop new and alternative technologies due to the rapid depletion of our natural resources

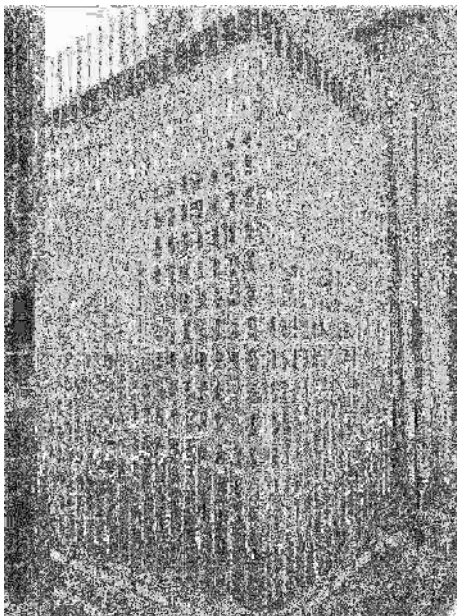


Figure 1.3-2 Direct Adhered Ceramic Tile Facade—Prefabricated panels on high rise construction, Los Angeles USA, 1960³

and the escalation of labor and material costs for traditional construction. New developments in ceramic tile, stone and thin brick and adhesive technologies have opened up an entire new world of aesthetic and technical possibilities for external cladding of facades. Combined with sound design and construction principles, direct adhered external cladding is likely to become one of the most important building construction technologies of the future.

1.4 SUMMARY OF MANUAL CONTENT

Section 2 - Exterior Wall Concepts

A primer on the theory and terminology

²H.M. Rothberg “The History of Latex in Portland Cement Mortars,” LATICRETE TDS 107.11

³Tishman 615 Building, Los Angeles, CA, USA—glass mosaic tile on pre-fabricated panels, metal frame - cement plaster and metal lath substrate, 22 stories

of exterior wall construction. Types of exterior wall structures and construction are presented, together with commentary on applicability to the direct adhered method for cladding facades.

Section 3 - Types of Direct Adhered Wall Construction

Architectural details show typical wall assembly configurations and recommended design for direct adhered cladding. Examples of exterior wall concepts presented in Section 2 are graphically depicted with various substrate/back-up wall material combinations. Details include design recommendations for interface details such as windows, roof parapets, movement joint sealants, flashings, and waterproof membranes.

Section 4 - Structural and Architectural Considerations

Direct adhered cladding must be designed and constructed with careful consideration of the complex interactions that occur between the other components of an exterior wall assembly. This section explores issues such as the effect and provision for structural movement, as well as recommendations for interface with architectural elements such as windows.

Section 5 - Substrates

The selection and preparation of a substrate is one of the most critical steps in design and construction of direct adhered cladding. Suitability and compatibility of the most common substrates is covered, together with comprehensive recommendations for preparation such as evaluation of levelness and plumb tolerances, surface defects, and the effect of climatic and site conditions on

substrates.

Section 6 - Selection of Exterior Cladding Material

Investigation and selection of the proper type of cladding is an important design decision. Detailed criteria for the assessment and selection of ceramic tile, stone, and thin brick are presented, together with important ancillary considerations such as color/temperature and moisture sensitivity of natural stone and man-made stone agglomerates.

Section 7 - Installation Materials and Methods - Adhesion and Grouting of Ceramic Tile, Stone and Thin Brick Cladding

This section covers the entire range of installation and construction issues, from selection criteria for adhesives, to the types of installation procedures and equipment required for the direct adhered method of construction.

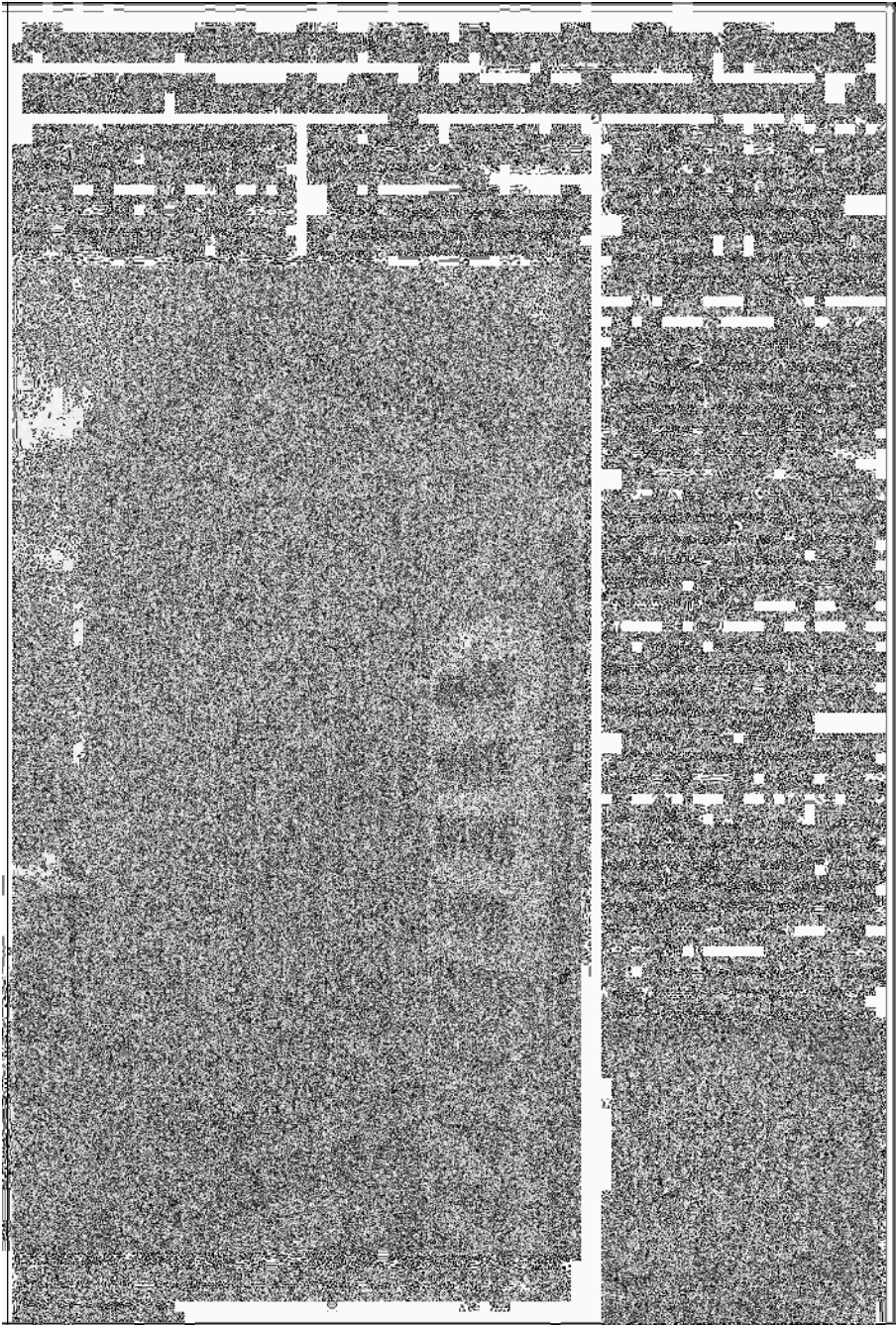
Section 8 - Industry Standards, Building Codes and Specifications

Detailed information on applicable industry standards for both ceramic tile adhesives and direct adhered external cladding is provided. Model building codes, including detailed excerpts from selected codes, are included. A chart lists the most common codes and standards from around the world that are applicable to direct adhered cladding.

Section 9 - Quality Assurance, Testing, Inspection and Maintenance Procedures

Recommendations for planning and implementation of a quality assurance program are outlined. Cleaning, protection, and preventative maintenance procedures are presented, along with design and construction diagnostic test methods. This section includes information on types,

causes, and remediation of defects.



1.5 CASE STUDY



Photo: Project: Portland Building, Portland, Oregon 1982, Architect: Michael Graves & Associates, Princeton, NJ
Description: Gail 10 x 10 inch (20 x 20mm) glazed brickplate and glazed ceramic tile
Direct Adhered Ceramic Tile, Stone &Thin Brick Facades–Technical Manual ©1998 LATICRETE International, Inc. **15**

SECTION 2

EXTERIOR WALL CONCEPTS

SECTION 2 EXTERIOR WALL CONCEPTS

2.1 FUNCTION OF EXTERIOR WALLS

The primary purpose of an exterior wall assembly is to separate the external environment from the internal environment. To perform this function, the exterior wall must act simultaneously as a restraint, a barrier and a selective filter to control a complex, often conflicting series of forces and occurrences.

Functions of Exterior Walls

- Wind pressure and seismic force resistance
- Thermal and moisture movement resistance
- Energy conservation and control of heat flow between interior-exterior
- Rain penetration resistance and control
- Water vapor migration and condensation control
- Sound transmission resistance
- Fire resistance and containment
- Daylight transmission to the interior environment; vision to exterior
- Air transmission between and within the interior-exterior
- Passage of occupants

2.2 TYPES OF EXTERIOR WALLS

Exterior wall assemblies are generally classified in three broad categories of wall type structures according to the method used to support the loads or forces imposed on the building, and the method of structural attachment to the building's internal components.

Types of Exterior Wall Structures

- Bearing walls
- Non-bearing walls
- Curtain walls

Bearing Wall

A bearing wall is defined as a wall which supports both its own weight, and

the weight all the other loads and forces acting on the building, including the weight of the floors, roof, occupants, and equipment. The bearing wall is supported by the building's foundation in the ground. It is the primary structural support of a building and an integral component of the other structural components such as the floors and roof. With the advent of modern structural (skeletal) framing systems, this wall type is typically used on buildings less than three stories high.

Non-Bearing Wall

This type of wall only supports its own weight, and is supported directly on the foundation in the ground. Non-bearing walls are also limited to low rise construction.

Curtain Wall

This is broad category for a type of exterior wall assembly which supports only its own weight and no roof or floor loads (similar to non-bearing wall types), but is secured and supported by the structural frame of a building. The curtain wall transmits all loads imposed on it (lateral wind/seismic and gravity loads) directly to the building's structural frame. This is the most common wall type, especially in multi-story construction.

2. 3 TYPES OF EXTERIOR WALL CONSTRUCTION

Within each category of wall structures, there are also three types of wall construction configurations. Each type of wall construction differs primarily by the method employed to prevent air, vapor, and water infiltration. Secondary differences are the methods and materials used to control other forces, such as heat flow or fire resistance.

Types of Exterior Wall Construction

- Barrier wall
- Cavity wall

- Pressure-equalized rainscreen wall

Bearing, non-bearing, and curtain wall structures can employ any of the above types of wall construction, although certain types of wall structures are more adaptable to certain types of wall construction.

Barrier Wall

Historically, we have relied on this type of wall for most of human history. The purpose of a traditional barrier wall design is to provide a relatively impenetrable barrier against water and air infiltration, relying primarily on massive walls to absorb, dissipate, and evaporate moisture slowly. The mass of the wall also controls other forces such as sound, fire, and heat flow quite efficiently. Openings or vulnerable joints are protected from water infiltration by roof overhangs, window setbacks, drip edges, and other types of physical shields.

Today, constructing a traditional barrier wall with massive walls and a complex configuration is cost prohibitive. Instead, economics of modern construction require that barrier wall construction be thin and lightweight. Modern barrier wall construction relies on impermeable cladding materials and completely sealed joints between exterior wall assembly components to resist all water penetration. While a barrier wall design typically has the lowest initial cost than other exterior wall configurations, the lower initial cost is offset by higher lifecycle costs, due to higher maintenance costs and lower expected life span caused by more accelerated rates of deterioration. However, with the pace of aesthetic and technological change in our culture, reduced life cycles for certain types of buildings have become acceptable.

A direct adhered ceramic tile, stone, or thin brick barrier wall facade does have limitations that may increase frequency of maintenance and decrease useful life. Stone and thin brick cladding materials will allow varying degrees of water penetration directly through the surface. Water penetration may also occur through hairline cracks in naturally fragile stone that, while not affecting safety, can occur from normal structural, thermal, and moisture movement

in the building. Similarly, hairline cracks in joints between the ceramic tile, stone, or thin brick that are grouted with cementitious material will also allow water penetration. While ceramic tile suitable for exterior walls can be impermeable, the cementitious joints between tiles will be permeable, unless they are filled with epoxy grout or silicone/ polyurethane sealants. In an attempt to prevent water penetration with impermeable joint fillers, the following new problems may be created:

- 1) it is impossible to achieve a 100% seal against water with a field applied sealant or epoxy grout over thousands of lineal feet/meters of joints.
- 2) a totally impermeable exterior wall may perform well in warm, humid climates; but in colder climates, water vapor from the interior of the building may get trapped within the wall and condense, causing internal deterioration of the wall.
- 3) sealant joints require frequent maintenance and replacement.

Cavity Wall

This type of wall construction consists of an inner and outer layer of wall components separated by an air cavity. Recognizing the difficulty of achieving a 100 percent effective water barrier, a cavity wall is designed to allow a certain amount of water to penetrate the outer layer into the cavity. Water cannot bridge the air cavity easily, so it drops by gravity and is then controlled and directed by properly designed drainage outlets back to the exterior surface of the wall.

Pressure Equalization

This type of wall construction is a more sophisticated type of cavity wall where specially placed and sized openings in the exterior cladding allow outside air to penetrate the cavity and reach the same pressure as the outside air, thus the term pressure equalize. This type of wall construction reduces the internal wall cavity pressure differential (Figure 2.3-1). A pressure differential could cause water

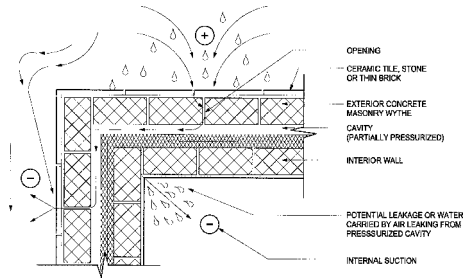


Figure 2.3-1 Typical cavity wall air pressure differentials

and vapor to be forced and suctioned in either direction across the cavity, resulting in leakage and deterioration. The internal wall cavity is normally at different pressures due to wind flow over the exterior facade, the “stack” rising effect of air flow in a building, and HVAC (heating/ventilating) system pressurization and imbalance.

To allow proper air pressure transfer, the inner layer of wall construction must be airtight. This is achieved by installation of an air retarder on the exterior surface of the inner layer of the cavity wall assembly.

Future Exterior Wall Technology - The Dynamic Buffer Zone

Studies have shown that moisture accumulation in wall cavities occurs more often from the water vapor migration and build-up of condensation than from rain or snow penetration. One study has demonstrated that in one month, approximately 31 pounds/15 kg of water could leak by air leakage and resultant condensation through an electrical outlet

⁴Quirouette, R.L., “The Difference Between a Vapor Barrier and an Air Barrier,” BPN 54, NRC Canada, 1985

⁵Quirouette, R.L., “The Dynamic Buffer Zone,” The Construction Specifier, August 1997

with a net open area of 1 inch²/6.5 cm² and an interior-exterior air pressure difference equivalent to a 9.3 mph/15 km/hour wind.⁴

The mechanism behind moisture condensation is the exfiltration of humid indoor air in cold climates, and to a lesser degree, the infiltration of humid air in warm climates to the cool internal wall cavity. Though vapor barriers and the more sophisticated air barriers provided by ventilated or pressurized rain screen wall designs have greatly improved air and water vapor resistance of exterior walls, a perfect seal is not feasible. Water vapor

condensation will continue to occur in buildings with moderate humidity levels in cold climates, and in air conditioned buildings in warm, humid climates.

In direct adhered cladding systems, many of the problems that we associate with apparent rain penetration are actually caused by accumulation of condensation. This internal wall moisture not only causes water leakage and staining, but is often responsible for problems such as efflorescence, mildew odors, diminished insulation value, corrosion of metal components, and reduced strength, or even failure of adhesives and membranes.

SECTION 3

TYPES OF DIRECT ADHERED WALL CONSTRUCTION

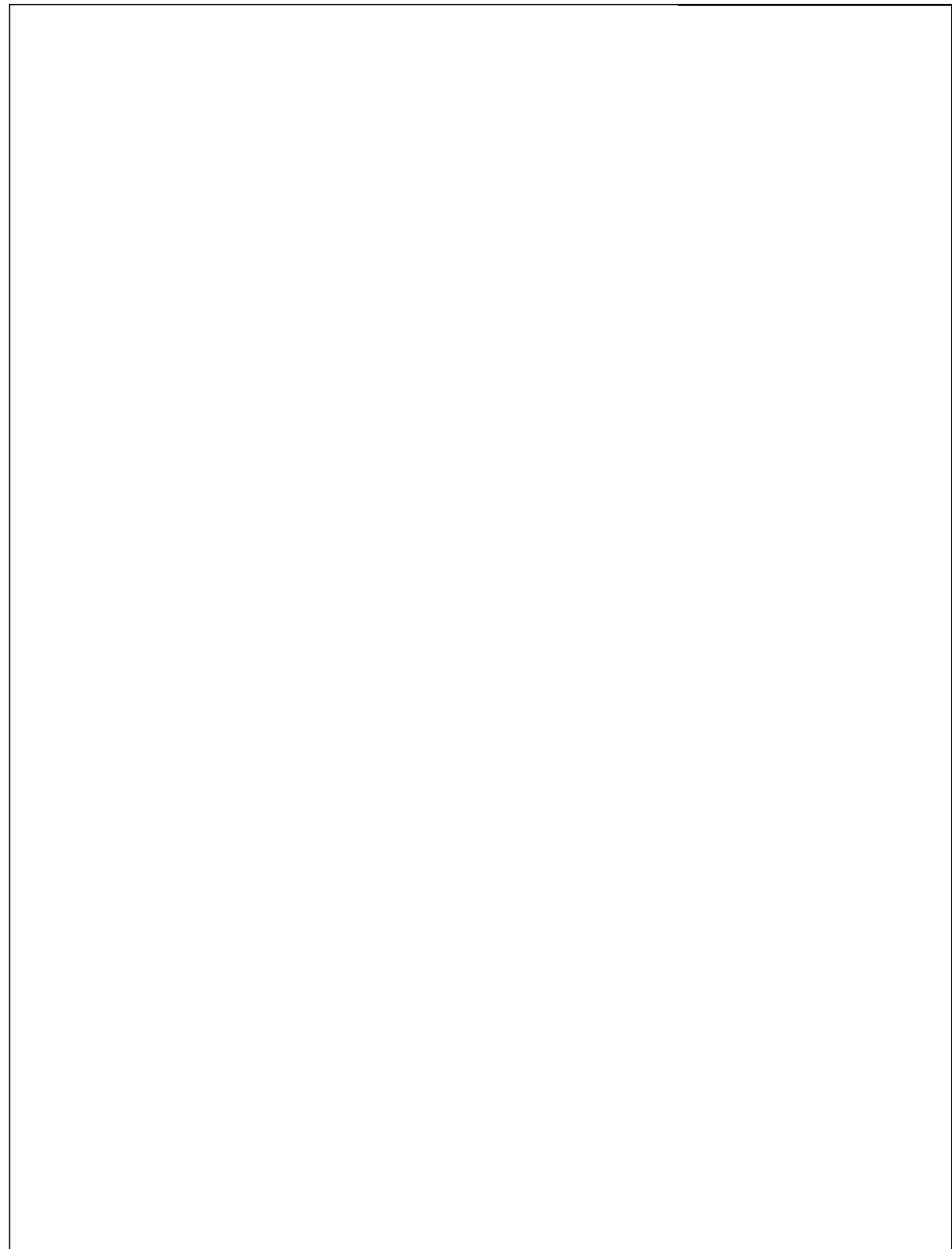


Photo: Project-Hotel Nikko, San Francisco, CA USA Architect: Takanaka Associates, Tokyo, Japan
Description: 2 x 2 inch (50 x 50mm) porcelain tile adhered by the negative cast method on precast concrete panels Direct Adhered Ceramic Tile, Stone &Thin Brick Facades–Technical Manual ©1998 LATICRETE International, Inc. **21**

SECTION 3

TYPES OF DIRECT ADHERED WALL CONSTRUCTION

Research and full scale testing was recently resurrected for an exterior wall concept known as the *Dynamic Buffer Zone (DBZ)*⁵, which was first proposed in the 1960's. The DBZ concept, while fairly sophisticated, has been demonstrated to significantly reduce or even eliminate moisture in the internal cavities of exterior walls by mechanically pumping dry outdoor air into the wall cavities in buildings located in cold climates. Thus far, this concept has not been tested in warm humid climates, but the technology has promise to also solve similar problems unique to warm humid climates, such as condensation and mildew growth/odors facilitated by air-conditioning. The DBZ technology works through pressurization of the exterior wall cavity using partially heated outdoor air in cold climates. A DBZ wall system is designed so that the wall cavity pressure is above the indoor room pressure, thus limiting passage of indoor humidity by air leakage. The most significant challenge in the practical application of the Dynamic Buffer Zone concept is not necessarily the cost (much of the infrastructure and equipment already exists in modern commercial buildings); the challenge lies in the extensive level of detail and coordination of mechanical engineering and architectural disciplines, and the correlating trades on the construction site.

Penetration and its Control," 1963

2.4 REFERENCES

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2. Persily, Andrew, "Envelope Design Guidelines for Federal Office Buildings," Progressive Architecture Magazine, March,1992
3. Robinson, G. & Baker, M.C., "Wind Driven Rain and Buildings," NRCC 14792 National Research Council, Canada,1975
4. Canadian Building Digest 40, National Research Council, Canada, "Rain

3.0 ON-SITE CONSTRUCTION

3.1 CONCRETE MASONRY UNIT BACK-UP WALLS

Concrete block masonry units (CMU) are the preferred back-up wall system for installation of direct adhered cladding in buildings where a long service life and maximum durability is desired. CMU wall thickness must be calculated based on engineering analysis as required by building codes. However, the empirical rule of a height to thickness ratio of 18 remains a good guide for preliminary selection of wall thickness. Walls should be a minimum thickness of 8 inches (200mm).

CMU walls usually require vertical and horizontal reinforcing in order to satisfy seismic requirements. Joint reinforcing should be used at every second horizontal bed joint.

Barrier Concrete Masonry Walls

Single wythe CMU back-up walls are barrier walls and therefore must be waterproofed, even if they are clad with a relatively impermeable cladding. Every joint between the ceramic tile, stone or thin brick cladding is a potential source of water penetration. Cement or latex cement leveling plasters (renders) or parge (skim) coats may provide adequate protection in extremely dry climates but water will penetrate during prolonged periods of rain and cause either leakage, deterioration of underlying materials, or sub-surface efflorescence which can result in adhesive bond failure.

Through-wall flashing and weep holes can be provided in the CMU at the bottom of the wall at windows splitting the wall into two thin wythes at the flashing.

Cavity Concrete Masonry Walls

The outside face of the internal wythe of CMU back-up walls should be damproofed, as cavity walls are designed with the anticipation of water penetration. Cavity walls should have an unobstructed air space between the inner and outer wythes. The air space prevents infiltrated water from bridging to the inner wall, and can be designed to equalize outside and

cavity air pressure to prevent water from being driven across the air space. Water can then be collected and directed back to the exterior surface of the cladding (see Section 2 - Pressure Equalization).

The recommended width of a cavity is 2 inches (50mm), and should not be less than 1 1/2 inches (32mm) or greater than 4 inches (100mm). If rigid insulation is used in the cavity in cold climates, a 2-inch (50mm) air space should be provided from the face of the insulation.

Weep holes should be placed at the bottom of each floor level, bottom of walls, at window sills, and any other locations where flashing is provided. Weep holes are normally spaced at 24 inches (600mm), but no greater than 32 inches (800mm) on center, and located where the vertical joints of both the CMU and external cladding align. The cavity base should be provided with drainage material, such as gravel or plastic drain fabric to prevent mortar droppings from blocking drainage.

Flashings (see Section 4) are used to collect and direct water which has infiltrated the cavity back to the exterior through weep holes. Flashings must be terminated in a horizontal CMU joint, and must be turned up at the ends of window sills or other horizontal terminations to form a dam, otherwise water will travel laterally and leak at the ends of the flashing. At the face of the external cladding, flashing should be terminated in a rigid sheet metal drip edge to direct any water away from the face of the cladding. If flexible sheet or fluid applied flashings are used, they need to be bonded to a rigid metal drip edge.

The external CMU wythe and external cladding are anchored to the back-up CMU wall with galvanized steel wall ties typically spaced 16 inches (400mm) on center vertically and horizontally. Anchors require flexible connections in order to allow for misalignment of the internal/external CMU coursing, and to permit differential movement both within the CMU wall, and between the external cladding-CMU wall and the internal backup wall and structural frame.

3.2 CLAY (BRICK) MASONRY

BACK-UP WALLS

Clay brick masonry back-up walls, whether designed as barrier or cavity walls, are generally constructed using the same principles and design techniques as concrete masonry back-up walls.

However, there is one important difference between the two materials. Clay brick will expand permanently with age as a result of moisture absorption. When a brick is fired during the manufacturing process, all the moisture has been removed, and clay brick will gradually increase in volume from the original manufactured dimensions. (See Section 6.4)

Consequently, clay brick masonry back-up walls must make provision for expansion. This is particularly important where clay brick is used in a barrier wall configuration to infill between structural concrete frames; restraint of expansion can cause the back-up wall to bow outwards.

3.3 LIGHT GAUGE STEEL METAL STUD, BACK-UP WALLS

Light gauge metal (galvanized steel) studs are commonly used as a back-up wall structure for directed adhered cladding. Metal stud back-up walls are only recommended in buildings with an anticipated facade service life of 30 years.

The metal stud frame can employ a variety of sheathings, the type of sheathing dependent on whether the wall is barrier wall requiring direct adhesion of the cladding material, or a cavity wall where the sheathing type does not affect adhesion. Metal stud walls can also be used for both pre-fabrication of panels, or construction in-place.

Metal stud size and gauge are selected based on known structural properties required to resist live and dead loads. The predominant live load is wind, therefore stiffness usually controls size of metal studs. Empirical experience has shown that 6 inch (150mm) wide, 16 gage studs spaced 16 inches (400mm) on center are appropriate for most applications. However, engineering calculations may show that other widths and gauges are required. *Deflection (measure of stiffness)*

of metal stud back-up wall construction for exterior facades should be limited to 1/600 of the unsupported span of the wall under live (wind) loads. While this is the current allowable deflection for metal stud back-up walls, some studies on conventional masonry veneer cavity walls have shown cracking can occur on walls that have significantly less deflection. There have been no definitive studies conducted on metal stud barrier walls used in direct adhered cladding, but empirical evidence indicates that the composite action of rigid cladding materials, high strength adhesives, and proper specification of sheathing material and attachment method to metal studs does create a more rigid diaphragm compared to a metal stud back-up wall separated by a cavity.

Metal stud framing typically requires lateral bracing to, or integration within the structural steel frame of a building. Bracing is dependent on the configuration and unsupported length of the stud frame. Empirical experience has again proven that integration within the structural steel system not only provides a stiffer metal stud wall by reducing the unbraced lengths of studs, but also improves accuracy and reduces errors by providing an established framework where studs are used as infill rather than the entire framework.

There are a wide variety of sheathing materials to choose from for metal stud walls, ranging from low cost exterior gypsum sheathing or plywood for cavity wall sheathing, to cement backer board, or lath and cement plaster for barrier walls requiring direct adhesion of the cladding material.

Gypsum sheathings historically have not been a very durable material for cavity walls, although new gypsum based sheathings with fiberglass facings and silicone impregnated cores have improved performance.

Cement plaster is an ideal sheathing for metal stud back-up walls. This sheathing provides a seamless substrate with no exposed fasteners, resulting in good water and corrosion resistance. The integral reinforcement also provides necessary stiffness, resistance to shrinkage cracking, and positive imbedded attachment points

for anchorage to the metal stud frame. The attachment of the reinforcing in a cement plaster sheathing and resulting shear and pull-out resistance of the fasteners within the sheathing material is superior to that of pre-fabricated board sheathings such as gypsum or cement backer unit boards (CBU). This factor is important in more extreme climates where there is more significant thermal and moisture movement which can affect sheathings that are poorly fastened or have low shear or pull-out resistance to fasteners.

Cement backer unit boards (CBU), fiber cement and calcium silicate boards are other choices for metal stud back-up walls requiring direct adhesion of the cladding material. CBU board is pre-fabricated, and provides an efficient, cost effective cementitious substrate for adhesion of cladding materials. While CBU is technically water resistant, it requires waterproofing, as the minimal thickness and corrosion potential of screw attachments increase the possibility for minor cracking, leaks, deterioration, and defects such as efflorescence. Fiber cement boards can be sensitive to moisture, and require waterproofing on both sides to resist dimensional instability that may be caused by both infiltrated rain water or condensation on the back side of the board.

There are proprietary direct adhered wall systems which employ corrugated steel decking as a sheathing and substrate for cladding adhered with special structural silicone adhesives. Because these systems employ spot bonding rather than a continuous layer of adhesive, the combination of open space behind the cladding and the corrugation of the steel decking provides a cavity for drainage and ventilation. This cavity anticipates water penetration, and re-directs water back to the exterior wall surface. However, the underlying metal decking and framing are subject to corrosion facilitated by abrasion of galvanized coatings during construction. Leakage may also occur due the difficulty in waterproofing the steel and multiple connections/penetrations. Corrugated steel sheathing cavity walls have a limited service life similar to that of barrier walls.

Generally, the light weight and minimal

thickness of most sheathing materials for metal stud barrier back-up walls make them more susceptible to differential structural movement and dimensional instability from thermal and moisture exposure. Therefore, careful engineering analysis of cladding-adhesive-sheathing material compatibility, and analysis of the anticipated behavior of the sheathing and its attachment are critically important.

3.4 CAST-IN-PLACE REINFORCED CONCRETE BACK-UP WALLS

Cast-in-place concrete is one of the most common back-up wall materials for direct adhered external cladding. However, it is unusual that an entire facade back-up wall construction will be concrete; typically only the face of the structure or walls at the base of the building are concrete. Cast-in-place concrete is only economical in barrier wall type of construction, and resists water penetration by virtue of mass and density. However, it is still recommended to waterproof concrete, as saturation with water can cause efflorescence.

There are several other important considerations unique to vertically cast-in-place concrete used as a back-up wall for external cladding (see Section 5 for detailed information):

- form release agents
- surface defects
- dimensional change and cracking caused by shrinkage

3.5 PRE-FABRICATED PANEL CONSTRUCTION

3.6 PRE-CAST CONCRETE WALL PANELS

Ceramic tile, stone, and thin brick clad pre-cast concrete panels combine durability and tremendous design flexibility with the strength and economy of pre-cast concrete. The primary advantage of this type of back-up wall construction is the economy of pre-fabricated, panelized construction. Prefabrication permits construction of panels well in advance of the normal sequencing of on-site construction of a building's exterior wall. Once the proper stage in the sequence of construction is

reached, panels can be erected quickly, without weather or scaffolding erection delays. Pre-cast concrete also allows more stringent quality control afforded by plant production of both the batching and casting of the concrete, as well as the installation of the cladding material.

The considerations for clad pre-cast concrete panels are generally the same as those for un-faced panels, with two exceptions; the method of installation for the cladding material, and investigation of differential thermal and moisture movement between the pre-cast concrete and the cladding material.

Pre-Cast Concrete Panels - Negative and Positive Cast Methods

There are two methods for installation of cladding on pre-cast concrete panels; the negative and positive cast methods. Negative cast panels involve the casting of the concrete and bonding of the cladding in one step. The cladding material is placed face down over the face of the panel mold; joint width and configuration are typically controlled by a grid to insure proper location, uniform jointing and secure fit during the casting operation. Joints are typically cast recessed, and pointed or grouted after the panel is cured and removed from the mold. This method requires the use of a cladding with a dovetail or keyback configuration on the back in order to provide mechanical locking action between the cladding and the concrete. The mechanical bond strength afforded by the integral locking of the concrete to the back is often augmented by the use of latex Portland cement slurry bond coats or polymeric bonding agents just prior to casting of the panel.

Positive cast panels are prefabricated in two separate processes. The pre-cast panel is cast, cured, and removed from the mold, and the cladding material is then installed using an adhesive in the production plant. Installation of the cladding after erection and attachment to the structure on-site is viable, but this sequencing defeats the goal of economy and quality control provided

by prefabrication.

Pre-Cast Concrete Panels - Differential Movement (Internal to Panel)

Differences in the physical characteristics of the pre-cast concrete and the cladding material make this type of back-up construction more susceptible to problems of panel bowing or excessive shear stress at the adhesive interface.

Bowing of panels can occur from several mechanisms. In negative cast panels, the concrete shrinks as it hydrates and excess water evaporates. The cladding, being dimensionally stable, can restrain the shrinkage of the concrete. The result is compressive stress in the cladding, and tensile stress at the adhesive interface, with the potential for outward bowing of the cladding surface.

The best techniques in preventing panel bowing is to control the concrete shrinkage and to provide the proper ratio of cross sectional area to stiffness (modulus of elasticity) of the panel. Avoid flat panels less than 5–6 inches (125–150mm) thick; panels as thin as 4 inches (100mm) can be used in panels with small areas, or in panels where stiffness is increased by configuration or composite action with a thick cladding material. Concrete mix design and curing conditions can be adjusted to minimize shrinkage.

Several other techniques, such as the amount, location, and type of (prestressing) reinforcement, or introduction of camber to the panel, have been developed to compensate for possible bowing caused by shrinkage.

Differential movement caused by different coefficients of thermal expansion between the cladding and the concrete can also result in panel bowing. The optimum condition is for the concrete to have a rate of thermal expansion that closely approximates that of the cladding. The thermal coefficient of expansion of concrete can be modified slightly by adjustment of aggregate type, size and proportion to provide compatibility with the cladding and minimize differential movement under temperature changes.

Pre-cast Glass Fiber Reinforced

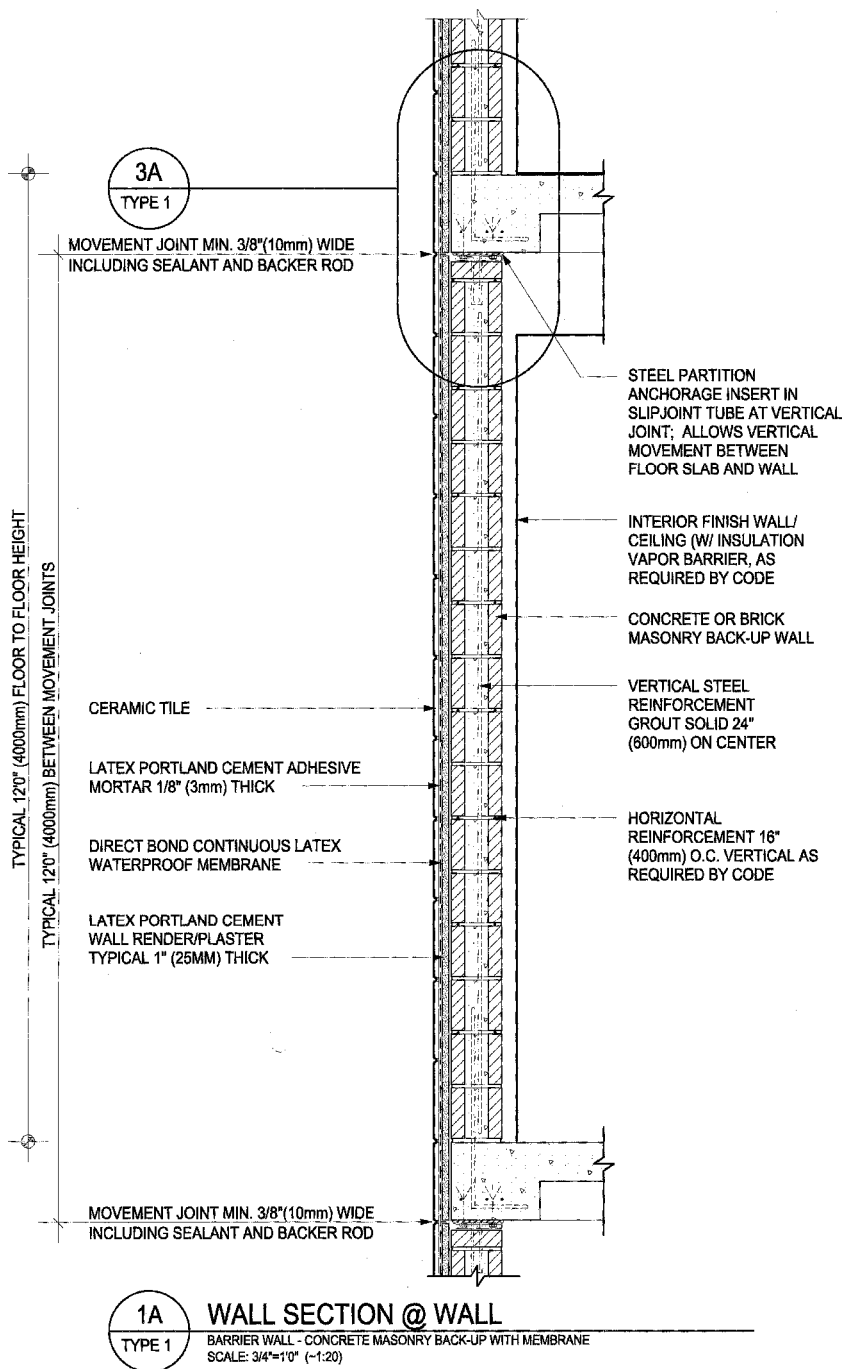


Figure 3.7-1 Architectural Details of Barrier Wall - Concrete masonry unit backup with continuous waterproof membrane

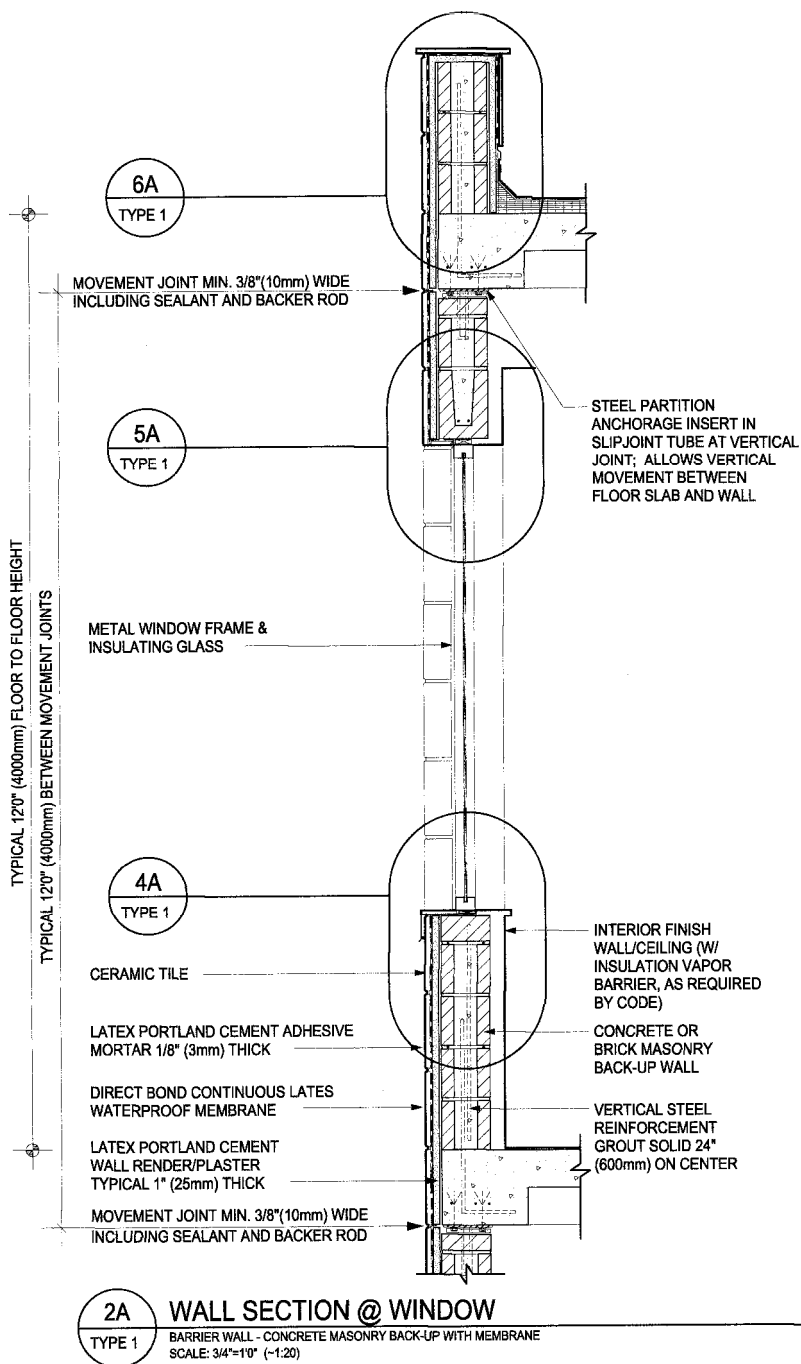
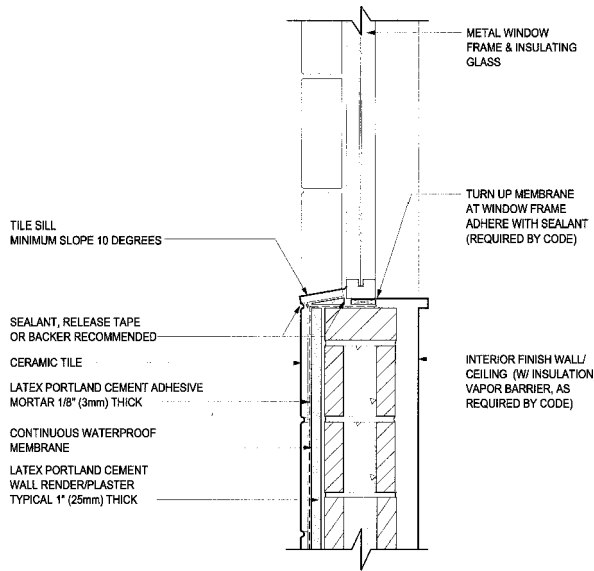
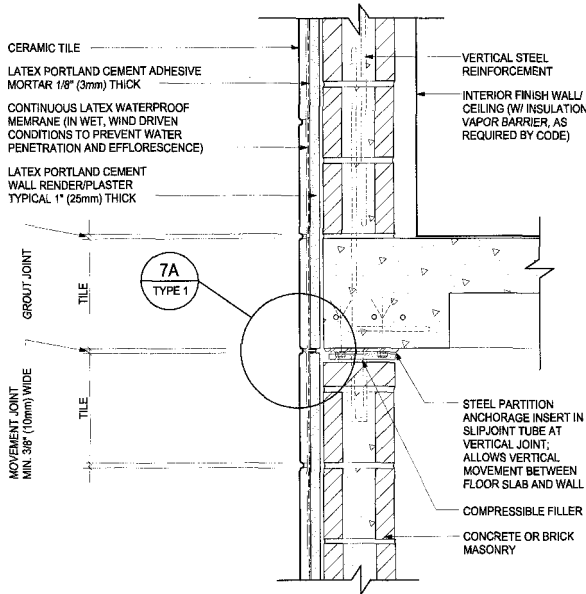


Figure 3.7-2 Architectural Details of Barrier Wall - Concrete masonry unit backup with continuous waterproof membrane

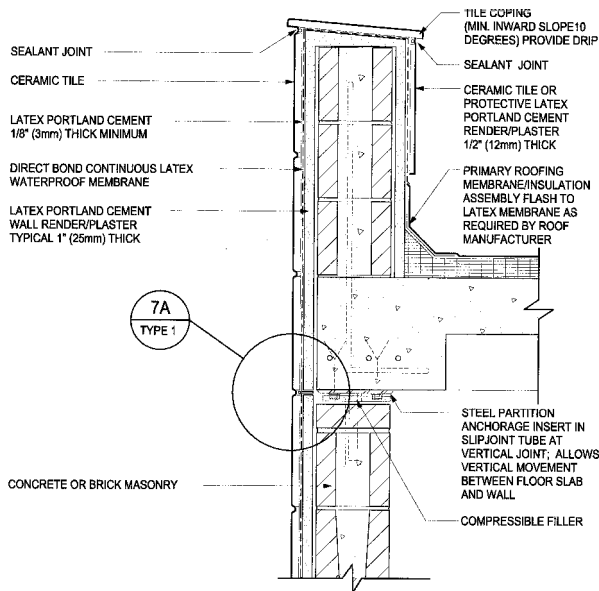


4A DETAIL @ WINDOW SILL
TYPE 1 BARRIER WALL - CONCRETE MASONRY BACK-UP WITH MEMBRANE
SCALE: 1-1/2"=1'0" (-1:10)

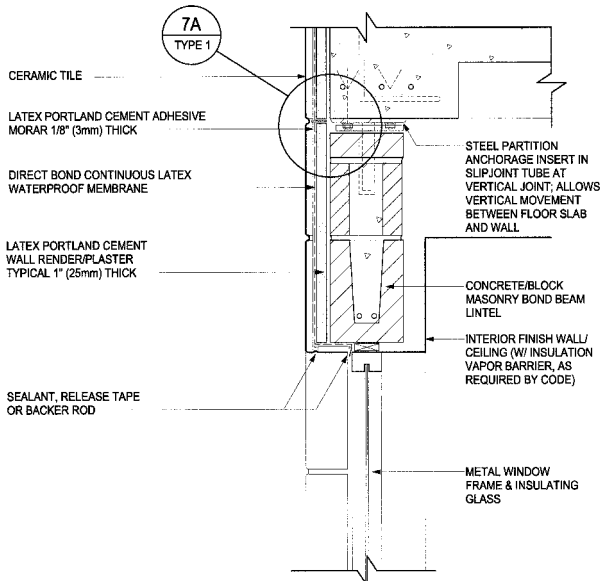


3A DETAIL @ SPANDREL
TYPE 1 BARRIER WALL - CONCRETE MASONRY BACK-UP WITH MEMBRANE
SCALE: 1-1/2"=1'0" (-1:10)

Figure 3.7-3 Architectural Details of Barrier Wall - Concrete masonry unit backup with continuous waterproof membrane



6A DETAIL @ ROOF PARAPET
 TYPE 1
 BARRIER WALL - CONCRETE MASONRY BACK-UP WITH MEMBRANE
 SCALE: 1-1/2"=1'0" (~1:10)



5A DETAIL @ WINDOW HEAD
 TYPE 1
 BARRIER WALL - CONCRETE MASONRY BACK-UP WITH MEMBRANE
 SCALE: 1-1/2"=1'0" (~1:10)

SECTION 3 Types of Direct Adhered Wall Construction

LATEX PORTLAND CEMENT ADHESIVE
MORTAR 1/8" (3mm) MIN.

CONCRETE SLAB

CERAMIC/STONE TILE
TYPICAL 3/8" (10mm) THICK SHOWN

LATEX PORTLAND CEMENT
WALL RENDER/PLASTER
TYPICAL 1" (25mm) THICK

LATEX PORTLAND CEMENT SLURRY BOND
COAT AS REQUIRED 1/16" (1.5mm) THICK

ROUNDED CLOSED CELL POLYETHYLENE
FOAM BACKER ROD

SEALANT JOINT (DEPTH 1/2 WIDTH)

3/8" (10mm) MINIMUM

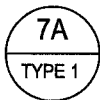
PLASTIC WEEP/PRESSURE
EQUALIZATION TUBE
24" (600mm) ON CENTER

DIRECT BOND LATEX WATERPROOF
MEMBRANE FLASHING
LOOP CONTINUOUS ACROSS JOINT
PREFABRICATED STRIP IMBED
IN LIQUID LATEX WATERPROOFING

COMPRESSIBLE FILLER BETWEEN
BACK-UP WALL AND STEEL
CLIP ANGLE

STEEL SLIP ANGLE

SAW-CUT MOVEMENT
JOINT AT RENDER
AFTER INSTALLATION



7A DETAIL @ MOVEMENT JOINT

TYPE 1

BARRIER WALL - CONCRETE MASONRY BACK-UP WITH MEMBRANE
SCALE: 1"=1' (1:1)

Figure 3.7-5 Architectural Details of Barrier Wall - Concrete masonry unit backup with continuous waterproof membrane

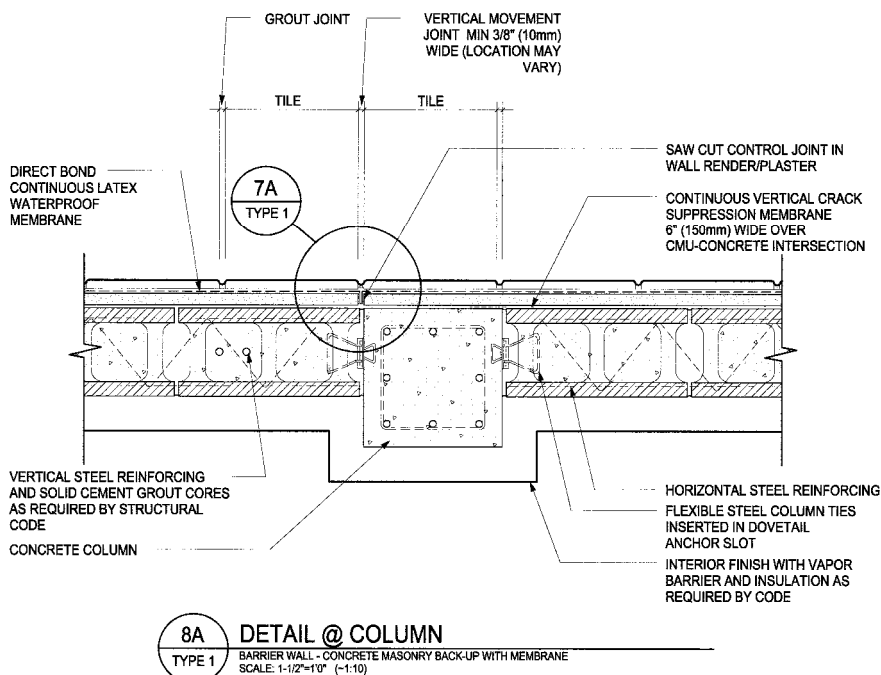
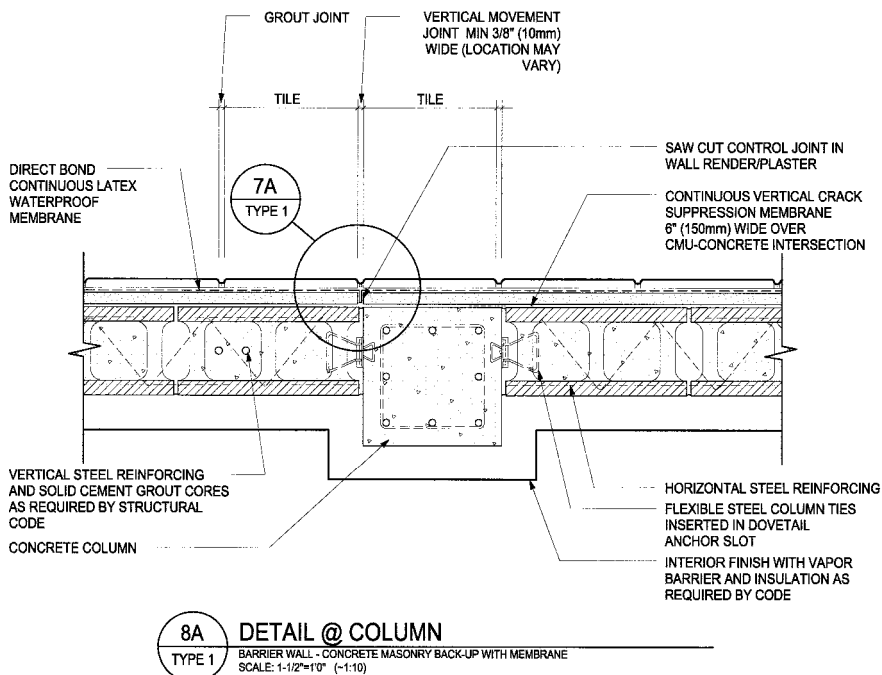
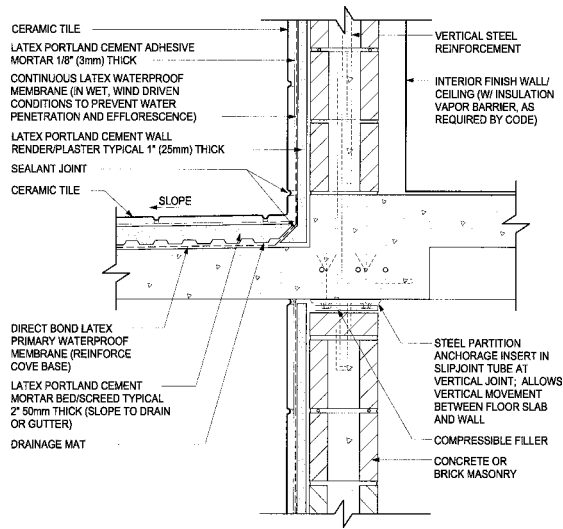
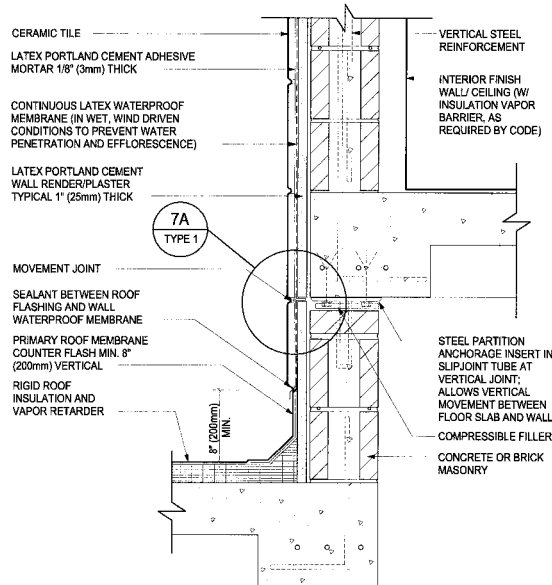


Figure 3.7-6 Architectural Details of Barrier Wall - Concrete masonry unit backup with continuous waterproof membrane



11A
TYPE 1 **DETAIL @ BALCONY**
BARRIER WALL - CONCRETE MASONRY BACK-UP WITH MEMBRANE
SCALE: 1-1/2"=1'-0" (~1:10)



7A
TYPE 1 **DETAIL @ ROOF - WALL**
BARRIER WALL - CONCRETE MASONRY BACK-UP WITH MEMBRANE
SCALE: 1-1/2"=1'-0" (~1:10)

Figure 3.7-7 Architectural Details of Barrier Wall - Concrete masonry unit backup with continuous waterproof membrane

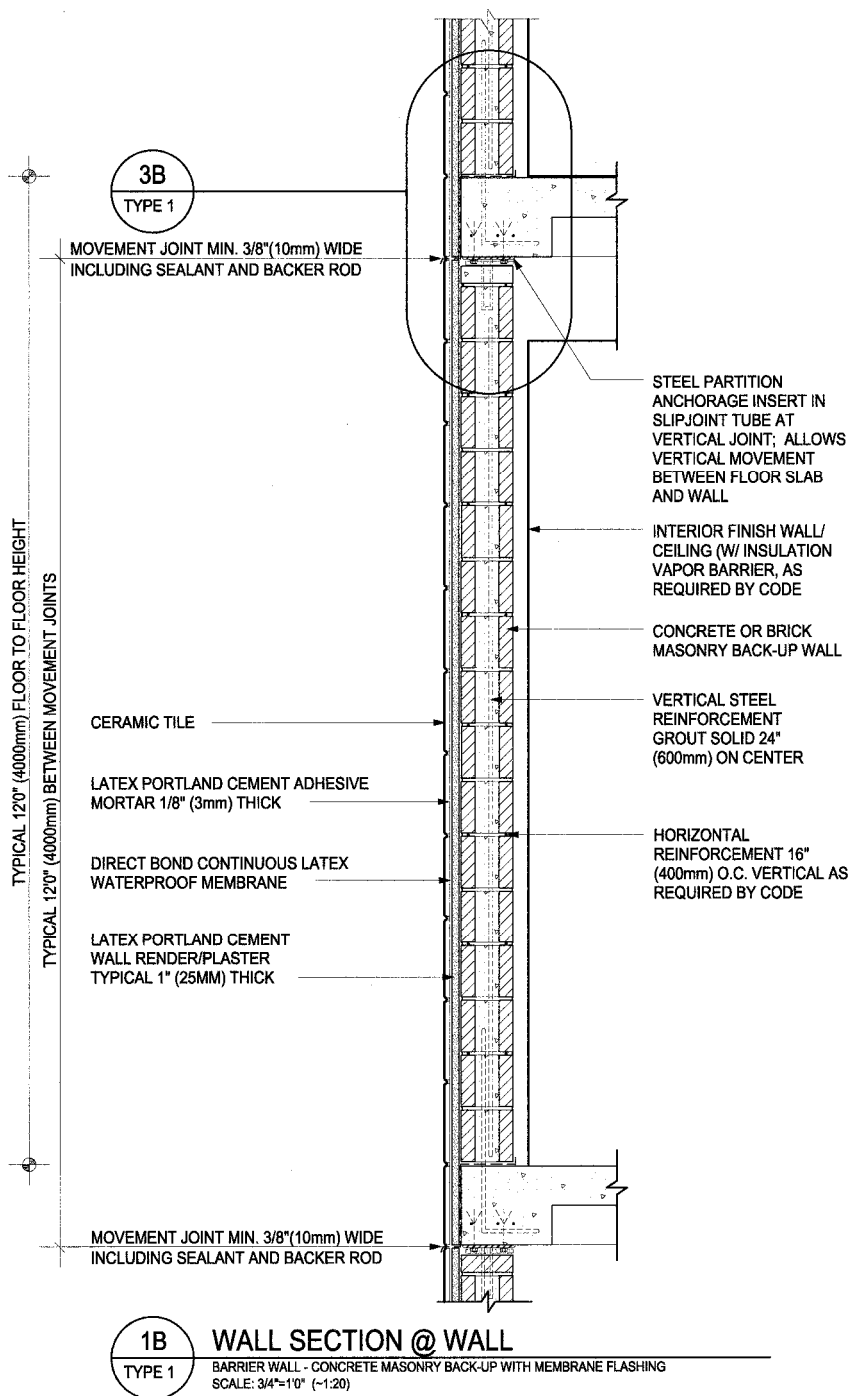


Figure 3.7-8 Architectural Details of Barrier Wall - Concrete masonry unit backup with membrane flashing

SECTION 3 Types of Direct Adhered Wall Construction

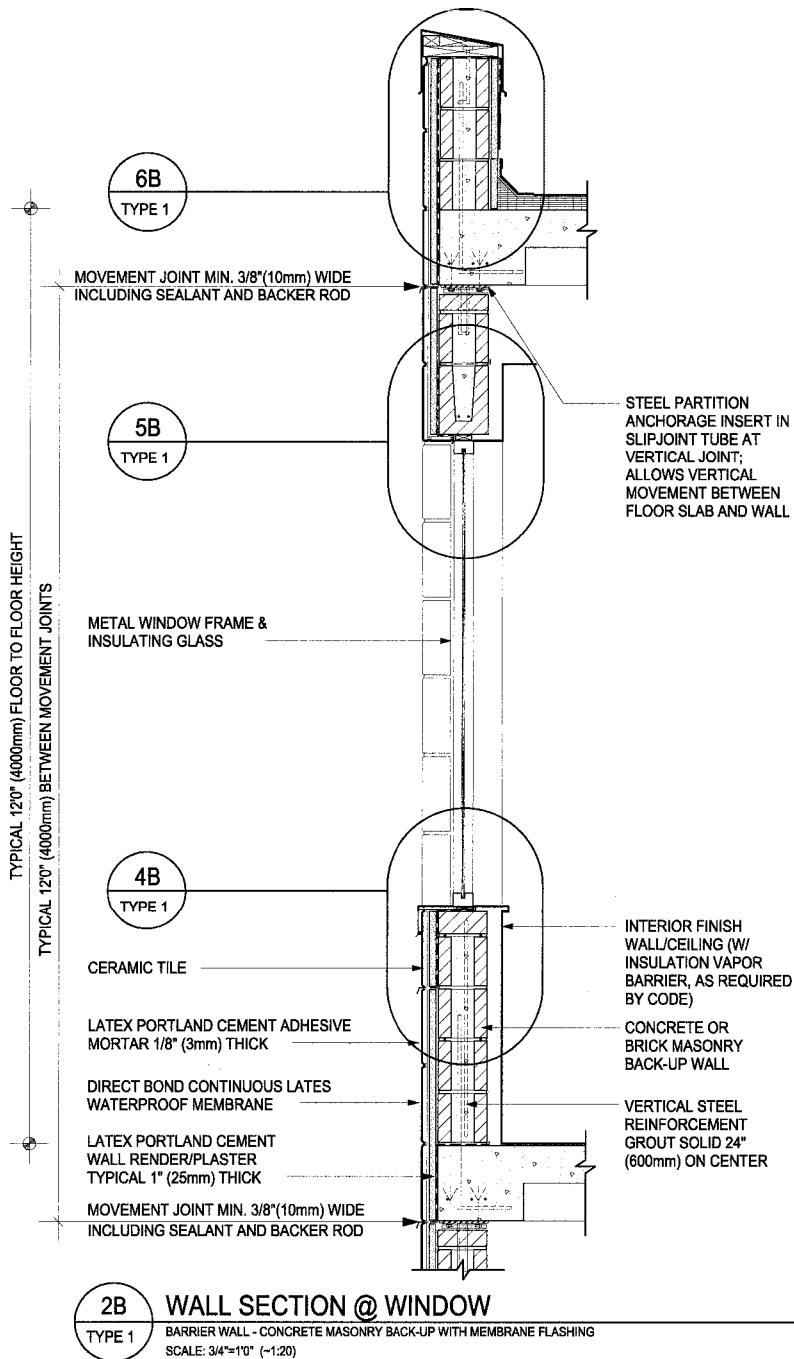
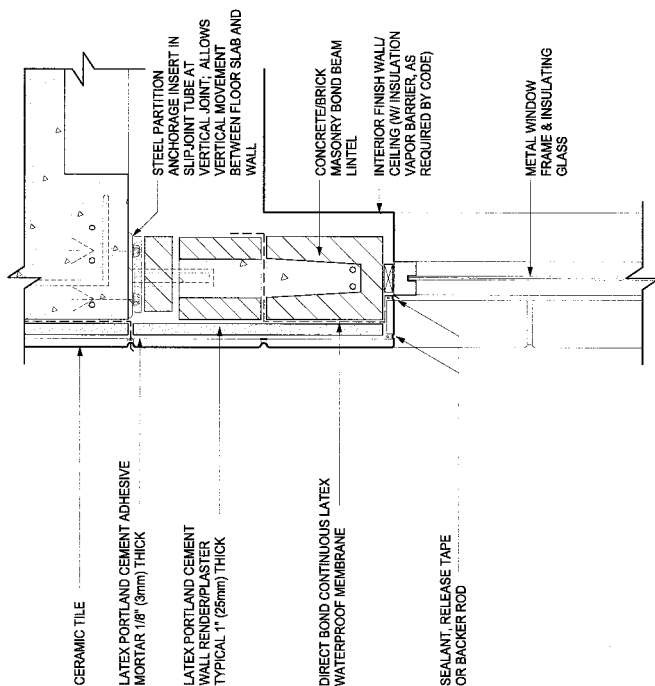
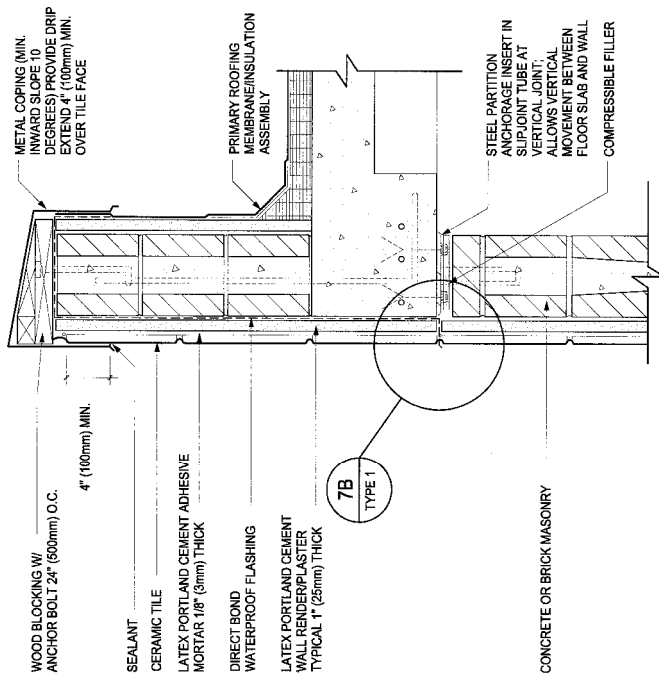


Figure 3.7-9 Architectural Details of Barrier Wall - Concrete masonry unit backup with membrane flashing

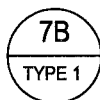
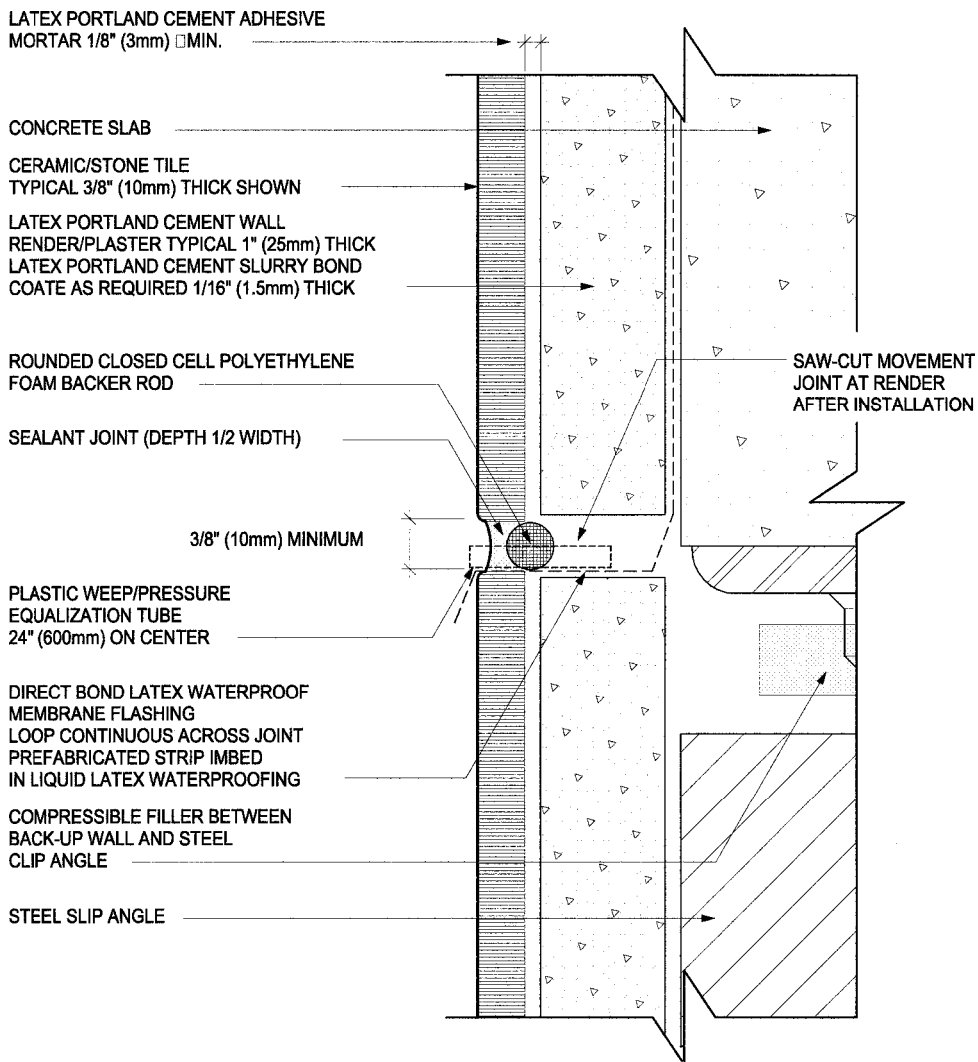


5B DETAIL @ WINDOW HEAD
 TYPE 1
 BARRIER WALL - CONCRETE MASONRY BACKUP WITH MEMBRANE FLASHING
 SCALE: 1/16"=1'-0" (1:10)



6B DETAIL @ ROOF PARAPET
 TYPE 1
 BARRIER WALL - CONCRETE MASONRY BACKUP WITH MEMBRANE FLASHING
 SCALE: 1/16"=1'-0" (1:10)

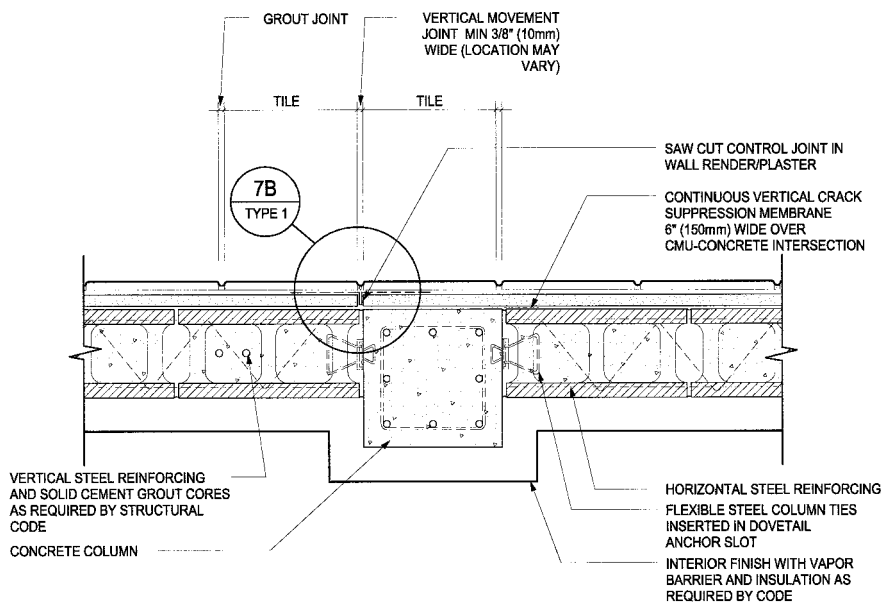
Figure 3.7-11 Architectural Details of Barrier Wall - Concrete masonry unit backup with membrane flashing



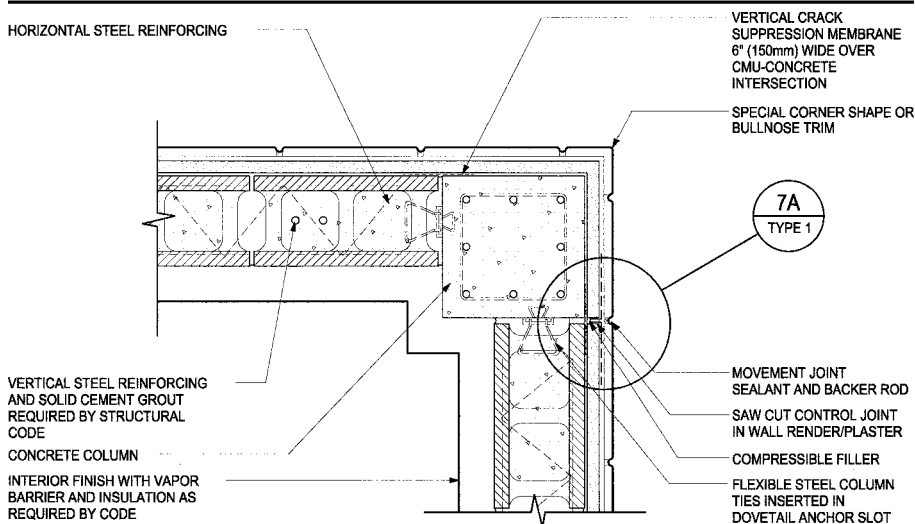
DETAIL @ MOVEMENT JOINT

BARRIER WALL - CONCRETE MASONRY BACK-UP WITH MEMBRANE
SCALE: 1"=1" (1:1)

Figure 3.7-12 Architectural Details of Barrier Wall - Concrete masonry unit backup with membrane flashing



8B **DETAIL @ COLUMN**
TYPE 1
BARRIER WALL - CONCRETE MASONRY BACK-UP WITH MEMBRANE FLASHING
SCALE: 1-1/2"=1'0" (-1:10)



9B **DETAIL @ CORNER COLUMN**
TYPE 1
BARRIER WALL - CONCRETE MASONRY BACK-UP WITH MEMBRANE FLASHING
SCALE: 1-1/2"=1'0" (-1:10)

Figure 3.7-13 Architectural Details of Barrier Wall - Concrete masonry unit backup with membrane flashing

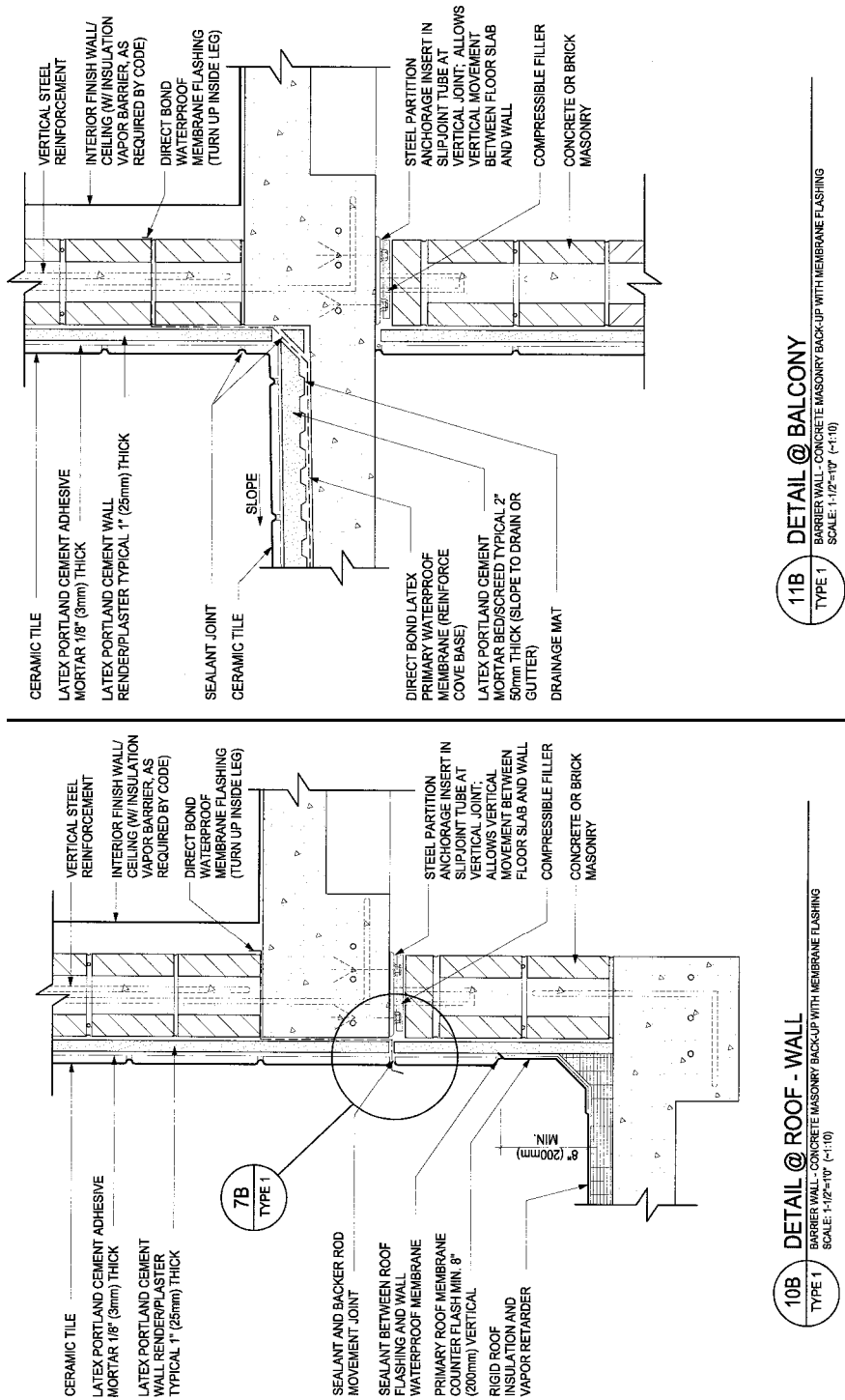


Figure 3.7-14 Architectural Details of Barrier Wall - Concrete masonry unit backup with membrane flashing

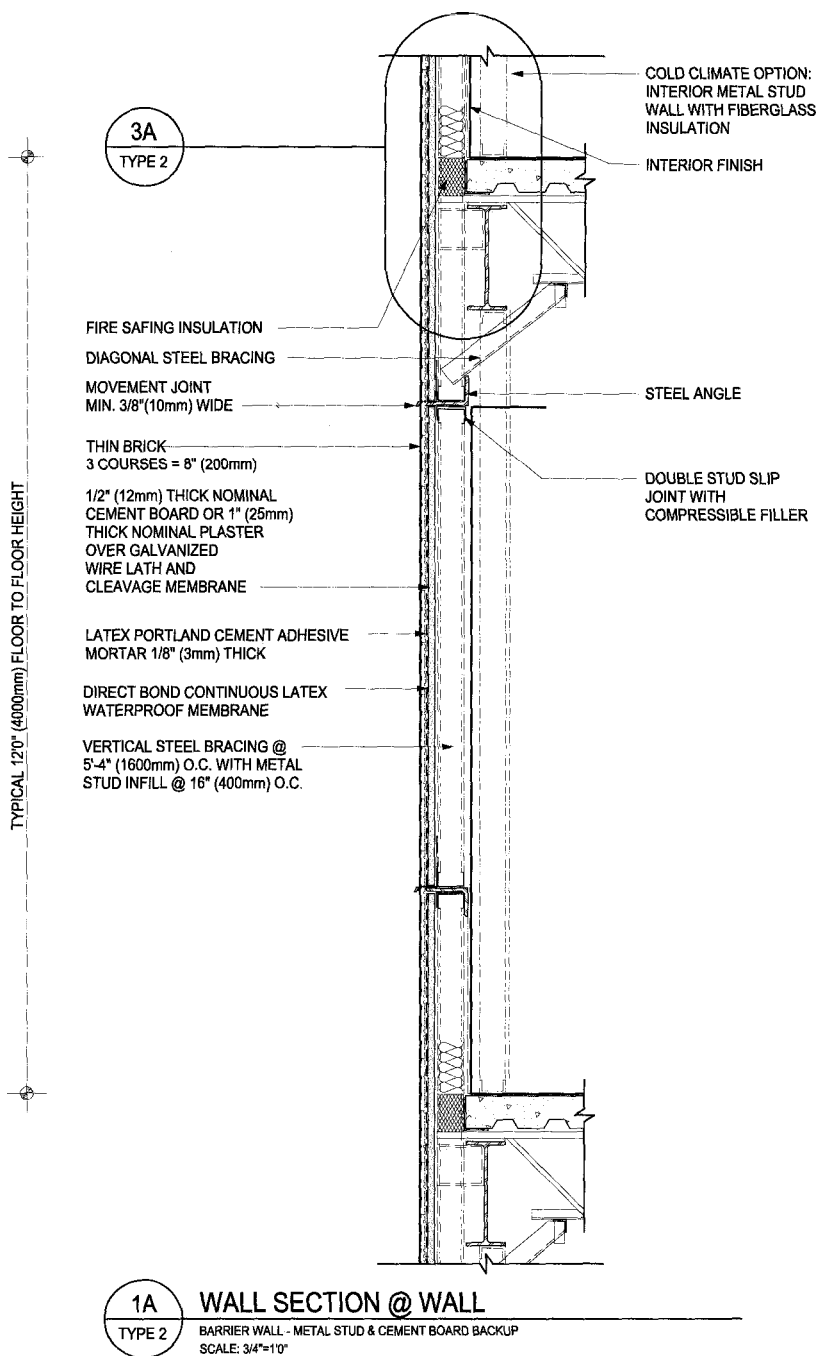


Figure 3.7-15 Architectural Details of Barrier Wall - Barrier Wall - Light gauge steel (metal stud) with cement backer board (CBU) or cement plaster backup

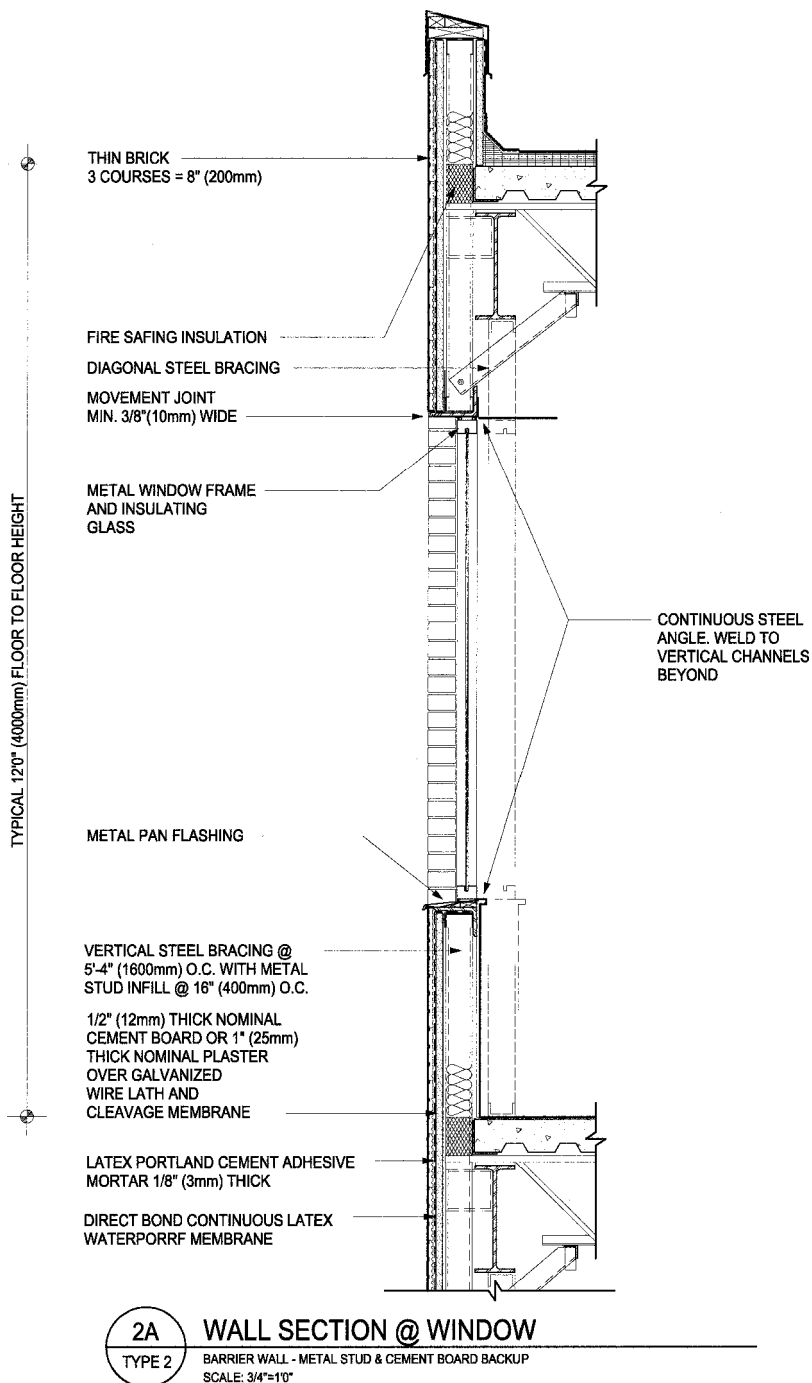
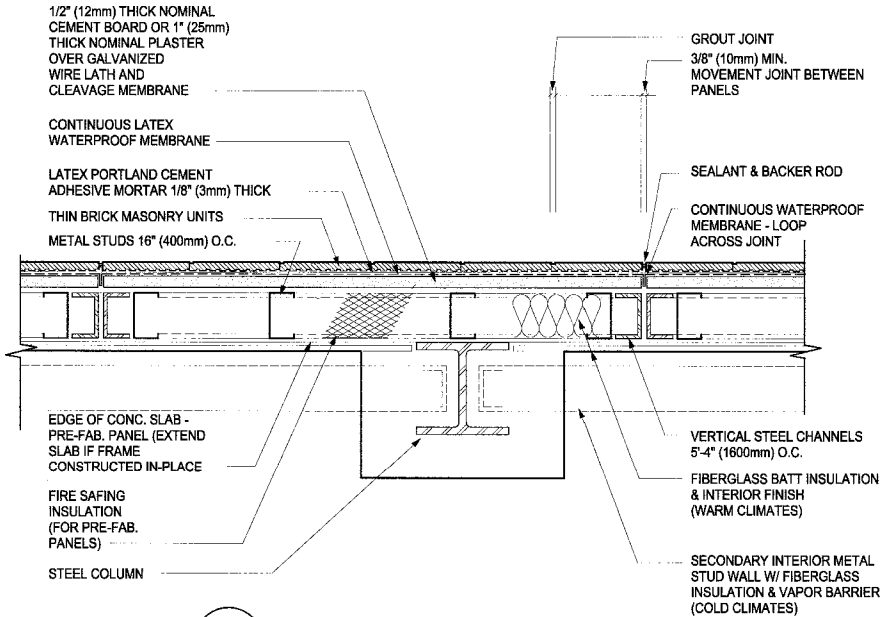
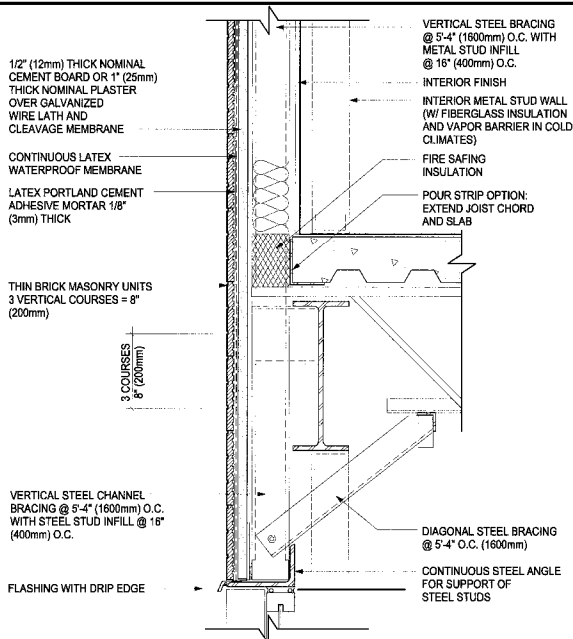


Figure 3.7-16 Architectural Details of Barrier Wall - Light gauge steel (metal stud) with cement backer board (CBU) or cement paster backup

SECTION 3 Types of Direct Adhered Wall Construction



8A DETAIL @ COLUMN
TYPE 2 BARRIER WALL - METAL STUD & CEMENT BOARD BACKUP
SCALE: 1-1/2"=1'0"



3A DETAIL @ SPANDREL
TYPE 2 BARRIER WALL - METAL STUD & CEMENT BOARD BACKUP
SCALE: 1-1/2"=1'0"

Figure 3.7-17 Architectural Details of Barrier Wall - Barrier Wall - Light gauge steel (metal stud) with cement backer board (CBU) or cement plaster backup

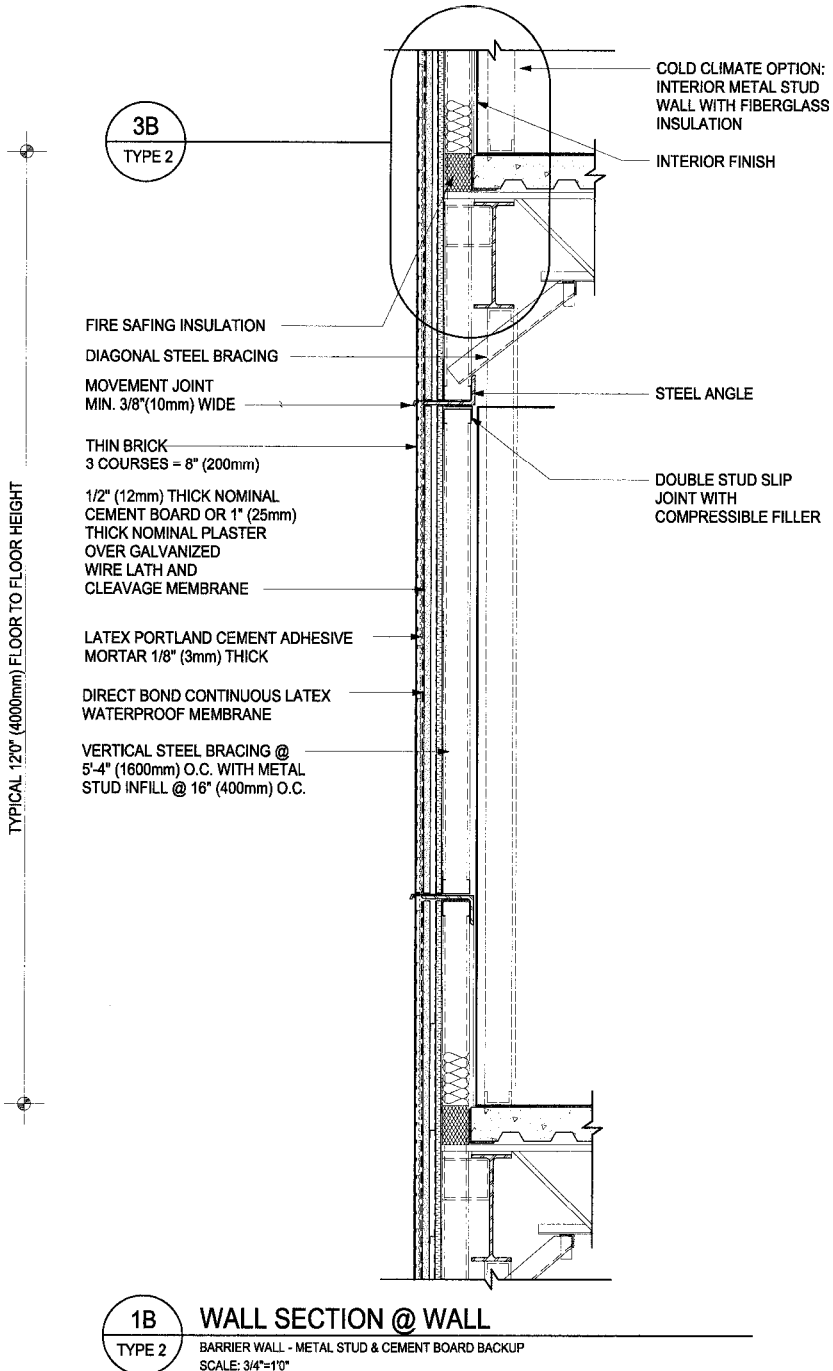
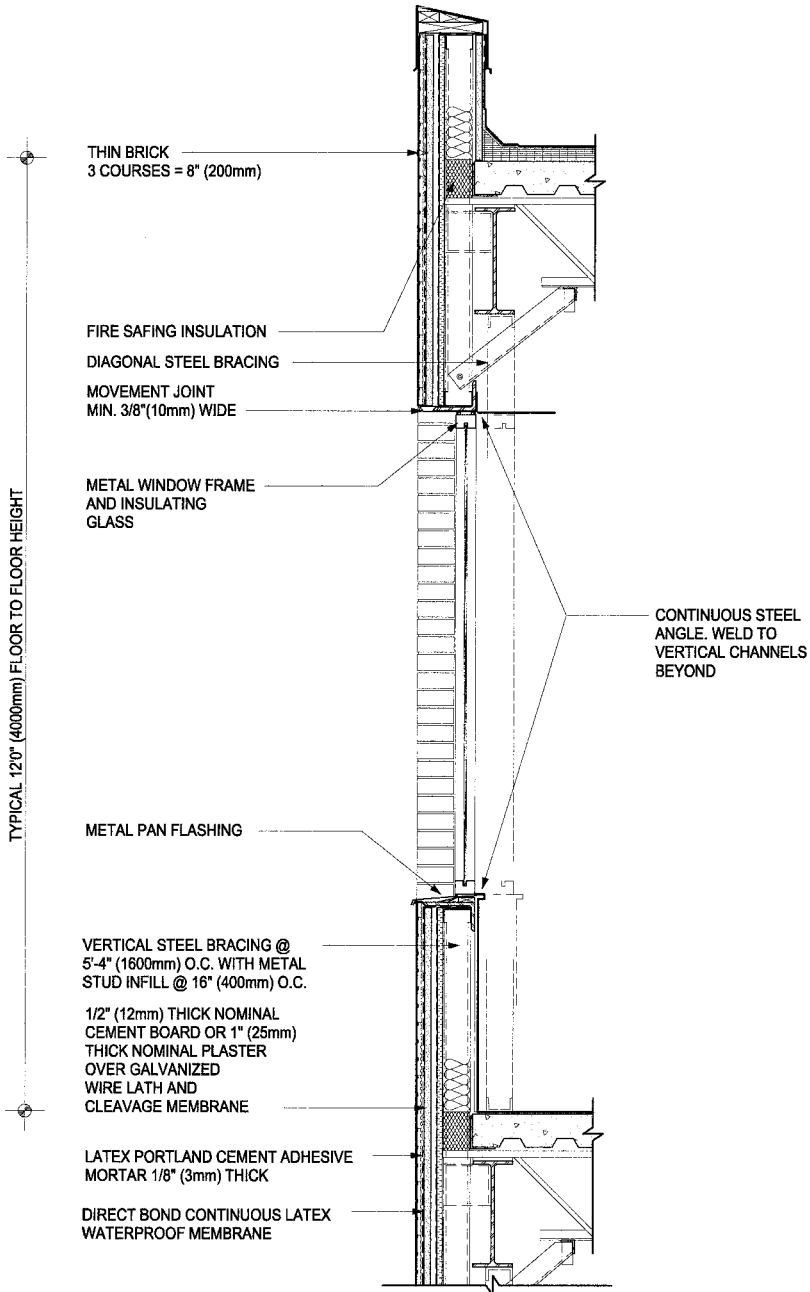


Figure 3.7-18 Architectural Details of Cavity Wall -- Light gauge steel (metal stud and cement board back-u p

SECTION 3 Types of Direct Adhered Wall Construction



WALL SECTION @ WINDOW

BARRIER WALL - METAL STUD & CEMENT BOARD BACKUP
SCALE: 3/4"=1'-0"

Figure 3.7-19 Architectural Details of Cavity Wall - Light gauge steel (metal stud and cement board back-u p

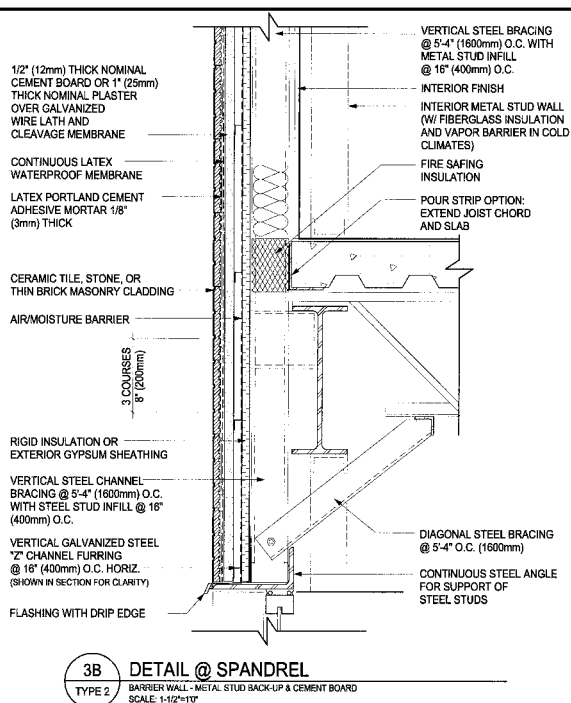
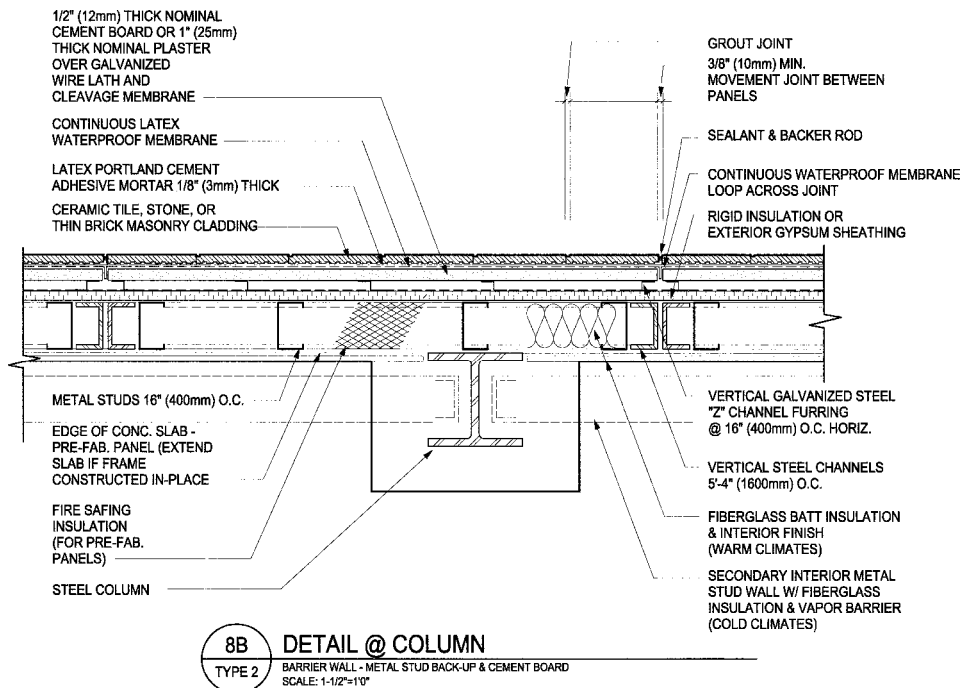


Figure 3.7-20 Architectural Details of Cavity Wall - Light gauge steel (metal stud and cement board back-u p

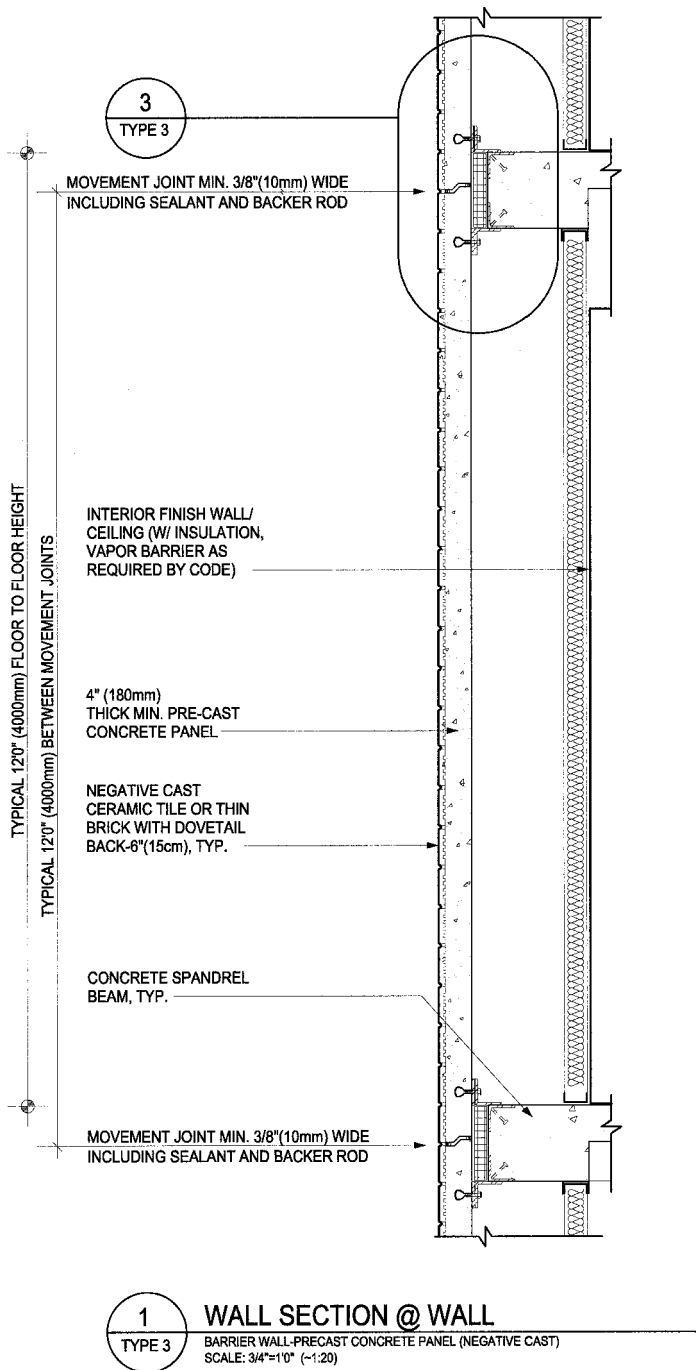
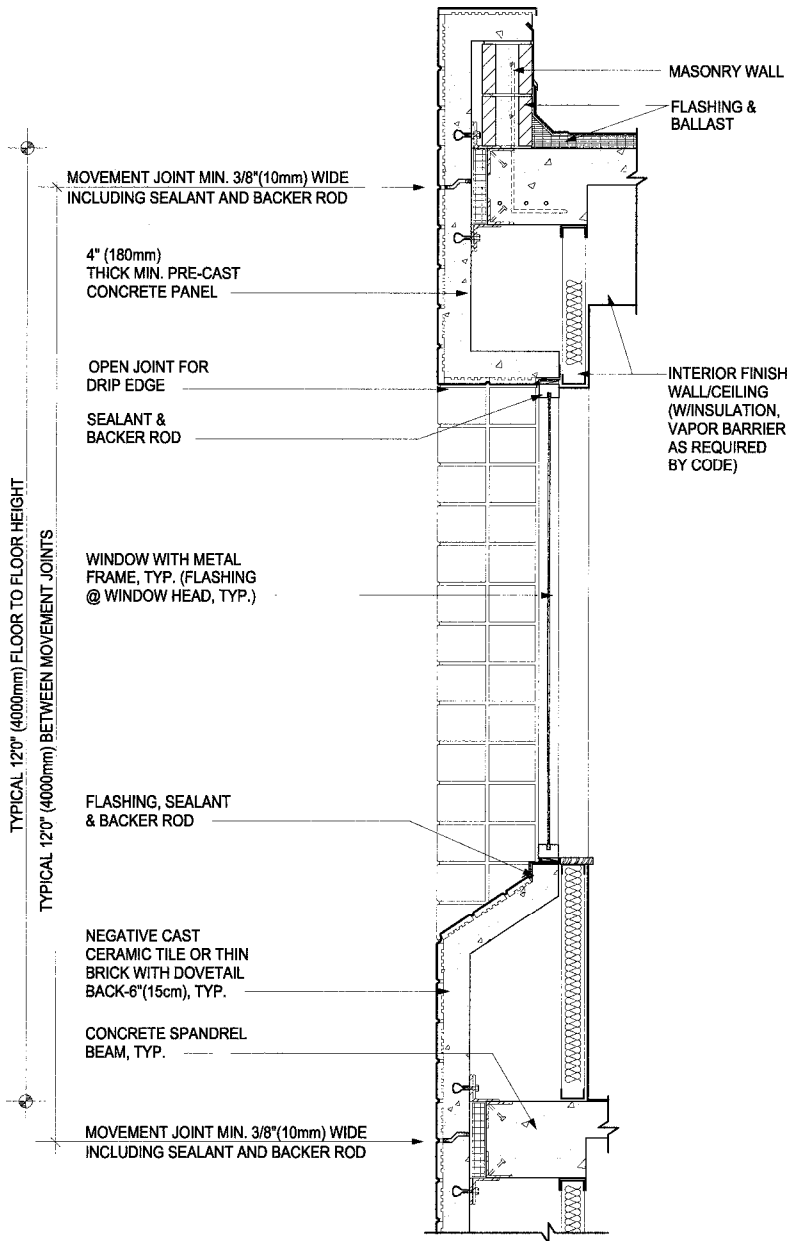


Figure 3.7-21 Architectural Details of Barrier Wall - Negative cast pre-cast concrete panels



2
TYPE 3

WALL SECTION @ WALL
BARRIER WALL-PRECAST CONCRETE PANEL (NEGATIVE CAST)
SCALE: 3/4"=1'0" (~1:20)

Figure 3.7-22 Architectural Details of Barrier Wall - Negative cast pre-cast concrete panels

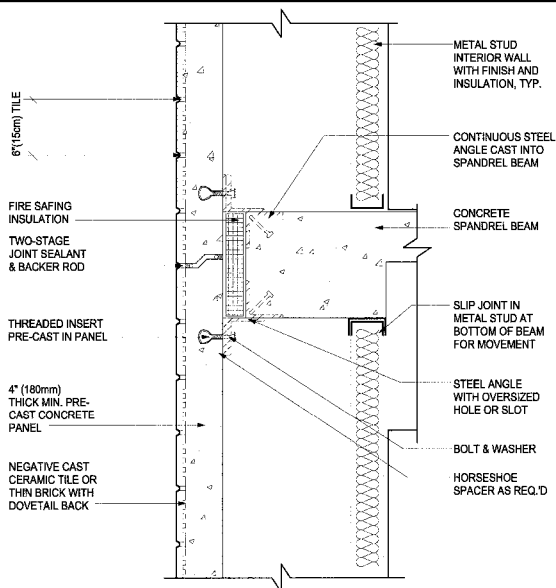
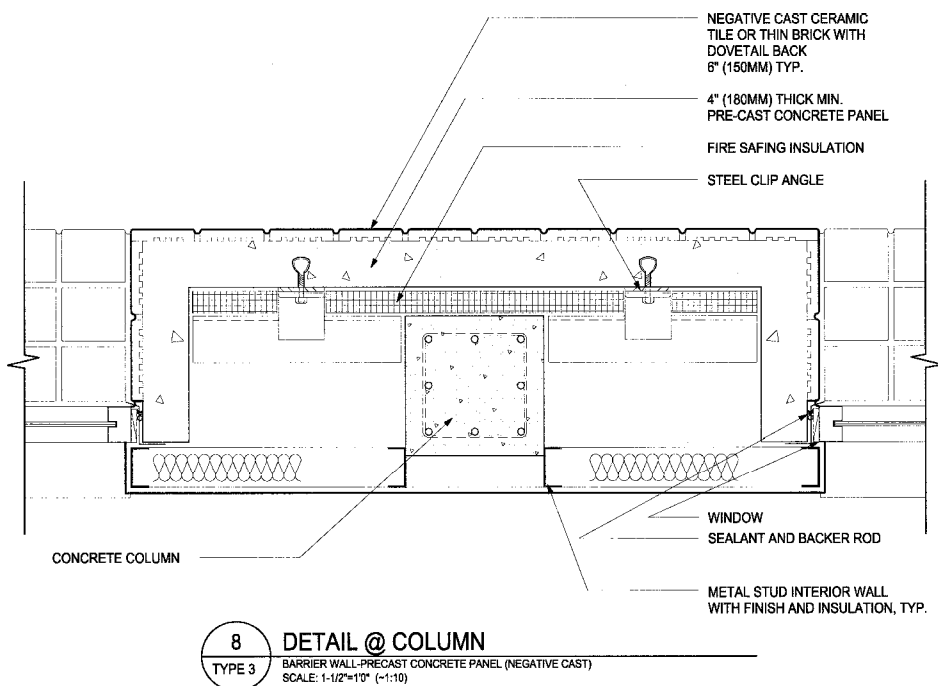
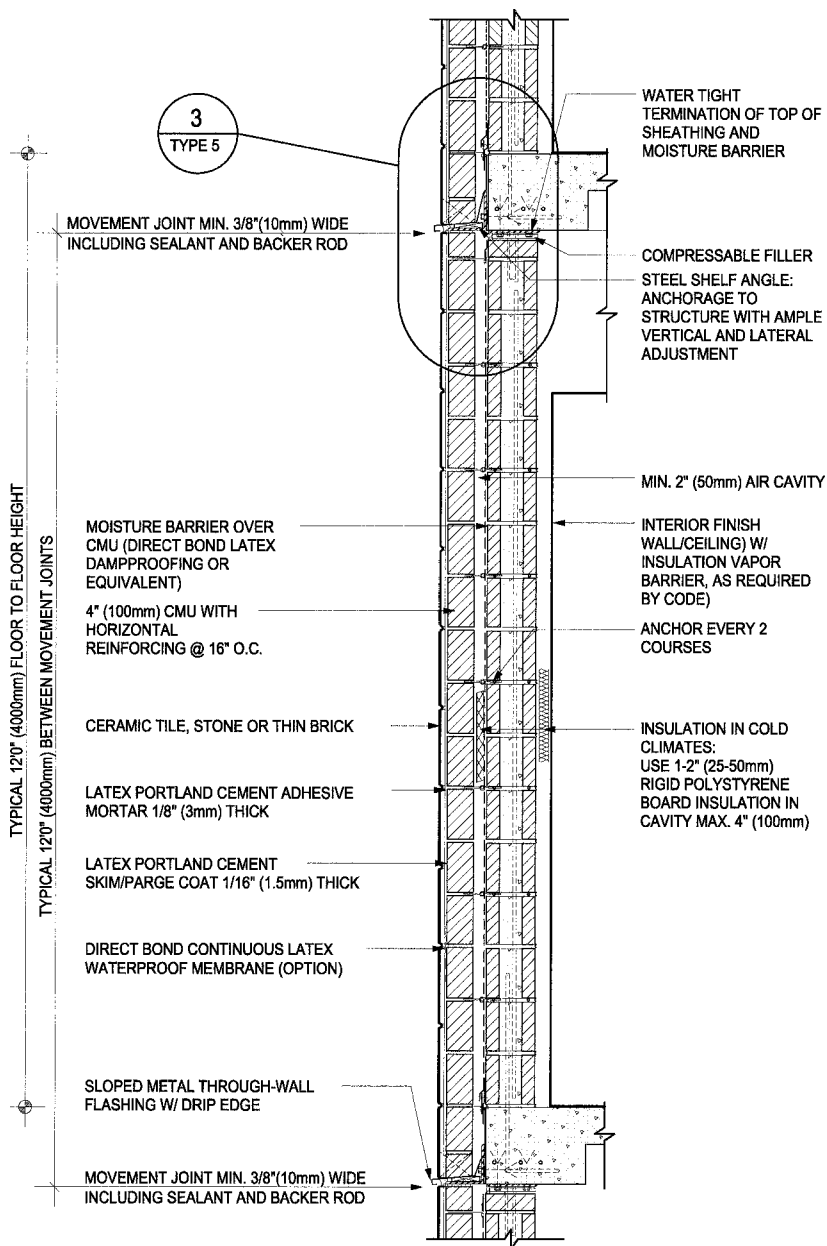


Figure 3.7-23 Architectural Details of Barrier Wall - Negative cast pre-cast concrete panels



1
TYPE 5 **WALL SECTION @ WALL**
CAVITY WALL - CONCRETE MASONRY BACK-UP
SCALE: 3/4"=1'0" (~1:20)

Figure 3.7-24 Architectural Details of Cavity Wall - Concrete masonry back-up

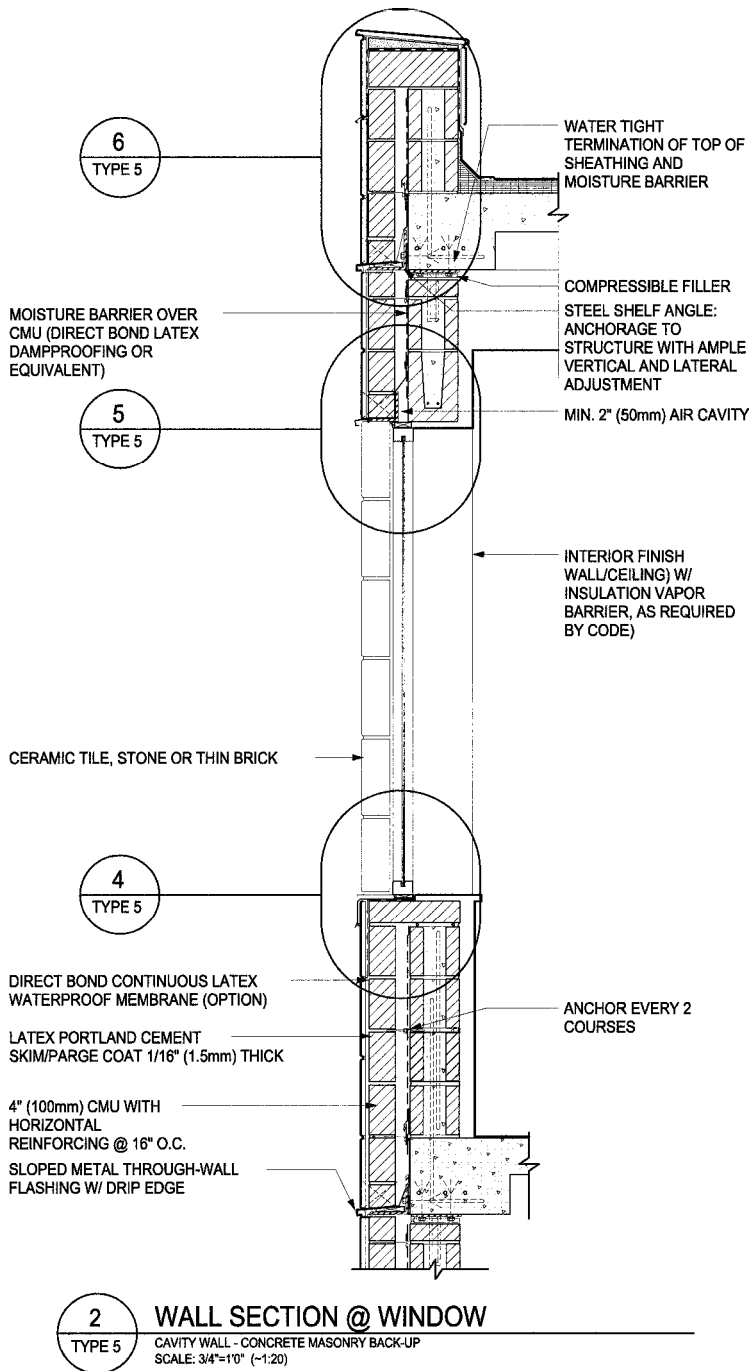
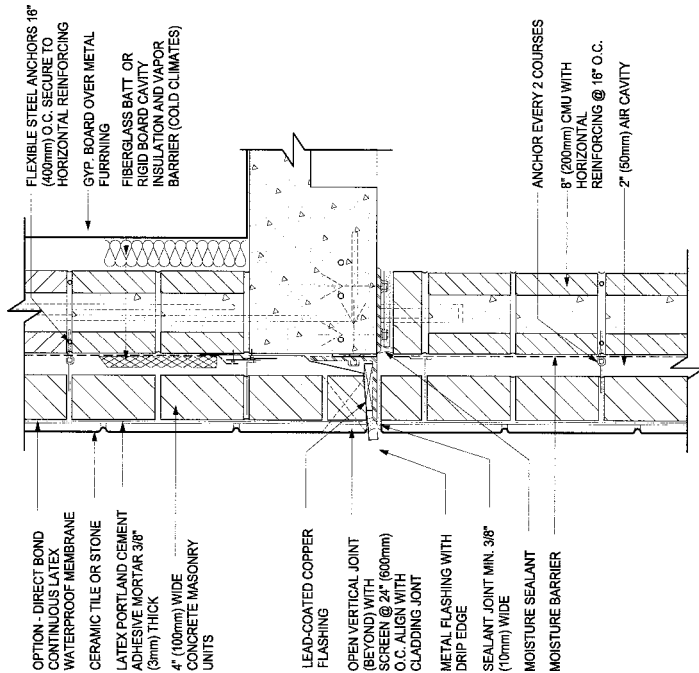
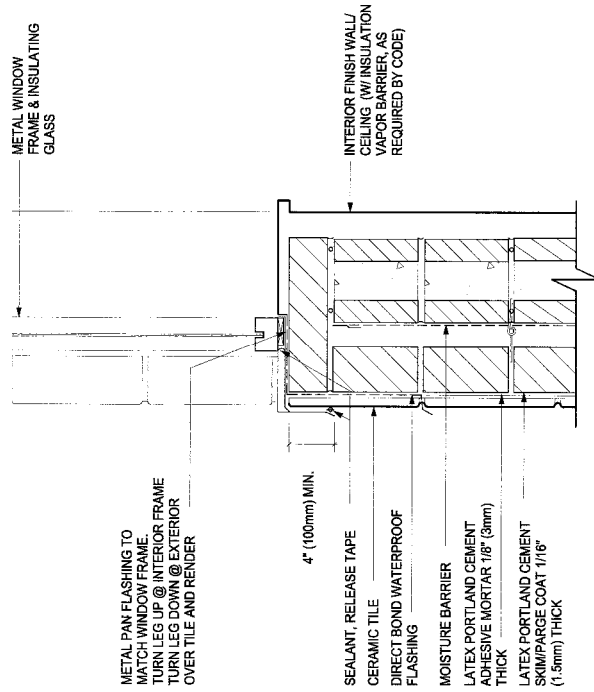


Figure 3.7-25 Architectural Details of Cavity Wall - Concrete masonry back-up

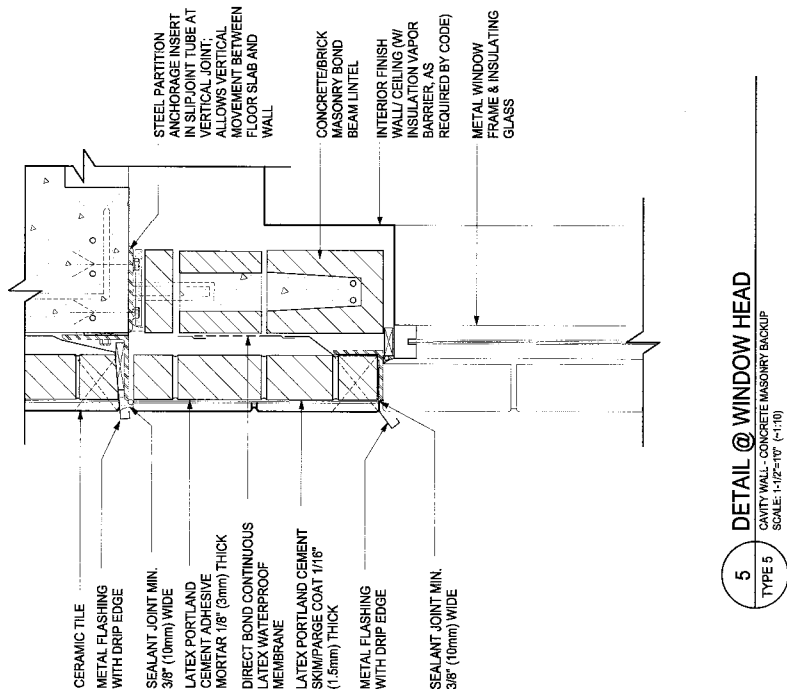


3 DETAIL @ SPANDREL
CAVITY WALL - CONCRETE MASONRY BACK-UP
SCALE: 1/2"=1'0" (~1:10)

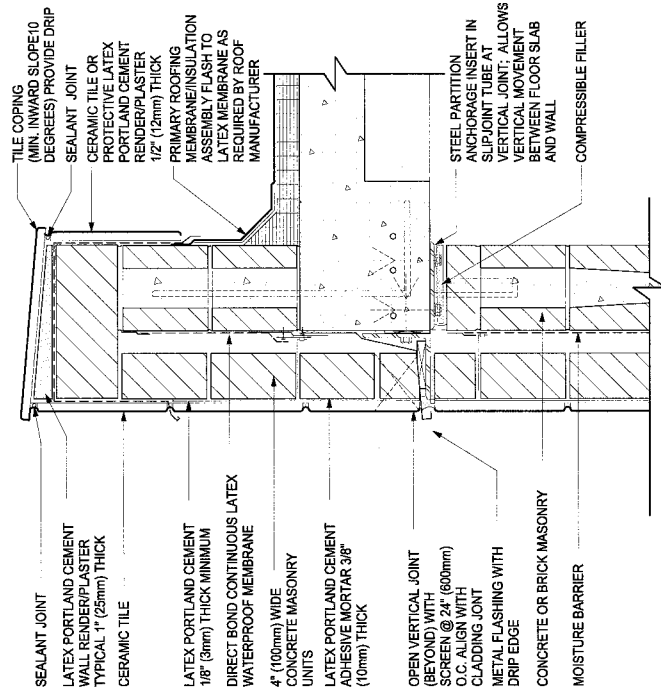


4 DETAIL @ WINDOW SILL
CAVITY WALL - CONCRETE MASONRY BACK-UP
SCALE: 1/2"=1'0" (~1:10)

Figure 3.7-26 Architectural Details of Cavity Wall - Concrete masonry back-up

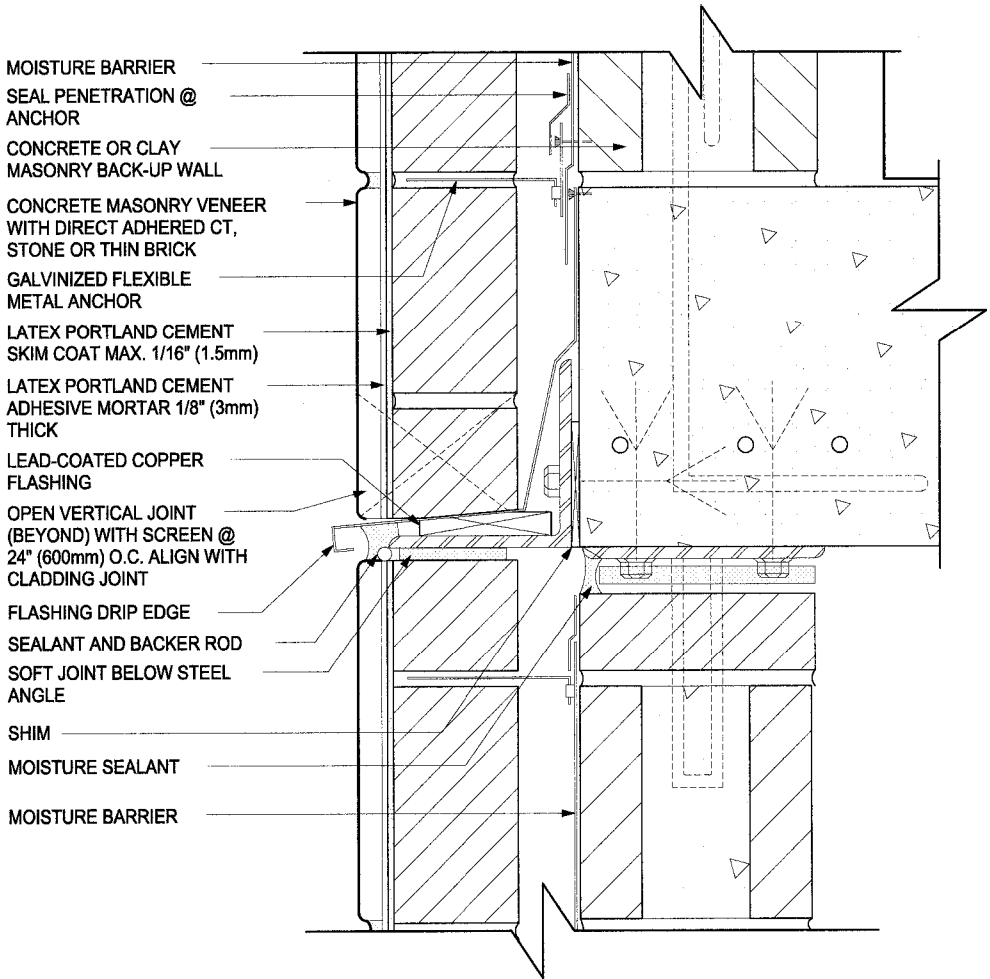


5 DETAIL @ WINDOW HEAD
Cavity Wall - Concrete Masonry Back-up
SCALE: 1-1/2"=1'-0" (1:10)



6 DETAIL @ ROOF PARAPET
Cavity Wall - Concrete Masonry Back-up
SCALE: 1-1/2"=1'-0" (1:10)

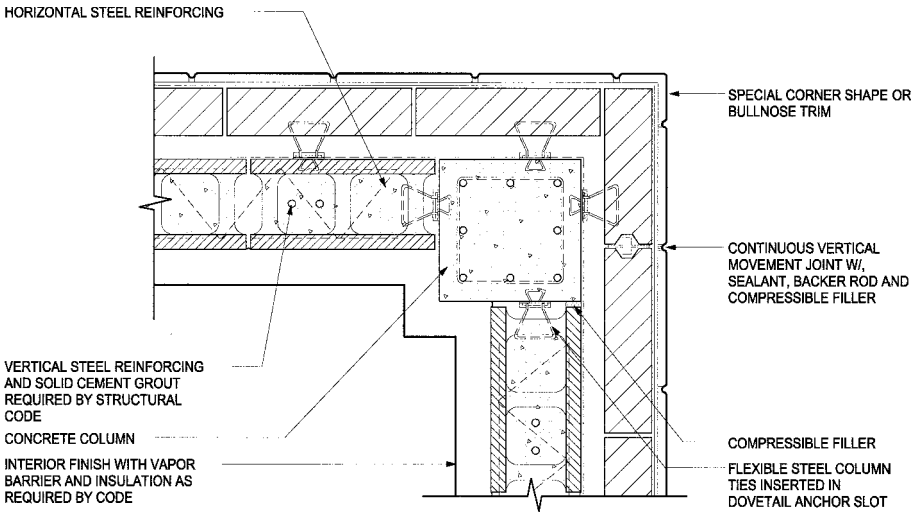
Figure 3.7-27 Architectural Details of Cavity Wall - Concrete masonry back-up



DETAIL @ MOVEMENT JOINT & RELIEVING ANGLE

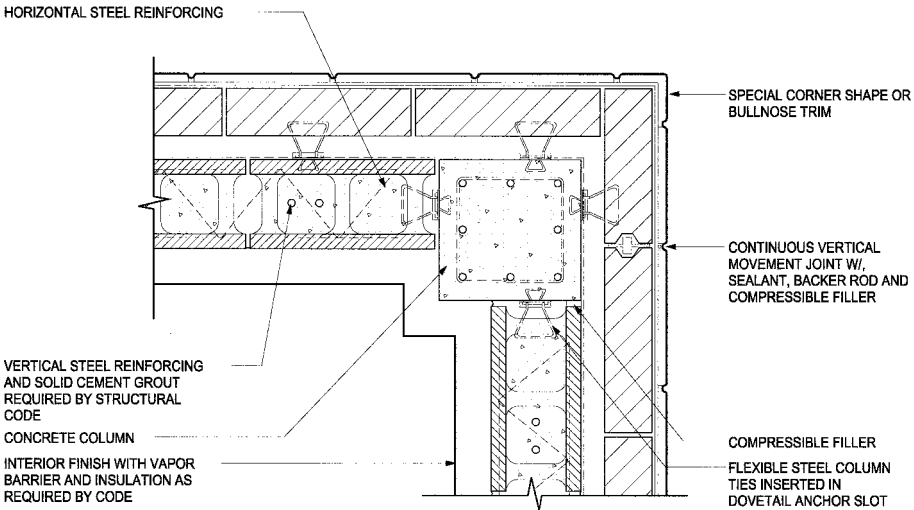
CAVITY WALL - CONCRETE MASONRY BACK-UP
SCALE: 3"=1'0" (~1:5)

Figure 3.7-28 Architectural Details of Cavity Wall - Concrete masonry back-up



9
TYPE 5
DETAIL @ CORNER COLUMN

CAVITY WALL - CONCRETE MASONRY BACK-UP
SCALE: 1-1/2"=1'0" (~1:10)



9
TYPE 5
DETAIL @ CORNER COLUMN

CAVITY WALL - CONCRETE MASONRY BACK-UP
SCALE: 1-1/2"=1'0" (~1:10)

Figure 3.7-29 Architectural Details of Cavity Wall - Concrete masonry back-up

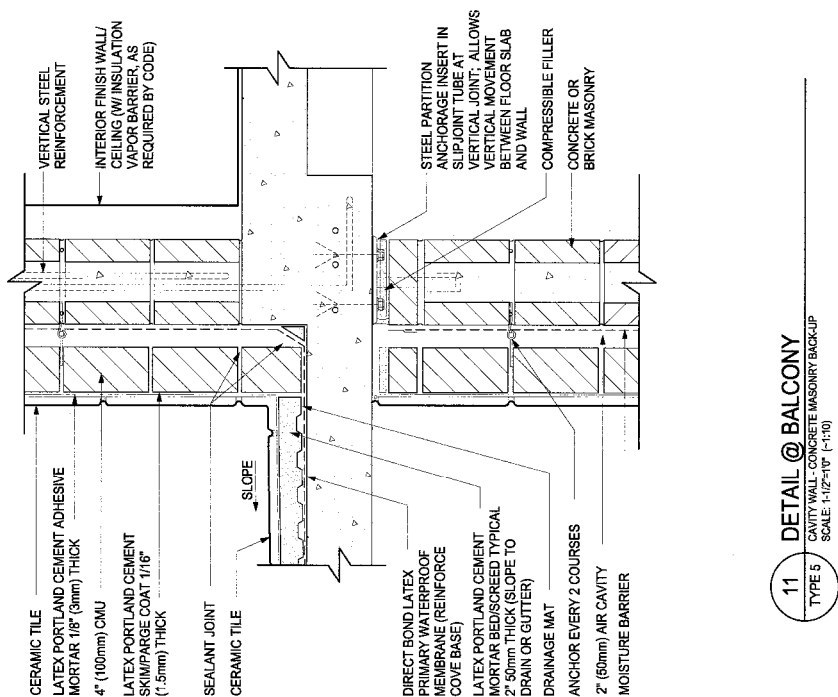
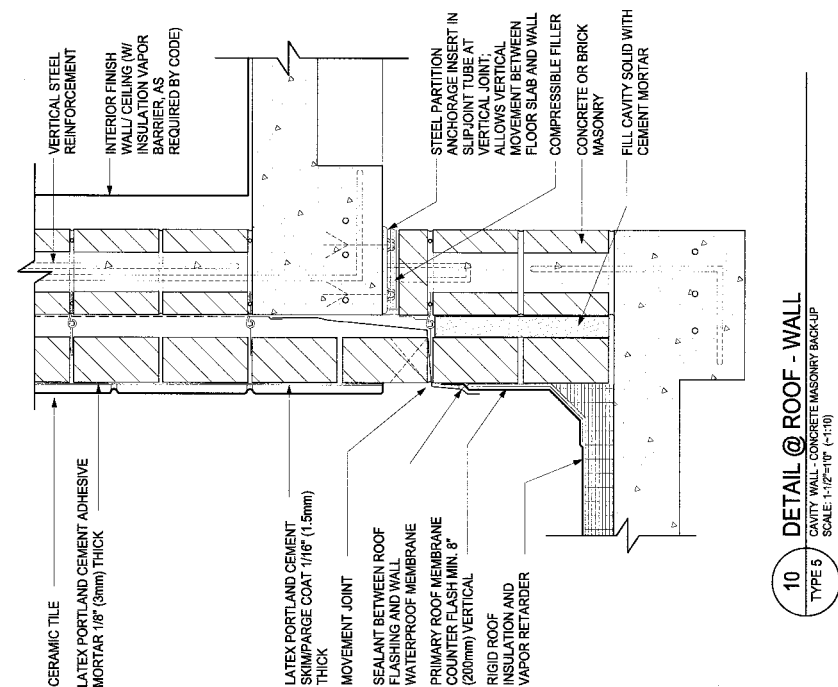


Figure 3.7-30 Architectural Details of Cavity Wall - Concrete masonry back-up

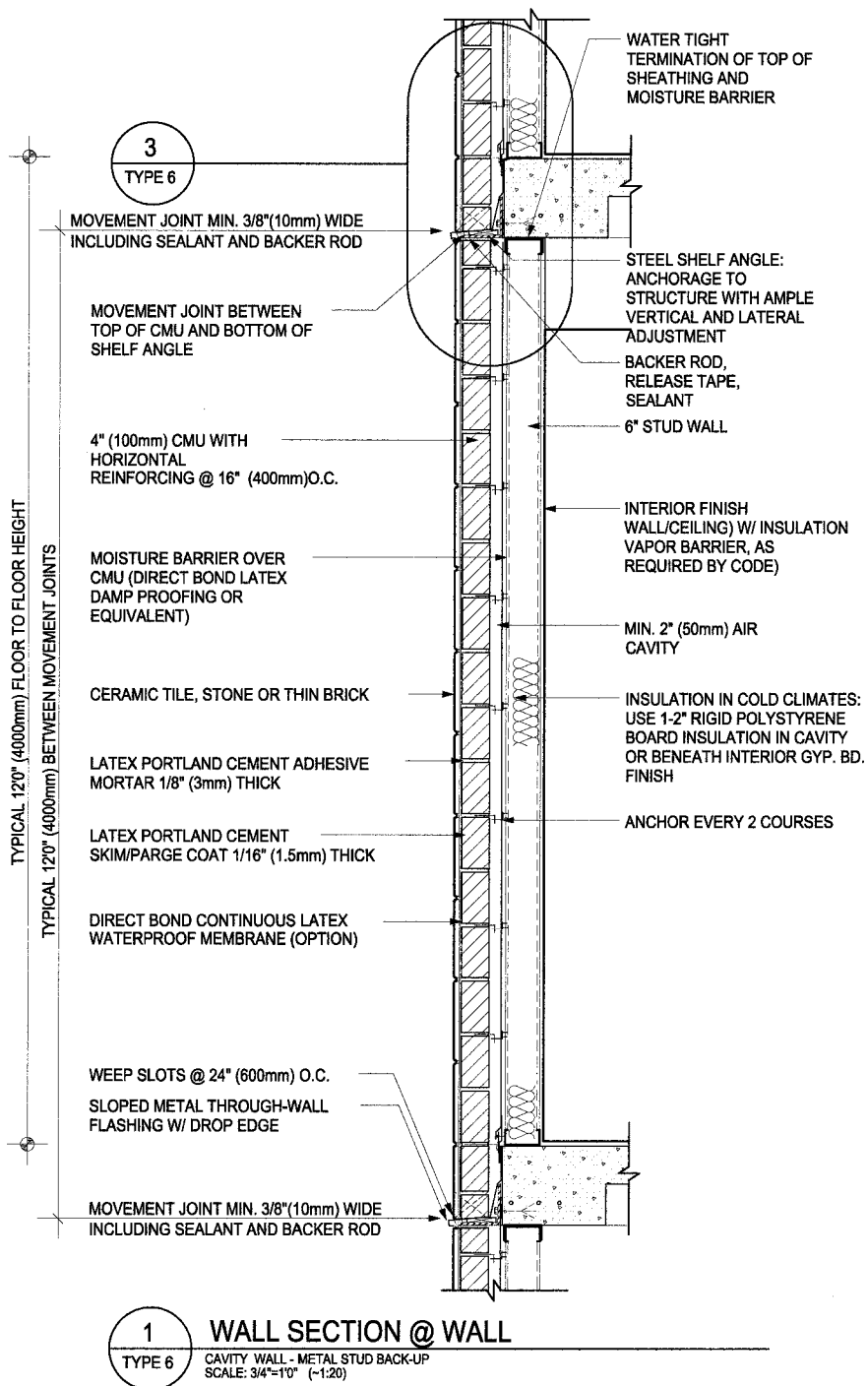
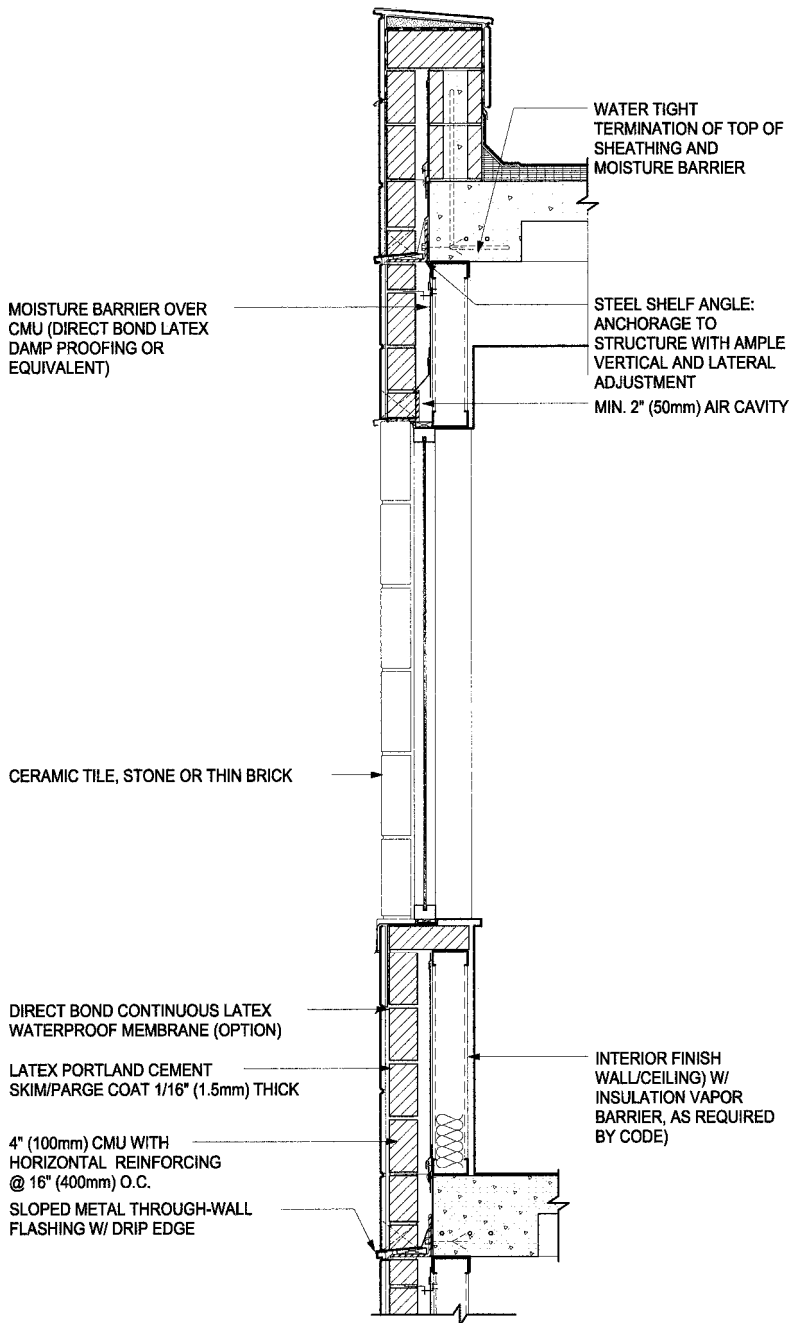
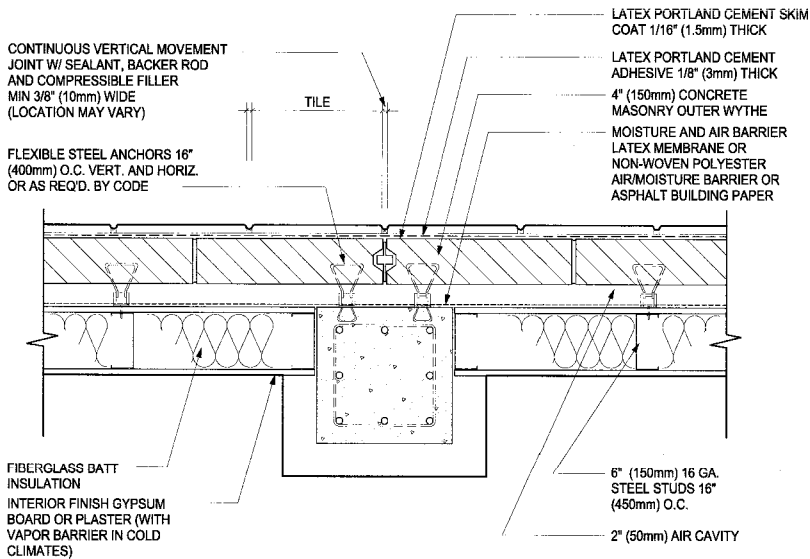


Figure 3.7-31 Architectural Details of Cavity Wall - Concrete masonry unit with steel stud backup

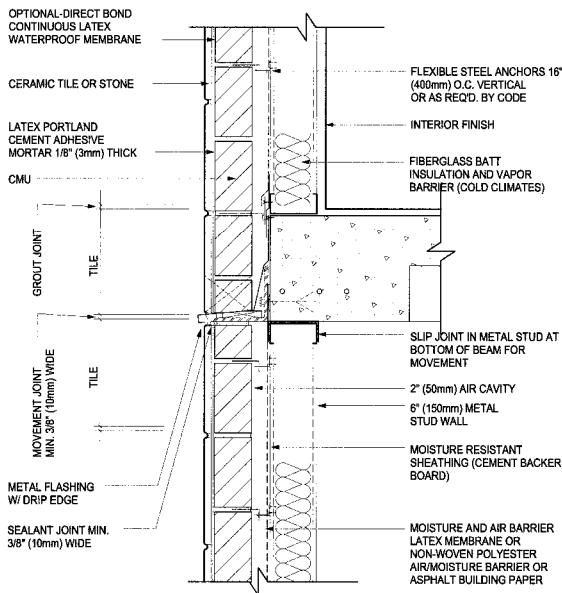


2 **WALL SECTION @ WINDOW**
 TYPE 6 CAVITY WALL - METAL STUD BACK-UP
 SCALE: 3/4"=1'0" (~1:20)

Figure 3.7-32 Architectural Details of Cavity Wall - Concrete masonry unit with steel stud backup



8 DETAIL @ COLUMN
TYPE 6 CAVITY WALL - METAL STUD BACK-UP
SCALE: 1-1/2"=1'-0" (~1:10)



3 DETAIL @ SPANDREL
TYPE 6 CAVITY WALL - METAL STUD BACK-UP
SCALE: 1-1/2"=1'-0" (~1:10)

Figure 3.7-33 Architectural Details of Cavity Wall - Concrete masonry unit with steel stud backup

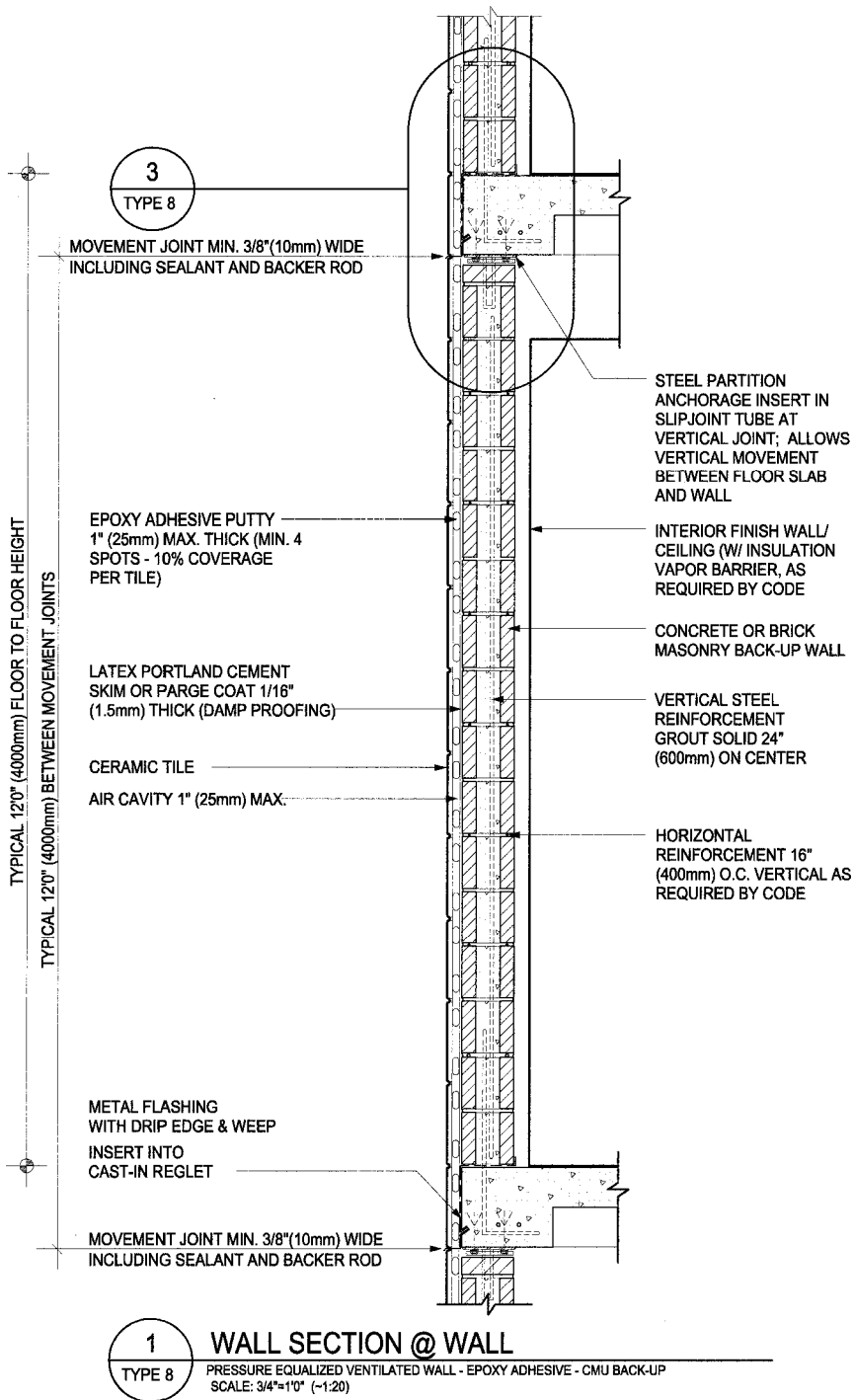


Figure 3.7-34 Architectural Details of Cavity Wall - Epoxy spot bonding over concrete masonry back-up

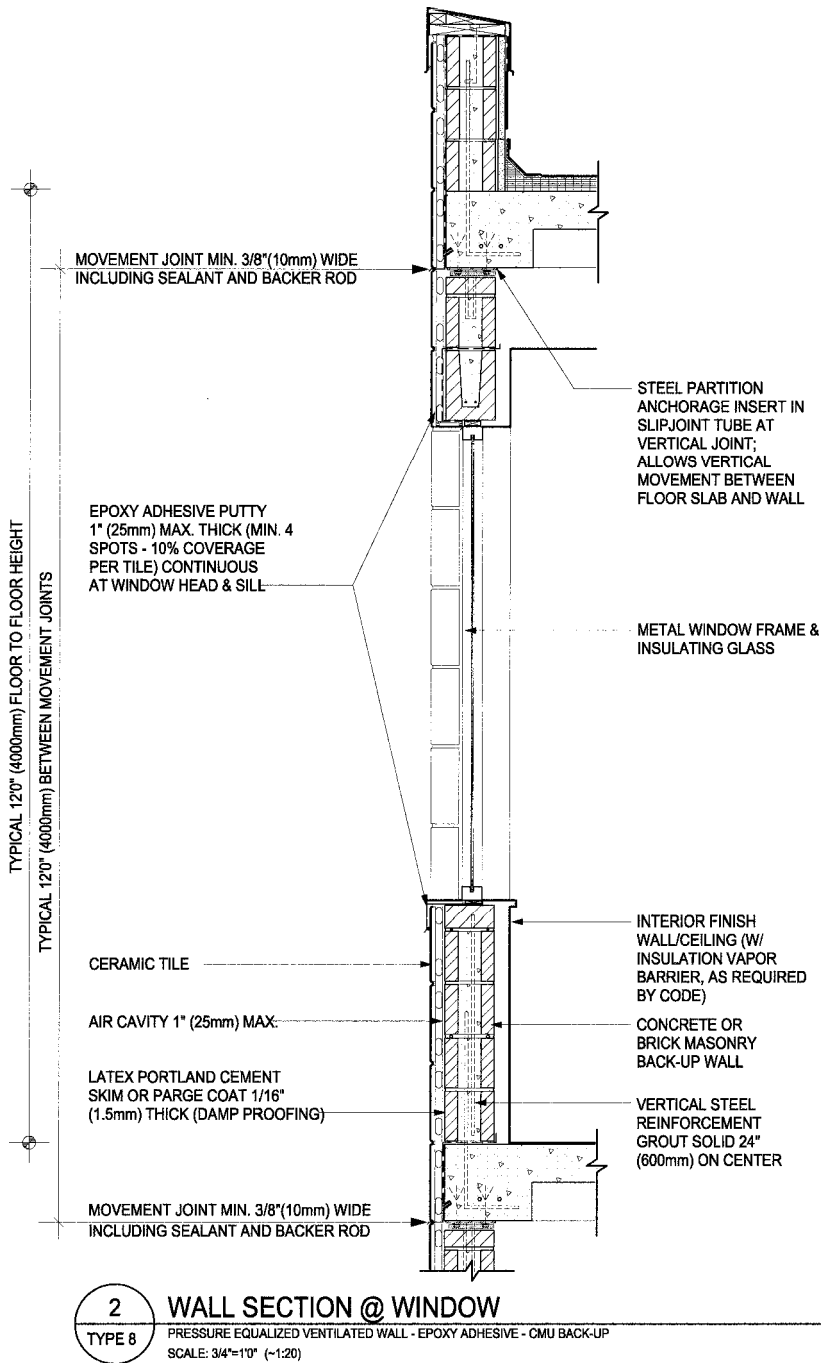


Figure 3.7-35 Architectural Details of Cavity Wall - Epoxy spot bonding over concrete masonry back-u p

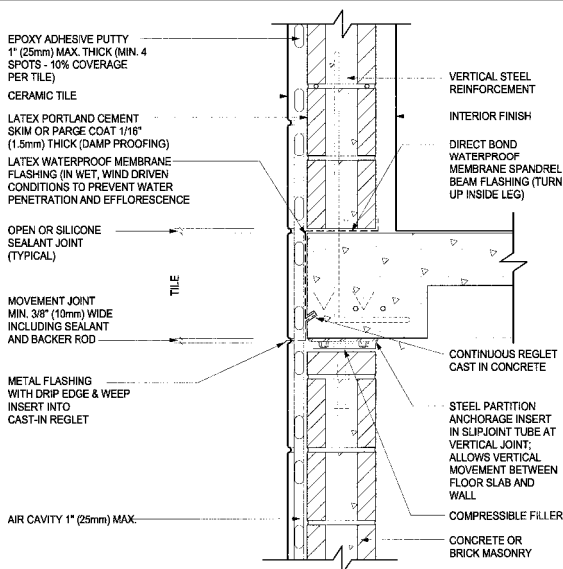
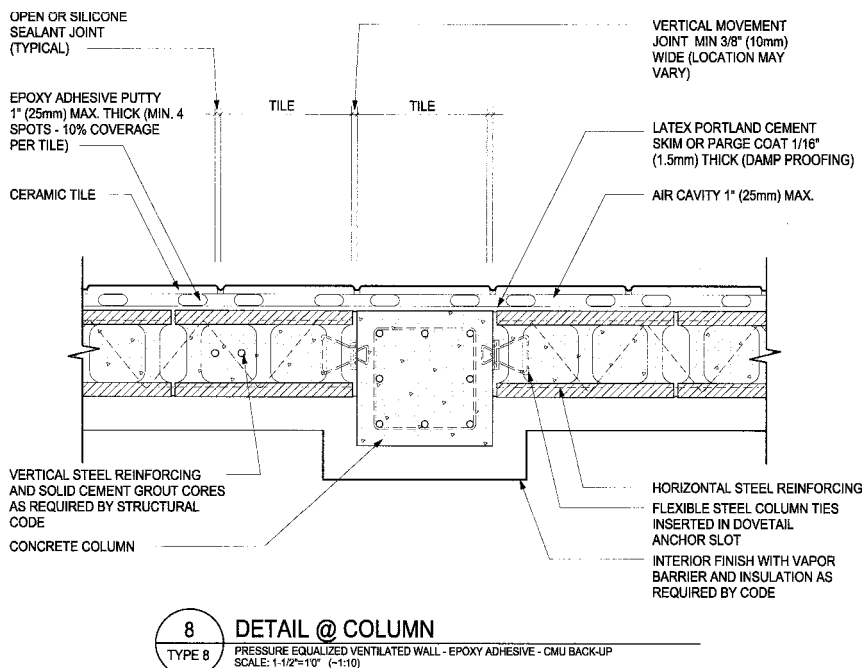


Figure 3.7-36 Architectural Details of Cavity Wall - Epoxy spot bonding over concrete masonry back-u p

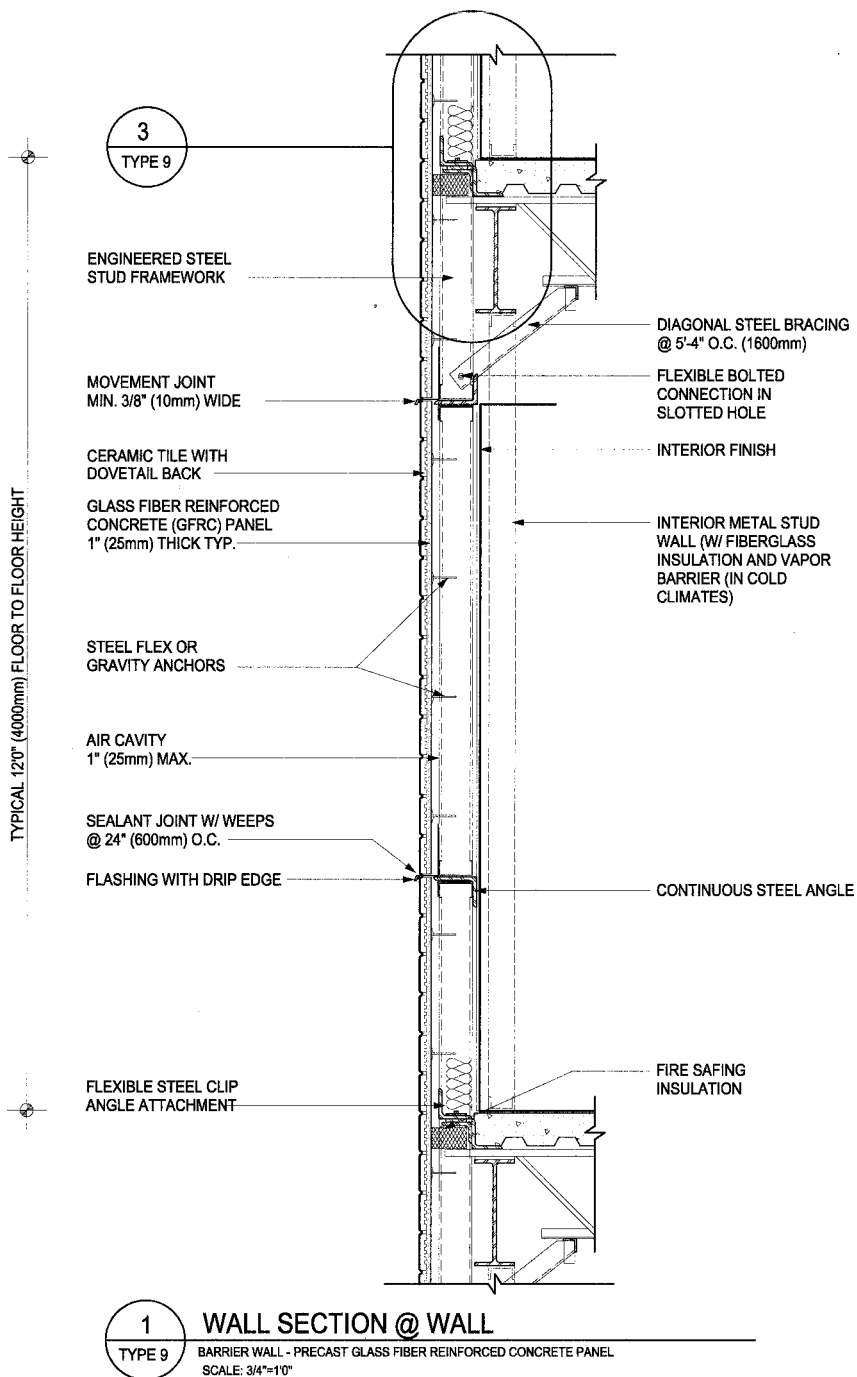
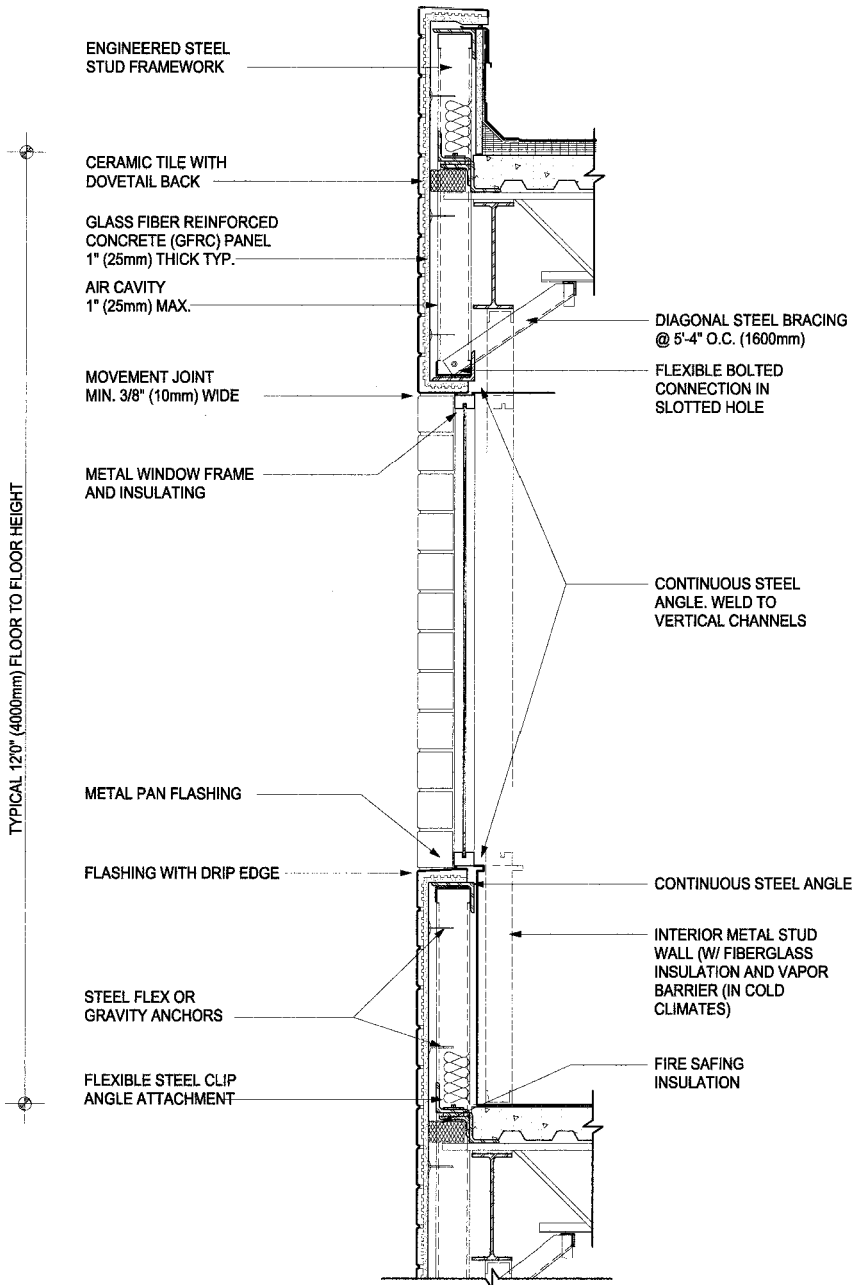


Figure 3.7-37 Architectural Details of Barrier Wall - GFRC pre-cast concrete panels - negative cast method



WALL SECTION @ WINDOW

BARRIER WALL - PRECAST GLASS FIBER REINFORCED CONCRETE PANEL
SCALE: 3/4"=1'-0"

Figure 3.7-38 Architectural Details of Barrier Wall - GFRP pre-cast concrete panels - negative cast method

SECTION 3 Types of Direct Adhered Wall Construction

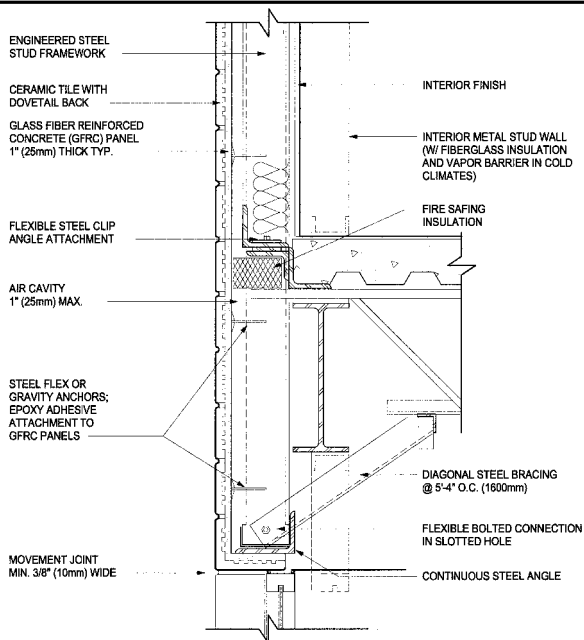
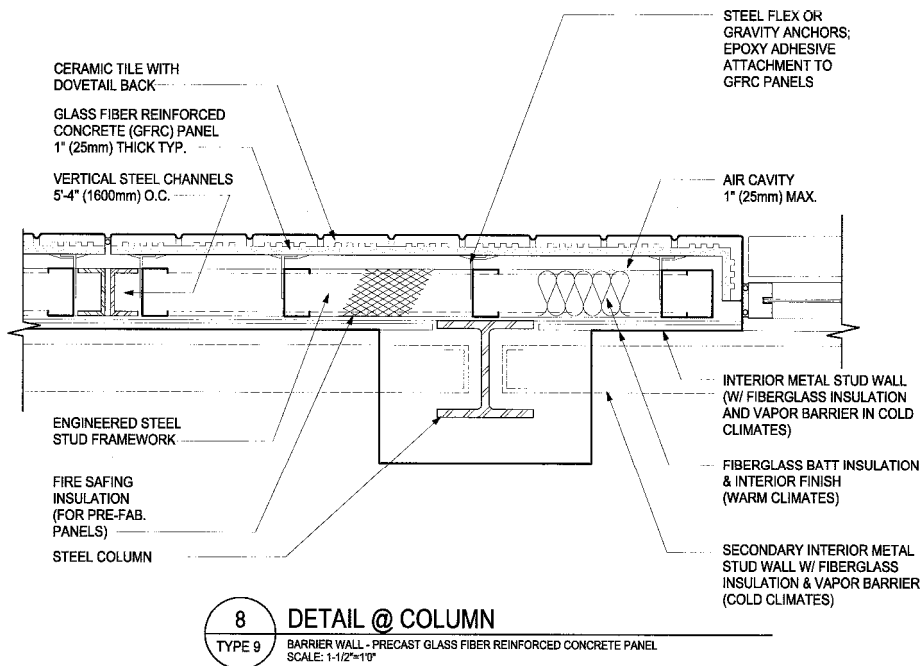


Figure 3.7-39 Architectural Details of Barrier Wall - GFRC pre-cast concrete panels - negative cast method

Concrete Wall Panels (GFRC)

Pre-cast glass fiber reinforced concrete (GFRC) is the term applied to a material which is fabricated from a cement-aggregate slurry and reinforced with alkali-resistant glass fibers. Mix composition and types of applications vary, but for installation of direct adhered cladding, GFRC panels consist of a mix which contains 5% by weight of glass fibers combined with a Portland cement-sand slurry which is spray applied onto a form. The form may contain a cladding material (negative cast method) to which a bond coat of latex Portland cement is applied just prior to application of the GFRC material, or the panel is cast, cured and removed from the form for subsequent application of a cladding material in a separate process (positive cast method). A single skin GFRC panel is the most common type of panel construction. This type of panel has a thickness of approximately 1/2 inch (12mm), however it is recommended to increase the thickness of the GFRC panel, to approximately 1 inch (25mm) to reduce and better resist differential movement stress. GFRC panels rely on a structural backing or stiffener of a steel stud framework. The steel frame is commonly separated from the GFRC by an air space and attached to the GFRC by means of 1/4

inch (6mm) diameter rods called flex anchors, which are imbedded into the GFRC and welded to the framework. These anchors, while rigidly attached, have flexibility inherent by diameter and orientation of the rods, which allow some panel movement to accommodate thermal and moisture movement. Heavier panels, or those requiring seismic bracing, also require additional anchors known as gravity or seismic anchors, and are differentiated from flex anchors by their size, configuration, and connection orientation to the GFRC. It is very important to consider the additional weight of the cladding material during the design and engineering of a GFRC panel; you cannot install direct adhered cladding using the positive method unless the panel was engineered specifically for that purpose.

Properly engineered and constructed GFRC panels have extremely high strength and good physical characteristics. However, due to the thin section employed in GFRC panels, differential thermal and moisture movement can cause panel bowing, resulting in cracking. Because GFRC expands and contracts from wet-dry cycling, the adhesion of a cladding can result in a different rate of moisture gain or loss between the front and back of the panel and induce bowing stress. Therefore,



Figure 3.8-1 Saskatoon City Hospital - Ceramic tile clad pre-cast concrete panels

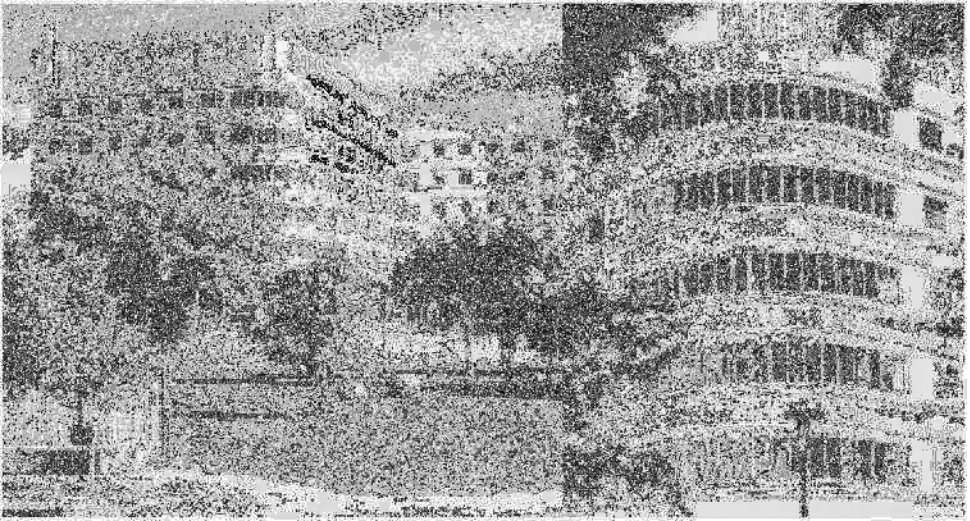


Figure 3.8-2 Saskatoon City Hospital - Ceramic tile clad pre-cast concrete panels

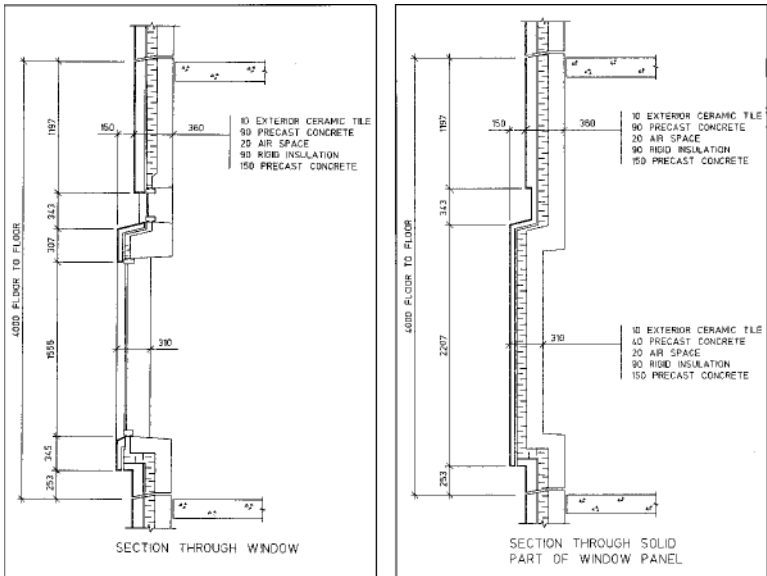


Figure 3.8-3 Wall Sections - Saskatoon City Hospital - Ceramic tile clad pre-cast concrete panels with pressure-equalized rain-screen cavity

careful attention to detailing to prevent rain infiltration and condensation within the wall (see Section 4) are important. Similarly, cladding materials with incompatible coefficients of thermal movement can induce stress. So thermal and moisture movement compatibility with cladding is important, as are low modulus adhesives and movement joints.

3.7 LIST OF ARCHITECTURAL DETAILS (See pages 27–65)

3.7-1 to 3.7-7 Barrier wall, concrete masonry back-up wall, continuous waterproof membrane

3.7-7 to 3.7-14 Barrier wall, -concrete masonry back-up wall, membrane flashing

3.7-15 to 3.7-17 Barrier wall, metal stud back-up with cement board or plaster

3.7-18 to 3.7-20 Cavity wall, metal stud back-up with cement board or plaster 3.7-21 to 3.7-23 Barrier wall, precast concrete panels

3.7-24 to 3.7-30 Cavity wall, double wythe concrete masonry

3.7-31 to 3.7-33 Cavity wall, concrete masonry and metal stud back-up wall 3.7-

34 to 3.7-36 Cavity wall, epoxy spot bonding

3.7-37 to 3.7-39 Barrier wall, GFRC panel