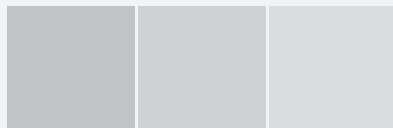




# Technical Manual

Revised as of January 2023



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## INTRODUCTION

ARCHITECTURAL CAST STONE is a highly refined architectural concrete building unit manufactured to simulate natural cut stone. Cast stone is a masonry product which provides architectural trim, ornamentation or functional features to buildings and other structures. The earliest known use of cast stone was in the year 1138. The product was first used extensively in London in the year 1900 and in America around 1920. Since the early 1920's, cast stone has earned widespread acceptance in the architectural community as a superior replacement for many masonry materials and for all types of natural cut building stone. The cast stone Institute® was formed and incorporated in 1927 to be the authoritative voice for the architectural cast stone industry.

### **Materials**

Cast stone can be made from white and/or grey portland cements, manufactured or natural sands, carefully selected crushed stone or well graded natural aggregates, chemical admixtures and mineral coloring pigments and water. Therefore it can be produced to achieve the desired color and the appearance of limestone, brownstone, bluestone, granite, slate, travertine, marble or terracotta while maintaining durable physical properties which exceed most natural cut building stones.

The raw material mixtures are proportioned for maximum density and to produce the required "fine grained texture similar to natural stone with no bug-holes permitted" dictated by industry standards. White Portland cement (ASTM C150) is usually used to achieve lighter colors and color consistency. Blending of grey Portland cement and coloring pigments (ASTM C979) with the white cement to achieve color is a fairly common practice. Sands are naturally available in a wide variety of colors and they can be crushed from quarried stones as well. Reinforcement can be added to provide the structural advantages of precast concrete with the beauty of natural stone.

### **Performance Testing**

Testing methods include ASTM C1194, Standard Test Method for Compressive Strength of Architectural Cast Stone, and ASTM C1195, Standard Test Method for Absorption of Architectural Cast Stone. These tests are evaluated according to the latest edition of the Standard for Architectural Cast Stone, ASTM C1364. Freeze-thaw resistance must be tested according to ASTM C666 with cold water testing to achieve less than 5% weight loss after 300 cycles. Specifiers should be aware that C666 tests can take months to perform so it is wise to find a manufacturer who has already tested the proposed materials.

Testing for color variation may also be performed according to ASTM D2244, Standard Test Method for Calculation of Color Differences from Instrumentally Measured Color Coordinates. Expect color variation to be about equal to other natural building materials.

### **Differences in Related Materials**

Since cast stone is a type of architectural precast concrete, the question is often asked: "What is the difference between cast stone and architectural precast concrete?" The short answer is that cast stone is used in place of natural stone. As a type of building stone, cast stone is specified under the masonry division 04 70 20. It is usually set by a masonry contractor using standard building stone anchors. Perhaps most important, unless otherwise specified, cast stone looks like natural, dimensional, cut building stone. Upon close examination, the finish of cast stone looks like limestone; some call it a "sugar cube finish" to distinguish its appearance from the "pebbly with voids" appearance which is normally associated with an architectural precast concrete product. This dense finish is more resistant to weather and dirt, and the fine aggregates retain the granular texture through decades of exposure to the elements. Sandblast or chemical retardation finishing methods (normally used in finishing of architectural precast concrete panels) are seldom used with cast stone because of the dulling of aggregates and the loss of fine detail, which are not acceptable in quality cast stone work.

## **Fabrication**

The manufacture of cast stone is the most labor-intensive of all concrete products. Specialized work is usually carried out on a departmental basis consisting of the Drafting/Engineering, Pattern/ Mold, Casting/Curing and Finishing / Shipping areas. Workers develop their various skills in both procedure oriented and craft-oriented ways. The manufacturers have developed procedures that work for the different job functions, but craftsmanship, talent and technique are passed along by the workers, sometimes for generations.

### **Planning**

To assure the success of the project, the detailer (draftsperson) assigned to a cast stone job must have knowledge of architectural styles and designs as well as experience with the manufacturing techniques and the installation methods. The manufacturer details each piece with an aim toward simplification and standardization. As with any custom product, a great deal of economy is achieved by taking advantage of repetition. Shop drawings should be specified as needed - usually to show details and sizes of stones, arrangement of joints, relationship with adjacent materials and the location of each piece on the structure.

Some builders and manufacturers, however, prefer to simply work with “shop tickets” which only show the part to be furnished; leaving jointery and fit up to the masonry contractor in the field.

Cast stone can be formed in a greater variety of shapes than other type of natural cut stone. Lengths should be within 15 times the minimum profile thickness whenever possible. Consult with a structural engineer and/or manufacturer if longer lengths are absolutely necessary. Longer lengths invite cracking and handling problems. Try to keep the backside flat and unexposed to view. Remember, most shapes are cast into a mold with four sides and a bottom. One side will always be unformed; typically the bottom of the stone.

Never design a piece with a thin projection; one, which has a thickness less than twice the length of the projection. Weight is approximately 135 lbs. per cubic foot. To figure weights per lineal foot simply multiply cross section dimensions in inches. For instance, a window sill measuring 6” high x 10” deep = 60 lbs. per lineal foot.

### **Molds**

The pattern or mold shop is the heart of any cast stone producer’s enterprise. Many cast stone manufacturers have craftsman on staff and/or a CNC machine that is able to produce custom molds. This allows manufacturers the ability to produce almost any stone design element required to fit a project’s needs.

In general, over 85% of cast stone is produced from new molds but the trend is increasing toward standard inventory availability, especially in the residential and landscape markets.

In restoration projects, full-length pieces are often salvaged from the original structure and used as models for the actual molds. Ornamental plaster is an excellent modeling material and there are a number of excellent plaster fabricators available for this purpose. One caution though, be sure the materials are not copyrighted.

### **Manufacturing**

The two most widely used casting methods in use today are the “Vibrant Dry Tamp” (VDT) and the “Wet Cast” methods, although machine made architectural cast stone is also a production method. All methods require meticulously proportioned mix designs developed by the specific Producer and tested according to ASTM and Cast Stone Institute standards for excellence.



### Economy

Cost per unit depends greatly on specifications and bid documents. On an average, however, cast stone costs less than quarried stone. There are several reasons for this: 1. It is a molded product and requires no further tooling after the initial pattern is made. Each piece of cut stone must be carved individually. 2. Freight is also a concern. Usually quarried stone must be hauled over long distances. Most of the limestone in this country is hauled from Indiana. Many stones come from overseas. Brownstone is now typically available from India and Germany. Imported brownstone is beautiful but the cost is several times more.

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Properly manufactured, designed and installed, cast stone can result in an architectural project of enduring beauty to be enjoyed for decades. For architectural cast stone used on a project, be sure to specify a Cast Stone Institute Certified Producer Member, engaged in the relentless pursuit of excellence in manufacturing. All parties need to hold to that specification so as to provide the owner the quality cast stone the project deserves.

The Cast Stone Institute® (CSI) is the recognized industry authority for architectural cast stone - providing expert counsel to the architectural, engineering and mason communities. It is our mission to improve the quality of Cast Stone and to disseminate information regarding its use.



# Standard Specification for Architectural Cast Stone

## Section 04-72-00

Revised and Approved 01/2023

This specification provides basic requirements for Cast Stone, a refined architectural concrete building unit manufactured to simulate natural cut stone, used in Division 4 masonry applications. Cast Stone is a masonry product, used as an architectural feature, trim, and ornament or facing for buildings or other structures.

Materials and processes used for manufacturing Cast Stone vary according to the aggregates locally available to the manufacturers and the processes and techniques used by the manufacturers to obtain the desired appearance and physical properties. Of paramount importance in molding Cast Stone is the need to use a properly proportioned mixture of white and/or grey cements, manufactured or natural sands, carefully selected crushed stone or well graded natural gravel and mineral coloring pigments to achieve the desired appearance while maintaining durable physical properties.

Although a variety of casting methods are used, production conforming to this standard will exceed minimum requirements for compressive strength and weathering qualities essential for normal installations as a suitable replacement for natural cut limestone, brownstone, sandstone, bluestone, granite, slate, keystone, travertine and other natural building stones. The specifier should not prescribe the casting method.

It is hoped that this specification may be helpful to the specifiers in understanding the inherent qualities of Cast Stone and its use. For details and samples of finishes available in your project area, contact your nearest Cast Stone Institute® Producer Member.

## Part 1 General

### 1.1. Section Includes - Architectural Cast Stone.

Scope - Cast Stone shown on architectural drawings and as described in this specification.

- Manufacturer shall furnish Cast Stone covered by this specification.

### 1.2. Related Sections

Section – 01 33 00 – Submittal Procedures.

Section – 04 05 13 – Masonry Mortaring.

Section – 04 05 16 – Masonry Grouting.

Section – 04 05 19 – Masonry Anchorage and Reinforcing.

Section – 04 20 20 – Unit Masonry.

Section – 07 90 00 – Joint Protection.

### 1.3. References

- ACI 318 – Building Code Requirements for Reinforced Concrete.
- ASTM A615/A615M – Standard Specification for Deformed and Plain Billet-Steel Bars for Reinforced Concrete.
- ASTM A1064 / A1064M – Standard Specification for Carbon Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete.
- ASTM C33 – Standard Specification for Concrete Aggregates.
- ASTM C150 – Standard Specification for Portland Cement.
- ASTM C595/C595M – Specification for Blended Hydraulic Cements
- ASTM C1157/C1157M – Performance Specification for Hydraulic Cement
- ASTM C173 – Standard Test Method for Air Content of Freshly Mixed Concrete by the Volume Method.
- ASTM C231 – Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method.
- ASTM C260 – Standard Specification for Air-Entrained Admixtures for Concrete.
- ASTM C270 – Standard Specification for Mortar for Unit Masonry.
- ASTM C426 – Standard Test Method for Linear Shrinkage of Concrete Masonry Units.
- ASTM C494/C494M – Standard Specification for Chemical Admixtures for Concrete.
- ASTM C618 – Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Concrete.
- ASTM C666/666M – Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing.
- ASTM C979 – Standard Specification for Coloring Pigments for Integrally Colored Concrete.
- ASTM C989 – Standard Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete.
- ASTM C1116 – Standard Specification for Fiber Reinforced Concrete and Shotcrete.
- ASTM C1194 – Standard Test Method for Compressive Strength of Architectural Cast Stone.
- ASTM C1195 – Standard Test Method for Absorption of Architectural Cast Stone.
- ASTM C1364 – Standard Specification for Architectural Cast Stone.
- ASTM D1729 – Practice for Visual Appraisal of Colors and Color Differences of Diffusely-Illuminated Opaque Materials.
- ASTM D2244 – Standard Test Method for Calculation of Color Differences from Instrumentally Measured Color Coordinates.
- ASTM D7957/D7957M – Standard Specification for Solid Round Glass Fiber Reinforced Polymer Bars for Concrete Reinforcement
- TMS 404-504-604 – Standards for Architectural Cast Stone Design – Fabrication - Installation

## 1.4. Definitions

Cast Stone - a refined architectural concrete building unit manufactured to simulate natural cut stone, used in Division 4 masonry applications.

- Dry Cast – manufactured from zero slump concrete.

Vibrant Dry Tamp (VDT) casting method: Vibratory ramming of earth moist, zero-slump concrete against a rigid mold until it is densely compacted.

Machine casting method: Manufactured from earth moist, zero-slump concrete compacted by machinery using vibration and pressure against a mold until it becomes densely consolidated.

- Wet Cast – Manufactured from measurable slump concrete.

Wet casting method: Manufactured from measurable slump concrete and vibrated into a mold until it becomes densely consolidated.

- Specifier Note: Slump, manufacturing method, and apparatus shall be selected by the manufacturer and not specified by the purchaser.

## 1.5. Submittal Procedures

Comply with Section 01 33 00 – Submittal Procedures.

Samples: Submit pieces of the Cast Stone that are representative of the general range of finish and color proposed to be furnished for the project.

Test results: Submit manufacturers test results of Cast Stone previously made by the manufacturer.

Shop Drawings: Submit manufacturers shop drawings including profiles, cross-sections, reinforcement, exposed faces, arrangement of joints (optional for standard or semi-custom installations), anchoring methods, anchors (if required), annotation of stone types and their location.

Warranty: Submit Cast Stone Institute® Member Limited Warranty.

Certification: Submit valid Cast Stone Institute® Plant Certification.

## 1.6. Quality Assurance

Manufacturer Qualifications:

- Cast Stone shall be produced in a plant certified by the Cast Stone Institute®.
- Manufacturer shall have sufficient plant facilities to produce the shapes, quantities and size of Cast Stone required in accordance with the project schedule.
- Manufacturer shall submit a written list of projects similar in scope and at least three (3) years of age, along with owner, architect and contractor references.



Standards: Comply with the requirements of the Cast Stone Institute® Technical Manual and the project specifications. Where a conflict may occur, the contract documents shall prevail.

Mock-up (Optional) Provide full size unit(s) for use in construction of sample wall. The approved mock-up shall become the standard for appearance and workmanship for the project.

Warranty Period: 10 years.

## Part 2 Products

### 2.1. Architectural Cast Stone

Comply with current version ASTM C1364

Physical properties: Provide the following:

- Compressive Strength - ASTM C1194: 6,500 psi minimum at 28 days.
- Absorption – ASTM C1195: 6.0% maximum at 28 days.
- Air Content – Provide sufficient air content to meet the freeze-thaw requirements for wet cast products, when the air content is tested in accordance with Test Method C173/C173M or Test Method C231/C231M. Air entrainment is not required for Vibrant Dry Tamp (VDT) products.
- Freeze-thaw – ASTM C666/C666M in accordance with ASTM C1364. The CPWL shall be less than 5.0% after 300 cycles of freezing and thawing.
- Linear Drying Shrinkage – ASTM C426: Test and report in accordance with ASTM C1364.

Job site testing – One sample from production units may be selected at random from the field for each 500 cubic feet (14 m<sup>3</sup>) delivered to the job site.

- Three field cut cube specimens from each of these samples shall have an average minimum compressive strength of not less than 85% with no single specimen testing less than 75% of design strength as allowed by ACI 318.
- Three field cut cube specimens from each of these samples shall have an average maximum cold-water absorption of 6.0%.
- Field specimens shall be tested in accordance with ASTM C1194 and C1195.

### 2.2. Raw Materials

Portland cement – Type I or Type III, white and/or grey, ASTM C150 or ASTM C595 Blended Hydraulic Cement (Type 1L).

Coarse aggregates - Granite, quartz or limestone, ASTM C33, except for gradation, and are optional for the Vibrant Dry Tamp (VDT) casting method.

Fine aggregates - Manufactured or natural sands, ASTM C33, except for gradation.

Colors - Inorganic iron oxide pigments, ASTM C979 except that carbon black pigments shall not be used.

Admixtures - Comply with the following:

- ASTM C260 for air-entraining admixtures.
- ASTM C494/C495M Types A - G for water reducing, retarding, accelerating, and high range admixtures.
- Other admixtures: Integral water repellents and other chemicals, for which no ASTM Standard exists, shall be previously established as suitable for use in concrete by proven field performance or through laboratory testing.
- ASTM C618 mineral admixtures of dark and variable colors shall not be used in surfaces intended to be exposed to view.
- ASTM C989 granulated blast furnace slag may be used to improve physical properties. Tests are required to verify these features.

Water – Potable

Reinforcing bars:

- ASTM A615/A615M: Grade 40 or 60.
- ASTM D7957/D7957M: Standard Specification for Solid Round Glass Fiber Reinforced Polymer Bars for Concrete Reinforcement
- Welded Wire Fabric: ASTM A1064 / A1064M where applicable for wet cast units.

Fiber reinforcement (optional): ASTM C1116

All anchors, dowels and other anchoring devices and shims shall be standard building stone anchors commercially available in a non-corrosive material such as zinc plated, galvanized steel, brass, or stainless steel Type 302, 304 or 316.

### **2.3. Color And Finish**

Match sample on file in architect's office.

All surfaces intended to be exposed to view shall have a fine-grained texture similar to natural stone, with no air voids in excess of 1/32 in. and the density of such voids shall be less than 3 occurrences per any 1 in.<sup>2</sup> and not obvious under direct daylight illumination at a 5 ft distance.

Units shall exhibit a texture approximately equal to the approved sample when viewed under direct daylight illumination at a 10 ft distance.

- ASTM D2244 permissible variation in color between units of comparable age subjected to similar weathering exposure.
  - Total color difference – not greater than 6 units.
  - Total hue difference – not greater than 2 units.

Minor chipping resulting from shipment and delivery shall not be grounds for rejection. Minor chips shall not be obvious under direct daylight illumination from a 20-ft distance.

The occurrence of crazing or efflorescence shall not constitute a cause for rejection.

Remove cement film, if required, from exposed surfaces prior to packaging for shipment.

## **2.4. Reinforcing**

Reinforce the units as required by the drawings and for safe handling and structural stress.

Minimum reinforcing shall be 0.25 percent of the cross section area.

Reinforcement shall be noncorrosive where faces exposed to weather are covered with less than 1.5 in. of concrete material. All reinforcement shall have minimum coverage of twice the diameter of the bars.

Panels, soffits and similar stones greater than 24 in. (600 mm) in one direction shall be reinforced in that direction. Units less than 24 in. (600 mm) in both their length and width dimension shall be non-reinforced unless otherwise specified.

Welded wire fabric reinforcing shall not be used in dry cast products.

## **2.5. Curing**

Cure units in a warm curing chamber approximately 100°F (37.8°C) at 95 percent relative humidity for approximately 12 hours, or cure in a 95 percent moist environment at a minimum 70°F (21.1°C) for 16 hours after casting. Additional yard curing at 95 percent relative humidity shall be 350 degree-days (i.e. 7 days @ 50°F (10°C) or 5 days @ 70°F (21°C)) prior to shipping. Form cured units shall be protected from moisture evaporation with curing blankets or curing compounds after casting.

## **2.6. Manufacturing Tolerances**

Minimum Thickness shall be 2.5" to facilitate testing for compressive strength and absorption as specified in ASTM C-1364 Standard Specification for Architectural Cast Stone.

Cross section dimensions shall not deviate by more than  $\pm 1/8$  in. from approved dimensions.

Length of units shall not deviate by more than length/ 360 or  $\pm 1/8$  in., whichever is greater, not to exceed  $\pm 1/4$  in.

Maximum length of any unit shall not exceed 15 times the average thickness of such unit unless otherwise agreed by the manufacturer.

Warp, bow or twist of units shall not exceed length/ 360 or  $\pm 1/8$  in., whichever is greater.

Location of dowel holes, anchor slots, flashing grooves, false joints and similar features – On formed sides of unit, 1/8 in., on unformed sides of unit, 3/8 in. maximum deviation.

## **2.7. Production Quality Control**

Testing:

- Test compressive strength and absorption from specimens taken from every 500 cubic feet of product produced.
- Perform tests in accordance ASTM C1194 and C1195.
- Have tests performed by an independent testing laboratory every six months.
- New and existing mix designs shall be tested for strength and absorption compliance prior to producing units.
- Retain copies of all test reports for a minimum of two years.

## **2.8. Delivery, Storage And Handling**

Mark production units with the identification marks as shown on the shop drawings.

Package units and protect them from staining or damage during shipping and storage.

Provide an itemized list of product to support the bill of lading.

## **3. Part 3 Execution**

### **3.1. Examination**

Installing contractor shall check Cast Stone materials for fit and finish prior to installation.

Unacceptable units shall not be set.

### **3.2. Setting Tolerances**

Comply with Cast Stone Institute® Technical Manual.

Set stones 1/8 in. or less, within the plane of adjacent units.

Joints, plus - 1/16 in., minus - 1/8 in.

### **3.3. Jointing**

Joint size:

- At stone/brick joints 3/8 in.
- At stone/stone joints in vertical position 1/4 in. (3/8 in. optional).
- Stone/stone joints exposed on top 3/8 in.

Joint materials:

- Mortar, Type N, ASTM C270.
- Use a full bed of mortar at all bed joints.
- Flush vertical joints full with mortar.
- Leave all joints with exposed tops or under relieving angles open for sealant.
- Leave head joints in copings and projecting components open for sealant.

Location of joints:

- As shown on shop drawings.
- At control and expansion joints unless otherwise shown.

### **3.4. Setting**

Drench units with clean water prior to setting.

Fill dowel holes and anchor slots completely with mortar or non-shrink grout.

Set units in full bed of mortar, unless otherwise detailed.

Rake mortar joints 3/4 in. in for pointing.

Remove excess mortar from unit faces immediately after setting.

Tuck point unit joints to a slight concave profile.

### **3.5. Joint Protection**

Comply with requirements of Section 07 90 00.

Prime ends of units, insert properly sized backing rod and install required sealant.

### **3.6. Repair and Cleaning**

Repair chips with touchup materials furnished by manufacturer.

Saturate units to be cleaned prior to applying an approved masonry cleaner.

Consult with the manufacture for appropriate cleaners.





### **3.7. Inspection and Acceptance**

Inspect finished installation according to Cast Stone Institute® Technical Bulletin #36.

Do not field apply water repellent until repair, cleaning, inspection and acceptance is completed.

### **3.8. Water Repellent (Optional)**

Apply water repellent in accordance with Cast Stone Institute® Technical Bulletin #35 or water repellent manufacturer's directions.

## MORTARS FOR CAST STONE INSTALLATION

Selecting the appropriate type of mortar for setting cast stone is perhaps the most important factor in the performance of a masonry wall. The mortar must have sufficient strength, be durable, resist rain penetration as much as possible and yet be flexible enough to accommodate slight movement within the wall assembly.

As noted in TMS 604-16, Standard Specification for Installation of Architectural Cast Stone, mortars used in the setting of cast stone should meet the requirements of ASTM C270, Type N mortars. These mortars generally consist of one part cementitious material (Portland cement and lime, or masonry or mortar cement) to three parts of clean, washed masonry sand (ASTM C144). The mortar may also contain iron oxide coloring pigments (ASTM C979) and admixtures (ASTM C1384).

The selection of a Type N mortar provides good bond strength with desired weather resistance and sufficient compressive strength relative to the cast stone when cured. Plasticizing agents, such as lime or ground limestone, enhance the workability of the mortar while reducing shrinkage. The practice of wetting the head and bed joints of the stone and tooling the mortar when thumbprint hard will further protect against joint shrinkage. Although Type N mortar is the standard used with cast stone (as well as many natural cut stone), the proportions may be varied to suit specific applications.

Proper mixing is essential to good consistency. All materials, except pigments, should be measured by volume. Sands should be placed in the spiral-blade or paddle type mixer first, followed by pigments (if required), pre-water, lime and cement, final water and 5-7 minutes of mixing time. Due to the various admixtures available for mortar, consult with the manufacturer for recommended addition rates and mix sequencing. Mortars unused after 2 ½ hours should be discarded (this time may be shorter depending on the ambient conditions).

Head joints in most hand-set cast stone may be set with the usual wet consistency mortar used in setting brick and block. Stiffer mortar must be used when setting larger stones and shims are recommended for all pieces over 300 lbs. When setting, fill all dowel holes, anchor slots and similar building stone anchor pockets completely with mortar. Non-shrink grout or anchoring cement may be specified for dowel connections. Caution should be used when the bed joint is on horizontal flashing as it will act as a bond breaker. Special anchorage may be necessary to accommodate this condition as well as in the vertical joints of the first course below a relief angle. Mechanical anchors are recommended to be installed within the first course above and below each relief angle.

Mortar systems have the ability to carry loads but cannot absorb much joint movement. For this reason, thoughtful designers often require that joints at parapets, copings and other particularly sensitive areas be left un-mortared for later filling with sealants. A mortar lock feature may be incorporated in the sides of the cast stone in order to add positive engagement of the mortar element into the cast stone unit. This helps to restrain the cast stone if the shear bond is lost between the cast stone and mortar.

When using a post-setting pointing system, all stone-to-stone joints should be raked to a depth of ¾ in. for later pointing. It should be noted that in many cases, but in particular when setting small veneer pieces, it is not practical to rake out and point all joints. In these instances, full bed setting and finishing in one operation can be used. Particular attention must be paid to the waterproofing systems incorporated into the veneer. Stone-to-brick joints are usually struck and tooled to a concave shape (See [Technical Bulletin #44](#) on Pointing). Sponge all mortar smears from the face of the cast stone with water as hardened, mortar smears are difficult to remove from the surface of cast stone. Clean with water and a stiff fiber brush or with a commercial masonry cleaner approved for use with cast stone. Metal bristle brushes should not be used. Consult the cast stone manufacturer before performing any cleaning procedure. Direct high pressure power washers should never be used to clean cast stone. See [Technical Bulletin #39](#) on Cleaning.

If lug sills, which extend beyond the masonry opening, are fully set in mortar, the mortar at the ends under the lugs (where the load is) may, in certain situations, compress or shrink more than the rest of the mortar (due to overburden forces), causing shear or bending stress in the sill and possibly leading to failure. One of two techniques can be used when setting lug sills. The first technique is to set only the ends of lug sills in a full bed of mortar and point the portion of the sill inside the masonry opening after the initial mortar bed has cured. The second technique is to shim under the lugs to bear any compressive loads. The designer should examine the lug sill configuration and how it interfaces with the adjacent and under-supporting masonry units to ensure that point bearing will not occur at the mid-span of the sill. Slip sills, which do not extend past the masonry opening, do not carry any load other than itself and are set in a full bed of mortar.

Designers should specify where to use mortar/pointed joints and where to use sealant joints. Typically, conventional masonry cast stone units may be set with mortar joints. Where panels are larger than conventional masonry units (1 ft. 6 in. tall by 2 ft. 6 in. in length for vertical applications), “soft” sealant joints are generally recommended. In such unique cases, a professional designer or engineer should be consulted for proper joint design and function. After setting, prime the ends of the stones (if necessary), insert a properly sized backup rod followed by application of a sealant using a caulking tool.

### Selection of Joint Type for Cast Stone

Control or Expansion Joint Location	Mortar/pointed joints	Sealant joints
Most bed joints	Recommended	As needed
Head joints at coping, joints at column covers, cornices, platforms, soffits, stone with projecting profiles, exposed top joints, rigid suspension connections	Not recommended	Recommended
Units larger than 1 ft. 6 in. x 2 ft. 6 in.*	Not recommended for vertical applications	Recommended

\*Proper joint design and function should be based on recommendations from an engineer or other design professional. For recommendations on sealants, please see [Technical Bulletin #43](#).

This Technical Bulletin addresses generally accepted practices, methods and general details for the use of Architectural Cast Stone. This document is designed **only as a guide** and is **not** intended for any specific application or project. It is the responsibility of design and construction professionals to determine the applicability and appropriate application of any detail to a specific project based on professional judgment, specific project conditions, manufacturer’s recommendations and solid understanding of product characteristics. The Cast Stone Institute makes no express or implied warranty or guarantee of the techniques or construction methods identified herein. Technical references shall be made to the edition of the International Building Codes for the location of the structure, the latest edition of the TMS 402/406 Masonry Standards document and TMS 404, 504, 604 Standards for Design, Fabrication and Installation of Architectural Cast Stone.

The Cast Stone Institute (CSI) is a not-for-profit organization created to advance the design, manufacture and use of Architectural Cast Stone. To further this goal, the CSI continually disseminates information to targeted construction industry audiences through presentations, programs and technical publications.

(Page 2 of 2)

## SEALANT JOINTS

The decision to use mortar with tooled joints or sealant joints between stones is common. To ensure performance, a professional designer or engineer should be consulted for proper joint design. In general, all cast stone sections with projecting profiles, exposed top joints or rigid suspension connections to the supporting structure should be “soft” sealant joints. Furthermore, “soft” sealant joints are recommended for conventional masonry units, all head joints at coping stones, column covers, cornices, platforms, soffits, window sills and larger than conventional masonry units (1ft. 6 in. tall by 2ft. 6 in. in length) for vertical applications.



Tooled mortar joints are best suited for masonry-bound trim items such as belt courses, lintels, window surrounds, date stones, inscription blocks, quoins, keystones and similar applications. Rake and point the mortar joints rather than full-bed setting and finishing in one operation. See Technical Bulletin #44 on Pointing.

Sealant joints allow for movement at the vertical joints. Leave head joints dry when setting. An allowance for expansion and contraction is required for the system to be effective. After setting, prime the ends of the stones (if necessary), insert properly sized foam backup rod and gun in sealant. If a mortared appearance is desired, a sanded sealant may be used.



Sealant systems are not intended to bear weight, so plastic setting pads or lead shims are required when setting the cast stones. The sealant is not intended to adhere to the foam backer rod. The sealant should adhere to the parallel surfaces only. The foam rod should be placed to a depth approximately equal to the width of the joint.

The most common types of sealants are one-part "moisture cure" or "air cure." Two part systems are also available which require the mixing of materials together to allow chemically induced curing.

The inherent properties of silicone products make them excellent sealant materials. Silicones provide superior weathering resistance and perform over a wide range of service temperatures. They are easy to apply, have low shrinkage rates, and can accommodate high movement. While organic materials tend to crack, dry up, and become brittle or even revert with age, silicones remain flexible and durable. Silicone sealants allow for elongation and compression up to 50% of the joint width.

Two-component, polyurethane sealants are tough and elastic, allowing for movement of up to 50% of the joint width. They are also durable, flexible and form a watertight bond with most building materials. Polyurethane sealants may not be suitable for all geographic locations.

The sealant manufacturer should be consulted to ensure the proper sealant is used for each application.

Minimum required allowance for thermal and other movement should be provided in the specification for the project or specified by the design engineer.

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The Cast Stone Institute (CSI) is a not-for-profit organization created to advance the design, manufacture and use of Architectural Cast Stone. To further this goal, the CSI continually disseminates information to targeted construction industry audiences through presentations, programs and technical publications.

## POINTING OF JOINTS

Tooled mortar joints are required for cast stone units larger than conventional masonry units because mortar shrinks modestly as it cures. Since mortar beds harden from the outside in, stresses can be applied to the edge of the stone which can cause spalling. Shrinkage also can create cracks at the joints; a condition which may lead to moisture penetration. Tooled mortar joints are best suited for masonry-bound trim items such as belt courses, lintels, window surrounds, date stones, inscription blocks, quoins, keystones and similar applications.

It should be noted that in many cases (and specifically when setting small veneer pieces) it is not practical to rake out and point all joints. In these instances, full bed setting and finishing in one operation can be used. Particular attention must be paid to the waterproofing systems behind and incorporated into the veneer.

Regardless of whether the mortar or sealant is selected as the face joint material, the mortar must be raked out of the joint to a minimum depth of 3/4 inch. If sealant is to be used at the head joints, then mortar is normally not used there at all.

Pointing is usually done in 1 or 2 stages to allow maximum sealing of shrinkage cracking in the mortar. It should not be done in areas exposed to hot sunshine and it is suggested that pointing be accomplished after touch and repair of cast stone and before final wash-down.

Apply pointing mortar using proper tools to compress the material against the edges of the cast stone. A concave joint is recommended for the best protection against leakage although other joint types are often available in the stone setting trade.

Pointing mortar should be softer than the stone so that thermal stress will not cause spalling at the edges of the joints. It is usually slightly drier than normal setting mortar consistency to prevent shrinkage and is usually composed of the following:

- 1 part Portland cement, ASTM C150
- 1 part hydrated lime, ASTM C207
- 6 parts masonry sand, ASTM C144

Coloring may be added to achieve almost any hue, however pointing mortar which sharply contrasts with the color of the cast stone may cause staining. Excess pointing material must be sponged away from the face of the stone immediately. Taping the cast stone adjacent to the joints prior to pointing can help protect the cast stone from staining as well. Colors added must be natural or synthetic mineral oxides which meet the requirements of ASTM C979 (sun-fast, lime-proof, alkali-resistant) and the dosage must not exceed 10% of the weight of the cement used. Carbon black or ultramarine blue pigments should not be used. In general, pigmentation types and amounts used in the manufacture of Cast Stone can also be used as a starting point when custom blending the pointing mortar to match or complement the color of the Cast Stone.

Always specify a mockup wall when approving final colors and be sure that it has been properly cleaned because cleaning will usually affect the color of pigmented masonry materials.

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## FLASHING, WEEP HOLES AND RELATED ANCHORAGE

Proper flashing and weep holes are essential elements of masonry construction. Together, they provide a means to control moisture in a wall. If not addressed, moisture can have damaging effects on exterior walls, such as crazing, efflorescence and spalling. Improper flashing can also lead to moisture in the interior of a building. An effective system to deal with exterior moisture penetration is necessary for a properly functioning cast stone wall.

A drainage wall, also known as a cavity wall, is the most effective solution for a cast stone wall exposed to the elements.

### THE DRAINAGE WALL

A drainage wall has five essential elements.

- Exterior wythe of masonry
- A clear cavity or air space of at least 1 inch
- An interior wythe of masonry or other backing material
- Flashing at all interruptions in the drainage cavity
- Properly spaced weep holes at all flashing locations.

The exterior wythe provides first line of defense against moisture penetration. Cast stone should be laid with full joints in mortar meeting the requirements of ASTM C 270, Type N mortar. (See [Technical Bulletin #42](#).) Care should be taken when laying the stone to ensure the cavity behind this wythe stays clear. A tapered bed joint can help minimize mortar droppings and protrusions into the drainage cavity. A minimum 1 in. cavity or air space is recommended. Cavities of 2 in. or more are easier to keep clear of mortar and debris. Cavities over 4 in. may require special ties and anchors. When insulation is specified, the space of the cavity is measured from the outer face of the insulation to the back of the exterior wythe. (See Technical Detail 4.)

Through-wall flashing and weep holes should be used at the base of the drainage wall and at all interruptions in the cavity, such as at window heads and relieving angles. Flashing must be continuous and properly lapped and sealed at the base of the wall and at relieving angles. When flashing is used over openings, such as at windows, end dams are required. (See Technical Detail 1.) Weep holes allow collected water to be directed from the drainage cavity to the outside. Head joints with an opening of 1 in. in height are recommended as they provide the best drainage. They should be spaced no more than 24 in. apart. Rope wicks can also be used, but weep holes should be placed closer together, at 16 in. o.c., since this type does not drain as quickly. Plastic tubes are not recommended because they are easily clogged by mortar or by insects. In stones over 24 in. in length, a 3/8 in. wide by 1 in. high notch through the base of the stone is recommended for drainage. Unnecessarily long lengths of stone are discouraged because adequate drainage between weep holes can be a problem. Moisture retained in the wall can lead to crazing of the Cast Stone.

### FLASHING AT BASES

Flashing and weep holes must be used at the base of a cavity wall and at all horizontal obstructions. Flashing should extend from the exterior face of the cast stone wythe into the cavity. For self-adhered flashing, cut back 1/2" from the face of the cast stone to prevent bleeding of the rubberized asphalt. In the case of a masonry backing wythe, the flashing should be turned up a minimum of 8 in. and extend into the masonry backing. In framed backing walls, the flashing should extend up the cavity at least 8 in. and be attached to the exterior sheathing with a termination bar. Building paper or other water resistant membrane on the interior wythe should overlap the top of the flashing.

Flashing is also recommended below all Cast Stone belt courses and watertables that sit on a relieving angle or occur at a change in material, i.e. stone to brick. In most cases, flashing and weep holes should be placed directly below the Cast Stone course for proper drainage of the cavity. In cases where stone and clay brick are used together in the same wythe, the flashing also serves as a bond break between the Cast Stone and the brick.

Because clay brick undergoes irreversible moisture expansion and Cast Stone, like other cementitious products, tends to shrink, flashing between the different courses allows horizontal movement to occur without cracking the mortar joints or units. The Brick Industry Association's Technical Notes 18 Series provides further information on this topic. Stones must be anchored, top and bottom, to the backing material when this detail is used.

## FLASHING OVER OPENINGS

Cast Stone window heads and arched openings also require flashing. If the Cast Stone is supported by a relieving angle, flashing and weep holes are located below the stone course, on the relieving angle. When no relieving angle is used, as in the case of structural stone lintels, flashing should be placed directly above the stone course. In either case, proper anchorage of the stone to the backing is imperative.

## FLASHING AT COPING AND CAPS

Experience has shown that Cast Stone coping perform best when the mortar bond with the masonry wall is maintained. For this reason, flashing should not extend over the full width below the Cast Stone coping. Instead, the flashing should be turned down into the drainage cavity and then out through the exterior supporting wythe below. (See Detail Plates 5, 6 & 7) This prevents the potential for water to pond underneath, which can deteriorate the mortar through the freeze-thaw process. In extreme cases, even the cast stone may be damaged due to repeated cycles of freezing and thawing while critically saturated for extended periods of time. This differs from recommendations found in the Brick Industry Associations Technical Notes.

At chimney caps, step flashing from below the Cast Stone coping down through the first course of supporting masonry below the weep holes should be located in the head joints of the first course of supporting masonry. (See Detail 3.)

## ANCHOR PENETRATIONS THROUGH FLASHING

The anchors for attaching Cast Stone may be required to penetrate flashing and building paper to allow a secure connection to the structure. Where this occurs, proper steps must be taken to ensure a watertight connection at the interface so that the anchor does not compromise the integrity of the flashing. Grommets, thimbles, sleeves, couplings and sealants are available for this purpose, but it is beyond the scope of this Technical Bulletin to provide specific guidance.

## FLASHING MATERIALS

Flashing is a key element in a drainage wall. Poor flashing materials can become brittle over time and may allow water to penetrate the building interior. As a result, longevity and life cycle cost should be considered, in addition to first costs, when choosing a flashing material.

Flashing materials used successfully with Cast Stone include stainless steel, copper, copper laminates, EPDM, and rubberized asphalt. Polyvinyl chloride (PVC) and galvanized steel flashing should be avoided because of their questionable long-term performance. (See the Brick Industry Associations Engineering & Research Digest, "Through-Wall Flashing", for a detailed discussion.) Table 1 lists some advantages and disadvantages of each flashing material that must be considered in making a final selection.

Table 1: TYPES of FLASHING MATERIAL

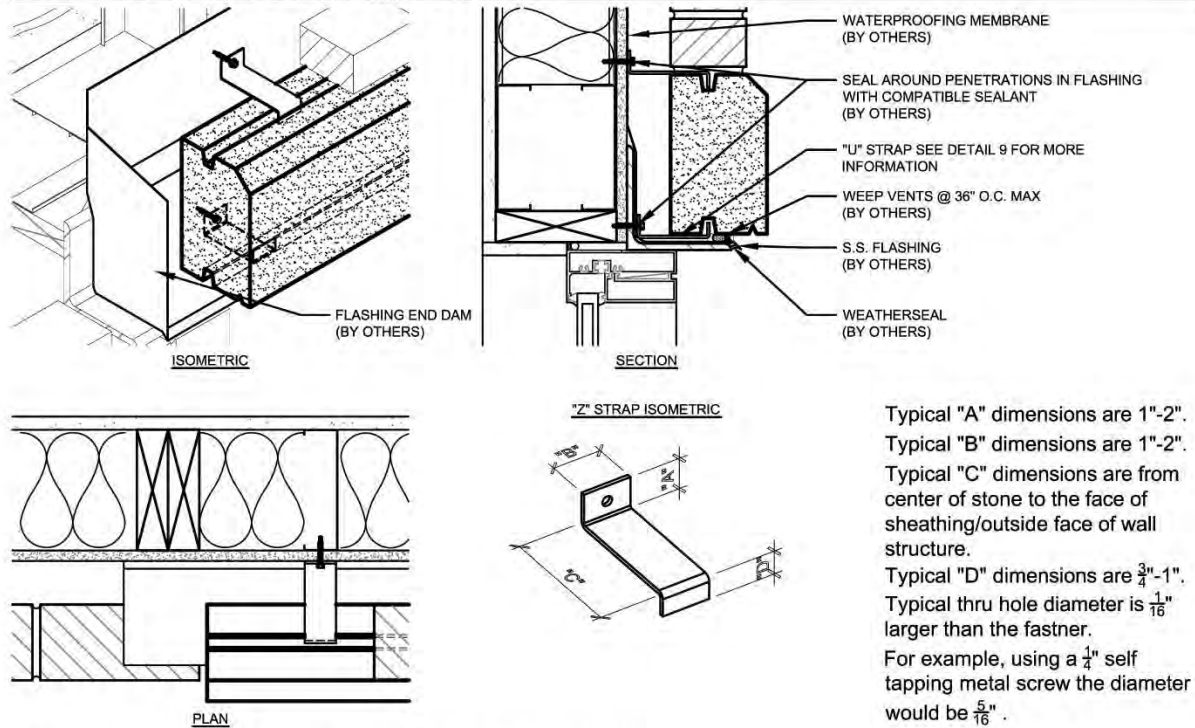
Material	Minimum Thickness	Advantages	Disadvantages
Stainless Steel	0.01 in. (0.25 mm)	Extremely durable, non-staining	Difficult to solder and form
Cold Rolled Copper	10 ounces/ft <sup>2</sup> (3100 g/m <sup>2</sup> )	Durable, easily formed, easily joined	Stains adjacent masonry
EPDM	30 mils (0.8 mm)	Flexible, easy to form, easy to join, non-staining	Metal drip edge required more easily torn
Rubberized Asphalt	40 mils (1.0 mm)	Self-healing, flexible, easy to form, easy to join	Dimensional instability, incompatibility with joint sealant, metal drip edge recommended
Copper Laminates	5 ounces/ft <sup>2</sup> (1500 g/m <sup>2</sup> )	Easy to form, easy to join, non-staining	Metal drip edge required, more easily torn

Table printed with permission from the Brick Industry Association Engineering & Research Digest, "Through-Wall Flashing".

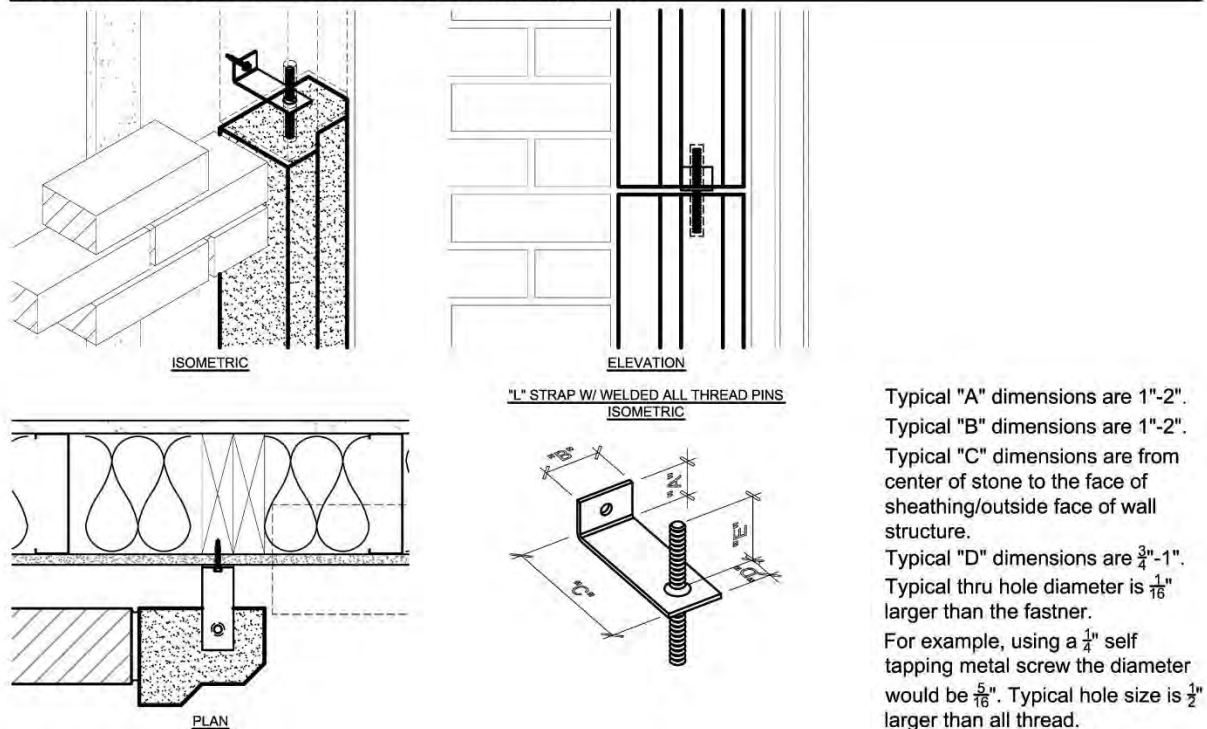
## Anchoring and Flashing Details

These are typical connections recommended by the Cast Stone Institute for similar applications. Consult your engineer for size and connection requirement before ordering anchors.

### DETAIL 1-"Z" STRAP ANCHOR @ HEADER



### DETAIL 2-"L" STRAP W/ WELDED DOWEL PINS @ JAMB

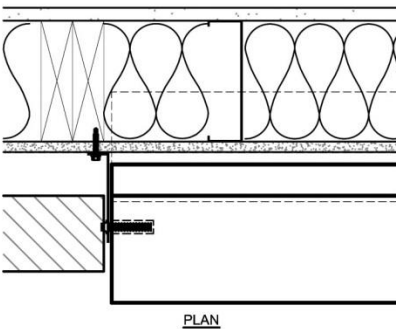
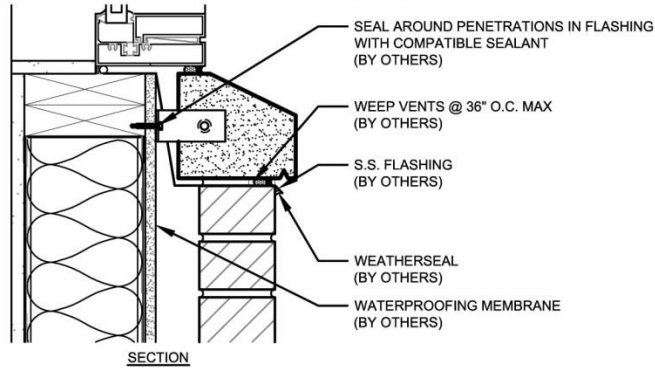
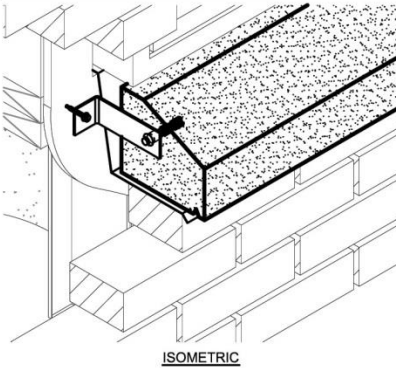




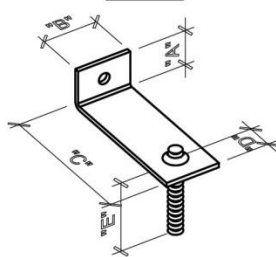
## Anchoring and Flashing Details

These are typical connections recommended by the Cast Stone Institute for similar applications. Consult your engineer for size and connection requirement before ordering anchors.

### DETAIL 3-"L" STRAP W/ WELDED DOWEL PIN @ SILL

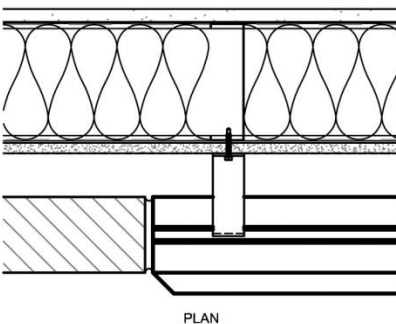
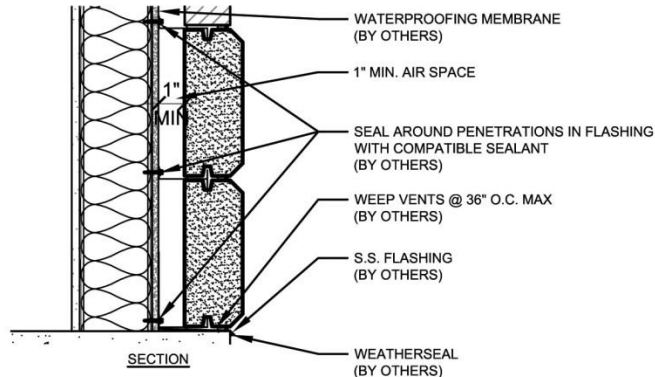
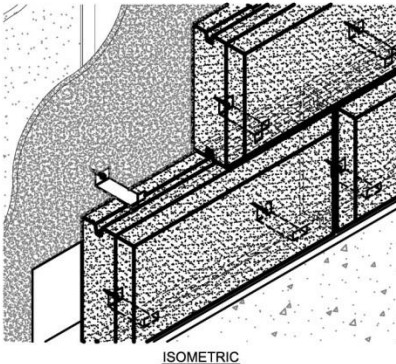


#### "L" STRAP W/ WELDED ALL THREAD PIN ISOMETRIC

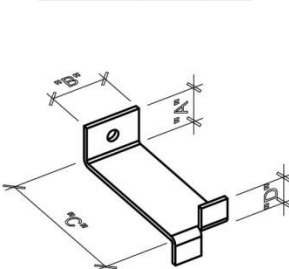


Typical "A" dimensions are 1"-2".  
Typical "B" dimensions are 1"-2".  
Typical "C" dimensions are from center of stone to the face of sheathing/outside face of wall structure.  
Typical "D" dimensions are  $\frac{3}{4}$ "-1".  
Typical thru hole diameter is  $\frac{1}{16}$ " larger than the fastener.  
For example, using a  $\frac{1}{4}$ " self tapping metal screw the diameter would be  $\frac{5}{16}$ ". Typical hole size is  $\frac{1}{2}$ " larger than all thread.

### DETAIL 4-"SPLIT TAIL" STRAP @ VENEER



#### "SPLIT TAIL" STRAP ISOMETRIC

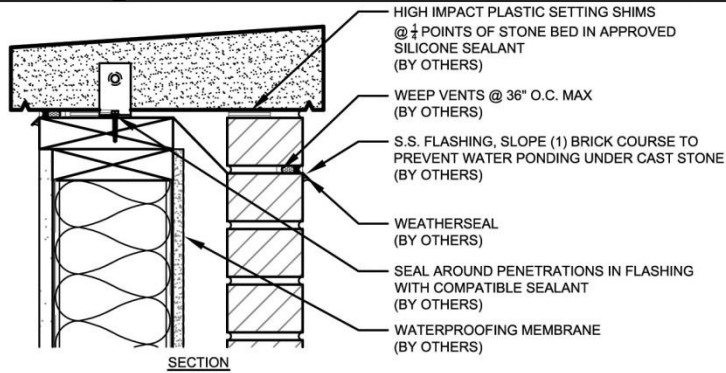
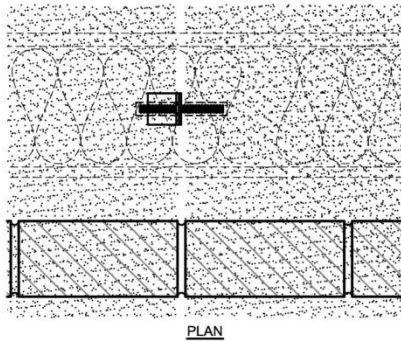
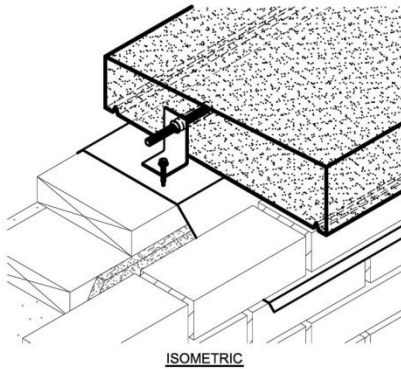


Typical "A" dimensions are 1"-2".  
Typical "B" dimensions are 1"-2".  
Typical "C" dimensions are from center of stone to the face of sheathing/outside face of wall structure.  
Typical "D" dimensions are  $\frac{3}{4}$ "-1".  
Typical thru hole diameter is  $\frac{1}{16}$ " larger than the fastener.  
For example, using a  $\frac{1}{4}$ " self tapping metal screw the diameter would be  $\frac{5}{16}$ ".

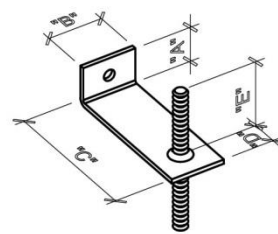
## Anchoring and Flashing Details

These are typical connections recommended by the Cast Stone Institute for similar applications. Consult your engineer for size and connection requirement before ordering anchors.

### DETAIL 5-"L" STRAP W/ WELDED DOWEL PINS @ COPING

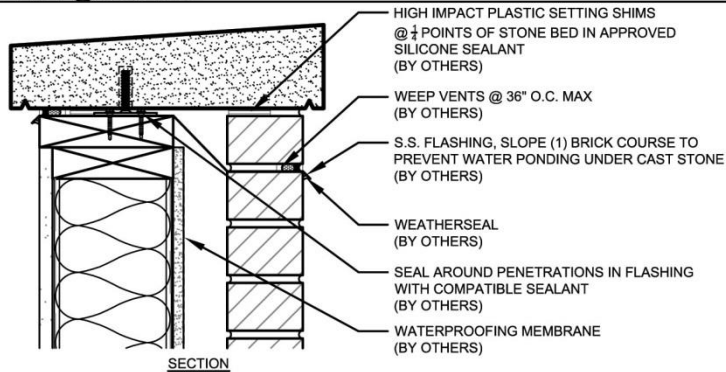
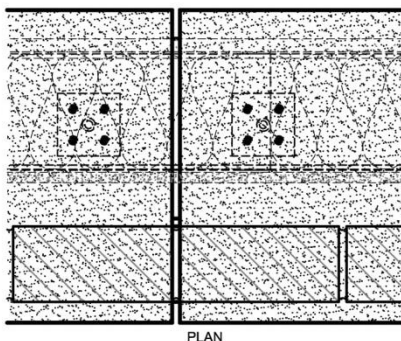
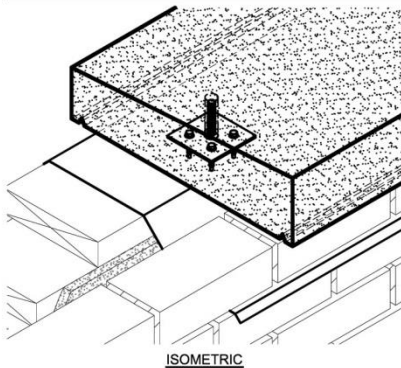


"L" STRAP W/ WELDED ALL THREAD PINS  
ISOMETRIC

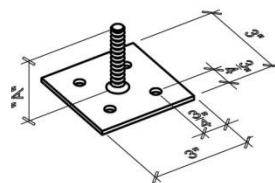


Typical "A" dimensions are 1"-2".  
Typical "B" dimensions are 1"-2".  
Typical "C" dimensions are from center of stone to the face of sheathing/outside face of wall structure.  
Typical "D" dimensions are 3/4"-1".  
Typical thru hole diameter is 1/16" larger than the fastener.  
For example, using a 1/4" self tapping metal screw the diameter would be 5/16". Typical hole size is 1/2" larger than all thread.

### DETAIL 6-WELDED DOWEL PIN AND PLATE @ COPING



WELDED ALL THREAD PIN AND PLATE  
ISOMETRIC



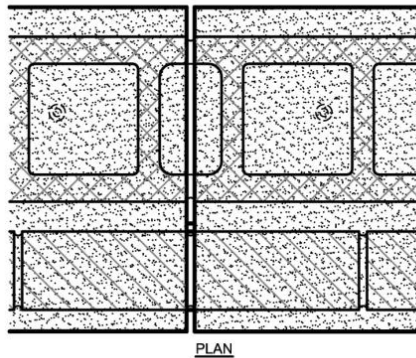
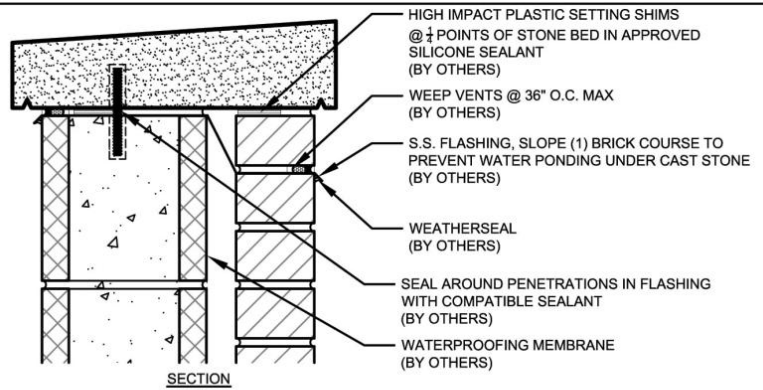
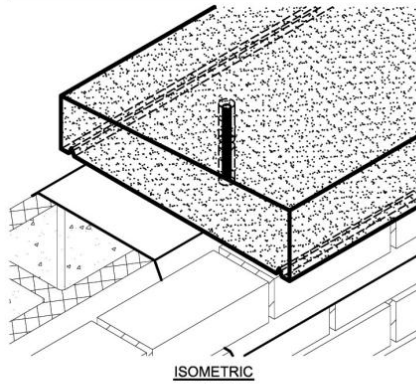
Typical "A" dimensions are 2"-3", with the most common being 2".  
Typical diameter varies from 3/8"-1" depending on the size of the stone. Most commonly used are 1/2" diameter x 2" LG. Field drill 1" diameter x 2" hole and fill with epoxy. Typical hole size is 1/2" larger than all thread.



## Anchoring and Flashing Details

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### DETAIL 7-DOWEL PIN @ COPING

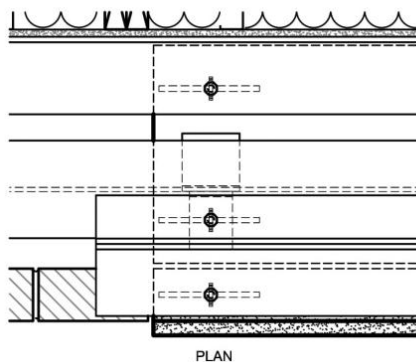
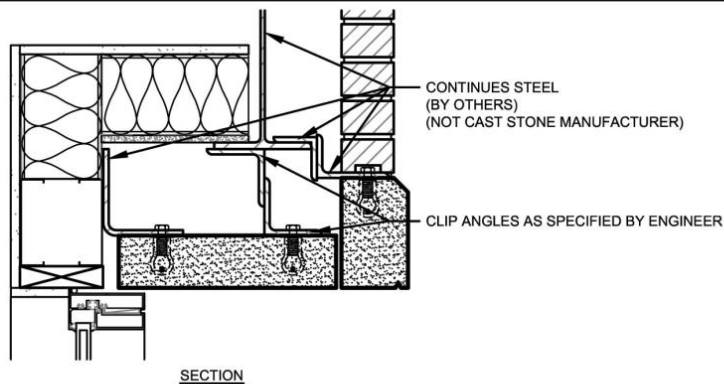
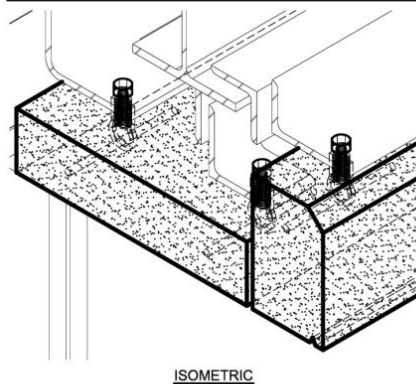


#### ALL THREAD PIN ISOMETRIC

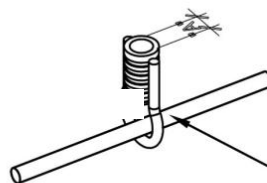


Typical "A" dimensions are 2"-6", with the most common being 4"  
Typical diameter varies from  $\frac{3}{8}$ "-1" depending on the size of the stone. Most commonly used are  $\frac{1}{2}$ " diameter x 4" LG. Field drill 1" diameter x 2" deep hole in to filled CMU and fill with non-shrink grout. Typical hole size is  $\frac{1}{2}$ " larger than all thread.

### DETAIL 8-FERRULE LOOP INSERT @ HEADER AND SOFFIT



#### NC THREADED FERRULE LOOP INSERT ISOMETRIC

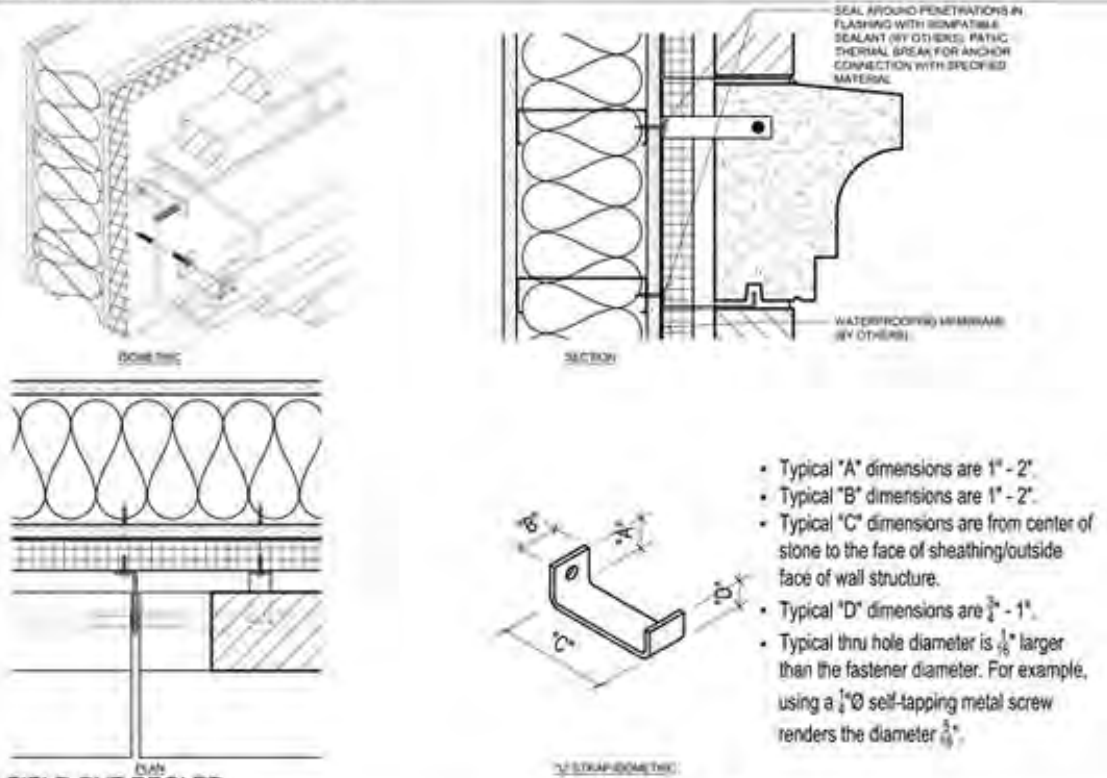


Typical "A" dimensions are  $\frac{3}{8}$ "-1", with the most common being  $\frac{1}{2}$ "

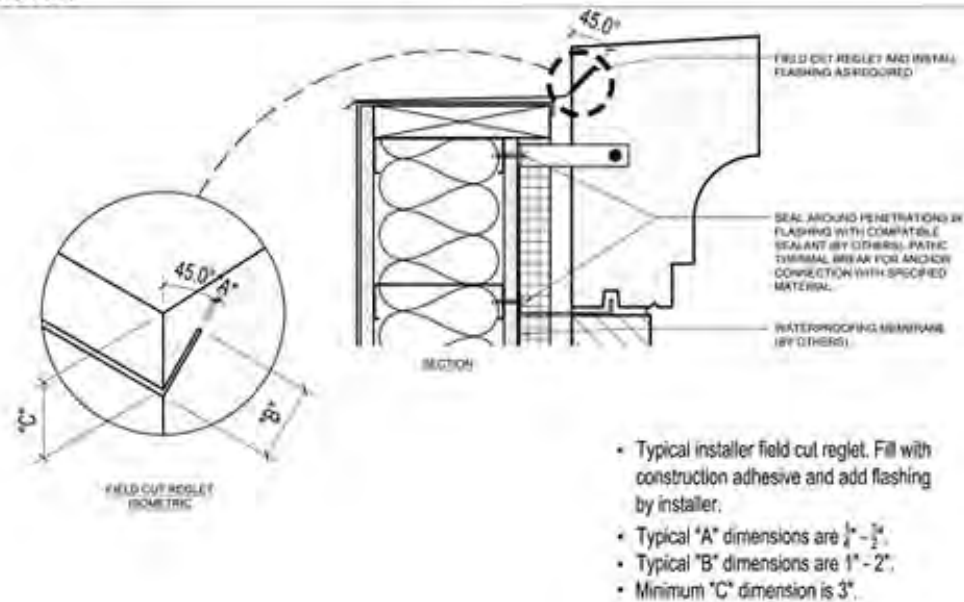
## Anchoring and Flashing Details

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DETAIL 9 - TYPICAL ANCHORAGE @ CORNICE



DETAIL 10 - FIELD CUT REGLET





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## USE OF REINFORCEMENT

One advantage of cast stone over natural stone is its ability to contain reinforcement. This gives cast stone an advantage by combining the high compressive strength of the cast stone with the flexural strength of reinforcement to provide additional stability and crack control. But despite this advantage, cast stone is an architectural element and should not be used to support the building structure or as a load bearing element.

It is important to understand that not all cast stone units require reinforcement in their design. Cast stone applications such as replacement for natural stone, manufactured masonry units and other non-structural applications that include units with low aspect ratios, do not benefit from reinforcing steel to control cracking. In general, reinforcement should only be added to the design when needed for shipping and handling, setting, increased safety or to address other non-structural stresses.

Due to the limitless shapes and sizes cast stone can take on, it is impractical to address every situation where reinforcement is beneficial. Generally, a minimum area of reinforcement equal to 0.25% of the unit cross-sectional area is recommended when units exceed fifteen (15) times the minimum thickness in any principal direction. Cantilevered, over hanging or other higher risk units should also be reinforced in the direction of greatest stress. Suspended units, including soffits, should be reinforced to engage the cast-in inserts and to hold together fractured pieces if damage were to occur.

One misconception about reinforcement in concrete is that it will prevent cracking, but reinforcing steel is only able to distribute cracks and minimize crack width. And no amount of reinforcement will prevent cracking in slender cast stone units (high aspect ratio). The Cast Stone Institute suggests that designers consult with the manufacturer to avoid incorporating units that will be prone to cracking based on their dimensions and geometry.

Most non-structural, low aspect ratio cast stone units may not benefit from embedded reinforcement. Therefore, the cast stone manufacturer should have the discretion to produce such units without reinforcement to avoid corrosion issues and increase the service life of the cast stone unit in the wall.

When required, reinforcing shall comply with the material requirements of ASTM C1364 – Standard for Architectural Cast Stone, TMS 504 - Standard for Fabrication of Architectural Cast Stone or D7957/D7957M Standard Specification for Solid Round Glass Fiber Reinforced Polymer Bars for Concrete Reinforcement. It should be noted that welded wire fabric reinforcement should not be used in Vibrant Dry Tamp (VDT) products. All reinforcement should be shown on the shop drawings that are submitted by the manufacturer for approval.

Some cast stone producers use synthetic fiber reinforcement to control plastic drying shrinkage and thermally-induced cracking in wet cast produced cast stone. Concrete meeting the requirements of ASTM C1116 - Standard Specification for Fiber-Reinforced Concrete and Shotcrete may be used but it's not a substitute for conventional steel reinforcement.

The size of reinforcing bars is indicated by a number that corresponds to its diameter in eighths of an inch. The typical sizes used to reinforce cast stone are #3 and #4 which are nominally 3/8" and 1/2" diameter respectively. Deformed bars are slightly larger than plain bars and provide improved bond strength with the concrete resulting in better tension resistance. Reinforcement type, size and placement within the cast stone should comply with the requirements of C1364 and TMS 504.



Tying reinforcing sections together prior to unit fabrication is usually not required with Vibrant Dry Tamp (VDT) units because the reinforcement is embedded into a layer of compacted fresh concrete during the manufacturing process. The use of three-dimensional reinforcing cage assemblies with stirrups is not recommended for Vibrant Dry Tamp units because voids can form around the reinforcement during the compaction process due to the non-fluid nature of the concrete. Eliminating these voids is important to developing bond strength between the bar and the concrete and reducing the potential for corrosion.

Cast stone units manufactured from wet cast concrete must have their reinforcement properly located and sufficiently rigid to prevent movement during the pouring process and to maintain the required concrete cover. Rebar chairs, which position the reinforcing steel away from the face of the mold are not recommended with cast stone. Special procedures must be followed to prevent reinforcing steel from telegraphing its location to the face of the units when this production method is used.

Reinforcing bar size should be kept to a minimum, even if this will require more bars to resist cracking and improve thermal stress distribution. Reinforcement should be placed symmetrically to prevent warping of longer units. The typical spacing of reinforcement is 12" on-center and should not exceed 18" on-center.

In summary, these guidelines should be considered, along with the discretion of the producer, to determine if reinforcement is needed for safe shipping and handling, setting, and non-structural stress. While an engineer is not required to review cast stone reinforcing steel placement, one may be consulted if a designer or producer has a unique application.

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## ALLOWING FOR MOVEMENT OF MASONRY MATERIALS

Building materials experience dimensional changes and movement due to environmental conditions, such as temperature and moisture or movement of adjacent building elements. If this movement is restrained, cracking may result. By accounting for movement in the wall design, cracking can be controlled. Movement joints are used to control and minimize cracking. There are two types of movement joints typically used in masonry construction; control joints and expansion joints.

Control joints are placed in concrete masonry walls to limit cracks due to shrinkage. Control joints are unbonded vertical separations built into a concrete masonry wall to reduce restraint and permit longitudinal movement. They are located where cracking is likely to occur due to excessive tensile stress. An expansion joint is typically used in brick masonry walls to provide means for expansion and contraction movements produced by temperature changes, moisture, loadings or other forces. Expansion joints allow for both expansion and contraction and may be vertical or horizontal.

### THERMAL MOVEMENTS

Most building materials experience reversible movements due to temperature change. Concrete masonry movement has been shown to be linearly proportional to temperature change. The coefficient of thermal movement normally used in design is 0.0000045 in./in./°F (0.0000081 mm/mm/°C). Actual values may range from 0.0000025 to 0.0000055 in./in./°F (0.0000045 to 0.0000099 mm/mm/°C) depending mainly on the type of aggregate used in the unit according to the National Concrete Masonry Association. These values ~~are~~ may also be appropriate for Cast Stone. The actual change in temperature is, of course, determined by geographical location, wall exposure, and color.

Overall, the amount of movement due to temperature change in a cast stone wall is relatively small. For example, a wall constructed during 70°F (21°C) weather and subjected to a minimum temperature of 0°F (-18°C) results in a shortening of about 0.38 in. (9.7 mm) in a 100 foot (30.48 m) long wall using the 0.0000045 in./in./°F (0.0000081 mm/mm/°C) coefficient.

### MOISTURE MOVEMENTS

Many building materials tend to expand with an increase in moisture content and contract with a loss of water, including concrete and concrete masonry units. However, clay brick units experience irreversible expansion slowly over time upon exposure to water or humid air.

### DRYING SHRINKAGE

Drying shrinkage is also due to a change in moisture content. However, drying shrinkage results from the natural moisture loss that results as concrete products are aged, rather than atmospheric moisture changes. Concrete products are composed of a matrix of aggregate particles coated by cement that bonds them together. The amount of cement content influences the amount of drying shrinkage that occurs.

Although mortar is also a cementitious product and does experience drying shrinkage, unit shrinkage has been shown to be the predominate indicator of the overall wall shrinkage principally due to the fact that it represents the largest portion of the wall. Therefore, the shrinkage properties of the unit alone are typically used to establish design criteria for crack control. The manufacturer should be consulted for the shrinkage characteristics their cast stone exhibits.

## CLAY PRODUCTS

As discussed previously, clay brick units expand irreversibly over time upon exposure to water or humid air. A brick unit is smallest in size when it cools after coming from the kiln. The unit will increase in size due to moisture expansion from that time. Most of the expansion takes place quickly over the first few weeks, but expansion will continue at a much lower rate for several years. According to the Brick Industry Association, the moisture expansion behavior of brick depends primarily on the raw materials and secondarily on the firing temperatures. Brick made from the same raw materials that are fired at lower temperatures will expand more than those fired at higher temperatures.

## CAST STONE UNITS

Because shrinkage is expressed as a percentage, individual cast stone units will experience actual shrinkage depending upon their length. In the case of differential movements, hairline cracking is likely to occur when units are designed to lengths which are beyond the general rule of 15 times the thickness or a maximum length specified by an engineer.

Visible movement cracks exceeding 0.005 in. within the cast stone unit are regarded as deficiencies in high quality Cast Stone installations. This is a much higher standard than is found in architectural concrete work. This has structural implications, as the structural stress limit of Cast Stone must be less than the modulus of rupture for the material to avoid any occurrence of cracking.

When considering non-structural cast stone units, units that do not carry any loads other than their own self-weight and transfer wind loads, limiting the length of the cast stone can reduce the potential of cracking. As a general rule, limiting the length of a Cast Stone trim element to no more than 15 times the least cross-sectional dimension should be observed in most applications. However, in many cases shorter lengths may be advised. For example, bearing conditions, high wind loads, large lengths of banding and unusual shapes are all factors that affect the structural stress and cracking potential, but vary from job to job.

Temperature and moisture changes can cause changes in the size of the Cast Stone. Increases in temperature can cause Cast Stone units to elongate, but decreases in temperature can have the opposite effect. The magnitude of these physical properties depends in part on the size of the unit. The combined effects of thermal and moisture movements in Cast Stone units and panels are often negligible, unless the units are 8 ft. or more in length in any direction. In this case, they may experience 1/8 in. or more in expansion or contraction due to combined thermal and moisture movements.

## HORIZONTAL JOINT REINFORCEMENT

Depending on the project location, bond pattern, and other factors, it may be common practice to install horizontal joint reinforcing in the bed joints of a cast stone wall. On a project located in a high seismic region, where required by code, horizontal joint reinforcement may be used in conjunction with conventional bed ties. However, joint reinforcing may not be required where seismic loads are negligible. If the cast stone is set using mechanical anchorage, there is no evidence that horizontal joint reinforcing will add any strength, but may only aide in holding the mortar in place. Should unplanned cracks occur in the wall due to the lack of adequate movement joints in the system, horizontal joint reinforcing may help to keep the cracks in the mortar to a minimum.

Reference TMS 404-16 Standard for Design of Architectural Cast Stone Section 4.2 regarding vertically aligned bond with Commentary and Figures C4.2-1 and C4.2-2. These are found on pages D5 and D6.



## RECOMMENDATIONS

In some cases, Cast Stone units laid in mortar may follow the same recommendations for other masonry units. The location of control joints in walls with Cast Stone will depend on the materials used in the entire wall. When Cast Stone is used as an isolated accent in clay brick walls, recommendations for expansion joints for clay brick should be followed. For isolated accent pieces, no other special requirements apply. When Cast Stone banding is used in clay brick walls, the spacing of vertical expansion joints for clay brick and the spacing of control joints for concrete masonry should both be examined. The expansion joint spacing should be based on the most stringent requirement. In addition, the Brick Industry Association recommends providing a bond break between the clay brick and concrete or Cast Stone banding to accommodate the differential movement that will occur. In this case, flashing is often placed either directly above or below the banding course. Using a bond break both above and below the banding course is not recommended unless proper mortar embedment of the anchors in the veneer can be achieved.

Hairline cracks may occur along the head and bed joints as both the mortar and the cast stone units experience shrinkage. But this can be minimized if the mortar is tooled when thumbprint hard. Furthermore, hairline cracks can be minimized by keeping lengths of Cast Stone units to within the limits dictated by principles of masonry construction. If the wall is properly designed, any hairline cracks that do occur will not affect the structural integrity of the wall. Large cracks can be avoided by incorporating control joints and other recommended details. Spacing of control joints depends on several factors such as project location, type of masonry, wall dimensions, etc. Therefore, the required spacing of control joints will vary greatly based on the project conditions. Cast Stone units that are to be wetted before installation must be wetted on those surfaces which are to be set in mortar in order to aid in achieving proper bond with the mortar and mitigate cracking in the mortar joints.

As required, total linear drying shrinkage shall be based on tests of cast stone units of any configuration or dimension made with the same materials, concrete mix design, manufacturing process, and curing method, conducted in accordance with Test Method C426 and within 24 months of production of the units.

Refrain from installing units until they have been cured to Cast Stone Institute specifications. Also, limit the maximum dimension of any Cast Stone piece to less than 8 ft. unless care is given to accommodate the possible expansion and contraction of the stone.

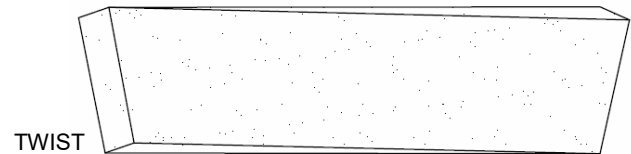
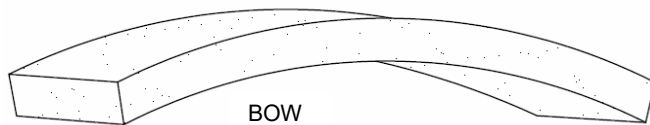
Consult a designer and/or engineer in order to determine where expansion joints should be placed to ensure the wall meets the design requirements.

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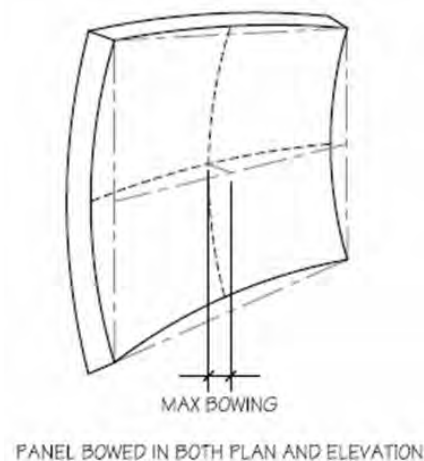
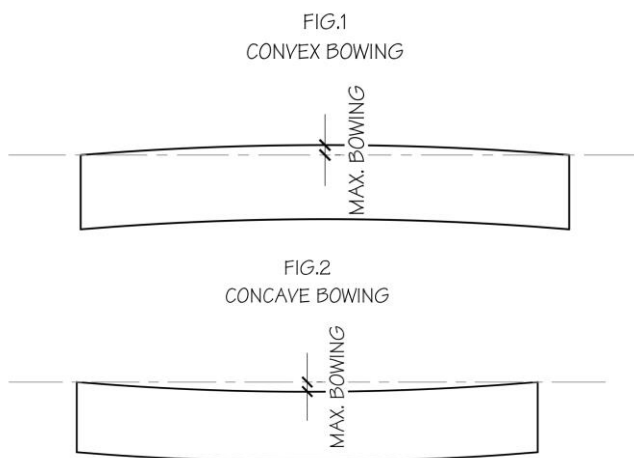
## BOW AND TWIST

Conditions of bow and/or twist, when combined with lighting from an unfavorable angle or misalignment during installation, detract from the cosmetics of a masonry structure. Bowing can be defined as an overall out-of-plane condition in which two opposite edges of a component, such as a panel, fall in the same plane and the portion of the panel between the edges is out of plane. Twisting (or warping) is a condition in which the corners of the panel do not fall within the same plane, resulting in overall out-of-plane curvature of surfaces. Below are two drawings illustrating bow and twist. While bow and twist are not structural issues, but rather aesthetic ones, the Cast Stone Institute's Standard Specification for Architectural Cast Stone defines strict limits for both conditions.



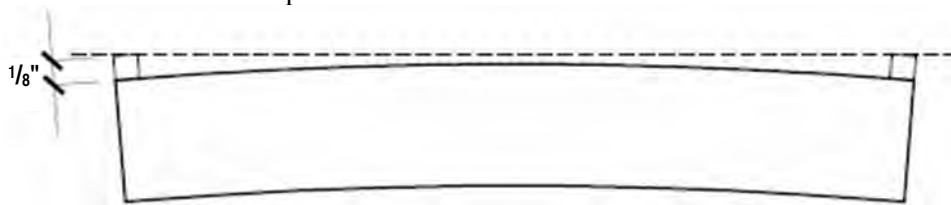
The Standard Specification for Architectural Cast Stone states, "Warp, bow or twist of units shall not exceed length/360 or  $\pm 1/8$  in., whichever is greater." If the pieces are 45 inches long or less,  $\pm 1/8$ " applies. For longer pieces, divide the length by 360.

### Measurement of Bow:

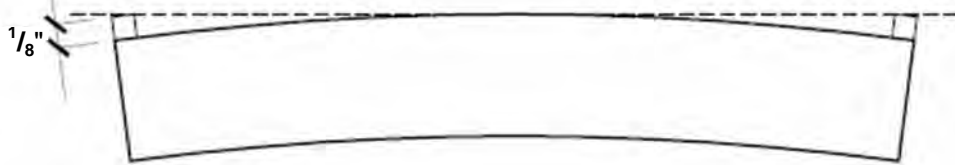


A problem encountered in the field is that convex bowing cannot be measured as shown after the stone has been installed. To measure convex bowing after installation, shims and a straight edge are employed.

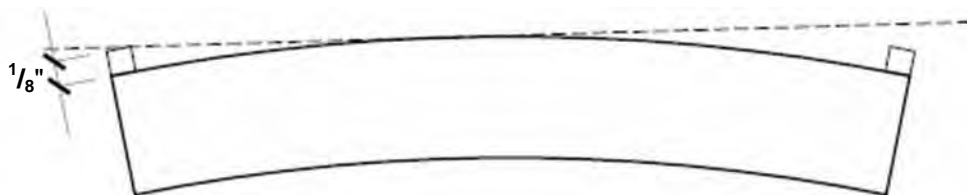
**Case #1:** With  $1/8$ " shims at both ends, the straight edge doesn't touch the stone. Therefore the bow is less than  $1/8$ " and the stone is within specification.



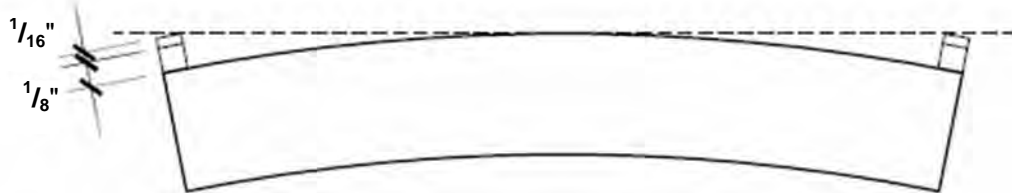
**Case #2:** With 1/8" shims at both ends, the straight edge just touches the stone. The straight edge cannot be rocked by applying more pressure to either end. Therefore the bow is equal to 1/8" and the stone is within specification.



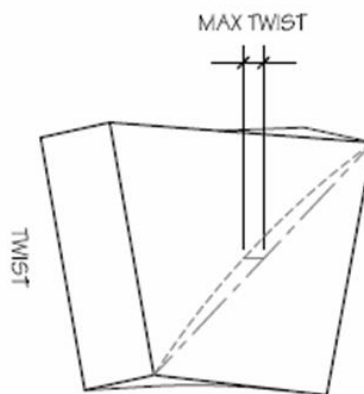
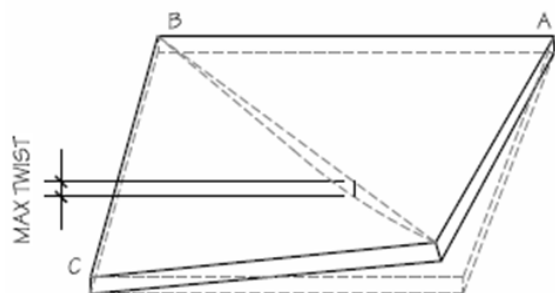
**Case #3:** With 1/8" shims at both ends, the straight edge can only touch one shim when in contact with the stone in the middle. The bow is greater than 1/8" and the stone is out of specification.



**Measuring Case #3:** To measure the bow in this stone, add additional equal shims to both sides until the straight edge touches both shims and the stone. The bow of the stones is equal to the amount of shim on either side, in this case, the bow is 3/16" and the stone is out of specification.



**Measurement of Twist is done in a similar manner:**

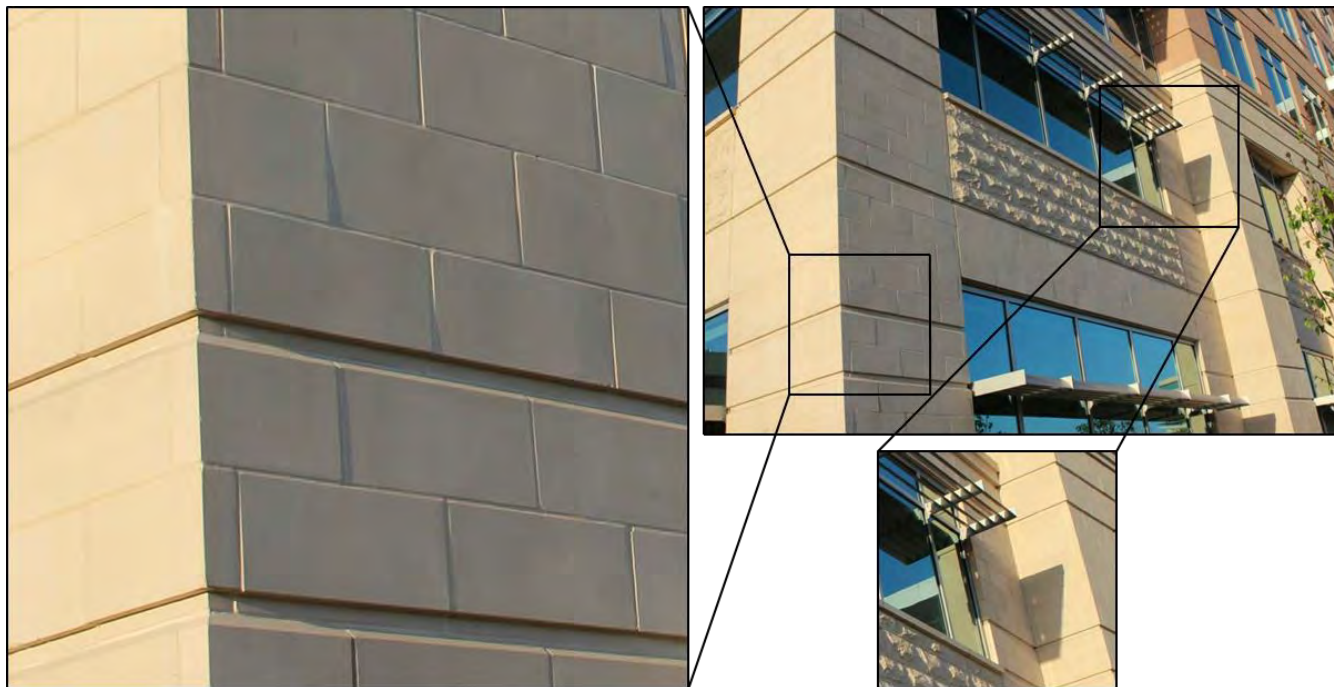




### **Shadow Lines:**

Shadow lines are formed when an irregular surface is lighted from an angle. A typical installation specification for alignment of adjacent masonry units is  $\pm 1/16''$  plus in-tolerance bowing or twisting of masonry units. Therefore, the total of installation and manufacturing tolerance can result in up to  $3/16''$  alignment differences in adjacent units, and potentially more if the units are longer.

*Under some lighting conditions, shadows will be cast which may make alignment seem to be much worse than actual and appear to be outside of specifications.*



**Notes:** The photo on the left shows the large shadows that can arise from small, within specification, setting misalignment. The photo on the lower right shows the angle of the sun. Note that the stones on the side of the building in direct sunlight do not show any of these shadows.

### **Shadow Length Calculations:**

This table shows the shadow lengths of a  $1/16''$  projection at several lighting angles.

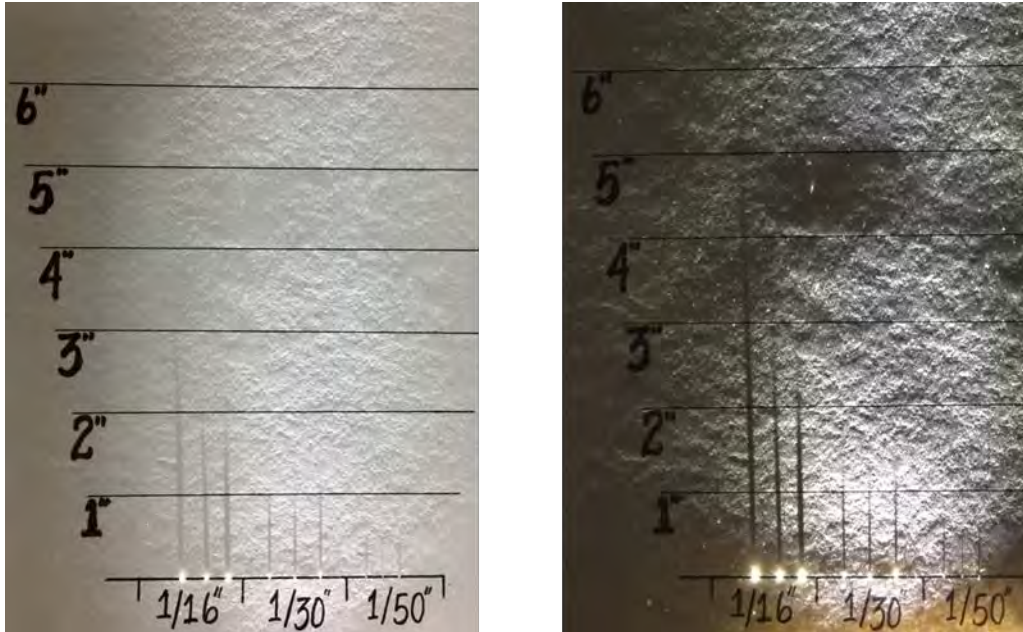
SUN ANGLE	COTANGENT	SHADOW LENGTH OF 1/16" PROJECTION
1 degree	57.29	3.581
2.5 degrees	22.9038	1.431
5 degrees	11.4301	0.714
10 degrees	5.6713	0.354
80 degrees	0.1763	0.011

When lit from a small angle, the shadow which is cast can be more than 50 times the amount of projection!



### Shadows Cast by Graded Sand:

These photos of sieved masonry sand have been taken at small lighting angles (about 2° and 1°).



- The sand labeled “1/16” passed through a sieve with 1/8” mesh and did not pass through a sieve with 1/16” mesh. These particles are therefore smaller than 1/8” and larger or equal to 1/16”
- Similarly, the sand labeled “1/30” passed through a sieve with 1/16” mesh and did not pass through a 1/30” sieve.
- The sand labeled “1/50” passed through 1/30” and not 1/50”.
- Note that shadows cast from in-specification masonry can easily exceed one inch and in extreme lighting conditions can be more than five inches long!

The Cast Stone Institute’s dimensional specifications on bow and twist are just as important as its specification on length. Cast stone producers must strictly adhere to the CSI specification limits on bow and twist. In addition, masons must be careful to minimize installation misalignment and to exercise care in “humoring” allowable manufacturing variances during installation. Even with the best practices, certain lighting conditions may cause masonry units to appear to be out of specification.

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## FREEZE/THAW DURABILITY

Architectural Cast Stone has been successfully used for decades in all climatic conditions. Cast stone has historically performed well when exposed to freezing and thawing environments, but like all building materials, cast stone can fail, too. Freeze/thaw damage occurs when the pore structure of the cast stone becomes fully saturated and cycles between freezing and thawing. Because water expands about 9% when it freezes, the concrete cannot withstand these expansive forces and the cast stone can fail over time. The problem is exacerbated when the cast stone is exposed to deicing salts.

In order to reasonably assure that the cast stone performs in-situ, the manufacturer must first produce a quality product. Second, the designer must use the cast stone in the manner that does not subject it to saturated conditions. Finally the contractor must install the cast stone according to plans.

There are three processes used to produce cast stone: vibrant dry tamp (dry cast), wet cast and machine made. Regardless of the process, all must comply with the requirements of ASTM C1364 Standard Specification of Architectural Cast Stone which references ASTM C 666, Procedure A - Test Method for Resistance of Concrete to Rapid Freezing and Thawing as the testing procedure as modified by ASTM C1364.

From a manufacturing standpoint, well performing cast stone starts with quality aggregates, cementitious materials and admixtures (see Technical Bulletin #50 for guidance on air entraining admixtures). Next these materials have to be properly proportioned, batched, placed or formed and cured. Finally, every 24 months or when changes to mixes or processes are made, the manufacturer must demonstrate through laboratory testing that their cast stone complies with specification.

The highest quality cast stone can still fail if it is not properly designed and installed. It is important that the designer locate flashing and weeps so as to allow for adequate drainage of water that may have breached the exterior. Additionally, care should be taken when using cast stone adjacent to areas where snow may accumulate and where deicing salts may be used. For mechanically set cast stone, the top kerf in the cast stone should be filled with sealant in order to mitigate breakage due to water infiltration and freeze/thaw. Finally, flashing and weeps that are not properly installed can restrict moisture drainage that can be detrimental to the cast stone.

In summary, cast stone enjoys a history of success. The options available and its versatility make cast stone a great alternative to natural stone. Using quality products that are properly designed and installed assures the end user of long term performance and satisfaction.

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## AIR ENTRAINMENT REQUIREMENTS

Freeze thaw durability is an important physical property of cast stone and ASTM C1364 Standard Specification for Architectural Cast Stone has specific performance requirements. ASTM C1364 requires that both “wet cast” and “dry cast” produced cast stone have a maximum 5.0% weight loss when subjected to 300 rapid freeze-thaw cycles, as per ASTM C666. But to produce durable cast stone, it is important to understand the mechanisms that cause concrete to deteriorate in freeze/thaw environments.

Freeze/thaw damage occurs when the pore structure of the cast stone becomes fully saturated with water and cycles between freezing and thawing. Because water expands about 9% of its volume when it freezes, the concrete cannot withstand these expansive forces and the cast stone can fail overtime. And the problem is exacerbated when the cast stone is exposed to deicing salts.

In the late 1930’s air-entraining admixtures (ASTM C260) were developed for slump concrete to increase their resistance to freeze/thaw degradation. Air-entraining admixtures form microscopic bubbles in the cement paste of the concrete matrix. According ACI 212.2R Admixtures in Concrete, there have to be enough bubbles, of the correct size and properly spaced (spacing factor) in the cement paste to be effective. Below are images from polished cross sections made from wet cast concrete illustrating different entrained air content.

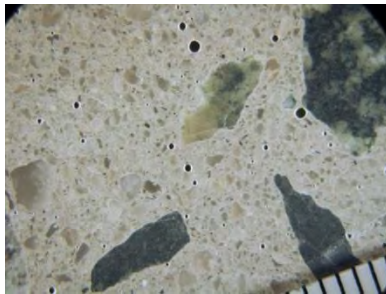


Figure 1 1.0% Hardened Air

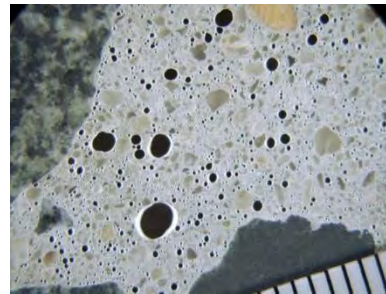


Figure 2 6.0% Hardened Air

During the freezing phase, these microscopic bubbles provide a hydrophobic void for the freezing water front to migrate into so that the freezing water will not expand in the capillary pores to a point where it will damage the paste structure. Upon thawing, the bubbles release the water and become empty and ready for the next freeze cycle. While not required, it is recommended that cast stone made with slump concrete contain an air entraining admixture to minimize freeze-thaw damage. Air entraining admixtures are an effective, low cost option to improving freeze/thaw durability of wet cast produced cast stone.

Experience has shown that traditional air entraining admixtures are not as effective for cast stone manufactured with zero slump concrete. Vibrant Dry Tamped cast stone (VDT) is manufactured using earth moist mixes having just enough water to make a compactable concrete mixture. This lack of water makes it difficult to produce properly spaced and stable air bubbles. Petrographic analyses of cast stone made with air-entraining admixtures have shown that the microscopic spheres, if any are detected, are not uniformly spaced throughout the mix, thus rendering the admixture less effective.

Vibrant dry tamp cast stone typically perform well in laboratory testing and in-situ. This is because the mixes are a cement rich mix, contain low water content and reduced capillary pores structure. Therefore, VDT cast stone has an appropriate pore structure, which will accommodate the hydraulic pressure necessary to prevent distress during freezing and thawing cycles.



There are a number of factors that affect how cast stone performs in freeze/thaw environments, but from a manufacturing standpoint, well performing cast stone starts with quality aggregates, cementitious materials and admixtures. Not only is it important to use quality materials, but they have to be properly proportioned, batched, placed or formed and cured. It's only through laboratory testing that the manufacturer can demonstrate that their cast stone complies with specifications.

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## WATER REPELLENT COATINGS

Cast stone is naturally permeable, which is similar to natural limestone and architectural concrete. The purpose of a water repellent coating should be to minimize water intrusion through the outer surface of the cast stone or mortar, while allowing sufficient vapor transmission to let moisture out of the wall cavity, thereby improving weathering qualities and the ability to easily clean the surface if it becomes dirty. The technology of water repellent coatings has improved considerably in the last few years with many durable products available that reduce water intrusion through cast stone and mortar joints. Proper application of water repellents can minimize efflorescence, mildew, staining and dirt. Some product manufactures offer 5-10 year warranties when following their specific recommendations.

The most popular and time-tested water repellent coating formulations are silicone, acrylic, silane and siloxane based. Silicones are relatively inexpensive, only provide a surface protection, and usually, only last a short time. Silicones are mainly used to keep cast stone clean during construction and they make the finished installation easier to clean. Many types of acrylics are available but most have poor vapor transmission, low penetration and inadequate resistance to ultraviolet light. Some acrylics have been known to turn yellow or produce a gloss.

When a water repellent coating is desired, the Cast Stone Institute® recommends using a silane or siloxane (or blends of each). Silanes and siloxanes work by penetrating the exterior surface and then undergoing a chemical reaction with the moisture to form a water-repellent silicone resin within the void structure. Since they react with water, walls may be slightly damp but if water is contained in the pores, penetration may be limited. It is important to follow the manufacturer's application recommendations.

Planter, fountain, and swimming pool coping, treads, risers, stone pieces above grade, and pavers may be treated with a silane or silane/siloxane blend water repellent coating after setting. For below grade applications, a dampproofing product, such as a cementitious waterproof stone backing or bituminous dampproofing may be applied to the back, sides and the below grade face surfaces. This will minimize the likelihood of dirt and groundwater entering the surface of the stone; a frequent cause of staining, efflorescence and enhancement of crazing. Verify that the water repellent coating does not affect color or texture when dry.

Water repellent coatings are not a remedy for moisture penetration problems caused by poor details such as the improper use of flashing, lack of weep holes, non-ventilated wythe, failure of joint materials or the use of hard mortar joints where sealant joints should be used. Water repellents should be applied after all pointing repair, cleaning and inspection operations are completed. Proper evaluation of suggested water repellents should include inspection of similar installations where the proposed material has been used under similar exposure conditions. The application should be guaranteed by the water repellent manufacturer or the applicator not to discolor the cast stone.

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## CRAZING

Crazing is defined as fine and random cracking extending through the surface, normally less than one millimeter in depth. It can appear along or perpendicular to the length, in polygonal shapes or as random "map cracking."



Crazing has been a concern since concrete has been in existence. The appearance of small cracks on the surface, especially when filled with water or dirt, can be alarming since it is assumed that the fissures are running through the entire cross section the concrete. But in general, crazing does not affect the structural integrity of the concrete and should not by itself be cause for rejection. All cement based products and many natural stones are susceptible to crazing.

There are many theories as to the causes of crazing, but typically it is due to differential contraction between the surface and interior sections of the concrete. Crazing can be caused by any factor which causes surface tension in excess of interior tension.

Conditions due to manufacturing include improper curing, a surface film richer in cement and fines than the body of the concrete and plastic shrinkage cracking. A producer, careful in proportioning mix designs and watchful of compaction techniques and curing methods, can minimize the likelihood of crazing. Manufacturers of Cast Stone who experience crazing should review their mix designs and production process and pay particular attention to the design and installation details during the shop drawing submission process.

Crazing can also be caused by design and installation factors which unusually cause high amounts of vapor transmission, excessive wetting and drying or inadequate ventilation in a wall assembly. There is also some evidence that atmospheric carbonization can cause crazing as well.

Common installation problems which can cause or enhance crazing include:

1. The use of through-wall flashing without or lack of sufficient weep holes
2. Use of Cast Stone without a ventilated wythe
3. Use of Cast Stone below grade or at planter type areas without a proper moisture barrier
4. Failure of joint sealant materials which allow water penetration
5. The use of mortar joints where soft sealant joints should be used
6. Lack of sufficient control joints.

Design professionals should ensure that the wall section details provide adequate ventilation and drainage behind Cast Stone and above flashing. Sealant joints should be used in accordance with CSI specifications and wherever thermal movement is likely.





Since crazing is only on the surface, the visual appearance of the cracks can usually be minimized by cleaning the affected areas with a mild acid solution. Severe cases of crazing may require application of a silane/siloxane sealer, following cleaning, to penetrate the cracks and to keep dirt from settling into the surface.

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## EFFLORESCENCE

Efflorescence is a crystalline material, usually white, that forms on the surface of masonry walls and concrete products. Efflorescence is unsightly and it is usually a source of disagreement among producers, contractors and architects as to why it occurs and what should be done about. While all masonry and concrete materials are susceptible to efflorescence, it is not detrimental to the structural integrity of the material. Furthermore, according to ASTM C1364, Standard Specification for Architectural Cast Stone, efflorescence by itself does not constitute a cause for product rejection.

As cement hydrates water soluble calcium hydroxide is formed. When moisture combines with calcium hydroxide, the likelihood of efflorescence occurring on the surface increases. As the calcium hydroxide solution is exposed to the elements, it reacts with the carbon dioxide and forms an insoluble compound called calcium carbonate, which is less water soluble. It is difficult to predict whether efflorescence will occur, but when it does, the sooner it is removed the better.

Efflorescence that occurs on the surface of the installed materials is typically due to:

- Improper use of through-wall flashing
- Lack of sufficient or improperly spaced weep holes
- Use of cast stone without a ventilated wythe
- Use of cast stone below grade or at planter type areas without proper moisture barrier (see below)
- Use of mortar joints when sealant joints should be used
- Failure of joint sealants which allow water entry
- Leaving joints open or wall uncovered during construction

There are several reasons why efflorescence occurs, but careful selection of building materials and the design and installation of the materials can significantly reduce its potential.

Planter, fountain and swimming pool coping, treads, risers, stone pieces and pavers may be treated with a silane or silane/siloxane water repellent coating on the surfaces that are above grade. For below grade applications, a dampproofing product, such as a cementitious waterproof stone backing or bituminous dampproofing may be applied to the back, sides and the below grade face surfaces. This will minimize the likelihood of dirt and groundwater entering the surface of the stone; a frequent cause of staining, efflorescence and enhancement of crazing. Check that the water repellent coating does not affect color or texture when dry. Finally, soffit stones are also susceptible to efflorescence from masonry walls above and should be designed to prevent them from becoming the “gutter” of the wall.

Efflorescence commonly occurs in the fall and winter months when the vapor transmission slows down and the masonry stays damp for extended periods of time. Calcium hydroxide is more soluble in water at cold temperatures than at warmer temperatures. This is another reason why efflorescence is more common in the winter than the summer. While most efflorescence is temporary and may wash off with rain water, it is also prudent to remove it prior to it converting to calcium carbonate. For new building construction it is recommended that a cleaning procedure be performed to remove any debris and efflorescence. Care should be taken to use the appropriate cleaning agent and method as further efflorescence could occur.

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## BASIC COMPARISONS BETWEEN VARIOUS MASONRY MATERIALS

Cast stone has been in existence for hundreds of years and is a cost effective alternative to natural cut stone. Through the product's history, technical and performance standards have been established and maintained to assure long-term performance. United States cast stone standards are designed to provide a product of "infinite life" which, in concrete terminology, means exceeding 100 years. Since other concrete and simulated stone products are available for use in construction, architects or other specifiers who are looking for such durable physical attributes should be sure to specify a product that meets established building codes and specifications for that level of performance.

Most other simulated stone, ordinary concrete and stone look-alike materials cannot meet the minimum physical requirements established as cast stone standards. The in-service impact of look-alike materials and their inability to meet rigorous endurance performance criteria are other issues that should be taken into account by designers when comparing the alternative materials and, are discussed below.

### Basic Material and Standards Comparisons

Of prime importance in selecting an enduring masonry product to be used as an architectural trim, feature or ornament for buildings and other structures should be the following, as measured by an ASTM Standard Test Method specifically designated for the particular product:

- Relative high compressive strength
- Relative low absorption
- Enduring freeze thaw resistance
- Inclusion of steel reinforcement to provide tensile and or flexure strength when needed

### PERFORMANCE CHARACTERISTICS PHYSICAL PROPERTIES COMPARISON CHART

The chart below points out the physical features compared to other types of building products.

Product	Minimum PSI	Maximum Absorption	ASTM Standard	Durability/Freeze-thaw	Can Be Reinforced
Architectural Cast Stone	6,500	6%	C1364	5% loss or less @ 300 cycles	Yes
Architectural Precast	5,000	6%	None	None	Yes
Limestone Grade II	4,000	7.5%	C568	None	No
Calcium Silicate	Grade MW 3,500	14.0%	C73	None	No
	Grade SW 5,500	11.6%			
(assuming average density of 129 lbs/cf)					
Adhered Manufactured Stone Masonry Veneer	2,100	None as per ASTM	C1670	1.5% loss or less @ 50 cycles	No

Referenced Specifications from the American Society of Testing Materials and the Architectural Precast Association (not all products have ASTM requirements).

Cast stone is an architectural concrete building stone product. It combines the strength and durability of reinforced precast concrete with the appearance of natural stone. It consists of Portland cement, fine and coarse aggregates usually of granite, quartz or limestone, natural or manufactured sands and high performance additives. ASTM C1364 exists for cast stone and references all of the raw materials standards it comprises.

All concrete products are not equal! The Cast Stone Institute® strives to maintain some of the highest quality concrete produced for the architectural community. With our Producer Certification Program and the high production standards, our products exceed most architectural requirements for building components.

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## SPECIFICATION OF CAST STONE PRODUCTION METHODS

Many articles have been written over the years concerning the process used for making cast stone and whether the method or apparatus should be specified by the purchaser or selected by the manufacturer. Most of these articles were written by producers promoting the method(s) used at a particular facility in an attempt to promote superiority over plants using another method.

Sometimes specifiers select one method over another, which can lead to disappointing results when their expertise may not be intrinsic to specialty concrete product manufacturing and its processes. Terminology most often used to describe a process in concrete is wet-cast, dry-cast, semi-dry, vibrant dry-tamped, vibratory dry-tamped, machine made, wet-poured, earth moist, etc. These methods can be subdivided into three basic groups according to CSI Specification 04 7200:

- “Vibrant dry tamp (dry cast) products, n—Cast Stone manufactured from earth moist, zero slump concrete densely compacted by apparatus.”
- “Wet cast products, n—Cast Stone manufactured from measurable slump concrete consolidated by apparatus.”
- “Machine casting method n—Cast Stone manufactured from earth moist, zero-slump concrete compacted by machinery using vibration and pressure against a mold until it becomes densely consolidated.”

*Cast Stone units covered by a project specification should not include the manufacturing method,* as ASTM C1364 – Standard Specification for Architectural Cast Stone - states that, “Slump, manufacturing method, and apparatus shall be selected by the manufacturer and not specified by the purchaser.” The project specification should cover the performance criteria (i.e. compressive strength, absorption, freeze-thaw durability) and referenced standards wherever possible, as opposed to prescriptive methods of achieving physical properties.

The designer should specify shape, color, finish and other technical and design attributes listed in the Cast Stone Institute Standard Specification. For most applications, the manufacturer should submit shop drawings showing details and sizes of stones, arrangements of joints, anchor details, etc., for approval, unless the units are a standardized shape.

The manufacturer selects the design mix proportions, water-cement ratio (including slump), mold construction, apparatus for consolidating the mix into the molds and other criteria used in the manufacturing process. Factors used in determining appropriate production method(s) to be used are usually size, weight, shape, finish, type of reinforcing, anchoring methods and application in the structure.

Specifying a Cast Stone Institute Certified Plant® that maintains rigorous quality control standards set forth by the Cast Stone Institute is your first step toward designing a successful project.

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## DEGREES OF CUSTOMIZATION

Improvements in the availability and economy of cast stone can often be achieved when the specifier balances the needs of a project with the degree of custom shapes desired for the installation project. The indirect labor costs of design, layout, supervision, coordination and mold making needed for a “full custom” project can greatly exceed the actual direct cost of just casting and delivering a basic or standard product to the jobsite. This causes wide variances in the price of cast stone and places a premium on the product, which is not always necessary. With this in mind, cast stone projects will generally fit into one of the following categories: Standard, Semi-Custom or Custom.

Standard cast stone are specified according to a manufacturer’s catalog. They may be ready made items or readily made to order. The units are usually priced individually. The architect or contractor determines the quantities and location of each unit on the structure as well as the method of anchoring to the structure. The cast stone manufacturer provides no layout drawings and cutting of units in the field may be required.

Semi-custom cast stone items are specified according to unit shapes shown on contract documents or according to shop tickets specially prepared to define the scope of the work. They are usually made to order either from custom or inventoried molds. The units may be priced either individually or as a lump sum contract for the project. The cast stone manufacturer prepares shop tickets for approval, which show the quantities, cross section, reinforcement, finished faces, anchoring provisions and a schedule of lengths to be provided. The architect or contractor confirms the quantities, sizes and location of each unit on the structure as well as the method of anchoring to the structure. The cast stone manufacturer provides no layout drawings. Some cutting of units in the field may be required.

Custom cast stone items are specified strictly according to contract documents and according to shop drawings specially prepared to confirm the scope of the work. They are usually made to order from custom molds. The units are usually priced as a lump sum contract for the project, according to plans and specifications. The cast stone manufacturer prepares shop drawings for approval, which show the details of stones, arrangement of joints, quantities, cross section, reinforcement, finished faces, and the location of the units on the structure. Anchoring methods and anchor designs could be included on the shop drawings, depending on the agreement between the producer and customer. The architect and contractor approve the shop drawings to confirm the cast stone manufacturer’s interpretation of the contract documents, quantities, sizes, location of each unit on the structure, method of anchoring to the structure and coordinate the interface of the cast stone with other trades. The cast stone manufacturer normally provides layout drawings. Cutting of units in the field is usually not required.

Many specifications today require layout drawings that call for the location of every joint on the building facade to be precisely located, while others desire standard products and consider custom products to be cost prohibitive. Methods are available for controlling joint locations when using semi-custom typical lengths and standard products as described herein and they should be used whenever possible.

Where jointing layouts are not clearly shown on contract documents or where shop drawing requirements are not clearly spelled out in the project specifications, misunderstandings and disappointment can develop between the architect and cast stone manufacturer, unless the parties first agree that the job will be fully custom in nature.

When the architect implements a standard or semi-custom design, which commits to a certain number of shapes and sizes, the approval process is significantly streamlined and delivery times are shortened. The masonry contractor may choose to receive a neat pallet of modular units, which can easily be cut to fit the exact as- built dimensions at the jobsite.

For most installations, typical lengths will be the common unit, with 4'-0" modules (3'-11 5/8") as the most popular size. Longer lengths are available but should generally not exceed 15 times the minimum cross section thickness. Control joint spacing should divide evenly by the size of the typical unit. Special corner and end units should be cast to suit the end-of-wall condition and intermediate units may be cut with a standard abrasive blade masonry saw. Cast stones with any exposed reinforcement, including cast stone that has been cut to expose rebar, should not be set without following the procedure set out below.

A typical fitting specification should include the following:

1. Follow architect's jointing pattern as shown on contract drawings.
2. If necessary, cut units to suit in-place wall dimensions.
3. All window and door surrounds shall consist of evenly sized units.
4. All exposed reinforcement is to be cut back to a minimum depth of 1 1/2".
5. Apply zinc primer or reinforcement protection or equivalent to all exposed reinforcement.
6. Fill recessed pocket containing coated reinforcement with repair material before setting the cast stone.

Window sills should be sized to fit the masonry opening or mullion spacing, with allowance for 3/8" joints. The height of all cast stone, which is built into masonry walls, should match the brick coursing. Profiles should be designed with the Cast Stone Institute® Value Engineering suggestions.

Standard cast stone jobs are best suited for designs that call for basic and popular items such as band courses and wall cap coping, pier caps, keystones, quoins and window sill units sized to replace brick. Semi-custom projects can include almost any application where the designer is willing to dimension the stone units on the contract documents.

Custom cast stone designs represent the majority of buildings under construction today. Layout drawings are needed for projects that have many different profiles running through changing wall sections or one-of-a-kind installations such as entrances, porticos and signs. Base courses of stone at changing grade elevations, radius walls and applications suspended from structural concrete or steel are other good applications for custom cast stone.

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## INSPECTION AND ACCEPTANCE

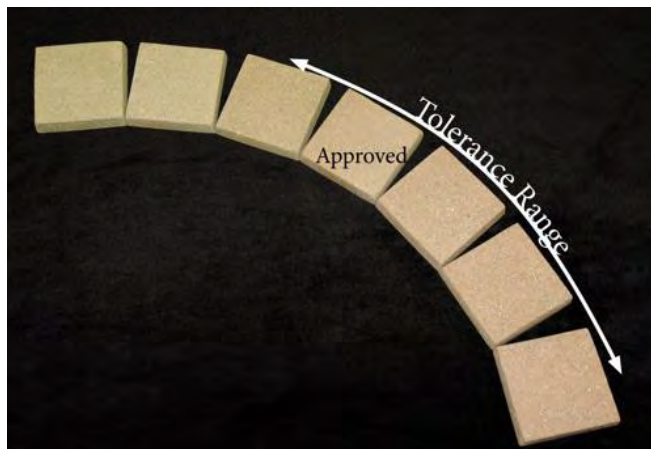
One key to the success of any masonry project is the careful selection and inspection of the cast stone elements. This Technical Bulletin focuses on the inspection and acceptance of cast stone prior to installation. The on-site inspector should be familiar with the project's contract documents, as well as the applicable reference standards. Test reports showing compliance with ASTM C1364, as well as the range of approved sample, should be on file.

On-site inspection and acceptance of cast stone should be performed at time of delivery. Before installation, check the color and texture of the approved sample against the delivered product. The cast stone should approximate the color and texture of the approved sample when viewed under typical lighting conditions and show no obvious imperfections other than minimal color and texture variations from a 20 foot distance. The cast stone should be dry when inspected for color as dampness will darken the surface color and make it appear blotchy. Furthermore, do not evaluate the texture under sunlight that is skimming across the surface parallel to the plane of the face as this will unfairly accentuate minor irregularities.

Cast stones are produced using naturally occurring materials. Minor variations in color and texture should be expected within limits of the approved range of samples. As per ASTM C 1364 Standard for Architectural Cast Stone, color and hue variations are tested as per ASTM D 2244. The permissible variations for color are defined as not greater than 6 units and the hue difference as not greater than 2 units from the approved sample or between units of comparable age subjected to similar weathering. In general expect color variation to be similar to natural cut limestone.



Some projects will show more color variation than others. Units containing gray cement will show more light-dark variations than those containing white cement. Colors, which require high amounts of integral pigments such as reds and browns, will vary more than earth tone shades such as buff. Special mixes containing contrasting and multi-colored aggregates may be subject to extreme color deviations when compared to homogeneous facing mixes.



Variations in color within the same stone may be caused by efflorescence or free lime migrating to the outer surface. This can usually be remedied by proper cleaning. Staining, mortar smears or uneven washing can also cause color variations. These variations are not necessarily inherent in the cast stone but as a result of installation or post construction cleaning. In such instances, the manufacturer should be consulted for recommended treatment of these variations.

Touch and repair is perhaps the greatest source of dissatisfaction with finished installations. When months have elapsed between the date of manufacture and the date of repairs, differences in color may exist between properly repaired areas and the remainder of the stone. It is a mistake to expect an instant color match at the time of the repair since this will usually cause dark patches later on. These areas should be left alone as they will blend in over time through curing and natural weathering.

To this point this Technical Bulletin has been focused on the aesthetic properties. In addition to color and texture, the inspector and/or mason should be familiar with the dimensional requirements of the installation as they pertain to joint sizes and interfaces with other materials. The cast stone should be true in shape, free of large cracks and ragged edges and within the tolerances specified in the contract documents.

Common deficiencies which are typically not acceptable of high quality cast stone include:

- Bug holes or air voids on the finished surfaces
- Ragged or chipped edges on formed edges
- Stains on exposed faces from foreign substances
- Twist, warp, out of square or bow exceeding tolerances
- Out of plane or pie shaped joints, or large or small joints out of tolerance.
- Areas of rough texture or smoothness not matching sample from 20 feet
- Backup concrete bleeding through exposed faces
- Visible cracks exceeding 0.007"
- Reinforcing shadows or exposure on face
- Rust on surface caused by staining, reinforcement or iron pyrites.
- Form marks or local depressions in excess of 0.030".

Building owners and their representatives will often apply some wishful thinking when viewing and touching a small 12" sample and then trying to imagine the way an entire facade will look. Wherever possible, an investment should be made in mockup panels and/or sample units. The sample units should demonstrate a variety of shapes and casting configurations and include vertically cast surfaces if they are specified.

Careful quality control of cast stone units by the manufacturer, combined with qualified ongoing inspection and acceptance at the job site ensures that all parties are satisfied with the completed project. Once the project is completed, little can be done to correct the appearance of the cast stone.

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## JOB SITE HANDLING AND INSTALLATION

The proper use of cast stone in the design of a project and the job site handling of the cast stone can affect the overall performance. On-site personnel should be familiar with the Cast Stone Institute® specifications and the project specification covering delivery, storage, setting, touch-up and repair, cleaning, pointing, caulking and sealing. In case of a conflict between the two specifications, the project specification should take precedent. Where the project specification may not include a particular issue, the industry standards should be followed.

The following checklist has been developed for the handling and installation of cast stone.

- Prior to delivery there should be a set of the approved shop drawings and color and texture sample on file. All test reports specified should be submitted as required.
- Upon delivery, all cast stone should be checked for chips, cracks, stains, or broken pieces. Any damage should be noted on the delivery slips and communicated to the manufacturer.
- Color and texture should be inspected in accordance to approved color sample or mock-up panel set up at the job site. In general, the color and texture of the cast stone should be approximately equal to the approved sample when viewed in typical daylight conditions at a distance of twenty foot. (See Technical Bulletin #36 Inspection and Acceptance.)
- Storage of cast stone should be above the ground on non-staining planks or pallets. The storage site should be away from heavy construction traffic. Cast stone stored for an extended period of time should be kept on pallets or non-staining planking and covered with non-staining tarpaulins. Allow for air circulation.
- Prior to setting, ensure climatic conditions are within thermal limitations of mortar. Cast stone should not be set if the environmental conditions are not within the acceptable temperature range specified by the manufacturer's recommendations. Mortar set retarders and set accelerators should be used according to manufacturer's recommendations but not with touch-up and repair material.
- Set cast stone within size limitations in full mortar joints and fill in all dowel holes and anchor slots completely with project approved bonding material (usually Mortar, Non-Shrink Grout or Epoxy). Ensure uniform joint widths within specification tolerances. If shims are required in the mortar joints, mortar should be raked back and caulked to mitigate hairline cracking in the joints. Sealant joints may be sanded to give the appearance of mortar when desired.
- Ensure that all specified flashing and dampproofing is installed. Flashing pierced by stone anchors must be sealed either by metal thimble, grommet or approved sealant.
- Concrete should never be poured against unprotected cast stone. Where poured in place concrete is placed against cast stone sills, separate with an appropriate barrier material prior to pouring concrete.
- Cast stone anchors must meet specified standards and be non-corrosive. Cast stone slots to receive anchors should be completely filled with project approved material usually mortar, non-shrink grout or epoxy.
- Prior to setting, each surface to be set in mortar should be wetted before mortar is applied. This helps to secure the bond between the mortar and the cast stone and may help to prevent shrinkage and hairline cracking in the joints.
- Weep holes must be installed over windows, at relieving angles and at the bottom of walls. No mortar droppings shall be allowed in the wythe between back of stone and face of back-up structure.
- All joints in cast stone units, which are set using mechanical anchors and plastic bearing shims, should be sealed. All control joints and any floor line joints at relief angles should be sealed to allow for movement.
- Only the ends of load bearing lug sills shall be set in a full bed of mortar to prevent cracking from future wall settlement. After setting, prime the joints, insert properly sized backup rod and gun in sealant.

- All trim items must align with control joints.
- Bridge parapet coping units over control joints to maximize their effectiveness. All coping should have a minimum ½" wash to control runoff.
- Do not bridge parapet coping over expansion joints.
- Cast stone should be handled to minimize chipping. Handle stones with the wide portion of the cross section in the vertical position to minimize breakage.
- After setting, columns, pilasters, entry jambs, window sills and all cast stone with projecting profiles should be protected during the remaining construction.
- During construction, cover the top of the walls when rain is anticipated.
- Chipped cast stone must be patched by skilled labor. A trial patch must be approved before general touch and repair is to commence.
- Planter coping, fountain coping, swimming pool coping, treads, risers, stone pieces above grade, and pavers may be treated with a silane or silane/siloxane blend water repellent coating after setting. A waterproof product may be applied to the back, sides and at and below grade surfaces. This will minimize the likelihood of dirt and groundwater entering the surface of the stone; a frequent cause of staining, efflorescence and enhancement of crazing. Check that the water repellent coating does not affect color or texture when dry.
- Load bearing cast stone units should be reinforced as necessary. They may not be designed to be handled in a different orientation than they will be installed in the structure. Lintels and large panels must be kept vertical.
- Any exposed reinforcement is to be cut back to a minimum depth of 1.5 inches. Apply a galvanized compound, zinc primer or other reinforcement protection to all exposed reinforcement. Fill recessed pocket containing coated reinforcement with repair material prior to setting the cast stone.
- When installing in extreme weather conditions consult Cold Weather Setting Practices Technical Bulletin #41, and Hot Weather Setting Practices Technical Bulletin #48.

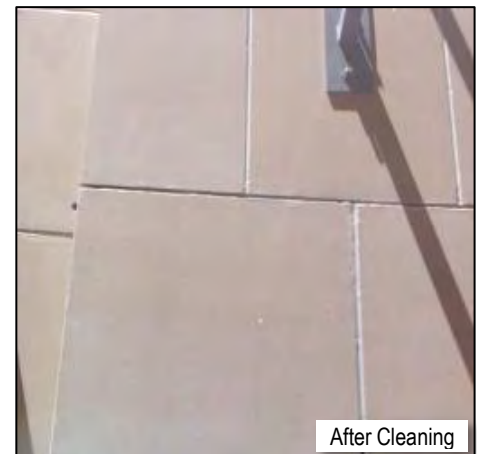
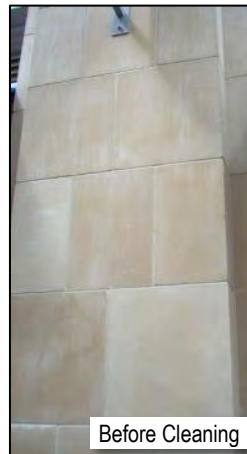
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## CLEANING

Despite all efforts to prevent dirt and staining on new building construction, a final wash down is recommended. To minimize the severity of cleaning though, every effort should be taken to protect the cast stone during storage and installation. Storage of cast stone should be above ground on non-staining planks or pallets and away from heavy construction traffic. Cast stone stored for an extended period of time should be kept on pallets or non-staining planking and covered with non-staining tarps. After setting, columns, pilasters, entry jambs, windowsills and all stone with projecting profiles should be protected with non-staining materials during the remaining construction.

The most common stains due to construction are dirt, mortar smears and efflorescence. A general rule of thumb is to use the least aggressive cleaning material and method to clean the building. There are a variety of commercial cleaners available to remove mortar smears, dirt and efflorescence without altering the finish or causing damage to the cast stone. Most contain detergents combined with mild solutions of phosphoric and/or muriatic acids. Use only the commercial cleaner developed for the specific stain to be removed.

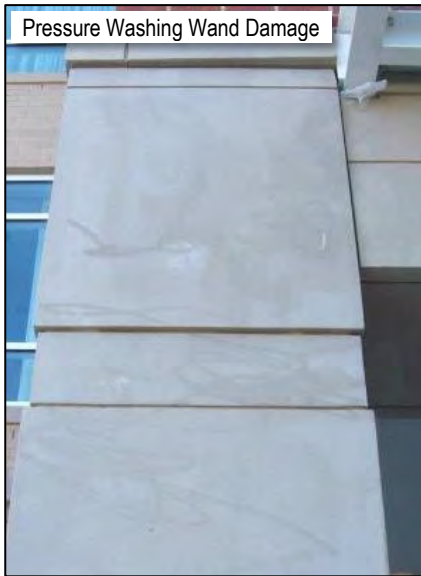


Dirt can be removed by scrubbing with a mild detergent and water and thorough rinsing. Extreme care should be taken when applying acidic based cleaners to areas where joints are left open or where joint sealant is used as jointing material. Hardened mortar stains are more tenacious and may require a more aggressive solution to remove. The manufacturers of adjacent building materials (clay brick, concrete block, windows, doors, sealant, etc...) should be consulted to determine compatibility with the cleaning materials.

Dunnage materials used in the packing and transport of cast stone can leave stains (or clean spots) after becoming wet. Wood packaging products can transfer resins to the surface, which may be easily removed. However, solid dunnage made from fresh timber can cause dunnage marks, which become difficult to remove. Packing and dunnage materials should always allow the exposed surfaces to breathe, especially when stones are palletized or placed into storage shortly after manufacture. This will avoid color differential due to moisture becoming trapped on the surface of the stone.

When unusual stains are encountered, the same procedures, which are recommended to clean concrete, will normally clean Cast Stone. The Portland Cement Association publishes a guide for the removal of stains in concrete.

The most important step to stain removal is identifying the stain and its cause. Manufacturers of cleaners should be contacted for guidance on removing particular stains. For the best result, follow the manufacturer's recommendations for using their product. Any treatment should be tested in a small inconspicuous area prior to cleaning the main wall. Also, ensure that lower cast stone courses are frequently rinsed with water because as acid is rinsed down the wall it can gather strength when reapplied. Take necessary steps to protect windows door and grade materials. Cleaners not fully rinsed from the building may cause corrosion to embedded steel later.



Direct high pressure power washing and sandblasting are not recommended procedures for cleaning cast stone. Furthermore, metal fiber brushes, rubbing stones and any tool or device that can scar the cast stone not to be used for cleaning cast stone.

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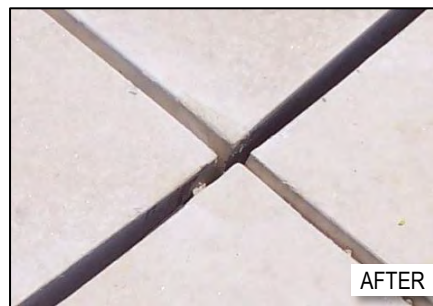
## TOUCH UP AND REPAIR

The best insurance against chipped cast stone is care in handling and protection of the unit after installation. Even with special care and protection, cast stone may still become chipped from time to time and a certain amount of touch up is to be expected. Damage to stone either while in transit or during installation is usually classified as a repair.

Any chip obvious from a 20' distance should be touched up with material provided by the manufacturer. Chips measuring ¼ inches and less across the face are usually left alone. The stone mason should include touch up as part of the ordinary pointing and wash down operations prior to final inspection. Repairs which are not conspicuous from a 20' distance when viewed in good typical lighting should be accepted. See Bulletin #36 on Inspection and Acceptance.

Chips measuring larger than ¼ inches across the face are usually addressed in a separate operation as soon as possible following occurrence of damage. The procedure for repair will include dressing the damage and applying fresh material to achieve the desired finish and shape, covering the repair with a wet rag and/or plastic cover, then taking steps to blend the repair into the adjacent areas. Cast stone units with chips larger than eight square inches should be replaced, unless the damaged portion can be salvaged and epoxied back to the unit.

Most cracks can be repaired if the units are reinforced. Units which are load bearing or having cracks larger than .007 inches should be epoxy injected after the cause of the restrained movement has been identified. Cracks which are observed in installed units can be grouted with native material if the crack is less than .007 inches and the forces which caused the crack have been eliminated.



Climatic conditions must be taken into consideration before the repair is to commence. Do not repair stone in freezing weather or if a freeze is anticipated within 24 hours. On hot sunny days repairs should be done during the morning hours where the cast stone is shaded or at temperatures less than 90 degrees Fahrenheit. Repairs should be covered with a damp cloth and plastic sheet to prevent the water from evaporating before the cement has hydrated.

The same material that was used to manufacture the cast stone should be used for touch up and repair. Test batches should be used to achieve a color match. The water/cement ratio used should be as close as possible to the mix at the time of manufacture. It is recommended that a non-redispersable latex bonding agent be used, but not in place of the mixing water. Use as a wetting agent, less than a tablespoon per handful of the concrete material, for plasticity. Never use metal tools for applying a repair. Cast stones which were acid etched at the factory will require the same applied treatment to the touch up or repair.





A properly executed repair will not match in color immediately. Dry tamp produced cast stone will appear lighter where repaired, while wet cast produced cast stone may appear darker. Repairs, matching immediately or in two or three days, have a tendency to change color later on after weathering. Through curing, weathering and ultraviolet light, the repair will eventually return to the original stone color. This process could take 3 months to a year or longer depending on the climatic conditions and exposure to the weather.

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## COLD WEATHER SETTING PRACTICES

Due to tight timelines, construction during cold temperatures often occurs and cold weather building practices have been developed to protect masonry against the perils of freezing when construction must be performed in such environments. It is important for all of the parties involved to be well versed in the building code requirements, as well as, industry guidelines. Table 1. Below offers guidelines based on the building code and industry recommendations:

Table 1

Ambient Temperature	Recommendations
Above 40°F,	Use normal masonry practices. Cover the walls at end of workday to prevent water entering masonry.
40°F - 25°F:	Heat the mixing water to produce mortar temperatures between 40°F - 120°F. Cover the walls with plastic or canvas to prevent wetting and freezing.
25°F - 20°F:	Heat the mixing water and sand to produce mortar temperatures between 40°F - 120°F. Cover the walls with plastic or canvas to prevent wetting and freezing. Mortar on boards should be maintained above 40°F. Cover walls and materials at the end of the day to prevent wetting and freezing. Maintain masonry above freezing for 16 hours using auxiliary heat or insulated blankets.
20°F - 0°F:	Heat the mixing water and sand to produce mortar temperatures between 40°F - 120°F. Cover the walls with plastic or canvas to prevent wetting or freezing. Mortar on boards should be maintained above 40°F. Cover walls and materials at the end of the day to prevent wetting and freezing. Provide enclosures and supply sufficient heat to maintain masonry enclosure above 32°F for 24 hours.

Additional guidelines include:

- Protect the cast stone and mortar materials from the elements.
- Avoid setting cast stone in extreme cold. Stonework set in temperatures below 40°F may expand and crack the mortar bond when temperatures eventually warm.
- Never set cast stone on frozen or ice covered walls.
- Touch up and repair should not be done in any environment which may be subject to freezing within 72 hours without conditioning of the cast stone or the repair environment.
- Non-chloride non-corrosive admixtures complying with ASTM C1384 are acceptable to accelerate the set of the mortar, but they are no substitute for the recommendations above. Chloride based admixtures should not be used.

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## HOT WEATHER SETTING PRACTICES

Masonry construction often occurs during periods of elevated temperatures. Hot weather is defined to be temperatures above 90° F (32° C). In such conditions, additional steps must be taken when setting cast stone to ensure that the quality of the installation does not suffer from high temperatures.

The primary concern of masonry construction during hot weather is the evaporation of water from the mortar. The increased rate of hydration of the mortar and accelerated curing conditions in hot, humid weather will help develop masonry strength provided sufficient water is present at the time of construction and for a period of three days. If sufficient water is not present, the strength of the mortar and bond between the cast stone unit and mortar may be compromised.

Cast stone is one of the materials in masonry construction that is least affected by hot weather. However, the interaction between the cast stone and mortar is critical. During hot weather construction, cast stone units tend to contain less moisture. This in turn will cause them to absorb more water from the mortar. Lower bond strength between the mortar and the units may result if insufficient water is not present in the mortar when the units are laid. A masonry wall can be fogged after it is constructed to assure the availability of adequate curing moisture.

According to industry sources, mortar will lose its workability rapidly due to evaporation of the water and the increased rate of hydration of the cement. Admixtures, specifically hydration stabilizers or retarders can be used to extend the life and increase the workability of the mortar. It is recommended that they comply with ASTM C1384 – Standard Specification for Admixtures for Masonry Mortars. Mortar mixed at high temperatures often has higher water content, lower air content, and a shorter board life than those mixed at normal temperatures. Tempering the mortar with cool water shall be permitted, but the mortar should be used within two hours.

Mortar temperatures must be controlled per the ambient air temperatures as specified in ACI 530.1. The installer should also follow the requirements in Tables 1 & 2 of The Masonry Industry Council's Hot and Cold Weather Masonry Construction guide for temperature control. High mortar temperatures will affect the mortars set times and mortar temperatures above 120° F (49° C) may cause flash set of the cement. Cold water may be used to help control the temperature of the mortar. Ice is highly effective in reducing the temperature of the mix water, but the ice should be completely melted before combining the water with any other ingredients. In any case, mortar should be used within two hours of initial mixing.

During periods of hot weather the temperature of the materials should be controlled for best results. Storing cast stone units and sand under cover of shade will help control heat gain of the materials. Sand should be stored on a raised platform and not in contact with a cover during the hot part of the day. Sand piles should be kept in a damp condition by sprinkling with water during times of high evaporation. This can help lower the temperature of the sand through evaporative cooling.

The following items are suggested for hot weather masonry construction. These items can be incorporated in the specifications of the project where applicable:

1. Mixers, mortar pans, wheelbarrows, mortar boards and other tools should be moistened with water prior to use to reduce their temperature and satisfy absorptiveness
2. Mix small batches and avoid prolonged mixing of mortar
3. Use cold water when mixing mortar and grout
  - Ice may be used to lower the mix water temperature, but it must be completely melted before adding the water to the other ingredients

4. Use the mortar within 2 hours of the initial mixing
5. Use caution when wetting the cast stone as this may lead to increased shrinkage after drying
6. Limit the spread of mortar beds to 4 ft (1.2m) ahead of the cast stone units when temperatures are 100° F (38° C) or above, or 90° F (32° C) with an 8 mph (3.6 m/s) or greater wind
7. Place cast stone within one minute of spreading mortar
8. Fog spray newly constructed masonry at least three times a day until moist
9. Cover the units at the end of the day with plastic sheets to control moisture evaporation

Construction requirements while work is in progress are based on ambient temperatures. Protection requirements, after masonry is placed, are based on mean daily temperatures. (The temperature calculated to be the average of the extremes forecast by the local weather bureau over the next 24 hours). For additional information, please refer to the Masonry Industry Council's Hot and Cold Weather Masonry Construction guide.

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## CAST STONE AND LEED® v4

### INTRODUCTION

Sustainable design has become one of the most prominent trends in the building industry. Designers aiming for a more environmentally-friendly building design often turn to building rating systems and certification programs to help them assess the environmental impact of a building and its components. The most widely used system in the U.S. is the LEED® green building certification program.

The U.S. Green Building Council (USGBC) developed the LEED rating system; LEED stands for Leadership in Energy and Environmental Design. A separate entity, the Green Building Certification Institute (GBCI) administers LEED project certification and professional credentialing programs. The LEED certification program was developed to provide a method to define and measure what are commonly called “green buildings.” From its inception as a pilot program for new buildings in 1998 to the present, the LEED certification program has expanded and grown dramatically. There are numerous LEED rating systems organized by type of construction and end use, including:

- BD+C (Building Design and Construction): New Construction, Core & Shell, Schools, Retail, Hospitality, Data Centers, Warehouses & Distribution Centers, Healthcare
- ID+C (Interior Design and Construction): Commercial Interiors, Retail, Hospitality
- EB:O+M (Existing Buildings: Operations and Maintenance): Existing Buildings: Operations & Maintenance, Schools, Retail, Hospitality, Data Centers, Warehouses & Distribution Centers
- ND (Neighborhood Development): Neighborhood Development Plan, Neighborhood Development
- Homes: Homes, Mid-Rise

The most widely used rating system in the U.S. is currently LEED® BD+C: New Construction™ (LEED for New Construction) though LEED Existing Buildings: Operations and Maintenance is also widely used. While each rating system is distinct, most of the topics covered can be grouped into the same general categories. This Bulletin examines the requirements of LEED v4 for BD+C: New Construction and its relevance to cast stone.

### THE USE OF CAST STONE

Cast stone is used primarily on the exterior of buildings. Cast stone veneer may be used alone or as an integral part of a clay or concrete masonry veneer. Cast stone may also be used as an accent or trim material on the exterior of buildings sheathed with other materials such as synthetic stucco. Other opportunities for use of cast stone include caps and copings on building walls and landscape walls, stair treads, and column covers. Though not as common, cast stone can also be used as pavers and in interior applications. Many of these applications can be part of a strategy to earn points in the LEED rating systems.

### LEED® v4

When LEED v4 was approved in July 2013 after a lengthy revision process, it contained significant changes from the previous version (LEED 2009) particularly in the area of materials and resources. LEED v4 is organized into six environmental categories plus credits for integrated design, innovation and regional priorities. In LEED v4 the credits related to the building site and location are split into two separate categories, Sustainable Sites and Location and Transportation. Each of the six credit categories may contain mandatory prerequisites as well as voluntary credits that are worth points toward a building project’s certification. Figure 1 shows the points allocated to each category.



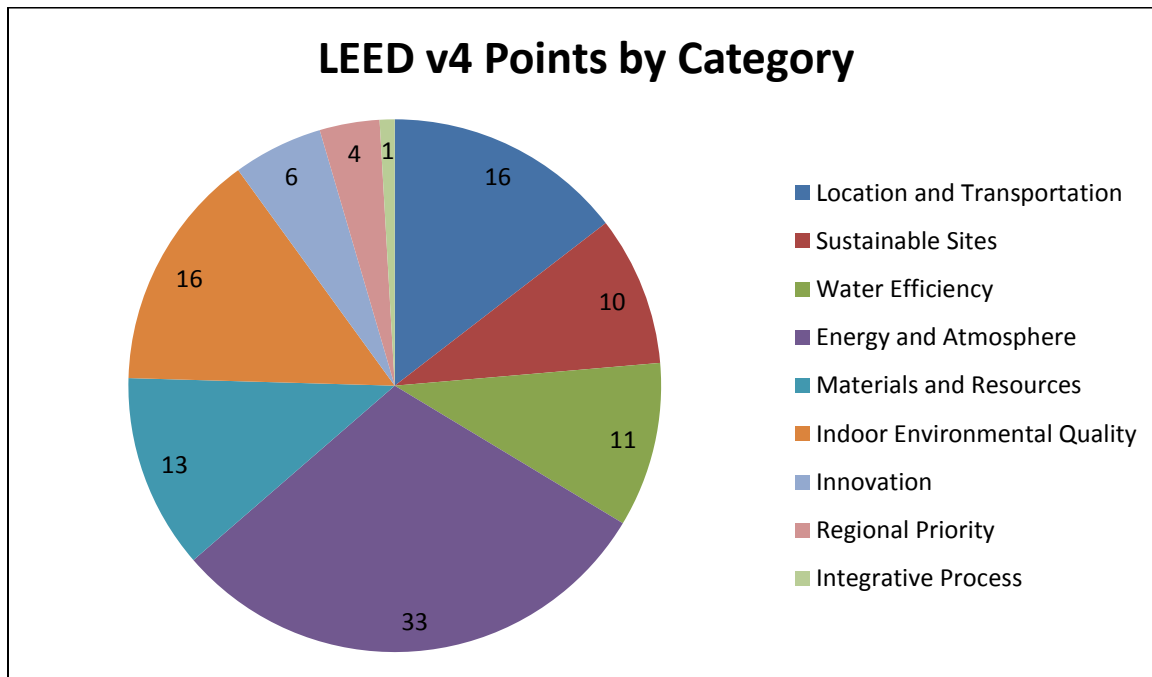


Figure 1: LEED v4 Points by Category

#### CERTIFICATION

Under LEED for New Construction a building project must earn at least 40 points out of a possible 110 to be a LEED-certified project. In the LEED rating systems, the more points a building project earns, the “greener” the building. The USGBC recognizes four levels of LEED certification (Figure 2).

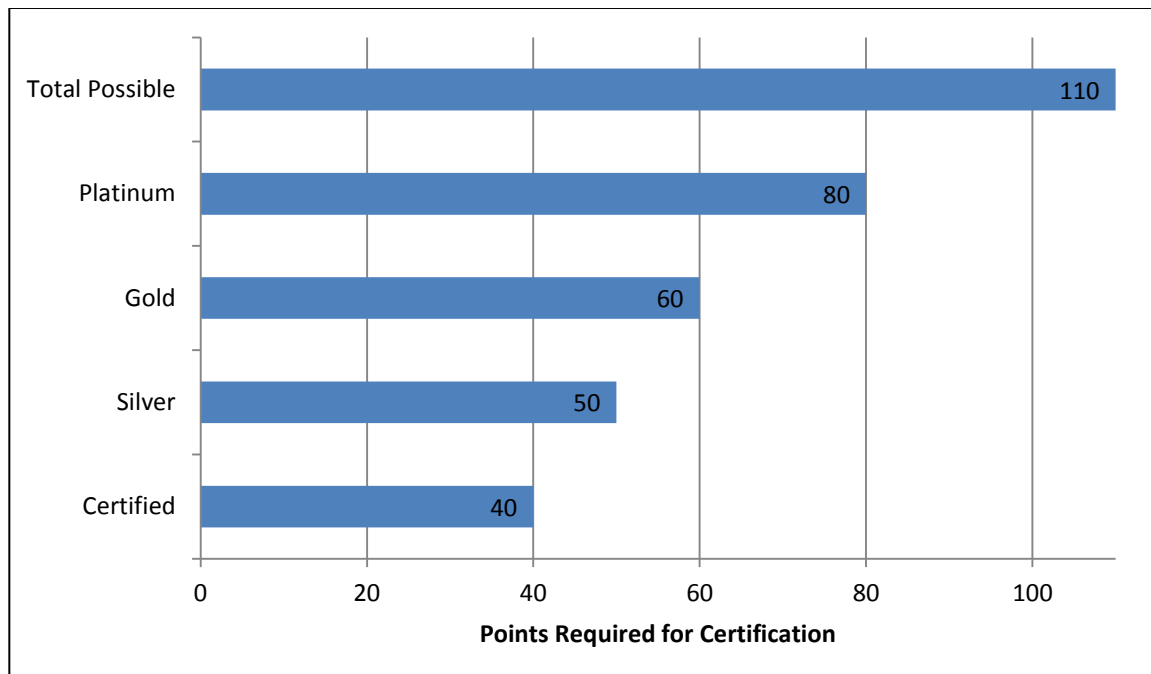


Figure 2: LEED for New Construction 2009 certification levels

## EARNING LEED POINTS

Cast stone masonry can make a significant contribution toward earning LEED points on a project. While no product or material alone can earn LEED points, cast stone masonry can be used as part of a strategy to earn points in many credits. It is important to remember that the calculations for these credits require inclusion of the entire building project and materials to determine the percent of qualifying material.

## LOCATION AND TRANSPORTATION (LT)

This category addresses issues related to the location of the project site and its connection to the surrounding community. A total of 16 points are available in this category with the majority given for locating the project in a densely developed area with a diverse array of businesses, residential areas, and services.

LT Credit 4 - Surrounding Density and Diverse Uses (1-5 points) – the intent of this credit is to encourage development in urban areas with existing infrastructure. Building products do not directly contribute to this credit. However, masonry materials are often used for urban infill development because of their appearance, size and scale, fire ratings, as well as for benefits in space required for construction. Cast stone masonry can often be installed without the use of a crane, thus helping to minimize the need for large equipment on site.

## SUSTAINABLE SITES (SS)

This category addresses issues associated with site preparation as well as impacts on surrounding areas after construction is complete. A total of 10 points are available in the Sustainable Sites category. Cast stone may play a role in strategies associated with SS credit 5.

SS Credit 5: Heat Island Reduction (2 points) – the intent of this credit is to reduce the retention of heat due to dark colored surfaces by providing shade, using materials that meet solar reflectance criteria, or other strategies for the roof and non-roof areas such that their weighted area exceeds the sum of the area of site paving and total roof area. Cast stone used as caps on landscaping walls, stair treads, and pavers on the site or on the building roof can meet the criteria for earning this point.

This credit requires that paving materials have a three-year aged solar reflectance (SR) value of at least 0.28. If three-year aged value information is not available, materials must have an initial SR of at least 0.33 at installation. A study [Ref. 1] by the Portland Cement Association of 135 concrete specimens all had a SR of at least 0.33. One specimen made with white Portland cement had a SR of at least 0.64. Cast stone elements typically meet the LEED requirements for solar reflectance, especially if white Portland cement is used.

## ENERGY & ATMOSPHERE (EA)

The Energy and Atmosphere category covers a variety of issues related to energy use associated with heating and cooling buildings including reduction in energy use, ozone reduction and use of renewable energy. There are four mandatory prerequisites and seven voluntary credits that have a total of 33 points associated with them. The thermal mass associated with cast stone and other masonry materials can help reduce the amount of energy used for heating and cooling a building. There is one prerequisite and one credit associated with this intent.

EA Prerequisite 2: Minimum Energy Performance (0 points) – as part of a masonry wall, cast stone can help mitigate temperature swings and achieve the required energy performance particularly when interior masonry is left exposed.

EA Credit 2: Optimize Energy Performance (up to 18 points) – as part of a masonry wall, cast stone can be used to help reduce the amount of energy consumed by the building. The benefit of thermal mass is best recognized when using energy modeling tools such as BLAST or EnergyPlus.

## MATERIALS & RESOURCES (MR)

The intent of this category is to minimize the impact on the environment, encourage product transparency, and reduce construction waste. There are a total of 2 prerequisites and 13 points available in the Materials and Resources category. Several of the MR credits in LEED v4 are focused on specific manufacturer practices such as developing an environmental product declaration or disclosing material ingredients. As a result, achieving the credits in this category may vary widely depending upon the specific manufacturer. A brief overview of each of the MR credits is provided below.

MR Credit 1: Building Life-Cycle Impact Reduction (up to 5 points) – this credit incorporates the former Building Reuse and Material Reuse credits, and gives more weight (points) to reuse of whole buildings than the previous version of LEED. This credit contains four different paths, with the first three focused on building and material reuse and the last on new construction. Masonry buildings, many of which incorporate cast stone details, are good candidates for reuse. Cast stone features on the building interior such as columns, fireplace mantels and surrounds, stair treads, etc. are also good candidates for reuse. Anchoring details that allow for disassembly can facilitate this. Larger elements not set in mortar are especially suited for salvaging. In addition, cast stone can be repaired to conceal damage that may occur during disassembly and removal.

MR Credit 2: Building Product Disclosure and Optimization – Environmental Product Declarations (2 points), is a new credit in LEED v4. This credit has two options, worth one point each. The first option focuses on reporting of environmental impact data via an Environmental Product Declaration (EPD), while the second rewards improved performance in specified environmental impact categories through life cycle assessment. Cast stone elements produced by manufacturers having an EPD can count toward this credit.

MR Credit 3: Building Product Disclosure and Optimization – Sourcing of Raw Materials (up to 2 points) has two different options worth one point each. Option 1, Raw Material Source and Extraction Reporting, requires use of at least 20 different permanently installed products sourced from at least 5 different manufacturers that have publicly released a report from their raw material suppliers. Third-party verified corporate sustainability reports are counted in full. Self-declared reports count as only ½ value, so for example, if only self-declared reports are used, 40 products would be required instead of 20.

The second option incorporates aspects of the recycled content, rapidly renewable, certified wood and material reuse credits found in LEED 2009. Option 2, Leadership Extraction Practices, requires use of products that meet at least one of the responsible extraction criteria below for at least 25%, by cost, of the total value of permanently installed building products in the project. When calculating the value of the products, those demonstrating extended producer responsibility are valued only at 50% of their cost. Other extraction criteria are valued at the full amount.

- Extended producer responsibility
- Bio-based materials: Sustainable Agriculture Standard
- Wood products: FSC certified
- Materials reuse
- Recycled content: post consumer + ½ pre-consumer
- USGBC approved program

Cast stone elements can help earn this credit when they incorporate recycled materials into their mix, most often as aggregates or supplementary cementitious materials. Pre-consumer (post-industrial) recycled materials that may be incorporated into cast stone include recycled aggregate or slag that can be used as an aggregate and supplementary cementitious materials like fly ash. Color may be affected by incorporation of certain recycled materials, so contacting the cast stone manufacturer is recommended.

**MR Credit 4: Building Product Disclosure and Optimization – Material Ingredients (up to 3 points)** – This credit has three options worth 1 point each. All three options require documentation of the raw material ingredients for building products. Several chemical and ingredient screening programs are listed as compliance paths including the GreenScreen™ for Safer Chemicals, Cradle to Cradle certification, and the Health Product Declaration (for more information see Resources), but Material Safety Data Sheets (MSDS) are not considered compliant with this credit. Cast stone producers that provide the chemical inventory for their products using the Chemical Abstract Service Registry Numbers (CASRN) can count toward Option 1 of this credit.

**MR Credit 5: Construction and Demolition Waste Management (up to 2 points)** – The intent of this credit is to eliminate construction waste from landfills. Up to two points can be earned for recycling or salvaging specified amounts of construction waste, or two points can be earned if the project does not generate more than 2.5 lbs of construction waste/ft<sup>2</sup> of the building's floor area. On-site waste from cast stone elements is limited primarily to packaging materials. Cast stone elements are carefully detailed and exact amounts are delivered to the site so that waste stone is nearly eliminated helping meet the reduction of total waste goal. Any waste cast stone elements that are present can be crushed and used as aggregate or fill.

#### INDOOR ENVIRONMENTAL QUALITY (IEQ)

This category aims to ensure quality indoor air among other goals. One way to achieve this is by reduction or elimination of volatile organic compounds (VOCs) in materials used in the interior of a building.

**IEQ Credit 2 – Low-Emitting Materials (up to 3 points)** – This credit focuses on volatile organic compound (VOC) emissions, rather than content. It also explicitly lists stone, glass, concrete, and clay brick as "...inherently non-emitting and comply without any testing if they do not include integral organic-based surface coatings, binders, or sealants." Thus cast stone elements without integral organic-based materials used on exposed interior walls or floors meet this credit without any testing required.

#### SUMMARY

LEED v4 for BD+C: New Construction rating system is one of the most commonly used tools in the U.S. for assessing the impact of a building and its components on the environment. LEED covers six environmental credit categories each containing numerous credits. Cast stone, like other masonry materials, can play a role in strategies designed to achieve many of these credits, particularly in the Materials and Resources credit category.

Designers utilizing the LEED v4 for BD+C: New Construction rating system are encouraged to contact cast stone manufacturers to determine relevant practices for achieving LEED credits and to look for opportunities and the synergy that can occur when cast stone is chosen for use on a project.

#### REFERENCES

1. "Concrete Shines as Solar Reflectance Material," <http://www.cement.org/for-concrete-books-learning/concrete-technology/concrete-construction/concrete-as-solar-reflectance-material>, accessed February 5, 2014.
2. LEED v4 User Guide (June 2013), U.S. Green Building Council, Washington, DC, <http://www.usgbc.org/resources/leed-v4-user-guide>.

**WRITTEN BY**

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Ms. Subasic has been a member of The Masonry Society (TMS) since 1992 and a member of the Board of Directors since 2002. She serves on the Design Practices committee and is a founding member of the Sustainability Committee. Ms. Subasic also represents the masonry industry on the ASHRAE 189.1 Standing Standard Project Committee for high-performing green buildings.

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## STANDARD ANCHORS

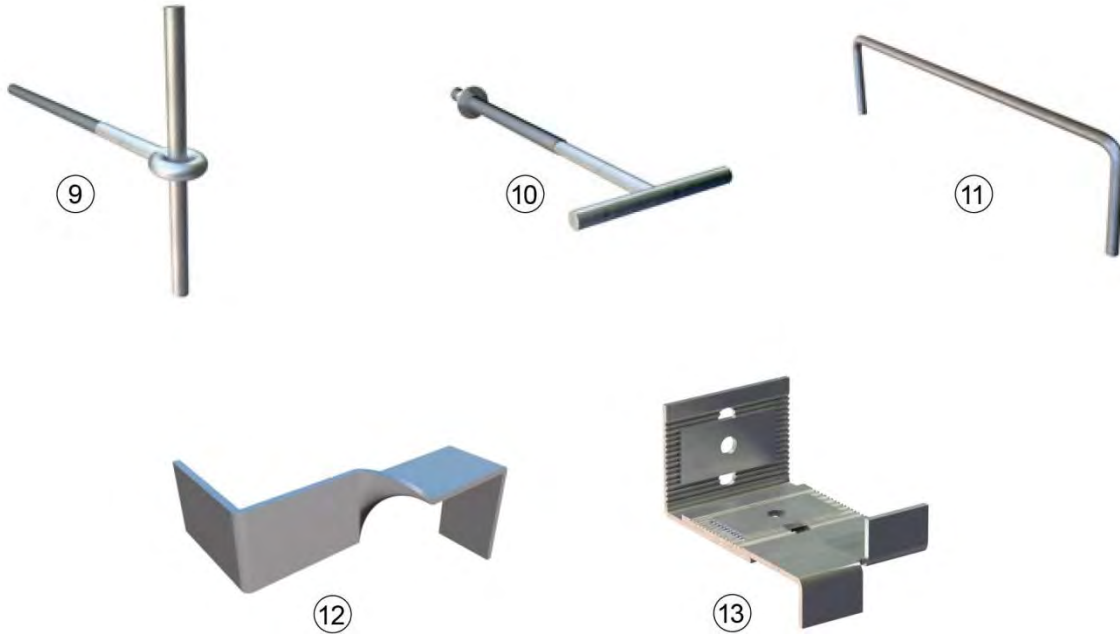
Standard masonry anchors are preferred over embedded hardware for use with Cast Stone. They are reliable, time-tested, and commercially available, need not be specially fabricated and afford great flexibility in meeting jobsite conditions.

Non-corrosive type anchors should be used for all anchoring. Stainless steel Type 304 or 316 are the standard type used in this class of work.

Typical sizes shown are 1/8" x 1" straps, 1/4" rods and 1/2" dowels. Dowel holes for 1/2" or 3/4" dowels are usually 1" diameter filled completely with mortar during setting. Anchor slots are typically 3/4" wide and similarly are filled with mortar.

Typical details are not universal. The Cast Stone Institute® strongly recommends that designers consult with the project engineer and Cast Stone Institute® producer member in the early stages of design to determine the appropriate anchoring strategy.





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## STANDARD INSERTS



**Threaded Loop Insert**  
Used where adjustment is not required.



**Threaded Insert**  
Similar to Threaded Loop Insert but used for thin sections.



**Cast Iron Adjustable Insert**  
Used to stabilize Stone which is otherwise supported. Allows for horizontal adjustment. Can be used to hang soffit stones.



**Non-Ferrous Threaded Insert**  
Used in non-loadbearing applications.



**Reglet**



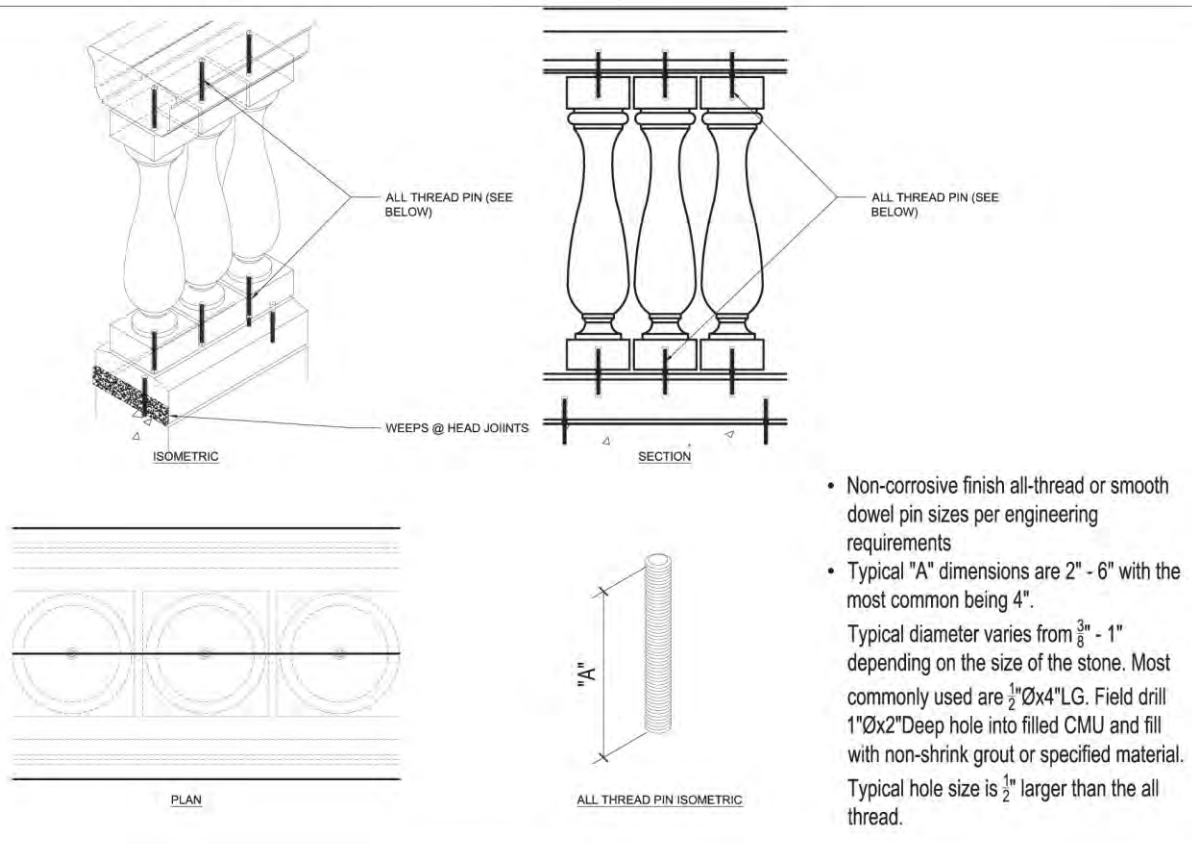
**Dovetail**

Engineering information is available by request.

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## BALASTRADE - DETAIL #1

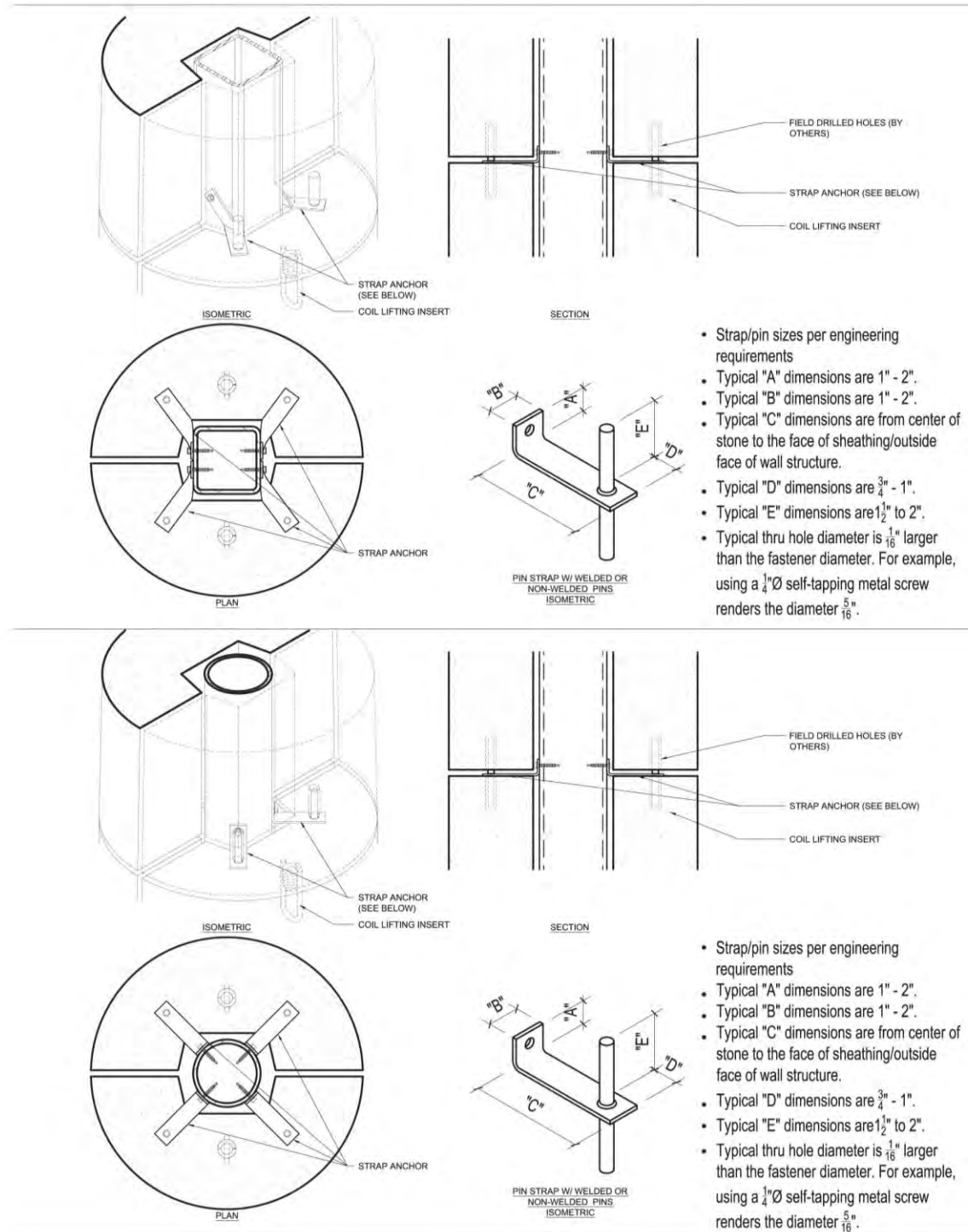


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## COLUMN - DETAIL #1

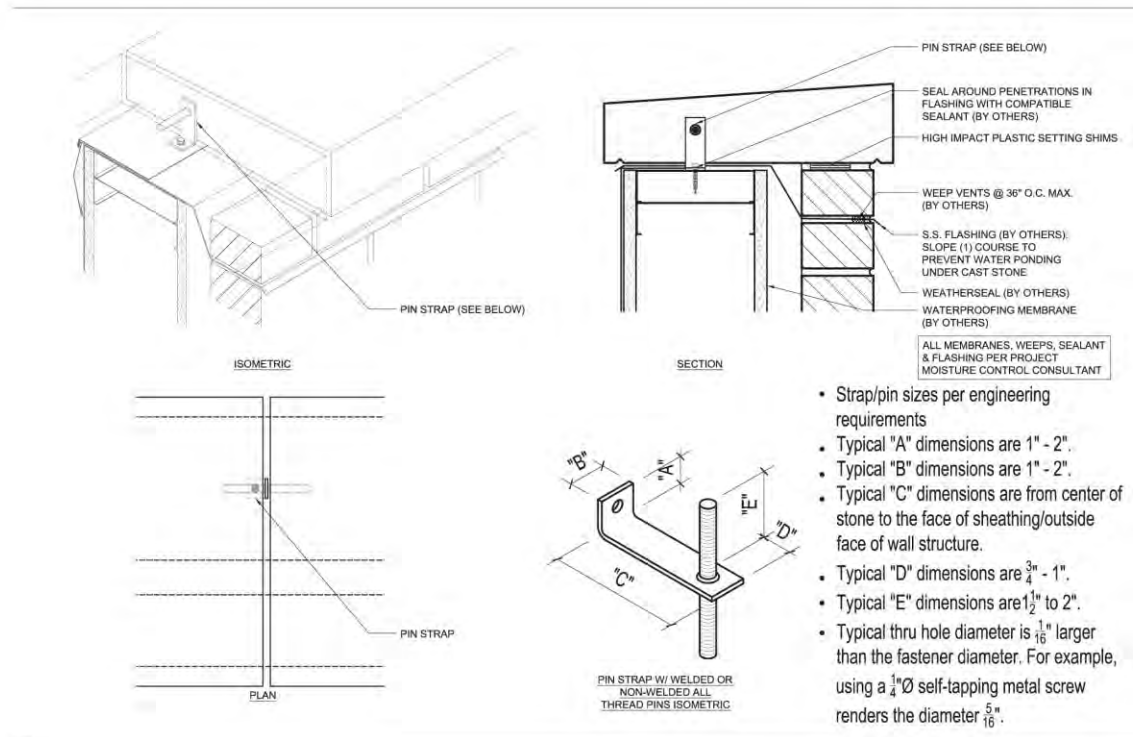


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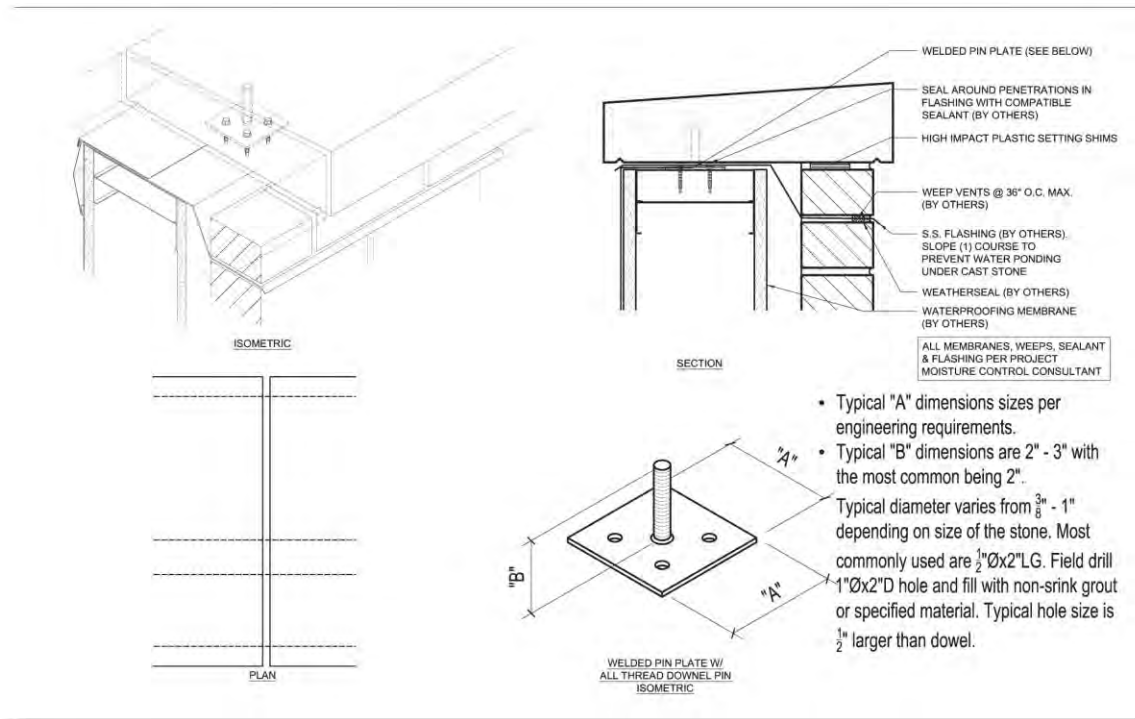
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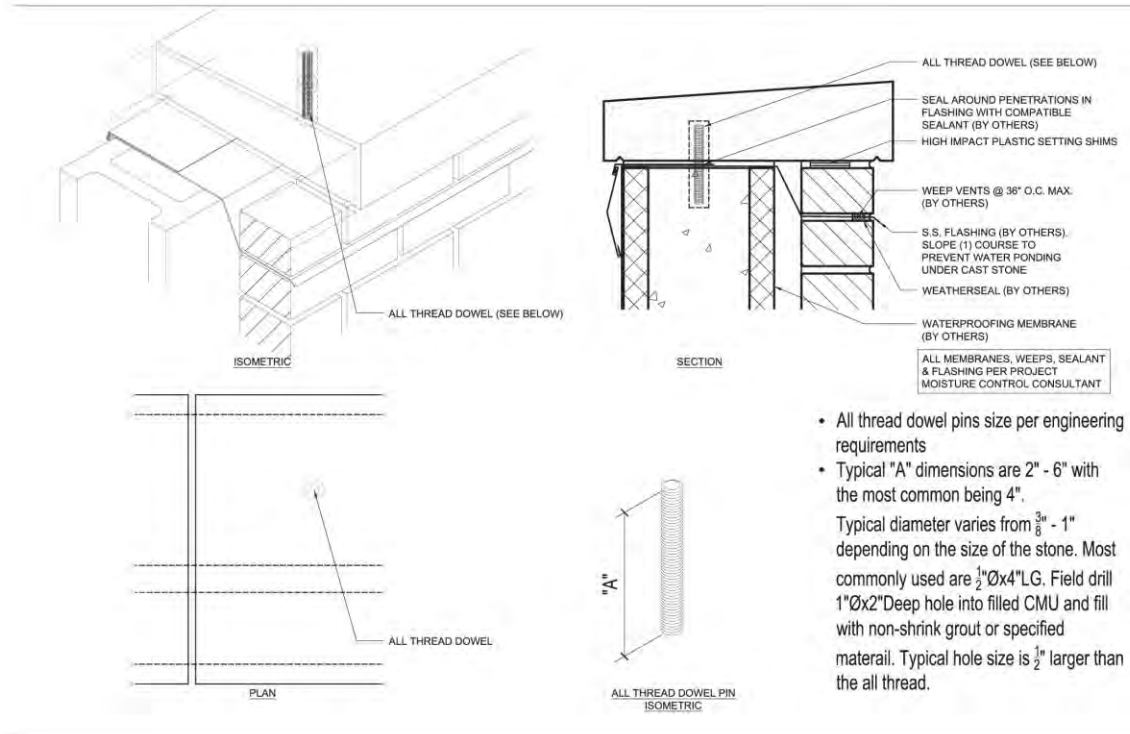
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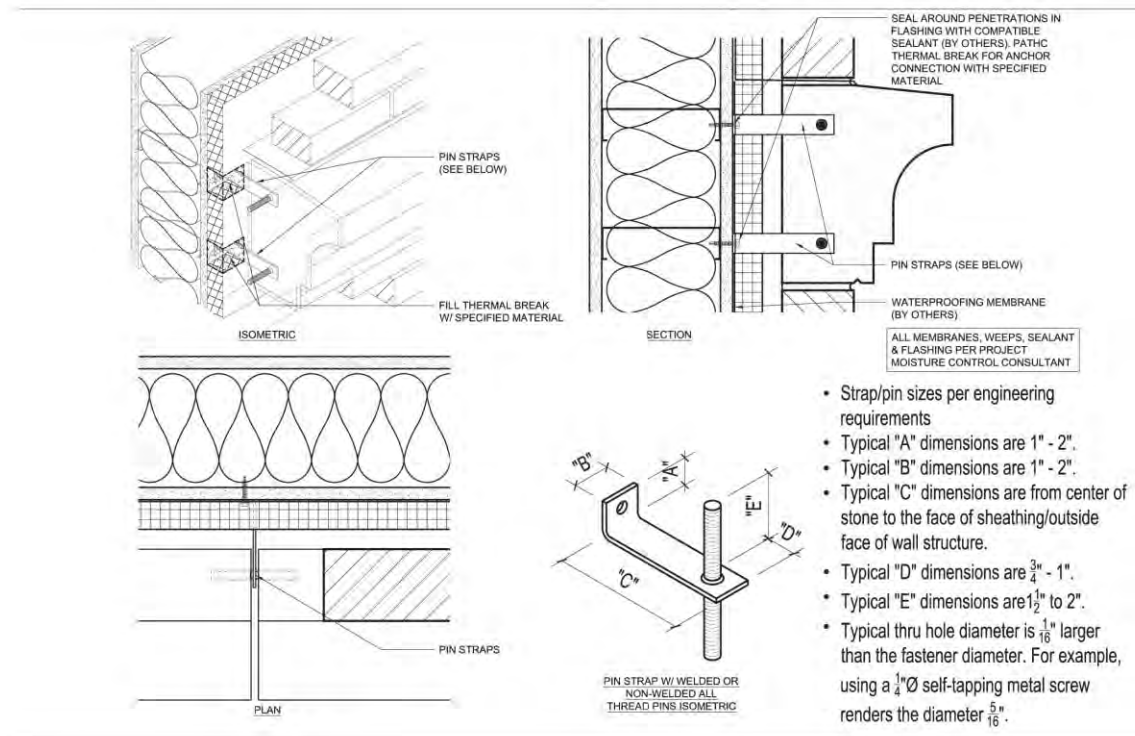
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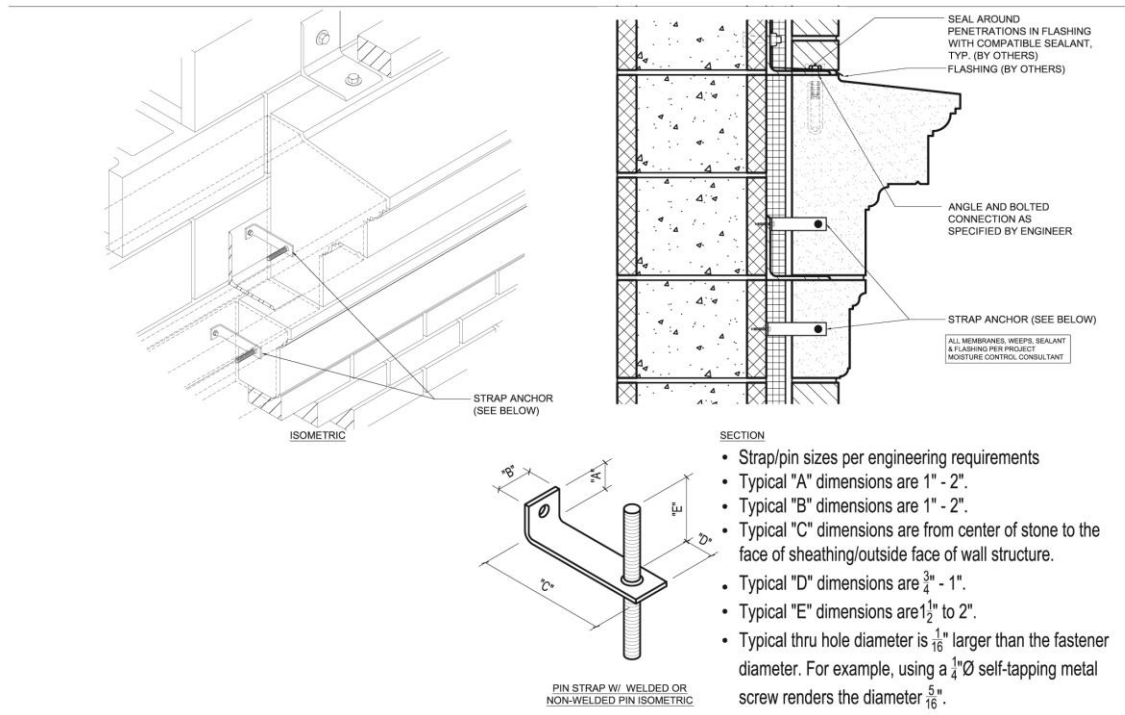
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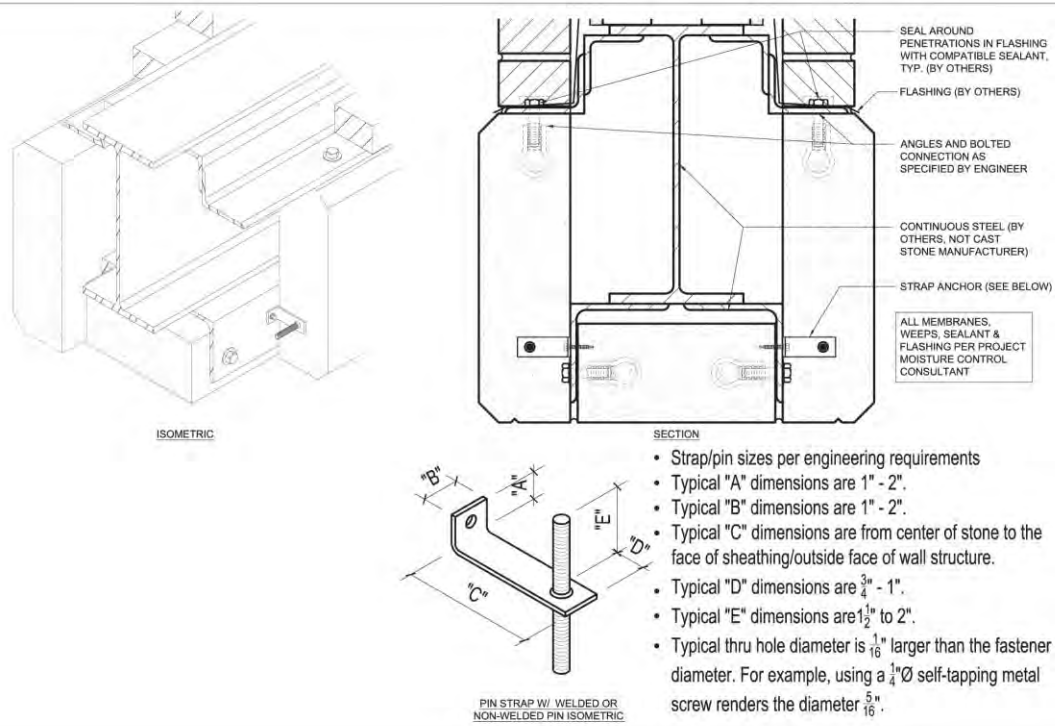


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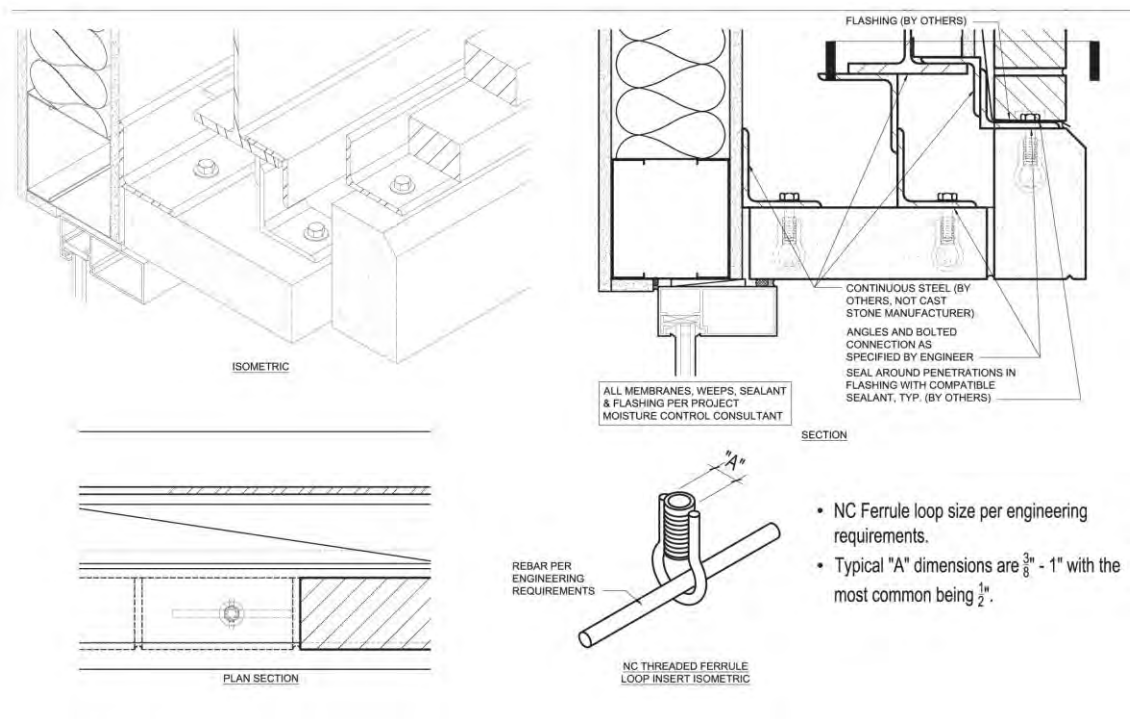
## FASCIA/SOFFIT - DETAIL #1



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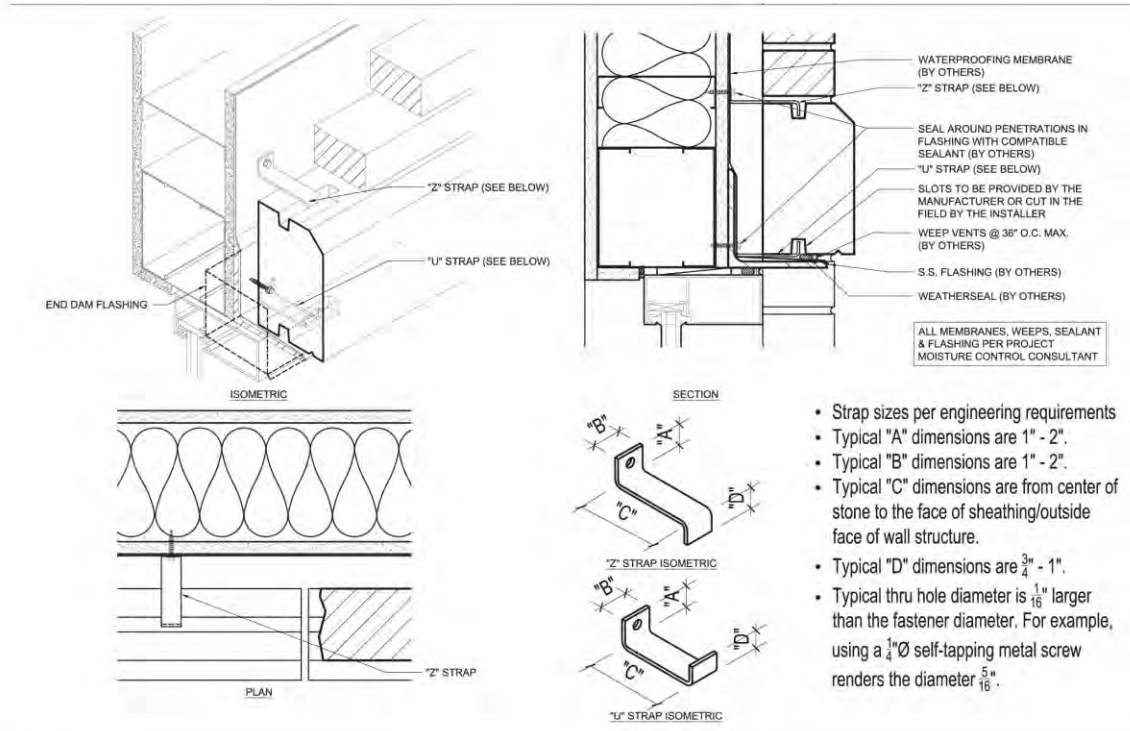
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## ANCHORING & FLASHING HEADER - DETAIL #1

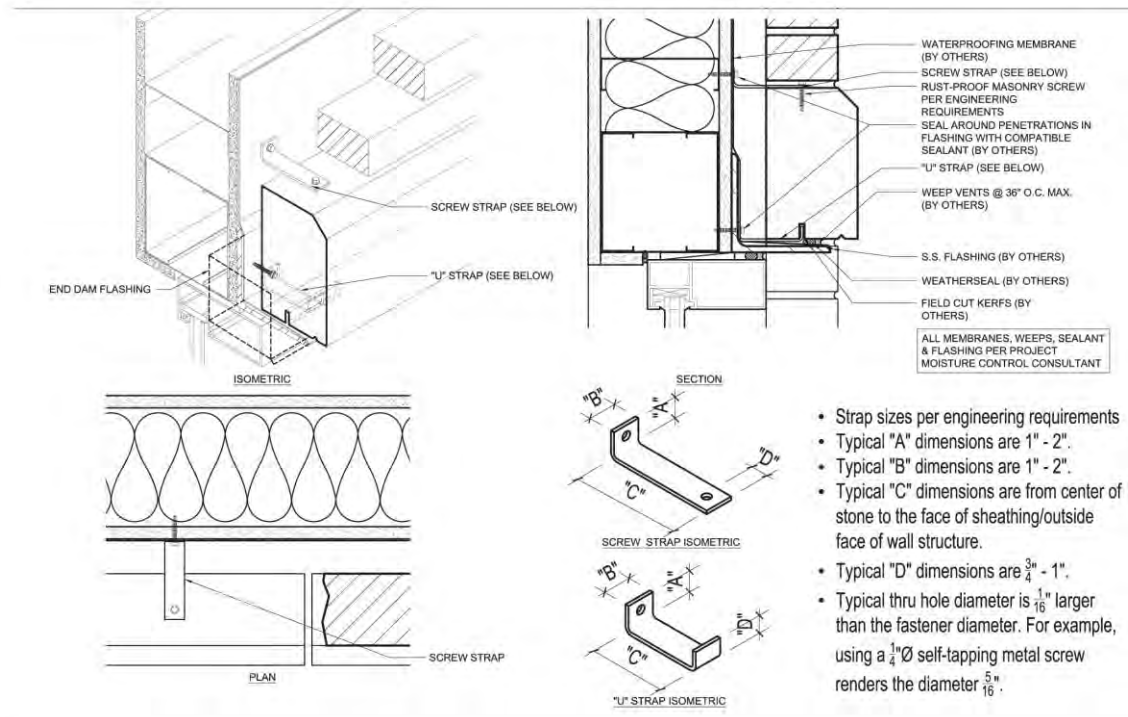


- Strap sizes per engineering requirements
- Typical "A" dimensions are 1" - 2".
- Typical "B" dimensions are 1" - 2".
- Typical "C" dimensions are from center of stone to the face of sheathing/outside face of wall structure.
- Typical "D" dimensions are  $\frac{3}{4}$ " - 1".
- Typical thru hole diameter is  $\frac{1}{16}$ " larger than the fastener diameter. For example, using a  $\frac{1}{4}$ " Ø self-tapping metal screw renders the diameter  $\frac{5}{16}$ ".

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## HEADER - DETAIL #2

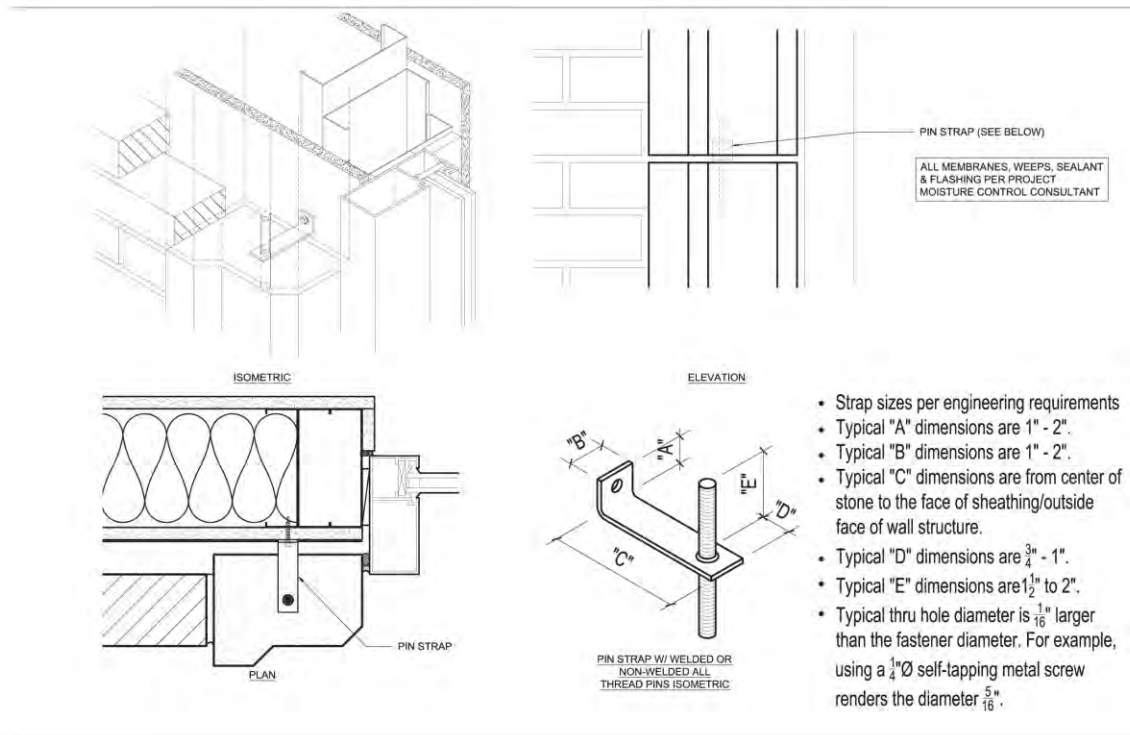


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## JAMB - DETAIL #1

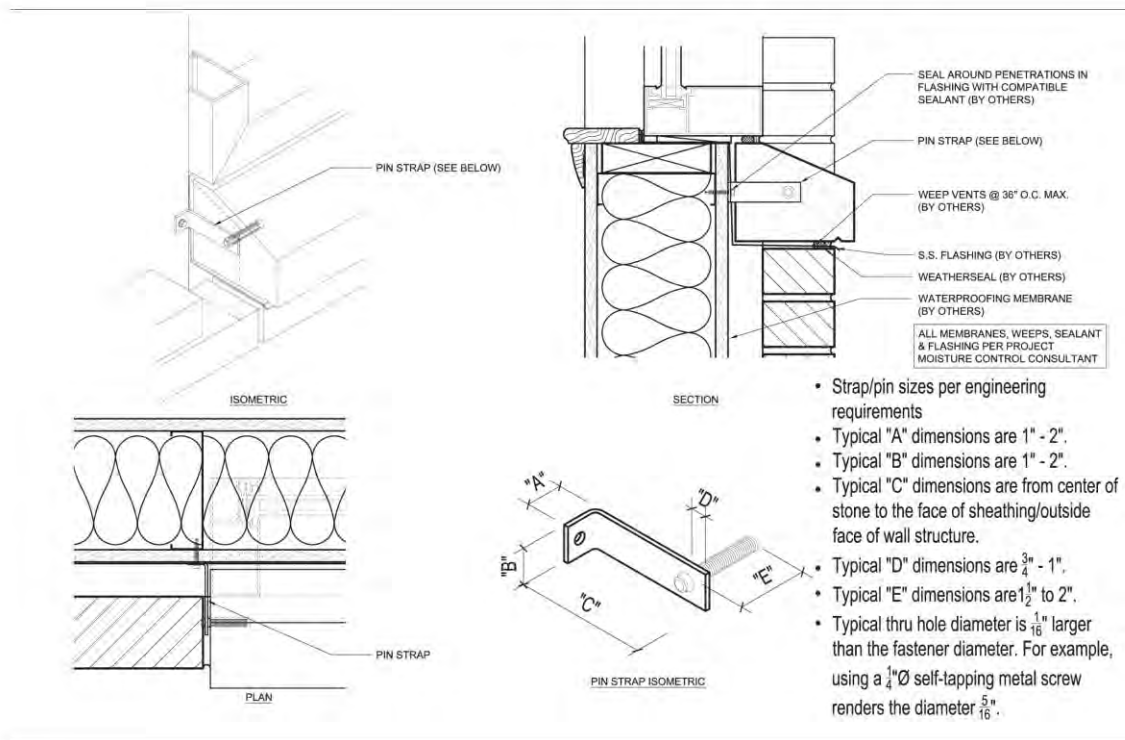


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## SILL - DETAIL #1



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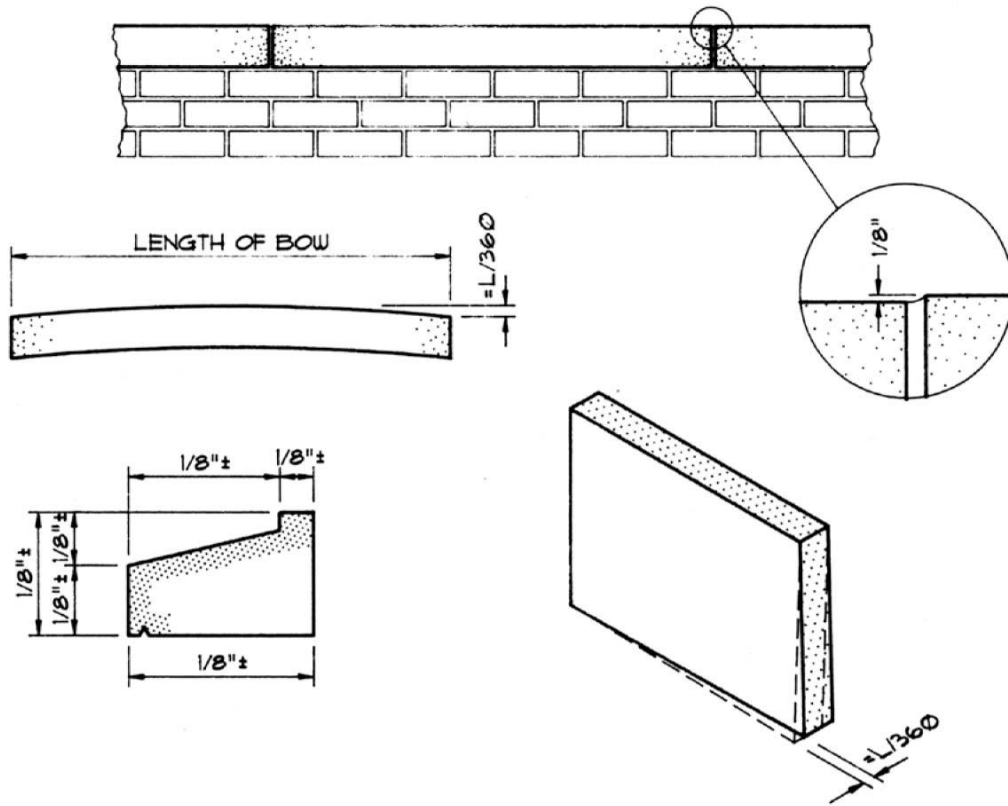
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## TOLERANCES

Tolerances dimensional tolerances for Cast Stone are the numerically greater of plus or minus 1/8" or length/360. This applies to all sectional dimensions: length, twist, square and camber.

Dowel hole and insert locations in the formed sides of pieces can be cast fairly accurately, within 1/8". Additional tolerance, totaling 3/8", must be allowed when they are located in the back or unformed side.

When assessing individual stones for tolerance, the setting tolerances of plus or minus 1/8" (allowable out of plane from adjacent unit) must also be taken into consideration as shown. This tolerance also applies to flashing grooves, false joints and similar reliefs.



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## GLOSSARY OF TERMINOLOGY

<b>ABSORPTION</b>	Percentage of moisture absorption by weight after immersion in water.
<b>ACID ETCHING</b>	Process of applying a solution of hydrochloric or muriatic acid and water to the exposed surface of Cast Stone in order to remove the cement film from the aggregates, achieving a fine-grained finish which simulates natural cut stone.
<b>ADMIXTURES</b>	Chemicals used to improve the physical properties of Cast Stone.
<b>AIR CONTENT</b>	The amount of entrained air in wet cast units.
<b>AIR-ENTRAINING ADMIXTURES</b>	Chemicals used to develop entrained air in wet cast units.
<b>AIR VOIDS</b>	Surface imperfections with restricted size and occurrences in cast stone units.
<b>ANCHOR</b>	Metal device used for securing Cast Stone to a rigid structure.
<b>ARCHITRAVE</b>	The bottom portion of an entablature bearing on the column capitals and supporting frieze.
<b>ARRIS</b>	Angle, corner, or edge of a Cast Stone unit.
<b>ASHLAR</b>	Flat units square or rectangle in size, bonded and laid in mortar.
<b>BACKUP MIX</b>	Concrete, normally composed of concrete, sand, gravel, and grey cement; used for the unexposed portion of Cast Stone.
<b>BALUSTER</b>	A small column or other vertical shape when placed in a series constitutes a miniature colonnade which is called a balustrade.
<b>BAND COURSE</b>	See <i>Belt Course</i>
<b>BASE COURSE</b>	Continuous horizontal course that sets on the brick ledge. It is the first course set in a wall.
<b>BED JOINT</b>	The joint, which the stone sets on. It is normally filled with mortar or backer rod and sealant.
<b>BELT COURSE</b>	Continuous horizontal course of Cast Stone incorporated in a wall above the base course and below the frieze.
<b>BEVEL</b>	See <i>Chamfer</i>
<b>BUGHOLE</b>	An unacceptable air void in a finished surface.
<b>BULL NOSE</b>	Convex molding which usually starts at the top of the Cast Stone unit and returns to the predominant face.
<b>CAPITAL</b>	Uppermost member of a column or a pilaster crowning the shaft.
<b>CAST STONE</b>	A refined architectural concrete building unit manufactured to simulate natural cut stone, used in unit masonry applications.
<b>COARSE AGGREGATE</b>	Aggregate predominately retained on the No. 4 (4.74-mm) sieve.
<b>COATED REBAR</b>	Rebar coated with a zinc alloy or epoxy. This rebar is normally used when rebar placement is within 1-1/2 inches from an exposed face.
<b>CHAIN</b>	A stack of quoins.
<b>CHAMFER</b>	Slanted surface which connects two external surfaces forming two arises.
<b>COLORING</b>	The process of (or material used for) tinting the hue of Cast Stone. It is normally achieved through the use of aggregates or inorganic iron oxide pigments.
<b>COLUMN</b>	Supporting pillar, usually consisting of a round shaft, a capital and a base.
<b>COPING</b>	Stone unit used to cap off the top of a wall. Its function is to protect the wall from the natural elements as well as adding an aesthetic value to the wall.

## GLOSSARY OF TERMINOLOGY

<b>CORNICE</b>	Molded piece at the top of an entablature projected with an ogee profile at the top leading edge with other relieves below.
<b>COURSE</b>	Horizontal scope of units incorporated in a wall.
<b>CRAMP</b>	”U” shaped metal anchors used to attach two abutting units.
<b>CRAZING</b>	A series of hairline cracks, normally less than a thirty-second of an inch in depth in the outer surface of a concrete product. Crazing does not constitute cause for rejection of Cast Stone.
<b>CURING</b>	The process of hydrating the Portland Cement in Cast Stone to a specified age or compressive strength in a warm, moist environment.
<b>CUT STONE</b>	Natural stone quarried and dressed to an architectural shape.
<b>DENTIL</b>	Block projections of an entablature below the cornice course.
<b>DOWEL</b>	Round (usually non-corrosive) metal pin used in anchoring and aligning Cast Stone.
<b>DRIP</b>	Continuous groove cut or cast into the bottom of the projecting edge of Cast Stone in order to disrupt the capillary attraction of water to the wall below.
<b>DRY CAST CONCRETE</b>	Manufactured from zero slump concrete. See <i>Vibrant Dry Tamp Concrete</i>
<b>EDGING</b>	The hand tooling of the arris.
<b>EFFLORESCENCE</b>	Visually observable signs of saline discharge onto a portion of a masonry wall.
<b>ENTABLATURE</b>	Incorporates an architrave, frieze, and cornice.
<b>ENTASIS</b>	The portion of a classic column, which has a diminishing arc on the shaft. The lower third of the column is straight (two-thirds entasis column).
<b>ERECTION</b>	Setting of large stones usually with a crane.
<b>EXTRADOS</b>	The outer portion of an arch.
<b>FACE</b>	The exposed portion of Cast Stone after it is installed.
<b>FACING</b>	Mix Materials used for the portion of Cast Stone, which is exposed to view after installed.
<b>FASCIA</b>	A broad and well-defined continuous horizontal band of Cast Stone at least header high.
<b>FINE AGGREGATE</b>	That portion of the aggregates passing the 4.75-mm (No. 4) sieve and retained on the No. 200 (75-µm) sieve.
<b>FEATHER EDGE</b>	A thin edge with an arris considerably less than ninety degrees. It is so named because of its frailty when handled (see <i>quirk miter</i> ).
<b>FILLET</b>	Continuous raised lug at the top back edge of a window sill. It serves as a moisture barrier and as the color a seat for the window sash.
<b>FINES</b>	Aggregate passing a #4 sieve.
<b>FINISH</b>	Final exposed surface of Cast Stone. It is independent of color, but it will control the color intensity. Acid etching is the most popular Cast Stone finish.
<b>FORM</b>	See <i>mold</i> .
<b>FRIEZE</b>	Flat unit of an entablature located between the architrave and cornice.
<b>FULL BED</b>	A horizontal joint completely filled with mortar.
<b>GROUT</b>	Mortar of pouring consistency.
<b>HEADER</b>	Stone unit running horizontally over an opening in a wall. Not self supporting (see <i>lintel</i> ).
<b>INSERT</b>	A metal device cast into a unit normally used for anchoring or handling.
<b>INCISE</b>	To cast concave or engrave.

## GLOSSARY OF TERMINOLOGY

<b>INSCRIPTION</b>	Characters incised into a unit.
<b>INTRADOS</b>	The inner portion of an arch.
<b>JAMB</b>	The vertical unit running up the side of an opening.
<b>JOINT</b>	Gap between masonry units filled with mortar or backer rod and sealant.
<b>JOINTING SCHEME</b>	The jointing pattern shown on contract documents.
<b>KEYSTONE</b>	The unit at the center of an arch. It is generally wedge shaped when viewed in elevation.
<b>LIFT HOOK</b>	A metal device embedded into the Cast Stone for the purpose of lifting and/or anchoring.
<b>LINTEL</b>	A unit spanning an opening and carrying the load of a wall above.
<b>LUG</b>	The portion of a Cast Stone unit running beyond an opening horizontally into a wall. The lug is normally less than a foot in length.
<b>LUG SILL</b>	Windowsill built into the wall, which runs horizontally beyond the masonry opening.
<b>MASONRY</b>	Construction made by the laying of units of substantial material such as brick, block and Cast Stone.
<b>MITER</b>	The splicing of two Cast Stone profiles at an angle ( <i>see quirk</i> ).
<b>MEDALLION</b>	An ornamental block.
<b>MODEL</b>	The positive shape that represents the final product. A mold is formed around a model.
<b>MODILLION</b>	Ornamental block located under the corona of a cornice.
<b>MOLDING</b>	Any linear plane, which deviates from a flat surface.
<b>MORTAR</b>	A blend of cement, lime, sand, and water which is applied at a pliable consistency to bond masonry units.
<b>MOLD</b>	A form in which Cast Stone is shaped. It can be constructed from wood, plaster, rubber, fiberglass, and other materials.
<b>MULLION</b>	A vertical member, which forms a separation from adjacent window or door frames.
<b>POINTING</b>	<i>See Tuck Pointing</i>
<b>PRECAST</b>	A concrete product not poured in place.
<b>QUIRK MITER</b>	An end condition cast with a forty-five degree angle and an edge put on the point at a ninety degree angle to eliminate feather edging.
<b>QUOIN</b>	Cast Stone block used to make up a corner of a wall.
<b>RECESS</b>	A depression in a flat surface.
<b>REGLET</b>	A continuous groove cast or cut into a Cast Stone unit to receive flashing.
<b>REINFORCING</b>	Rebar placed into a Cast Stone unit during the manufacturing process to augment the unit during handling or to enable it to carry a structural load (i.e. lintel).
<b>REBAR</b>	A deformed steel unit used for reinforcing Cast Stone.
<b>RELIEF</b>	Ornamentation.
<b>REPRISE</b>	An internal corner of a profiled unit.
<b>RETURN</b>	An external corner of a profiled unit.
<b>REVEAL</b>	The side of an opening (as for a window) between a frame and the outer surface of a wall.
<b>RUSTICATION</b>	An incision cast around the outer edges of a unit to produce a shaded affect.
<b>SAMPLE</b>	The specimen submitted to represent the color and texture of Cast Stone. This specimen dictates the general range of the color and texture of production pieces.

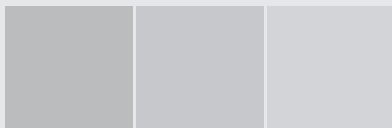
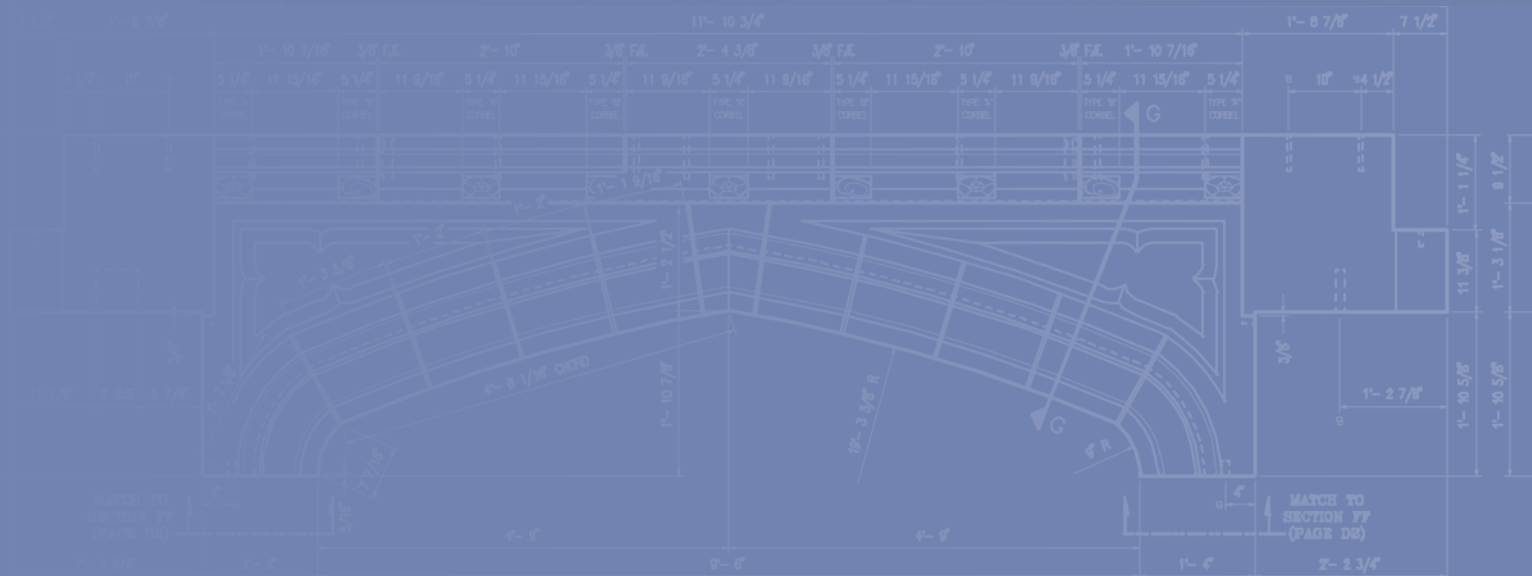


## GLOSSARY OF TERMINOLOGY

<b>SETTING</b>	The mason's process of installing and anchoring Cast Stone.
<b>SETTING PADS</b>	Non-corrosive pads used to set Cast Stone on in order to prevent the bed joint from compressing at the time of setting.
<b>SETTING DRAWING</b>	Drawing which the Cast Stone manufacturer submits for approval detailing all aspects of the installation with piece markings and final locations of stones.
<b>SHOP DRAWING</b>	The drawing, which the Cast Stone manufacturer submits for approval showing size and shape of pieces, exposed faces, jointing, anchoring, reinforcing and unit cross section.
<b>SLIP SILL</b>	A Cast Stone windowsill that fits within the masonry opening.
<b>SOFFIT</b>	The exposed underside portion of a unit.
<b>SPANDREL</b>	A unit spanning an opening with bearing beyond the opening. It is not normally load bearing, but supporting.
<b>SPRINGER</b>	A unit that is located at the spring line of an arch.
<b>SURROUND</b>	An encasement of an opening.
<b>TEMPLATE</b>	A type of model used to convey the pattern, shape, or profile to be used by the manufacturer in the molding process.
<b>TEXTURE</b>	The finish structure consisting of visual and tactile surface qualities.
<b>TOLERANCE</b>	Allowable deviation from specified dimensions.
<b>TRACERY</b>	Arched ornamental work with interlacing, branching lines. Usually consists of openwork in the head of a Gothic window.
<b>TOOLED FINISH</b>	A finish obtained by texturing either the mold or the Cast Stone (ex. bushhammered, six-cut).
<b>TROWEL FINISH</b>	A finish normally given to the back or unformed side of Cast Stone. This finish may look slightly different than the molded sides of the piece.
<b>TUCK POINTING</b>	The final tooling or pointing of a raked out mortar joint.
<b>VIBRANT DRY TAMP</b>	Vibratory ramming of earth moist, zero-slump concrete against a rigid mold until it is densely compacted.
<b>VOLUTE</b>	The scroll shaped ornament forming the chief feature on an Ionic capital.
<b>WARP</b>	Twist or bowing of final casting measured by deviation from plane and tolerance.
<b>WASH</b>	A sloping horizontal surface formed to cause water to run off.
<b>WATER REPELLENT</b>	Normally a clear sealer sprayed or brushed on the exposed portion of a masonry wall to deflect moisture.
<b>WATERTABLE</b>	The course of Cast Stone that sits on the base course. This course normally transcends an offset in the building.
<b>WEEP-HOLE</b>	An opening normally in a masonry head joint at the bottom of a unit to allow any moisture behind it to escape.
<b>WELD PLATE</b>	A square metal device cast flush to the surface for attachment by means of welding.
<b>WET CAST CONCRETE</b>	Manufactured from measurable slump concrete.



# Technical Manual



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