CHAPTER 1

CONCRETE DETAILS

1-1 CONCRETE SLAB-ON-GRADE TOLERANCES

Description

Because no building can be perfectly level, plumb, and straight, there are certain acceptable tolerances for various types of construction, which have become industry standards. These tolerances give architects, engineers, and contractors allowable variations from given dimensions and elevations. Knowing these tolerances is important in detailing because allowances must be made for variations from idealized dimensions when several materials are connected, when clearances are required, or when appearance is critical. This section and Sections 1-2, 1-3, 1-11, 1-13, 1-22, and 1-23 give some of the industry standard tolerances regarding concrete construction.

Slabs-on-grade (as well as elevated slabs) are subject to two tolerances. One is the overall tolerance above and below the specified elevation, and the other is the flatness and levelness of the floor finish. Flatness is the degree to which the surface approximates a plane. Levelness is the degree to which the surface parallels the horizontal plane.

Limitations of Use

- These tolerances are for slabs-on-grade as specified by the American Concrete Institute (ACI). See Section 1-2 for tolerances of other slab surfaces.
- The tolerances given can also be used to specify sloped surfaces.
- Verify the size of temperature reinforcement, the concrete strength, and the size and spacing of rebars (if any) with a structural engineer.

Detailing Considerations

- Do not specify a tolerance higher than that actually required for the project because higher finish tolerances generally cost more to achieve. For example, a moderately flat floor (±3/8 in. in 10 ft [10 mm in 3 m]) is generally sufficient for carpet or an exterior walk.
- Verify the slab thickness required for the project. A 4 in. (100 mm) slab is the minimum thickness allowable and is used for residential and lightly loaded commercial floors subject to foot traffic. A 5 in. (127 mm) thickness is required for light industrial and

commercial floors where there is foot traffic and pneumatic wheeled traffic. Floors with heavy loads require thicker slabs and special reinforcing.

Coordination Required

- In order to maintain the specified level of the slab, proper compaction and subgrade preparation must be specified and maintained during construction. Soil and fill under slabs should be compacted to 95 percent of standard Proctor density.
- Locate joints according to the information given in Sections 1-5, 1-6, and 1-7.
- Vapor barriers should be used under slabs to prevent moisture migration into the slab, to prevent shrinkage cracks, and to provide a barrier to radon penetration. However, in order to prevent plastic and drying shrinkage caused by differential water loss between the top and bottom of the slab, the slab must be properly cured following ACI recommendations.
- Reinforcing and concrete strength should be selected based on the service requirements of the slab. Generally, lightly loaded slabs require a minimum compressive concrete strength of 3500 psi (24,000 kPa), while light industrial and commercial slabs require a compressive strength of 4000 psi (27,500 kPa).

Allowable Tolerances

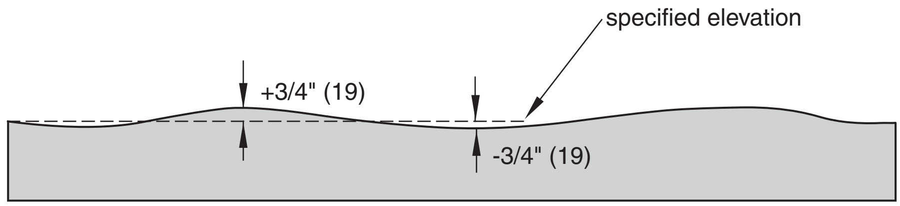
Level alignment tolerance is shown in Fig. 1-1(a). This means that over the entire surface of a concrete slab, all points must fall within an envelope 3/4 in. (19 mm) above or below the theoretical elevation plane.

Random traffic floor finish tolerances may be specified either by the traditional 10 ft (3 m) straightedge method, shown in Fig. 1-1(b), or by the F-number system. For a complete discussion of the F-number system refer to ACI 302.1R-89, *Guide for Concrete Floor and Slab Construction*, and ACI Compilation No. 9, *Concrete Floor Flatness and Levelness.*

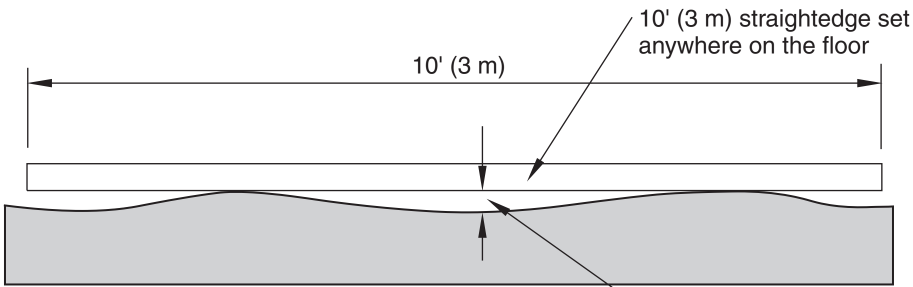
If the 10 ft (3 m) straightedge method is used, there are three floor classifications: conventional, moderately flat, and flat. In order for a surface to meet the requirements of one of these three classifications, a minimum of 0.01 times the area of the floor measured in ft^2 (0.1 times the area in m^2) must be taken. Ninety percent of the samples must be within the first column shown in Fig. 1-1(b), and 100 percent of the samples must fall within the second column in Fig. 1-1(b). The orientation of the straightedge must be parallel, perpendicular, or at a 45 degree angle to the longest construction joint bounding the test surface. ACI 117, *Specifications for Tolerances for Concrete Construction and Materials and Commentary*, details the other requirements for taking the samples.

The F-number system, diagrammed in Fig. 1-1(c), is a statistical method used to measure and specify both the local flatness of a floor within adjacent 12 in. (300 mm) intervals (the F_F number) and the local levelness of a floor (the F_L number) over a 10 ft (3.05 m) distance. The higher the F_F or F_L number, the flatter or more level the floor. To determine if a floor falls within the tolerances of a particular F_F and F_L, number measurements must be taken according to the procedure set forth in ASTM E1155-87. In most cases, a sophisticated instrument must be used that can take the measurements and perform the calculations necessary for determining the F numbers. Although there is no direct correlation, an F_F50 roughly corresponds to a 1/8 in. (3.2 mm) gap under a 10 ft (3.05 m) straightedge. An F_F25 roughly corresponds to a 1/4 in. (6 mm) gap under a 10 ft (3.05 m) straightedge.

Figure 1-1 Concrete slabs-on-grade tolerances 03 05 03

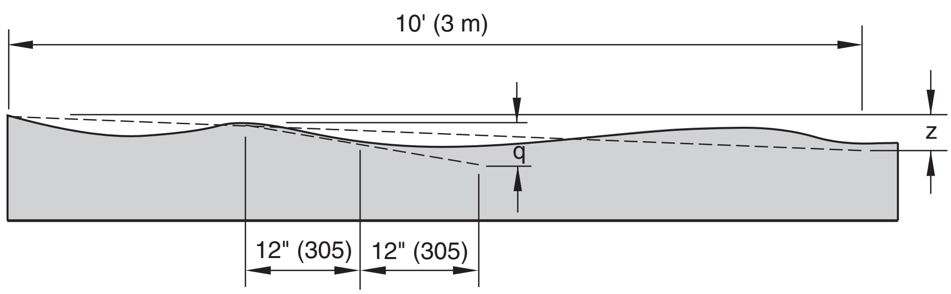


(a) level alignment



floor surface classification	90% compliance	100% compliance
conventional:	1/2" (13)	3/4" (19)
moderately flat:	3/8" (10)	5/8" (16)
flat:	1/4" (6)	3/8" (10)

(b) 10-ft straightedge method



(c) F-number system

For slabs-on-grade the F-number system works well. However, to determine the F numbers, measurements must be taken within 72 hours of floor installation and, for suspended slabs, before shoring and forms are removed. Therefore, for suspended slabs, the specified levelness of a floor may be compromised when the floor deflects when the shoring is removed and loads are applied.

ACI 117 gives requirements for five classes of floors that can be specified: conventional, moderately flat, flat, very flat, and superflat. In order to meet the requirements for whatever class of floor is specified, the procedures of ASTM E1155 must be followed and the test results must meet certain overall flatness (SOF_F) values and specified overall levelness (SOF_L) values. In addition, minimum local values for flatness and levelness must also be achieved. These are 3/5 of the SOF_F and SOF_L values. For example, a "conventional" floor must have an SOF_F of

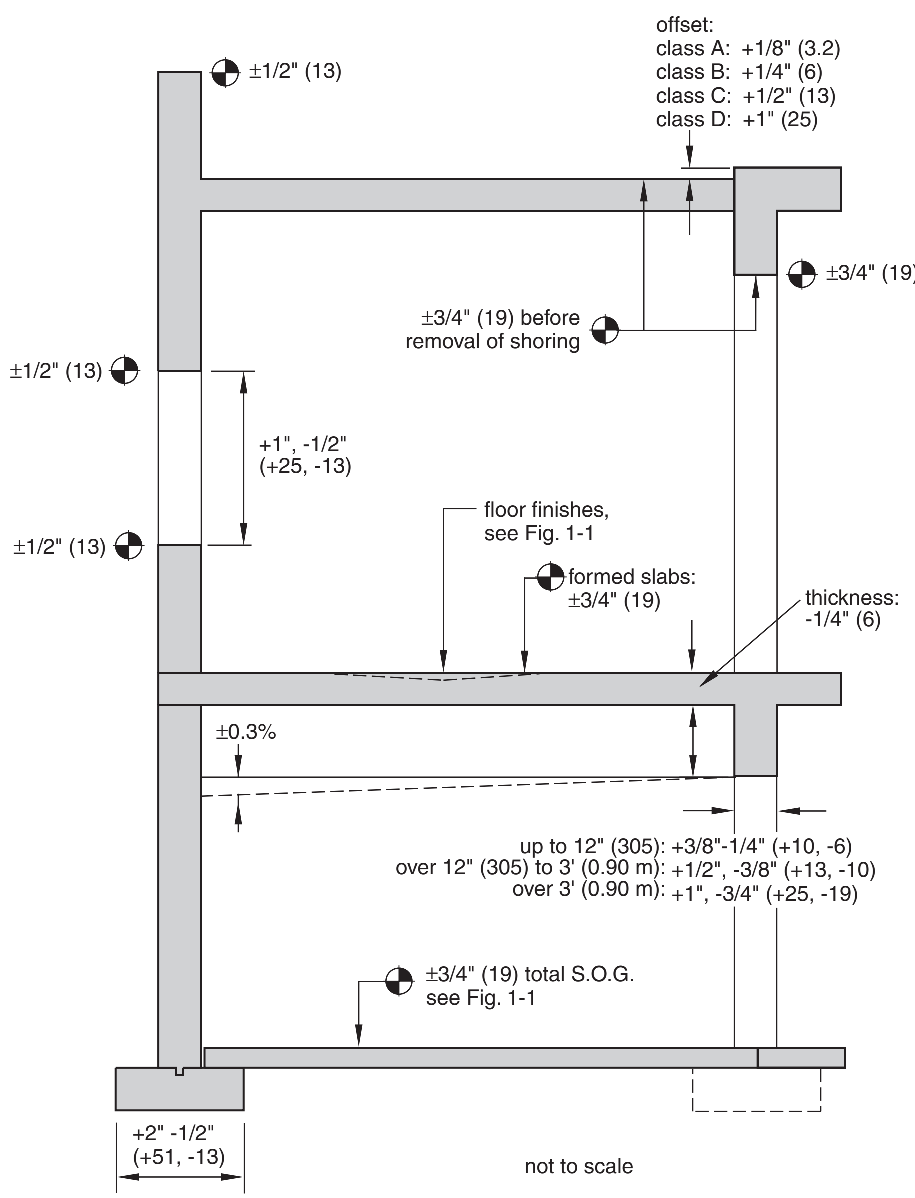
20 and an SOF_L of 15, while a superflat floor must have an SOF_F of 60 and an SOF_L of 40. Refer to ACI 117 for detailed requirements.

1-2 CAST-IN-PLACE CONCRETE SECTIONAL TOLERANCES

Description

Figure 1-2 shows dimensional tolerances for cast-in-place concrete elements. It includes elevation tolerances as well as cross-sectional tolerances for elements such as columns, beams, walls, and slabs.

Figure 1-2 Cast-in-place concrete sectional tolerances 03 05 04



Limitations of Use

- The tolerances shown in this drawing should be used with judgment as a range of acceptability and an estimate of likely variation from true measurements, not as a basis for rejection of work.
- Floor tolerance measurements must be made within 72 hours after the concrete is finished and before the shoring is removed.
- For additional tolerances, refer to ACI 117.
- If smaller tolerances are required, they should be clearly indicated in the contract documents and discussed with the contractor prior to construction.

Detailing Considerations

- In some cases tolerances may accumulate, resulting in a wider variation from true measurement than that due to individual tolerances alone.
- In general, higher accuracy requires a higher construction cost.
- A floor poured over metal decking will generally deflect significantly. If deflection must be limited, extra support or more rigid decking may be needed.

Coordination Required

- If other materials are being used with or attached to the concrete, the expected tolerances of the other materials must be known so that allowance can be made for both.
- Benchmarks and control points should be agreed on by the contractor and architect prior to construction and should be maintained throughout construction.
- Refer to Sections 1-11 and 1-13 for tolerances of precast concrete.

Allowable Tolerances

The various sectional tolerances are shown diagrammatically in Fig. 1-2. The level alignment tolerance of ±1/2 in. (13 mm) for lintels, sills, and parapets also applies to horizontal grooves and other lines exposed to view. Offsets listed as Class A, B, C, and D are for adjacent pieces of formwork facing material. Note that the level alignment of the top surface of formed slabs and other formed surfaces is measured *before* the removal of shoring. There is no requirement for slabs on structural steel or precast concrete. The tolerance for the top of a wall is ±3/4 in. (19).

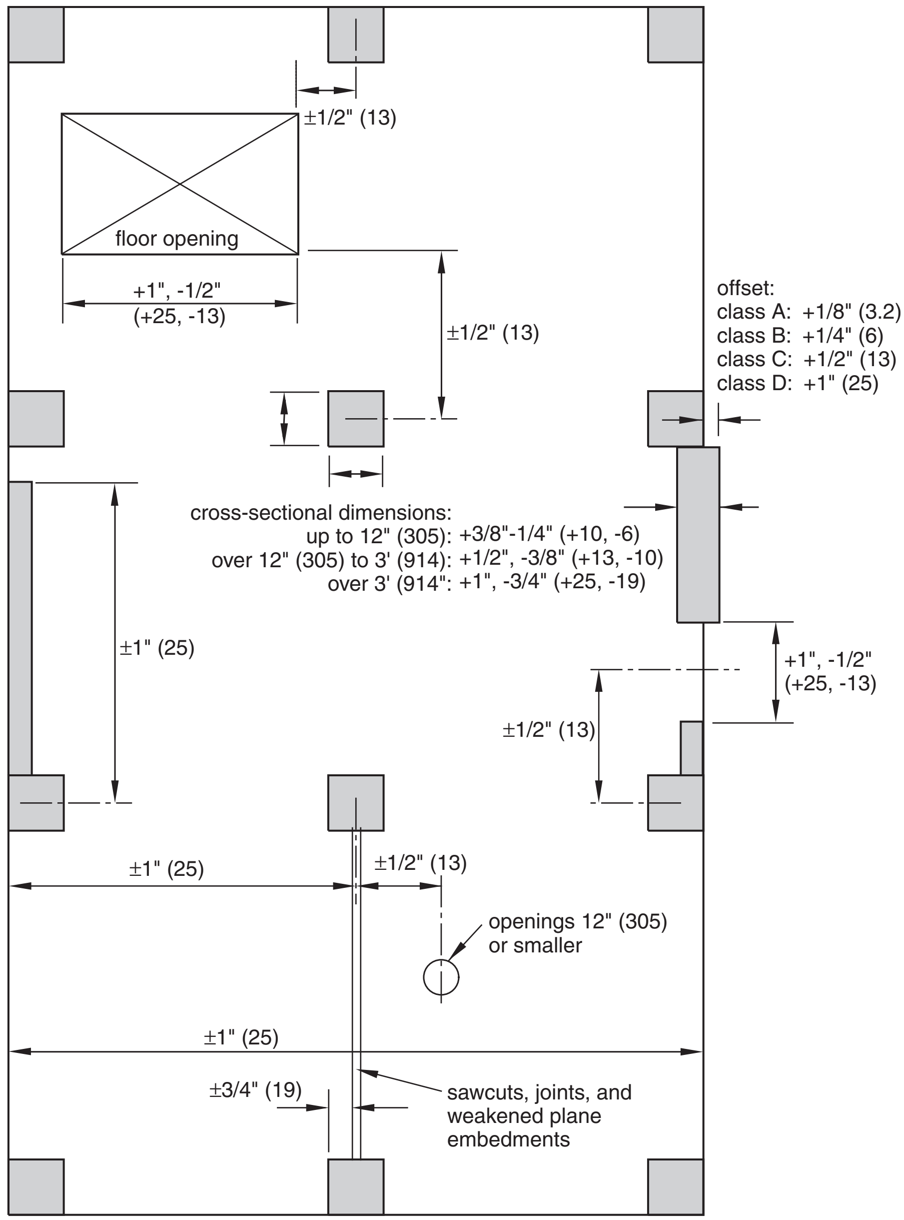
For slabs-on-grade, the tolerance is −3/8 in. (−10 mm) for the average of all samples and −3/4 in. (−19 mm) for an individual sample. The minimum number of samples that must be taken is one per 10,000 ft^2 (929 m^2).

1-3 CAST-IN-PLACE CONCRETE PLAN TOLERANCES

Description

Figure 1-3 complements Fig. 1-2 and illustrates allowable variations from lateral dimensions for various concrete elements such as columns, piers, walls, and openings. The tolerances

Figure 1-3 Cast-in-place concrete plan tolerances 03 05 05



shown in Fig. 1-3 are based on recommendations of the ACI. In some cases, the tolerances may conflict with individual ACI documents. In these cases, the tolerances required should be specified in the contract documents.

Limitations of Use

- The tolerances shown in Fig. 1-3 should be used with judgment as a range of acceptability and an estimate of likely variation from true measurements, not as a basis for rejection of work.

- If smaller tolerances are required, they should be clearly indicated in the contract documents and discussed with the contractor prior to construction.
- For additional tolerances, refer to ACI 117.

Detailing Considerations

- In some cases tolerances may accumulate, resulting in a wider variation from true measurement than that due to individual tolerances alone.
- Generally speaking, higher accuracy requires a higher construction cost.
- Details should provide sufficient clearance for the tolerances shown as well as for attached materials.

Coordination Required

- If other materials are being used with or attached to the concrete construction, the expected tolerances of the other materials must be known so that allowance can be made for both.
- Benchmarks and control points should be agreed on by the contractor and architect prior to construction and should be maintained throughout construction.
- Refer to Sections 1-11 and 1-13 for tolerances of precast concrete.

1-4 WATERSTOPS

Description

A waterstop is a premolded sealant used across concrete joints to stop the passage of water under hydrostatic pressure. There are dozens of different styles and sizes of waterstops made from several types of materials to suit particular situations. Waterstops are made for two basic types of joints: working and nonworking. Working joints are those where significant movement is expected; nonworking joints are those where little or no movement is expected.

Figure 1-4 shows two typical types of joints. A centerbulb waterstop is shown in the working joint in Fig. 1-4(a), which allows movement both parallel and perpendicular to the plane of the concrete. For a nonworking joint, as shown in Fig. 1-4(b), a dumbbell or flat, serrated waterstop can be used. The dumbbell shape shown here holds the waterstop in place and provides a longer path for water to travel across the joint, improving its watertightness. If a great deal of movement is expected, a U-shaped, tear-web center section can be selected, as shown in Fig. 1-4(c)

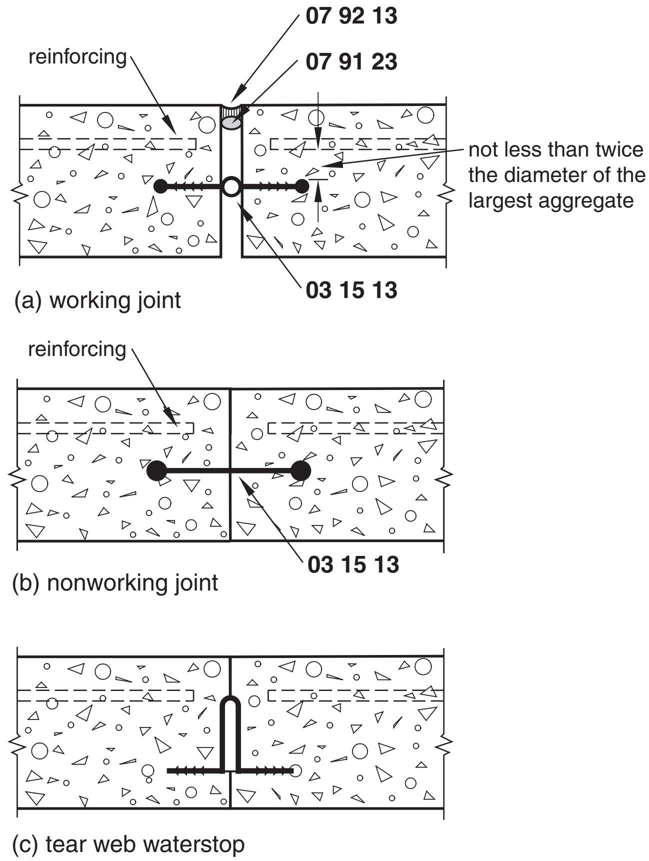
Limitations of Use

- The details included here show only two of the many styles of waterstops available for various applications. Refer to manufacturers' literature for specific recommendations on material and configuration of a waterstop.

Detailing Considerations

- Most waterstops are either 6 in. (152 mm) or 9 in. (229 mm) wide; some are available up to 12 in. (305 mm).

Figure 1-4 Waterstops 03 15 13



- Select the type and shape of waterstop based on the requirements of the joint, either working or nonworking.

Likely Failure Points

- Splitting of the joint due to the use of an incorrect type of waterstop for the movement expected
- Leaking due to honeycombing near the seal caused by displacement of the waterstop during placing and consolidation of the concrete
- Leaking caused by incomplete or improper splicing
- Leaking caused by contamination of the waterstop by form coatings

Materials

03 15 13 WATERSTOP

Waterstops for general construction are typically made from polyvinyl chloride (PVC), styrene butadiene rubber (SBR), and neoprene. Other materials are available, including metal, which are resistant to certain types of chemicals or which are more appropriate for special uses.

PVC can be easily spliced, while other materials require the use of preformed fittings for angles or the use of skilled workers to make the correct fittings and splices.

The width of the waterstop should not be greater than the thickness of the wall.

07 91 23 Backer rod

Closed cell polyethylene foam, with the diameter at least 25 percent greater than the joint width.

07 92 13 Sealant

Materials

Polysulfide, polyurethane, or silicone, ASTM C920, are the most common types used. Sealant may either be Type S or M (one part or multicomponent), Grade P or NS (pourable or nonsag), and Class 25.

Sealant must be compatible with the type of joint filler used.

Execution

Sealant depth equal to the width of the joint up to 1/2 in. (13 mm), with a minimum depth of 1/4 in. (6 mm).

Sealant depth 1/2 in. (13 mm) for joint widths from 1/2 in. to 1 in. (13 mm to 25 mm).

For sealants with a ±25 percent movement capability, the joint width should be four times the expected movement of the joint.

Sealant should not bond to the joint filler.

1-5 SLAB-ON-GRADE CONTROL JOINT

Description

Figure 1-5 shows one of the three types of joints used in concrete slabs-on-grade. Control joints, also called *contraction joints*, are used to induce cracking in preselected locations when the slab shortens due to drying, shrinking, and temperature changes. For lightly loaded slabs, a minimum thickness of 4 in. (102 mm) is required. For most light industrial and commercial work, slab thicknesses of 5 in. or 6 in. (127 mm or 152 mm) are recommended, depending on the loading conditions. Industrial floors may require even thicker slabs.

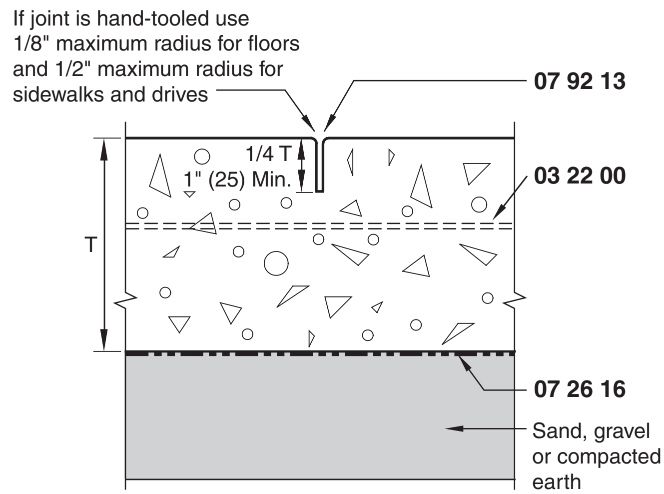
Limitations of Use

- The detail shown is for lightly loaded and moderately loaded interior and exterior slabs. Heavy-duty industrial floors, street pavements, and other heavily loaded slabs require special considerations for reinforcement, design thickness, and joint construction.
- Verify the size and spacing of rebars, if required, with a structural engineer.

Detailing Considerations

- Control joints may be formed by sawcutting shortly after the slab hardens (as shown in Fig. 1-5), by hand tooling, or by using preformed plastic or metal strips pressed into the fresh concrete.

Figure 1-5 Slab-on-grade control joint 03 30 07



- For interior slabs, control joints should be placed 15 ft to 20 ft (4.6 m to 6.1 m) apart in both directions. Slab sections formed with control joints should be square or nearly square. For sidewalks or driveways control joints should be spaced at intervals approximately equal to the width of the slab, but walks or drives wider than about 12 ft (3.6 m) should have an intermediate control joint in the center. If control joints will be visible in the completed construction, their location should be planned to coincide with lines of other building elements, such as column centerlines and other joints.
- Isolation and construction joints can also serve as control joints.
- Vapor barriers should be used under slabs to prevent moisture migration into the slab, to prevent shrinkage cracks, and to provide a barrier to radon penetration. However, in order to prevent plastic and drying shrinkage caused by differential water loss between the top and bottom of the slab, the slab must be properly cured following ACI recommendations.
- Seal control joints to prevent spalling of the concrete.

Coordination Required

- Select a vapor barrier and granular fill under the slab to satisfy the requirements of the project. In most cases, a gravel subbase should be placed under the slab to provide drainage.
- Reinforcing and concrete strength should be selected based on service requirements of the slab.
- The subgrade should be compacted to 95 percent of standard Proctor density prior to placing the subbase.

Likely Failure Points

- Cracking of the slab in undesirable locations if control joints are placed farther apart than 20 ft (6.1 m) or if sections of the slab are elongated (length-to-width ratio greater than 1.5) or are L-shaped

- Cracking of the slab if control joint grooves are not deep enough
- Random cracking before sawing of control joints usually means that the sawing was delayed too long

Materials

03 22 00 Welded wire reinforcement

6 × 6 —W1.4 × 1.4 (152 × 152 –MW9 × MW9), minimum or as required by the structural requirements of the job.

Place welded wire reinforcement in the top one-third of the slab.

If fabric is carried through control joints, cut every other wire to ensure that the cracking will occur at the joint.

Reinforcement is often not used where frequent control joints are used.

Welded wire reinforcement should extend to about 2 in. (51 mm) from the edge of the slab but no more than 6 in. (152 mm) from the edges.

07 26 16 Vapor barrier

6 mil (0.15 mm) polyethylene.

Permeance of less than 0.3 perm (17 ng/s • m^2 • Pa) determined in accordance with ASTM E96.

Barrier should not be punctured during construction activities.

Edges should be lapped a minimum of 6 in. (152 mm) and taped and should be carefully fitted around openings.

07 92 13 Sealant

Materials

Polysulfide, polyurethane, or silicone, ASTM C920, are the most common types used. Sealant may be either Type S or M (one part or multicomponent), Grade P or NS (pourable or nonsag), and Class 25.

Sealant must be compatible with the type of joint filler used.

Use epoxy resin when support is needed for small, hard-wheeled traffic.

Execution

Sealant depth equal to the width of the joint up to 1/2 in. (13 mm), with a minimum depth of 1/4 in. (6 mm).

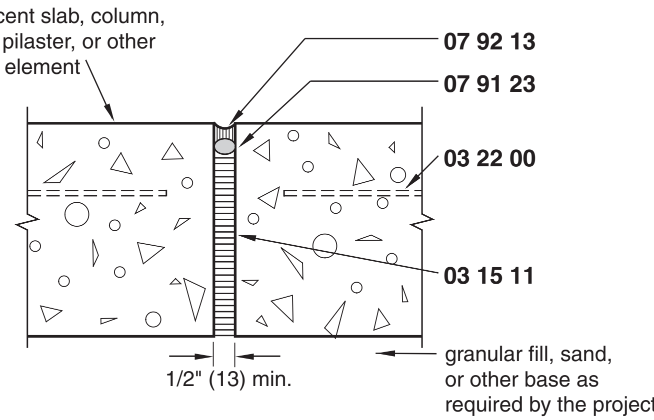
Sealant depth 1/2 in. (13 mm) for joint widths from 1/2 in. to 1 in. (13 mm to 25 mm).

For sealants with a ±25 percent movement capability, the joint width should be four times the expected movement of the joint.

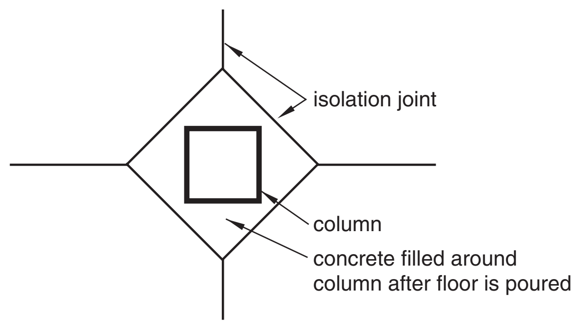
Sealant should not bond to the joint filler.

Thoroughly clean the joint of dirt and debris prior to application of the sealant.

Figure 1-6 Slab-on-grade isolation joint 03 30 08



(a) joint design



(b) isolation joint at column

1-6 SLAB-ON-GRADE ISOLATION JOINT

Description

Figure 1-6(a) shows one of the three types of joints used in concrete slabs-on-grade. Isolation joints, also called *expansion joints*, are used to structurally separate the slab from other building elements to accommodate differential movement. They are usually located at footings, columns, walls, machinery bases, and other points of restraint such as pipes, stairways, and similar fixed structural elements. Figure 1-6(b) shows the general configuration when an isolation joint is located at a column.

For lightly loaded slabs, a minimum thickness of 4 in. (102 mm) is required. For most commercial work, slab thicknesses of 5 in. (127 mm) or 6 in. (152 mm) are recommended, depending on the loading conditions. Industrial floors may require even thicker slabs.

Limitations of Use

- The detail shown here is for lightly loaded and moderately loaded interior and exterior slabs. Heavy-duty industrial floors, street pavements, and other heavily loaded slabs require special considerations for reinforcement, design thickness, and joint construction.
- If required, verify the size and spacing of rebars with a structural engineer.

Detailing Considerations

- Isolation joint fillers must extend the full thickness of the joint.
- The width of isolation joints should be sized to accommodate the expected movement of the slab, allowing for about a 50 percent maximum compression of the joint. In most cases, a $1/2$ in. (13 mm) joint is adequate, but wider joints may be needed for large slabs or extreme conditions.
- In certain noncritical locations such as garage floors, protected exterior slab/foundation intersections, and similar conditions, the sealant and backer rod may be omitted, with the joint filler placed flush with the top of the slab.
- Vapor barriers should be used under slabs to prevent moisture migration into the slab, to prevent shrinkage cracks, and to provide a barrier to radon penetration. However, in order to prevent plastic and drying shrinkage caused by differential water loss between the top and bottom of the slab, the slab must be properly cured following ACI recommendations.
- A bond breaker should be used with isolation joints if the joint filler does not serve this purpose.

Coordination Required

- Select a vapor barrier and granular fill under the slab to satisfy the requirements of the project. In most cases, a gravel subbase should be placed under the slab to provide drainage.
- Reinforcing and concrete strength should be selected based on service requirements of the slab.
- The subgrade should be compacted to 95 percent of standard Proctor density prior to placing the subbase.

Likely Failure Points

- Cracking of the slab near walls or columns if proper isolation joints are not formed
- Cracking near the isolation joint if the joint filler is displaced during construction
- Slab settlement if the ground under the slab is not compacted to the proper density

Materials

03 22 00 Welded wire reinforcement

6 × 6—W1.4 × 1.4 (152 × 152 –MW9 × MW9), minimum or as required by the structural requirements of the job.

Place welded wire reinforcement in the top one-third of the slab.

Reinforcement is often not used where frequent control joints are used.

Welded wire reinforcement should extend to about 2 in. (51 mm) from the edge of the slab but no more than 6 in. (152 mm) from the edges.

03 15 11 Expansion joint filler

Compressible joint fillers may be bituminous-impregnated fiberboard or glass fiber or one of several other types of joint fillers. In some situations, the joint filler may be used alone without a sealant.

07 91 23 Backer rod

Closed cell polyethylene foam, with the diameter at least 25 percent greater than the joint width.

07 92 13 Sealant

Materials

Polysulfide, polyurethane, or silicone, ASTM C920, are the most common types used. Sealant may be either Type S or M (one part or multicomponent), Grade P or NS (pourable or nonsag), and Class 25.

Sealant must be compatible with the type of joint filler used.

Execution

Sealant depth equal to the width of the joint up to 1/2 in. (13 mm), with a minimum depth of 1/4 in. (6 mm).

Sealant depth 1/2 in. (13 mm) for joint widths from 1/2 in. to 1 in. (13 mm to 25 mm).

For sealants with a ±25 percent movement capability, the joint width should be four times the expected movement of the joint.

Sealant should not bond to the joint filler.

Thoroughly clean the joint of dirt and debris prior to application of sealant.

1-7 SLAB-ON-GRADE CONSTRUCTION JOINT

Description

Figure 1-7 shows two variations of a construction joint. Construction joints provide stopping points for construction activities. A construction joint may also serve as a control or isolation joint. Construction joints can be formed with separate wood strips placed on the form after the first pour to form the keyway or prefabricated forms made specifically for this purpose may be used.

For lightly loaded slabs, a minimum thickness of 4 in. (102 mm) is required. For most commercial work, slab thicknesses of 5 in. (127 mm) or 6 in. (152 mm) are recommended, depending on the loading conditions.

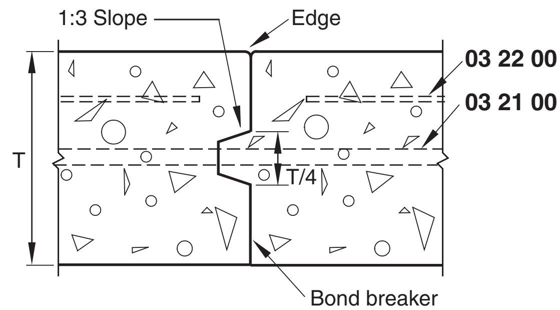
Limitations of Use

- The details shown here are for lightly loaded and moderately loaded interior and exterior slabs. Heavy-duty industrial floors, street pavements, and other heavily loaded slabs require special considerations for reinforcement, design thickness, and joint construction.
- Verify the size and spacing of dowels, if required, with a structural engineer.
- Butt-type construction joints (those without reinforcing dowels, or keyed joints) should be limited to lightly loaded slabs 4 in. (102 mm) thick.

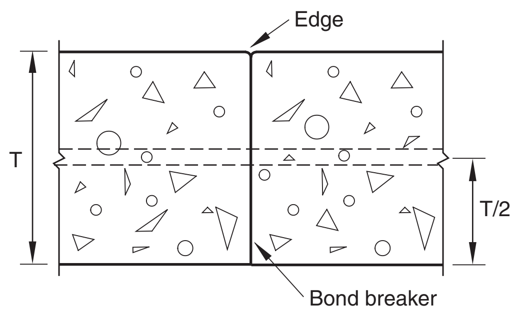
Detailing Considerations

- Construction joints should not be placed closer than 5 ft (1525 mm) to any other parallel joint.

Figure 1-7 Slab-on-grade construction joint 03 30 09



(a) construction joint with keyway



(b) construction joint without keyway

- A bond breaker must be used with construction joints.
- Vapor barriers should be used under slabs to prevent moisture migration into the slab, to prevent shrinkage cracks, and to provide a barrier to radon penetration. However, in order to prevent plastic and drying shrinkage caused by differential water loss between the top and bottom of the slab, the slab must be properly cured following ACI recommendations.
- The top of the joint should be given a slight radius edge to avoid spalling of the concrete.

Coordination Required

- Select a vapor barrier and granular fill under the slab to satisfy the requirements of the project. In most cases, a gravel subbase should be placed under the slab to provide drainage.
- Reinforcing and concrete strength should be selected based on service requirements of the slab.
- The subgrade should be compacted to 95 percent of standard Proctor density prior to placing the subbase.

Likely Failure Points

- Cracking caused by misaligned dowels in construction joints
- Cracking due to omission of the bond breaker on the joint or one end of the dowel
- Slab settlement if the ground under the slab is not compacted to the proper density

Materials

03 21 00 Reinforcing dowels

Materials

Use reinforcing dowels in construction joints for heavily loaded floors and where wheeled traffic is present.

#6 (#1) rebar for slabs 5 in. (127 mm) to 6 in. (152 mm) deep.

#8 (#25) rebar for slabs 7 in. (178 mm) to 8 in. (203 mm) deep.

Minimum 16 in. (406 mm) long dowels for 5 in. (127 mm) to 6 in. (152 mm) slabs; minimum 18 in. (457 mm) dowels for 7 in. (178 mm) to 8 in. (203 mm) slabs.

Execution

Space 12 in. (305 mm) on center.

A dowel extending into the second pour must be coated with bond breaker.

Align and support dowels during pouring.

03 22 00 Welded wire reinforcement

6 × 6—W1.4 × 1.4 (152 × 152 –MW9 × MW9), minimum or as required by the structural requirements of the job.

Place welded wire reinforcement in the top one-third of the slab.

Temperature reinforcement is often not used where frequent control joints are used.

Welded wire reinforcement should extend to about 2 in. (51 mm) from the edge of the slab but no more than 6 in. (152 mm) from the edges.

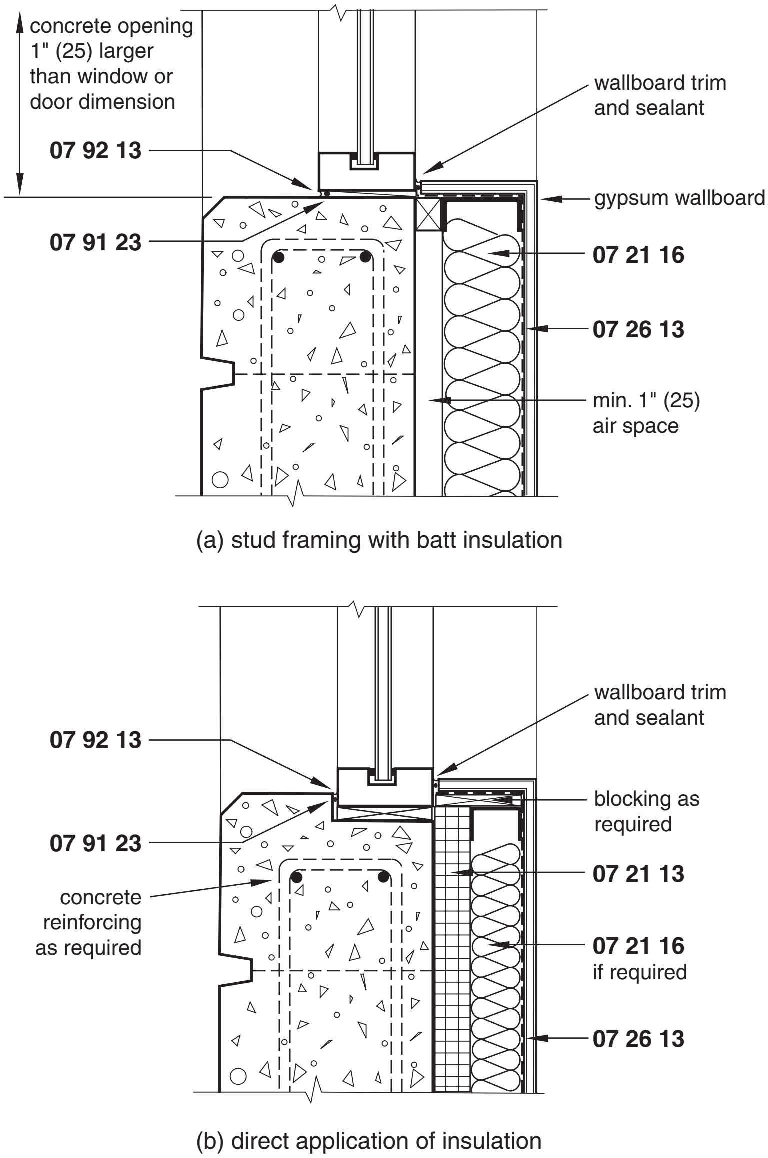
1-8 CAST-IN-PLACE CONCRETE WALL WITH INSULATION

Description

Figure 1-8 shows two basic methods of detailing a cast-in-place wall to include insulation and interior finish. Figure 1-8(a) shows the use of stud framing to provide a space for insulation as well as the substrate for the interior finish. Figure 1-8(b) illustrates the application of rigid insulation directly to the concrete, with the finish being applied to smaller framing. As an alternative, Z-shaped furring strips can be attached to the concrete. However, furring attached directly to the concrete creates a thermal bridge and reduces the overall R-value slightly. Depending on the building use, separate framing is useful to provide space for additional insulation as well as space for electrical service and plumbing pipes. In both cases a window jamb is shown, but the door framing is similar.

One of the detailing problems with cast-in-place concrete is accommodating construction tolerances, both for the opening size and for the window or door, which is usually steel or aluminum. ACI tolerances allow for an opening to be oversize by 1 in. (25 mm) or undersized by 1/2 in. (13 mm). This means that at each jamb, the edge of the concrete opening may be larger by 1/2 in. (13 mm) or smaller by 1/4 in. (6 mm). Tolerances for steel door frames at each jamb are 1/16 in. (1.6 mm) larger or 3/64 in. (1.2 mm) smaller than their listed dimension. To allow for tolerances and a workable sealant joint, the design dimension of the concrete

Figure 1-8 Cast-in-place concrete wall with insulation 03 30 53



opening shown in Fig. 1-8(a) should be 1 in. (25 mm) wider than the width of the door or window frame (1/2 in. [13 mm] at each jamb). This allows the concrete to be undersized and the frame to be oversized while still allowing sufficient space for sealant.

Figure 1-8(b) illustrates the use of a notch in the concrete to account for construction tolerance issues. In this case, variations in opening size or frame size can be accommodated with blocking in the notch and covered with interior finish or trim. Although notching the concrete increases the formwork costs slightly, it accommodates tolerances and maintains a uniform joint width for sealant.

Limitations of Use

- These details do not include requirements for the concrete wall. Refer to Section 1-9 and ACI requirements for formwork, concrete composition, and reinforcement.

Detailing Considerations

- Maintain an air space of at least 1 in. (25 mm) between the inside face of the concrete and the batt insulation to minimize thermal bridging through the studs and avoid possible wetting of the insulation from any moisture that might penetrate the concrete wall.
- If joints in the concrete are well sealed, the concrete will act as an air barrier. Joints between the roof and floor structure should be well sealed to maintain the continuity of the air barrier. Refer to Section 5-5 for more information on air barriers.
- Verify the need for a vapor retarder and its location. Place it as shown on the warm side of the insulation in a cool or cold climate. Refer to Section 5-5 for more information on vapor retarders.
- Window sills should be detailed with flashing (including end dams) to drain any moisture to the outside.
- Maximum furring or stud spacing is 24 in. (610 mm) on center.
- Precast concrete insulated panels can also be used in lieu of cast concrete. This construction eliminates thermal bridging and provides an extra layer of insulation.
- Foam insulation must be covered with a code-approved thermal barrier. This is a minimum 1/2 in. (13 mm) layer of gypsum wallboard.
- Refer to Section 1-9 for information on architectural concrete.

Likely Failure Points

- Degradation of foam plastic insulation if a compatible adhesive is not used
- Degradation of batt insulation if subjected to moisture
- Air leakage due to an inadequate seal between concrete and framing
- Moisture penetration due to lack of an adequate seal between vapor retarder and framing

Materials

07 21 16 Batt insulation

Fiberglass, ASTM C665, Type I or Type II (unfaced or faced).

Mineral fiber, ASTM C553.

Apply in the thicknesses required for thermal resistance.

07 21 13 Board insulation

Materials

Polyisocyanurate foam board, ASTM C591.

Extruded polystyrene, ASTM C578.

Apply in the thicknesses required for thermal resistance.

Verify compatibility with the adhesive used.

Execution

If mastic is applied, use a full adhesive bed or grid of adhesive.

Insulation may be installed with metal or plastic stick clips placed in a grid pattern. Follow manufacturers' recommendations for spacing. Metal clips provide a minor thermal bridge.

07 26 13 Vapor retarder

4 mil (0.1 mm) polyethylene film, 0.08 maximum perm rating.

07 92 13 Elastomeric joint sealant

Materials

Solvent-based acrylic, ASTM C834.

Acrylic latex may also be used.

One-part polyurethane, ASTM C920, Type S, Grade NS, Class 25 or 50, as required.

One-part silicone, ASTM C920, Type S, Grade NS, Class 25 or 50, as required.

Execution

Sealant depth equal to the width of the joint up to 1/2 in. (13 mm), with a minimum depth of 1/4 in. (6 mm).

See Section 5-38 for methods of sizing joints.

07 91 23 Backer rod

Closed cell foam, ASTM D1056, Type 2.

25 percent to 33 percent larger than joint width.

1-9 ARCHITECTURAL CONCRETE

Description

Architectural concrete is exposed concrete that is intended to act as a finished surface either on the interior or exterior of a structure. Special attention is required in detailing and specifying architectural concrete to ensure that the final appearance has minimal color and texture variation and minimal surface defects when viewed from a distance of 20 ft (6.1 m).

Although there are many considerations in achieving a quality architectural concrete surface, including concrete mix, curing, and finishing procedures, Fig. 1-9 illustrates some of the primary considerations for detailing openings, joints, formwork, and reinforcement placement.

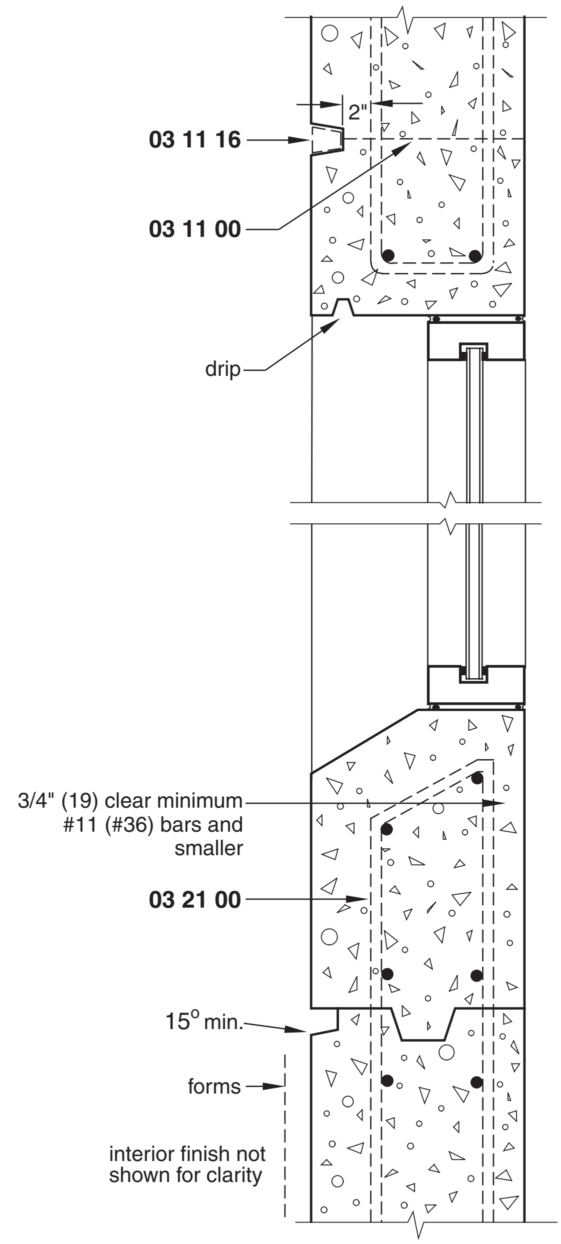
Limitations of Use

- Refer to ACI 303R for additional recommendations concerning concrete mix, requirements for forms, curing, and methods of treating and finishing the concrete surface.

Detailing Considerations

- Best results are obtained when large areas of concrete are constructed with textured forms or have textured finishes.
- Joint layout should be designed to divide large concrete surfaces into manageable sections for construction.
- Horizontal control joints may be needed at the top and bottom of openings in walls.

Figure 1-9 Architectural concrete 03 33 00



- Common vertical cracking in walls can be concealed with vertical rustication joints at the midspan of bays unless other vertical joints are provided.
- In long walls, vertical cracking can be controlled by providing construction joints not more than 20 ft (6.1 m) on center or by placing deep, narrow rustication strips on both sides of the wall to induce cracking. The depth of this type of joint should be 1.5 times the maximum aggregate size.
- Sills and similar horizontal surfaces should be sloped to encourage washing of airborne dirt from the concrete by rainwater. Smooth surfaces should have a minimum slope of 1:12, while extremely textured surfaces may have a slope of up to 1:1. Parapets should slope away from the face of the concrete.

- Recommended joint depths are 3/4 in. (19 mm) for small rustication or pattern grooves and 1 1/2 in. (38 mm) for control joints and panel divisions.
- Generally, avoid right and acute angle corners because of the difficulty of form removal without potential damage during construction. Use chamfer strips on right angle corners. Wood chamfer strips should have a minimum face width of 1 in. (25 mm) and be spliced only at concrete joints.
- Drips should be cast into all horizontal offsets and placed as near to the exterior surface as possible but not closer than 1 1/2 in. (38 mm).
- Refer to Section 1-8 for information on insulation and interior finish details.

Coordination Required

- Joint locations must also meet the structural requirements of the wall.
- Regions of flexural tension in beams and other elements should be identified with the help of the structural engineer so that the depths of rustication strips can be kept to a minimum. The increased concrete cover over reinforcing due to the strips can cause any cracks that occur to be wider than they normally would be with less concrete cover.

Likely Failure Points

- Defects on the surface caused by leakage from form joints
- Form joints must be made grout-tight. This can be done by using low-slump concrete, using various types of liners, using pressure-sensitive rubber gaskets, or caulking and using a lumber batten backing.

Materials

03 21 00 Reinforcing steel

The clear distance between forms and reinforcing bars should be 2 in. (51 mm), 1.25 times the bar size, or 1.5 times the maximum aggregate size, whichever is largest. This is done to minimize the chance of rust stains and to facilitate the placement of the concrete. If part of the concrete will be removed after removal of forms, additional coverage should be provided.

The clear distance between bars should be 2 in. (51 mm), 1.25 times the bar diameter, or 1.75 times the maximum aggregate size, whichever is largest.

Horizontal reinforcing in walls should be 1.5 times the ACI 318 minimum to minimize the width of cracks.

Horizontal reinforcing crossing construction joints or control joints formed by deep rustication strips should not exceed one-half of the horizontal reinforcement elsewhere in the wall.

Tie wire, chairs, spacers, and bolsters should be stainless steel.

03 11 16 Rustication strip

Wooden strips used for rustication joints should have a width at least equal to their depth. Metal strips should have a minimum width of 3/4 in. (38 mm).

Strips used to form joints should be angled at least 15 degrees to allow for removal.

End joints of insert strips should be mitered and tightly fitted.

03 11 00 Form tie

Various types of form ties can be selected, depending on the appearance desired. Cones are available that will form a hole up to 2 in. (51 mm) deep and about 1 in. (25 mm) in diameter. Cones from he-bolt form ties leave a hole 1 in. to 2 in. (25 mm to 51 mm) in diameter. Cones from she-bolt form ties leave a hole 3/4 in. to 1 1/2 in. (19 mm to 38 mm) in diameter, depending on the strength category of the tie. Snap ties will result in holes about 1/4 in. (6 mm) in diameter and about 1 in. (25 mm) deep but leave a rough appearance and are usually not used for architectural concrete.

Tie holes may be patched or left as cast for architectural effect.

1-10 PRECAST CONCRETE SPANDREL WITH INSULATION

Description

Figure 1-10 illustrates a common method of detailing a precast concrete panel on a cast-in-place concrete structural frame. Details for precast panels on a steel frame are similar. While this detail indicates panel attachment to concrete structural columns at either end of the panel, panels may also be attached at the floor line, as shown in Figs. 1-19 and 1-20. For a full discussion of precast concrete design, refer to *Architectural Precast Concrete*, published by the Precast/Prestressed Concrete Institute.

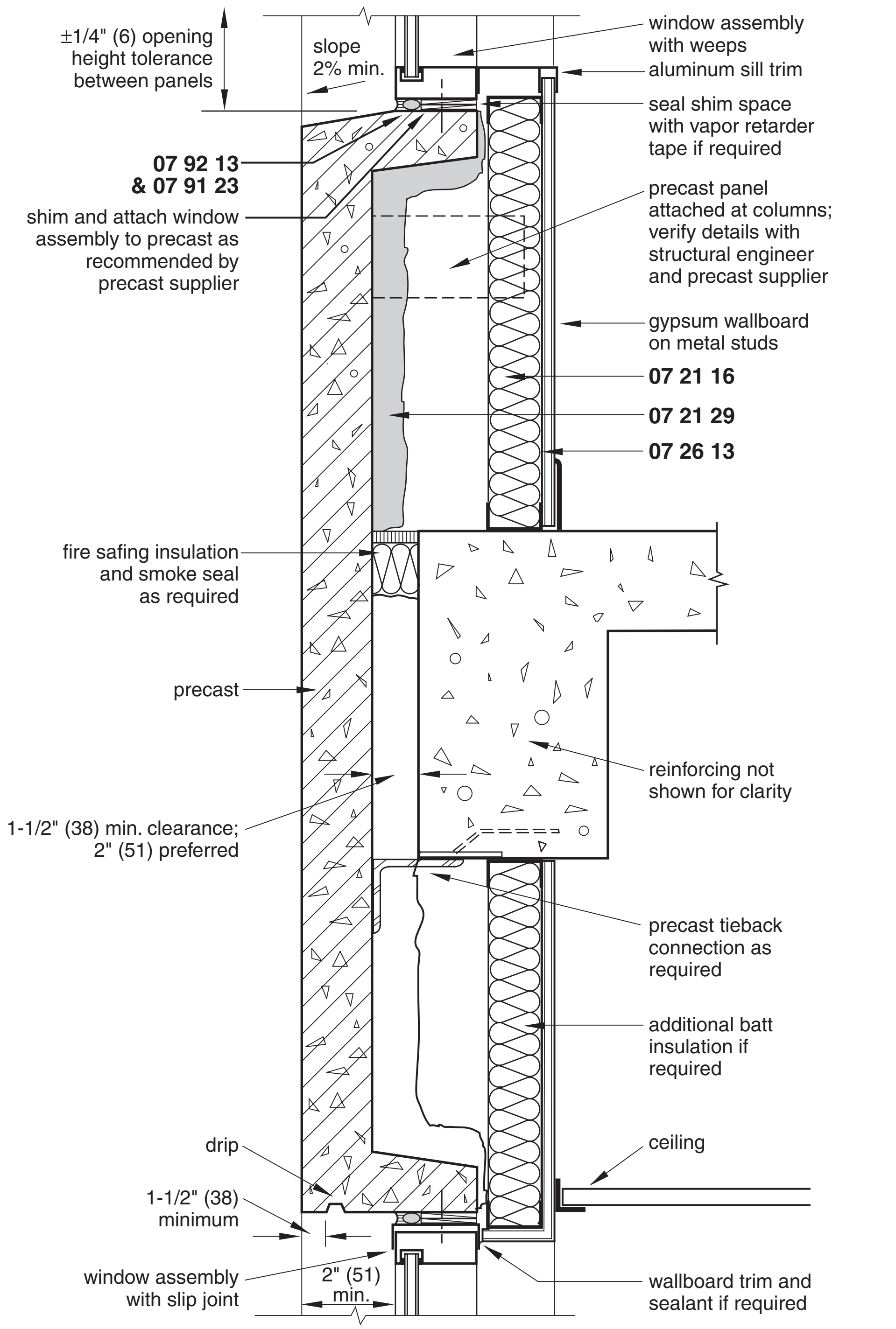
Limitations of Use

- This detail shows a cladding panel not intended to support any additional gravity loads other than its own weight, wind, seismic forces, and the load of the window system.
- This detail illustrates the use of an open precast frame for the window unit. That is, the four sides of the window opening are separate precast units. Closed window openings are entirely contained in one panel and are generally more economical than open designs.
- Because there are many possible variations in panel configuration and attachment methods, this detail shows only one possible method of detailing. Specific project details must be based on the structural requirements of the building, climate, types of windows used, interior finish requirement, exterior panel appearance, and the preferred methods of casting by the local precaster.

Detailing Considerations

- Locate the window frame a minimum of 2 in. (51 mm) from the face of the precast panel to avoid water dripping from the panel across the window.
- Precast panel connections should provide for adjustability in three dimensions.
- Panel connections should allow for a concrete beam and slab tolerance of ±3/4 in. (38 mm), a horizontal location of beam edge tolerance of ±1 in. (25 mm), and a precast panel tolerance of +1/4 in. (6 mm).

Figure 1-10 Precast concrete spandrel with insulation 03 40 01



- If a rough texture is specified for the precast panel, specify the extent of the texturing to provide for a smooth surface where window framing and sealant are installed. Hold the concrete texturing at least 1/2 in. (13 mm) from the interface of the precast and the window frame.
- Provide flashing with end dams under the window sill if required.

- Verify the need for a vapor retarder based on climate and building use.
- If spray polyurethane foam is used, a thermal barrier may be required by the local building code. A 1/2 in. (13 mm) layer of gypsum wallboard is usually sufficient for this purpose.

Coordination Required

- Develop panel sizes and connection methods with the structural engineer to minimize deflection and movement of each panel and to avoid conflicts between connections and interior finish requirements.
- Coordinate with the precast supplier to determine the most economical configuration for panels, proper draft for casting (see Section 1-15), attachment methods, erection sequencing, and other aspects of panel manufacturing.
- Consider window washing methods when recessing windows deeply into precast units.
- Use stainless steel, galvanized steel, or plastic for trim, inserts, flashing, and other items incorporated into the precast. Other materials require separation with dielectric materials.

Materials

07 21 16 Batt insulation

Fiberglass, ASTM C665, Type I or Type II (unfaced or faced).

Mineral fiber, ASTM C553.

Apply in thicknesses as required for thermal resistance.

07 21 20 Sprayed insulation

Closed cell polyurethane foam, ASTM C1029.

Open cell Icynene foam.

07 26 13 Vapor retarder

ASTM C1136.

4 mil (0.1 mm) polyethylene film, 0.08 (4.6 ng/s • m^2 • Pa) maximum perm rating.

07 91 23 Backer rod

Closed cell foam, ASTM D1056, Type 2.

25 percent to 33 percent larger than joint width.

07 92 13 Sealant

Materials

Solvent-based acrylic, ASTM C834.

Acrylic latex may also be used.

One-part polyurethane, ASTM C920, Type S, Grade NS, Class 25 or 50, as required.

One-part silicone, ASTM C920, Type S, Grade NS, Class 25 or 50, as required.

Execution

Sealant depth equal to the width of the joint up to 1/2 in. (13 mm), with a minimum depth of 1/4 in. (6 mm).

See Section 5-38 for methods of sizing joints.

1-11 PRECAST CONCRETE BEAM AND DOUBLE TEE TOLERANCES

Description

Figure 1-11 gives some of the primary size tolerances of two types of precast concrete structural elements. As with cast-in-place concrete, knowing these tolerances is important for developing connection details between structural components and for detailing other building materials that may use the concrete structure as a substrate. During construction, one surface is usually designated as the primary control surface, the location of which is controlled during erection.

Limitations of Use

- These guidelines are generally considered standard in the industry. If closer tolerances are required, they should be clearly indicated on the drawings and specifications.
- These tolerances are for components whose appearance is not critical. See Section 1-13 for architectural precast tolerances.

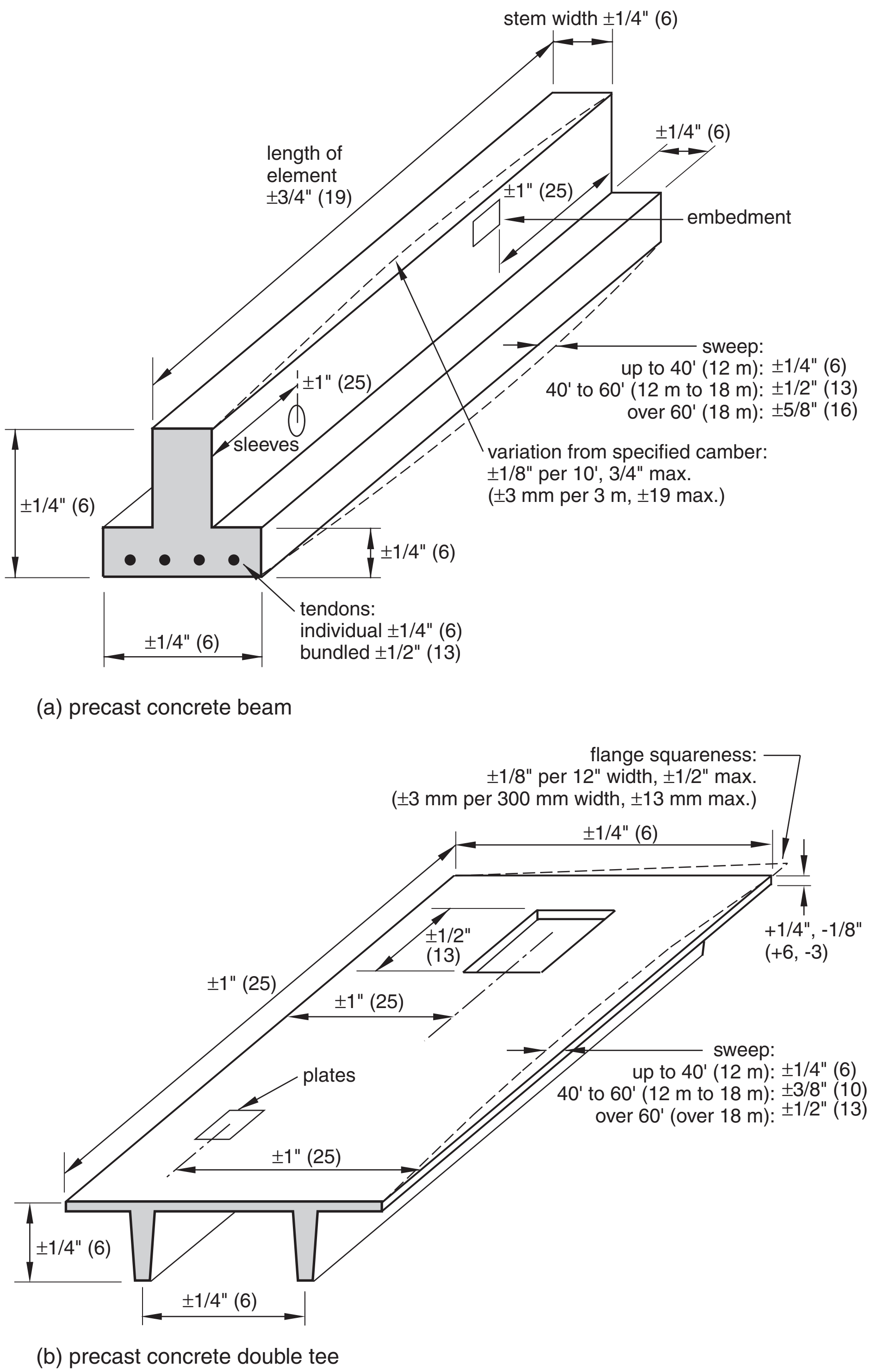
Detailing Considerations

- In general, fabrication and erection costs are proportional to the level of tolerance required. Tolerances higher than industry standard should not be specified unless they are absolutely necessary.
- Tolerances may be cumulative between two elements or between a structural element and another building component that has its own tolerance.
- Erection tolerance from the theoretical building grid is ±1/2 in. (13 mm).
- Horizontal alignment tolerance for beams is ±1/4 in. (6 mm) for architectural edges where appearance is important and ±1/2 in. (13 mm) for visually noncritical edges.
- Horizontal end alignment tolerance for double tees is ±1 in. (25 mm).
- The erection tolerances of the primary control surface are not additive to the product tolerances shown in Fig. 1-11. See Section 1-23 for more information on precast erection tolerances.

Coordination Required

- Required tolerances for each project should be included in the specifications so that there is no misunderstanding. Reference should be made to industry standard publications, such as ACI 117, or specific tolerances should be itemized, especially if they deviate from normal trade practices.

Figure 1-11 Precast beam and double tee tolerances 04 41 00



1-12 AUTOCLAVED AERATED CONCRETE PANELS

Description

Autoclaved aerated concrete (AAC) is a concrete-like material made with portland cement, lime, water, silica sand or recycled fly ash, and an expanding agent, such as aluminum powder. When combined and poured into molds, the aluminum reacts with the lime and cement to form microscopic hydrogen bubbles, expanding the mixture by about five times its original volume. Once the mixture has partially hardened, it is cut to size and steam-cured in a pressurized autoclave.

ACC is typically formed into blocks or panels for use as exterior walls, floors, and roofs and interior partitions. Blocks are typically 8 in. by 8 in. by 24 in. (200 mm by 200 mm by 600 mm), and panels are available in thicknesses from 2 in. to 15 in. (50 mm to 375 mm), 24 in. (600 mm) wide, and up to 20 ft (6000 mm) long. Bond beams and other specialized shapes are also available. The size availability of all products depends on the manufacturer. ACC is formed to varying densities, depending on the strength required. Compressive strengths of 290 psi (2.0 Mpa), 580 psi (4.0 Mpa), and 870 psi (6.0 Mpa) are available.

Because of its structural qualities and limitations, ACC is typically used as a bearing material for residential or commercial low- to mid-rise buildings, but it can be used as nonstructural cladding for buildings of any height, especially when its qualities of fire resistance, light weight, thermal mass, and sound insulation are desired. Figure 1-12 shows one possible use of an ACC panel product in a load-bearing application.

ACC provides many advantages as a building material. It is structurally sound, lightweight (about 20 to 50 lbm/ft^3 or 400 to 800 kg/m^3), easily cut in the field, fire resistant, dimensionally stable, functions as a thermal mass, and is thermally and acoustically insulating. In addition, it has many sustainable benefits. ACC is made of plentiful raw materials, and some products use recycled fly ash instead of sand. The product does not produce indoor air quality problems, nor are pollutants produced in its manufacture. ADD can be reused or ground up for use in other products at the end of a building's life cycle. The most problematic part of manufacturing is the use of energy in the autoclaving and drying process.

Panels are assembled on a thin mortar bed on the foundation with anchoring as recommended by the manufacturer. Panels used for walls can be oriented vertically or horizontally, while floor and roof panels are laid flat. Additional reinforcing bars or straps are used as required by the structural needs of the building and to anchor other building materials to the ACC. Refer to Section 2-15 for information on AAC unit masonry.

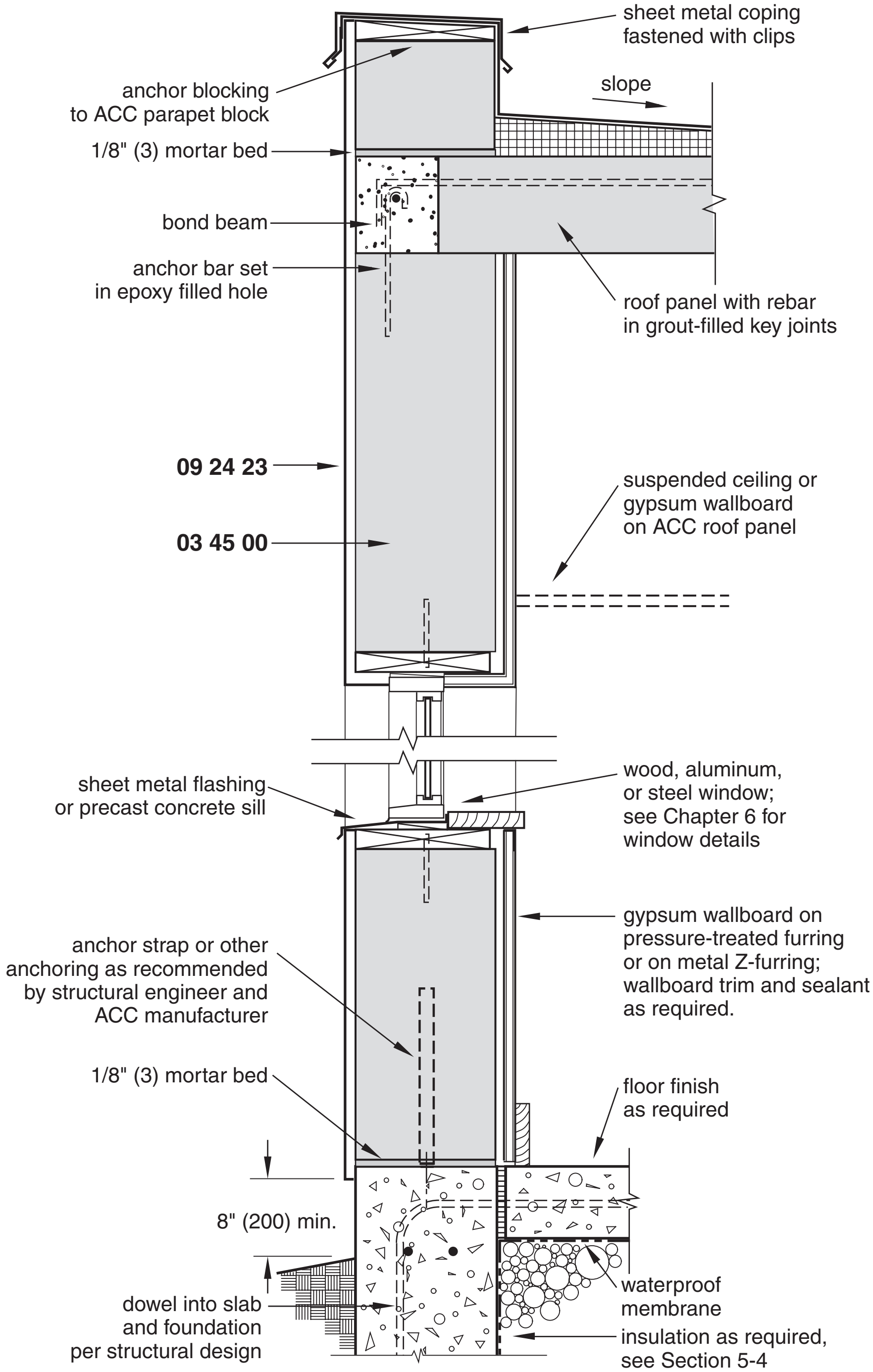
Because of its closed-cell formation, ACC is lightweight and can be cut with common power or hand tools. Shapes, reveals, signage, and other effects can also be carved or routed into the material. The R-value of ACC is approximately 1.25 $hr\text{-}ft^2\text{-}°F/Btu$ per inch (8.66 RSI/m), depending on the density, with the added benefit of having thermal mass, which can increase its effective R-value, especially in warmer climates. Because the product is uniform throughout, there is no thermal bridging due to studs or other framing.

More information can be obtained from individual manufacturers and from the Autoclaved Aerated Concrete Products Association.

Limitations of Use

- Currently, there are only a few ACC manufacturing plants in the United States, all located in Texas, Arizona, Florida, and Georgia. Although ACC is lightweight, its shipping costs may be excessive for delivery to northern locations.

Figure 1-12 Autoclaved aerated concrete panels 04 22 23.1



- Because construction with ACC is relatively new in the United States, it may be difficult to find skilled contractors and workers.
- Additional time may be required for the ACC to dry thoroughly to stabilize at its long-term moisture content of 4 percent to 8 percent. In some climates or where construction schedules are short, dehumidifiers may be required to hasten the drying process. Exterior finishes should be vapor permeable, and vapor barriers on the interior

should be limited when possible. Verify specific applications and construction details with the manufacturer.

- Blocking applied and attached to the ACC should be pressure treated.

Detailing Considerations

- Building with ACC is specific to each manufacturer. Consult with the manufacturer for materials recommended for mortar, grout, anchoring, miscellaneous fasteners, and other accessories.
- Roofs may be constructed of ACC panels, wood trusses, or other structural material as recommended by the engineer and as required by the design of the building. If ACC panels are used for a flat structural roof, use tapered insulation to provide drainage.
- Details of window and door openings may vary slightly, depending on the type of frame used. Wood frames should include a rough buck attached to the ACC. Aluminum frames may be attached directly. Verify suggested attachment of frames with the ACC manufacturer.
- Figure 1-12 shows a wood frame with a sheet metal sill and flashing on rough wood framing. A precast concrete sill may also be used; however, flashing should be installed under the concrete sill.

Coordination Required

- Verify all structural requirements with the structural engineer and manufacturer.
- Exterior finish should be vapor-permeable, polymer-modified stucco. Brick and other cladding may also be used.
- When wall and roof panels are used together, an airtight envelope is created. If possible, the building should be allowed to dry for several months before enclosing it. Alternately, the heating, ventilating, and air-conditioning (HVAC) system can be used to dehumidify the air.
- Interior wall finishes for ACC panel products are commonly mineral-based plaster applied about 1/8 in. (3 mm) thick or gypsum wallboard placed on pressure-treated furring strips. Metal furring can also be used if additional space is required for insulation or electrical services.
- Interior wall tile can be applied using a thin-set mortar or organic adhesive over a portland cement or gypsum-based base coat applied to the ACC.
- As adjacent floor panels are well aligned, floor finishes such as carpet, resilient tile or sheet goods, ceramic tile, and linoleum can be placed directly over the ACC. However, in some cases, it may be necessary to apply a topping, such as gypsum, over the ACC to provide a smooth subsurface for finish materials.

Materials

03 45 00 Autoclaved aerated concrete panel

ASTM C1452.

Strength class ACC 2.0, ACC 4.0, or ACC 6.0 as required.

Foundation attachment and reinforcing as required by the structural engineer and manufacturer.

09 24 23 STUCCO

Portland cement, polymer-modified stucco.

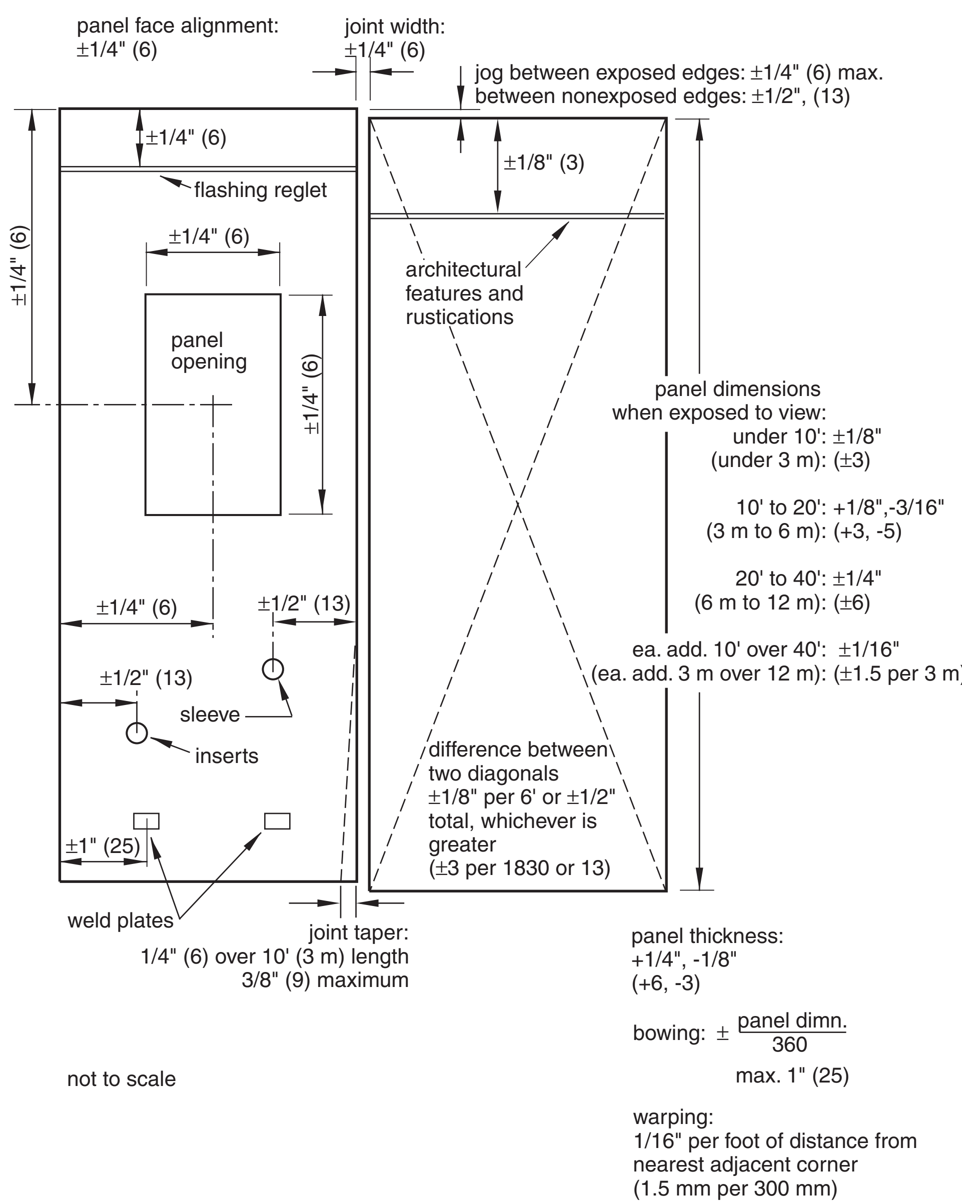
Apply according to ASTM C926 or as recommended by the ACC manufacturer.

1-13 ARCHITECTURAL PRECAST CONCRETE PANEL TOLERANCES

Description

Figure 1-13 shows some of the manufacturing tolerances for precast panels commonly used as exterior cladding. These tolerances are some of the most common ones with which architects

Figure 1-13 Architectural precast panel tolerances 03 45 13



are concerned. They can serve as a guideline for developing details of panel connections and for coordination of details with other materials. Manufacturing tolerances must be coordinated with erection tolerances and tolerances for other building systems. During construction, one surface is usually designated as the primary control surface, the location of which is controlled during erection. The product tolerances given in this section are *not* additive to the erection tolerances of the primary control surfaces. However, product tolerances are additive to secondary control surface erection tolerances. Refer to *Tolerance Manual for Precast and Prestressed Concrete Construction* (MNL-135), published by the Precast/Prestressed Concrete Institute, for more information.

Limitations of Use

- These tolerances apply to architectural panels, spandrels, and column covers.
- These guidelines are generally considered standard in the industry. If closer tolerances are required, they should be clearly indicated on the drawings and specifications. Requirements for closer tolerances should be reviewed with the precaster to determine the cost and scheduling consequences of tighter tolerances.

Detailing Considerations

- Sufficient clearance between precast units and the structural frame should be provided to allow for the erection of the precast without having to alter its physical dimensions or deviate from detailed structural connections.
- In some cases, allowable tolerances for steel or concrete framing in tall buildings may require that attachment of precast elements follow the frame up the height of the building without being in a true plane.
- Details should be developed so that architectural precast elements overlap cast-in-place framing. This conceals any differential tolerances in the two materials.
- Bowing is an overall out-of-plane condition in which the corners of the panels may be in the same plane but the portion between the corners is out of plane. Warping, on the other hand, is an out-of-plane condition in which the corners do not fall in the same plane. Both conditions can affect the alignment and appearance of panels. The difference between diagonals applies to major openings as well as to the panel itself.
- The likelihood of bowing or warping is decreased if the panel contains ribs or other design features that provide additional stiffness.
- In some instances, the higher cost of tooling required for close tolerances may be offset by the use of a highly repetitive panel product.

Coordination Required

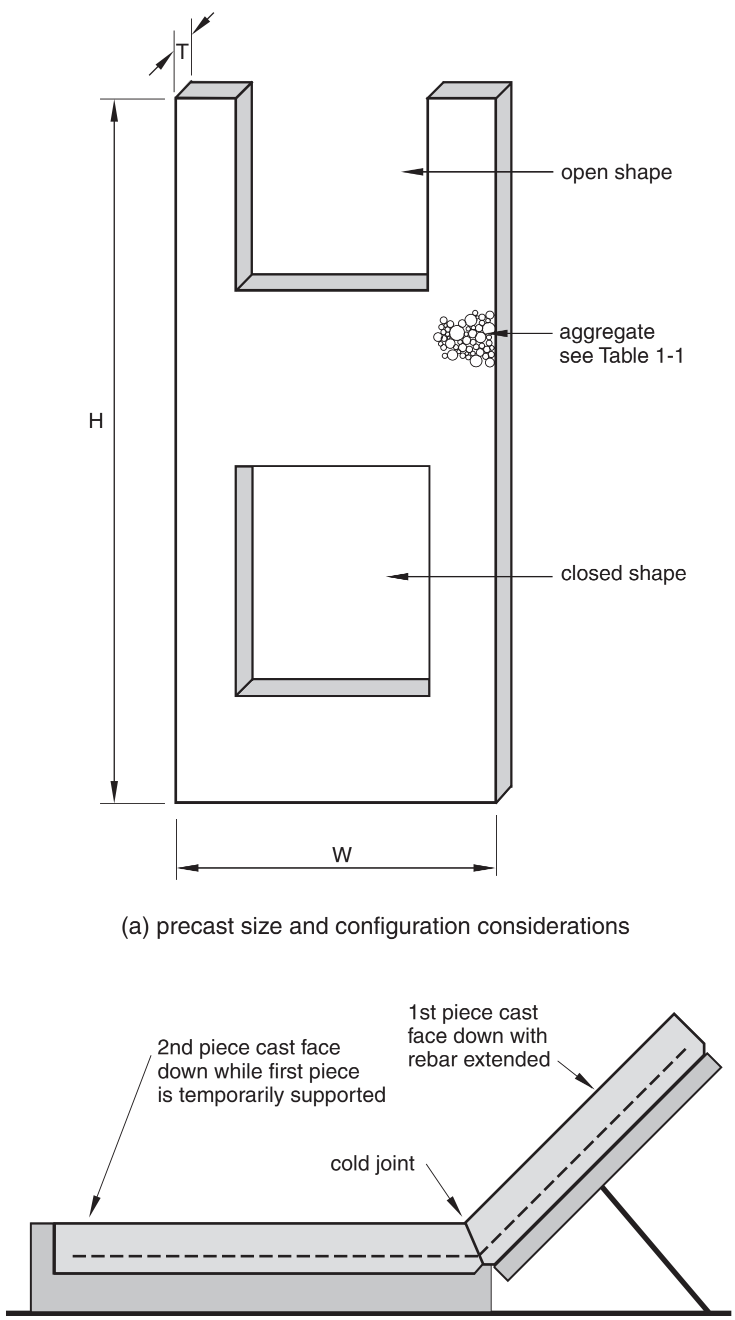
- Required tolerances for each project should be included in the specifications so that there is no misunderstanding. Reference should be made to industry standard publications, such as ACI 117, the AISC *Code of Standard Practices,* and the *Tolerance Manual for Precast and Prestressed Concrete Construction* or specific tolerances should be itemized, especially if they deviate from normal trade practices.

1-14 ARCHITECTURAL PRECAST PANEL SIZE AND CONFIGURATION

Description

Figure 1-14 illustrates some of the considerations for determining the size, general configuration, and typical detailing requirements for non-load-bearing architectural precast concrete

Figure 1-14 Architectural precast panel size and configuration 03 45 14



(a) precast size and configuration considerations

(b) sequential precasting

panels. These types of panels are used for window walls, column and beam covers, spandrel panels, mullions, and similar applications. Figure 1-14(a) illustrates a panel cast in one operation. For more complex shapes, panels can be fabricated in two or more castings, as shown in Fig. 1-14(b). Because there are so many possible variations of precast panels, this section only outlines some of the general requirements.

Limitations of Use

- Non-load-bearing panels only resist forces resulting from transfer of wind and seismic loads and transfer of the panel's own weight to the structure.
- Special connections, which allow pronounced lateral movement, are required in high seismic areas.

Detailing Considerations

- Closed shapes are easier to handle than open shapes due to their inherent rigidity. Open shapes may require more reinforcing, temporary braces during transportation and erection, and thicker castings.
- Precast panels should be made as large as possible to minimize shipping and erection costs. Large panels also minimize the number of joints, which must be sealed in the field. The maximum size of panels is usually determined by the limitations of the precasting plant, transportation, and clearances at the job site for access and erection.
- Although minimum panel thickness depends on many factors, such as the minimum cover required over reinforcing, the following guidelines for slenderness ratios are useful for preliminary design decisions. The slenderness ratio is the panel thickness, T, divided by the unsupported length when the panel is in its final position.
  - Flat panels that are not prestressed: 1/20 to 1/50.
  - Flat panels that are prestressed: 1/30 to 1/60.
- Connections of adjacent panels should be designed to minimize deviation in casting and erection tolerances.
- Provide adequate clearances between the structure and the panel to allow access for making adjustments and connections.
- Panel shapes should be designed to minimize the number of joints.
- When possible, a single spandrel panel should be used in lieu of several smaller panels. The connections should be made at the column lines to minimize deflection of the floor slab and to reduce the size of or eliminate the need for an edge beam.
- Connections should be designed to allow for lateral translation and frame shortening. See Section 1-19.

Coordination Required

- The optimum panel size for a project can best be determined with close coordination between the architect, the engineer, and the precast fabricator.
- Maximum panel size may depend on the available room on site for truck access and crane capacity and location.
- The optimum panel size may be controlled by the local highway load limits and the maximum truck size. Although regulations vary by state, standard flatbed trucks can carry loads 8 ft (2440 mm) wide by 8 ft (2440 mm) high by 45 ft (13.7 m) long without a special permit. With other types of trucks and permits, the size can be increased to

Table 1-1 Concrete Aggregate Visibility

Aggregate size, in in. (mm)	Distance at which texture is visible, in ft. (m)
1/4–1/2 (6–13)	20–30 (6.1–9.1)
1/2–1 (13–25)	30–75 (9.1–22.9)
1–2 (25–51)	75–125 (22.9–38.1)
2–3 (51–76)	125–175 (38.1–53.3)

accommodate panels from 10 to 12 ft (3050 mm to 3660 mm) wide. The typical load limit is 20 tons (18,140 kg). Exact requirement for each geographic area should be determined early in the design process.

- One of the criteria for determining aggregate size is the desired appearance of the finished concrete. For textured surfaces to be apparent, the size of the aggregate used depends on the typical distance from which the concrete will be viewed. Table 1-1 gives the recommended aggregate size for various viewing distances. Note that this is based on a single-color aggregate. A full-size mock-up should be constructed before the final aggregate size is specified.
- Detailing of the panels may require provisions for window-washing equipment.
- Expected frame shortening must be calculated to establish the actual elevations required for fabricating the panels.

Likely Failure Points

- Unequal deflection between adjacent panels because they are supported on portions of the building structure that have differing stiffnesses
- Bowing and cracking of the panel caused by thermal gradients and rigid restraint on all four edges

1-15 ARCHITECTURAL PRECAST CONCRETE FORMING

Description

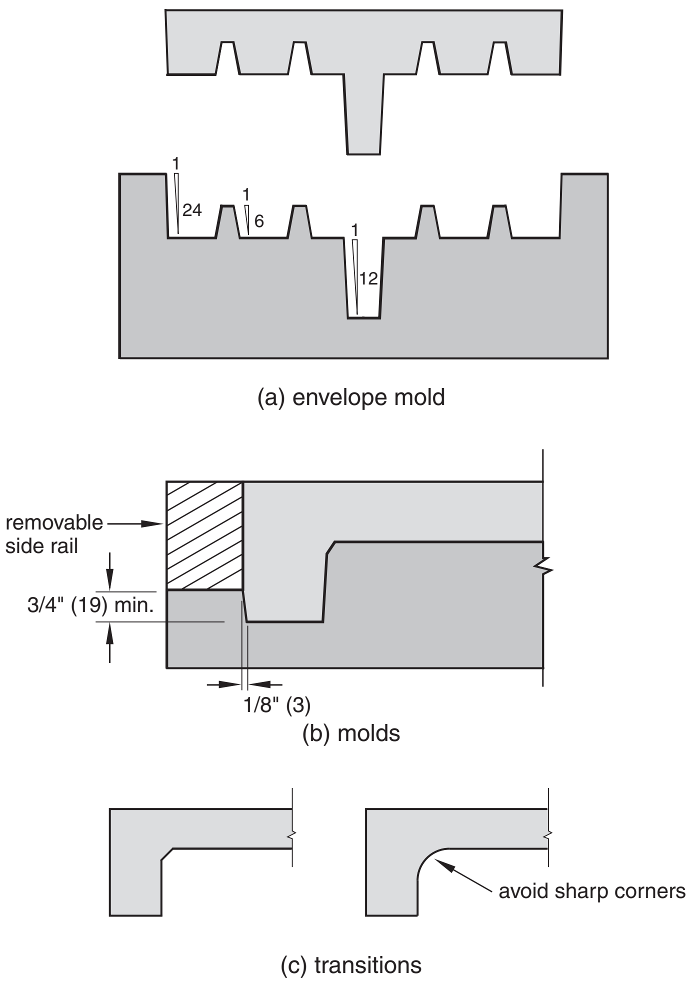
This section gives general guidelines for developing precast details based on the limitations and requirements of the precast forming process. Although an enormous range of shapes, details, and finishes is possible with precast concrete, economic considerations usually require the designer to limit the number and complexity of individual shapes.

The greatest economy is achieved with the use of an envelope mold, as shown in Fig. 1-15(a). With this type of mold, all surfaces and sides remain in place during casting and stripping. However, the normally high tooling costs for envelope molds require high reuse to make them economical. Other types of molds, such as the one shown in Fig. 1-15(b), require one or more pieces to be removed before the concrete is stripped. This makes complex shapes possible but increases the cost and time required for forming. In addition, there is an increased chance of misalignment when the removable sections are reinstalled for the next casting.

Limitations of Use

- Because of the many variables in selecting the optimum forming method, consult with local precasters early in the design process.

Figure 1-15 Architectural precast concrete forming 03 45 15



- Envelope molds do not allow lifting hooks to be installed in the sides of a panel.
- Figure 1-15(a) illustrates one-piece forming. Individual units may be formed from two or more castings with cold joints, as shown in Fig. 1-14(b). In addition, molds may be rotated during casting to obtain a uniform surface finish on multifaceted units.
- Negative drafts are possible but require removable form pieces.

Detailing Considerations

- The greatest economy is achieved by limiting the number of molds that must be made and by reusing the same master mold as many times as possible. However, several different configurations can be made from one master mold by the use of blockouts and bulkheads.
- The draft, or slope, of side pieces on a panel should be designed within the minimum limitations shown in Fig. 1-15(a). Side forms should have a 1:24 draft, panel projections a 1:12 draft, and false joints, ribs, and reveals a 1:6 draft. Removable side pieces such as the one shown in Fig. 1-15(b) allow flat edges to be formed and conceal any leakage that may occur by locating it away from the visible face of the panel.

- Avoid the use of thin or fragile edge pieces.
- Whenever possible, design chamfered or rounded edges, as shown in Fig. 1-15(c), to minimize the possibility of edge damage and to conceal slight misalignment between panels.
- Design gradual transitions from one mass of concrete to another.

1-16 ARCHITECTURAL PRECAST CORNERS

Description

Figure 1-16 illustrates two common methods for forming outside corners with adjacent precast concrete and for providing for adjustment at corner points. The primary considerations in designing corners are to avoid special corner molds whenever possible, providing for corners that minimize chipping, allowing for alignment of the panels, and providing the proper joint width for sealants.

Figure 1-16 Architectural precast corners 03 45 16

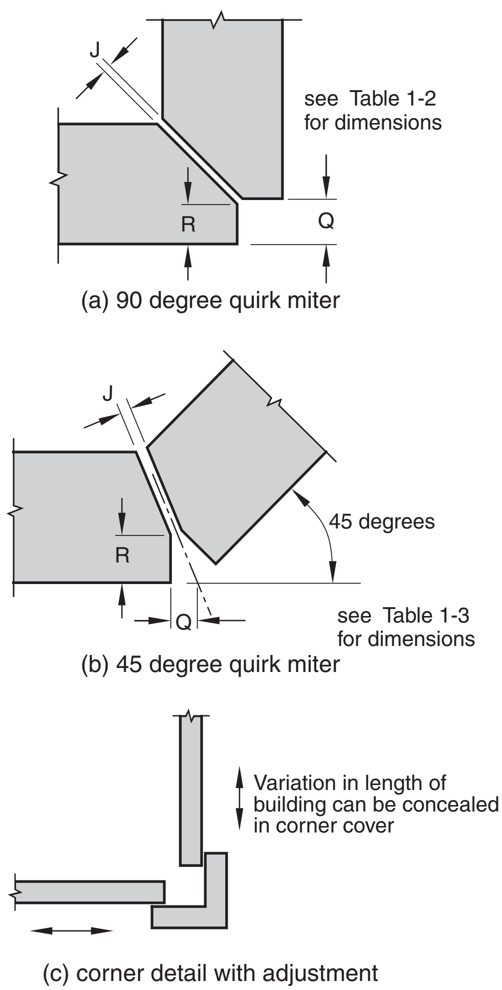


Table 1-2 Recommended Dimensions of 90 Degree Quirk Miters, in. (mm)

	Quirk, Q		Return, R	
Joint, J	in.	mm	in.	mm
3/4 (19)	1 1/4	32	3/4	19
	1 1/2	38	1	25
	1 3/4	44	1 1/4	32
	2	51	1 1/2	38
1 (25)	1 1/2	38	13/16	21
	1 3/4	44	1 1/16	27
	2	51	1 5/16	33

Detailing Considerations

- Whenever possible, edges should be chamfered or rounded to minimize the possibility of edge damage and to conceal slight misalignment between panels. The optimum size of a radius depends on the size of the aggregate, the mold materials, and the production techniques used.
- When the aggregate size exceeds 1 in. (25 mm), it should be stopped at a demarcation joint (see Fig. 1-17) and a smooth outside corner made with a 1/4 in. to 1/2 in. (6 mm to 13 mm) radius.
- If possible, outside corners should be formed from the same type of panels used for the walls. This avoids the need to make a special mold just for the corners.
- Forty-five and ninety degree corners should be formed with a quirk miter, as shown in Fig. 1-16(a and b). Quirk returns should not be less than 3/4 in. (19 mm) or 1.5 times the maximum size of the aggregate. The sizes of quirks and returns based on joint widths as recommended by the Precast/Prestressed Concrete Institute are given in Tables 1-2 and 1-3.
- To avoid alignment problems with mitered corners, a separate corner piece may be cast or the miter connection assembled in the shop and shipped to the site in one piece.

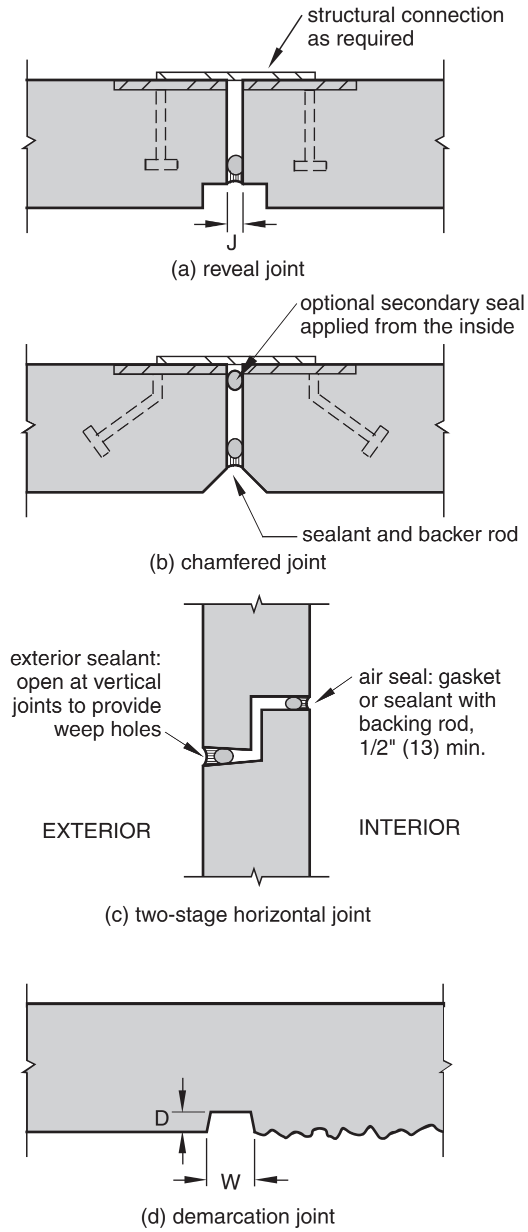
Coordination Required

- Detail corner pieces to accommodate erection tolerances.
- Size and locate joints to accommodate building movement as well as fabrication and erection tolerances. The proper type of sealant must be selected to fit the joint and allow for expected movement. See Section 1-17.

Table 1-3 Recommended Dimensions of 45 Degree Quirk Miters, in. (mm)

Joint width, J in in. (mm)	Quirk, Q, in in. (mm)	Return, R, in in. (mm)
3/4 (19)	3/4 (19)	13/16 (21)
	7/8 (22)	1 1/16 (27)
1 (25)	7/8 (22)	13/16 (21)
	1 (25)	1 1/16 (27)

Figure 1-17 Architectural precast joints 03 45 17



- Accommodation for variations in the overall length of the building frame and casting tolerances may be taken up with the corner pieces or with joints between panels. Some types of corner designs do not allow any tolerances to be made up at the corner. See Fig 1-16(c).

Likely Failure Points

- Misalignment of mitered corners due to normal fabrication and erection tolerances
- Cracks caused by sharp transitions between areas of unequal mass

1-17 ARCHITECTURAL PRECAST JOINTS

Description

Like other types of construction, joints in precast concrete components are required to join several pieces together, to allow for fabrication and erection tolerances, and to accommodate movement caused by temperature changes, moisture, structural loading, and deflection.

The most common type of precast joint is a one-stage joint field molded with elastomeric sealants. See Fig. 1-17(a and b). Two-stage joints, as shown in Fig. 1-17(c), are sometimes used in areas subject to severe weather. Two-stage joints are detailed to provide a vented cavity behind the exposed concrete. The cavity equalizes pressure between the outside and the inside and allows any water that penetrates the outer surface to drain back to the outside before it penetrates the interior seal.

Limitations of Use

- The guidelines given here are for one-stage joints only.
- Good inspection and maintenance are required for one-stage joints to ensure that the weathertightness of the joint is maintained throughout the life of the building.
- This detail does not include major building movement joints or preformed compression sealants or gaskets.

Detailing Considerations

- The number of joints should be kept to a minimum whenever possible.
- Joints should be located at the maximum panel thickness.
- Joints should be recessed with a reveal or chamfer, as shown in Fig. 1-7(a and b). This not only minimizes the appearance of slightly nonaligned panels but also provides a channel for rain runoff.
- A second seal is often applied behind the exposed seal. This seal can be applied from the outside or the inside. However, the cavity created should be vented and drained to the outside, just as with a two-stage joint.
- Avoid joints in forward-sloping surfaces such as under window sills.
- Joints should be aligned vertically and horizontally instead of being staggered.
- For demarcation joints, as shown in Fig. 1-17(d), the minimum depth of the joint, *D*, should be at least 1.5 times the aggregate size. The width, *W*, should be greater than the depth and equal to a standard dimensional lumber size, such as 3/4 in. or 1 1/2 in. (19 mm or 38 mm).
- Joint width should be determined by the expected movement of the joint, the movement capability of the sealant, fabrication tolerances, and the appearance desired. Generally, precast joints should never be less than 1/2 in. (13 mm). Most joints are between 1/2 in. (13 mm) and 3/4 in. (19 mm) wide. Unless otherwise specified by the manufacturer, the depth of the joint depends on the width according to the following guidelines:
  - Sealant depth should be equal to the width of the joint up to 1/2 in. (13 mm) with a minimum depth of 1/4 in. (6 mm).
  - For joints 1/2 in. to 1 in. (13 mm to 25 mm) wide, the sealant depth should be one-half of the width.

- For joints wider than 1 in. (25 mm), the sealant depth should be 1/2 in. (13 mm) maximum.
- Joint width can be calculated using the procedures given in Section 5-38.

Coordination Required

- Joints must accommodate thermal movement, structural deflections, creep, and building drift.
- Sealants must be compatible with the expected movement of the joint. Proper preparation and priming of the joint are required for a good installation.
- Backer rod sizes should be selected so that, when installed, they are compressed 30 percent to 50 percent.
- Because sealants must be applied over relatively smooth surfaces, panel finishes, especially on inside corners, must be detailed to provide an appropriate base for the sealant.

Likely Failure Points

- Water leakage caused by pressure differentials between the inside and outside of a single-stage joint
- Dirt accumulation in joints due to slow-curing sealants
- Sealant failure when joints are staggered, causing possible shear forces to be induced in the sealant

Materials

- Nonstaining elastomeric joint sealants should be specified. For precast concrete, either one- or two-component polysulfides, polyurethanes, or silicones are used.
- Refer to Section 5-38 for sealant types and recommendations.

1-18 ARCHITECTURAL PRECAST WEATHERING DETAILS

Description

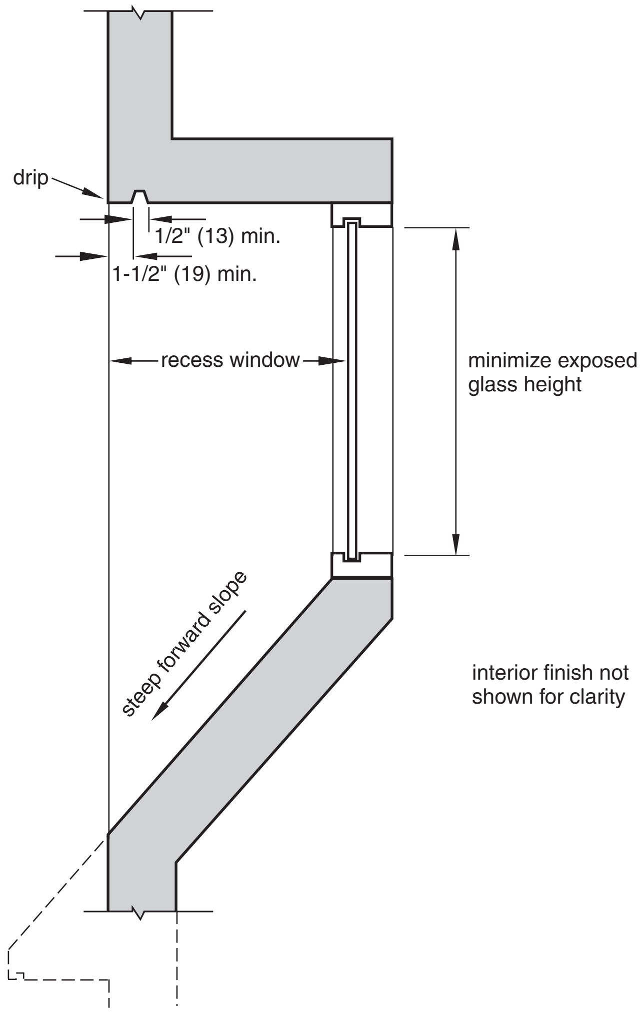
Weathering is the change in appearance of a building component over time caused by the effects of the environment. One of the most common effects of weathering on architectural precast units is the staining of accumulated, water-washed dirt on surfaces, creating an undesirable appearance.

The effects of weathering are complex because of the many variables involved. Weathering can be affected by the texture and orientation of precast surfaces, local climatic conditions, the type of dirt and pollution in the air, and the amount and location of glass, among other factors. This section outlines only a few of the many considerations useful for developing architectural precast sections that will weather well. See Fig. 1-18.

Detailing Considerations

- If possible, water runoff should be directed away from the building with overhangs, drips, and other treatments. Drips should be provided at soffits and under any horizontal

Figure 1-18 Architectural precast weathering details 03 45 18



projections. Drips may be stopped short of the sides of recessed areas by about 1 in. or 2 in. (25 mm to 51 mm) to avoid water concentrations at the sides of the recess.

- Sloped surfaces should be smooth, with a steep angle to encourage natural washing.
- Windows should be recessed when possible and protected from runoff from vertical surfaces above to avoid staining and streaking on the glass. Water flow on a window tends to concentrate toward the edges, so provisions should be made to collect this water and direct it away from the building or disperse it.
- When windows are flush or nearly flush with the vertical concrete surface, the precast should be textured or have projections such as vertical ribs to disperse the water flow and conceal any staining.
- Because vertical surfaces and elements such as projecting fins can concentrate water, the intersection of vertical and horizontal surfaces should be given special attention. As shown in the detail, this may take the form of drips over vertical surfaces. Avoid stopping vertical joints flush with a solid panel face.

- Special consideration should be given to runoff under windows because wind-driven water will run off the glass faster than on adjacent concrete surfaces, resulting in differential staining.

Coordination Required

- To minimize the visibility of weathering, precast concrete units should have a gray or dark color and either a rough texture or a polished or honed surface.
- Sealing the concrete may lessen the effects of weathering by reducing absorption of the concrete and by increasing natural washing of the surfaces.
- If window framing is flush with the concrete surface, drips may be built into the window head rather than in the precast panel.

1-19 ARCHITECTURAL PRECAST PANEL CONNECTIONS

Description

Figure 1-19 illustrates some of the basic principles for designing non-load-bearing precast panel connections to a structural frame. Because there are so many possible connection details to meet the requirements of a specific project, this section only gives general guidelines for preliminary design. In most cases, the final connection design will depend on several variables in addition to the preferences of the precast fabricator.

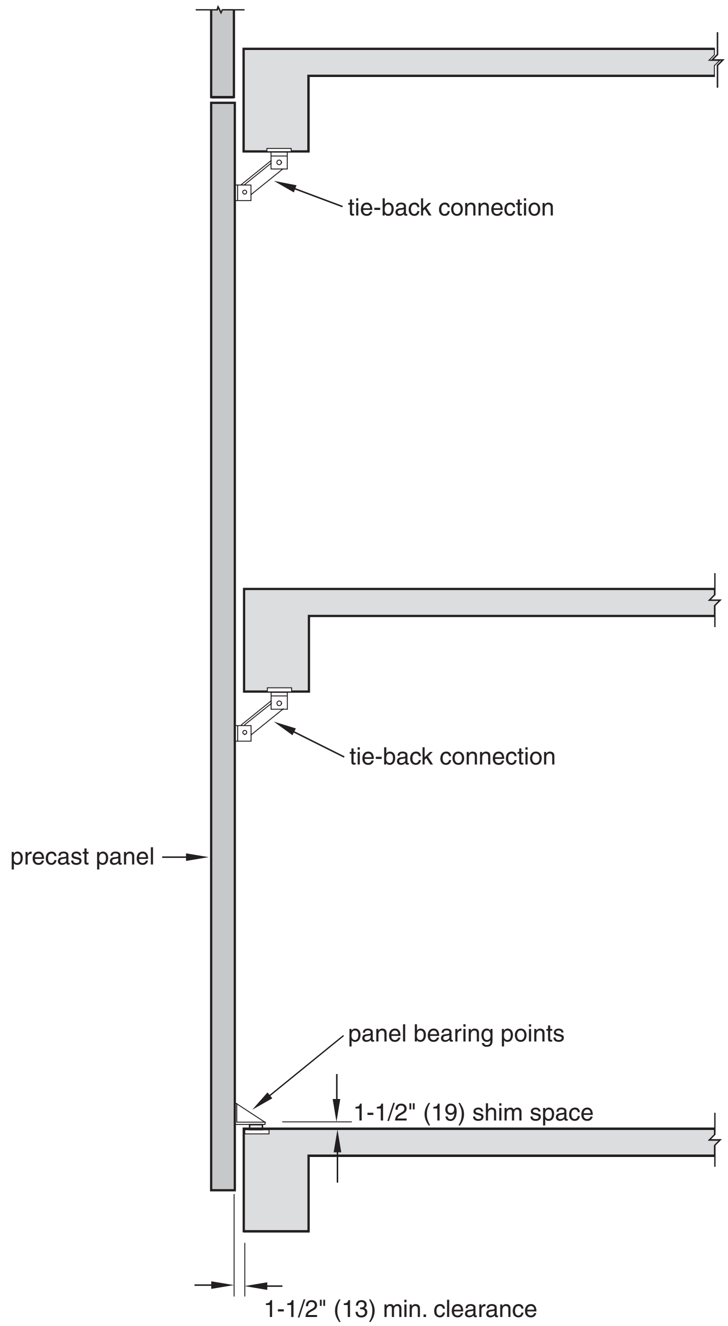
Limitations of Use

- Detailed engineering design is required for panel reinforcement as well as for individual connector design.
- Special engineering design is required in high seismic areas.

Detailing Considerations

- Only two points of bearing should be designed into the panel support system. These are best located on only one structural level at the bottom of the panel, as shown in Fig. 1-19, but they may be located at the top of the panel or at the intermediate floor. One bearing point should have a rigid connection, and the other should allow for lateral movement. Other tie-back connections should allow for movement vertically and laterally.
- Panel connections should provide for at least 1 in. (25 mm) of vertical adjustments and 2 in. (51 mm) of horizontal adjustments to accommodate manufacturing and erection tolerances of both the panel and the building frame. Slotted holes, oversized weld plates, leveling bolts, shims, and similar devices can provide for these adjustments. Clearances and shim space, as shown in Fig. 1-19, should also be provided.
- Tie-back connections may be made with bolted connections, weld plates, or rods.
- Connections should be standardized as much as possible throughout the building.
- Connection locations must allow room for accessibility during erection.

Figure 1-19 Architectural precast panel connections 03 45 19



Coordination Required

- Because panels spanning two or more floors should not be supported on alternate floors, one floor should be designed by the structural engineer to carry the gravity load of all the panels adjacent to that floor.

Likely Failure Points

- Cracking of the panel if a sufficient number of points of connection do not allow for movement

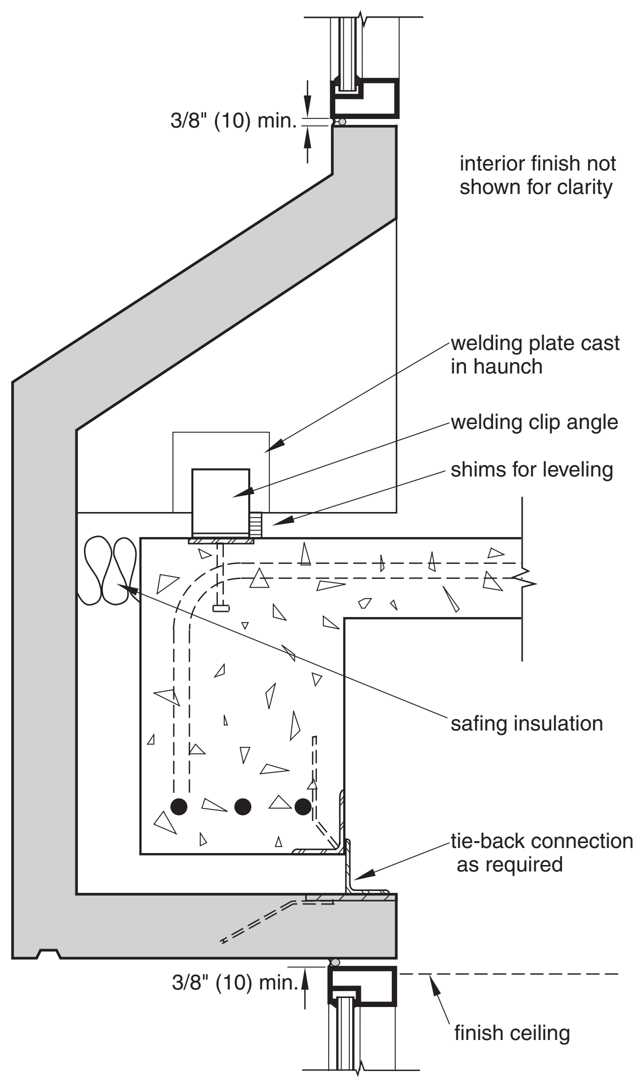
- Cracking or other damage to the panel caused by differential movement of the supporting structure if the panel is supported at more than one level

1-20 ARCHITECTURAL PRECAST SPANDREL PANELS

Description

Figure 1-20 illustrates some of the construction requirements that should be considered in developing details for non-load-bearing spandrel panels. As with precast panel connections, there are many possible configurations and connection details for spandrel panels. Therefore, Fig. 1-20 only gives a few of the general requirements that are helpful for the preliminary design. A concrete structural frame is indicated, but panels can just as easily be attached to a steel frame. See Fig. 1-10 for another type of spandrel panel.

Figure 1-20 Architectural precast spandrel panels 03 45 20



Limitations of Use

- This detail shows the use of non-load-bearing spandrel panels only.
- Detailed engineering design and review with the precast fabricator are required prior to developing details for a specific project.
- Special engineering design is required in high seismic areas.

Detailing Considerations

- If possible, spandrel panels should be cast in one piece to span between columns and should be attached to the columns as close to their centerlines as possible. This avoids possible differential movement between the floor structure and the panel. Figure 1-20 shows a typical bearing connection made at the floor line instead of at the column.
- Two bearing points are preferred, one rigid and one allowing for lateral displacement to accommodate temperature changes and frame movement.
- Avoid supporting spandrel panels on cantilevered beams or floor slabs.
- Connections should be standardized as much as possible throughout the building.
- Design connection locations to allow room for accessibility during erection.

Coordination Required

- Provisions must be made for the placement and anchoring of window frames. Generally, a 3/8 in. (10 mm) minimum shim space should be provided between the precast unit and the window frame.
- In cold climates, provisions for installing insulation must be considered.
- Safing insulation is required between the fire-rated structure and the back of the panel.
- Complex spandrel panel shapes may create problems with erection inside the line of crane cables. The precast fabricator and erector should be consulted.

1-21 ARCHITECTURAL PRECAST PARAPET

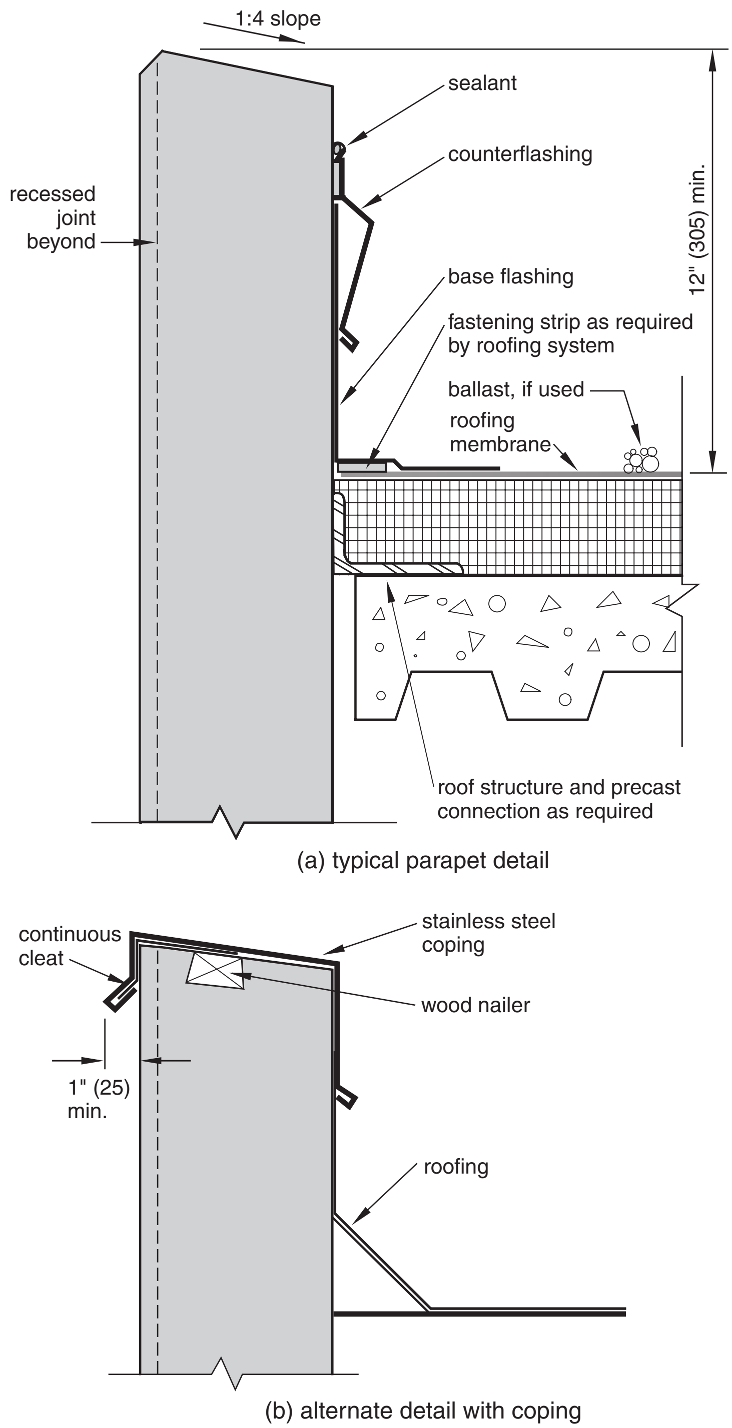
Description

Figure 1-21 shows some of the detail requirements for roofing at a precast concrete parapet. Although cap flashing over the top of the parapet may be used, most designers prefer not to expose a strip of metal along the top edge. However, if coping is not used, the horizontal panel joints on top of the parapet must be given careful consideration. In addition, this detail illustrates the use of surface-applied counterflashing rather than a recessed flashing reglet cast into the panel because it is difficult to achieve close enough tolerances so that the cast-in reglets match up at adjacent panels.

Limitations of Use

- This detail shows only one general method of describing a single-ply roof. The exact details of the precast panel must be coordinated with the type of roofing used.
- This detail does not address the use of gravel stops.

Figure 1-21 Architectural precast parapet 03 45 21



Detailing Considerations

- The top of the parapet should be sloped toward the roof to prevent runoff over the face of the precast panel.
- The parapet should be a minimum of 12 in. (305 mm) high to prevent water from being blown over the edge of the parapet. However, this minimum dimension may need to

be increased based on the minimum distances from roof surface to counterflashing demanded by the specific type of roofing system used. See Chapter 5 for roofing details.

- Metal counterflashing must not be attached to the roofing membrane. Metal should not be used for base flashing.
- Surface-applied counterflashing should be attached to the concrete panel with slotted anchor holes.
- Provide slip joints between adjacent pieces of counterflashing (and cap flashing, if used) to allow for panel movement.
- If cap flashing is used over the parapet, the drip edge on the face of the panel should extend at least 1 in. (25 mm) from the panel's face. The top of the wall may also be capped with a stone or cast stone coping.
- Provide expansion space between the edge of the roof and the precast panel if large movements are expected. See Figs. 5-17, 5-22, and 5-27.
- The side of the panel to receive single-ply roofing must have a smooth trowel finish.

Coordination Required

- Specific types of roofing systems will require modifications to the schematic arrangement shown in this detail.
- Some flashing materials, such as copper, may cause staining on precast concrete.
- Built-up and modified bitumen roofing require cant strips.
- Flashing reglets normally have an installation tolerance of $\pm 1/4$ in. (6 mm). However, for roof flashing, the dimension from the top of the panel to the reglet should be held to $\pm 1/8$ in. (3 mm).
- Exposed concrete surfaces on the back of the parapet should be waterproofed.
- Flashing installation should be periodically inspected. Regular maintenance is required to prevent leakage.

Likely Failure Points

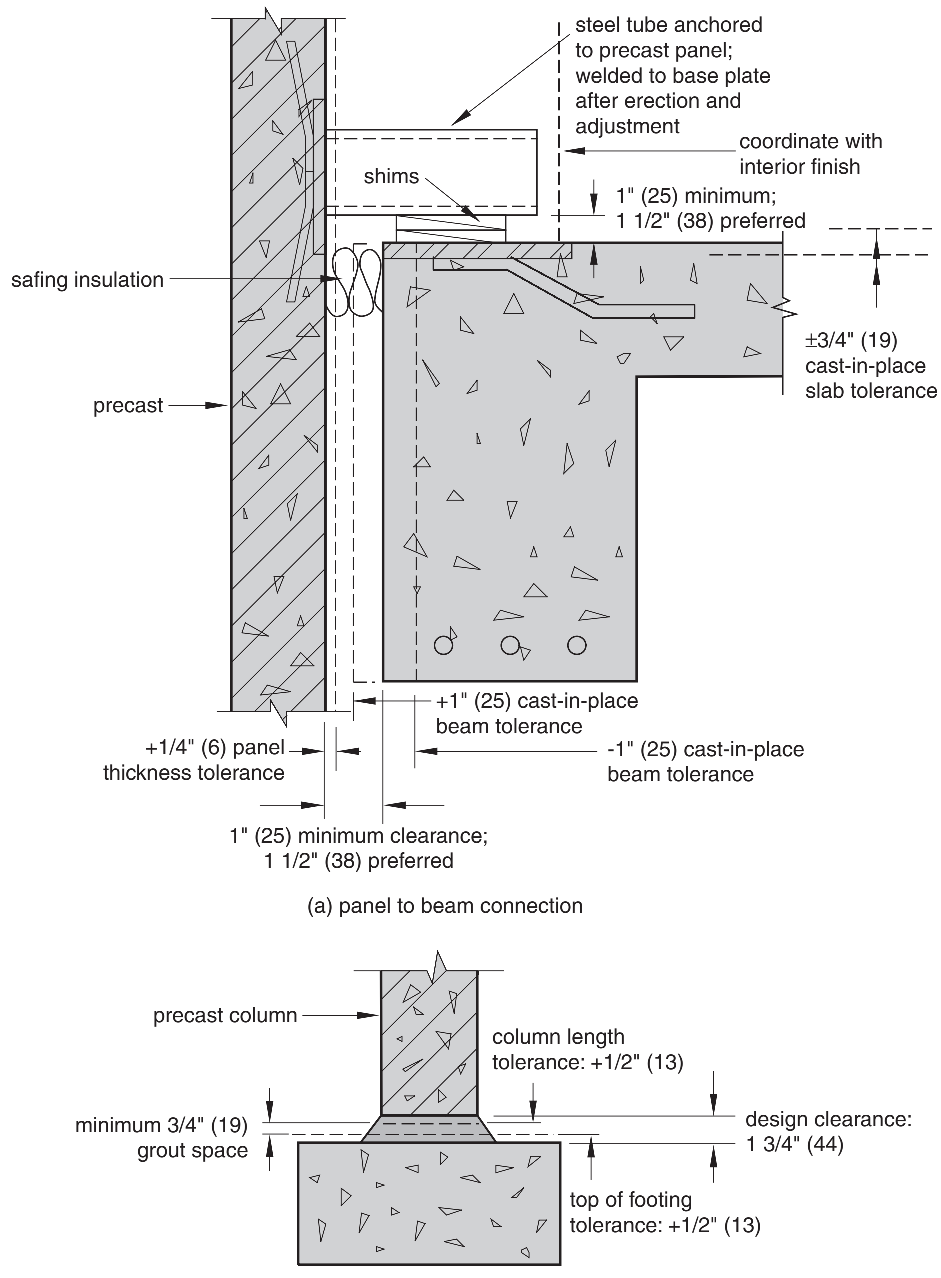
- Splitting or tearing of the roofing membrane if cap flashing or counterflashing is fixed to the roofing
- Water leakage caused by sealant failure at the horizontal joints along the top edge of the parapet
- Buckling or failure of counterflashing if adequate slip joints are not provided

1-22 CAST-IN-PLACE/PRECAST CONNECTION

Description

Figure 1-22 illustrates one of many ways to attach a precast panel to a cast-in-place concrete frame and to attach a precast column to a cast-in-place foundation. Because both systems have relatively large tolerances, connection detailing must accommodate the worst expected combination of tolerances while still providing for erection clearances and minimizing erection time.

Figure 1-22 Cast-in-place/precast connection 03 45 90



(a) panel to beam connection

(b) column to footing connection

Figure 1-22(a) shows a steel tube welded to a plate cast into the panel. Other steel shapes, such as angles and channels, can be cast into the panel to provide a connection. Vertical adjustment can be made with shims or with leveling bolts.

The recommended lateral design clearance is 1½ in. (38 mm). This allows the beam to be out by the maximum of 1 in. (25 mm) and the panel thickness to be over by the allowable ¼ in. (6 mm).

Figure 1-22(b) shows the design clearance required to accommodate tolerances for both cast-in-place footings and precast columns. The footing height must be designed to accommodate possible variations in the length of the column and placement tolerances of the footing while providing for sufficient clearance for grouting under the base plate cast onto the bottom of the column. In most cases, the elevation of the haunch used to support beams or panels is the primary control surface and may determine the clearance between the bottom of the column and the top of the footing.

Limitations of Use

- Figure 1-22 shows only one possible method of attachment. The structural engineer and the precast manufacturer should be consulted to determine the most appropriate connection method.
- This detail shows a gravity connection. For large panels, tieback connections are also required, as shown in Fig. 1-19.
- The specific connection method must be coordinated with the interior finish and mechanical system so that the steel support and any piping are concealed.

Detailing Considerations

- For horizontal alignment of several panels within a cast-in-place structural bay, the vertical joints are typically used to accommodate tolerance problems, with each joint accommodating a portion of the total expected tolerance. Procedures for determining joint width are given in Section 5-38.
- Connections should be designed to be made on the top of the concrete frame so that access is not required between the back of the panel and the face of the beam.
- To minimize costs, the connections should be designed to minimize the time the panel must be held in place with a crane while adjustments and fastenings are made.
- If the cast-in-place beam and floor structure are large enough, a blockout may be used to keep the top of the steel connection below the level of the floor to minimize conflicts with interior finishes.

Likely Failure Points

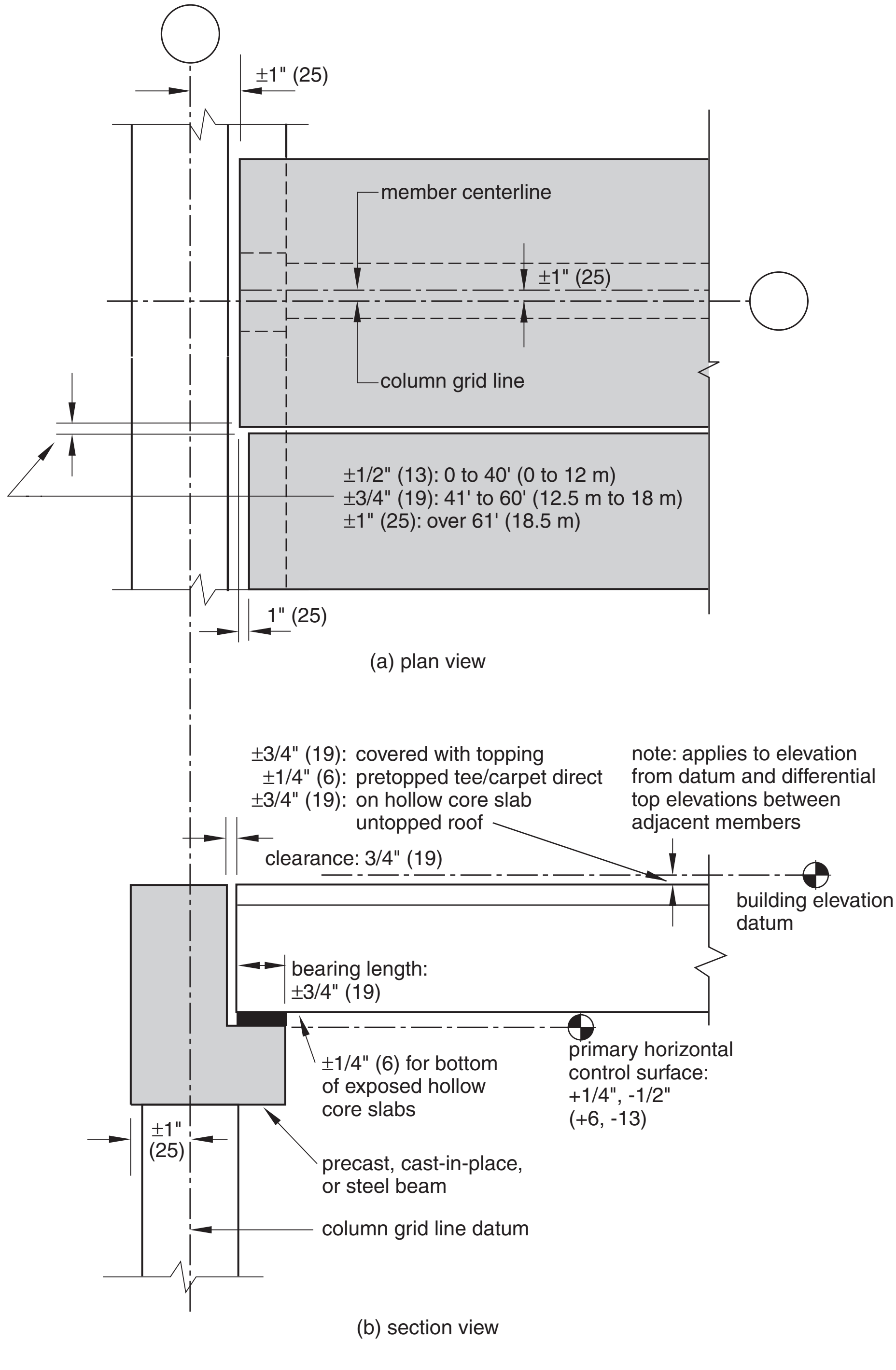
- Failure of the connection due to eccentric loading when excessive tolerances are encountered.

1-23 PRECAST FLOOR/BEAM ERECTION TOLERANCES

Description

The tolerances shown in Fig. 1-23 are recommended tolerances rather than strict standards for floor and roof members. They are reasonable variations that can be expected in most situations. However, because precast erection is subject to many variables and because some situations are visually more critical than others, tolerances should be reviewed with the precast supplier prior to finalizing specifications. To minimize costs, the tolerances described in this section can be increased where the members will be covered with other finish material or in structures where visual appearance is not critical.

Figure 1-23 Precast floor/beam erection tolerances 03 45 91



Limitations of Use

- This section includes only some of the tolerances for precast elements. For a complete listing, refer to *Tolerance Manual for Precast and Prestressed Concrete Construction*, published by the Precast/Prestressed Concrete Institute.

Detailing Considerations

- The erection tolerances shown in this section apply to precast elements attached to other precast elements, to cast-in-place concrete or masonry, and to steel members.
- The erection tolerances shown in this section must be coordinated with manufacturing tolerances and tolerances for other building systems to which the precast system is connected. The erection tolerances are based on the primary control surfaces, which are the surfaces that are controlled during erection. The erection tolerances are *not* additive to any product tolerances. However, erection tolerances are additive to the product tolerances for secondary control surfaces.
- When a precast beam is placed on a steel column, the 1 in. (25 mm) horizontal location tolerance still applies, but it is measured from the centerline of the steel.

1-24 GLASS FIBER REINFORCED CONCRETE PANELS

Description

Glass fiber reinforced concrete (GFRC) is a product manufactured with a cement/aggregate slurry reinforced with alkali-resistant glass fibers. GFRC panels are typically used for exterior cladding, column covers, and interior finish panels. They can be manufactured with or without a face mix of conventional concrete with decorative aggregates. When a face mix is used, GFRC panels have the same appearance as standard precast concrete panels. Because of their light weight, GFRC components are easier and less expensive to transport and install than precast concrete and can be manufactured in a wide variety of shapes and sizes.

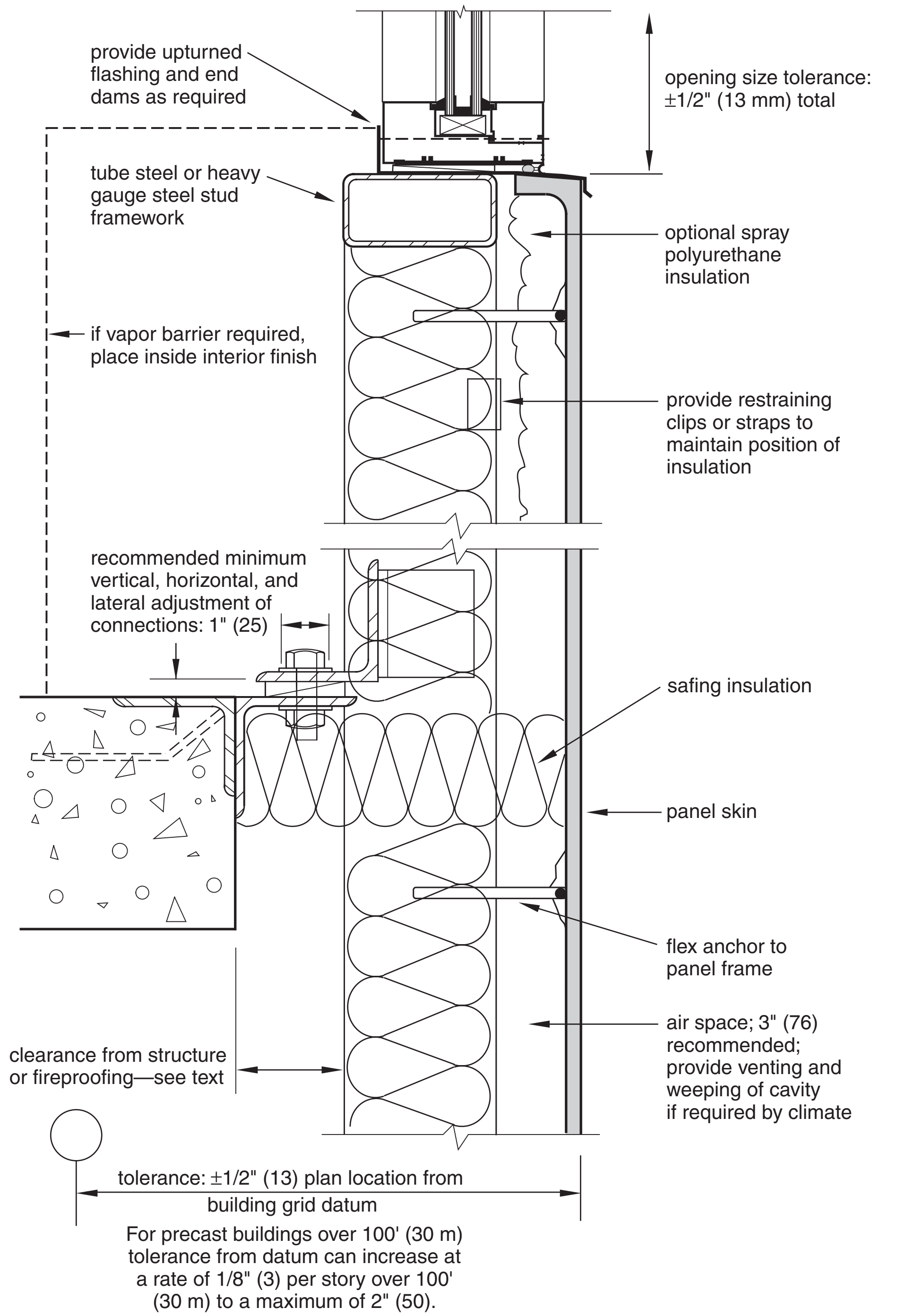
GFRC panels are normally 1/2 in. to 5/8 in. (13 mm to 16 mm) thick, not including any exposed aggregate or veneer finish, if used. The panels are normally attached to a stiffening assembly of metal studs, structural tubes, or integral ribs made by spraying over rib formers. The framework is then attached to the building structure. The panel frame provides support for window framing, interior finish, and other finish elements. As long as sufficient clearance and adequate adjustable fasteners are provided, GFRC panels can be installed to fairly tight tolerances.

Figure 1-24 illustrates a typical GFRC spandrel panel connection to the building structure. Most GFRC installations are specific to the manufacturer producing them. Exact panel formulations, framing, connection details, and other aspects of the project must be verified with the manufacturer.

Limitations of Use

- This section includes only some of the requirements and tolerances for GFRC. For a complete listing, refer to *Recommended Practice for Glass Fiber Reinforced Concrete Panels*, published by the Precast/Prestressed Concrete Institute.
- Verify exact details with the manufacturer.
- This detail does not show provisions for seismic anchoring.

Figure 1-24 Glass fiber reinforced concrete panels 03 49 00



Detailing Considerations

- GFRC panels should be attached to the building structure at only two bearing points on one level. Flexible tie-back connections must be provided at another level to stabilize the panel and accommodate wind and seismic loads.

- Window framing should be attached to the panel frame only. Joints should be designed to allow the GFRC skin to expand or contract 1/8 in. per 10 ft (3 mm per 3 m) due to thermal and moisture effects.
- Required joint widths should be calculated using the procedures given in Section 5-38. The minimum recommended joint width for GFRC panels is 3/4 in. (19 mm) for field panels and 1 in. (25 mm) for corners. The minimum recommended panel edge return for sealant application is 1 1/2 in. (38 mm), with 2 in. (51 mm) preferred.
- Verify fire safing details and specifications with local codes and fire rating requirements of the floor assembly.
- Maintain a 2 in. (51 mm) clearance between the GFRC panel and cast-in-place concrete.
- Maintain a 1 1/2 in. (38 mm) clearance between the GFRC panel and steel fireproofing or precast structure.
- Maintain a 3 in. (76 mm) clearance between GFRC covers and columns.
- If an air space is provided between the GFRC panel and insulation and the cavity is properly ventilated, the assembly becomes a rain screen system. If spray-on insulation is applied to the back of the panel, the assembly becomes a barrier system. Refer to Section 5-5.

Coordination Required

- Coordinate the window layout with joint and structural locations so that openings are least affected by structural movement. Windows are best located entirely within one panel.
- A dew point analysis should be done to determine the amount of insulation required and whether a vapor retarder is required. See Section 5-5 for more information on weather barrier concepts.
- An adhesion test should be done to determine the compatibility of the sealant with the GFRC surface.

Likely Failure Points

- Staining of the panel due to improper application of sealant primer
- Cracking of the panel skin due to restraint by the window frame