TECHNICAL BULLETIN 2

EXTERIOR STONE RESTORATION

INTRODUCTION

Each building is unique and every stone presents its own characteristics. Because stone restoration is such a broad topic, encompassing a variety of applications, the information offered in this Technical Bulletin is general in nature and should be adapted to suit the individual circumstances of the restoration project.

DESIGN CONSIDERATIONS

1. **Poor stone quality/suitability:** Improper or unsuitable use of a particular stone type. For example, limestone, due to its porous nature, should not be utilized at grade or in a location at which moisture could absorb (wick) upward from the base of the stone. In addition, de-icing salts used at those locations would also tend to wick into the limestone, thereby contributing to accelerated corrosion of embedded metal components, recrystallization of solubilized salts and potential spalling or exfoliation of stone surfaces.

2. **Improper bedding:** During installation, the bedding planes or layers of the individual stone should be oriented to lie perpendicular to the wall surface. Stone, when installed such that the bedding planes are parallel to the wall surface, will have a tendency to exfoliate whereby the layers separate and become dislodged from the remaining stone body.

3. **Improper repointing (mortar):** When tuckpointing, or during initial installation, the use of a mortar mix of higher compressive strength than the adjacent stone component will contribute to spalling of the stone's edges due to thermal expansion, structural movement (creep), etc.

4. **Improperly sized/placed expansion or control joints:** Control and/or expansion joints must be of sufficient size and quantity to compensate for anticipated thermal expansion within the wall assembly. Insufficient placement and/or sizing of these joints will contribute to cracking, bowing and displacement of the wall surface due to its inability to accommodate this movement. In addition, poorly maintained joint sealants would allow excessive water to enter the assembly, thereby contributing to further accelerated deterioration.

5. **Roof leaks:** Water enters the wall assembly at deteriorated or failed roof membranes, flashings, gutters or parapet walls, resulting in a continually damp wall surface and subsequent moisture-induced deterioration of wall components.

6. **Creep:** Structural steel framing members have a tendency to "shrink" (creep) thereby exerting a downward pressure on adjacent stone components. As a result, cracking and/or spalling of specific components can occur.

7. **Oxide jacking:** Corrosion of ferrous metal support elements results in an expanding cross sectional height of the steel component due to the formation of scale (rust). The pressure exerted by this scale formation is exerted on the surrounding stone surfaces and results in cracking, spalling and/or bulging of specific stone components. In addition, corrosion of ferrous metal anchors, wall ties, etc. could compromise the structural integrity of the wall assembly and, in some instances, allow for potential collapse or displacement of specific wall areas.

8. **Fire/heat:** The use of water to douse fires may result in discoloration of the stone surfaces as the relatively cold water comes in contact with the "hot" stone surfaces. In some instances, this temperature differential could contribute to delamination of the outer stone surface.

9. **Staining:** Unsightly surface discolorations, such as efflorescence, oxidation of metallic inclusions, or rundown deposits from copper components, are generally aesthetic considerations, but can also be harmful to the stone.

10. **Vegetation:** Organic growth, such as ivy, can cause damage through continuous dampness in stone surface and through root penetration into the stone surface.

APPLICATION CONSIDERATIONS/PROCEDURES

1. Patching

Generally this is an inexpensive method of repair. While this method can be cost effective, the lifespan of the repair may be less than alternative methods. In addition, several conditions may inhibit the use of this process. For example, patching repairs should not be completed on the nosings of steps. Areas of severe exposure, such as window sills, units that are exposed on three sides, projecting ornamental details or areas that are eye level or highly visible, should be carefully assessed prior to implementing repairs.

A. Preparation

- Remove all defective material to sound substrate by using a diamond blade saw to cut out the circumference of the defective area on a small dovetail angle. This process constitutes cutting into solid stone and serves to secure the repair mortar in place. The recommended minimum depth of repair is typically 2 inches and is accomplished by using a small chipping hammer to remove the defective material until sound stone is reached.

- Using a small grinder and/or a sawtoothed or bull-point chisel, roughen the back of the repair area to produce a mechanical key. Avoid vibrating the stone. Excessive vibration could destroy the bond at the existing mortar joint between the defective stone and adjacent stones, or may cause small fractures in the stone, allowing moisture to enter.

- Corroded steel must be cleaned to white metal by abrasive means and covered with a corrosion-inhibiting coating. Anchors that are severely corroded may need to be replaced. Sandblasting the repair area is preferred but not always possible.

B. Anchorage

- There are many options and devices for anchoring stonework. Selecting an anchoring method and system is dependent on the following factors: the necessity of the repaired stone to be fastened to the substrate, the installation of anchors to hold the repair material, and whether the repair is structural or aesthetic. Once the parameters of the repair are considered, the proper anchoring system can be determined.

- When attaching the repaired stone to the substrate, a hole, 1/8 inch larger than the stainless steel threaded rod being used, is drilled through the stone and into the backup material. Brush and blow out the hole to remove all dust and debris caused by drilling. Depending upon the spacing between the back of the stone and the substrate (cavity), a screen tube may be required to prevent the epoxy from leaking through the cavity space. Fill the screen tube with epoxy and insert it into the hole. Insert the stainless steel threaded rod into the epoxy-filled screen tube by pushing and turning slowly.
- There are many methods to conduct repairs that require installation of anchors to hold the repair material. The threaded stainless steel rod and epoxy method outlined above may be used. The insertion of lead shields with brass screws (wire is wrapped around the head of the screws to form a type of mesh system) is also effective, or new plastic and fiberglass rods resembling a reinforced rod can be inserted to eliminate rusting potential. Note: Regardless of whether the repair is structural or aesthetic, it is imperative, as in all repairs, to choose a non-corrosive anchor to be placed a minimum depth of 1 1/2 inch below the surface.

C. Cementitious material

- When choosing a cementitious patching material, consideration must be given to the stone that requires repair. The type of stone, vapor permeability (porosity), and density (thermal movement) are the most important considerations to ensure longevity of the repair. Other stone conditions may include tooling on the stone face and exposed or weathered aggregate so as to approximate the surrounding surface texture.
- The second concern is the color of the repair material. The patching material manufacturer uses representative samples of stone material from the building to make the color match. The stone samples should be properly labeled for identification. The patching material samples must be properly cured to determine the ultimate color of the repair material.
- Certain repair materials may require tooling the face of the patch prior to its initial cure. Others may require waiting until the material has cured. Follow the manufacturer's specifications regarding proper mixing, bonding, application and curing of the repair material.

D. Bonding materials

- Latex is the predominant bonding material used for marble repair, while epoxy bonding agents are typically utilized for granite. Some bonding agents require surface drying before application of the repair material while other manufacturers suggest bonding agents remain wet when the repair material is applied. Consult each manufacturer's specifications regarding the proper use of the chosen bonding agent.
- The repair material itself may, at times, be utilized as a bonding agent. Make a slurry of the material and brush it onto the stone surface to be patched. The repair material can then be applied to the wet slurry.

E. Miscellaneous

- Avoid drastic temperature extremes to ensure a durable repair. To prevent cracking (resulting from sudden drying of the material), shade the repair area from direct sunlight when possible. Wet burlap or a similar material may also be used to prevent the repair material from drying too quickly by exposing the repair to continual moisture.
- To create a weathered look to match an existing structure, spray a small amount of retarder on the repair surface before it cures. Wash it off the following day.
- To prevent erosion of the repair material, select a material of similar density to the stone to be repaired.

2. Dutchman (grafting)

In lieu of patching, defective or damaged areas of stone may be repaired by grafting. This method, generally referred to as a "Dutchman" repair, includes the installation of a matching or similar stone component into the deteriorated section.

A. Preparation

- Remove the defective area of stone by cutting a square area slightly larger than the defective area. The repair opening should be wider in the back than in the front, at a depth of 2-3 inches so as to provide a mechanical "key." Dutchman can be obtained from stones previously removed from the building and/or stones cut and removed from less visible areas of the building, such as the parapet. New stones may also be utilized, however, the color and texture may contrast with the existing adjacent surfaces
- After being cut to size, the Dutchman should be set into the opening so as not to exceed 1/16- inch spacing between the Dutchman and the opening, ensuring a proper fit.

B. Anchorage (armatures)

- Use stainless steel threaded rods and epoxy as the anchoring system.

C. Installation

- Drill a hole in the backup and in the backside of the Dutchman so as to align the holes. Install epoxy into both holes and insert stainless steel threaded rod into the backup hole. Place Dutchman so that all holes align. The resulting joint cavity (approximately 1/2 inch deep by 1/16 inch wide) between the Dutchman and the stone can be filled with a mixture of cement and stone dust. New mortar should be designed to be of lower compressive strength than the surrounding stone. Where the repair adjoins an existing mortar joint, place new Dutchman so as to maintain existing joint width.
- Based on conditions, the Dutchman repair method outlined above may not be suitable. At locations where this repair is not applicable, other similar repair techniques that utilize springloaded anchors and/or drop down anchors may be required. It should be noted that this technique might be more labor intensive and require a higher skill level.

3. Surface scaling

The removal of loose, eroded or deteriorated layers of stone from the exterior surface to a level at which sound substrate is achieved.

- Requires the use of small hand tools and sculpting tools and is a relatively moderate-cost repair. However, a high skill level is required to achieve desirable results.

- Typically occurs at exposed, unprotected parapets, projecting belt courses, water tables, etc. and at areas that require, but lack, proper flashings and/or rain leaders.
- Upon completion of scaling repairs, proper flashing assemblies, rain gutters, coping, etc., which may be advisable, should be provided to inhibit further erosion and deterioration.

4. Consolidants

Liquid consolidating compounds designed to restore lost compressive strength and structural integrity may be applied to severely deteriorated weathered stone surfaces. Consolidants are intended to increase density and reduce porosity of the stone, however, the process is irreversible.

- Potential exists for delamination between the treated stone portion and untreated backup portion at the depth of penetration level due to differential densities.
- Due to relatively new technology related to the repair process, it is difficult to establish the anticipated service life of this repair method. At this time, opinion is split regarding its viability as a long-term repair technique.

5. Stone replacement

The removal and replacement of a damaged, deteriorated or defective stone component.

- Saw cut mortar joints around the perimeter of deteriorated/damaged stone to be removed to allow for its removal. For ease of removal, it may be necessary or desirable to saw cut or chisel the damaged unit into smaller sections, however, care should be taken to avoid overcutting or damage to adjacent stone that will remain.
- Remove stone using handheld electric or pneumatic hammers and chisels. Be careful to avoid excess vibration that may dislodge adjacent components. Note: Shoring or pinning of the surrounding stones may be required prior to removal to prevent collapse or displacement.
- Install new stone components of same type and similar configuration as surrounding stone units. New component should be placed so that its graining (bedding) is oriented perpendicular to the wall surface, to inhibit exfoliation. Note: Mismatching of replacement stone with the existing components should be avoided due to potential compatibility concerns (i.e. limestone and sandstone are geological mismatches). The installation of these two stones oriented adjacent to each other will result in accelerated deterioration of both components, whereby each stone contributes to the deterioration (consumption) of the other.
- Artificial or simluated weathering or aging of replacement units may be desirable to blend with surrounding surfaces. A light abrasive blasting or a high-pressure water wash with an injected abrasive generally accomplishes this.

6. Epoxy pinning (assumes removal of a damaged unit or Dutchman veneer from wall assembly)

Repair and re-attachment of a cracked or broken stone component by mechanical anchorage that consists of non-corrosive dowels and epoxy adhesive.

- Remove defective stone or damaged section from the wall assembly.
- Clean area in and around cracks and/or edges of broken stone sections.
- Piece components together to reestablish its original configuration.
- If possible, drill through stone component from sides that will be hidden when reset by adjacent stones. Install stainless steel rods embedded in epoxy. Apply epoxy to broken surfaces prior to installation of epoxy pins to provide for full embedment and attachment of separated pieces.
- If sides of unit will remain visible following installation, perform the following:
- Drill holes in each separate section so that holes align.
- Apply epoxy into holes and insert stainless steel threaded rod reinforcement into one side. Ensure full engagement of threads in rod by twisting rod during insertion. Slide other stone fragment onto the stainless steel rod.
- Again, apply epoxy to cracked surfaces prior to re-attachment to provide for full embedment and adhesion.
- Clean all epoxy residue from exposed stone surfaces. If possible, patch remaining crack with a suitable repair mortar to restore the original aesthetic quality of the component.
- Re-set stone as required.

7. Epoxy injection (repair in place)

Reattachment of cracked, delaminated or broken stone units by forcing epoxy adhesive under pressure into the fissures and material substrate. This method is also utilized to fill cracks or voids in stone components to restore structural capacity and/or inhibit water infiltration.

A. High-pressure injection

- Drill holes into stone at an angle along each side of crack to be injected to extend into and through the crack.
- Place injection ports over holes and attach to the stone surface. Apply appropriate epoxy sealer over exposed crack surfaces and around base of ports to contain the epoxy compound within the void.
- Inject epoxy into the lower-most port until epoxy becomes visible at the next port in line. Cease pumping epoxy at the lower port and resume at the second port. Repeat process until all ports have been injected.
- Allow epoxy to cure properly and remove the epoxy crack sealer and injection ports from the exterior crack surface. Note: Generally an abrasive process (grinding) may be required to remove epoxy and/or sealer residue from the repaired crack surfaces. Additional patching and other such cosmetic repairs may be required to blend the repair area with the adjacent stone surfaces.

B. Low-pressure injection

- Place ports directly over the crack surface (generally no drilling into the surface is required).
- Apply a silicone sealant over the crack and around base of ports to contain the injection epoxy.
- Install low-pressure, spring-loaded manual injection devices at each port and commence injection at all ports simultaneously. The epoxy will permeate the crack through capillary action.
- If necessary, re-fill individual injectors that have emptied and reinstall onto the injection ports. Repeat process

TECHNIQUE	SKILL LEVEL REQUIRED	RELATIVE COST	SERVICE LIFE
PATCHING	Moderate	Moderate	Short/Moderate
GRAFTING	Very High	Moderate	High
SCALING	High	Moderate	Moderate
REPLACEMENT	High	High	High
EPOXY INJECTION/ PINNING	Very High	High	High

until epoxy compound is no longer acceptable.

- Peel silicone crack sealer for the surface and remove port bases. Scrape remaining residue from the crack surface using a heat gun and handheld scrapers.
- As with high-pressure injection, some surface cosmetic repairs may be required.

8. General
Refer to manufacturer's data sheets and material safety data sheets for any necessary precautions regarding exposure to all materials. Clean up the site daily and follow government regulations regarding disposal of excess materials and empty containers.

DEFINITIONS

GEOLOGICAL STONE TYPES

Igneous rock: Formed by the solidification of liquid molten rock (magna) at or within the earth's crust.

Metamorphic rock: Formed by the transformation of other rock types that results from pressure and temperature extremes within the earth's crust.

Sedimentary rock: Stone formed at or near the earth's surface that consists of organic sediment, inorganic remains of organisms (shells, skeletons, etc.) and/or from the weathering of other rock types.

BUILDING STONE

Granite: Hard, igneous rock formation exhibiting a medium to coarse crystalline texture primarily consisting of quartand feldspar. Generally a durable building material; however, it is difficult to work with due to its density (hardness).

Marble: Metamorphic rock formation. Typically formed from crystallized limestone, which can vary considerably in texture from granular to smooth. It is a generally desirable material for sculptures and architecture due to high-gloss finishes that can be achieved by polishing its surface.

Sandstone: Sedimentary stone formed from quartz sands bonded together by clay, siliceous cement, and/or calcium carbonate. Appearance is homogeneous, exhibiting a medium to fine grain.

Limestone: Sedimentary stone formed by accumulation of organic remains (shells, coral, etc.) that consists mainly of calcium carbonate. Extensively used as a building material.

NATURAL CAUSES

Water: Eroding of exposed stone surfaces over time as a result of repeated water flow.

Pollution: Surface degradation that results from acidic pollutants such as acid rain, bird droppings, etc.

Freeze/Thaw deterioration: Surface spalling and/or cracking of a stone component that results from the freeze-induced expansion of liquid water trapped within cracks or voids.

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