42 PRESERVATION BRIEFS

The Maintenance, Repair and Replacement of Historic Cast Stone

Richard Pieper

U.S. Department of the Interior
National Park Service
Cultural Resources
Heritage Preservation Services

An Imitative Building Material with Many Names

The practice of using cheaper and more common materials on building exteriors in imitation of more expensive natural materials is by no means a new one. In the eighteenth century, sand impregnated paint was applied to wood to look like quarried stone. Stucco scored to simulate stone ashlar could fool the eye as well. In the 19th century, cast iron was also often detailed to appear like stone. Another such imitative building material was "cast stone" or, more precisely, precast concrete building units (Figs. 1, 2 and 3).

Cast stone was just one name given to various concrete mixtures that employed molded shapes, decorative aggregates, and masonry pigments to simulate natural stone. The basic mixtures included water, sand, coarse aggregate, and cementing agents. Natural cements, portland cements, oxychloride cements, and sodium silicate based cements were all used as binding agents. The differences in the resulting products reflected the different stone aggregates, binding agents, methods of manufacture and curing, and systems of surface finishing that were used to produce them. Versatile in representing both intricately carved ornament and plain blocks of wall ashlar, cast stone could be tooled with a variety of finishes.

During a century and a half of use in the United States, cast stone has been given various names. While the term "artificial stone" was commonly used in the 19th century, "concrete stone," "cast stone," and "cut cast stone" replaced it in the early 20th century. In addition, Coignet Stone, Frear Stone, and Ransome Stone were all names of proprietary systems for precast concrete building units, which experienced periods of popularity in different areas of the United

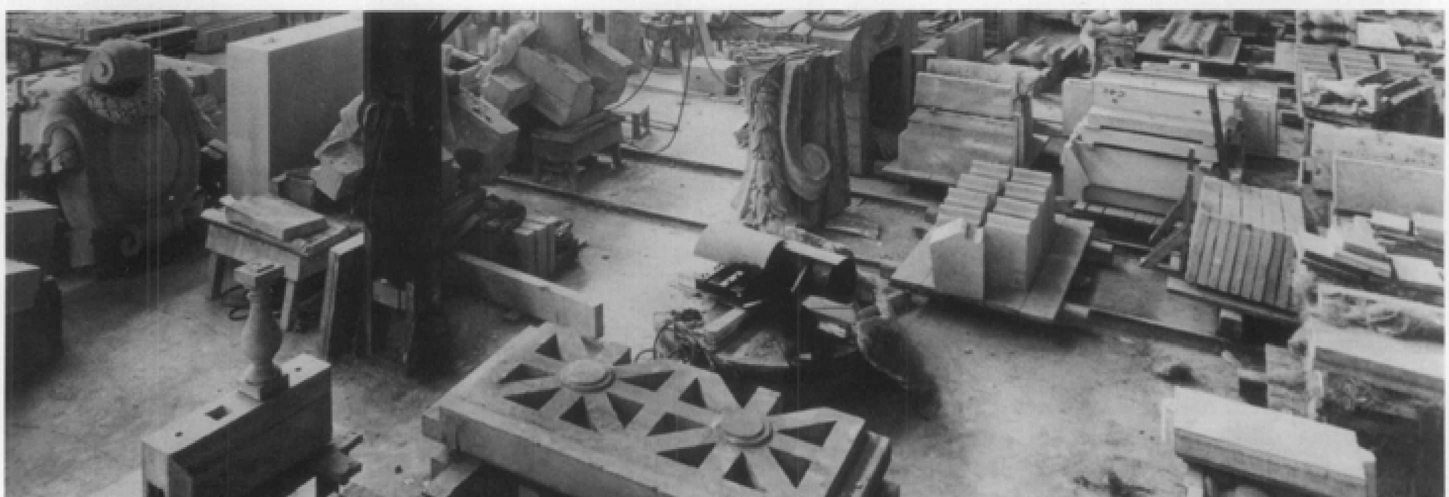


Figure 1. In the early 20th century, elaborate custom building ornament was frequently produced in cast stone. Here, at the Benedict Stone Company's plant in Chicago, cartouches, balustrade panels, railings, and balusters await finishing and shipment. Photo: Courtesy, National Building Museum.

Figure 2. The prominent Delaware and Hudson Building in Albany, New York (1916) made extensive use of cast stone as trim combined with a random ashlar facing of natural granite. The elaborate gothic trim was produced by the Onondaga Litholite Company of Syracuse, New York.

States in the 19th century. These systems may be contrasted with "Artistic Concrete," decorative molded concrete construction, both precast and cast-in-place, which made little effort to simulate natural stone (Fig. 4).

Having gained popularity in the United States in the 1860s, cast stone had become widely accepted as an economical substitute for natural stone by the early decades of the 20th century. Now, it is considered an important historic material in its own right with unique deterioration problems that require traditional, as well as innovative solutions. This *Preservation Brief* discusses in detail the maintenance and repair of historic cast stone--precast concrete building units that simulate natural stone. It also covers the conditions that warrant replacement of historic cast stone with appropriate contemporary concrete products and provides guidance on their replication. Many of the issues and techniques discussed here are relevant to the repair and replacement of other precast concrete products, as well.

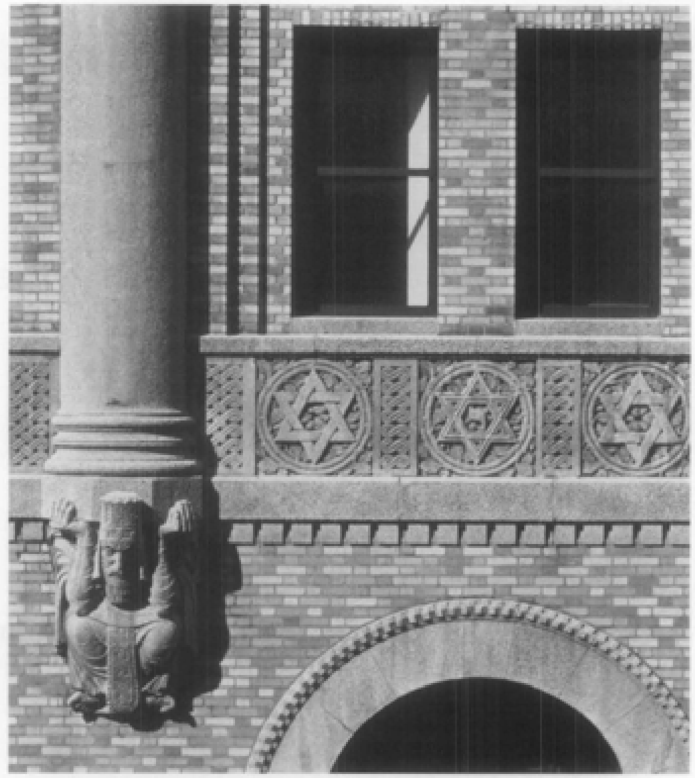


Figure 3. Sculptural ornament was frequently produced in cast stone. Repetitive detail, such as these banding course panels on the Level Club in New York City (1926), were produced much more economically than they could be in natural stone.

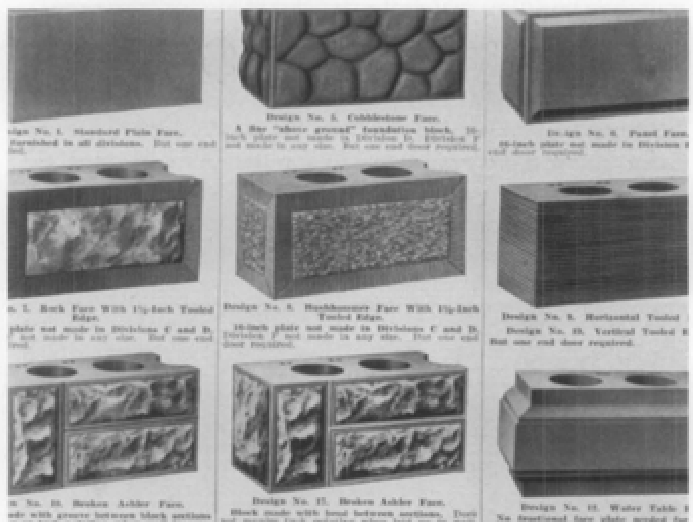


Figure 4. As shown in this Sears, Roebuck and Co. concrete machinery catalog, artistic concrete used standard concrete mixes to produce precast and cast-in-place concrete in molded forms, but made little effort to simulate natural stone.

History of Use and Manufacture

Early Patented Systems

While some use of cast stone may be dated to the Middle Ages, more recent efforts to replicate stone with cementitious materials began in England and France at the end of the 18th century. Coade Stone, one of the best known of the early English manufactures, was used for architectural ornament and trim, and saw limited use for interior decoration in the United States as early as 1800. Significant advances in the artificial stone industry in the United States were tied to the production of natural cement or hydraulic lime, which began about 1820.

A large number of patented American, English, and French systems were marketed immediately after the Civil War. One of the earliest American patents for cast stone was awarded to George A. Frear of Chicago in 1868. Frear Stone was a mixture of natural cement and sand, to which a solution of shellac was added to provide initial curing strength. Frear's system was widely licensed around the country, and the resultant variation in materials and manufacturing methods apparently resulted in some significant failures.

Another product which utilized natural cement as its cementing agent was Beton Coignet (literally, "Coignet concrete," also known as "Coignet Stone"). Francois Coignet was a pioneer of concrete construction in France. He received United States patents in 1869 and 1870 for his system of precast concrete construction, which consisted of portland cement, hydraulic lime, and sand. In the United States the formula was modified to a mix of sand with Rosendale Cement (a high quality natural cement manufactured in Rosendale, Ulster County, New York). In 1870 Coignet's U.S. patent rights were sold to an American, John C. Goodrich, Jr., who formed the New York and Long Island Coignet Stone Company. This company fabricated the cast stone for one of the earliest extant cast stone structures in the United States, the Cleft Ridge Span in Prospect Park, Brooklyn, New York (Fig. 5).

Some proprietary systems substituted other cements for the portland cement or hydraulic lime. The British patent process of Frederick Ransome utilized a mixture of sand and sodium silicate, combined with calcium chloride, to form blocks of calcium silicate. The sodium chloride by-product was intended to be removed with water washes during the curing process. The Sorel cement process, developed in 1853 and later applied to the manufacture of grindstones, tiles, and cast stone for buildings, combined zinc oxide with zinc chloride, or magnesium oxide and magnesium chloride, to form a hydrated oxychloride cement mixture that bound together sand or crushed stone. The Union Stone Company in Boston manufactured cast stone using the Sorel process. Ultimately, however, alternate cementing systems were abandoned in favor of portland cement, which proved to be more dependable and less expensive.

Figure 5. Constructed in 1868 of Beton Coignet, the Cleft Ridge Span in New York City's Prospect Park is one of the earliest extant cast stone structures in the United States.

Late 19th and 20th Century Development

The use of cast stone grew rapidly with the extraordinary development of the portland cement and concrete industries at the end of the 19th century. In the early decades of the 20th century, cast stone became widely accepted as an economical substitute for natural stone. It was sometimes used as the only exterior facing material for a building, but was more often used as trim on a rock-faced natural stone or brick wall (Fig. 6). In most early 20th century installations, cast stone was used for exterior window and door surrounds or lintels, copings, parapets and balustrades, banding courses, cornices and friezes, and sculptural ornament. On occasion, decorative interiors were also finished with cast stone, although elaborate interior cornices and ornaments were more frequently fabricated of plaster.

Manufacture

Manufacturers of cast stone used graded mixes of crushed marble, limestone, granite, and smelting slag to produce a variety of stone effects. A light cement matrix with an aggregate of crushed marble could replicate limestone, while a mix of marble and small amounts of smelting slag would give the effect of white granite (Fig. 7). Some manufacturers added masonry pigments and varied colors on the faces of the stone to give a somewhat stylized effect of variegated sandstone. Each manufacturer prepared a variety of stock mixes as well. Not surprisingly, aggregates varied in different localities. In New York State, for example, crushed Gouverneur and Tuckahoe marbles were popular facing aggregates; in other areas, crushed feldspar or granite and even silica sand were commonly used.

The two basic cast stone production systems were "dry tamp" and "wet cast." The **dry tamp** process employed a stiff, low-slump concrete mix that was pressed and compacted into the molds. The decorative aggregate mix was frequently distributed only on the exterior facing of the cast units (typically 3/4" to 1 ½" thick), while the cores of the units were common concrete. Because of the stiff mix, dry tamp units required a relatively short period of time in the molds, which could then be used several times a day. After removal from the molds, the dry tamp units were often cured in steam rooms to assure proper hydration of the cement. The **wet cast** process, on the other hand, used a much more plastic concrete mix that could be poured and vibrated into the molds. This system used significantly more water in the mix, assuring proper hydration of the cement mix without elaborate curing, but requiring that the units be left in the molds for at least a day. Because of this method of fabrication, wet cast products necessarily distributed their decorative aggregate mix through the entire unit, rather than simply an outer facing.

Concrete was cast in molds of wood, plaster, sand and, early in the 20th century, even hide glue or gelatin, depending upon the production method, the intricacy of the piece to be cast, and the number of units to be manufactured. Metal molds were sometimes used for stock ornamental items, less frequently for custom architectural work. When the units were adequately hard, finish surfaces were worked to expose the decorative stone aggregate. When removed from the mold, wet cast units exhibit a surface film of cement paste, which must be removed to expose the aggregate. Partially cured units could be sprayed with water, rubbed with natural bristle brushes, etched with acid, or sandblasted to remove the cement layer. The surface of dry tamp products required less finishing.

Figure 6. Cast stone was commonly used for molded trim in conjunction with brick or natural stone. This brick building in Rochester, New York, uses cast stone for the entry surround, and natural stone for unornamented window sills, thresholds, and water table units.

Figure 7. A combination of crushed white marble and black smelting slag was frequently used to give the appearance of a "white granite". The hammered finish on this early twentieth century cast stone would have been produced with a pneumatic chisel.

High quality cast stone was frequently "cut" or tooled with pneumatic chisels and hammers similar to those used to cut natural stone (Fig. 9). In some cases, rows of small masonry blades were used to create shallow parallel grooves similar to lineal chisel marks. The results were often strikingly similar in appearance to natural stone. Machine and hand tooling was expensive, however, and simple molded cut cast stone was sometimes only slightly less costly than similar work in limestone. Significant savings could be achieved over the cost of natural stone when repetitive units of ornate carved trim were required.

Finally, cast stone is sometimes used today to replace natural stone when the original historic stone is no longer available, or the greater strength of reinforced concrete is desired. Reinforced cast stone columns, for instance, are frequently used to replace natural stone columns in seismic retrofits of historic structures. Fine-grained stones, such as sandstones, may be very successfully replicated with cast stone. Coarse-grained granites and marbles with pronounced patterns or banding are, for obvious reasons, not so successfully matched with cast stone. The replacement of natural stone with cast stone requires careful attention to selection of fine aggregates and the pigmentation of the cementing matrix (Fig. 8). Coarse aggregate, which is generally used in cast stone to control shrinkage and assure adequate compressive strength, can present an aesthetic problem if it is visible at the surface of cast stone elements which simulate sandstone. Careful control of aggregate sizes in the mix formulation can reduce this problem.

Figure 8. For this column, the appearance of a "pink granite" was simulated by using a pinkish matrix with white and black aggregate. Erosion of a tinted matrix results in a significant lightening of the cast stone surface.

Tooling Cast Stone

Figure 9. Onondaga Litholite Company Catalog: (a) Section of Hand-Finishing Department. (b) Tooling machines are set up with a series of carborundum wheels that grind grooves into the surface of the stone (c) Pneumatic hammers are used to produce six or eight cut finish (d) Point Finish is put on with a single pointed chisel. Courtesy, Collection of Michael F. Lynch.

Figure 9. Onondaga Litholite Company Catalog: (a) Section of Hand-Finishing Department. (b) Tooling machines are set up with a series of carborundum wheels that grind grooves into the surface of the stone (c) Pneumatic hammers are used to produce six or eight cut finish (d) Point Finish is put on with a single pointed chisel. Courtesy, collection of Michael F. Lynch

Mechanisms and Modes of Deterioration

The best historic cast stone can rival natural stone in longevity. Many quality cast stone installations from the first decades of the twentieth century are still in excellent condition, and require little repair. Like any other building material, however, cast stone is subject to deterioration, which may occur in several ways:

- **Separation of the facing and core layers**
- **Deterioration of the aggregate**
- **Deterioration or erosion of the cementing matrix**
- **Deterioration of the iron or steel reinforcement**
- **Deterioration of cramps and anchors used in its installation**

Separation of the Facing and Core Layers

Separation of the facing and core layers of dry tamp units is not uncommon, and often reflects fabrication defects such as poor compaction, lengthy fabrication time, or improper curing. Where separation of facing and core layers is suspected, cast stone units may be "sounded" to establish the extent of delamination.

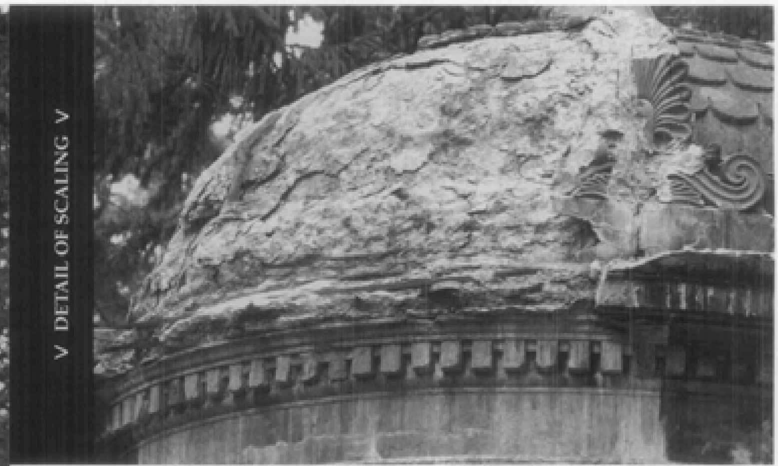


Figure 10. Scaling of cast stone units signals problems with the cementing mix and method of manufacture. Serious deterioration of cast stone, such as this, warrants replacement.

Deterioration or Erosion of the Cementing Matrix

While it is relatively uncommon in twentieth century cast stone, serious deterioration of the cementing matrix can cause extensive damage to cast stone units (Fig. 10). A properly prepared cementing mix will be durable in most exterior applications, and any flaking of exterior surfaces signals problems in the cementing mix and in the method of manufacture. The use of poor quality or improperly stored cement, impure water, or set accelerators can cause cement problems to occur years after a structure is completed. Improper mixing and compaction can also result in a porous concrete that is susceptible to frost damage and scaling. Severe cement matrix problems may be impossible to repair properly and often necessitate replacement of the deteriorating cast stone units.

More common and less serious than flaking or scaling caused by deterioration of the cementing matrix is the erosion of the matrix surface (Fig. 11). This usually occurs on surfaces of projecting features exposed to water runoff, such as sills, water tables, and window hoods. In these areas, the matrix may erode, leaving small grains of aggregate projecting from the surface. The resultant rough surface is not at all the intended original appearance. In some historic cast stone installations, the thin layer of cement and fine sand at the surface of the cast stone units was not originally tooled from the molded surface, but was finished with patterns of masonry pigments in a stylized imitation of highly figured sandstones or limestones (Fig. 12). Erosion of the pigmented surface layer on this type of cast stone results in an even more dramatic change in appearance.

Deterioration of the Aggregate

Cast stone failure caused by deterioration of the aggregate is uncommon. Granites, marbles, and silica sand are generally durable, although limestone and marble aggregate are subject to the same dissolution problems that affect quarried units of these stones. In rare instances, a reaction between the alkalis in the cement matrix and the stone aggregate may also cause deterioration.

Figure 11. Erosion of the cementing matrix on the surface of cast stone is common in areas exposed to water runoff, such as window sills and copings. If no other deterioration is present, this condition does not warrant repair or replacement, but should be considered normal weathering. The unweathered surface at the left of this photograph shows the appearance of the original hammer-dressed finish. At right, the matrix has eroded, and the aggregate is much more prominent than on the unweathered surface.

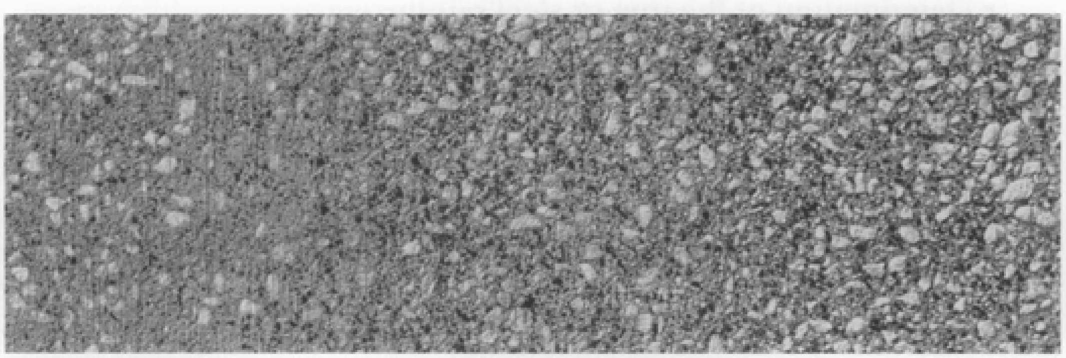


Figure 12. Elaborate pigmentation of the cementing matrix sometimes gave a rather stylized or unnatural appearance to the finished cast stone (left). Texts state that effects like this were sometimes produced by drawing strings dipped in masonry pigments across the surface of the uncured units. Cast stone, such as this, has its coloration only at the outer surface of the stone, and was not intended to be brushed or tooled to expose the aggregate. Erosion of the cementing matrix of this type of cast stone, as seen on the base of the wall (right), will result in a significant alteration of appearance.

Deterioration of the Iron or Steel Reinforcement

During their original manufacture, unusually long and thin cast stone units, such as window sills or balustrade railings, and units requiring structural capacity, such as lintels, were generally reinforced with mild steel reinforcing bars. Large pieces sometimes had cable loops or hooks cast into them to facilitate handling and attachment. On occasion, this reinforcement and wire may be too close (less than 2") to the surface of the piece and rusting will cause spalling of the surface (Fig. 13). This frequently happens to sills, copings, and water tables where repeated heavy wetting leads to loss of alkalinity in the concrete, allowing the reinforcement to rust. If damage from the deteriorating reinforcement is extensive, as for instance, the splitting of a baluster from the rusting of a central reinforcing rod, the cast stone unit may require replacement.

Deterioration of Cramps and Anchors

Even when reinforcement has not been added to individual cast stone units, mild steel cramps may have been used to anchor a cast stone veneer to backup masonry. Where spalls have occurred primarily at the tops of ashlar or frieze units, this is generally the cause.

Maintenance of Cast Stone Installations

Cleaning

Cast stone installations with marble or limestone aggregates may sometimes be cleaned with the same alkaline pre-wash/acid afterwash chemical cleaning systems used to clean limestone and other calcareous natural stones. If no marble or limestone aggregates are present, acidic cleaners, such as those used for natural granites and sandstones, may be used. In either case, dark particulate staining in protected areas may be persistent, however, and require experimentation with other cleaning methods. Some micro-abrasive cleaning techniques used under very controlled circumstances by skilled cleaning personnel can be appropriate for removing tenacious soiling. Ordinary sand blasting or wet grit blasting can seriously damage the surface of the cast stone and should not be used (Fig. 14).

Figure 13. Rusting of reinforcement near the surface of the stone may result in spalling. Sections of reinforcement, such as this, may be cut out and the spall repaired with a matching composite mortar.

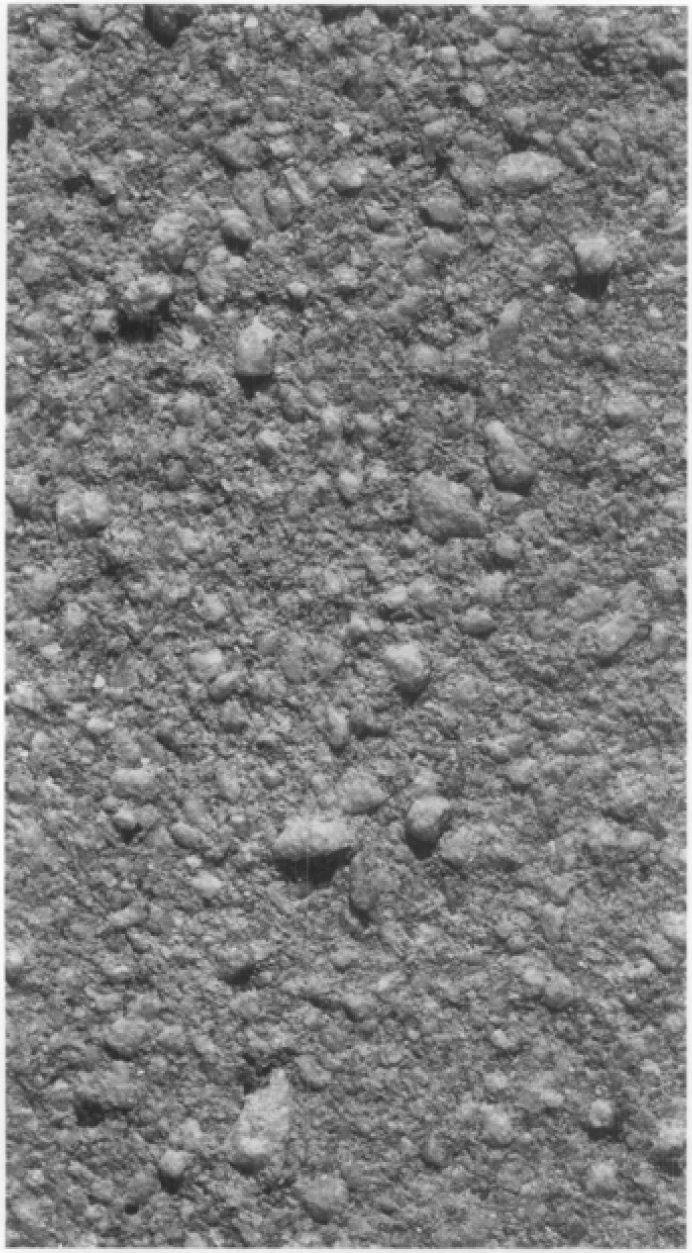


Figure 14. Sandblasting and wet grit blasting can seriously erode the surface and should not be used to clean cast stone surfaces.

Repointing

Early cast stone installations may have been constructed with natural cement mortars, but in late 19th century and 20th century installations, cast stone units were generally bedded and pointed with mortars composed of portland cement, lime, and sand. When repointing or replacement of the historic mortar is required, a Type N mortar (about one part cement, and one part lime to six parts of sand) is generally appropriate. When repointing any historic masonry, it is important to match both the character and color of the sand and color of the cement matrix in the historic mortar. Cement matrix color can often be adjusted by using combinations of white, "light," and gray portland cement in the mortar.

Joints in historic cast stone installations can be quite thin and the dense mortar thus difficult to remove. Unnecessary repointing can cause significant damage to historic cast stone. Cracked and open joints will most often be found on exposed features, such as balustrades and copings, and, of course, require repointing. When a hard and tenacious mortar was used in the original installation or a later repointing, the removal of the mortar can easily chip the edges of the cast stone units.

While the careless use of "grinders" to remove mortar has damaged countless historic masonry buildings, a skilled mason may sometimes use a hand held grinder fitted with a thin diamond blade to score the center of a joint, and then remove the rest of the mortar with a hand chisel. If this method is not done carefully, however, wandering of the blade can widen or alter joints and cause significant damage to the cast stone. Care must be taken to prevent damage from over cutting of vertical joints by stopping blades well short of adjacent units. The use of small pneumatic chisels, such as those used to tool stone, can also work well for mortar removal, but even this method can cause chipping to the edges of cast stone units if it is not done carefully.

Methods of Repair

Much historic cast stone is unnecessarily replaced when it could easily be repaired *in situ*, or left untreated. This is especially true of areas that exhibit isolated spalls from rusting reinforcement bars or anchorage, or installations where erosion of the matrix has left a rough surface of exposed aggregate.

The weathering of cast stone, while different from that of natural stone, produces a patina of age and does not warrant large-scale replacement, unless severe cement matrix problems or rusting reinforcement bars have caused extensive scaling or spalling. Severe rusting of reinforcement bars on small decorative features, such as balusters, may signal carbonation (loss of alkalinity) of the matrix. Where carbonation of the matrix has occurred, untreated reinforcement will continue to rust. Replacement may be an acceptable approach for exposed and severely deteriorated features, such as hand railings, roof balustrades, or wall copings, where disassembly is unlikely to damage adjacent construction. Conversely, small areas of damage should generally be repaired with mortar "composites", or left alone.

Re-securing Separated Surface Facing

Where the decorative facing of dry tamped cast stone has separated from core layers, injected grouts may be used to re-secure the facing. Re-attachment of a separated facing layer may be time consuming, and should be undertaken by a conservator, rather than a mason (Fig. 15). This technique may be the best, most economical, approach for repair of figurative sculpture or unique elements that are not repeated elsewhere on a building. Theoretically, cementitious grouts are most appropriate for re-attaching separated facings, but hairline fissures may require the use of resin adhesives. Low-viscosity epoxies have been used for this purpose, and may be applied through small injection ports. Cracks that would allow the adhesive to leak must be repaired prior to injection, of course. Holes made for adhesive injection will require patching after re-attachment is complete.

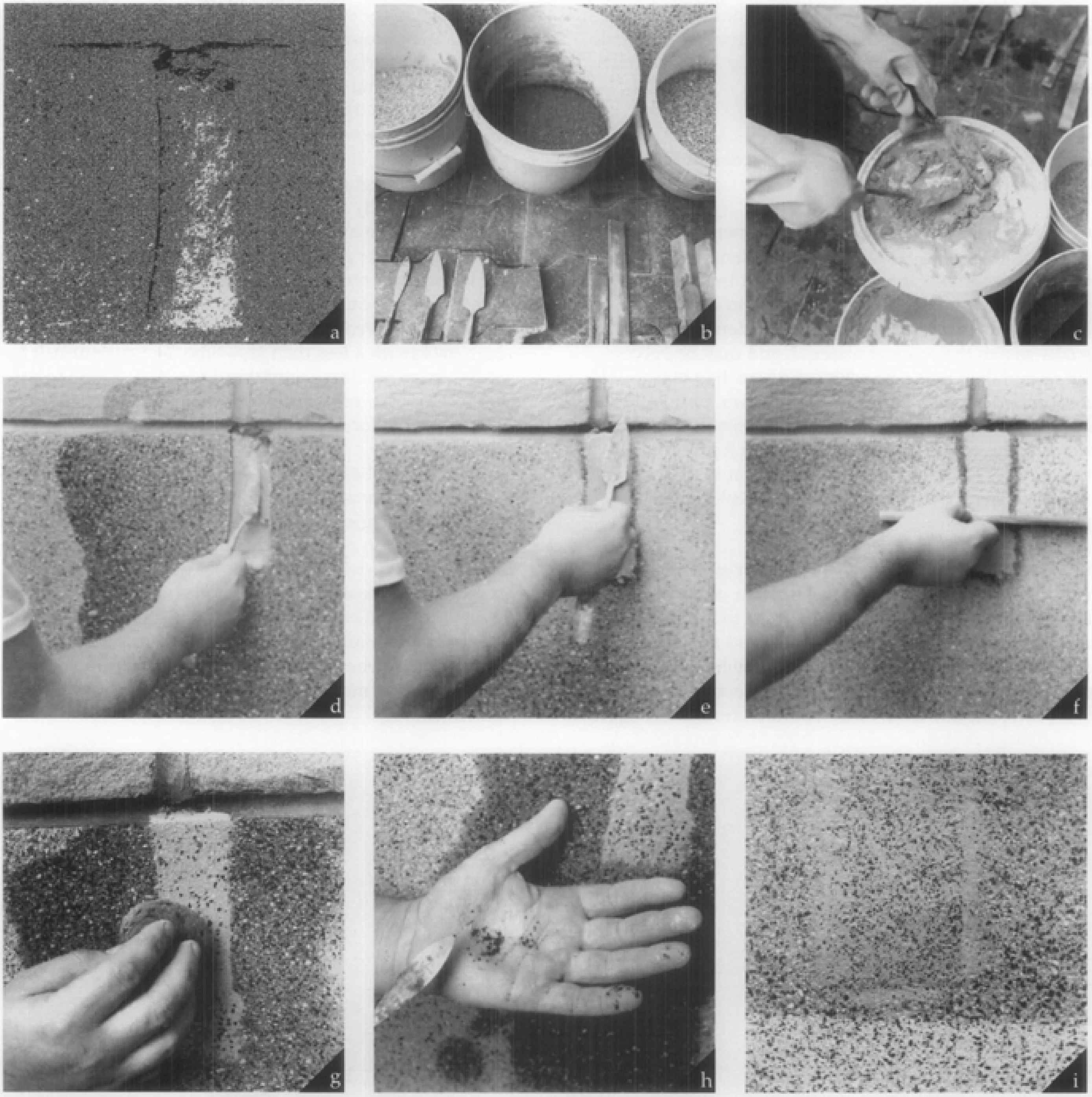
Repairing Spalls from Rusting Reinforcement Bars and Mechanical Damage

Drilled holes, mechanically damaged corners, and occasional spalls from rusting reinforcement bars and anchorage are repairable conditions that do not warrant the replacement of cast stone. Small "composite " repairs to damaged masonry units can be made with mortar formulated to visually match the original material, and may be successfully undertaken by a competent and sensitive mason. If deterioration appears widespread, however, or if large surface areas are spalling or cracking and replacement appears necessary, the owner may wish to consult a preservation architect or consultant to determine the cause of deterioration and to specify necessary repairs or replacement, as appropriate.

The methods of composite repair used for stone masonry are also generally applicable for the repair of historic cast stone. For repairs to damaged cast stone to be successful, however, both the cement matrix color and the aggregate size and coloration must match that of the historic unit. Crushed stone and slag (such as "Black Beauty" abrasive grit), which are similar to many common traditional aggregates, are widely available, although some additional crushing and/or sieving may be necessary to obtain aggregate of an appropriate size. Remember that half or more of a weathered surface is exposed aggregate, so careful aggregate selection and size grading is extremely important for patching. Even differences in aggregate angularity (rounded pebbles vs. crushed stone) will be noticeable in the final repair. If more than one aggregate was used in the cast stone, the ratio of the selected aggregates in the mix is, of course, equally important. Variation in coloring of the cement matrix may be achieved through the use of either white, "light, " or gray portland cement. If additional tinting is required, only inorganic alkali-resistant masonry pigments should be used. Because most historic cast stone was manufactured primarily from portland cement and aggregate (with a less than 15% lime/cement ratio), it is not necessary to add large amounts of hydrated lime to cast stone composite repair mixtures. Small amounts of lime may be added for plasticity of the working mix.

To repair a spall caused by deterioration of a ferrous reinforcement bar or anchorage, it is necessary to remove all cracked concrete adjacent to the spall; grind and brush the reinforcement to remove all rust and scale; and paint the metal with a rust-inhibiting primer prior to applying the cast stone composite. If the reinforcement bar is much too close to the surface of the stone, it may be advisable to cut out the deteriorating section of reinforcement after consultation with a structural engineer. If deteriorating cramps are removed, it may be necessary to install new stainless steel anchorage.

Figure 15. A delaminated layer of ornamental cast stone on the Orpheum Theater, San Francisco, California (1925), was successfully re-attached using epoxy. The multiple delivery ports for the epoxy are removed after treatment and the holes patched. Photo: David P. Wessell.



Composite Repair of Damaged Masonry Units

Figure 16. The (a) damaged area is cut out to create a shallow void of even depth, ½" or more. Undercutting the sides of the void may provide better adhesion while the composite is being applied. A small grinder fitted with a diamond blade may be used to prepare the void. (b) A range of aggregates matching those in the cast stone is required. Matching aggregate size and angularity is very important. Small spatulas and trowels are used for application of the composite. The aggregates are mixed to a ratio approximating that in the cast stone. (c) Matching the color of the cementing matrix may require numerous tests. Only small amounts are required for any one repair. Lime may be added to the mix for workability. (d) The composite mortar is applied to the void with a small spatula or trowel. An aggregate rich mix may not adhere properly, and it may be desirable to apply a more cement rich mix directly to the substrate. (e) The composite mix is pressed into the void, leaving the patch slightly proud of the surface. (f) The composite is struck flush with the adjacent surfaces. (g) Patting the patch with a moist sponge removes matrix and exposes the aggregate. (h) It may be desirable to impress additional aggregate into the surface of the patch to achieve a better match to surrounding surfaces. If so, the mix aggregate should be crushed to a smaller size. Laying in larger aggregate may result in a mosaic appearance which does not match adjacent surfaces. (i) This completed composite repair could have been improved by brushing to remove the matrix residue at the edges of the repair before the surface cured.

Where spalls have a feather edge, it will be necessary to cut back the repair area to a uniform depth (1/2" or more). As with natural stone composite repairs, a bonding agent may assist adhesion of the repair material to the original concrete. For unusually large or deep patches, mechanical anchoring of the repair with small nylon or stainless steel rods may be required. If the adjacent cast stone is tooled or weathered, it will be necessary to scribe or brush the repaired area to give it a matching surface texture. Adding enough coarse aggregate to match adjacent original material will sometimes interfere with adhesion of the composite, and it may be necessary to press additional aggregate into the applied patch prior to finishing. If this is not skillfully done, however, the surface of the patch may take on a mosaic appearance. For this reason, it is advisable to undertake test composite repairs in an unobtrusive location first (Fig. 16).

Figure 17. Unlike natural stone, cast stone generally may not be tooled in place to reduce lippage of uneven surfaces at joints. Tooling often exposes coarse aggregate from below the surface.

Surface Refinishing

While re-tooling deteriorated natural stone may sometimes be appropriate, restoring the original appearance of cast stone where surface erosion has occurred is difficult or impossible. Tooling or grinding of the cast stone surface may expose coarse aggregate and will not, in any case, restore original patterned pigmentation that has weathered away (Fig. 17). Silicate paints or masonry stains may be applied in patterns to replicate the original appearance, but may not be durable or completely successful aesthetically.

Where matrix has eroded, it is advisable to accept the weathered appearance of the cast stone, unless extensive replacement is mandated by other factors.

Because cast stone depends on exposed aggregate to achieve its aesthetic effect, the use of an applied cementitious surface coating dramatically alters the visual effect of the material and is inappropriate as a cast stone repair technique. A cementitious surface coating can also trap moisture in the cast units and cause surface spalling.

Figure 18. Long or thin cast stone elements require reinforcement. When possible, reinforcement of new cast stone should be made of stainless steel.

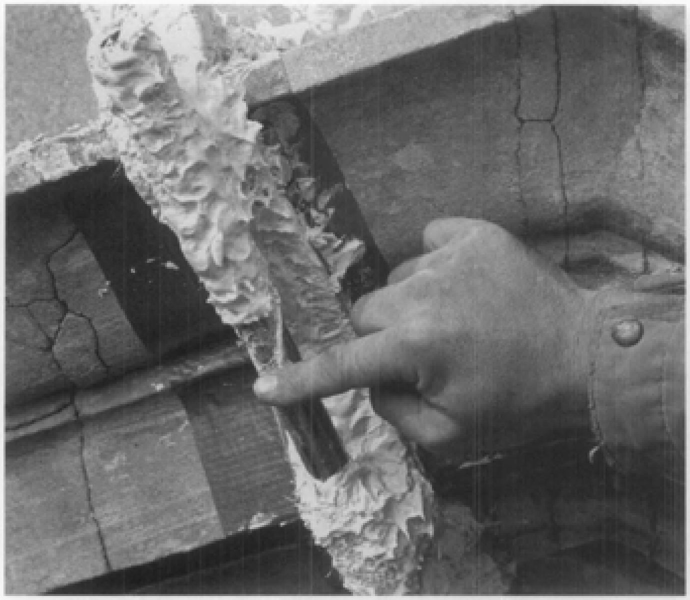


Figure 19. Molds for the replication of cast stone may be made on site using rubber materials and reinforcement. The molded profile of this window pediment will be used to run a plaster mockup, from which a production mold will be made. Photo: Michael Devonshire.

Replacement of Historic Cast Stone Installations

Individual cast stone units, which are subject to repeated wetting (such as copings, railings and balusters) and exhibit severe failure due to spalling or reinforcement deterioration, may require replacement with new cast stone (Fig. 18). Fortunately, a number of companies custom manufacture precast concrete units and can replicate deteriorated units in existing buildings (Fig. 19). The variables involved in manufacture are considerable, and it is wise to use a firm with experience in ornamental and custom work rather than a precast concrete firm which manufactures stock structural items, concrete pipe, or the like. Several trade organizations, including the Cast Stone Institute, the National Precast Concrete Association, and the Architectural Precast Association, have developed recommendations and/or guide specifications for the manufacture of cast stone and precast concrete. These specifications set standards for characteristics such as compressive strength and water absorptivity, and discuss additives such as air entraining agents and water reducing agents, which influence the longevity of new cast stone. Trade references and guide specifications should be consulted before contracting for replacement of historic cast stone.

Fabrication Defects in New Cast Stone

While the cement matrix coloration and aggregate considerations previously described require the most careful attention, project staff should also look for defects which are common to cast stone fabrication:

Air bubbles. Small pits on the surface of the stone may form if the unit is not given adequate vibration to release trapped air during pouring. Bubbles can also be a problem

Figure 20. (top) After removal from the mold, new cast stone units are scrubbed, as shown, to remove surface paste and expose underlying aggregate. (middle) End cast pieces, such as columns or sculpture, may have numerous air bubbles at the surface. (bottom) The holes on the surface of the casting are filled with a mortar similar to the concrete mix used to cast the element.

Figure 20. (top) After removal from the mold, new cast stone units are scrubbed, as shown, to remove surface paste and expose underlying aggregate, (middle) End cast pieces, such as columns or sculpture, may have numerous aur bubbles at the surface. (bottom) The holes on the surface of the casting are filled with a mortar similar to the concrete mix used to cast the element

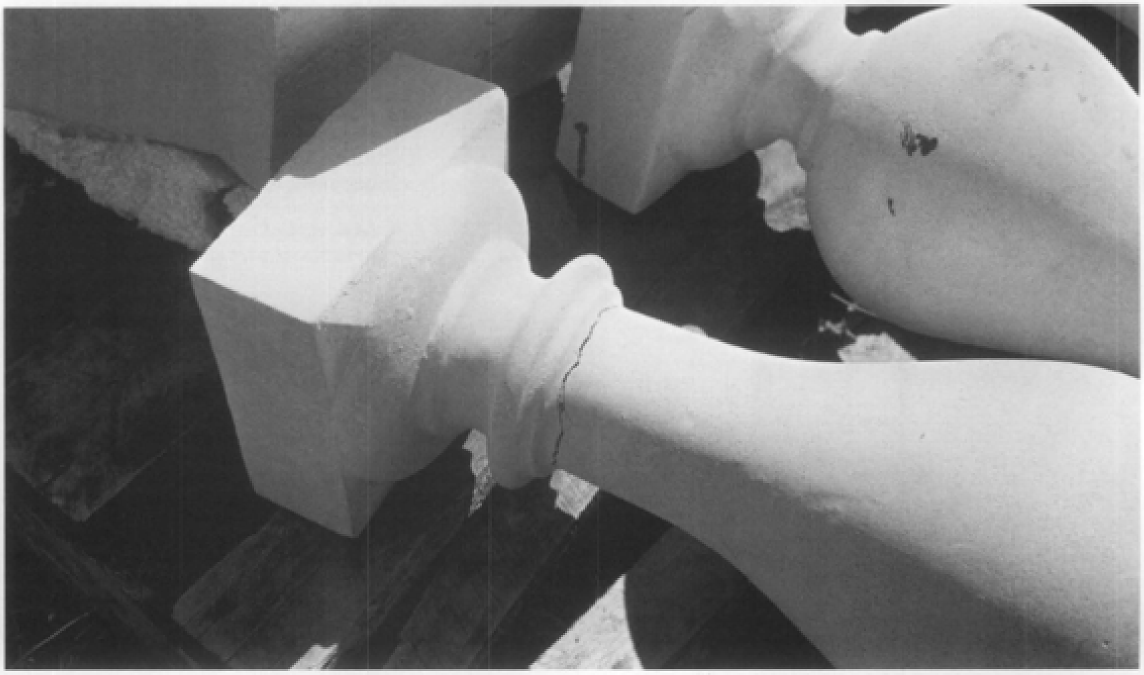


Figure 21. Surface cracking may reduce the durability of cast stone units. Cracking is often problematic on reinforced elements with thin "necks," such as balusters, unless curing is carefully controlled.

when end casting long items such as columns or railings, where it is difficult to vibrate bubbles away from the finish surface of the unit (Fig. 20).

Surface cracking or checking. Overly wet mixes and insufficient moisture during curing can result in surface cracking of large castings, such as columns. Such cracking dramatically reduces the durability of new cast stone. Small reinforced elements, such as balusters, also frequently crack at thin "necks" in the castings (Fig. 21).

Aggregate segregation. Cast stone formulations generally include a range of coarse aggregates (crushed stone) and fine aggregates (sand) (Fig. 22). When units are vibrated to assure compaction of the mix and liberate trapped air bubbles, coarse aggregates may begin to settle and separate from the paste of cement and sand. Aggregate segregation results in a visible concentration of coarse aggregate at one end of the casting. Segregation is more problematic when end casting long pieces, such as columns.

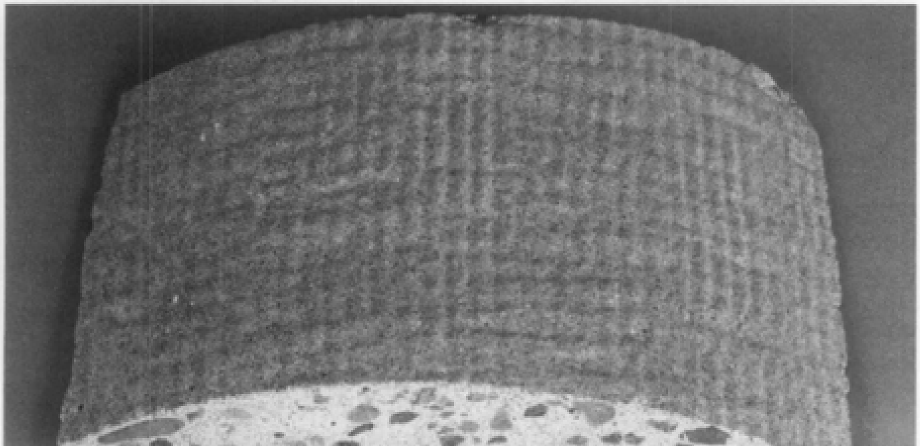


Figure 22. Most cast stone formulations use a mixture of coarse and fine aggregates. Coarse aggregates are not usually as visible from the surface, but may settle in end cast pieces.

Surface rippling or irregularity. Production molds for fabrication are often made of rubber mold facings encased in larger "mother molds" of plaster and wood (Fig. 23). Vibration can loosen the rubber facing from the outer mold and result in rippling or irregularities on the surface of the finished casting (Fig. 24). Even when rippling is not noticeable, irregularity caused by mold movement can make it difficult to line up surfaces of adjacent units when assembling cast stone installations.

Mold lines. Freestanding elements, such as columns, must be cast in two-part molds, which are separated to release the completed cast piece. If the mold parts do not join tightly, some leakage of cement paste will occur at the mold joint, resulting in a projecting line on the surface of the casting. This is generally tooled off before the casting completely cures. A mold line will be visible on the completed piece if the projecting material is not completely removed, or if the tooling at the mold line does not match the adjacent surface of the casting. Tooling at mold lines may also expose contrasting coarse aggregate beneath the surface of the casting.

Figure 23. Production molds (left) made of durable rubbers backed with wood and plaster supports are used to fabricate new cast stone. Production molds may be made from original elements which have been repaired with epoxies and plaster, or from new plaster mockups. (below)

Other Considerations for Replacement of Cast Stone

Several other considerations are worth noting when it is necessary to replace historic cast stone elements with matching new cast stone.

Reinforcement. The alkalinity of new concrete generally provides adequate protection to steel reinforcement. In exposed areas where deterioration due to rusting of reinforcement has previously been a problem, however, the use of stainless steel reinforcement is recommended.

Surface finishing. Post-fabrication surface tooling of new cast stone is not currently common. Sandblasting is typically used to remove the surface film of cement and expose the aggregate. For replacement units replicating historic cast stone pieces in highly visible locations, it is sometimes possible to make a mold of a sound or repaired existing piece to incorporate the original tooling in the casting process. If the historic unit is too deteriorated to use as a pattern, a plaster model may be made to replicate the damaged piece. This is tooled to replicate the desired surface treatment or appearance, and a production mold is then made from the plaster model.

Moist curing. Surface crystallization of soluble salts (efflorescence) during curing may lighten the surface of some precast units, especially those simulating darker stone. Some manufacturers use a series of wet/dry curing cycles or washing with acetic acid to remove soluble salts that might otherwise discolor finished surfaces. For most wet cast products, simple moist curing under a plastic cover is sufficient.

Appropriateness of Glass Fiber Reinforced Concrete as a Replacement Material

Light-Weight Alternative

Glass fiber reinforced concrete (GFRC) is more and more frequently encountered in building rehabilitation and is used to replicate deteriorated stone and cast stone, and even architectural terra cotta (Fig. 25). This is a relatively new material that uses short chopped strands of glass fiber to reinforce a matrix of sand and cement. GFRC has become a popular low-cost alternative to traditional precast concrete or stone masonry for some applications. Fabricators use a spray gun to spray the mortar-like mix into a mold of the shape desired. The resulting concrete unit, typically only ¾" thick, is quite rigid, but requires a metal frame or armature to secure it to the building substrate. The metal frame is joined to the GFRC unit with small "bonding pads" of GFRC.

GFRC has a dramatic advantage over traditional precast concrete where the weight of the installation is a concern, such as with cornices or window hoods. Many cast stone mixes can successfully be replicated with GFRC. Where it is used to simulate natural stone, GFRC, like cast stone, is most appropriate for simulation of fine-grained sandstones or limestones.

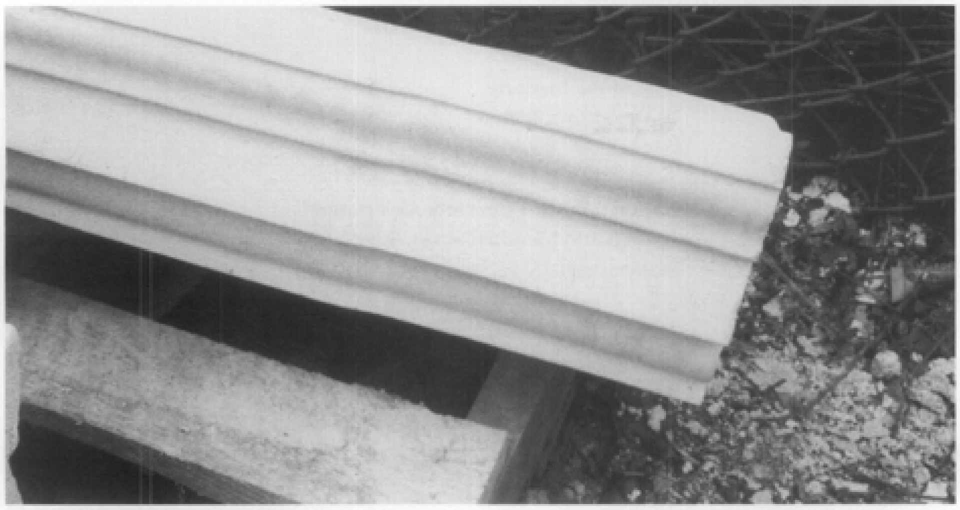


Figure 24. Separation of an interior rubber mold from a plaster mother mold during casting may result in rippling or irregularity of the completed casting.

Not for Use in Load Bearing Applications

Because the GFRC system is in effect a "skin," GFRC cannot be used for load bearing applications without provision of additional support. This makes it unsuitable for some tasks, such as replacement of individual ashlar units. It is also not appropriate for small freestanding elements, such as balusters, or for most columns, unless they are engaged to surrounding masonry or can be vertically seamed, which may significantly alter the historic appearance. GFRC units must also allow for expansion and contraction, and are generally separated by sealant joints, not by mortar. A sealant joint may be unacceptable for some historic applications; however, substitution of GFRC for cast stone may be appropriate when an entire assembly, such as a cornice, roof dormer, or window hood, requires replacement. Great care must be taken when detailing a GFRC replacement for existing cast stone.

Deterioration of GFRC

Because it is a relatively new material, the long term durability of GFRC is still untested. When GFRC was first introduced, some installations experienced deterioration caused by alkaline sensitivity of the glass fiber reinforcement. Alkali resistant glass is now used for GFRC manufacture. Even when the GFRC skin is well manufactured, however, the steel armature and bonding pad system used to mount the material is vulnerable to damage from leakage at sealant joints or small cracks in wash surfaces. The use of galvanized or stainless steel armatures, and stainless steel fasteners and bonding pad anchors is advisable.

Summary

Cast stone--a mixture of water, sand, coarse aggregate, and cementing agents--has proven over time to be an attractive and durable building material, when properly manufactured. It gained popularity in the 1860s and, by the early decades of the 20th century, became widely accepted as an economical substitute for natural stone. Unfortunately, much historic cast stone is unnecessarily replaced when it could easily be repaired and preserved *in situ*, or left untreated. Appropriate repair of damaged units can extend the life of any cast stone installation. Because of the necessity of matching both matrix color and aggregate size and ratio, conservation projects which involve repair or replication of cast stone should allow adequate lead time for the assembly of materials and the preparation of test samples. Understanding which conditions require repair, which warrant replacement, and which should be accepted as normal weathering is key to selecting the most appropriate approach to the protection and care of historic cast stone.

Figure 25. Glass Fiber Reinforced Concrete (GFRC) is sometimes used to replicate deteriorated elements of cast or fine grained natural stone. Because the GFRC element is a rigid, but relatively thin shell, it must be supported and attached with an interior framework of steel. The attachment hardware inside this GFRC cartouche (left) will not be visible when the unit is installed (armature visible at right). Photos: Towne House Restorations, Inc.

Selected Reading

Childe, H.L. *Manufacture and Uses of Concrete Products and Cast Stone,* London: Concrete Publications Limited, 1930.

Jester, Thomas C., ed., *Twentieth Century Building Materials,* New York, NY: McGraw-Hill, 1995.

Precast/Prestressed Concrete Institute, *Architectural Precast Concrete, 2nd ed.,* Chicago, Illinois: Precast/Prestressed Concrete Institute, 1989.

Whipple, Harvey, *Concrete Stone Manufacture,* Detroit: Concrete-Cement Age Publishing Company, 1918.

Helpful Organizations

Cast Stone Institute
10 West Kimball Street
Winder, GA 30680-2535

National Precast Concrete Association
10333 North Meridian Street, Suite 272
Indianapolis, IN 46290

Architectural Precast Association
P.O. Box 08669
Fort Myers, FL 33908-0669

Acknowledgements

Kay D. Weeks, Heritage Preservation Services, National Park Service (NPS), served as project director and general editor. The author wishes to thank Alan Barr of Towne House Restorations, Inc., Ron Moore of Western Building Restoration, architect Theo Prudon, and conservator David Wessell of the Architectural Resources Group for their assistance in the preparation and review of this brief. Chuck Fisher and Anne Grimmer, Technical Preservation Services, NPS, offered valuable comments during its development. MJM Studios provided access for photography of cast stone fabrication. Michael F. Lynch, Vice President, SPNEA, and Michael Devonshire, Principal, Jan Hird Pokorny Associates, generously lent images from the personal collections for the Brief.

This publication has been prepared pursuant to the National Historic Preservation Act, as amended, which directs the Secretary of the Interior to develop and make available information concerning historic properties. Comments about this publication should be directed to: Chuck Fisher, Technical Publications Program Manager, Technical Preservation Services, National Park Service, 1849 C Street, NW, NC-200, Washington, DC 20240. <www2.cr.nps.gov/tps>

ISSN: 0885-7016

September 2001