Chapter 10: Treatments and Procedures

Regulations and Standards

Treatment and protection regulations and standards are set forth by the *National Historic Preservation Act* of 1966, as amended, and *The Secretary of the Interior's Standards for the Treatment of Historic Properties* (1995 and 1996).

Objectives

The objectives of any treatment program for a large integrated group of historic structures are to maintain integrity, preserve character-defining features, and to retain, to the greatest extent possible, the original materials. These objectives are modified by the limitations of budget, manpower, codes, life-safety regulations, hazardous materials abatement, and requirements for efficient operations and interpretation.

Inspection Procedures

An effective treatment program has as its foundation a regular and comprehensive building inspection procedure. Inspections should be accomplished by trained and experienced staff members on a regular basis and according to standardized procedures. While a comprehensive inspection program can greatly assist in gathering information, the knowledge and experience of the inspector is essential. A standardized inspection procedure is needed to identify and list deleterious conditions. Personnel are advised to use side two of the Coast Defense Resource Checklist to identify and document problems, and to use the Action Log to record site visits, products applied, and actions taken. Both forms are provided in Appendix C. In any procedure the skill of the inspector is called upon to synthesize the various data, to identify patterns of deterioration, and to make critical judgments about treatment requirements. When a condition of deterioration is identified, it may be an isolated problem or it may involve other related conditions. The inspector must be able to determine the involvement of related materials and conditions in setting forth a detailed treatment program.

Documentation and Records Maintenance

Documents that pertain to the treatment of the fortifications may be found at the Park Archives of the Golden Gate National Recreation Area. These documents include:

- Original architectural drawings
- Annual reports of the Chief of Engineers, U.S. Army, to the Secretary of War (selected excerpts)
- Manuals
- Historic maps
- Historic photographs
- Aerial photographs
- Maintenance records

A file should be established for each site and should include updated copies of the Coast Defense Resource Checklist and Action Log, and record-photographs as well as reproductions of historical documentation. The development of working files with reproductions is important to make information readily accessible to those who actively deal with the fortifications and to minimize use of original records. When completed Coast Defense Resource Checklist and Action Log forms are superceded, the non-current forms should be kept as a part of a site's permanent maintenance file.

Testing Procedure

Materials testing is an essential element in any treatment program, particularly where historic resources are involved. Determining composition, constituent and proportional parts of materials, and characteristics of materials for analysis of the causes of deterioration should be considered early in the treatment process. A base line testing program should include the following materials:

Concrete (various types)
Brick
Mortar
Paints and Coatings (various types)
Soils and Geotechnical
Hazardous Materials

All testing should be as non-destructive as possible. Where testing requires the taking of samples for off site analysis, samples should be taken carefully and from inconspicuous places. Testing should be to standards generally governed by the ASTM (American Society for Testing Materials, latest standard or revision) or other recognized testing standard. Test data should be placed in site files. Specific testing requirements are included in appropriate technical sections that follow.

Procedures and Controls

Procedures and controls refer to the administration of treatment programs. Treatment programs for complex historic preservation projects require careful coordination and consistent administration. Before any treatment program is initiated coordination meetings are required and should include all interested parties. Where culturally and environmentally sensitive resources are involved preliminary scoping meetings are essential. For the treatment of fortifications, these meetings should include:

Architects
Historians
Archeologists
Botanists
Landscape Architects
Interpretive Planners
Engineers
Material Testing Engineers
Wildlife Biologists
Law Enforcement
Hazardous Materials Specialists
Maintenance Specialists

Safety

General safety requirements are covered in OSHA General Industry Safety and Health Standards (29 CFR 1910), Publication V2206, and OSHA Construction Industry Standards (29 CFR 1926) and other related standards. Other health and safety related information is contained in OSHA Publication 2207, National Emission Standards for Hazardous Air Pollutants (40 CFR, Part 6), and Environmental

Protection Agency Final Rule (40 CFR, Part 761, latest edition). Note: OSHA, EPA, and other local and state regulations are subject to regular revision. Always check for revisions, latest editions, and newly promulgated regulations.

Material Safety Data Sheets are governed by Federal Standard 313A. Submission of Material Safety Data Sheets should be required for all products and materials used for treatment. The Data Sheets should be reviewed prior to the initiation of work.

Protection

1. Take all necessary precautions to prevent injury or property damage.
2. Store, position, and use equipment, tools, materials, and other associated items in a safe manner in order to avoid hazards.
3. Maintain unobstructed work paths and exit corridors.
4. Provide and install fences, barricades, scaffolding, bracing, shoring, and other appurtenances as required for safe operations.
5. Institute safety measures specifically designed for excavation, trenching, scaffolding, and bracing as prescribed by applicable laws and regulations.

Products and Materials

All products and materials should be of high quality and appropriate for the work. Products and materials should be carefully evaluated prior to application or installation. General requirements for evaluating, handling, and using products and materials are as follows:

1. Select material based on sound research and evaluation.
2. Require Material Safety Data Sheets for all products and materials.
3. Select materials appropriate for the particular work.
4. Where materials or products are selected to duplicate, replace, or approximate historic building materials greater care must be used in determining product and material appropriateness and compatibility.
5. Assure that products and materials meet required standards and regulations and that labels reflect compliance.
6. Use standard products that are compatible with other materials.
7. Deliver, handle, and store products and materials in accordance with manufacturer's recommendations in order to prevent damage, deterioration, or loss.
8. Maintain and enforce product warranty. Coincidental product warranty is available when manufacturers publish or list a warranty in connection with a product without regard for specific application except as limited by terms of the warranty. Document date of installation, inspection, and expiration of warranties.
9. Install products according to a manufacturer's written instructions.
10. Maintain all product information, inspection reports, warranties, Material Safety Data Sheets, and other records.

Recommended Treatments

Following are forty-five recommended treatments for subcategories of sitework, concrete, brick construction, metals, carpentry, moisture protection, doors and windows, finishes, and special items. Each is presented in a single-page format, and most are illustrated by architect sketches, or, historic and contemporary photographs.

Sitework: General

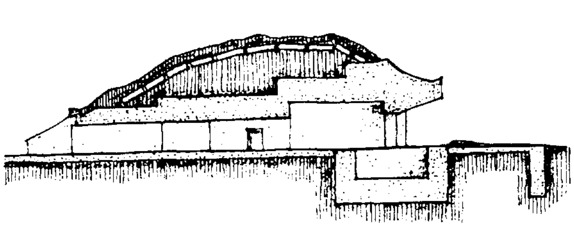
Due to the mass and weight of masonry and concrete, extensive site preparation was a major component of original construction. Excavation, backfilling, cutting, and grading permanently altered the natural terrain around the fortifications. Steep slopes, unstable soils, seismic activity, and the massive nature of construction activities contributed to site disturbance.

Identification:

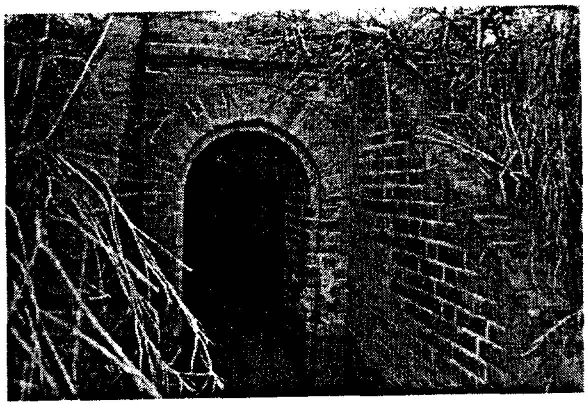
Sitework associated with coastal fortifications is limited to the immediate area of disturbed earth around or adjacent to the original construction. Sitework includes excavation, soil stabilization, earthwork, drainage, landscaping, paving, vegetation, walkways and paths, and other related items.

Inspection and Testing:

It is essential that disturbed areas be inspected in order to mark limits of responsibility, to constrain environmental regulation that would otherwise include previously disturbed areas, and to provide accurate quantities for estimating treatment costs. It should be noted that environmental regulations may still apply inside disturbed area boundaries, particularly regulations concerning botanical and biological habitat. Coordination with environmental managers within the Golden Gate National Recreation Area is recommended at the earliest stages of project planning. Locate and protect existing underground utilities.



Battery Wallace. Cross section showing gun pit, concrete mass, burst slab, and earthworks.



East Battery. Flooded magazine entry.

Treatment

Site drainage is critical to move both surface water and water collected by fortification drainage systems away from the base of the fortification. Over the years grades adjacent to buildings tend to build up with soil and organic matter. The accumulated soil traps moisture and impedes drainage. Achieving effective drainage at fortifications is often key to all site treatments.

Work Categories:

1. Excavation.
2. Soil stabilization.
3. Earthwork.
4. Drainage.
5. Landscaping and vegetation control.
6. Trails and paving.

Sitework: Excavation

Causes:

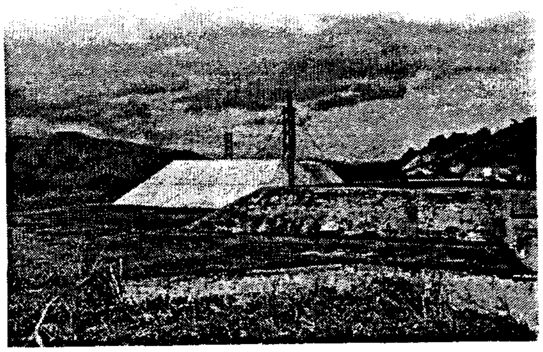
Excavation is usually associated with other construction operations. Excavation may provide useful information about original construction by exposing covered items such as waterproofing coatings, protective tile, evidence of soil stabilization methods, and compaction levels or "lifts." Excavation may also identify the extent to which fill materials were imported from remote sites.

Identification:

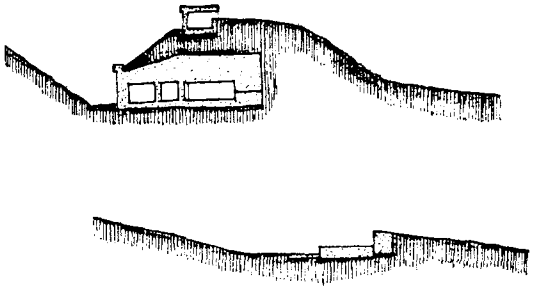
Excavation is limited to designated areas and only for the purpose of earth removal to expose structures for investigation and treatment, to repair or install underground utilities, or to remove accumulated earthen fill adjacent to structures. Excavation includes removal of soil fill covering fortification features. Excavation should only be initiated under the direct supervision of the project architect/engineer.

Inspection and Testing:

Take and mark samples during excavation for storage and classification. Field notes and photographs should be made of all excavations.



Battery Crosby. Concrete elevations for ammunition hoist (right) and crow's nest (center).



Battery Duncan. Cross sections through battery (top) and gun emplacement (bottom). Note the weakened plane joints and the relationship between earthwork and concrete.

Treatment:

Excavate using hand tools and equipment under controlled conditions. Excavate only to the depth and extent indicated. Excavated materials should be carefully stored on the site and covered to prevent erosion. After excavation backfill using original soil materials. Compact backfill in lifts of not more than six inches to match original density. Monitor any settlement and install additional fill as needed to achieve original grades.

Coordination:

Coordinate any excavation with a park archeologist and with a military historian familiar with coast defense fortifications.

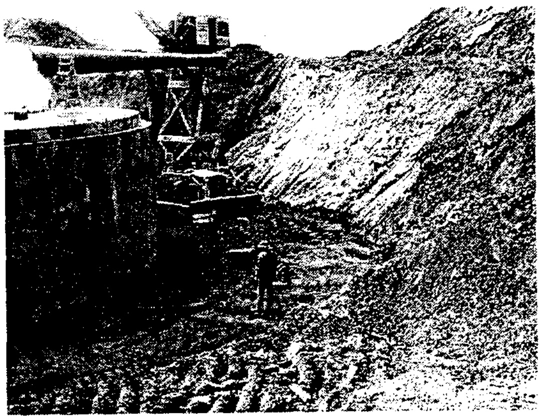
Sitework: Soil Stabilization

Soil stabilization refers to strengthening soil stability by means of the addition of lime and/or Portland cement to soil or by the use of soil base materials that are inherently resistant to expansion or migration—such as crushed limestone or granite. This type of soil stabilization is only appropriate where excavation has exposed original construction or stabilization is to correct erosion. Berm stabilization by means of vegetative ground cover or netting is covered under Sitework: Landscape and Vegetation.

Battery Davis. Cement-soil stabilization, second operation, April 1938.

Identification:

Historic soil stabilization, such as that carried out with stable base materials during the Endicott and Taft periods and soil-cement mixing as carried out during the World War II period may be identified by changes in soil color and composition. Base materials will appear in contrast to soils of the local site. Lime or cement stabilizers were surface applied to subsoils and wetted. These stabilizers may appear as thin friable layers with indistinct edges when viewed in section.



Battery Davis. Cement-soil stabilization, first operation, April 1938.

Inspection and Testing:

Inspection should be by a civil engineer. Testing is not required except in extreme conditions of erosion, settlement, or soil movement. Testing includes but is not limited to:

Field Density
Plasticity Index

Treatment:

1. Compact soil to at least ninety percent of Standard Proctor (ASTM D 698) maximum dry density.
2. Scarify soil surface to a depth of six inches.
3. Apply cement (or lime) at a rate of not less than sixteen pounds per square yard. And disk in to achieve a soil cement mix.
4. Add water and compact to maximum density.
5. Add additional layers of compacted soil to achieve desired grades.

Note: The installation of geosynthetic fabric soil stabilizing materials or degradable jute mesh may be appropriate in order to provide additional stability.

Coordination:

Coordinate all soil stabilization with recommendations provided in Sitework: Excavation; Earthwork; Drainage; and, Landscape and Vegetation.

Sitework: Earthworks

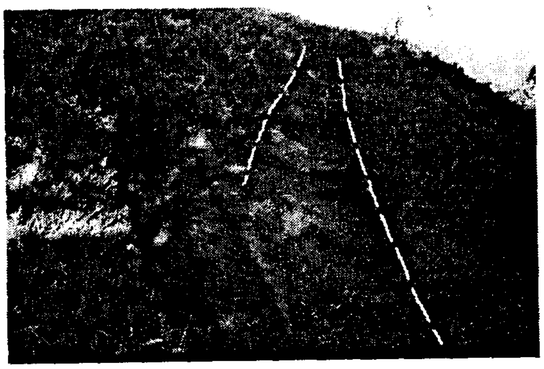
Earthwork consists of cutting, filling, and grading earth adjacent to fortifications. Earthwork includes existing earthen berms built in association with masonry or concrete fortifications. Original earthen berms have suffered isolated erosion and settlement. Treatment includes cutting, filling, grading, and reshaping existing berms.

Identification:

Earthen berms are integral components of fortifications and are found on or adjacent to related masonry or concrete structures. The berms are usually steep-sloped, flat-topped formations that contrast with natural terrain. However some earthworks appear as extensions of natural topography and, due to overgrown vegetation, may be difficult to distinguish.

Inspection and Testing:

Not required.



East Battery. Erosion of earth cover on magazine roof as a result of informal trail.

Treatment:

Where berms have been damaged by erosion, soil instability, or seismic activity, corrective action is required. Depending on the level of treatment prescribed, earthwork may involve work ranging from interim stabilization to full restoration.

Stabilization:

1. Add selected fill material to eroding areas and compact by hand.
2. Monitor erosion and replace soil wash.

Preservation:

1. Add selected fill to eroding areas and compact by hand.
2. Add approved ground cover to bare areas and maintain.
3. Monitor erosion and plant growth and replace soil wash.
4. Install degradable jute grid fabric to stabilize slopes.

Restoration:

1. Perform excavation and soil stabilization as required.
2. Excavate to stable soil materials and make repairs to structures, foundations, and waterproofing materials. Install new drainage systems or repair existing systems.
3. Install geotextile fabric reinforcement sheets according to manufacturer's written instructions and the Federal Highway Administration (FHWA), American Association of State Highway and Transportation Officials (AASHTO), and Geosynthetic Research Institute (GRI) standards.
4. Backfill with original earthen materials and compact soils in six-inch lifts.
5. Hand grade topsoil to achieve original lines and grades.
6. Install vegetative materials. (See Sitework: Landscaping and Vegetation.)

Coordination:

Coordinate all earthwork with other related sitework sections and with a park archeologist.

Sitework: Drainage

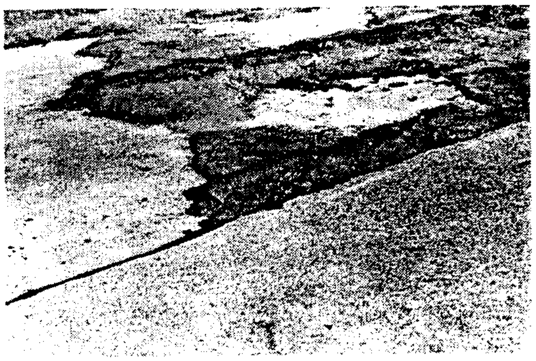
Drainage work includes repair or replacement of existing surface and subsurface drainage systems. These systems include French drains, piping, intercept and trench drains, area drains, rock drainage courses, and tile drainage cavities adjacent to vertical concrete surfaces. These drainage systems were designed and originally installed to remove and disperse surface water from rainfall. Drainage systems were a consideration in the original design of the fortifications and are shown on drawings and described in engineers reports. The critical importance of drainage is illustrated by notations on drawings for regular maintenance of drainage lines and gutters.

Identification:

Existing drainage systems may be identified by reviewing original drawings, by visual inspection in the field, and by investigation. French drains and drainage courses usually occur at the base of vertical wall planes of structures. Subsurface drain lines usually drain from downspout leaders and can be located by digging and following the lines. Metal detectors may locate cast iron piping. Area and trench drains occur in locations where surface water can be intercepted. Surface drainage is across sloped surface planes.

Inspection and Testing:

Individual site inspections coordinated with the use of original drawings should locate visible and suspected drainage lines. Selective excavation may determine actual locations, depths, and slopes. Testing with high pressure water may help to locate lines and leaks.



Battery Godfrey. Surface drainage system on blast apron composed of pipe, earth fill, and asphalt or oil-saturated earth.

Treatment:

Cleaning and repair of existing drainage lines:

1. Flush existing drain lines using high pressure water to remove accumulated debris. Insert hose in drainage inlet and observe outflow or leaks. Excavate where leaks are observed.
2. Repair or replace broken or deteriorated segments of drainage piping with like materials.
3. Retest with high pressure water and observe outflow. Clean excess soil and debris from outflow opening.

Installation of new drainage lines:

1. Where drainage lines have collapsed, replace with like materials or Schedule 40, four-inch diameter PVC piping and connections.
2. Slope drain lines a minimum of one-eighth inch per linear foot.
3. At inflow clean, repair, or replace drain device.
4. At outflow, position splash block to avoid erosion.

Installation of trench and area drains:

1. Install trench drains or area drains to replace deteriorated or missing units or install new drain inlets where required to protect existing fortifications from erosion damage.
2. Install additional piping, fittings and drain lines as required.

Sloped surface drainage:

1. Slope drainage surfaces a minimum of one-eighth inch per linear foot.
2. Remove impediments to drainage and maintain clear drainage paths.
3. **Note:** Repair of drainage systems is associated with waterproofing and clay tile in the Moisture Protection section.

Sitework: Landscaping and Vegetation

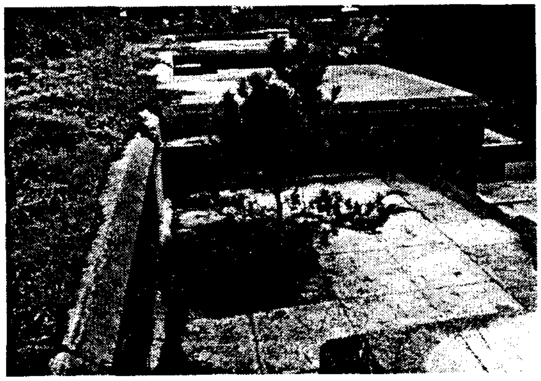
Landscaping and vegetation include the control of overgrown, intrusive vegetation and the installation of appropriate vegetative ground cover for earthworks and berms. Changes in vegetative cover since the construction of the various fortifications have altered original appearances. Post-Civil War fortifications used earthworks for protection. Fortifications from the Endicott and Taft periods combined earthworks with concrete construction for protection and camouflage. The advent of aviation changed World War I and World War II-era earthworks by including overhead protection and camouflage.

Identification:

Review of historic photographs, drawings, and military reports should be compared with existing vegetation conditions at each fortification. The extent of vegetative changes should be noted and recorded. Accurate identification of vegetative materials by a botanist experienced in local plants is critical.

Inspection and Testing:

A complete vegetative survey should be completed for each fortification. Trees, shrubs, woody vines, and grasses should be noted as well as any endangered plants or critical habitat.



Battery Blaney. Volunteer coniferous tree growing through a gun mounting ring.

Treatment:

1. Preservation of historic earthworks.
2. Retention or restoration of character-defining earthwork features.
3. Restoration, to the greatest extent possible, of the landscaping and vegetative elements as originally planned.
4. Compliance with existing environmental requirements.
5. Ease of maintenance.

General treatment priorities:

1. Remove all dead wood and fallen trees.
2. Selectively remove trees that are causing root damage to existing historic structures.
3. Encourage the establishment of a natural mix of low maintenance native grasses for ground cover.
4. Remove invader species.
5. Thin trees to remain, especially to allow adequate sunlight for the ground cover and to reduce the accumulation of organic matter.

Specific treatment requirements:

1. Cut trees flush with the ground using chain saws. Treat stumps of deciduous trees with an approved herbicide. (Coniferous tree stumps require no treatment.)
2. Tree cutting and pruning should be accomplished by a trained arborist and felling should be carefully planned to avoid damage to historic resources.
3. Install a naturally proportioned mix of low maintenance native grasses.
4. Mowing should be minimized and limited to areas adjacent to trails. String-type powered weed cutters may be used but not adjacent to historic structures. Weed cutters can damage original historic materials if used inappropriately.
5. Due to the danger of fire spread and the dense urban environments nearby, controlled burning is a carefully monitored procedure in the Golden Gate National Recreation Area. It is generally inappropriate as a treatment for controlling vegetation in the immediate vicinity of gun batteries.

Coordination:

Coordinate all landscaping and vegetation control with environmental regulations.

Sitework: Trails and Paving

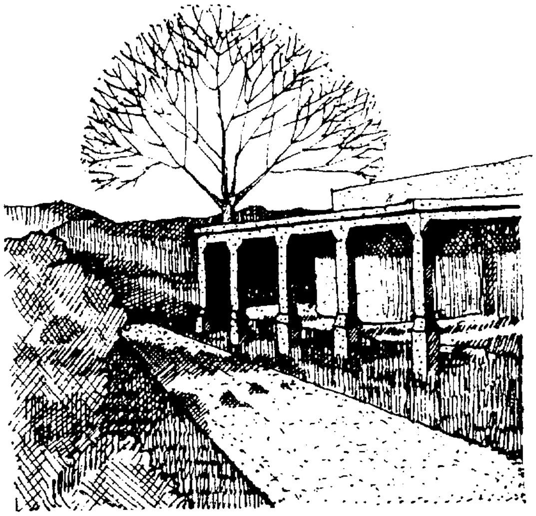
Trails and paving include work to establish trails and to retain and treat original paved surfaces associated with fortifications. Trails are for use by the visitor while historically paved areas are a part of the fabric of the fortifications. Existing trails require repair and maintenance and, in some cases, improved trails are required to enhance the visitor experience and augment interpretation. Existing historic paving includes compacted soil materials, bituminous surfaces, and concrete walkways.

Identification:

To determine original paved areas and walkways associated with the construction and use of the fortifications refer to original drawings and historic photographs. These areas should be noted and compared to existing trail configurations. The extent of paved areas, walkways, and trails should be recorded and included in each site folder. In addition, informal paths made by visitors should be noted and evaluated for potential damage to earthworks.

Inspection and Testing:

Bituminous and asphalt paving materials should be sampled and the composition noted in site folders.



Battery Marcus Miller. General view showing a well-defined trail adjacent to a battery structure.

Treatment:

1. Develop a trail system for each site and, where possible, link trails to adjacent sites.
2. Lay out trails to follow natural terrain and to minimize disturbance to historic earthworks.
3. Select appropriate trail materials that achieve maximum compaction and are low maintenance.
4. Avoid steep slopes and, where possible, comply with *Americans with Disabilities Act* requirements and National Park Service standards.
5. Where existing historic paving, such as bituminous surfacing, has been applied minimize access in order to preserve original fabric. Due to environmental and surface drainage considerations, restoration of bituminous surfaces should be avoided.

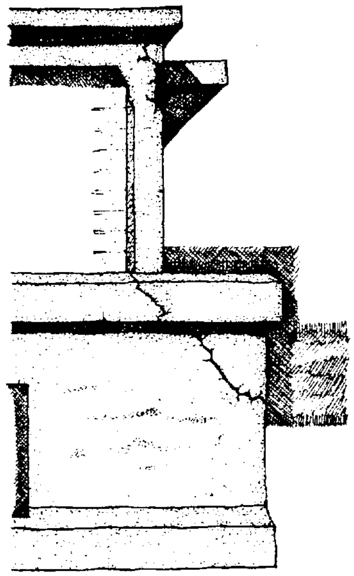
Materials:

Trails: crushed local red rock compacted to maximum density and sloped to drain.
Edging: pressure treated wood, metal, or concrete.
Steps: treated timber or concrete.

Concrete: Causes of Deterioration

Historic concrete work at the Golden Gate National Recreation Area fortifications consists of cast-in-place, plain and reinforced concrete. The late nineteenth and early twentieth century concrete was frequently cast in wooden board forms resulting in a rough surface and finished with a fine cement finish coat. Improved forming techniques and materials resulted in abandonment of the finish coat. By the mid-1930s concrete was cast in plywood forms, and burnished and spot patched with cement grout.

Although concrete is considered to be a durable construction material it is subject to deterioration caused by a number of factors which range from poor workmanship and materials to environmental effects.



Battery Godfrey. Concrete construction indicating structural cracking, spalling, and surface erosion.

Materials and Workmanship:

Concrete may experience deterioration caused by materials used in the mix or by errors that occurred in mixing, forming, or placing. Materials and workmanship problems include:

1. Improper aggregate.
2. Alkali-aggregate reactions.
3. Improper aggregate sizing.
4. Calcium chloride or similar salt additives.
5. Incomplete consolidation in tamping (voids and honeycombs).
6. Placement of reinforcing steel too close to surface.
7. Improper handling of cold or weak plane joints.
8. Inadequate curing.

Environmental Factors:

Concrete is subject to deterioration caused by absorption of moisture and thermal expansion and contraction. Extreme temperature ranges can cause freeze-thaw cycles. Moisture absorbed by the concrete expands and contracts with temperature changes and the resulting mechanical action causes fractures and spalling. Airborne components, such as carbon dioxide, can cause adverse chemical reactions which can cause surface deterioration.

Structural Design Defects:

Defective structural design in historic concrete can cause subsequent deterioration. Typical design defects include:

1. Inadequate concrete coverage over reinforcing steel.
2. Inadequate or improperly placed expansion joints or cold joints.
3. Improper sizing and placement of reinforcing steel.
4. Inadequate cross-sectional area or depth to resist loading forces.
5. Inadequate soil and site preparation.
6. Instability of slopes and seismic movement.

Maintenance Procedures:

Improper or inadequate maintenance procedures can contribute to concrete deterioration. Maintenance related deterioration may be attributed to:

1. Moisture exposure and penetration caused by unrepaired leaks.
2. Improper application of surface sealers and coatings.
3. Failure to clean drains and drainage paths.
4. Inadequate control of vegetation.

Concrete: Identifying the Problem

Concrete deterioration may be observed visually and more precisely determined through testing.

Cracking: The types and severity of cracks in concrete are varied and include dormant and active cracking. Dormant cracking is caused by shrinkage during curing and is not a cause for concern except for potential moisture infiltration. Active cracking is more serious and can indicate severe problems. Active cracks show movement and are related to structural overloading, foundation settling, inherent design flaws, or other deleterious conditions. Active cracking can be temporary or continuous. Active cracking requires monitoring and may require corrective action. Inactive, or dormant, cracking usually requires observation and limited corrective action to prevent moisture infiltration. Random surface cracking, or crazing, may indicate an adverse reaction between cementitious alkalis and aggregates and requires surface corrections.

Spalling: Surface concrete loss in pieces of various sizes is called spalling and is caused when expansive forces inside and near the surface of concrete act along a weak plane or create a weakened plane. The expansive force can be caused by the stress of corrosion of reinforcing steel or imbedded metal items. Corrosive oxidation (rust) causes expansion which in turn creates additional stress. Internal expansion can also be caused by moisture absorbed by porous aggregate that expands and contracts in thermal cycles. Moisture may be trapped inside the matrix of the concrete by paints or sealants that do not allow moisture to migrate and escape at the surface. Spalling can occur due to a condition called laitance where concrete, during placement, was mixed too wet and cement rich paste rises to the surface of the concrete thereby depriving other portions of the mix of cement-related cohesion and consolidation.

Deflection: Concrete footings, foundations, beams, columns, slabs, and walls are subject to deflection that can be seen in bending, bowing, or sagging. Deflection can be caused by overloading, the effects of corrosion, inadequacies in original construction, seismic stress, and by long-term shrinkage. Deflection, by creating internal stress within a concrete mass, may cause spalling at the concrete's extreme surfaces. Most design standards rate structural failure as deflection exceeding 1/360 or about a one-inch drop over a length of thirty feet.

Stains: Stains on concrete surfaces that are not purposely applied may indicate internal problems such as corrosion or adverse chemical reactions. Corrosion usually involves reinforcing steel and the resulting stains are rust-colored. Alkali-aggregate reactions are usually seen as a white efflorescence. Moisture-related stains may appear as a variety of colors.

Erosion: Weathering of concrete surfaces by wind, rain, snow, or other mechanical action can cause surface loss. Temperature related expansion and contraction of surface moisture exerts a mechanical action and results in the gradual wearing away of the concrete surface. Exposed aggregates are particularly susceptible due to differences in the rates of expansion among the various constituent materials.

Corrosion: Reinforcing steel that has been placed too close to the surface of the concrete or that has been exposed by spalling, erosion, or cracking, can corrode, or rust. Oxidation of the steel in the presence of moisture causes rust. The presence of salt-rich moisture adds to the rate of deterioration. Corrosion is an active chemical process that exerts its own expansive stress. High alkalinity in the concrete promotes corrosion and causes, in addition to expansion, a loss of surface bonding between steel and concrete. This loss of bonding reduces the unified effect of reinforced concrete to resist tensil and compressive forces.

Concrete: Inspection and Testing

Determining the causes of concrete deterioration requires careful analysis by experienced architects and structural engineers. Structural deterioration can have life-safety implications and threaten a structure's existence. In addition to inspection and observation by experienced professionals, materials testing and analysis may be needed. Procedures for testing and inspection involve field analysis and documentation, review of documents, testing, monitoring, and laboratory analysis.

Testing and Inspection Procedures:

Field Analysis: Locate and record nature and extent of concrete deterioration.

Document Review: Refer to original drawings and engineering reports and compare to field data. Check historic records and photographs for further information.

Field Testing: If required, after visual inspection, institute a testing program to determine the nature and extent of deterioration. A testing program involves both on-site testing and laboratory analysis. On-site testing includes:

1. Use of calibrated metal detectors, sonic meters, and other devices to locate imbedded metals.
2. Use of sounding hammers and chains to locate voids.
3. Use of direct application of controlled water spray to determine moisture penetration.
4. Use of a moisture meter to determine presence and extent of moisture in concrete.
5. Use of computer simulation and test models to calculate deflection.
6. Measuring for deflection with a transit.

Typical concrete cold joint showing minor spalling, surface deterioration and original form marks. This cold joint is at Battery Marcus Miller.

Laboratory Analysis:

1. Compressive strength testing.
2. Mix composition analysis by weight and volume.
3. Chemical reaction analysis testing for alkalinity, carbonation, porosity, chloride presence, and other components.

Analysis:

Analysis of field data, inspection reports, documents, and testing data requires careful and thorough analysis by structural and materials testing engineers to determine the exact scope of corrective action. This is particularly important where historic concrete is involved. Since improper repairs can cause additional deterioration, no action may be preferable to improper measures.

Concrete: Treatment Overview

Standards:

Contemporary standards may not be directly applicable to historic concrete mixes. Comparison of historic materials to current standards is a useful basis for evaluation.

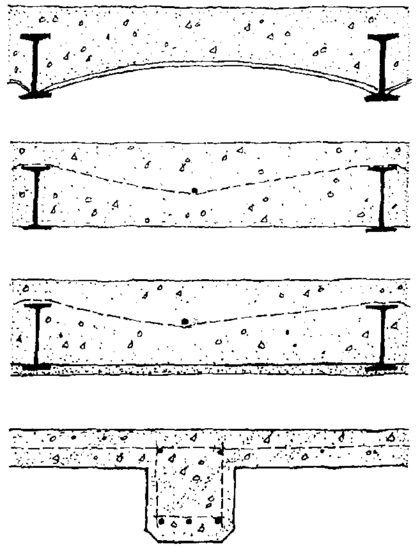
Comply with the provisions of the following minimum codes and standards:

1. American Concrete Institute (ACI) 301, *Specification for Structural Concrete for Buildings.*
2. American Concrete Institute (ACI) 318, *Building Code Requirements for Reinforced Concrete.*
3. Concrete Reinforcing Steel Institute (CRSI), *Manual of Practice.*

Materials:

Materials used in concrete repair and maintenance should conform to the following standards:

Portland Cement:	ASTM C-150, Type I or II.
Reinforcing Bars:	ASTM A-615, Grade 40 or 60
Welded Wire Fabric:	ASTM A-185
Wire:	ASTM A-82
Stainless Steel Rods:	one-fourth inch to one-half inch diameter, smooth and threaded
Non-Shrink Grout:	CRD-C-621, factory pre-mixed grout
Bonding Compound:	compatible with patch
Epoxy Bonding Agent:	epoxy resin type, MIL-B-19235
Epoxy Adhesive:	ASTM C-881
Gravel Aggregate:	local crushed stone to match existing
Sand Aggregate:	local beach sand to match existing
Filler:	molten sulfur
Non-Sag Mortar:	one-component, polymer-modified, silica flume enhanced, passing ASTM C-884 (Modified)
Corrosion Inhibitor:	two-component, polymer-modified, cementitious, trowel grade migrating mortar, passing ASTM C-884 (Modified)



Evolution of reinforced concrete from imbedded I-beams to reinforcing bars.

Concrete Repair System Products:

A wide range of products are available for concrete restoration including grouts, epoxy systems, hardeners, and coatings.

Manufacturers include Sika Corporation, Thoro Products, Dayton Superior Corporation, and Master Builders Technologies.

Procedures:

Examine areas and conditions under which work is to be accomplished. Plan work in a systematic way and follow manufacturer's written instructions. Avoid work during periods of extreme weather.

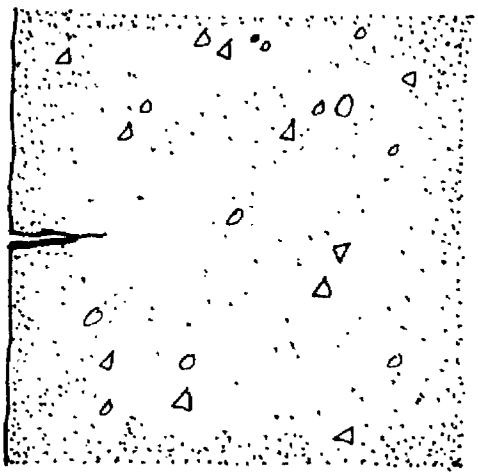
Concrete: Cracks

Narrow Cracking:

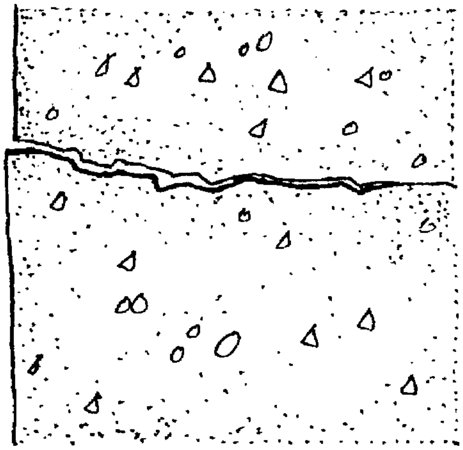
Cracking can be repaired using a variety of methods depending on the size and severity of the crack. Narrow cracks one-fourth inch wide or less that are not structural can be repaired with "neat cement" mortar (a Portland cement and water mix) or by the use of a wide range of non-shrinking grout. Non-shrinking grouts usually contain silica flume or other stable aggregates.

Large to Severe Cracking:

The addition of a small amount of fine sand to the neat cement acts as a shrinkage reducer for slightly larger cracks. In cases where cracks are deeper than one-and-one-half inch, a backer rod is recommended. Where severe cracking has occurred and extends through a structural member, is over one-half inch wide, and shows signs of movement, extensive repair is required. Insertion of dowels and/or epoxy injection may be required. Epoxy injection is a complex repair process addressed in Concrete: Epoxy Injection.



Typical detail. Small surface crack in concrete.



Typical detail. Structural crack through concrete showing displacement.

Repair Procedure:

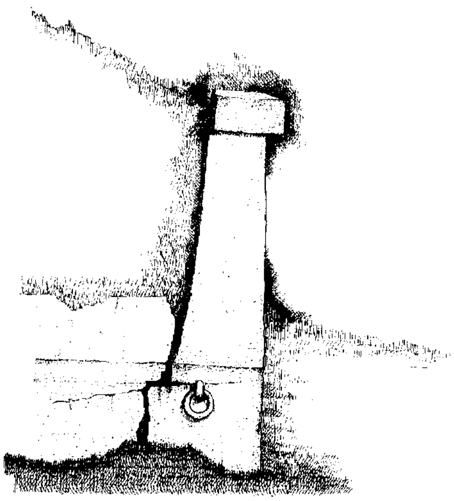
1. Clean crack free of accumulated debris and roughen surfaces. Remove any loose or soft concrete.
2. Wash out crack and allow to dry. Rake out crack if additional depth is required to achieve bonding and penetration. A bonding agent compatible with the mortar mix may be required, but is not always appropriate.
3. Apply crack-repair mortar or grout according to manufacturer's written instructions. It may be necessary to build the patch up in layers.
4. Finish surface to match existing adjacent surface.

Note: Test repair a crack using the prescribed mortar mix and finishing technique before attempting other repair work. Surface finish color may not match original concrete finish color. Adjustments may be made in the color of the mix or a different product may more closely approximate the original color. Age will help to diminish color differences.

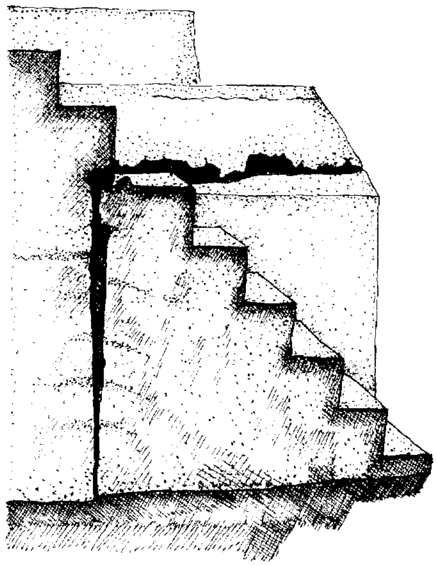
Concrete: Separation

Causes:

Separation occurs when independently cast concrete elements move apart because of settlement or differential movement. Separation may also occur when unreinforced concrete elements cannot withstand lateral forces and are forced apart. Intrusive tree roots are a primary causes of separation. Repair of separations requires more extensive intervention.



Battery Stotsenburg-McKinnon. Separation of unreinforced concrete. Lateral forces overcome tensile resistance in unreinforced concrete wing wall. A weakened plane crack through the maneuvering ring mounting predates the separation.



Typical. Concrete separation at unreinforced steps.

Repair Procedure:

1. Clean out separation by removing all debris and loose or soft concrete. Remove trees, roots, and earthen fill that may be causing the separation.
2. Drill concrete to receive threaded stainless steel dowels and grout dowels in place. with epoxy grout mix.
3. Install underpinning and slip braces as needed.
4. Apply pressure to close separation. When repositioning is accomplished, complete dowel installation. Apply final pressure to close opening until excess mortar is compressed out of separation. Brace concrete in final position until epoxy mortar sets.
5. While wet, remove excess mortar and clean surfaces.
6. When cured, reinstall fill materials.

Note: Prior to repairing a separation, decide whether it is better to leave the separation in place and treat it as a crack, or to move the separated portion back into place.

Concrete: Spalling

Identification and Inspection:

Repair of spalled areas involves removal of loose or deteriorated material, surface preparation, removal of exposed, imbedded reinforcing corrosion, application of patching materials, and surface treatment. Where spalling has been caused by corrosion of reinforcing and reinforcing is exposed, removal of non-critical reinforcing elements or sandblasting to remove rust may be required. Exposed reinforcing must be cleaned to bare bright metal before treatment. For vertical and overhead conditions, forming may be required for proper installation of the mortar or grout. Spalling also occurs around imbedded conduit and piping.

Treatment:

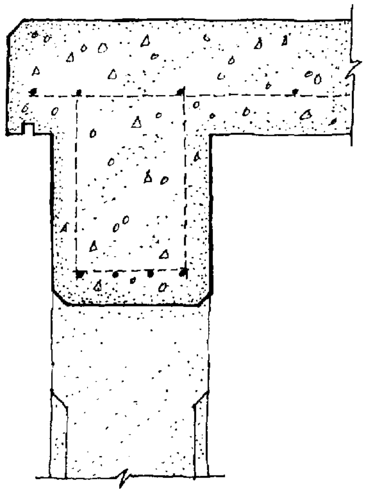
Removal of deteriorated or loose materials is easily accomplished with hand tools and small power tools. A hammer and masonry chisel will remove most loose or deteriorated concrete. Surface preparation requires removal of dust, dirt, grime, and mildew from surfaces to receive repairs. While wire brushing, washing, and similar measures may clean most surfaces, light gritblasting, limited to the affected area, may be required. When gritblasting, shield areas adjacent to the treatment area. After blasting wipe surfaces with solvent and immediately apply protective primer.

Spalling that exposes imbedded reinforcing, clips, angles, or metal anchors requires removal of all exposed corrosion. Where surface corrosion is to be removed, either by brushing or sandblasting, the application of a seal coating over the cleaned metal is critical to the repair. Migrating rust inhibitors may be applied to the general area. Coordination of material compatibility is essential.

Replacement of large areas of spalled concrete will require the use of steel dowels to anchor the epoxy, cement mortar or grout. The dowels should be inserted in holes drilled in the concrete in the area to be repaired.

Application of spall repair mortars or grouts should be accomplished by laying up successive layers of material. For vertical and overhead applications, use only those epoxy adhesives recommended by the manufacturer for vertical or overhead applications.

Battery Marcus Miller. Detail view of spalling concrete. Spalling can be caused by expansive corrosion acting on reinforcing steel.



Cross section through concrete showing profile, reinforcing bars, and articulated, chamfered corners and edges.

Materials:

Epoxy Putty:	100 percent solid, two-component, epoxy adhesive.
Metal Dowels:	one-fourth inch to one-half inch diameter threaded stainless steel dowels.
Metal Sealant:	as recommended by epoxy or grout manufacturer.

Installation:

1. Install according to manufacturer's written instructions
2. Drill dowel holes allowing at least one-fourth inch between the perimeter of the dowel and the side of the hole. Dip dowel in epoxy putty and insert.
3. Apply epoxy putty with a spatula or putty knife. Fill solid and work out to align with original surface. Work material flush and work surface to match adjacent surface.
4. It may be necessary to construct a form matching the original lines of the structure in order to contain and shape the repair.

Concrete: Epoxy Injection

Identification and Inspection:

Epoxy injection is an extreme measure and should be used in rare circumstances where concrete has lost structural integrity. The concrete must be in failure or eminent failure and must threaten life-safety or the loss of the structure.

Epoxy injection should be accomplished by a certified applicator of the Structural Concrete Bonding Process Association.

Materials:

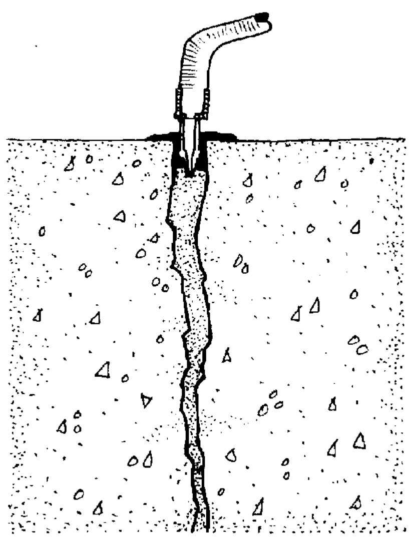
Epoxy Resin Adhesive for Injection: Two-part, solventless, low viscosity adhesive, or similar approved product.

Surface Seal: Material adequate to hold injection fittings firmly in place and to resist injection pressure.

Equipment:

Automatic pressure control equipment with displacement pumps with interlock to provide positive ratio control of exact proportion at the nozzle. The pumps shall be electric or air powered and shall provide in-line metering and mixing.

Discharge Pressure: Not to exceed 160 psi.



Epoxy injection. Cross section showing concrete crack, dam, and injection port.

Treatment:

Surface Preparation: Clean surfaces adjacent to cracks free of dirt, dust, grease, oil, efflorescence, or other foreign matter. Do not use acids or corrosives for cleaning. Provide entry ports along the crack at intervals of not less than the thickness of the concrete at that location. For through-cracks, surface seal both faces. Allow adequate time for the surface seal to gain adequate strength to withstand injection pressure.

Epoxy Injection: Begin epoxy injection at lower entry port and continue until there is an appearance of epoxy adhesive at the next entry port adjacent to the entry port being pumped. When epoxy adhesive travel is indicated by appearance at the next adjacent entry port, discontinue injection on the entry port being pumped and transfer to next port. Perform epoxy injection until all cracks are filled.

Finishing: When cracks are completely filled, epoxy adhesive should be allowed to cure sufficiently to allow removal of the surface seal. Finish crack flush with adjacent concrete. Where historic architectural finish must be matched, work surface to achieve matching finishes.

Quality Control:

Perform tests required to confirm structural integrity. Cracks must be ninety percent filled to a bond strength of approximately 6,500 psi.

Brick Construction: General

Masonry work includes historic brickwork from the post-Civil War period and the materials and operations associated with its treatment. The brick used in the fortifications is a dense, reddish-brown, common brick laid in a running bond pattern with regularly spaced header joints. Laid in multiple wythe walls and utilizing arches and vaulting to span openings, the brickwork is set in a Portland cement-sand mortar. Little or no lime was used in the mortar.

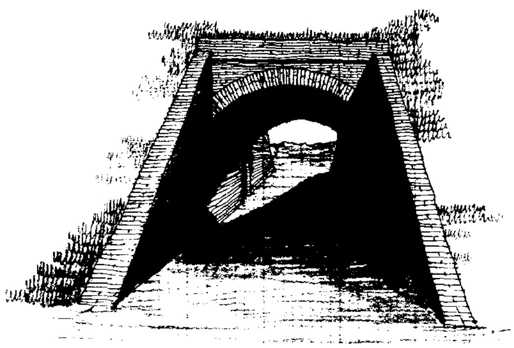
Causes of Deterioration:

1. Rising damp from subsurface moisture sources.
2. Windblown moisture in the form of rain.
3. Condensation due to lack of ventilation.
4. Moisture infiltration through deteriorated moisture joints.
5. Moisture accumulation from the encroachment of vegetation.
6. Moisture from inadequate surface drainage.
7. Improper maintenance.
8. Improper coatings that trap moisture.
9. Failure of waterproofing, roofing, or protective coatings.

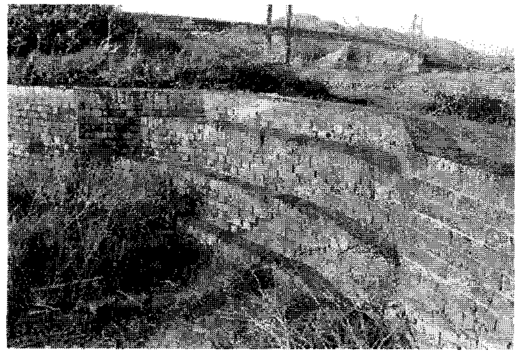
Identification:

Brickwork deterioration can be readily identified by visual inspection. Identifying characteristics include:

1. Mildew, staining, or efflorescence.
2. Soft, loose, or crumbly mortar.
3. Spalling.
4. Cracking.
5. Deflection.
6. Loose bricks.



Cavallo Battery. Detail view of brickwork at vaulted passageway through earthworks. Note arched vault facing with brick headers.



East Battery. Brick parapet at forward edge of gun emplacement.

Inspection and Testing:

Determining the causes and extent of deterioration of historic brick work requires careful field investigation, analysis, and laboratory testing. Review of drawings and other documents can enhance the identification of deterioration. Inspection and testing procedures include:

1. **Field Inspection:** Locate and record the extent of brickwork deterioration.
2. **Document Review:** Refer to original drawings and engineering reports and compare to field data. Check historic records and photographs.
3. **Field Testing:** If required, institute a field testing program including moisture meter readings and sampling of bricks and mortar for laboratory analysis.
4. **Laboratory Analysis:** Laboratory analysis includes:

   Brick compression tests
   Mortar composition analysis (by volume)
   Moisture absorption of brick

Review of field inspection, field testing, and laboratory analysis should give a comprehensive view of the causes of deterioration. Based on the results, a plan for corrective treatment can be developed and tailored to meet treatment objectives.

Brick Construction: Identifying the Problem

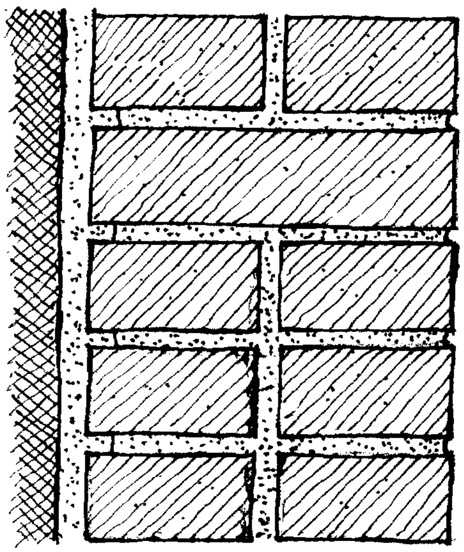
Brickwork deterioration can be the result of individual causes or a number of related causes acting in concert.

Spalling:

Spalling is a loss of surface material due to moisture infiltration. It occurs when moisture inside the brick expands and contracts due to thermal action and when moisture evaporates at the surface of the brick. In climates where freeze-thaw cycles are frequent and extreme, spalling is more pronounced. Expansion and contraction, and evaporation, are mechanical actions that exert force and stress inside the brick. The presence of spalling may indicate that a mortar either too dense or too high in cement content has been used in joints. Dense and brittle mortars obstruct the migration of moisture from the interior of the brick to the point where evaporation occurs. Mortar joints act as sacrificial wicks allowing inevitable deterioration to occur at a location and in a material that is easily repaired. The critical relationship between bricks and mortar relies on the fundamental rule that the mortar should never be harder or more dense than the brick.

Cracking:

Cracking may occur along mortar joints or through bricks. Cracking can be caused by structural movement due to expansive soils, by tree roots too close to a building, by inherent defects in the original construction, by imbedded materials, or by the use of rigid mortars that do not allow normal expansion and contraction. Cracks that follow mortar joints can be addressed through normal treatment procedures while cracks through bricks indicate more severe structural problems. Cracks most often occur at masonry openings.



Cross section of brick wall showing header course and cement plaster parging on earthwork side of brick wall.

Efflorescence:

Efflorescence indicates that soluble salts are present within a brick and are migrating to the surface of the brick. An indication of chemical reactions within the brick, efflorescence can signal moisture-related deterioration.

Mortar Deterioration:

Loss of mortar, while an expected masonry condition, can contribute to further deterioration by allowing continued moisture infiltration. Loss of mortar can be caused by normal leaching-out of lime and through cracking of rigid, high-cement mortars.

Structural:

Structural deterioration is caused by excessive loading, differential load distribution, soil instability, and inadequate foundation support.

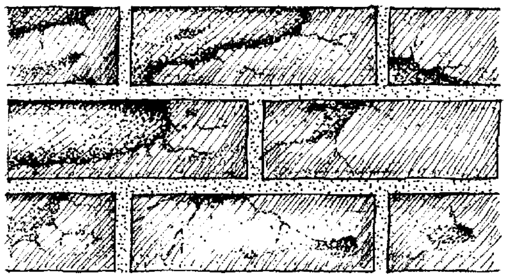
Brick Construction: Treatment Overview

Eliminate the Retention of Moisture:

Clean drains and clear drainage paths. Clear encroaching vegetation and slope grades to drain away from the structure. Install additional drains and repair existing drains.

Eliminate or Minimize Rising Damp:

Install damp course or mechanical barriers that resist hydrostatic pressure. The barrier may be in the form of thru-wall flashing, chemical injection, or surface-applied moistureproofing. Install the barrier above grade. Thru-wall barriers are best installed in mortar joints by raking out the mortar and inserting flashing material in small sections that do not exceed the width of the wall. Flashing sections may be shingled, or lapped as the work proceeds horizontally along the joint. Injection of chemical consolidant involves the saturation of a portion of the masonry with a material that will render the masonry impermeable. Such a procedure depends on the porosity of the masonry and requires extensive testing and coordination. Surface applied waterproofing involves digging out around the base of a wall and installing a vertical barrier from the base of the wall to a point above grade. The vertical barrier is in the form of a membrane material or trowel-applied asphaltic material. In some cases vertical barriers enhance hydrostatic pressure by creating a wick. Vertical barriers must be used in conjunction with other treatment methods that relieve the hydrostatic pressure before it can rise in the wall.



Brick spalling caused by moisture and thermal expansion and contraction and the use of high-cement mortars.

Consider Cracked Brick:

Cracked brick should be replaced only if the cracking goes all the way through the brick and is a part of a larger, more extensive cracking pattern. Replacement will depend on the availability of matching brick. Small hairline cracks that do not extend through the brick should be left alone. Cracks wider than one-sixteenth inch can be repaired with tinted grout that matches the color of the brick.

Brick Spalling is Almost Impossible to Repair:

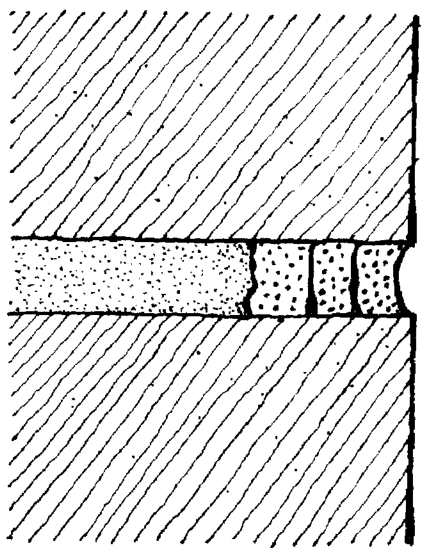
In some cases, individual bricks may be removed from the wall, cleaned, and reinstalled with the damaged face to the inside of the wall. Where spalling is severe, and reversing the bricks is not possible, remedial efforts may be taken to save the remaining fabric of the material. Remedial measures include application of a water-repellent coating or the application of paint that matches the original brick color. Application of protective coatings is not generally recommended but if used, the coating should be breathable and should not significantly alter the brick finish. If salvaged or replica bricks can be obtained, severely damaged brick may be replaced.

Brick Construction: Mortar and Repointing

Mortar joints deterioration is the most common brick masonry problem. The repointing of deteriorated mortar joints requires the careful removal of deteriorated, inappropriate, or loose mortar; cleaning the joints; and installation of new mortar.

Identification and Inspection:

Original mortar should be tested to determine its original constituent materials by volume. The constituents will include cementitious materials and aggregate. The cementitious materials are composed of Portland cement and/or lime. The aggregate is usually sand. The usual and accepted ration of cementitious materials to aggregate is 1:3. That is: one part cementitious materials to three parts aggregate (by volume). While most nineteenth century mortars before 1880 were lime-sand mortars, the mortar used for fortification construction around San Francisco Bay for brick masonry was high in Portland cement content. The extensive use of Portland cement mortar was successful because of the relatively constant climatic conditions of humidity and temperature, and the rarity of freeze-thaw cycles. The hardness of the brick was also a factor allowing the use of a harder mortar. The character-defining features of the mortar depend on the color of the binders, the aggregate, and the joint treatment or finish. Mortar joints from the post-Civil War period were found to be flush to slightly concave joints about three-eighths to one-half inch wide.



Typical brick joint showing repointing technique where deteriorated mortar is raked out to a depth equal to about twice the joint width and replacement mortar is built up in layers.

Treatment:

Rake out loose mortar from joints using handtools, such as chisels, and remove dust and small debris with a brush of compressed air. Avoid damage to adjacent brick.

Mortar for repointing brickwork should be mixed in the following proportions, subject to adjustments based on laboratory analysis:

White Portland Cement: ASTM C 207, Type S	one part
White Hydrated Masons Lime: ASTM C 150, Types I or III	one part
Screened Local Beach Sand: ASTM C 144	six parts

The mortar should be mixed in a paddle mixer or by hand with clean potable water. Based on laboratory analysis, the proportion of lime to cement may vary but the cementitious to aggregate ratio of 1:3 by volume must be maintained.

Finish joints to match original construction profile; concave or flush. After pointing, mortar may be tooled, brushed, or wiped (with burlap) when mortar has set to "thumbnail" hardness.

Brick Construction: Cleaning and Restoration

Masonry cleaning and restoration involves the removal of stains, mildew, dirt, grime, efflorescence, and paint from the brick surface. Masonry cleaning should be approached in a graduated manner. In arriving at an appropriate cleaning and restoration program, proceed from the least strong cleaning method to stronger methods. Use only enough chemicals and force to clean the material. It is preferable to retain existing imperfections than to permanently damage the structure by improper cleaning. Under no circumstances should brick masonry be abrasively cleaned or blasted.

Inspection and Testing:

Masonry cleaning and restoration should be accomplished only by experienced specialists implementing a comprehensive program. The cleaning and restoration program should be based on the approved results of field testing and sample panels. The cleaning and restoration program must be tailored to specific needs. Most cleaning can be accomplished with low pressure water blasting in association with scrubbing with a soft bristle brush. Isolated areas that retain staining or painted coatings such as graffiti after initial cleaning may require stronger measures.

Treatment:

1. Prior to the start of overall cleaning, clean a sample control panel for approval and reference. Demonstrate materials and methods to be used for cleaning the brick on the sample panel. The panel should be selected to include a range of cleaning and restoration requirements and should be of adequate size. Allow panel to stabilize for seven days before proceeding with other cleaning work. Longer observation may be appropriate.
2. Prepare a written program of procedures to be used including a description of the cleaning methods, working pressures, materials, equipment, and other information for each type of cleaning procedure. Comply with safety and environmental requirements.
3. Clean masonry surfaces only when the air temperature is between forty degrees Fahrenheit and eighty degrees Fahrenheit and will remain so for at least forty-eight hours after completion of the work.
4. Perform cleaning and restoration work in sequence with other masonry work. Clean masonry surfaces prior to repointing or other restoration work.
5. Proceed with cleaning in an orderly manner; work from the top to the bottom of each segment and from one end of a structure to the other. Clean in a uniform and consistent manner. Rinse off any residue by working upward from the bottom to the top of each treated area of each segment.
6. Apply water or cleaners in compliance with pressure, volume, and temperature requirements. Hold spray nozzle not less than six inches from the masonry surface and spray from side to side in overlapping bands to insure uniform coverage. Use low-pressure spray from 100psi to 300psi at three to six gallons per minute.
7. Pre-wet masonry to soften and loosen surface materials. Wash, scrub, and spray with low-pressure spray. Apply cleaner only in accordance to manufacturer's written instructions. Rinse as required to remove all chemicals and residue. Repeat cleaning process if required.

Materials and Equipment:

Water: clean, potable, non-staining, and free of oils, acids, salts, and organic matter.

Brushes: fiber bristle only

Spray Equipment: low-pressure tank or chemical pump with a fan-shaped spray tip with an angle of not less than fifteen degrees.

Chemical Cleaning Solutions: dilute all cleaning solutions to produce mixes of a concentration not greater than that required to clean the masonry.

Note: Coordinate cleaning and restoration with other applicable sections in chapter 10.

Brick Construction: Graffiti Removal

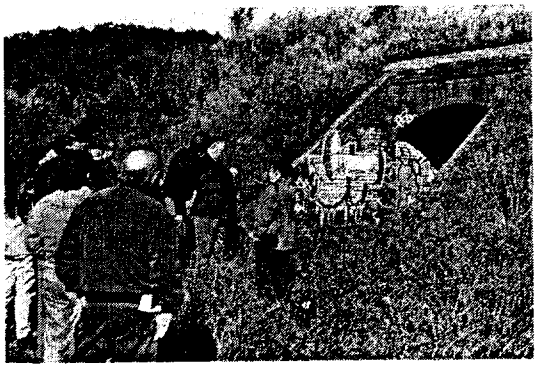
Graffiti removal should be treated as a separate and distinct cleaning process. Graffiti removal will require specific treatment based on the type of paint used, the number of layers, the condition of the substrate, and the degree to which cleaning may permanently affect the historic materials involved. Where large areas have been painted with many coats of paint treatment may be different than small areas that have a single coat of paint. If graffiti removal, based on tests and sample panels, will permanently harm the historic materials a non-permanent, reversible sacrificial coating may be applied to enhance the visual effect.

Painting Out Graffiti:

Temporary solutions for problem graffiti areas include painting over the graffiti with two coats of any high quality latex paint of commercial grade. No special specifications are required.

Note: Refer to Finishes: General; Exterior Concrete Coatings; and Graffiti Removal, for details and coordination.

See also Martin E. Weaver, *Removing Graffiti from Historic Masonry*, Preservation Briefs, No.38, National Park Service, 1995, and, Anne E. Grimmer, *Keeping It Clean: Removing Exterior Dirt, Paint, Stains and Graffiti from Historic Masonry Buildings*, National Park Service, 1988.



Cavallo Battery. Preservation charette discussing treatments for graffiti cleaning or breathable, non-permanent coating.

Cavallo Battery. Graffiti on brickwork forming angle above vault.