MASCA MUDBRICK / ADOBE CONSERVATION INTERM REPORT

DARREL J. BUTTERBAUGH [X]
VINCENT C. PIGOTT [XX]

SUMMARY

Since 1973 a number of field tests have been undertaken in conjunction with an on-going laboratory program in experimental mudbrick conservation sponsored by MASCA at the University Museum of the University of Pennsylvania. The field test areas include Arizona, Florida, Pennsylvania, Iran and Guatemala.

Both laboratory and field experiments have shown that the soaking of mudbrick in dilute solutions (2-3%) of certain hard and soft methacrylic polymers resulted in significant penetration, binding and waterproofing. Furthermore, the incorporation of acrylic emulsions in mudbrick and mud plaster markedly strengthened brick and surfacing against weathering due to precipitation and cyclical freezing.

X Research Associate, MASCA

XX Research Specialist, MASCA, Unversity Museum, Philadelphia, Pennsylvania

July 4, 1980

MASCA LABORATORY TEST PROCEDURES AND RESULTS

Various laboratory test procedures have been devised by which to investigate the successs of the various polymer treatments. One polymer, A-21, a poly methyl methacrylate of medium molecular weight plus adhesion enhancers, has proven to be of particular importance. Penetratio in mudbrick for a 3-4% toluene solution of A-21 generally runs about 2-3 cm. in a period of 30-60 minutes. After several days, during which the toluene has evaporated, depth of penetration is determined by the beading of water droplets.

However, "wick-action" tests by means of a vertical migration of the same polymer solution from the bottom surface of a mudbrick column indicate a solvent wetting rate of:

Table 1:	3.4 cm. in 30 minutes	:al time
	4.7 cm. in 60 minutes	:al time
	6.0 cm. in 90 minutes	:al time

Water beading on the dried column indicated a penetration of 4.0 cm. This test in conjunction with the controlled sand-blast technique, described below, shows that the polymer has indeed penetrated beyond the 4.0 cm. level. Sand-blast abrasion below the 4.0 cm. mark is 20-25% of untreated adobe, but is still 55-70% of untreated above the 4.0 cm. mark. This is support for the belief that a sharp interior boundary between treated and untreated adobe does not exist, and, hence, strains between the two zones will be reduced. A diffuse boundary not prone to strains and/or spalling along the entire treated zone is thought to exist.

Sand-blast sting

Sandblasting of treated adobe, clay and stone samples has been used to evaluate and measure the binding action of polymer treatment and thereby the protection against dry weathering action. The Air-brasive jet unit (Model K) of S. S. White Products Co. has been adapt to produce a controlled sand-blast for abrasion of treated flat surfaces. Each test was quantified by filling the sharp edged erosion cavity in the test sample with a dry abrasive, emptying, and then weighing the powder.

Strengthening of the treated sample was determined by comparing the treated and untreated cavities. Multiple holes were drilled to even out any variability in the structure. In general, A-21 treated adobe and clay blocks exhibit only 10-20% of the erosion of untreated blocks. Mudbricks treated with 3% A-21 solution show only 5-10% erosion By contrast, mudbricks treated with a silicone waterproofing exhibit 75% erosion, indicating that the dry strength improvement in the A-21 bricks is due to a chemical-binding action, not water-proofing action.

Table 2:

Treatment	Sample type	Erosion %
12% E-330	adobe block (Tuscon)	7.5%
16% E-330		5.1%
3% A-21	clay block (Florida)	13.0%
3% A-21	" " "	10.2%
3% A-21/6% A-21	" " "	9.0%
3% A-21/Silicone	" " "	14.1%
5% Silicone	" " "	76.6%

We feel that this is a simple, reliable way of evaluating dry strength improvement.

Wet freeze/thaw tests

Wet freeze/thaw tests have been conducted by soaking small adobe and Florida clay blocks in water for 30 minutes, then freezing them in an ordinary food freezer for 18-20 hours, followed again by soaking (in the frozen state) in water to complete one cycle. Failure is equated with easy wet "rub off" of surface grains.

Table 3:

Treatment	Sample type	Failure rate
12% E-330	clay block (Florida)	-failed 20 cycles
16% E-330	" " "	-failed 40 cycles
16% E-330	clay plaster on concrete block (Florida)	-no failure in 150 cycles
3% A-21	clay block (Florida)	-failed 60 cycles
3% A-21	soft sandstone	-160 cycles no deterioration
untreated sandstone		-to powder 15 cycles
untreated mud		-melts in first cycle

Water vapor test

Water vapor passage through an A-21 treated, sand, Florida clay lock and stone has been measured by trapping water vapor as it passes through a treated outer zone from a wet untreated core. These tests were done by wrapping a plastic bag of desiccant around the top of a rectangular Florida clay block that had been only partially treated to leave a large inner core to absorb and transmit water throughout the inner portions of the block. One end of the treated block had been cut off in order to expose this inner core to a water-wet paper wick. The area of the treated block exposed to the desiccant was 96 cm^2. Desiccant absorbed 5.0g of water in the first 24 hours (desiccant was about 75-80% saturated at this point).

Experiments with A-21 treated soft Chaco sandstone show a very slow absorption of water over 200 hours to a steady state which represents 50-60% of the water normally absorbed by untreated stone in 5-10 minutes. Yet, both treated and untreated stone dry out to original weight at essentially the same rate.

These experiments demonstrate that should water get behind the treated zone of an adobe wall, the wall will still dry in a natural way without buildup of water pressure behind the treated zone. In other words, A-21 treatments with proper penetration will stop water liquid but will allow water vapor to pass through.

FIELD TEST WEATHERING EXPOSURES

Hasanlu Tepe, Iran

This archaeological site is situated in west Azerbiajan province in northwestern Iran. Excavations conducted there for nine seasons between 1957 and 1974 by Dr. Robert H. Dyson, Jr. for the University Museum have revealed an impressive Iron Age citadel capping a 25 meter high mound. The citadel was destroyed in an attack and conflagration about 800 B.C. Much of the Iron Age mudbrick architecture, though fortunately burned in many places, lies exposed to the ravages of erosion by wind, water and frost.

In 1975 a total of 16 different test areas comprising approximately 140 square meters were established at Hasanlu, and since that time field observations were done in 1976 and 1977. We have not had contact with the tests since 1977. Both hard and soft methacrylic polymers, including A-21 in dilute toluene, solution were soaked into selected test areas. Other test areas were covered with a mud plaster mixed with an acrylic emulsion, polymer E-330. A combination of both plaster and wall polymer soaking were used in several instances and two test walls were built using mudbricks made with acrylic emulsion.

Test areas at the site were chosen with the guidance of the excavator and were eroded mudbrick walls in non-critical areas of the site. Failure of the tests in these non-critical areas would not have affected significantly the architectural plan of the site. The present rates of erosion at Hasanlu destroy ordinary water-mud/straw plaster in less than two years. Results of these tests after two years of exposure, previously published (Pigott and Butterbaugh, 1978), have been corroborated by our on-going tests in other geographical areas and are subsumed in the interim conclusions in this report.

Chimaltenango, Guatemala

These tests started in April 1976 and presently under observation, were set up at the edge of a small corn field owned by an agricultural cooperative in Chimaltenango. The fence and wall have had no supervision since having been established and as a result, the fence was torn down during the past year while the wall still remains. This exposure is in highland Guatemala, where heavy and violent rains occur in the spring and summer rainy season.

Test #1

An adobe wall 45 x 120 x 30 cm. was constructed on the field with local adobe bricks salvaged from a nearby earthquake toppled house. A water-mud mortar was used to lay the courses of bricks. A water-mud cap was formed on this wall to make it shed water. The total surface exposed was 1.8m^2. No significant cracks in the wall were apparent prior to the start of the test. After drying in the sun for 6 days, this wall was sprayed for 45 minutes to the point of run-off with a 3% toluene solution of A-2. This completed test #1.

After 36 months, the adobe wall cap showed some surface cracks, but erosion did not appear to be occurring in these cracks. Hand smoothing marks were still sharply defined on the side of the wall after 36 months. After 48 months, the cracks had widened somewhat. A large crack on the left end of the wall was caused by human interference early in the test period. The brick had to be repositioned.

Test #2

Test #2 was a double chicken wire fence 1.5 x 1.2 m. stretched between wooden posts, on which a water-wet mixture of local adobe soil and chopped straw was smeared. The plaster was about 2.5 cm. thick. This "adobe" fence was allowed to dry in the sun for 6 days and was then sprayed for 25 minutes on both sides to the point of run-off with a 3% toluene solution of A-21. This completed test #2.

Test #3

A second chicken wire fence of the same dimensions and type was built, and smeared with a wet mixture of adobe soil and a 16% E-330 emulsion to form a 2-5 cm. thick, fence-reinforced wall. The mixture was smoothed by hand and then allowed to sun dry. This completed test #3.

The fences held up for 36 months in excellent condition with hand smoothing marks still sharp on both the E-330 and the A-21 tests. The fences were semiflexible, and moved in the wind.

ande Nati

The Western Archaeological Center of the U.S. Park Service set up an adobe test at Casa Grande in late 1977 and early 1978. They very generously provided us with two adobe brick walls on which to conduct an A-21 test. The purpose was to evaluate the efficacy of A-21 treatment in controlling ground-water deterioration at the base of an adobe wall. Each wall was monolithic, 115 cm. long, 45 cm. thick, 85 cm. high above ground level, and 25 cm. below ground level. The walls were constructed in a plastic lined pit, 25 cm. deep, in which perforated water pipes delivered water to the wall base from an above ground 220 liter reservoir. The walls were to be soaked at the base for 4 hours each week. However, the head on the system was such that water would break through at a crack in its base, flow out in a stream and erode away large areas of the wall. Thus, the weekly flooding had to be stopped, but the walls remain subject to normal weathering.

The test was conducted by spraying for 50 minutes a 3% toluene solution of A-21 over the toal exposed surface of 3 m^2. of one wall (the other wall served as a control). Application was 9.7 kilos of solution per m^2. Immediately after the test a cut into the wall showed a toluene penetration to a depth of 3.8 cm. Following one day's drying a water beading test indicated a polymer penetration of at least 2.0 cm. After one day's drying a second short spray of 6% A-21 toluene solution was performed for 10 minutes to provide a hardened surface. Total 6% solution applied to the wall was 2.0 liters. Total 3% and 6% solutions was 30 kilos over 3 m^2. equal to 10 kilos of solution per m^2.

Just prior to our treatment, heavy rains fell. The walls were covered with plastic in an attempt to keep them dry, but the ground surface around the test site was thoroughly damp, as well as the base of each wall. This dampness was recorded in pre-treatment photographs and we believe that the dampness was the cause of incomplete penetration of A-21, and hence, the erosion that has occurred around the base of the treated wall.

These walls have now weathered for 28 months. Comparison of 1978 and 1979 photographs show that the upper portions of the treated walls are holding very well vs. the control wall's untreated surfaces. No erosion seem to be occurring other than that of the previously mentioned base of the treated wall.

Boc Florida

Samples were placed on exposure at various times beginning in 1975 on the campus of Florida Atlantic University in Boca Raton, Florida. They rest on a concrete pad positioned under the edge of an unguttered roof overhang with the drip line cutting across most sample Thus, in the heavy Florida rains, a sheet of water descends directly o these samples.

rt April 197

Six 10 x 20 x 20 cm. bricks were cast in a wooden mold from a thick but fluid mixture of sandy Florida clay and 12% E-330 emulsion. Following thorough drying, a three tier brick stack was built, using an E-330/Florida clay mortar. After 60 months, these bricks show only one small surface crack and a considerable growth of mildew. There appears to be no significant rain erosion. The mildew can be removed with clorox solution without damaging the E-330 binding action.

3% A- adobe block started February 1976

A 10 x 20 x 20 cm. modern adobe block made in Albuquerque, New Mexico was treated by paint brush for 45 minutes with a 3% toluene solution of A-21. Following thorough drying it was mounted in a vertical position for exposure. After 28 months this block had begun to show some surface erosion, but the edges were still sharp and embedded pebbles were still tightly bound in the surface. The most serious erosion was occurring at one spot on the base of the block where the splash from the overhead roof hit the concrete pad. The brick toppled and broke in 3 pieces some time between the 32nd and 35th month. It should be noted that a comparable brick exposed in the same way melted and completely disappeared in two weeks.

3% A-21 Florida clay brick started March 1977

A 5 x 15 x 30 cm. brick was cast with a water-Florida clay mixture. After thorough drying this brick as brush treated for 45 minutes with a 3% A-21 solution. Following drying this brick was mounted on edge on the exposure pad. After 37 months exposure the A-21 treated surface showed no erosion; it is hard and still water repelling. Little or no mildew grows on the A-21 treated samples.

3% A-21/6% A-21 Florida clay brick started March 1977

A water-Florida clay brick was cast in the same fashion previously described. After drying, this brick was first given a 45 minute treatment with 3% A-21 solution, dried overnight, and then given a 10 minute treatment with a 6% A-21 solution. This second treatment produced a hardened surface coat that was more resistant abrasion. After 37 months exposure no evidence of erosion or cracking is evident. No mildew growth is appearing.

3% A- 30 pla rida clay brick started March 197

A dried, water-Florida clay brick comparable to the previous o was first brush treated for 45 minutes with 3% A-21 solution, dried thoroughly and then plastered with a 0.5 cm. coat of E-330-Florida clay plaster. The dried brick was placed on edge exposure. After

37 months, no evidence of failure is occurring. As with the other E-330 surfaces this brick is showing some mildew growth. It should be noted that the untreated Florida clay bricks have little natural binding and dissolve completely in the first hard rain.

Philadelphia, Pennsylvania

Two 10 x 20 x 20 cm. E-330 Florida clay bricks identical to the six placed on exposure at Florida Atlantic University, were placed on the roof of the University Museum in Philadelphia in July 1975. One block was placed at a 45 degree angle leaning on another placed flat. After 59 months of exposure to heat, rain and freezing winter weather, both blocks show no deterioration. There is some mildew growth, but much less than in Florida.

A-21 on carved Florida clay brick started November 1977

A water-Florida clay brick 5 by 15 by 25 cm. was carved so as to produce 1.0 cm. raised numbers "10-77". The brick was first brush coated for 30 minutes with 3% A-21 solution, dried overnight and then given a short brush coating for 10 minutes with a 6% A-21 solution. This brick was then placed on roof exposure. After 31 months exposure to both summer and winter weather conditions, the raised numerals are still as sharp as when the brick was first placed on exposure. This brick is an attempt to demonstrate what treatment could be applied to ancient carved or molded surfaces, such as those found at sites in Peru.

INTERIM CONCLUSIONS

Advantages of E-330 treatment (for future testing)

E-330 is a water miscible emulsion which, when mixed with soil, can produce a highly weather resistant mudbrick for wall capping and small scale reconstruction (costs of the emulsion may be limiting on a large scale). E-330 will provide a weather resistant mud plaster and/(grout which can be used successfully, but only under conditions where the subsurface is stable, or has been stabilized with a compatible chemical treatment.

Advantages of A-21 treatment (for future testing)

-strengthens greatly against rain erosion
-strengthens 10-fold against sand-blast erosion
-protects against repeated wet-freeze-thaw
-blocks transmission of water liquid, but passes water vapor (the walls can "breathe")
-penetrates deeply, 2.4 cm. in 1 hour
-does not fill interstices in mudbrick (only 0.3% by weight of polymer remains in penetrated soil)
-virtually no visible changes as a result of treatment
-treated surface wears away a grain at a time with no crust delamination
-affords a number of benefits at reasonable cost

FINAL THOUGHTS

The level of progress in, and the advantages to our polymer treatment system have been detailed above. Two thoughts merit mention. In those particular situations where mudbrick is being excavated, it is urged that testing begin soon after exposure for the loss of cohesion of soil particles in exposed mudbrick over time only acts to retard the ultimate effectiveness of any treatment applied. Secondly, we would like to suggest that those countries with major, exposed mudbrick complexes in varying states of erosion, who would be willing, should make noncritical areas at these locations available for testing, and also facilitate the implementation of such testing through cooperative efforts. In that field exposure is the ultimate arbiter of the success of mudbrick conservation it is essential that more field opportunities arise for experimentation, and that more advantage be taken of such opportunities.

Pigot , and Butterbaugh Darrel J programme in
experimental mudbrick preserva ion at Hasanlu Iran, 16:1