DIFFICULTIES ENCOUNTERED AND SOLUTIONS DEVELOPED IN RESTORING MASONRY BUILDINGS - INVESTIGATION OF FIVE SIGNIFICANT BUILDINGS

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ABSTRACT

Durability is a hallmark of brick masonry construction, but even time-tested materials require maintenance to ensure long life. Managing a National Historic Register property or locally significant landmark may also mean negotiating regulatory restrictions, building codes, and community interests when considering how best to remediate deteriorating masonry. With all of these considerations, even a quality brick structure can feel more like a liability than an asset. But with the right strategy, masonry repairs need not overwhelm one's schedule or budget.(8) This paper reviews the conditions and opportunities challenging the stabilization and repair of five unique masonry buildings: The Wrigley Building - Chicago, Illinois, USA; The Orthodox Monastery - Praxis Germany; Church of the Nanto Bell Tower - Vicenza, Italy; Bennington Battle Monument - Bennington, Vermont; Ashbel Smith Building - Galveston, Texas, USA.

INTRODUCTION

Regional traditions, customs, environment, and material resources are conspirators to the stability, durability, and longevity of the assembly humbling robust preventative maintenance budgets.

Chicago's climate is very tough on buildings. Every structure is vulnerable to the wind driven snow, sleet and rain. In addition, the city's extreme temperatures and rapid temperature changes exacerbate exterior problems by causing expansion and contraction of building facing units that create lifting and heaving of building materials. By the time the effects of weather are acknowledged, it's probable that serious deterioration has already occurred to masonry, supporting steel and wall ties.(9)

Often, the damage starts at the top of the structure through leaking roofs and flashing. In more modern buildings, leaks in and around metal window frames can migrate and cause damage to the wall and to interior spaces. Rusting of supporting elements can affect the integrity of exteriors.

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Original paper presented November 24, 1994, in a series, to the School of Architecture at Texas A&M University

This can be seen in concrete spalling at columns, spandrels, floor slabs and balconies, as reinforcing bars rust and expand. Maintenance and timely repair of weather related problems, combined with regular surveillance, is the only sure way to beat Chicago's notorious climate.(9)

The history of masonry in Italy centers mainly with stone. Buildings constructed in Venetian architecture employed the popular soft limestone quarried in and around Vicenza. The ancient church and bell tower of Nanto, Vicenza was constructed during the 11th century with some changes during the 16th century. The poor quality of the materials and lack of maintenance during the tower’s colorful history made it necessary to required several methods of investigation and repair techniques of the stone structure (2).

Significant events occurring during the history of the United States have prompted the citizens to mark the passing of the events with a variety of monuments. The State of Vermont has paid tribute to the native sons that fought in The Revolutionary War by constructing the Bennington Battle Monument. Dedicated in 1891, the 306 foot tall structure made of blue-grey magnesium limestone (dolomite - containing mainly calcium and magnesium carbonate) suffers from lack of maintenance and water infiltration due in part from natural deterioration (3,4). The work of the project dealt with the repair of the cracked stones and repointing of the masonry for the tapered monument.

The palette of Galveston Island is replete with rich architecture indicative of its prosperous past and colorful citizens. Names like Moody, Sealy, and Clayton paint the past with glamorous stories and elegant buildings. One such indelible print on the landscape is the Ashbel Smith Building, funded in part by Moody, and designed by Nicholas Clayton. Such was to be the home of the state of Texas Medical School Opened in October, 1891, the facility was an intense exercise, by Clayton, to ensure its design benefitted from the most recent ideas concerning construction, layout and medical equipment (5). Plagued by abuse, poor maintenance and a lack of money, the building quickly fell into disrepair and deterioration. Beginning in 1980 a full scale restoration project began to return "Old Red" to past elegance and splendor.

<u>WRIGLEY BUILDING</u> **Maintenance of Terra Cotta**

Consisting of two separate structures [Figure 1], the headquarters of the Wm. Wrigley Jr. Company, was designed by the firms of Graham, Anderson, Probst and White and clad in a white color glazed terra cotta (6). Complete in 1924, the south building is 25 stories in height and the north building is 18 stories in height.

Cleaning of the building’s terra cotta followed various schedules and methods from its completion to the present time which are described as follows:

- ❏ 1929 through mid-1960’s twice a year, method and material used - unknown,
- ❏ mid-1960’s through 1971 facades only once a year,
- ❏ completely cleaned in 1975,
- ❏ partial cleaning of the lower three floors in 1977,

- ❑ method used from mid-1960’s through 1977 was brushing and low pressure water with dilute hydrofluoric acid (HF). Concentration of solution and dwell time on the building is not known.

Replacement of damaged terra cotta stones was by replication using polymer concrete (6).

Development of a cleaning program for the building had to include processes that would not only regard the damages of past cleanings, but consider the various types of terra cotta and the replacement replica stones. The available cleaning techniques considered were as follows:

- ❑ Water Cleaning involves the use of steam or water under pressure, additionally the:
  - ❍ pressure used and time length of application may vary with the results desired,
  - ❍ intent is to loosen dirt particles and rinse away simultaneously,
  - ❍ use of large quantities of water, over extended time periods, may effect the metal anchorages of the terra cotta thus allow water to penetrate the interior.
- ❑ Abrasive Cleaning involves the use of aggregate under pressure, additionally the:
  - ❍ type aggregate used and application pressure may vary with results desired,
  - ❍ abrasive action wears down the dirt particles blowing them away,
  - ❍ abrasive action may result in the loss of surface and portions of the material surfaces,
  - ❍ method is not recommended on glazed terra cotta.
- ❑ Chemical Cleaning involves the use of acidic solutions applied directly to the material surfaces by brush or spray, allowed to dwell on the material surface and then rinsed away with water under pressure. Additionally the:
  - ❍ past solutions consisted of either dilute muriatic acid (hydrochloric) or hydrofluoric acid,
  - ❍ currently, many proprietary solutions are available that are formulated for the particular masonry materials and the type of dirt encountered,
    - ❖ ideally chemicals will react with the dirt and not the masonry surface.

Establishing the appropriate cleaning program and process to implement required an in depth testing program to determine what effects the past actions have had on the terra cotta and the replicated replacement stones found on the building. Eighteen samples from horizontal and vertical surfaces including terra cotta and replica stones were sampled and evaluated as follows:

- ❑ samples were examined using a scanning electron microscope equipped with a high energy dispersive X-ray analyzer to determine the carbon content of the dirt,
- ❑ prior to cleaning the surface glaze on the terra cotta samples were virtually and microscopically examined. This revealed the presence of numerous "crazing" in the glaze surfaces [Figure 2], (6),
- ❑ examination of the cross-section of the glaze surfaces revealed a varying thickness of the terra cotta glaze between 1.33mm and 1.48mm [Figure 3],

- the average thickness found on the replacement terra cotta stones averaged .533mm. The finely graded matrix of the polymer concrete stones average .33mm in thickness,
- examination of cross-section of the glaze surface of the original terra cotta samples indicated that many of the crazing cracks extended through the glaze and into the clay body of the stone. (When crazing cracks extend through die depth of the glaze, moisture permeance will not be resisted. Dirt particles may also penetrate into the clay body and cause discoloration [Figure 4], (6),
- examination of the uncracked surface glaze of the samples were found to be etched and eroded resulting from past cleanings with strong acid solutions [Figure 5],
- to evaluate the extent of damage, terra cotta from a different building of comparative age were removed and examined [Figure 6]. The surfaces were roughened from exposure to pollution and acid cleanings. The deterioration was not as severe as on the Wrigley Building.

Resulting from all the testing, research and discovery, several cleaning solutions were selected and tested as follows:

- each solution was applied in a manner recommended by the manufacturer,
- each allowed to stand for the specific dwell time and thoroughly rinsed off,
- a second application of the same solution or a different solution was applied if recommended by the manufacturer then rinsed off,
- scrubbing of particular soiled samples was performed as recommended by the manufacturer,
- all samples were given a thorough rinse and allowed to dry at room temperature.

Upon completion of the testing, portions of the glaze samples "were magnified and examined [Figure 6]. Test results indicated the dirt was sufficiently removed and the glaze was not adversely affected. Such was also true for the replacement terra cotta and the polymer concrete stone.

Additional tests were made to determine if the selected clean solution and process would effect the permeance resistance of the terra cotta, the replacement terra cotta and the polymer concrete stone. Results of the testing indicated that the original terra cotta experienced significant increases in permeability rates. The resistance before cleaning was determined to be 67% and after cleaning the percentage resistance was 58% effective. This reduction in resistance was believed to result from the removal of the dirt. Though not desirable, this was not believed to be of great concern (6).

Cleaning sequences were determined based upon the number of summer days required to dry the shaded north elevation. Thus the north side was first followed by the east, south and west. Performance of the cleaner is affected by the surface temperature of the material it is to clean as follows:

- excessively high the solution can evaporate before the dirt particles are completely reacted with and a solution laden with dirt particles can be drawn into the clay body,

- ❑ excessively low the reaction time of the chemical is increased,
- ❑ excessively high surface temperatures can be cooled with cool water rinse and excessively low surface temperatures can be raised with warm water rinse.

The success of a cleaning program can be assured by doing the following:

- ❑ eliminating all the guess work, testing and research prior to beginning work,
- ❑ developing a proper cleaner and process resulting from research and testing,
- ❑ developing a proper process and solution will eliminate irreparable damage resulting from poor planning,
- ❑ development of the specifications that will be enforced and adhered to be closely selected qualified contractors,
- ❑ periodic monitoring in the field reduces deviations from the specifications and program.

THE ORTHODOX MONASTERY **Redevelopment Mortars**

Over the past eighteen years the use of redevelopment-plaster has proven to be a simple and sure method for arresting the damage resulting from damp and over-salted masonry. Used as a standard practice in Germany, its application is an integral part of post-installation of horizontal damp courses and for the restoration of the plaster coatings without involving the existing masonry covered by the plaster. Moisture in the masonry can diffuse as vapor through the plaster and due to the specific structure of the material, sufficient space exists for the crystallization of salt. Redevelopment plaster has been proven several fold to last longer than lime-cement mortars even when the horizontal insulation (damp course) is missing (1).

The benefits of using redevelopment plaster are [Figure7]:

- ❑ low capillarity and its high permeability of water molecules,
- ❑ the pore structure’s ability to "collect" the salt,
- ❑ moisture can evaporate through its pore structure.

The hazards of using lime-cement plasters are [Figure 8]:

- ❑ salt content in the evaporation zone will increase, destroying that area over time,
- ❑ plaster is destroyed and has fallen off, the destruction on the masonry will continue,
- ❑ lime-cement plasters are anhydrous and will absorb and hold moisture.

The moisture ascends in the masonry through capillary action, which is due mostly to missing or defective horizontal insulation and to standing water (7). Under these conditions damage to the paint, the plaster and the masonry is caused mostly by the transported salt. Moisture entering the masonry will ascend in five basic mechanisms:

- ❑ absorption of water through capillary action,
- ❑ absorption of water due to pressure of water leakage or runoff water,
- ❑ hygroscopic water absorption,

- ❏ absorption of water through capillary condensation,
- ❏ absorption of water through condensation.

The first three mechanisms are mostly responsible for dampness ascending in the masonry, of which, the capillary action of water plays the biggest role. Since condensation mechanisms require a different type of restoration process, it is important that it not be confused with the other water absorption mechanisms.

The greatest damage of ascending moisture in the masonry is caused by transported salts. Salts are often hygroscopic, which means, they attract water molecules from the atmosphere. In addition, salts, due to crystallization and hydration processes, can produce quite a bit of pressure to building materials. Because of the pressure, very strong materials, like concrete, can be destroyed.

In Germany as in the United States, having the proper knowledge of material applications and the appropriateness of it use, is often assailed for less costlier methods. Prior to restoration, the wall of the Orthodox Monastery was improperly treated with of very hard and steam tight cement-plaster [Figure 9], or the application of so-called ventilation pipes, were utilized on damp masonry. Removal of the plaster from the masonry, leaving the wall exposed is likewise inappropriate. With this the effects of salts can directly affect the masonry. The damage and subsequent restoration will be more extensive and difficult to do. An example, from Venice [Figure 10], shows the negative effect of such an undertaking.

Companion work that should be under taken when using redevelopment plasters, should include horizontal insulation and vertical sealing. More often than not, on many projects, the horizontal insulation is not performed due to high cost, or problems with static cold could arise.

Important processes for horizontal insulations are:

- ❏ process of cutting masonry,
- ❏ foundation work,
- ❏ process of chrome-steel sheet metal (damp course),
- ❏ process of drill and injection, (fluid grouts or consolidants),
- ❏ process of replacing masonry,
- ❏ process of electrophysics.

The vertical sealing can be improved by the following:

- ❏ placement of concrete jackets at the foundation,
- ❏ resistance plaster in different levels,
- ❏ watertight caulking,
- ❏ sealants,
- ❏ sealants with bitumen.

Work on the Orthodox Monastery in Praxis, Germany began with most of the exterior wall totally involved with rising damp and deterioration of the masonry [Figure 11]. Decaying efflorescent salts covered much of the surfaces and the internal pressures were spalling the brick, popping the plaster from the masonry and contributing to staining and damage to the internal surfaces. Upon completion of the researching the building's history, determining how the water and moisture was migrating into the masonry, work began to correct the problems.

Horizontal insulation included the damp course, consolidation and replacement of deteriorated units. Vertical insulation included cleaning of the brick, application of the redevelopment plaster on the interior and exterior and repainting with vapor porous paint. Figure 12 is typical of the other elevations of the monastery. The interior plaster has functioned just as well.

Redevelopment plasters should have the following properties:

PROPERTY	VALUES
air-pore space of fresh plaster	> 25 Vol. %
vapor-diffusion-resistance number μ	< 12
capillary water intake after 24 hours	.28" > h > .119"
pressure resistance after 28 days	hg < .03 Lbs/in
proportion of pressure to elasticity after 28 days	hg < 3.0 E

Paints that would be used over redevelopment plaster should have an Sd (Pore) value of < .008". Coating having appropriate Sd values would be silicate based paints, dispersion-silicate paints and silicone-resin paints, (1).

<u>CHURCH OF NANTO BELL TOWER</u> **Stone Masonry**

Primary issues concerning this 11th century tower [Figure 13] were:

Structural:

- ❑ small and diffused cracks in the stones,
- ❑ large vertical structure separation crack in the south wall of the tower,
- ❑ the foundation system on sloping and irregular surface bedrock,
- ❑ the slope was covered by a thin layer of limestone that would vary in thickness.

Preservation and Architectural:

- ❑ maintaining the character and integrity of the tower,

- ❑ using all the stones in place,
- ❑ replacing only if absolutely necessary,
- ❑ develop a work program that would allow the tower to remain open.

Close investigations of the tower structure and stones revealed critical information that would lead to several methods of non-destructive investigations. Figure 14a shows the severe deterioration of the stone. Figure 14b reveals the nature of the local cracks with individual stones. Figure 15 shows the major vertical crack in the South Wall (2).

Restoration interventions were developed based upon a combined experimental-numerical procedure consisting upon the following steps:

- ❑ in-situ (the original positions in place) evaluations of the actual state of stress, strength and deformity of the masonry by means of flat-jack technique,
- ❑ analysis of the masonry bonding and composition by means of bore-scope and video,
- ❑ in-situ investigations of the ambient vibrations, before and after the strengthening work,
- ❑ construction of a numerical model, assuming the mechanical properties of the material experimentally derived and inspected,
- ❑ calibration of the model through static and design values analysis comparing experimental and theoretical values of local stresses and of the fundamental period of vibration measured before the restoration,
- ❑ re-calibrate the model to estimate the efficiency of the restoration work repeating the measurement and numerical calculation for the fundamental period of vibration after restoration.

Initial bore-scope investigations revealed the through-the-wall composition of the masonry. Typical core samples showed a poor quality of masonry behind the external wythe, made with dressed stones. The mortar, which did not completely fill the large spaces and joints between the stones, was found to be an equally poor quality with no apparent consistency (2).

Results of the flat-jack testing revealed that the stresses in the two sections of the tower (both sides of the crack and the central entrance), were quite different. The east part of the tower had mean stresses that were twice that of the west portion. Also indicated was that the external, more stiff wythe of dressed stones, induced very significant stress concentrations.

Data deduced from the experimental and numerical investigations methods were:

- ❑ values of the normal stresses measured in the internal face of the tower masonry walls were almost identical to the stress levels measured in the materials,
- ❑ the major cracks behaved as structural joints.

Primary to the solution was the concept of increasing the compressive strength of the masonry, and improving the ability of the structure to transmit lateral forces along the major crack. The methods used were:

- epoxy injections and horizontal steel tie rods to increase the compressive strength at each level of the tower - this will allow the walls to co-operate structurally,
- stainless steel bars and plates for ties passing through the masonry and for external anchoring devices - bolted connections are used and the ties are inserted in small holes drilled through the stones which will remain void so that the systems can be removed, if necessary [Figures 15&16].

BENNINGTON BATTLE MONUMENT

Dedicated in 1891 to honor the American patriots who fought in the historic battle of the American Revolution, this 306 foot high obelisk received little maintenance to counteract natural deterioration for nearly 100 years since. This facility is the state of Vermont's most popular historic tourist attraction.

The base of the monument is approximately 37 feet square. The walls taper from a thickness 7 feet 6 inches at the base and 2 feet at the top [Figure17]. The structures tapers inward in height and width. Since its dedication the monument has under changes in, ownership, maintenance, and repairs and physical condition as indicated here:

- 1891 - monument construction and dedicated by the Bennington Battle Monument Association,
- 1920's - first appearance of cracks in the exterior stone,
- 1953 - earliest report on the monument indicated that only minor repairs were made prior to 1953, which by this time was badly deteriorated,
- 1953 - State of Vermont took control because the local association was unable to raise the funds necessary to make repairs,
- 1954 & 1955 - masonry repairs included,
    - repointing and stone waterproofed,
    - bronze pins driven in cracks of exterior stone,
    - six electric fan steam heaters and two ventilation louvers added to help reduce humidity levels,
- 1955 - elevator was added and observation level windows closed,
- 1959 - issuance of a report that criticized the previous repairs as being haphazard,
- 1959 - top 30 feet repointed and stone waterproofed with silicone,
- 1980 & 1981 - top 90 feet repointed and sealant installed in stone and mortar cracks, plastic weeps were installed in caulked relief joints,
- 1987 - began the current restoration in three phases, emergency repairs to the interior stairs and landings (Phase One) and a new Masonry Restoration Study (Phase Two),
- 1989 - Phase Two complete,
- 1990 & 1991 - Restoration repair work (Work Phase Three) began and was

completed.

The masonry investigation study (Phase Two) of the restoration program identified the following concerns regarding the masonry:

<u>Investigation Techniques Used:</u>

- ❏ Visual
  - ❍ examinations of the surfaces were made through field glasses and photographs,
  - ❍ direct access was only possible below 30 feet,
  - ❍ observations were made seasonally and verifying weather conditions and understanding climatic effects on the stone.
- ❏ Physical
  - ❍ two cores taken from the interior to the exterior without penetrating the exterior face of the exterior stone,
  - ❍ core samples verified the capacity and integrity of the rubble wythe and the mortar,
  - ❍ samples of mortar taken from the exterior and interior using a masonry drill, to determine the dept of previous repointing versus the overall joint depth an the integrity of the original mortar behind the pointed mortar.
- ❏ Chemical
  - ❍ laboratory analysis of the original and pointing mortar samples to determine composition constituents and proportions.
- ❏ Structural Analysis of Masonry
  - ❍ test performed was to determine the stresses due to weight of masonry in combination with wind forces, seismic effects were not analyzed,
  - O results comparing the calculated stresses versus the material strength indicated a safety factor for the stone to be 8 which was indicative of the engineering principles at the time of the original design.

Summary results of the masonry study indicated that:

- ❏ cracking of the stone was not likely due to structural effects,
- ❏ repairs could be made on a stone by stone basis,
- ❏ almost 95 percent of the problems came from moisture infiltration due to mortar deterioration resulting from freeze-thaw effects. The entire monument must be totally repointed,
- ❏ monument’s poor condition was due to lack of and appropriate maintenance and repair program,
- ❏ due to no anticipated structural tension applied to the stones, the deteriorated mortar could remain if confined and not erode. All joints must be made watertight,
- ❏ waterproofing of the stone faces would not be necessary do to the low IRA (Initial Rates of Absorption) values,
- ❏ previous caulking accelerated the deterioration of the underlying mortar due to trapped moisture not allowed to escape,
- ❏ repointing mortar should have an air entrainment content between 16% and 18%.

This would provide resistance to at lease 1200 freeze-thaw cycles.

Stone - Blue-Grey Magnesium Limestone (Dolomite)

- ❏ cracks in the stone are both horizontal and vertical through the stone,
- ❏ cracks appear on the interior and exterior faces of the monument. The cracks on the exterior are more extensive,
- ❏ exterior cracking patterns do not relate to the interior patterns, except for the top stone, which is a single stone,
- ❏ cracks sizes vary from hairline to 3/8" wide,
- ❏ exterior stone cracks started with vertical mortar joint, continued through one or two courses and ended with vertical mortar joint,
- ❏ alternating cracks with mortar joints continued through eight to ten courses at wall mid-face, [Figure 18],
- ❏ corner cracks of exterior stone, at the corners, follow similar pattern of starting and ending with vertical mortar joints,
- ❏ corner cracks, alternating with the mortar joints, were more extensive and continued through 20 or more courses [Figure 18],
- ❏ horizontal or bed joint cracks appeared at random and were more isolated.

Stone and Mortar Deterioration

- ❏ except for some cracked edges due to pointing mortar of the 1950's and some exfoliation of the faces due natural weathering and some having gypsum coatings due to acid rain, the exterior faces stone was found to be in good condition,
- ❏ exterior mortar was a pointing mortar of the 1950's and the interior mortar was found to be original,
- ❏ exterior re-pointing mortar was generally hard and in good condition, but the underlying mortar was wet and in many locations reduced to a sandy consistency resulting from freeze-thaw effects,
- ❏ interior mortar was found to be soft and in varying stages of deterioration,
- ❏ efflorescence was evident on the interior due to moisture penetration through the deteriorated mortar joints.

Water Infiltration

- ❏ interior was often wet and humid as water would enter through the cap stone,
- ❏ Prior to 1955, all the window and vent openings in the walls were open to the weather elements. Water and snow would enter the monument,
- ❏ the majority of the masonry discoloration is attributed to the infiltration damage prior to enclosing the openings.
- ❏ previous attempts to limit infiltration included the following:
    - ❍ repointing,
    - ❍ applying a silicone coating to stone,
    - ❍ installing caulking to the mortar joints at the top of the monument,
    - ❍ installing caulking to the horizontal joints and enclosing the openings in the exterior wall.

Information and facts for the above (3).

Phase Three of the project included the actual restoration repairs to the monument. The highlights are detailed as follows:

Water Infiltration Repairs

- ❑ Majority of the problems resulted from water infiltration,
- ❑ Total repointing was required in varying degrees at different levels,
  - ❍ mortar was removed in three phases,
    - ❖ a grinder was used to saw-cut and weaken the hard repointing mortar
    - ❖ a pneumatic carving tool with a flat tip the broken mortar was removed [Figure 19]
    - ❖ the original mortar was removed to the prescribed depth using a curving tip on the pneumatic tool.
  - ❍ 5" deep for the upper 100 feet of height,
  - ❍ 2-1/2" deep for the remaining 206 feet,
  - ❍ mortar was built-up in 3/4" increments and was required to be thumb-print hard prior to the next increment being applied,
  - ❍ 10 to 15 courses of mortar were removed at a time and then replaced prior to continuing,
  - ❍ joints were sprayed with water bottles as the work continued such that they were kept moist for at least two days,
  - ❍ mortar component were dry mixed and sufficient water was added to dampen the mix,
  - ❍ the mix pre-hydrated for 30 to 60 minutes then final mixing water was added and mixing completed.
- ❑ Mortar proportions,
  - ❍ 2 parts of Glenn Falls masonry light cement,
  - ❍ 5 parts masonry sand from a pit in Poestenskill, New York

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Stone Repairs

- ❑ As the mortar joint work progressed from the swinging stage, damaged stones were marked on a daily basis and recorded,
- ❑ Small cracks less than 1/4" in width were repaired by epoxy injection. Previous testing indicated the cracks to be surface only,
- ❑ Larger cracks were treated like mortar joints,
- ❑ Active cracks were routed out and deep repointed up to one inch from the surface which was then treated like an expansion joint with a backer rod and sealant,
- ❑ To drain any water that might permeate the joint, weep tubes were installed at the base of each such stone,
- ❑ Larger cracks required stainless steel staples to be embedded into the stone, set with epoxy and the opening filled with sealant and covered with limestone dust,
- ❑ Damaged stone faces were patched with a cement based patching compound

placed over wire that was wrapped around stainless steel pins. The compound was built-up over the mesh and cured,
- ❑ Thicker stone repairs included the actual stone pieces, that were pinned back to the base stone with epoxy and mortar applied.

Information and facts for the above (4).

ASHBEL SMITH BUILDING **Stone Masonry**

The island city of Galveston suffered greatly from the hurricane of 1900. The Ashbel Smith building lost its west end cupola and much of the central pavilion roof, but the building known as "Old Red" survived. Following the hurricane the roof was rebuilt eliminating the central pavilion and the cupolas on the semi-circular ends. The red clay roof was eventually replaced with green and blue slate tiles (5).

Over the succeeding years, the interior experienced a variety of changes and the exterior was tuck pointed as needed, fire escapes appeared and the harsh corrosive sea winds began to exact their toll on the masonry and stone. The building began to deteriorate and slowly change its original character.

Between 1960 and 1980 the building experienced the several studies and changes as listed here:

- ❑ 1966 - an engineering study was made to access the structural integrity to determine if building could be used for three more years,
- ❑ 1969 - slated to be demolished for a new building,
- ❑ 1969 - approximate date entered on the National Register of Historic Places and Texas Historical Survey,
- ❑ 1971 - UTMB commissioned a use feasibility study investigating the options of rehabilitation, conservation, and demolition,
- ❑ 1973 - Feasibility study made by Architectural Firm of Wilson, Crane, Anderson, Reynolds, Inc. which included proposals to making the building a viable part of the medical school system,
- ❑ 1974 - study was presented. Building stood vacant awaiting funding during which time the building experienced severe damage resulting from water leakage and shifting masonry,
- ❑ 1975 - an attempt to raise funds and expand the historical significance and future value of the building,
- ❑ 1975 - paper issued by Chester Bums, M.D., Ph.D. listing several reasons why the building should be saved,
  - ❍ the Ashbel Smith Building is the only medical school building in the United States constructed before 1900 that once housed an entire medical school complex and is still an integral part of the complex [Figure 20],
  - ❍ it is the only extent medical school building west of the Mississippi River built before 1900,
  - ❍ it is the only medical school building of its kind that is designated as a historical landmark in its state,

- ❍ The building is listed on the National Register of Historical Places,
- ❍ 1980 - Crain/Anderson, Inc. was commissioned to update its earlier study and revise drawings and cost estimates to current needs, existing conditions and market trends.
- ❑ Upon completion and presentation of the study funding was made available.

The damage assessment phase of the restoration program identified the following concerns regarding the masonry:

<u>Clay Masonry</u>

- ❑ Tuckpointing was required for the majority of the mortar joints,
- ❑ Found over the arched window heads and throughout the brick walls were cracks ranging from hairline to over one inch [Figure 21],
- ❑ Rusted flat plate steel lintels had sagged thus causing displacement of the adjacent masonry,
- ❑ Masonry at the floor lines had been fully involved with moisture,
- ❑ Resulting moisture was responsible for failure in the bond and erosion of the mortar and separation of the wythes,
- ❑ The exterior wythes experienced separation at the collar joints in excess of 2". Face brick wythe on the west wall had moved as much as 5" prior to restoration work beginning,
- ❑ Interior wythe of the exterior walls required repointing,
- ❑ Damage to the interior wythe of the semi-circular wall of the amphitheater was extensive enough to require relaying.
- ❑ Surfaces of the veneer brick of the masonry stepped footings crumbled but the brick was solid below the grade,
- ❑ Brick and mortar analysis indicated that the mean strength was 5550 psi with a standard deviation of 665 psi,
- ❑ Original mortar was weak and friable; non air entrained and composed of fine natural sand, Portland cement, and hydrated lime. Proportions varied from 1:1:14, 1:1:17, 1:1/5:16 for cement, lime and sand.
- ❑ Halite (NaCl) was also found in the mortar. This may have resulted from the use of sea water of by the uptake of chloride from the atmosphere.

<u>Stucco Masonry</u>

- ❑ Exterior stucco masonry experience deterioration from internal moisture and atmospheric erosion from the salt air,
- ❑ Spalling and cracking occurred from expansion movement of adjacent masonry caused by trapped moisture. Stucco masonry was used as artificial sandstone.
- ❑ Bleaching and discoloration occurred over time,
- ❑ Many of the decorative elements had been smoothed by the salty winds - the column capitols of the entry porch were particularly effected [Figure 22].

Rehabilitation of the building was to bring the exterior to its condition prior to the 1900 hurricane. The masonry work was very important in that not only was it visible but much of it was structural. Work accomplished was as follows:

Clay Masonry

- ❑ Tuckpointing mortar was specified to be soft and proportioned by volume as 1:1:6. Portland cement (ASTM C150, Type II), hydrated lime (ASTM C207, Type S) and sand (ASTM C144),
- ❑ Cleaning and preparation of the brick joints was carried out using hand and power tools [Figure 23]. The joints were raked one inch deep and the loose mortar was washed out during a wall saturation process a day before tuckpointing began,
- ❑ All masonry to be tuckpointed for the day was to be wet with no standing water on the brick or in the joints to be worked,
- ❑ Initial mortar installation (using a harder mortar) filled all voids to with one-half (1/2") of the brick face. This was for structural purposes,
- ❑ Second application (cosmetic) was with a dark grey mortar to match the building's original color. Hand tooling of the joint followed,
- ❑ Taping of the brick to prevent staining was not permitted due to the softness of the brick,
- ❑ Cleaning process of the stained building was carried out according to previously conducted tests,
- ❑ Building was washed downed with low pressure spray,
- ❑ Pre-cleaning fluid was applied and allowed a dwell time,
- ❑ Bricks were the scrubbed by hand using soft bristled brushes,
- ❑ Cleaning solution was rinsed off using low pressure spray and a neutralizer put on, allowed to stand briefly and then rinsed off,
- ❑ Efflorescence began to appear and the neutralizer was applied and rinsed off again. This additional step removed the majority of all the discoloration and dirt.

Stucco Masonry

- ❑ Prior to repair work, a thorough cleaning of all stucco masonry was conducted.
- ❑ Loose stucco was removed and cracked stucco was cut bask and patched,
- ❑ Prior to the application of the stucco skim coat, samples of the existing material were taken from various locations on the building,
- ❑ A medium target color was selected from various color samples; several more samples were made and compared with the building color and a final was approved,
- ❑ Stone like appearance of the ashlar patterns were recreated,
- ❑ Rubber casting of the artificial sandstone castings were taken and then recast in wax,
- ❑ The fine details were sharpened by adding wax to the forms,
- ❑ Plaster casts were made from the completed wax forms, then a positive cast was made,
- ❑ Positive casts were refined and negative casts were made to be used as master molds,

- ❑ Four to five molds were necessary for a complete capital,
- ❑ The existing capitols were removed; the final casts made; the color corrected and put in place with dowels. The void back was poured full with grout. The new product was a replica.

The granite dedication plaque was re-cut and reinstalled. Figure 24 is an artist's sketch of the finished building. Figure 25 is photograph of the building in 1985.

SUMMARY

The five buildings discussed in this paper were constructed of different materials categorized under the broad heading of masonry. Each problem was addressed according to its uniqueness yet respectful of the ten major standards of the Secretary of the Interior and, on an international scale, the same respect and premiss that work should be reversible and replications made only when the originals can not saved or do not exist.

Each project achieved the goals established from logical and appropriate methods by always keeping the integrity of the building at the forefront of the effort. Restoration work requires the talents and skills of many professionals and disciplines as these case studies indicate. The project costs were budgeted but the quality of the work within the goal standards was paramount and the focus.

FIGURES

Figure 1 - Wrigley Building as Viewed from South Street

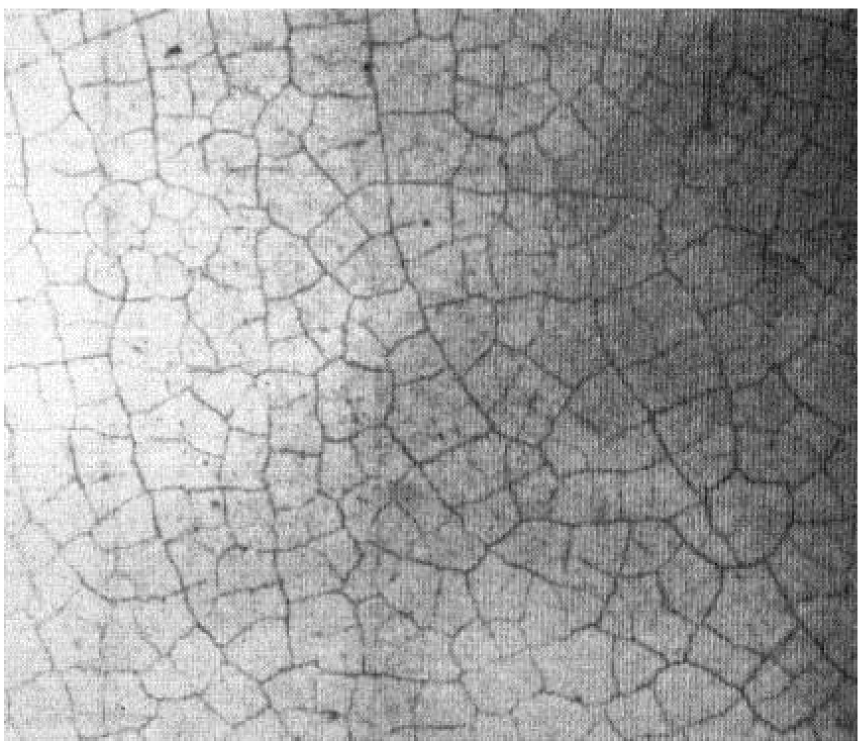


Figure 2 - Typical crazed conditions of terra cotta found on the building

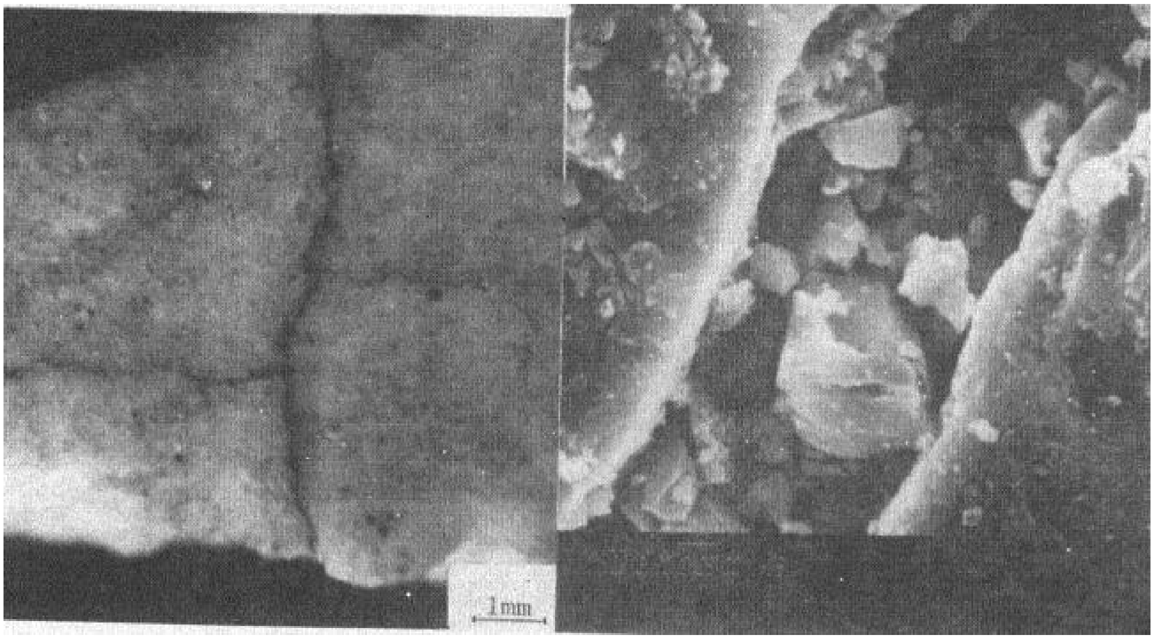


Figure 3 - Photograph on the left shows a typical crazing crack found on the samples. Photograph on the right is a 5000x magnification of a crazing showing the accumulated dirt particles.

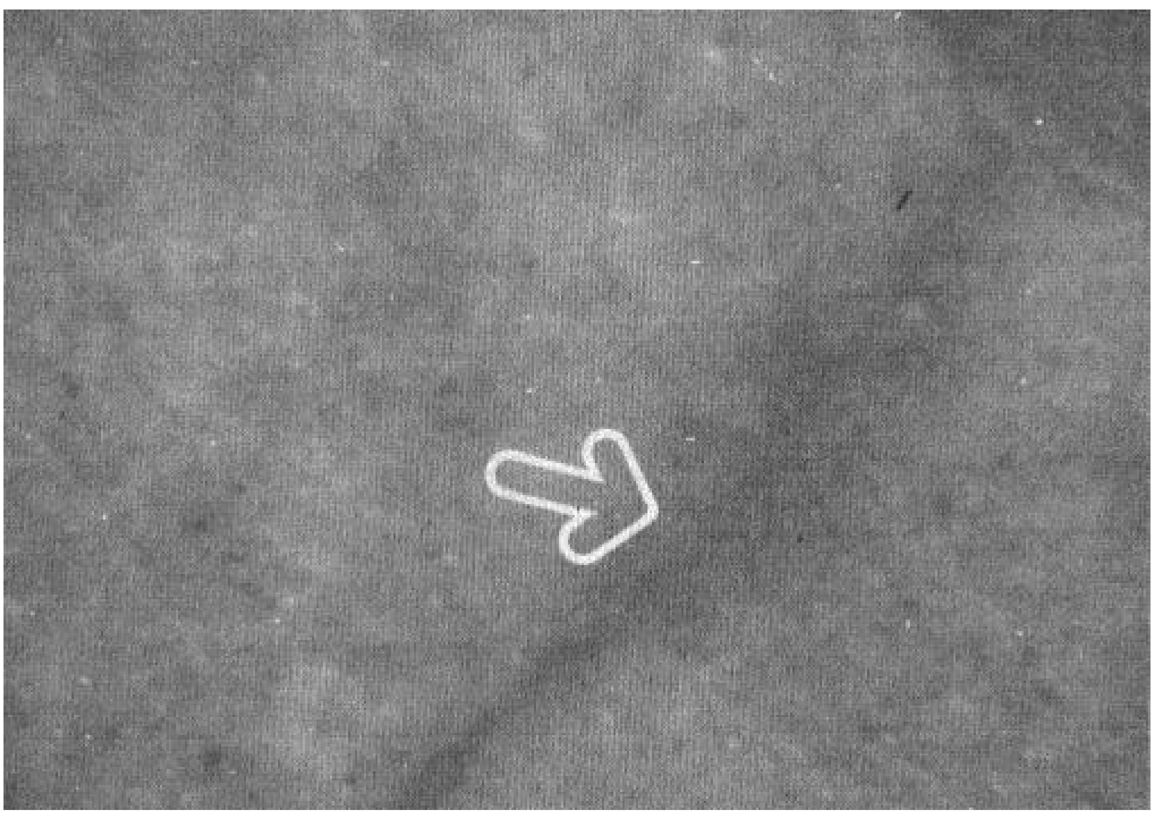


Figure 4 - Accumulation of dirt particles behind the surface glaze (arrow)

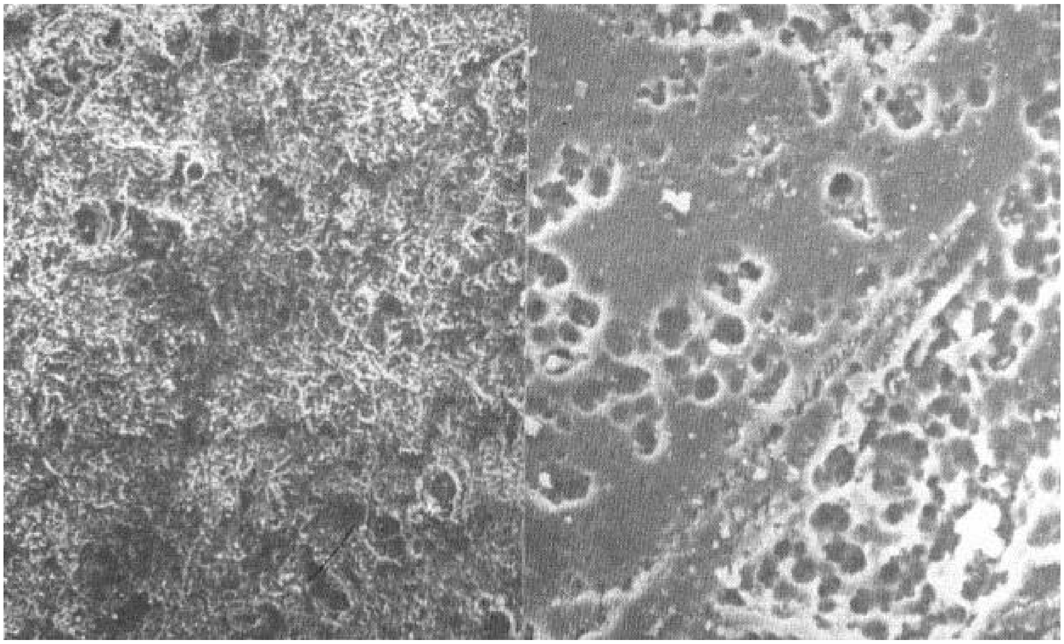


Figure 5 - Micrographs of hte uncracked glaze surface when viewed using 100x and 1000x magnification respectively.

Figure 6 - Close-up views of a terra cotta sample after cleaning. The photograph on the right is a crazing crack when viewed using 5000x magnification.

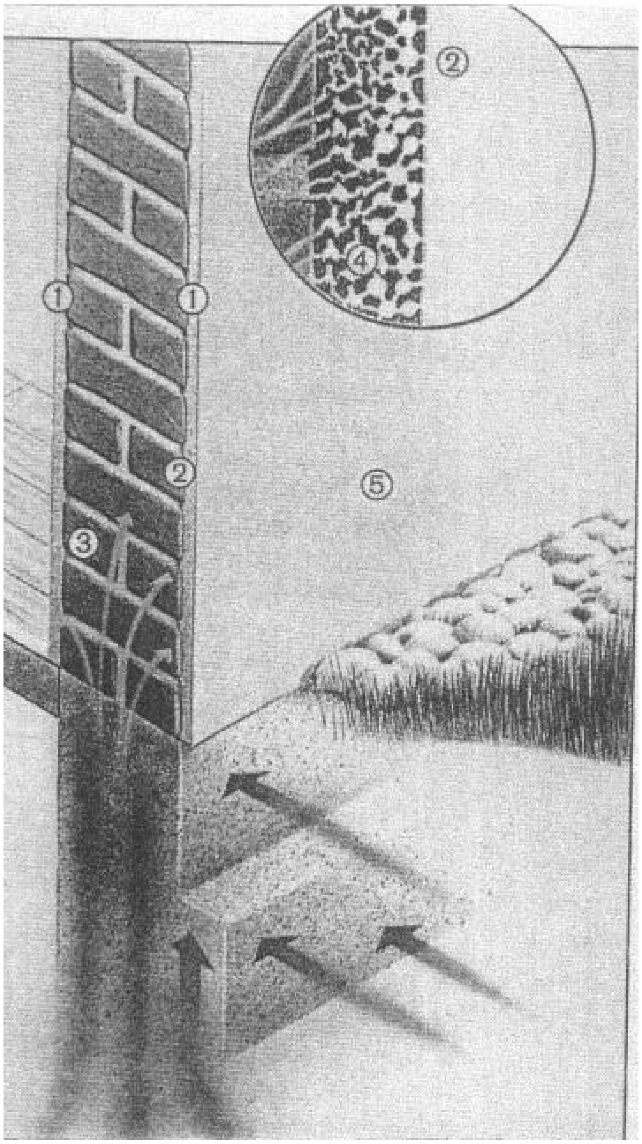


Figure 7 - Characteristics of BAYOSAN Plaster under water load.

1. BAYOSAN redevelopment plaster is layered onto a section

2. Quick and easy evaporatio9n due to pore-structure

3. Zone of moisture is lowered

4. Crystallization of sale within the pores and without damage

5. Plaster and Paint keep perfectly dry and clean

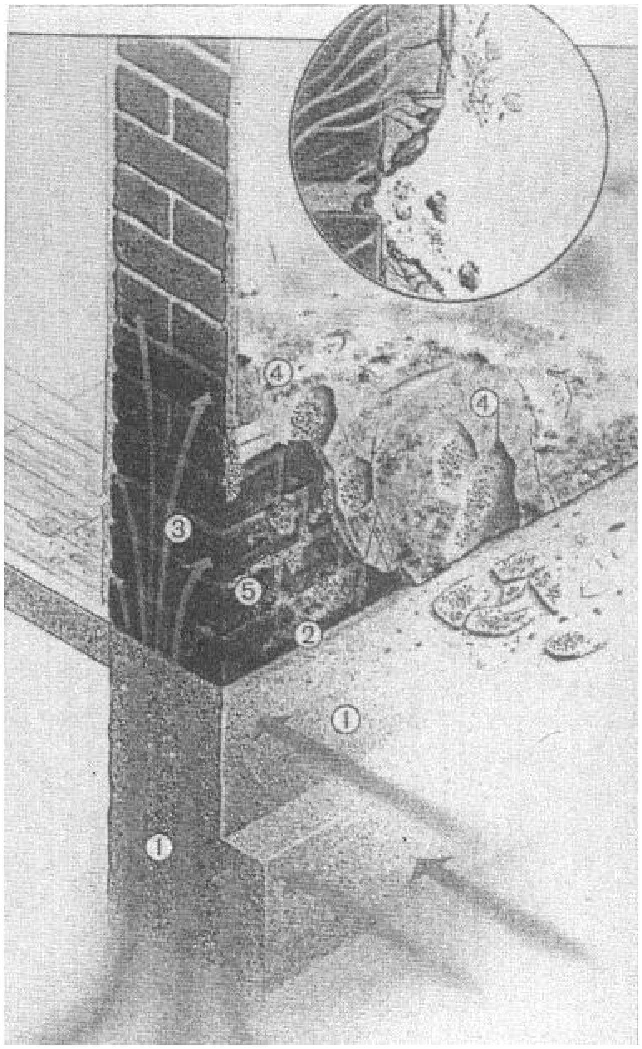


Figure 8 - Characteristics of normal lime-cement plaster under water load

1. Water has access to the foundation
2. Horizontal insulation missing or defective
3. Water and soil-salt entering masonry
4. Plaster and paint destroyed
5. Masonry is attacked

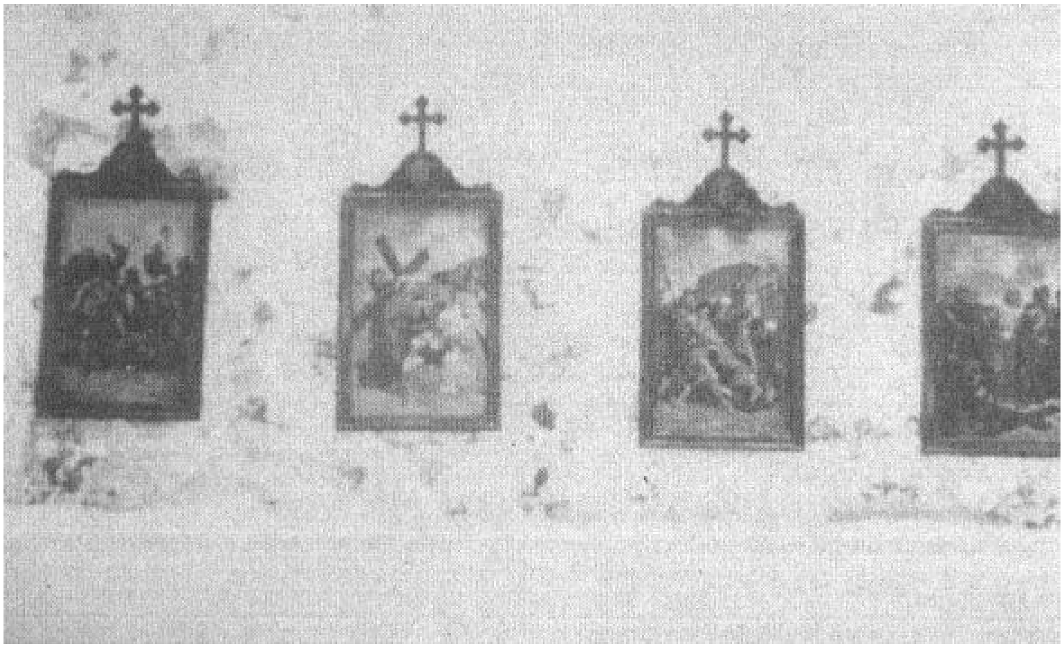


Figure 9 - Incorrect practice using a tight cement type plaster

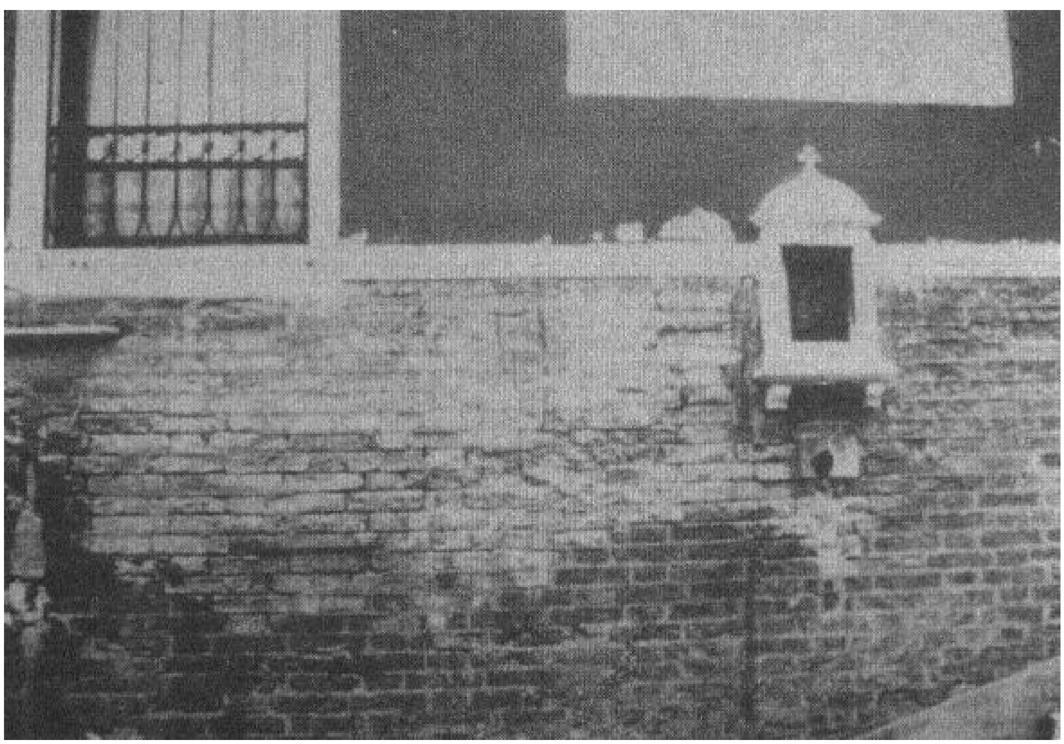


Figure 10 - Inappropriate practice - unprotected masonry

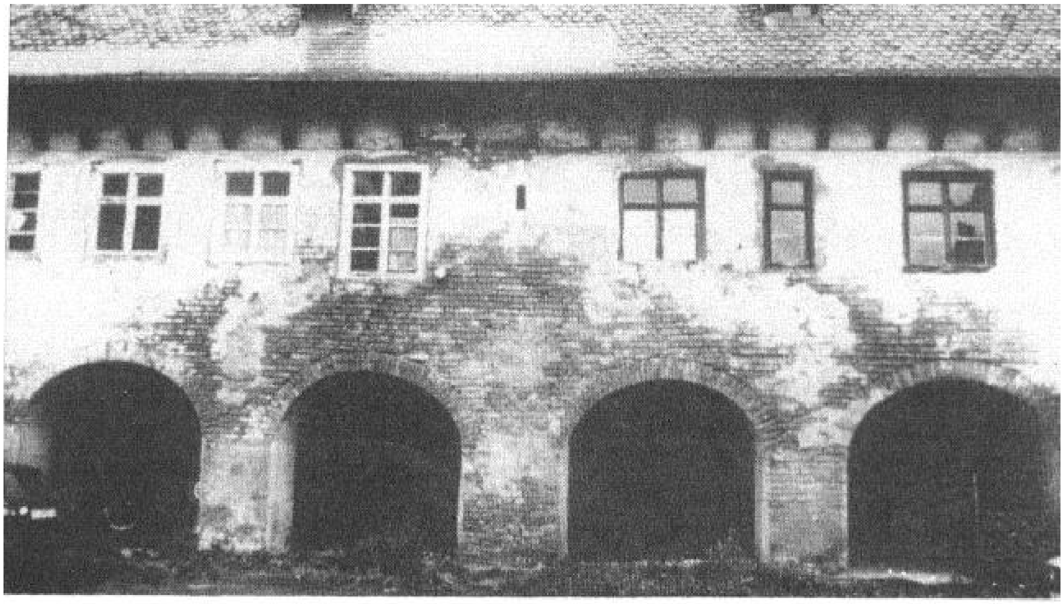


Figure 11 - Inappropriate practice and maintenance on the Monastery

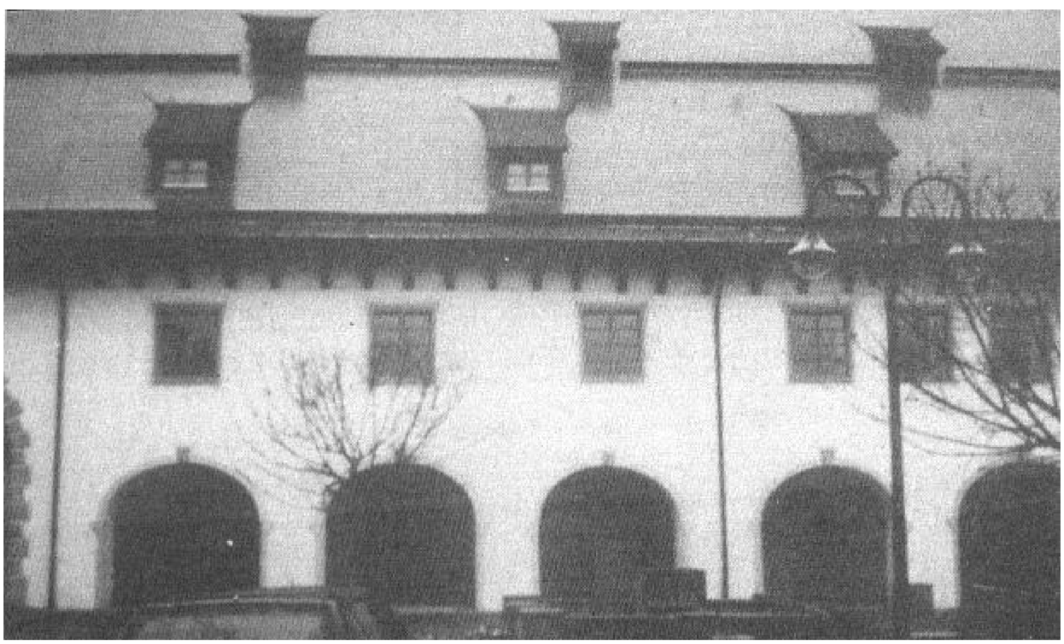


Figure 12 - Repair of the Monastery using re-development plaster

Figure 13 - View of the Ancient Nanto Church Bell Tower

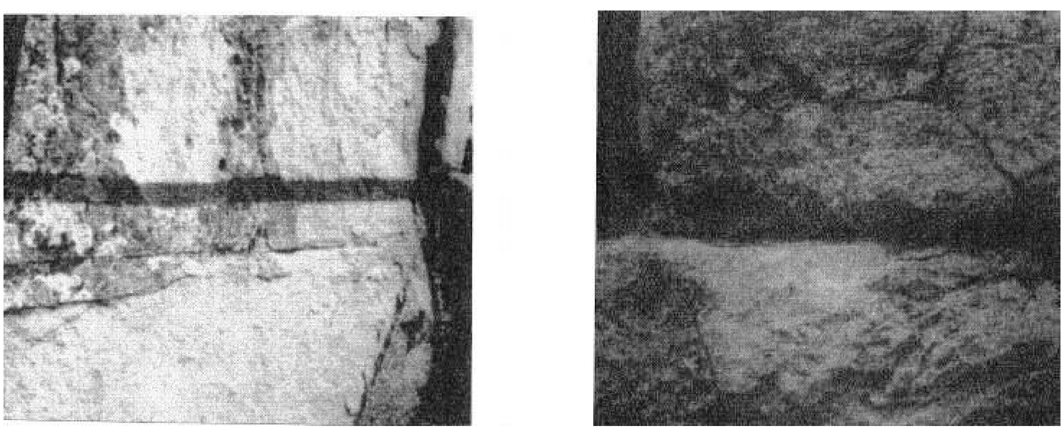


Figure 14 - Left photograph shows stone deterioration. Right photograph shows local stone cracking

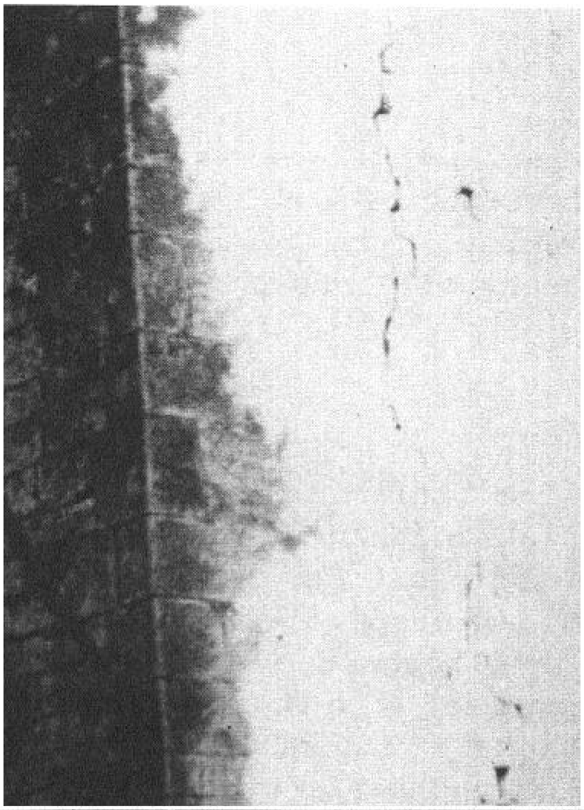


Figure 15 - Cracking of the South wall

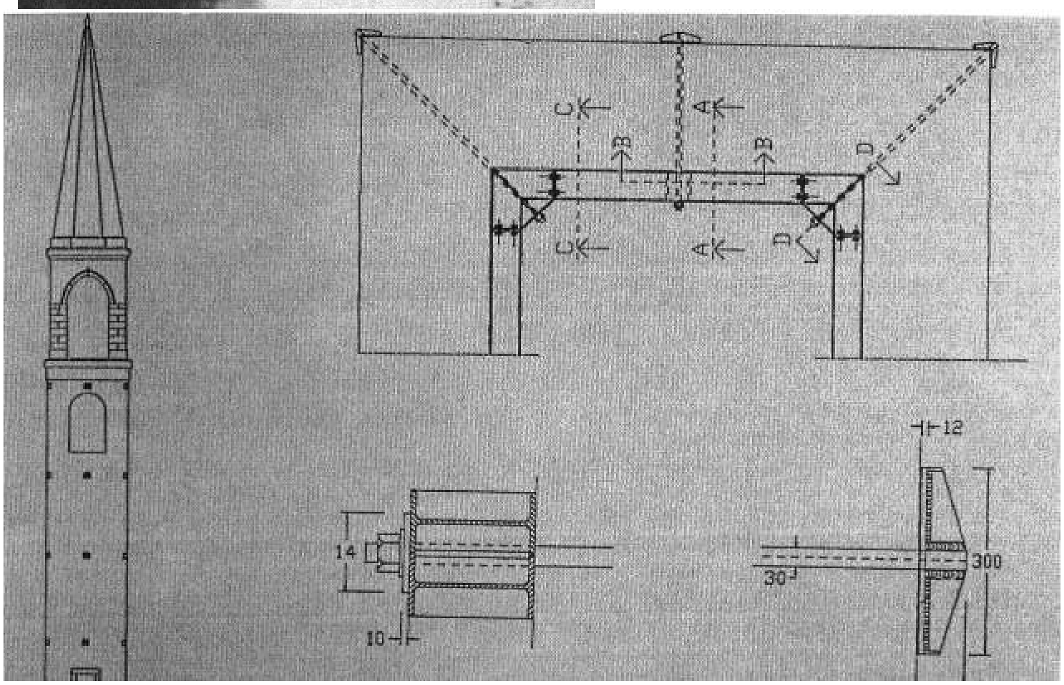


Figure 16 - General view and details of the steel work made for strengthening the bell tower.

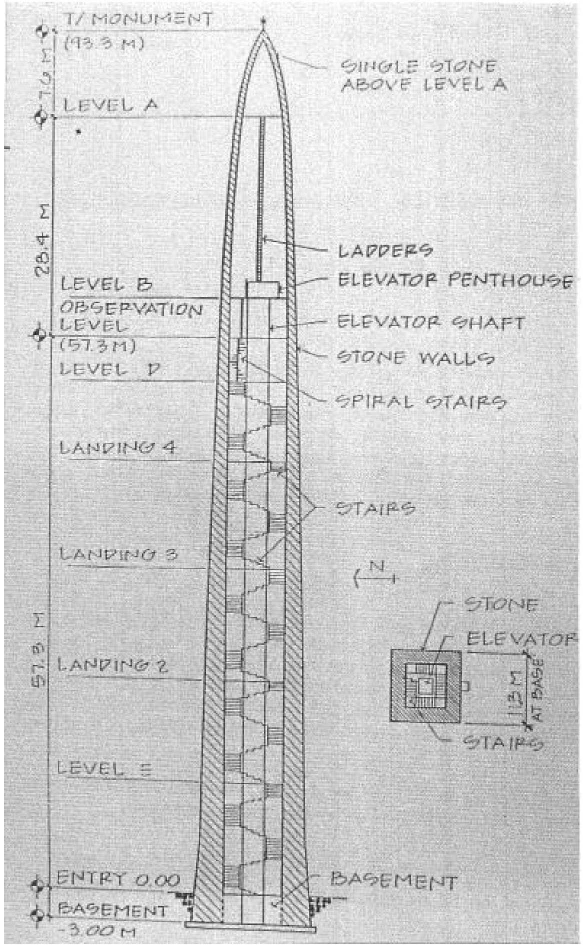


Figure 17 - Monument section

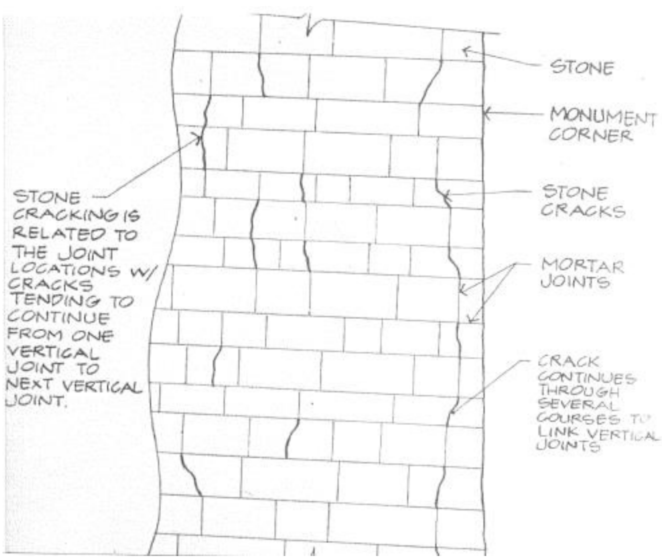
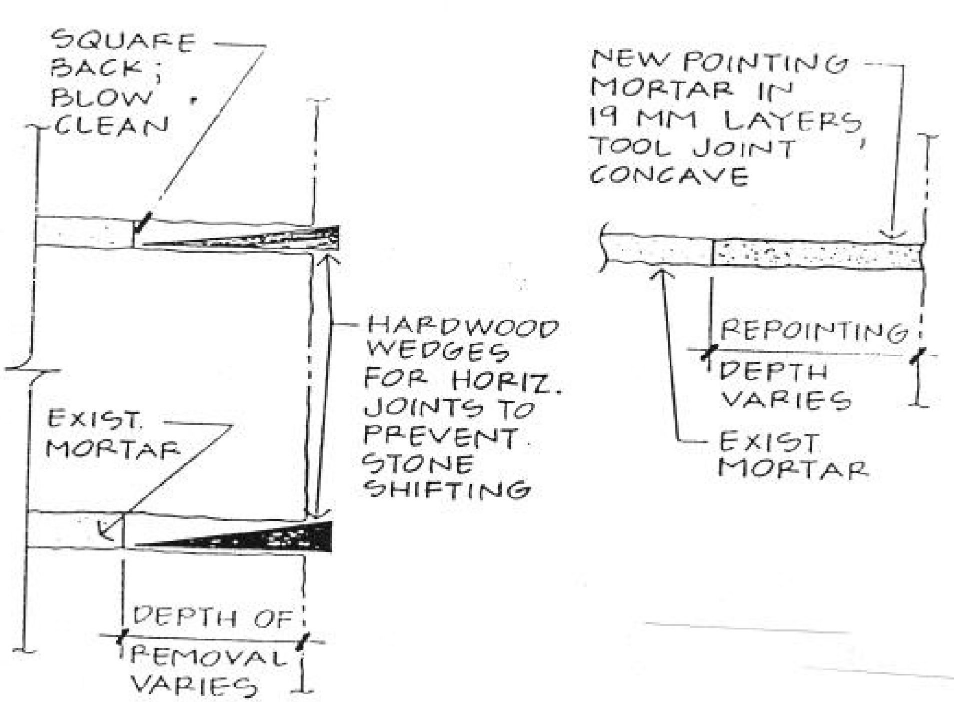


Figure 18 - Exterior crack pattern



"A" "B"

Figure 19 - "A" shows mortar removed. "B" shows mortar repointing

Figure 20 - Early photo of the Ashbel Smith Building approximately early 1890s.

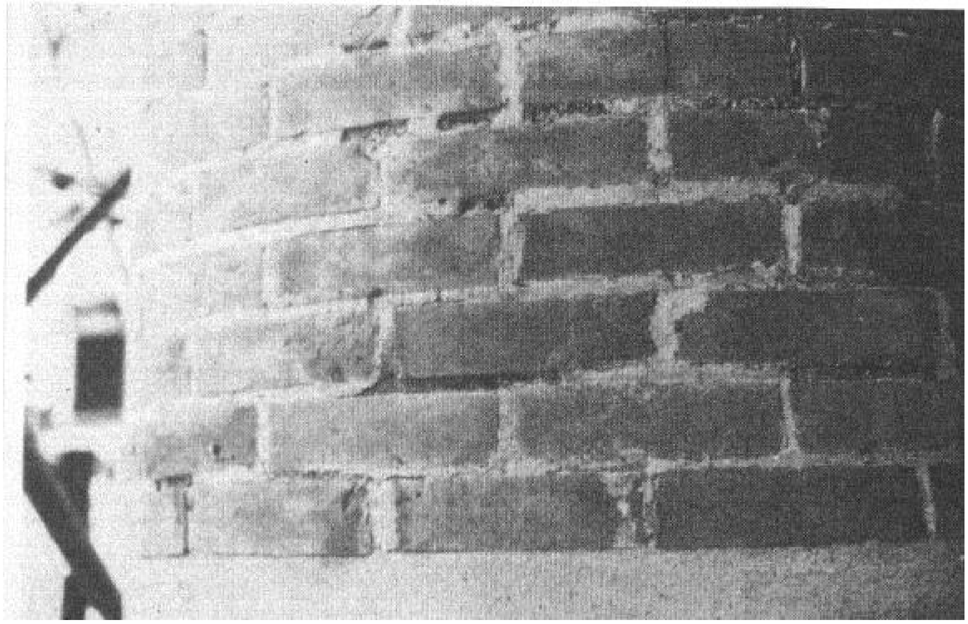


Figure 21 - Brick pilaster before tuckpointing phase

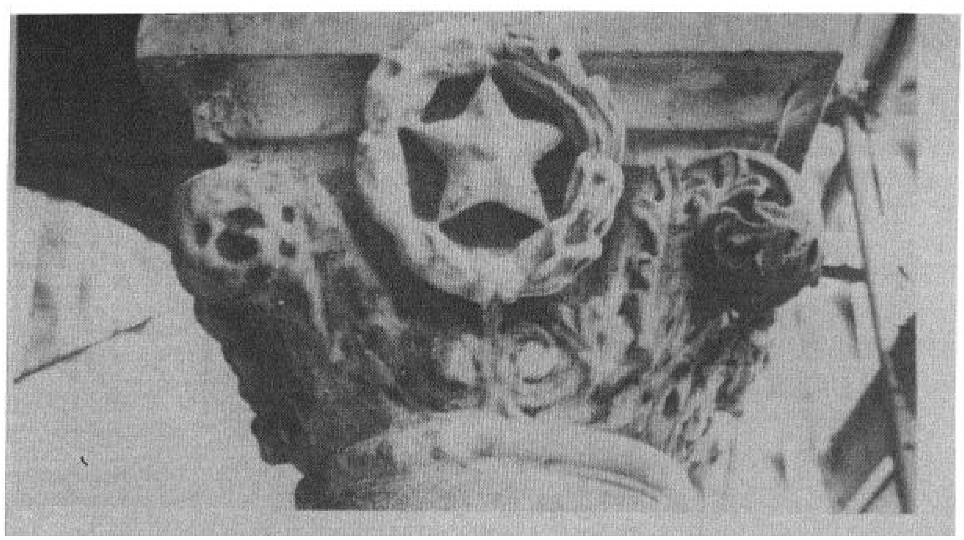


Figure 22 - Column capital smoothed by ocean winds

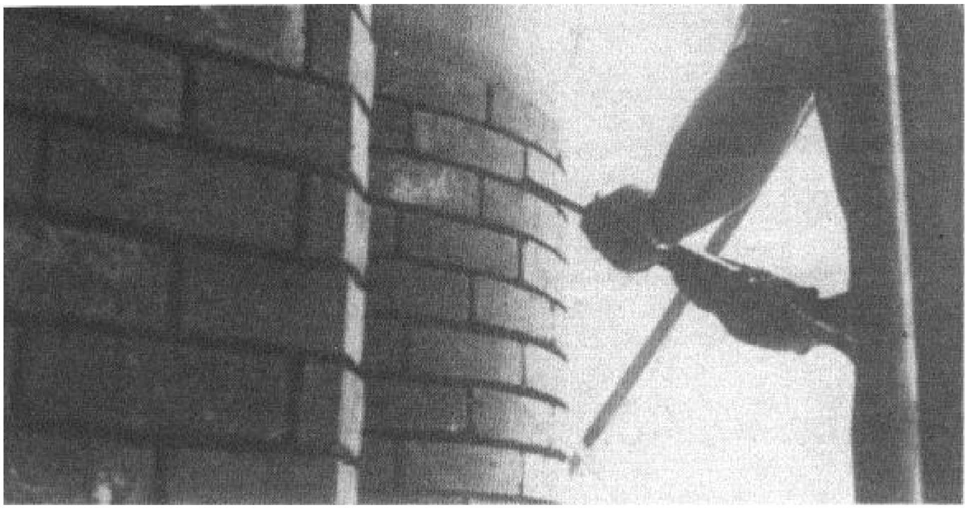


Figure 23 - Removing mortar with power chisel. Preparing the wall for tuckpointing phase

Figure 24 - Artist sketch of Ashbel Smith Building

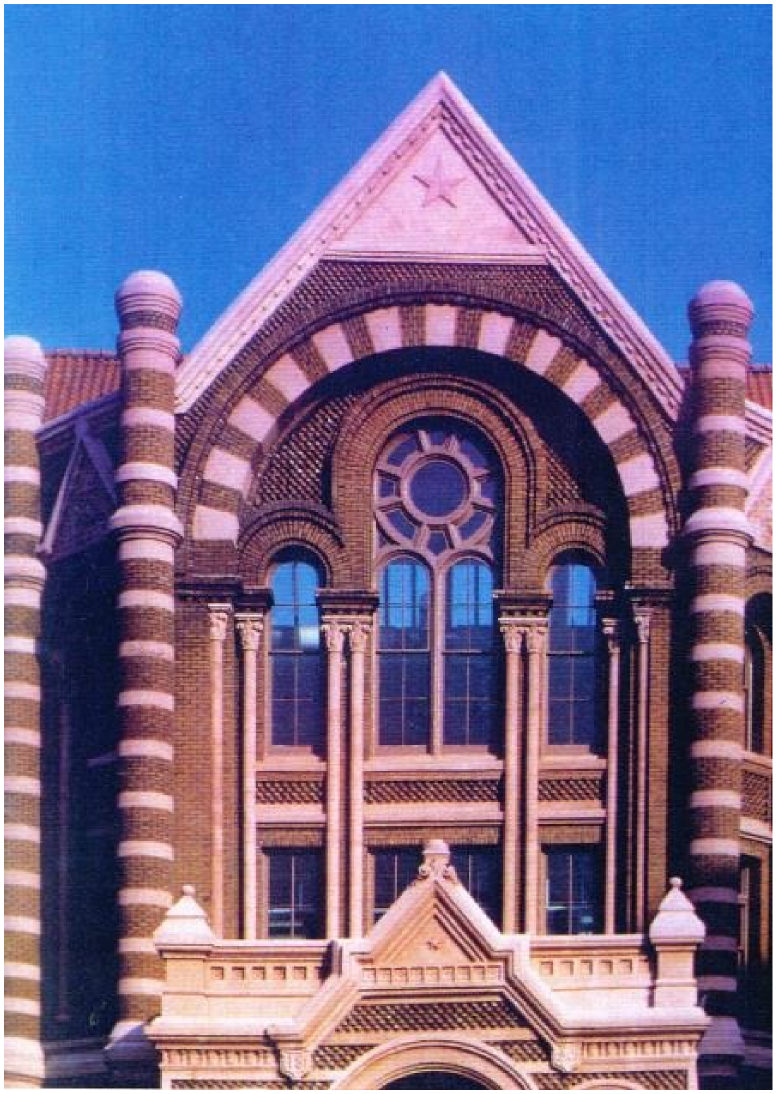


Figure 25 - Front of Ashbel Smith Building in 1986

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