CONSERVATION OF MUD-BRICK BY CHEMICAL METHODS

The conservation of mud-brick monuments is very complex and its problem are in many respects different from those encountered with the preservation of structures made of backed bricks and natural stones.

One of the main causes of deterioration of these materials is the action of water soluble sulphates.

Although this deterious effect is also present in the breakdown of mud-brick, much of the damage is the result of erosion through rain water which is responsible for the detrition and the formation of cracks at the top of the walls and deep furrows on the vertical faces.

Besides the erosion effect of rain water another cause of deterioration is the surface-stress produced by swelling and shrinkage of the clay-material due to periodical wetting and drying.

Condensation can play an important role in this respect because daily fluctuations in relative humidity of more than 60% are reported to be quite normal in the arid climatic zone were most of the mud-brick monuments can be found.(1)

In addition to the many different causes of deterioration there is also the great variety of the monuments themselves which makes an instant solution for the conservation of mud-brick inconceivable.

Inhabited abandoned cities, historical monuments of archaeological sites each demand very specific solutions to their conservation.

In the author's opinion consolidation of fragile mud-constructions by chemical methods will primarly be relevant to archaeological sites, the remains of which can be saved by structural consolidation or partial reconstruction with the original clay material.

But even where archaeological sites are concerned extreme precaution should be exercised in the use of chemical materials.

As has been stated above the main causes of the deterioration are the direct erosive action of rain water (leading to detrition at the top and the creation of deep furrows at the top and on the vertical faces of the monument) and the action of salts in the ground water in accelerated weathering at the base of the monument.

First of all the causes of damage should be eliminated by covering the structure with a water-resistant material such as soil-cement bricks or mud-bricks reinforced during their manufacture through addition of an organic polymer such as polyurethane.(2)

Another possibility is the use of a deeply penetrating chemical, which should be applied in situ after the necessary repair of cracks. This material should be able to transform the fragile top into a strong, water-resistant layer a few centimeters in thickness.

To exclude the action of ground-water, damp-proof courses may be applied, for instance by injecting water-repellant silicone solutions or by using a similar low-viscosity consolidating material such as that mentioned above for the treatment of the top of the monument.

The vertical surfaces are mostly fairly well preserved. If they should need any treatment at all it is suggested to apply only a thin surface impregnation, which is to be anchored into the underlying layers through partial impregnation in depth.(1)

Besides the direct erosive action of rain-water, corrosion by soluble sulphates should be taken into account as well. These salts, (Na_2SO_4, $MgSO_4$, $CaSO_4$), crystallize in the pores of the stone on the evaporation of water as hydrates, (Na_2SO_4. 10aq., $MgSO_4$. 7 aq., $CaSO_4$. 2 aq.).

Under certain conditions (e.g. low relative humidity), they can lose the chemically bound crystal-water and then a porous anhydrous salt-mass is formed. This mass can absorb more of the solution by capillary forces, which eventually results in a complete filling of the pores with anhydrous salts. Increase of the relative humidity of the air will hydrate the anhydrous salt mass with subsequent volume-expansion and pressure on the walls of the pores, leading to breakdown.

Alternating cycles of dry and wet conditions may thus lead to corrosion. Concentrations of 0.1% Na_2SO_4, sodium sulphate, are already considered to be harmful.(3)

The failure of most of the chemical consolidating agents can also be made clear by means of the process mentioned above.

Due to the poor penetration into the brick, these agents only

consolidate the urface, thereby closing the pores and impending water-transport.

Evaporation of water will then take place through cracks in the consolidated surface layer, leading to crystallization and thus to corrosion-effects immediately behind the impregnated layer, which as a result may flake off eventually. To prevent this effect it has been suggested to consolidate the stone as deep as possible with an agent with a low viscosity.(4)

This is evident in conflict with the recommendation made for other reasons above of a thin surface treatment for mud-brick walls. This contradiction shows again the difficulty of the problem.

Organic as well as inorganic products have been used for the impregnation.

They include sodium and potassium waterglass, tetraethyl silicate, which produce a silicium dioxide gel in the pores; furthermore different kinds of soap, waxes, drying oils solutions of natural and synthetic polymers, and chemical curing systems, such as epoxy and polyester resins, have been applied.

All these materials, however, show poor penetration. Initial dilution improve their penetration. The evaporating solvent, however, transports the consolidating material to the surface, which again results in a superficial treatment only.

At the Central Research Laboratory for Objects of Art and Science in Amsterdam experiments were carried out to develop a material with a low viscosity and deep penetration without the use of solvent-diluents.

Initially the use of acrylic monomers seemed to be promising. These materials, such as methyl methacrylate and butyl methacrylate, show a very fast and deep penetration and can be cured to stable polymers at room-temperature by chemical means.

In practice, however, serious difficulties were encountered due to the inhibition of the polymerization-reaction by oxygen of the air. At small scale this effect could be prevented by several tricks, but with larger objects it became too imperactical.

Good results were achieved using small epoxy molecules. 'ommon commercial epoxy-resins have a viscosity of 10,000-16,000 centipoise at 25° C, (as compared with a viscosity of 1 centipoise for water) which is much too high to be used for the impregnation.

Other epoxy-resins are commercially available which are already diluted with 11-13% butyl glycidylether.

This monofunctional epoxy compound has a viscosity of 2-3 centipoise and considerably decreases the viscosity of the epoxy-resin to 500-700 centipoise, which is still much too high.

Instead of these products we fixed pure bifunctional epoxy-diluents at room temperature with polyamine hardeners. Bifunctional epoxy-diluents have a complete epoxy-reactivity in a relatively small molecule, and therefore have a very low viscosity.

Of the few commercially available products belonging to this category, such as butadiene dioxide, vinylcyclohexene dioxide and butanediol diglycidylether, only the latter (CIBA DY 022), gave satisfactory results with menthane diamine, (Rutapox SG, Rütgerswerke, Germany) as a curing agent.

A mixture of 2.5 parts of DY 022 and 1 art of Rutapo SG has n extremely low viscosity of about 10 centipoise.

For most of the impregnation purposes this was still considered to be to high and a suitable diluent was sought.

Tetraethyl silicate proved to be the best material to dilute this combination with.

An equal amount in weight of ethyl silicate, (viscosity 0.6 centipoise), added to the mixture of DY 022 and Rutapox SG decreased its viscosity to about 2 centipoise, ensuring in this way a very fast and deep penetration in corroded building materials.

Moreover, the siliconester not only acts as a solvent but presumably reacts also chemically with the formed polymer so that the silicium is chemically bound.

The cured product is a tough, assy an

Accelerated weathering showe
bination as compared with commonly em

Good results were achieved in the use of this system for the impregnation of mud-bricks. Very deep penetration and consolidation were obtained.

As has been stated before care should be taken however to prevent the indiscriminate use of these systems for mud-bricks.

Besides its possible use for the treatment of wall-surfaces, its possibilities for damp-proof coursing and of in situ capping of mud-walls are worthwhile considering.

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R. MUNNIKENDAM