Rehabilitation and Maintenance Design for Durability

Réparation et maintenance pour une meilleure durabilité

Instandstellung und Unterhaltung für eine bessere Dauerhaftigkeit

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SUMMARY

The durability of a historic structure is affected by the choice of rehabilitation and maintenance materials and techniques. Interventions which will improve durability are based on a thorough investigation, compatiblity with the existing materials, their weathering characteristics, their use in the building. As illustrated in this paper, both traditional methods and modern technology are used in the repair of adobe and sandstone structures.

RÉSUMÉ

La durabilité d'une structure est fonction des réparations et de la maintanance, au niveau des matériaux et des techniques utilisés. Les interventions, desquelles dépendent la durabilité, sont basées sur une investigation exhaustive, en adéquation avec les matériaux existants et les différentes actions des agents atmosphériques liés à la construction. Comme décrit dans cet article, les méthodes traditionnelles et la technologie moderne sont utilisées dans la réparation des structures en briques et en grès.

ZUSAMMENFASSUNG

Die Dauerhaftigkeit historischer Bauwerke wird durch die Wahl der Instandstellungsmaterialien und -techniken beeinflusst. Massnahmen zur Verbesserung der Dauerhaftigkeit sind aufgrund einer gründlichen Prüfung, der Verträglichkeit mit den vorhandenen Materialien, ihrem Witterungsverhalten und ihrer Verwendung im Bauwerk festzulegen. Wie dieser Beitrag zeigt, werden sowohl traditionelle als auch moderne Methoden zur Reparatur von Sandstein- und Lehmziegelbauten angewendet.

1. INTRODUCTION

The primary aim of conservation of a historic structure is defined in the Venice Charter [1] as the preservation of the authentic and historical values of the structure. Preservation of these values is best achieved by the minimal degree of intervention with the minimal loss of historic fabric. To improve the durability of a historic structure the intervention must be guided by sound conservation principles.

2. GUIDELINES FOR REHABILITATION AND MAINTENANCE

2.1 Building Investigation

A well documented inspection and evaluation of the building should be performed periodically and before major restoration. This investigation should include:

- Review of existing documentation, including original drawings and specifications, previous reports and assessments, maintenance records, and historic photographs.
- A visual assessment and documentation of existing conditions with photographs and drawings. Identification of materials and deterioration problems.
- Field testing. Collection of samples and laboratory analysis. Structural analysis.

2.2 Selection of Repair Materials

Two factors to consider in the selection of repair materials are the properties of the repair material itself and the function of the repaired element in the structure. The repair will be most durable when the repair material has mechanical, thermal and weathering characteristics compatible with the adjacent materials. Structural retrofits must be compatible with the existing load carrying system of the building.

2.3 Duplicating Historic Building Techniques

Existing structures have survived because of the durability of the original construction techniques. The durability of each specific feature of a building can be analyzed and the most successful techniques utilized in rehabilitation and maintenance work. In addition, today's knowledge and technology allows for improvements in design and materials.

Traditional methods and materials are appropriate, for example, in repointing and patching sandstone. However, modern technology can be integrated into the consolidation and structural strengthening of a sandstone building required to meet earthquake standards.

Use of a traditional method and material may be appropriate in a rural New Mexico community where the church and the triannual replastering of the church with mud plaster have historic value. However, improvements in the mud plaster mix by using the optimum particle size distribution, a nonexpansive clay and an improved mixing process will increase the durability of the plaster.

3. CASE STUDY: SANDSTONE REHABILITATION AND MAINTENANCE

Sandstone has been a popular building material in the United States, where it was widely used in the east for 19th Century "brownstone" row houses. On the west coast many high-rise buildings were clad with local sandstone, especially following the 1906 San Francisco earthquake and fire. Sandstone is easily worked but notorious for its tendency to decay, with signs of deterioration sometimes appearing within 20 years of the date of construction. [2] "Replacement in kind" of deteriorated sandstone is often not a viable option, as most sandstone quarries in the United States are now closed. The continued durability of these structures, therefore, rely on a variety of maintenance and rehabilitation techniques.

3.1 Investigation

Sandstone rehabilitation begins with a thorough investigation of the stone material in the context of the building as a whole in order to determine the cause of decay before any restoration is attempted.

3.2 Cleaning

The building is usually cleaned first in order to expose deterioration and prepare the surfaces for repair. Future durability of a building can be profoundly affected by cleaning techniques. Cleaning methods should be tested prior to use, starting with the gentlest and progressing to harsher methods until a satisfactory level of cleaning is achieved.

Sandblasting and other abrasive cleaning techniques can irreparably damage the stone surface and destroy delicate details. Because sandstone deterioration is often water-related, prolonged contact with water is not recommended. Chemical cleaning with a weak acid solution, or with a combination of alkaline prewash and acid afterwash is often effective.

3.3 Repointing

Use of a modern, high strength "durable" material for repointing mortar joints often results in lessened durability for the building as a whole. In general, repointing should be done with a "soft" mortar, lower in strength than the adjacent masonry so that stresses from expansion, moisture migration or settlement can be accommodated within the joints rather than the stones. Use of a hard portland cement mortar can result in accelerated deterioration of the stone, while the mortar joints remain intact, as shown in Fig. 1.

Periodic maintenance of mortar joints will greatly increase the durability of the building by reducing water infiltration into the stone.

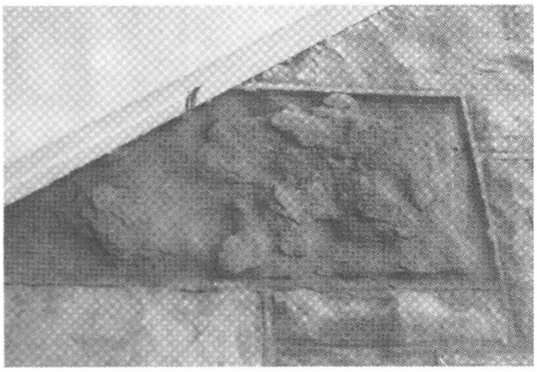

Fig. 1 Stone deterioration at repointed joint

3.4 Composite Patching

Mortar material is used to rebuild deteriorated sections of stone. The mortar is placed by hand or cast into forms to reproduce original details, as shown in Fig. 2. The durability of the patch improves when the patching material is similar to the stone in strength, porosity, and thermal expansion characteristics. The surface preparation, application method, reinforcement, and curing also control the success of the patch. Failure of the repair shown in Fig. 3 occurred because the patch was placed across a mortar joint with no provision for movement of the stones on either side of the joint.

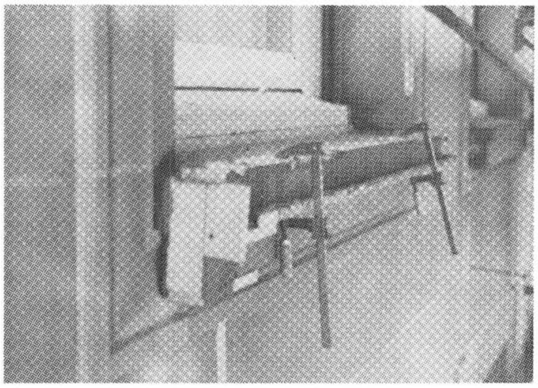

Fig. 2 Stone window sill rebuilt with mortar

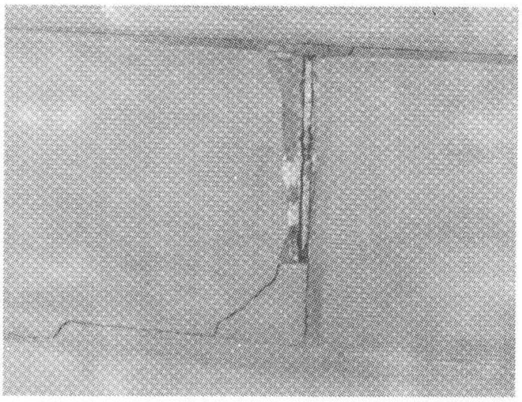

Fig. 3 Failure of patch installed across mortar joint

3.5 Coatings and Consolidants

Painting a sandstone building will, in many cases, decrease durability. Moisture may become trapped and the stone will decay behind the paint film. In isolated cases, coating with a "breathable" paint or water repellent may be appropriate, but such a treatment should be thoroughly tested before general application.

Consolidants are liquids brushed or sprayed onto the stone in order to reinstate cohesion between adjacent grains of stone when the natural cementing material has been lost by weathering. When successfully applied to fairly sound stone, consolidants can increase the durability. However, if proper depth of penetration is not achieved, a hardened surface skin may form which will later spall. Careful testing should be performed before applying a consolidant since the process is irreversable.

3.6 Protective Systems and Maintenance

Durability of a sandstone building depends to a great extent upon the ability to design and maintain details which will keep water away from the building. [3] Rehabilitation and maintenance should include repairs to defective roofs and gutters, installation of flashings, caulking or repointing joints, and solving rising damp and humidity problems. A regular maintenance program will prolong the durability of the stone and help avoid costly large scale restoration.

4. CASE STUDY: ADOBE (MUDBRICK) REHABILITATION AND MAINTENANCE

Adobe, or mudbrick, composed of sand, silt and clay binder, is one of man's oldest building materials, and is still used by an estimated thirty percent of the worlds population [4]. Mudbrick is primarily used in hot dry arid climates because of the deleterious effects of moisture. Water entering the mudbrick physically reacts with the clay reducing the cohesive properties and compressive strength. Consequently, an objective of rehabilitation and maintenance programs for mudbrick is to keep moisture away from the structure.

4.1 Investigation

Early detection and prevention of moisture related deterioration by frequent inspection and early repair is the best way to increase the durability of the mudbrick structure. Typical areas of moisture penetration are the bases of walls, cracked window sills, cracked surface renderings, roof and building joints, and penetrations through the roofs and walls. Typical sources of moisture are improper site drainage, snow or water collection at the wall base, broken sewer and water pipes, high or fluctuating groundwater tables, and deposition of roof runoff near the building base. Water enters the base of walls by capillary action, particularly where the adjacent grade is higher than the foundation.

Often, a detailed investigation, including destructive and nondestructive testing is required when visual inspection is prevented by the presence of a hard rendering. Nondestructive testing using a neutron moisture probe at a two foot grid will provide a map of the moisture content. Destructive tests by sampling with a split tube sampler or removing one square foot sections of the exterior and interior renderings may be necessary when high moisture content is suspected. Changes in the structure and the effect of previous repairs should be evaluated by research of historical data, weather data, and previous repair records.

4.2 Surface Coatings

The primary maintenance procedure for mudbrick structures is periodic applications of a coating as a protection against water and wind erosion. Traditionally, mudplaster has been applied every three years and has served as an easily renewable sacrificial layer. Mudplaster is a porous coating with properties similar to mudbrick units and it allows moisture trapped within the wall to evaporate. Deterioration of the mudbrick is easily detected since the mudplaster will crack in the same location as the substrate and if the wall becomes wet, dark spots will appear on the mudplaster.

A practice in New Mexico is to apply hard nonporous renderings such as cement plaster, soil cement plaster and silicone sprays to mudbrick structures. These renderings trap moisture inside the wall resulting in slumping failure of the mudbrick. Because cement plaster is a brittle coating, movement of a mudbrick wall supported on a drylaid rubble stone foundation causes cracking in the plaster and opens new avenues for moisture penetration.

4.3 Patching

Basal erosion caused by the presence of moisture and freeze thaw action, requires immediate repair because it reduces the load bearing capacity of the wall. The west wall of the San Jose Church in Upper Rociada, New Mexico, shown in Fig. 4, slumped recently after the removal of interior wood furring and removal of adjacent exterior grade. The base of the wall had a moisture content of 17 to 24 percent and the imposition of additional loads on the moist mudbrick base caused the wall failure. Basal erosion is repaired by removing loose material and adding new mudbrick, using

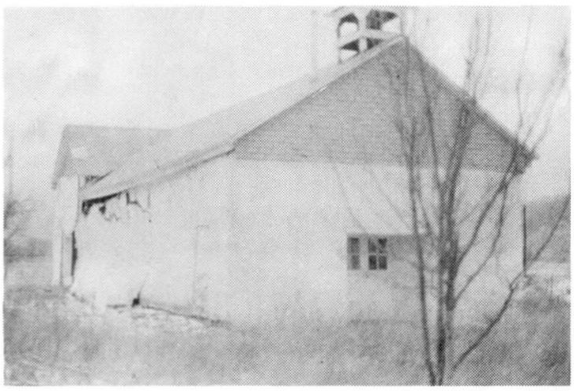

Fig. 4 Wall failure resulting from high moisture content

matching mud mortar. Specifying a good particle size distribution, a nonexpansive clay, and using correct manufacturing procedures for the replacement mudbrick will increase the durability of the repair. [5]

Erosion and cracks at the top of walls are repaired by removing loose material, keeping as much historic fabric as possible, wetting the wall and relaying new mudbricks in mud mortar. Holes and cracks in the wall provide access for water and should be patched using mud mortar applied to a moistened surface in 1/2-inch layers.

4.4 Structural Repairs

Early mudbrick structures in New Mexico were often constructed with a minimal understanding of structural design. Consequently, structural details such as unkeyed corners and large height to width ratios result in wall instability and dangerous movement.

The Pueblo of Acoma in central New Mexico consists of three-story contiguous southfacing mudbrick structures on a high sandstone mesa built by Indians in the eighteenth century. Moisture deterioration has not been a problem in these structures but construction with unkeyed corners and narrow widths of three-story high mudbrick walls caused collapse of a section of an Acoma structure, as shown in Fig. 5. The collapsed wall was rebuilt with additional thickness of adobe and with keyed in corners.

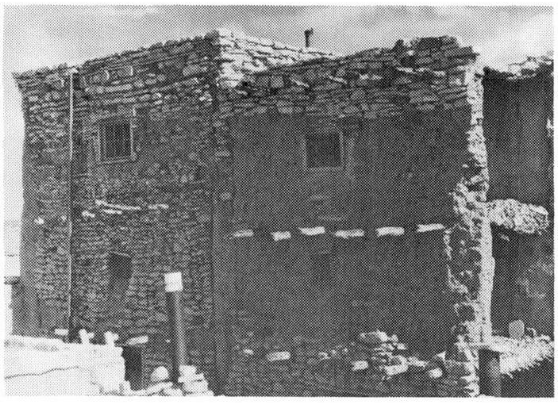

Fig. 5 Mudbrick wall collapse

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