PROGRAM COMMENT FOR DEPARTMENT OF DEFENSE
REHABILITATION TREATMENT MEASURES

APPENDIX 5

SECTION 04400.01 **IDENTIFYING MASONRY TYPES AND FAILURES**

PART 1 – GENERAL

1.01 DESCRIPTION

A. This specification provides guidance for determining stone types and their typical failures.

B. This specification has been developed for use on historic properties (defined as any district, site, building, structure, or object that is listed in or eligible for listing in the National Register of Historic Places) and provides an overview of accepted practices.

C. All work described herein and related work must conform to the Secretary of the Interior's Standards for the Treatment of Historic Properties.

D. The Contractor shall provide all labor, materials, equipment, and operations required to complete the rehabilitation work indicated herein.

E. All work described herein and related work must have the approval of a Cultural Resources Manager, Conservator, Historic Architect, or other professional who meets the standards outlined in the Secretary of the Interior's Standards – Professional Qualifications Standards pursuant to 36 CFR 61. Such person is referred to in this document as the ***Architect***.

F. Site-specific specifications, when appropriate, will be provided by the Architect.

1.02 SECTION INCLUDES

A. Stone identification

B. Identification of deterioration patterns and failure modes

1.03 RELATED SECTIONS

A. Section 04100 – Historic Mortar

B. Section 04500 – Masonry Restoration (pending issuance)

C. Section 04510 – Masonry Cleaning (pending issuance)

1.04 DEFINITIONS

A. Igneous Rock. Rock formed under conditions of intense heat or produced by the solidification of volcanic magma on or below the Earth's surface.

B. Metamorphic Rock. Preexisting igneous rock and sedimentary rock, and other metamorphic rock, that has undergone a transformation in physical form, appearance, or character, to form a new stone with properties distinct from the original stone. Metamorphic rock is formed through pressure, heat, or both within the Earth's crust.

C. Sedimentary Rock. Rock that is formed from material, including debris of organic origin, deposited as sediment by water, wind, or ice, and then consolidated by pressure.

1.05 REFERENCES

A. *The Secretary of the Interior's Standards for the Treatment of Historic Properties with Guidelines for Preserving, Rehabilitating, Restoring & Reconstructing Historic Buildings* available at the National Park Service (NPS) website at <http://www.nps.gov/history/hps/tps/standards_guidelines.htm>.

B. See General Services Administration, Historic Preservation Technical Procedures Standards for Marble, Limestone, Granite and Sandstone.

C. *Conservation of Historic Stone Buildings and Monuments.* Report of the Committee on Conservation of Historic Stone Buildings and Monuments. Washington: National Academy Press, 1982.

D. Weaver, Martin E. *Conserving Buildings: A Manual of Techniques and Materials.* Revised edition. New York: John Wiley & Sons and the Preservation Press, 1997.

E. Wheeler, George S., et al. Stone Masonry. *Historic Building Facades: The Manual for Maintenance and Rehabilitation*. William Foulks, editor. Prepared for the New York Landmarks Conservancy. New York: John Wiley & Sons and the Preservation Press, 1997.

F. ASTM Standards as follows:

1. C97 Test Methods for Absorption and Bulk Specific Gravity of Dimension Stone

2. C99 Test Method for Modulus of Rupture of Dimension Stone

3. C119 Terminology Relating to Dimension Stone

4. C120 Test Methods for Flexure Testing of Slate (Modulus of Rupture, Modulus of Elasticity)

5. C121 Test Method for Water Absorption of Slate

6. C170 Test Method for Compressive Strength of Dimension Stone

7. C217 Test Method for Weather Resistance of Slate

8. C241 Test Method for Abrasion Resistance of Stone Subjected to Foot Traffic

9. C503 Specification for Marble Dimension Stone

10. C568 Specification for Limestone Dimension Stone

11. C615 Specification for Granite Dimension Stone

12. C616 Specification for Quartz-Based Dimension Stone

13. C629 Specification for Slate Dimension Stone

14. C880 Test Method for Flexural Strength of Dimension Stone

15. C1201 Test Method for Structural Performance of Exterior Dimension Stone Cladding Systems by Uniform Static Air Pressure Difference

16. C1242 Guide for Design, Selection, and Installation of Exterior Dimension Stone Anchors and Anchoring Systems

17. C1352 Test Method for Flexural Modulus of Elasticity of Dimension Stone

18. C1353 Test Method for Using the Taber Abraser for Abrasion Resistance of Dimension Stone Subjected to Foot Traffic

G. *The American Standard Specifications for Interior Marble* and *Dimensional Stone—Design Manual IV* as published by the Marble Institute of America.

H. *Recommended Practices* as published by The Building Stone Institute, Elgin, Illinois.

I. *ILI Handbook – 21st edition* as published by the Indiana Limestone Institute of America.

1.06 SUBMITTALS

A. Samples: Stone and mortar samples shall be submitted as requested by the Architect. The Contractor shall furnish for the Architect's approval not less than five stone samples, showing variations in color, texture, and finish.

B. Product Literature: The Contractor shall submit stone supplier's literature regarding the source of the selected building stone, and any available testing information regarding the material's physical properties, such as compressive strength, absorption, and resistance to abrasion, demonstrating conformance to the referenced standards.

1.07 QUALITY ASSURANCE

A. Work Experience: The selected Contractor shall have a demonstrated experience in masonry conservation with emphasis on Architectural Stone, ideally a minimum of 10 years. The Contractor shall demonstrate a working knowledge of *The Secretary of the Interior's Standards for the Treatment of Historic Properties with Guidelines for Preserving, Rehabilitating, Restoring & Reconstructing Historic Buildings*, including experience in historic masonry conservation.

B. The Contractor shall not change sources or manufacturers of mortar or stone materials during the course of the work unless approved by the Architect.

C. Warranty: The Contractor shall provide a warranty in writing against defects in material and installation for a period of five (5) years.

1.08 DELIVERY, STORAGE, AND HANDLING (as applied to products and materials)

The Contractor shall:

A. Transport and handle stone units in such a manner as to prevent chipping and breakage; locate storage piles, stacks, or bins to avoid and protect material from heavy and unnecessary traffic; and store stone slabs on pallets on edge.

B. Coordinate stone deliveries with the construction schedule and sequence. Stone materials shall be delivered in an order consistent with the order of installation at the project site to avoid unnecessary handling of materials.

C. Protect stones from the ground and weather and keep them free from exposure to contaminants such as mud, dust, or materials that could cause staining.

D. Deliver materials to the site in original packaging, unopened, with manufacturer's name and product identification thereon. Cementitious materials shall be protected from contamination by foreign matter and deterioration by moisture or temperature. Contaminated or deteriorated material shall not be used. Products stored longer than six months shall not be used.

E. Store masonry materials in such a manner as not to interfere with the operation and daily maintenance of the facility. Proposed storage locations shall be approved by the Owner prior to the delivery of materials. Masonry materials shall not be stored inside the building.

1.09 PROJECT / SITE CONDITIONS

A. Stone repairs shall be executed only when the air and surface temperatures are 40 degrees F and rising or less than 90 degrees F and falling. Minimum temperature for masonry work shall be 50 degrees F and above for at least 2 hours after completion and above freezing for at least 24 hours after completion. Work shall not commence when rain, snow, or below-freezing temperatures are expected within the next 24 hours. All surfaces shall be free of standing water, frost, and ice.

B. The Contractor shall cover the top of the wall with strong waterproof membrane at the end of each day or shutdown. The Contractor shall cover partially completed walls when work is not in progress. Covering shall extend a minimum of 24 inches on each side of openings and be fastened securely.

C. The Contractor is responsible for protecting existing adjacent materials and surfaces during the execution of the work and shall provide all necessary protection and follow all necessary work procedures to avoid damage to existing material assemblies not a part of the work in this Section.

D. The Contractor shall provide visible barriers and / or warning tape around the perimeter of the work area for visitor protection. Nearby vehicles and adjacent structures and foliage shall be protected from damage during the course of the work.

E. The Contractor shall coordinate stone repairs with the other trades involved in exterior and interior restoration work, including but not limited to masonry cleaning, sealing, and painting.

PART 2 – PRODUCTS

2.01 STONE TYPES AND DEFINITIONS

A. Gneiss. A metamorphic rock with a banded or coarsely foliated structure, often commercially referred to as granite. Composed essentially of silicate minerals with interlocking and visibly granular texture in which the foliation is primarily the result of alternating layers, regular or irregular, of contrasting mineralogic composition.

B. Granite. Commercial granite includes almost all rocks of igneous origin. True granites are a very hard, crystalline, igneous rock, gray to pink in color, composed of alkali feldspar, quartz, and lesser amounts of dark ferromagnesium materials and can include minerals such as micas and hornblende. Geologically, granite is distinguished form other rocks that it resembles on the basis of the percentages of quartz, potassium feldspar, and plagioclase feldspar. Commercially, this distinction is not utilized. Black fined-grained igneous rocks, such as basalt or traprock (diabase), are called “black granite.” Although similar to true granites in structure and texture, “black granites” and other dark “granites” are composed of different minerals.

C. Greenstone. Greenstone is defined by ASTM as a metamorphic rock principally containing chlorite, epidote, or actinolite.

D. Limestone. ASTM defines limestone as a sedimentary rock composed primarily of calcite (calcium carbonate) or dolomite (calcium magnesium carbonate). The texture of limestone varies greatly, from uniform grain size and color to “cemented-shell mash.” Some limestones have varying amounts of other material, such as quartz sand or clay mixed in with the carbonate minerals. Most limestones are formed of shells or shell fragments, although many commercial limestones, including oolitic and very fine-grained and compact varieties are chemical precipitates. The varieties of limestone used as dimensional stone are usually well consolidated and exhibit a minimum of graining or bedding direction. Recrystallized limestones and compact, dense, relatively pure microcrystalline varieties (or partially metamorphosed limestone) that are capable of taking a polish are commercially known as marbles.

1. Calcarenite: Calcarenite is composed of sand-sized grains of calcite, usually in the form of tiny fossils, shell aggregates and fossil debris. Some calcarenites contain oolites. When oolites are present in sufficient quantity, the stone is called oolitic limestone. Oolitic limestone is a subcategory of calcarenite.

2. Coquina: Coquina consists of raw, unaltered shell fragments, often quite large, loosely cemented by calcite. It is generally very coarse and porous, frequently consisting of oyster shells and fragments.

3. Dolomite: Dolomite is a sedimentary carbonate rock composed of calcium and magnesium carbonate. Limestones that contain not more than 5 percent magnesium carbonate may be termed calcite limestone; those that contain from 5 percent to 40 percent magnesium carbonate are called magnesium limestone; and those that contain in excess of 40 percent as dolomite.

4. Microcrystalline Limestone: A limestone structure of crystals too small to be seen without magnification.

5. Oolitic Limestone: A calcite cemented calcareous stone composed of shell fragments, practically non-crystalline in character. Generally without cleavage, and

extremely uniform in composition and texture, oolitic limestone adjusts to temperature changes. Oolitic limestone, a popular building stone in the U.S., Britain, and France, consists of cemented round grains of calcite or aragonite generally under 2 millimeters in diameter.

6. Travertine: Travertine is a variety of limestone deposited from solution in ground-waters and surface waters. Hard and compact varieties, such as that from Rome, are quarried for building stone. Generally it is characterized by a variegated gray and white or buff color with irregularly shaped pores distributed throughout the ground-mass.

E. Marble. According to ASTM, commercial marble includes all crystalline rocks composed predominantly of calcite, dolomite, or serpentine and capable of taking a high polish. Geologically, marble is a metamorphic (recrystallized) limestone composed predominately of crystalline grains of calcite or dolomite or both, having interlocking or mosaic texture. As a result, commercial marble includes many crystalline limestones, travertine, and serpentine, a metamorphosed ultramafic rock. The color and pattern associated with marble are due to striations of accessory minerals, such as talc, chlorite, amphiboles, and pyroxenes, as well as iron oxides, hydroxides, sulfides, and graphite.

F. Quartzite. Quartzite is a metamorphosed sandstone consisting almost entirely of quartz. It is a locally used stone found in South Dakota and Wisconsin.

G. Sandstone. ASTM defines sandstone as a "consolidated sand in which the grains are composed chiefly of quartz and feldspar, of fragmental texture, and with various interstitial cementing materials, including silica, iron oxides, calcite, or clay." This sedimentary rock is durable, has a very high crushing and tensile strength and a wide range of colors or textures. Commercially used sandstone is a clastic sediment consisting almost entirely of quartz grains, 1/16 to 2 millimeters in diameter, with various types of cementing material. Enough voids generally remain in the rock to give it considerable permeability and porosity.

1. Brownstone: Deep brown, red, purple, and pink sandstones are commonly called brownstone. Brownstone is an arkosic sandstone that is rich in feldspar grains and was quarried in the Triassic basins of the eastern states. Popular from the 1840s through the early twentieth century, brownstone was used on urban row houses, commercial buildings, and churches.

H. Schist. A foliated metamorphic rock (recrystallized) characterized by thin foliae that are composed predominantly of minerals of thin platy or prismatic habits and whose long dimensions are oriented in approximately parallel positions along the planes of foliation. Because of this foliated structure, schists split readily along these planes and so possess a pronounced rock cleavage. The more common schists are composed of the micas and other mica-like minerals (such as chlorite) and generally contain subordinate quartz and/or feldspar or comparatively fine-grained texture; all graduations exist between schist and gneiss (coarse is foliated feldspathic rocks).

I. Shale. Shale is a dark fine-grained sedimentary rock composed of layers of compressed clay, silt, or mud that has been subjected to high pressure until it has hardened rock-like.

J. Slate. ASTM requires a slate to possess an excellent parallel cleavage that allows the rock to be split with relative ease into thin slabs. Slate is a fine-grained metamorphic rock derived from argillaceous sediments (clay and shales) consisting of extremely fine-grained quarts, mica and other platy minerals. The color of slate is generally determined by the oxidation state of the iron or the presence of graphite or pyrite.

K. Traprock. is a microcrystalline volcanic or dike rock that consists primarily of pyroxene and a calcic plagioclase, known for its stark black color. Commercially, traprock includes basalt, gabbro, diorite, and andesite.

2.02 CHARACTERISTICS

A. Granite: Granite is one of the most durable stones used for artistic and architectural applications. Compared to calcareous sandstones, marble and limestone, granite is not an acid soluble stone and is much more resistant to the effects of acidic solutions, rainwater, or cleansing agents. In general, igneous building stones, such as granite, have a more inert composition; show much lower rates of deterioration; have lower water absorption, and are harder than marbles, limestones, and sandstones.

B. Limestone: Limestone is a soft rock and is easily scratched. It will effervesce readily in any common acid. Limestone may vary greatly in texture and porosity from coquina, which is a matrix of oyster shells loosely cemented by calcite, to oolitic limestones and microcrystalline limestone whose structures are so fine that they can be seen only under magnifications. Limestone coloration is generally a consistent pure white or off-white. Many varieties do not take a polish well, so that the surface is typically a matte finish, no-gloss surface. Limestone that does take a polish is sometimes commercially called marble. Limestones, like marble and other calcareous stones, are referred to as acid sensitive. Calcareous stones are readily dissolved in acid, therefore acidic products should not be used on limestones and marbles.

C. Marble: Fully metamorphosed marble (not to be confused with trade marbles that are actually limestones) is an extremely hard stone composed of calcite. The stone has a very tight crystalline structure and small but definite porosity. Marble can take a very high polish. The limited porosity of marble, especially polished marble, makes it less vulnerable to the leaching effects of water. Calcium carbonate, however, of which marble is composed is highly susceptible to attack by acidic agents. Marble is readily dissolved by acids, even very dilute acids, however the actual results of acidic exposure will vary with the nature of the acid. Chlorides, nitrates, sulfates, and other chemical compounds react differently with marble and produce various by-products, which have a wide range of solubility and impact on the durability of marble. For this reason, it is always important to determine the exact type of pollutants causing marble deterioration. Marble can be of two types, one composed of calcite and the other of dolomite. Dolomitic marble is much more resistant to acid attack than calcitic marble. The color of marble ranges from brilliant white of calcite to black, including blue-gray, red, yellow, and green, depending upon the mineral composition.

D. Sandstone: Sandstone is very porous and is easily penetrated by water. The stone weathers best when its end-grain faces the weather (naturally bedded). Face-bedded stone is subject to greater deterioration. Water damages a face-bedded stone by spalling or flaking off entire sheets. The stone is also highly subject to deterioration through freeze-thaw cycles, which can cause layers to split off. During the nineteenth century, the grain was often placed parallel to the weather side (face-bedded) for aesthetic reasons, especially around doorways. Sandstone can contain a variety of minerals, which determine the stone's color. The mineral makeup can also make the stone susceptible to some chemicals.

2.03 CONSTRUCTION TERMINOLOGY/METHODS

A. Ashlar/Ashlar Masonry: Ashlar masonry refers to stone that has a flat-faced surface that is generally square or rectangular, and has sawed or dressed beds and joints. The rectangular blocks include a finished or rock-faced surface, contrasted with cut blocks that are accurately sized and surface tooled. Ashlar masonry is comprised of rectangular blocks of stone or equivalent, generally larger in size than a brick.

B. Course: A layer of masonry units, bonded with mortar, that runs horizontally in a wall or much less commonly, that is curved over an arch.

C. Coursed Ashlar/Coursed Masonry: Stone masonry in which the stones within each course are identical in height, although the courses themselves need not be the same height.

D. Dimension Stone: Natural stone quarried for the purpose of obtaining blocks or slabs that meet specifications as to size (width, length, and thickness) and shape, color, grain texture and pattern, and surface finish. Durability (essentially based on mineral composition and hardness and past performance), strength, and the ability of the stone to take a polish are other important selection criteria. Although a variety of igneous, metamorphic, and sedimentary rocks are used as dimension stone, the principal rock types are granite, limestone, marble, sandstone, and slate.

E. Dressed/Hand Dressed: The cutting of rough chunks of stone by hand to create a square or rectangular shape. A stone that is sold as dressed stone generally refers to stone ready for installation.

F. Dry-Laid Stone/Drystone Masonry: Stonework constructed stone-upon-stone, without mortar, using unquarried native stone collected locally; also referred to as dry wall. The stones are tightly fitted and stacked with precision to form a strong wall. This method was utilized in wall construction for walls and foundations of buildings and structures through the first quarter of the nineteenth century.

G. Dutchman: A small, matching piece of stone that is cut, finished, and attached with the tightest possible joint to repair or replace a missing or damaged area.

H. Rubble/Rubble Masonry: Masonry construction in which stones of random size (sometimes roughly dressed) are used.

I. Rusticated Stone: Any stone masonry having strongly emphasized recessed joints; the exposed face of the masonry may be smooth or roughly textured. The border of each masonry block may be beveled on all four sides, only at the top and bottom, or on adjacent sides.

J. Veneer Stone: Any stone used as a decorative facing material that is not meant to be load bearing. A non-load-bearing stone wall that is securely anchored to the back-up wall.

K. Wythe: A masonry wall, one stone or brick thick, that either faces a back-up or is a back-up wall and secured to its neighboring wythes by bond stone or grout; or forms either half of a cavity wall, and is attached to the other half by metal ties.

2.04 MORTAR FOR HISTORIC MASONRY (see Sections 04100.02 and 04500.02)

PART 3 – EXECUTION

3.01 GENERAL

A. Stone masonry shall use techniques, methods and materials as similar as possible to those of the original. Work should be sequenced not only to assure the stability of the structure and protection of personnel during the work, but also to address a sensible order of construction to integrate new work with existing work.

B. The Contractor shall coordinate stone work with the other trades involved in exterior and interior restoration work including, but not limited to, masonry cleaning, sealants, and painting.

C. Masonry cleaning shall be completed prior to beginning repair or replacement work.

3.02 CONDITIONS ASSESSMENT

The Contractor shall:

A. Identify each type of stone.

B. Examine the overall surface condition and appearance.

1. Note presence of staining:

   a. Nature and color of staining

   b. Extent and location of staining or crusting from oxidations

2. Inspect structural soundness of the stone. Note extent and location of:

   a. Cracks

   b. Settling

   c. Block Movement

   d. Pointing failure

   e. Repairs

   f. Moisture

3. Examine condition of mortar joints:

   a. Flaking

   b. Powdering

   c. Leaking

   d. Cracking and Distortion

4. Note nature, location, and condition of any surface coatings:

    a. Pigment residue

    b. Partial erosion

    c. Cracks and crazing of coating

    d. Cloudiness

    e. Gilding

    f. Flaking or peeling of coatings

    g. Bubbles or blisters in coating

5. Note location and condition of areas where water collects or pools:

    a. Standing water

    b. Streaking

    c. Pockets or perforations

    d. Areas of biological growth

6. Note any loss of finish surface as evidenced by flaking or spalling; its extent, and location:

    a. Peeling and flaking usually follow uncorrected efflorescence or sub-florescence and represent a more advanced stage of failure.

    b. Rust or corrosion may be evident in areas left unprotected as a result of coating loss through flaking.

    c. Is the flaking or peeling localized or general in nature?

7. Look for areas with signs of erosion and/or wear and note the nature and location:

    a. Distinguish between erosion caused by environmental factors and normal exposure, versus that caused by human factors, such as touching or vandalism.

    b. Carefully monitor and record all noted areas of erosion and wear. Use information gathered in planning for future stone maintenance.

8. Note presence, location, and type of graffiti.

9. Identify structural and/or mechanical problems and examine surfaces for evidence of movement, cracks, and breaks in the surface:

    a. Hairline cracks/crevices. Active or inactive?

b. Structural Cracks. Active or inactive? Assess whether monitoring is needed.

c. Broken and/or missing pieces

d. Damaged or shifting at joints

e. Corrosion jacking from embedded metals

3.03 GRANITE PROBLEMS AND DETERIORATION

A. Weathering: Deterioration resulting from the mechanical and chemical action of wind, rain, snow, thermal change, and atmospheric pollutants. Of all the commonly used building stones, granite is perhaps the most resistant to the action of the elements. Its hardness resists abrasion by wind and its chemical composition is resistant to the acid rain that destroys calcareous stones. The chemical composition of granite renders it resistant to the formation of gypsum crusts (see Limestone).

B. Erosion: The mechanical wearing away of the material surface by the natural action of the wind, windblown particles, and water. In some cases, erosion can result in localized areas from contact with landscaping or mowing equipment. The hardness of granite resists abrasion and therefore erosion by most natural causes.

C. Efflorescence. Deposition of soluble salts on the surface of masonry. Efflorescence on new construction is commonly caused by leaching of salts from new mortar and/or masonry units and is typically washed away by rain or water washing. However, recurring efflorescence or new efflorescence appearing on an existing structure is an indication of a possible problem such as rising damp, roof or other leakage, exposure to de-icing chemicals or other source of salts or run-down from calcareous stones above (seen frequently on the granite water tables of limestone and marble buildings). Improper chemical cleaning (the use of overly strong chemicals, inadequate rinsing and failure to neutralize chemical residue) is also a common cause of visible efflorescence.

D. Sub-florescence: Internal accumulation of soluble salts deposited just beneath the masonry surface as moisture in the wall evaporates. Salts enter the stone dissolved in rainwater or groundwater via absorption, rising damp, or poor joints. Possible sources of salts include de-icing salts, chemical cleaners, landscaping products, mortar, and air pollution. Treatments include poulticing, removal of identified salt sources, elimination of moisture in the stone, and damp-proofing.

E. Rising Damp: The suction of groundwater into the base of masonry through capillary action. The level of water drawn into the stone may rise and fall according to conditions of temperature, humidity, site grading, absence or failure of damp courses, and/or treatments to the masonry surfaces that affect evaporation. Signs of rising damp include darkening of the masonry near ground level during active or wet periods, staining and efflorescence, flaking, peeling and spalling. The effects of rising damp can be mitigated by elimination of the water source or interruption of its path into the stone by physical or chemical damp-proofing.

F. Blistering. A swelling on the surface followed by a rupturing of a thin, uniform skin. Blistering is typically caused by the use of de-icing salts and/or leaching of salts from groundwater, and is usually localized near ground level. The condition may stabilize and remain constant; however, blistering frequently precedes additional problems such as exfoliation or spalling. No effective treatment exists for this condition, however, discontinuing the use of de-icing salts may slow the progress of the deterioration.

G. Flaking. The detachment of small, flat, thin pieces of the outer layers of stone from a larger piece of stone caused by capillary moisture, freeze-thaw cycles, the application of water-repellent coatings that trap moisture beneath the surface, sub-florescence or some combination thereof. Flaking is often an early stage of more serious problems such as peeling, exfoliation, delamination, or spalling. To determine whether flaking is caused by sub-florescence, check for signs of whitish salt buildup.

H. Peeling: Flaking away of the surface from the substrate in strips or layers. In granite, peeling can result when improper application of masonry coatings leads to failure of the coating and/or stone surface. In calcareous stones, peeling can follow encrustation of the surface caused by chemical reactions with environmental elements.

I. Spalling: In granite, the separation and breaking away of pieces of stone due to sub-florescence, freeze-thaw, improper repointing (too hard mortar or portland cement), corrosion of embedded metals,or structural overload. Less common in granite than in softer stones.

J. Chipping. The separation of small pieces or larger fragments from a masonry unit, frequently at the corners, edges, or mortar joints. Chipping may be caused by impact resulting from an accident or vandalism or may be the result of deterioration and/or inappropriate repairs, especially the use of excessively hard pointing mortar.

K. Cracking. Appearance of narrow fissures ranging from less than 1/16 inch to ½ inch or more in width in the stone. Causes of cracking include structural overloading due to settlement, use of excessively hard mortar, corrosion of embedded metals and/or flaws in the stone. Minor cracks, although not necessarily harmful, can be an indication of structural problems. Cracks can allow water entry, promoting salt migration, further corrosion jacking and/or damage from freeze-thaw cycles. Repairs for cracking include epoxy or cementitious patching, dowelling, Dutchman patching and replacement of the damaged unit.

L. Detachment. Results from a failure of the construction system, connectors and/or joints. Failure of structural anchors or metal connectors that lead to detachment may be caused and/or accelerated by corrosion caused by water penetration. Adequate pointing and caulking is required to prevent water entry into the structural system. Detachment is typically corrected by removal of the failed unit and replacement of the failed component(s) followed by reinstallation or replacement of the masonry unit.

M. Staining: Discoloration, whether general or localized, is staining and can result from exposure to a variety of exterior substances or to internal occlusions in the stone or structural elements. Types of staining and causative agents include:

   1. Organic stains caused by direct contact with decomposing organic matter such as bird or animal droppings, flowers, and tea or coffee.

   2. Metallic stains

      a. Rust Stains are caused by oxidation of iron (rust) and usually result from water penetration that activates or accelerates rusting of iron structural or connecting components. Rust stains may also occur from alteration of ferrous compounds within the stone.

b. Copper stains are caused by copper salts (from copper or bronze) that wash onto the stone from adjacent metal features or embedded cuprous metals and then oxidize.

3. Efflorescence, white stains caused by leaching of soluble salts from mortar joints, de-icing chemicals, adjacent calcareous stones or other sources.

4. Paints and similar coatings applied in the course of building maintenance.

5. Accretion of atmospheric particulates (dirt, soot, etc.)

6. Oil/grease stains generally resulting from human contact or contact with food or petroleum products.

7. Biological growth, blackish or green staining due to accumulation of fungal or algal growth on rough, unfinished granite surfaces.

8. Graffiti, generally localized around area of contact.

   a. Paints

   b. Dyes and inks

9. Etching or bleaching due to application of strong, acidic cleaning compounds.

3.04 LIMESTONE PROBLEMS AND DETERIORATION

A. Weathering: Deterioration resulting from the mechanical and chemical action of wind, rain, snow, thermal change, and atmospheric pollutants. Causes surface losses and loss of detail.

1. Gypsum crusts are a specific weathering phenomenon that occurs when calcium carbonate in the limestone surface reacts with humidity and airborne sulfur from automobile emissions, creating a crust of water-soluble gypsum. The gypsum crust is then vulnerable to dissolution by cleaning or other exposure to water, often resulting in significant losses of surface detail.

2. Acid rain is a particularly destructive form of chemical weathering occurring in areas subject to high concentrations of airborne industrial pollutants. Airborne pollutants combine with moisture to form acidic precipitation that destroys the calcitic binder in calcareous stones, causing significant loss of surface detail. See Crumbling / Sugaring below.

B. Erosion: The mechanical wearing away of the material surface by the natural action of the wind, windblown particles, and water. Limestone is susceptible to loss of carved and incised detail. In some cases, erosion can result in localized areas from contact with landscaping or mowing equipment.

C. Efflorescence (see Granite above)

D. Subflorescence (see Granite above)

E. Rising Damp (see Granite above)

F. Crumbling/Sugaring: Indicative of a certain brittleness or tendency of the stone to break up or dissolve. Also called sugaring when the limestone breaks up into small crystals that look and feel like coarse sugar. Stones generally have to be replaced when crumbling occurs. Causes include:

   1. An inherent weakness in the limestone

   2. Gradual breakdown of the binder (See Acid Rain above)

   3. External factors affecting the strength and durability of the stone such as de-icing salts (called salt fretting), or any other source of salt migration (like rising damp).

   4. Acids produced by accumulated biological growth such as moss or lichen may result in localized sugaring of limestone surfaces. The mechanical action of the microscopic rootlets of these lower plants also contributes to sugaring as they penetrate the stone surface.

G. Blistering (see Granite above)

H. Flaking (see Granite above). Limestone is significantly softer than granite and is therefore more prone to flaking, particularly along joints and patches where an inappropriately hard mortar is used.

I. Peeling (see Granite above). Limestone is particularly prone to peeling associated with the formation of gypsum crusts. The presence of sedimentary bedding planes may further aggravate surface losses.

J. Spalling (see Granite above): Spalling is less frequent with limestone than with softer sedimentary stones.

K. Chipping (see Granite above).

L. Cracking (see Granite above)

M. Detachment (see Granite above)

N. Staining (see Granite above). Limestone is significantly more porous than granite, allowing stains to penetrate more deeply into the exposed surface.

   1. Organic stains

   2. Metallic stains

      a. Rust Stains

      b. Copper stains

3. Efflorescence. Acidic cleaners commonly used to remove efflorescence from new construction may be harmful to acid-sensitive limestone surfaces and should be avoided for limestone. The use of any acidic compound on limestone must be carefully evaluated and tested to prevent irreversible damage to building surfaces.

4. Paints and similar coatings applied in the course of building maintenance.

5. Accretion of atmospheric particulates (dirt, soot, etc.) Accretions of atmospheric particulates are particularly damaging to calcareous stones such as limestone as they promote the formation of gypsum crusts.

6. Oil/grease stains. Substances may be absorbed into the stone upon contact. The depth of penetration depends on the viscosity of the oil/grease, temperature, stone porosity, finish and dryness.

7. Biological growth. Relatively porous limestone surfaces often prone to biological staining, particularly on north-facing elevations and in sheltered locations. Limestone affected by acid rain often develops a roughened texture that readily supports fungal growth, resulting in a grayish black stain.

8. Graffiti, including paints, dyes and inks

9. Etching or bleaching due to application of strong, acidic cleaning compounds. irreversible.

3.05 MARBLE PROBLEMS AND DETERIORATION

A. Weathering: Deterioration resulting from the mechanical and chemical action of wind, rain, snow, thermal change, and atmospheric pollutants. Although marble has low porosity, it is highly reactive when exposed to acids. Sensitivity to acid, coupled with the elliptical shape of the pores that allows greater dissolution, makes marble extremely susceptible to weathering.

1. Gypsum Crusts (see Limestone above): Many marbles are highly uniform and easily carved and were therefore widely used for sculpture and other decorative uses. The formation of gypsum crusts is especially detrimental to these works as the distortion and eventual loss of detail significantly compromises their artistic and/or decorative value.

2. Acid Rain (see under Limestone): Marble lends itself not only to the sculpting of artistic works but also to the carving of inscriptions, particularly plaques and grave markers. The constant exposure of sculpted and/or inscribed surfaces to acidic precipitation causes not only the loss of artistic detail but also the loss of valuable inscriptions.

B. Erosion (see Limestone above)

C. Efflorescence (see Granite above)

D. Subflorescence (see Granite above)

E. Rising Damp (see Granite above)

F. Crumbling / Sugaring (see Limestone above) Fine-grained marbles, are particularly susceptible to this form of deterioration.

G. Blistering (see Granite above)

H. Flaking (see Granite above). Marble is softer than granite and is therefore more prone to flaking, particularly along joints and patches where an inappropriately hard mortar is used. However, the uniform crystalline structure of marble makes it more resistant to flaking than limestone and other sedimentary rocks.

I. Peeling (see Granite above). Marble is particularly prone to peeling associated with the formation of gypsum crusts.

J. Spalling (see Granite above): Marble was frequently used in copings, landings and curbs and in decorative items such as urns and finials. Spalling in these applications is frequently associated with corrosion of embedded posts and anchors. Spalling is less frequent with marble than with sedimentary stones, which are less dense.

K. Chipping (see Granite above)

L. Cracking (see Granite above)

M. Detachment (see Granite above)

N. Staining (see Granite above). Limestone is significantly more porous than granite, allowing stains to penetrate more deeply into the exposed surface.

1. Organic stains

2. Metallic stains

    a. Rust Stains

    b. Copper stains

3. Efflorescence. Acidic cleaners commonly used to remove efflorescence from new construction may be harmful to acid-sensitive limestone surfaces and should be avoided for limestone. The use of any acidic compound on limestone must be carefully evaluated and tested to prevent irreversible damage to building surfaces.

4. Paints and similar coatings applied in the course of building maintenance.

5. Accretion of atmospheric particulates (dirt, soot, etc.) Marble can be discolored by atmospheric dirt, grime, and other airborne particulates which adhere to the material and can result in a dull or gray appearance. Some waterproof and water-repellent coatings increase static attraction that results in the stone getting dirty faster. Accretions of atmospheric particulates are particularly damaging to calcareous stones such as marble as they promote the formation of gypsum crusts.

6. Oil/grease stains. Substances may be absorbed into the stone upon contact. The depth of penetration depends on the viscosity of the oil/grease, temperature, stone porosity, finish and dryness.

7. Biological growth. Relatively porous limestone surfaces often prone to biological staining, particularly on north-facing elevations and in sheltered locations. Algae, lichens, and moss can produce acid by-products that also damage the acid-sensitive stone.

8. Graffiti, including paints, dyes and inks

9. Etching or bleaching due to application of strong, acidic cleaning compounds. Irreversible.

3.06 SANDSTONE PROBLEMS AND DETERIORATION

A. Weathering: Deterioration resulting from the mechanical and chemical action of wind, rain, snow, thermal change, and atmospheric pollutants. Causes surface losses and loss of detail. Sandstones vary widely in their resistance to weathering due to the wide variety of binders that may be present. As a sedimentary rock, sandstone is often non-uniform and may contain inclusions more or less durable than the surrounding stone and may weather unevenly. The generally high porosity and layered structure of sandstone makes it particularly susceptible to freeze-thaw damage.

1. Gypsum Crusts: Sandstones differ widely in their susceptibility to gypsum crust formation. Those with calcareous binders may be severely affected. Petrographic and chemical analysis may be employed to further characterize the binder of a particular stone and assess its durability.

2. Acid Rain: Sandstones differ widely in their resistance to acid rain. Those with calcareous binders may be severely affected. Petrographic and chemical analysis may be employed to further characterize the binder of a particular stone and assess its durability.

B. Erosion (see Limestone above)

C. Efflorescence (see Granite above)

D. Subflorescence (see Granite above)

E. Rising Damp (see Granite above)

F. Crumbling / Sugaring (see Limestone above). Calcareous sandstones may be severely affected by this condition.

G. Blistering (see Granite above)

H. Flaking (see Granite above). Marble is softer than granite and is therefore more prone to flaking, particularly along joints and patches where an inappropriately hard mortar is used. However, the uniform crystalline structure of marble makes it more resistant to flaking than limestone and other sedimentary rocks.

I. Peeling (see Granite above). Marble is particularly prone to peeling associated with the formation of gypsum crusts.

J. Exfoliation / Delamination. Separation and loss of large areas of stone along the bedding planes. It is often caused by having laid the stone with the bedding planes running parallel with the surface of the wall (face-bedding) rather than perpendicular to the wall plane (naturally-bedded). Blind exfoliation occurs where layers are still loosely attached behind the surface. Blind exfoliated stone will sound hollow when lightly tapped with a rubber mallet. Painting over deteriorated surfaces or using inappropriately dense patching materials may aggravate this condition.

K. Spalling (see Granite above): Marble was frequently used in copings, landings and curbs and in decorative items such as urns and finials. Spalling in these applications is frequently associated with corrosion of embedded posts and anchors. Spalling is less frequent with marble than with sedimentary stones, which are less dense.

L. Chipping (see Granite above).

M. Cracking (see Granite above)

N. Detachment (see Granite above)

O. Staining (see Granite above). Limestone is significantly more porous than granite, allowing stains to penetrate more deeply into the exposed surface.

1. Organic stains

2. Metallic stains

   a. Rust Stains

   b. Copper stains

3. Efflorescence. Acidic cleaners commonly used to remove efflorescence from new construction may be harmful to certain sandstones. The use of any acidic compound on sandstone must be carefully evaluated and tested to prevent irreversible damage to building surfaces.

4. Paints and similar coatings applied in the course of building maintenance.

5. Accretion of atmospheric particulates (dirt, soot, etc.) Some waterproof and water-repellent coatings increase static attraction that results in the stone getting dirty faster.

6. Oil/grease stains.

7. Biological growth. Relatively porous sandstone surfaces often prone to biological staining, particularly on north-facing elevations and in sheltered locations. Algae, lichens, and moss can produce acid by-products that also damage acid-sensitive sandstones.

8. Graffiti, including paints, dyes and inks.

9. Etching or bleaching of dark-colored stones due to application of strong, acidic cleaning compounds. This discoloration is irreversible.

3.07 FINAL REPORT

A. The Contractor shall provide a final report of completed characterization of the stone(s) and the completed assessment of the condition of the masonry assemblies as directed. At a minimum, the final report shall include the following as applicable:

1. Characterization

a. Available archival or documentary information regarding the specification and source of the stone(s) and any past treatments.

b. Results of any laboratory testing of the stone(s) such as compressive strength, salt content, etc.

c. Results of any petrographic examination of the stone(s).

2. Assessment

a. Narrative and/or graphic documentation of the condition of the stone(s) and masonry assemblies including, but not limited to, structural conditions, attachment and anchorages, deterioration mechanisms observed, etc.

b. Results of mortar analyses and other laboratory testing of secondary or accessory materials included in the stone masonry assembly.

c. Results of any test treatment implemented including provisions for monitoring test areas, if applicable.

END OF SECTION