INTERNATIONAL CENTRE FOR THE STUDY OF THE PRESERVATION AND THE RESTORATION OF CULTURAL PROPERTY
CENTRE INTERNATIONAL D'ETUDES POUR LA CONSERVATION ET LA RESTAURATION DES BIENS CULTURELS

ICCROM

5TH INTERNATIONAL MEETING OF EXPERTS ON THE CONSERVATION OF EARTHEN ARCHITECTURE

5E REUNION INTERNATIONALE D'EXPERTS SUR LA CONSERVATION DE L'ARCHITECTURE DE TERRE

Rome, 22-23 / X / 1987

CRATerre

CENTRE INTERNATIONAL DE RECHERCHE ET D'APPLICATION POUR LA CONSTRUCTION EN TERRE
INTERNATIONAL CENTRE FOR THE RESEARCH AND THE APPLICATION OF EARTH CONSTRUCTION

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DOCUMENT PREPARATION/PREPARATION DU DOCUMENT

ICCROM : Cynthia ROCKWELL
CRATerre : Titane GALER
Régine RIVIERE
Pierre-Eric VERNEY

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5e REUNION INTERNATIONALE D'EXPERTS SUR LA CONSERVATION DE L'ARCHITECTURE EN TERRE

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THE INTERNATIONAL CENTRE FOR THE STUDY OF THE PRESERVATION AND THE RESTORATION OF CULTURAL PROPERTY

LE CENTRE INTERNATIONAL D'ETUDES POUR LA CONSERVATION ET LA RESTAURATION DES BIENS CULTURELS

ICCROM

And
et

LE CENTRE INTERNATIONAL DE RECHERCHE ET D'APPLICATION POUR LA CONSTRUCTION EN TERRE
CRATerre

ECOLE D'ARCHITECTURE DE GRENOBLE

DIRECTION DE L'ARCHITECTURE ET DE L'URBANISME

In collaboration with:
En collaboration avec :

THE ICOMOS INTERNATIONAL COMMITTEE FOR THE STUDY AND CONSERVATION OF EARTHEN ARCHITECTURE

LE COMITE INTERNATIONAL DE L'ICOMOS POUR L'ETUDE ET LA CONSERVATION DE L'ARCHITECTURE EN TERRE CRUE

CO-ORDINATION/COORDINATION

Alejandro ALVA
ICCROM

Hugo HOUBEN
CRATerre/EAG

CO-ORDINATION/COORDINATION

Alejandro ALVA
ICCROM

Hugo HOUBEN
CRATerre/EAG

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PREFACE

Time has gone by quickly, and it is now nearly twenty years since strong interest began at an international level for the conservation of adobe. To review developments briefly, in 1968, ICCROM participated in research carried out at that time in Iraq, along with the Institut Royal du Patrimoine Artistique in Brussels and the Institute of Mineralogy and Archaeology of the University of Turin. While this research was being carried out, two international symposia on the subject were organized and held in Yazd, in 1971 and 1976, by the Iranian National Committee of ICOMOS.

The second meeting aimed at establishing a methodology for the study of adobe structures and archaeological ruins. Toward that aim, ICCROM prepared a questionnaire and presented it at the Regional Meeting on Conservation held in Santa Fe, New Mexico, in 1977. An important model for investigation of the use of adobe was thus obtained.

A third symposium, organized in Ankara in 1980, provided an opportunity to review the more important test carried out after the second Yazd meeting. The workshop, an exchange of experiences over the previous four years, showed that many problems, particularly the long-term reliability of testing methods, remained unsolved.

It is clear that it is not possible to arrive at a definitive solution on the basis of a few international meetings, and research takes much longer than some conservators think. International meetings can only serve to indicate possible areas of study and field work, and the Ankara meeting identified and promoted several actions. In 1983, it was felt that a sufficient amount of time had elapsed to justify the organization of another international meeting. It was also felt, however, that special emphasis should be placed upon training, which led us to select experts who were also trainers and participants who could be readily integrated into the workshop.

With this criterion in mind, ICCROM, in collaboration with the Regional Project on Cultural Heritage of UNDP/UNESCO in Lima and the ICOMOS International Committee on Adobe, with the support of the World Cultural Heritage Fund of UNESCO and under the auspices of the National Institute of Culture in Peru, organized the International Symposium and Workshop on the Conservation of Adobe from the 10th to the 22nd of September 1983, in Lima and Cusco.

Thus this meeting, which followed up the previous international symposia on adobe conservation at the national level, had the ambitious aim of expanding current knowledge of appropriate methods and techniques for adobe conservation among those technicians responsible for the conservation of cultural heritage, and we believe that this aim was achieved to a large extent.

The organization of the symposium and the Peruvian contribution to it were excellent, and the results lightened our pessimism. We may even say that they heralded a turning point in the field. The very attractive publication, which appeared in English and Spanish, covered major papers and helped immensely to disseminate knowledge and create an awareness of the need for conservation of adobe structures.

However, our attempts to organize similar meetings, especially in African countries, have all failed, much to our regret. We are therefore tremendously pleased to have been able to organize this meeting, in spite of heavy budgetary pressures. We are extremely grateful to CRATerre/EAG, an Associate Member of ICCROM, for their encouragement and financial support, and to the ICOMOS International Committee for the Study and Conservation of Earthen Architecture. We are also especially grateful to all the colleagues present here who kindly accepted our invitation.

Prof. Dr. Cevat Erder

Chairman

PREFACE

"Il serait vain de se détourner du passé pour ne penser qu'à l'avenir. C'est une illusion dangereuse de croire qu'il y ait même là une possibilité. L'opposition entre l'avenir et le passé est absurde. L'avenir ne nous apporte rien, ne nous donne rien. C'est nous qui, pour le construire devons tout lui donner, lui donner notre vie elle-même. Mais pour lui donner il faut posséder, et nous ne possédons d'autre vie, d'autre sève, que les trésors hérités du passé et digérés, assimilés, recreées par nous. De tous les besoins de l'âme humaine, il n'y en a pas de plus vital que le passé."

Simone Weil (1909-1943)
"L'Enracinement"
Ed. Gallimard, Paris, 1950

C'est à l'écoute du passé, en observant et en étudiant minutieusement les architectures en "pisé" de la région Rhône-Alpes, site privilégié de son travail, que l'équipe du CRATerre s'est fortifiée dans l'idée de projeter l'avenir de l'architecture de terre. Cette connaissance instruite sur l'héritage du temps et du savoir-faire des anciens est un leg inestimable, un trésor qui peut être aujourd'hui recréé avec l'apport de la technique moderne et de la science. Les nouveaux outils de la construction du futur sont imprégnés de mémoire. Aujourd'hui, un élan vital pousse à dresser des ponts entre les traditions et la modernité. L'avenir de l'architecture de terre ne sera pas seulement fait de nouvelles créations, il sera aussi fait de restauration, de réhabilitation, de recréation des patrimoines qui constituent la substance vitale de notre existence féconde.

Le CRATerre et l'Ecole d'Architecture de Grenoble s'engagent dans cette voie et la collaboration active établie dans ce sens avec l'ICCROM, soutenue par la Direction de l'Architecture et de l'Urbanisme, fonde la perspective du développement d'un travail fructueux.

Patrice DOAT
Professeur à l'EAG
Responsable Scientifique
du Laboratoire Architecture de Terre
Président du CRATerre

Claude VERDILLON
Professeur à l'EAG
Président du Conseil
d'Administration

RECOMMENDATIONS

A - INTRODUCTION

It was the wish of the Assembly that every recommendation be acted upon as soon as possible, and that for the next meeting an audit be organized to examine the extent of implementation of the present recommendations and those of all the previous meetings.

B - RECOMMENDATIONS

1. That the name of the International Mud Brick Committee be changed to "International Committee for the Study and Conservation of Earthen Architecture".

2. That the Committee act as a clearinghouse for important international development:

   a) By newsletter to inform practitioners in a more timely fashion of current developments. For this purpose, a special space will be reserved in the ICOMOS bulletin.

   b) By preparing a comprehensive annotated bibliography on earthen architecture, to be compiled with the assistance and collaboration of all. This could be organized by members of the Conservation Information Network.

3. That a specific training programme be created on the study and conservation of earthen architecture. This 6/8-week training course should be held every other year in Grenoble in the facilities offered by CRATerre/EAG/USTMG.

4. That links be established between the Committee and industrial laboratories, so:

   a) That the concerns of the Committee be taken into consideration in the research programmes of these laboratories;

   b) That the technical expertise acquired by these laboratories be transferred to the members of the Committee.

   In order to control the ethical applications of eventual results, the Committee must take the necessary steps in order to maintain supervisions of the development of techniques and evaluate the possibilities and conditions of their applications.

5. That the members of the Committee initiate and support national sub-committees. One of the tasks of these national sub-committees should be to develop strategies and recommendations for their governments. These recommendations should include such points as:

   a) That archaeological excavation must not proceed without a conservator on site;

   b) That a certain percentage of the excavation budget be devoted to on-site conservation.

6. That more attention be given to the monitoring of physical-chemical processes of test sites.

7. That a comprehensive inventory of significant earthen architecture in the world be conducted, to include archaeological sites, ruins and existing buildings.

8. That a multidisciplinary state-of-the-art report be drafted for general circulation. The preparation of this report would include:

   a) Field investigation;
   b) A study of traditional preservation techniques and new developments;
   c) An outline of terminology and a soil classification system specifically adapted to conservation problems.

   (A proposal was made by the Italian team to draft the state-of-the-art report for Italy.)

   (A proposal was made by the Chief Technical Advisor of the UNDP/Unesco Regional Cultural Heritage Project in Latin America to finance a mission in order to evaluate the works performed on 3 to 4 sites (e.g. Chan-Chan, Peru; Sana'a, North Yemen; Baltit, Hunza Valley, Pakistan, or elsewhere. This mission could enter into activity as early as March 1988, by drawing up guidelines for observation techniques, report writing, etc.)

9. That a 6th International Meeting of Experts be organized in the near future.

   (A proposal was made by the New Mexico State Monuments and the Getty Conservation Institute to host this meeting in 1990 in Las Cruces, New Mexico, USA).

RECOMMANDATIONS

A - INTRODUCTION

L'Assemblée souhaite que chaque recommandation soit exécutée le plus rapidement possible et que, lors de la prochaine réunion les réalisations des recommandations adoptés cette fois ci ainsi que celles des réunions précédentes soient examinées.

B - RECOMMANDATIONS

1. Remplacer le nom du "Comité International pour la Brique Crue" par "Comité international pour l'étude et la conservation de l'architecture en terre crue".

2. En vue d'un important développement international, promouvoir le rôle centralisateur (coordination et diffusion de l'information) du Comité;

   a) Par l'intermédiaire d'un bulletin destiné à informer d'une manière plus opportune les praticiens sur les développements en cours. A cet effet, un espace spécial sera réservé dans le bulletin de l'ICOMOS.

   b) Par la préparation d'une bibliographie analytique sur l'architecture en terre crue, réalisée avec l'assistance et la collaboration de tous. Ceci peut-être organisé par des membres du "Conservation Information Network".

3. Créer un programme de formation spécifique sur l'étude et la conservation de l'architecture en terre crue. Ce cours de formation de 6/8 semaines devrait avoir lieu tous les deux ans à Grenoble dans les installations mises à disposition par le CRATerre/EAG//USTMG.

4. Etablir des liens entre le Comité et des laboratoires industriels, afin :

   a) Que les intérêts du Comité soient pris en compte dans les programmes de recherche de ces laboratoires;

   b) Que les résultats d'expertises techniques établies par ces laboratoires soient transmis aux membres du comité.

   Pour contrôler l'application éthique des résultats éventuels, le Comité doit prendre les mesures nécessaires afin de garder une supervision sur le développement des techniques et évaluer les possibilités et les conditions de leurs applications.

5. Par l'intermédiaire de ses membres, lancer et soutenir des sous-comités nationaux. Une des tâches de ces sous-comités devrait être de développer des stratégies et des recommandations pour leurs gouvernements. Ces recommandations doivent notamment contenir les points suivants:

   a) Que les fouilles archéologiques ne puissent se dérouler sans la présence d'un conservateur sur le site;

b) Qu'un certain pourcentage du budget des fouilles soit alloué à la conservation sur le site.

6. Contrôler avec plus d'attention les procedés physico-chimiques sur les sites pilotes.

7. Dresser un inventaire détaillé des importantes architectures en terre crue dans le monde, incluant les sites archéologiques, les ruines et les constructions existantes.

8. Rédiger, pour une diffusion générale, un rapport multidisciplinaire sur l'état de la situation. La préparation de ce rapport devrait comprendre :

   a) Enquêtes sur le terrain;

   b) Une étude des techniques traditionnelles de préservation et de ses nouveaux développements;

   c) Une esquisse de terminologie et un système de classification des sols spécifiquement adaptés aux problèmes de conservation.

   (L'équipe italienne a fait la proposition de préparer celui sur l'Italie).

   Le Chief Technical Advisor du Projet PNUD/Unesco du Patrimoine Culturel Régional en Amérique latine a fait la proposition de financer une mission d'évaluation des travaux menés dans 3 ou 4 sites (p.ex., Chan-Chan, Pérou; Sana'a, Yemen du Nord; Baltit, Hunza Valley, Pakistan, où ailleurs. Cette mission pourrait commencer par la mise au point des principes régissant les techniques d'observation, la rédaction des rapports, etc.).

9. Organiser la 6ème Réunion Internationale d'Experts prochainement.

   (Une proposition a été faite par le "New Mexico State Monuments" et le "Getty Conservation Institute" de recevoir cette réunion en 1990 à Las Cruces, New Mexico, Etats Unis).

PROGRAMME

Background	Following the meetings held in Yazd (Iran), 1972-76, Ankara (Turkey), 1980, and Lima (Perú), 1983, ICCROM and CRATerre are organizing the 5th International Meeting of Experts on the Conservation of Mud-brick, in collaboration with the Icomos International Committee for the Conservation of Mud-brick.
Objectives	To discuss current activities in the field of preservation of mud-brick, promote collaboration between various institutions on related research projects, and recommend future lines of action in the technology of preservation of mud-brick.
Dates	October 22-23, 1987.
Place	The International Centre for the Study of the Preservation and the Restoration of Cultural Property (ICCROM).
Participation	By invitation.
Languages	English and French.
Organizing Committee	Prof. Cevat ERDER Director of ICCROM, Chairman of the Icomos International Committee for the Conservation of Mud-brick. Arch. Alejandro ALVA ICCROM Eng. Hugo HOUBEN CRATerre Ms. Susan Inman ICCROM

SCHEDULE

Thursday, Oct 22.

Chairman: J. Vargas N.

09:30-10:00	ERDER, Cevat	Introduction
10:00-10:30	ERIÇ, M.	Vernacular Adobe Architecture in Turkey and Proposals for its Re-evaluation
10:30-11:00	STEVENS, A.F.A.	Les 'Casas de Haciendas' des Andes Equatoriennes
11:00-11:30	Coffee Break	
11:30-12:00	HUGHES, R.	Problems and Techniques of Using Fresh Soils in the Structural Repair of Decayed Wall Fabric
12:00-12:30	DAYRE, M.	No title available.
12:30-13:00	NARDI, R. (ROBY, Tom)	Conservation of Medieval Structures of Mud-brick and Fired Brick Laid in Clay
13:00-14:30	Lunch Break	ICCROM

Chairman: H. Houben

15:00-15:30	AGNEW, N.- PREUSSER, F.- DRUZIK, J.R.	Strategies for Adobe Preservation. The Getty Conservation Institute Research Program
15:30-16:00	CAPERTON, T. J.	Fort Selden Ruins Stabilization
16:00-16:30	TAYLOR, M. R.	Fort Selden Test Wall Status Report
16:30-17:00	Coffee Break	
17:00-17:30	CHIARI, G.	Consolidation of Adobe with Ethyl Silicate: Control of Long Term Effects Using SEM
17:30-18:00	VARGAS N., J.- HEREDIA Z., E. A.- BARIOLA B., J.J.- MEHTA, P. K.	Preservation of Adobe Construction in Rainy Areas

Friday, Oct. 23

		Chairman: T. J. Caperton
09:30-10:00	HOUBEN, H.- ALVA, A.	Computer animated simulation of ethyl silicate stabilization (A new pedagogical tool for making complex chemical processes understandable to the layman)
10:00-11:30		Discussion of papers
11:30-12:00	Coffee Break	
12:00-13:00	ROBY, Tom	Visit to the 'Cripta di Balbo'
13:00-14:30	Free	
		Chairman: G. Chiari
15:00-16:30	ALL	Discussion of Recommendations
16:30-17:00	Coffee Break	
17:00-18:00	ERDER, C.	Approval of Recommendations and Conclusions
18:00		Drinks

PARTICIPANTS

Neville AGNEW
Queensland Museum
Queensland Cultural Centre
South Bank, South Brisbane
P.O. Box 300
South Brisbane Qld 4101. Australia

Tel.: (07) 240.75.55

Alejandro ALVA
ICCROM
Via di San Michele 13
00153 ROMA RM. Italia

Tel.: (06) 580.90.21

Mauro BERTAGNIN
Istituto di Urbanistica e Planificazione
Università di Udine
Viale Ungheria 43
33100 UDINE

Guido BISCONTIN
Università degli Studi di Padova
Dipartimento di Chimica Inorganica Metalorganica ed Analitica
Via Loredan 4
35131 PADOVA PD. Italia

Tel .: (049) 83.12.90

Thomas J. CAPERTON
New Mexico State Monuments
P.O. Box 2087
SANTA FE, NEW MEXICO 87503. USA

Tel.: (505) 827.32.41

Duane CHARTIER
ICCROM
Via di San Michele 13
00153 ROMA RM. Italia

Tel .: (06) 580.90.21

Giacomo CHIARI
Dipartimento di Scienze della Terra
Università degli Studi di Torino
Via S. Massimo 22
10123 TORINO TO. Italia

Tel.: (011) 83.21.93 - 83.78.25

Michel DAYRE
IRIGM
Université Scientifique et Médicale de Grenoble
B.P. 53
F - 38041 GRENOBLE CEDEX
France

Michel DUBUS
Musée de la Céramique
Place de la Manufacture
92310 SèVRES
France

Tel.: 45.34.99.05

Cevat ERDER
ICCROM
Via di San Michele 13
00153 ROMA RM. Italia

Tel.: (06) 580.90.21

Murat ERIÇ
Mimar Sinan Universitesi
Güzel Sanatlar Fakültesi
Findikli, ISTANBUL
Turkey

Hugo HOUBEN
Centre international de recherche et d'application pour la construction en terre. CRATerre
Centre Simone Signoret B.P. 53
38090 VILLEFONTAINE. France

Tel. : 74.96.60.56
Telex: 308658 F

Richard HUGHES
Ove Arup & Partners
13 Fitzroy Street
LONDON W1P 6BQ. United Kingdom

Tel. : (01) 636.15.31
Telex: 295341 OVARPT G

Jukka JOKILEHTO
ICCROM
Via di San Michele 13
00153 ROMA RM. Italia

Tel. : (06) 580.90.21

Noël LACOUDRE
E.D.F.
2, rue Louis Murat
75008 PARIS. France

Jacques MONTLUçON
Direction des Etudes et Recherches
E.D.F.
2, rue Louis Murat
75008 PARIS. France

Sylvio MUTAL
UNDP/UNESCO Regional Cultural Heritage
Project in Latin America
P.O. Box 4480
LIMA. Perú

Tel .: 40.24.01 - 41.91.35
Telex: 25375 PE

Roberto NARDI (Tom ROBY)
Via Zanardelli 16
00186 ROMA RM. Italia

Olivier SEDNAOUI
Viale Famagosta 21
20142 MILANO MI. Italia

Tel .: (02) 813.51.67
Telex: 215415 MORING I

André STEVENS
Brusselsesteenweg 138
3009 HERENT (Winksele). Belgium

Tel .: (016) 48.81.29 - 48.82.71

Michael R. TAYLOR
New Mexico State Monuments
P.O. Box 2087
SANTA FE, NEW MEXICO 87503. USA

Tel .: (505) 827.32.41

Julio VARGAS NEUMANN
Centro Latinoamericano de Estudios y
Difusión de la Construcción con Tierra
CLEDTIERRA
Av. Garcilaso de la Vega 1351 (4to. Piso)
LIMA. Perú

Tel .: 32.40.57
Telex: 25447PE FERREYCO

Mr. John WARREN
100 Station Road,
Horsham, SUSSEX RH135EU
United Kingdom

Tel .: (0403) 21.06.12

Cultural Heritage
rica

: for

: 40.24.01 - 41.01.35
28375 FF

berto NARDI (Tom BOBY)
Zanardelli 16
. Italia

31
. Italia

.67

CONFERENCE PAPERS

COMMUNICATIONS

STRATEGIES FOR ADOBE PRESERVATION

THE GETTY CONSERVATION INSTITUTE RESEARCH PROGRAM

Neville AGNEW
Queensland Museum
PO Box 300
South Brisbane
Australia 4101

Frank PREUSSER
The Getty Conservation Institute
4503 Glencoe Avenue
Marina del Rey
California 90292-6537

James R. DRUZIK
The Getty Conservation Institute
4503 Glencoe Avenue
Marina del Rey
California 90292-6537

ABSTRACT

Laboratory research at the Getty Conservation Institute and the Queensland Museum has shown the potential of a number of techniques and materials for the preservation of archaeological and historic adobe. These are polyisocyanates and silanes as chemical preservatives, permeable aerotextiles for site shelters, geotextiles for drainage and the use of composite synthetic fibre geobars as structural reinforcing elements. The next phase in the strategy of the program is field testing of the laboratory results in conjunction with the existing trials being conducted by the New Mexico State Monuments on test walls at Fort Selden. The experiments are due to start at the beginning of 1988 on 30 test walls. Research design for field testing is presented. Results will be applied to a real site for further evaluation prior to eventual dissemination of the findings in the GCI technical report series Research in Conservation.

INTRODUCTION

The versatility of mud as a building material has resulted in its ubiquitous use in every inhabited region. Increasingly its contemporary and historic significance is being acknowledged. From the prodigious 50 metre high mud-brick spire of Al Mohdar Mosque in the Hadramawt region of South Yemen, to the ancient arch at Tel Dan in Israel, and the organic forms of African architecture; while in the Americas and Asia its use has been adapted to every style and need of mankind's purpose. However, its erosional fragility is such that preservation of archaeological and historic sites is difficult, because of the material itself - its compositional and mineralogical variability, its metastability with respect to reversion to its origins under the influence of many physical, chemical and biological agencies, but above all water - and because many sites that require comprehensive analysis and treatment regimens are in remote, arid or sparsely populated areas.

The Getty Conservation Institute, in keeping with its charter, is undertaking a program of research into the preservation of archaeological and historic adobe structures. The project is a collaborative one with the Queensland Museum, where laboratory testing is being done, and the New Mexico State Monuments, Museum of New Mexico, which has an existing field testing facility at Fort Selden historic monument in southern New Mexico.

The strategies of the program are dictated by the conviction that research must be directed towards the development of field tested materials, techniques and ideas, and that only then will analysis allow selection of appropriate preservation options and the synthesis of a whole-site methodology. Chemical preservation, site shelters, ground-water control, structure reinforcement and quantitative erosional modelling are thus the main thrusts of the program.

LABORATORY RESEARCH

Preliminary results - Preliminary laboratory results were reported [Agnew, Druzik, Caperton and Taylor, 1987] recently at the ICOM Committee for Conservation meeting in Sydney. As stated at this meeting the most promising chemical preservative tested, on blocks cast from an adobe soil from the site of the historic Olivas Adobe in California, was a polyisocyanate based on hexamethylene diisocyanate. Other polymeric classes showing good performance were, in decreasing order of effectiveness, Stone Strengthener H, methyl trimethoxysilane, Dri Film 104, methyl methacrylate polymerized in situ, and Acryloid A-21 applied in aromatic hydrocarbon solution.

Adobe soils - The preliminary results are being extended now to two other soil types and a wider range of diisocyanate prepolymers. The physical and mineralogical characteristics of the soils are different - the Olivas soil is a swelling soil high in smectite/montmorillonite;

the second, from the current test wall program at Fort Selden is an alkaline calcitic adobe soil; and the third, an Australian soil from Samford, is acidic, high in iron and kaolinite, non-swelling, with organic matter present. Based on sieve analysis and particle size distribution by photo-sedimentation the composition of the test blocks, after addition of quartzite sand, is:

	Vol. % sand	Vol. % silt	Vol. % clay
Olivas soil	45	45	10
Fort Selden test wall adobe	54	36	10
Samford soil	70	20	10

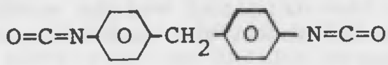
<u>Polymeric systems</u> - Diisocyanates are supplied by the manufacturers as prepolymers (for reasons of safety), believed to be between three and six oligomers. Two important types of reaction of organic isocyanates involve the hydrogen atoms of alcohols and water. The former yields a urethane and the latter a urea linkage. We have concentrated our attention on one-component diisocyanate systems which, on reaction with moisture, generate polyisocyanates containing urea linkage groups. The stoichiometry of the reaction is:

$$\text{R-N=C=O} + \text{O=C=N-R} + H_2O \longrightarrow \text{R-NH-}\overset{\overset{\text{O}}{\|}}{\text{C}}\text{-NH-R} + CO_2$$

The reaction is catalysed by bases and alkyltin compounds among others.

A range of starting diisocyanate prepolymers supplied by Bayer/Mobay and du Pont is being tested. These are based on hexamethylene diisocyanate (I), diphenylmethane diisocyanate (II), and the fully hydrogenated analog of the latter- dicyclohexylmethane diisocyanate (III). Table 1 gives formulas.

I $\text{O=C=N}\!\leftarrow\!\text{CH}_2\!\rightarrow_6\!\text{N=C=O}$

II 

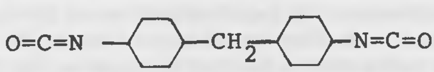
III 

Table 1. Structures of diisocyanate monomers.

These substances have proven outdoor durability, although the aromatic tends to yellow. In addition, Stone Strengthener H (a mixture of methyl triethoxysilane 37%, tetraethoxysilane 18.7%, tetraethoxysilane dimer 18.7%, methylethylketone 20%, and acetone 6% with dibutyltin dilaurate catalyst, ProSoCo/Wacker), Acryloid A-21 (acrylic copolymer, Rohm and Haas), Dri Film 104 (silicone resin, General Electric) and a number of other systems are being tested in parallel. They are being evaluated on cast test blocks of the three soil types.

With regard to the diisocyanates the influence of solvents, particularly polarity (polar n-butyl acetate versus non-polar xylene), catalysts (basic triethylamine versus dibutyltindilaurate) and the role of prepolymer concentration are being investigated systematically.

Test methods - Tests have been developed to rank order the various systems against each other. The purpose is not at this stage, to define an absolute measure of resistance - this will emerge from the field trials where only the best systems from the laboratory work will be tested. They are wet-dry cycling at 50°C of infiltrated test blocks (both surface coated and fully impregnated), liquid water transmission through infiltrated blocks, and resistance to sodium sulphate solution. A freeze-thaw test is currently being developed. Other auxiliary tests - rates of leaching of sodium sulphate from consolidated blocks and rates of penetration of infiltrant solution - are also being used.

Our results are now sufficiently defined to undertake a final stage of laboratory work prior to field testing at Fort Selden. This will encompass measurements of porosity and permeability, compressive strength, and the distribution of polymer in the composite matrix by electron microscopy.

Results - In general terms the best all-round performance is shown by the polyisocyanates, in particular Desmodur N 3390 (Bayer/Mobay) and Imron (du Pont). Test blocks with these two systems cured to a tough, hard stone-like finish, and with only slight darkening in hue. Polymer loading in the matrix was low (0.3-1.3% by weight). No deterioration or cracking occurred on testing; even the surface coated blocks, with a layer 1-2 mm thick, repeatedly absorbed 13% by weight of water and could then be dried at 50°C to the original weight without cracking of the skin. Water transmission and sodium sulphate resistance are good.

Stone Strengthener H performed nearly as well, but tended to crack on wet-dry cycling. Methyl trimethoxysilane behaved similarly but with formation of a dark, brittle hydrophobic skin. Both the polyisocyanates and Stone Strengthener H allowed near quantitative extraction of sodium sulphate on immersion for 20 hours.

Acryloid A-21 performed well in wet-dry cycling but showed poor resistance to sodium sulphate crystallization tests and low liquid water transmission. The silicone resin Dri Film 104, applied in solution, proved very resistant, but impermeable to water.

The general conclusions are that in situ polymerization is essential to ensure coated particles. Viscous polymer solutions - of whatever type whether acrylic, silicone, or epoxy - will penetrate poorly and tend to clog pores. Reverse migration of polymer as the solvent evaporates will exacerbate this effect, and if the polymer is very hydrophobic, as is Dri Film 104, a separation or abscission layer will form at the interface on wetting. Consequently, if internal wetting occurs the surface will eventually slough off.

<u>The "ideal" chemical preservative</u> - From the evidence of the present project it is possible to define the requirements of a hypothetical ideal adobe preservative which will minimally alter the inherent properties and appearance and yet confer durability. These are:

(i) The system - whether a polymer solution or monomer - should have a very low viscosity to ensure thorough penetration.

(ii) Water itself is generally not a suitable carrier for a chemical infiltrant because (a) it tends to swell clays (especially montmorillonite group clays) and close capillary pores to further penetration; (b) water weakens clay structures and prolonged infiltration attempts could lead to severe loss of compressive strength. Hence, organic solvents are preferred carriers, and of these the less volatile ones are better than those that evaporate rapidly, since the latter tend to redeposit consolidant on the surface. Kerosene and mineral spirits, which are inert to clays, have been shown to be preferable to more volatile toluene, xylene and acetone [Winkler and Clifton, 1978] in this regard.

(iii) It should confer mechanical strength and abrasive resistance (i.e. act as a consolidant) on adobe, both dry and when wet, and it should do this at low polymer loading in the matrix.

(iv) It should leave pores and capillaries open and not significantly fill them, i.e. not decrease permeability to gases and liquids.

(v) Deep surface coatings should grade into untreated core material rather than show an abrupt transition boundary.

(vi) It should not be extremely hydrophobic since hydrophobicity, if coupled with a sharp transition layer between infiltrated and untreated core adobe, will result in spalling at an abscission layer especially if permeability has been decreased by pore filling.

(vii) The system should show resistance to both salt crystallization by capillary rise of ground-water and freeze-thaw attrition.
(viii) It should be hydrolytically inert and photolytically stable. UV-radiation is an important cause of deterioration of polymers, and, although polymer in the interstices of adobe is not exposed, if photolysis or photo-oxidation occurs it is likely that deterioration of the polymer will accelerate surface deterioration of the substrate itself.
(ix) It should have a thermal coefficient of expansion similar to that of the adobe it is protecting. The importance, or otherwise, of this requirement is not well documented. Generally polymers have a higher coefficient than adobe and differences, unless the polymer is elastic, are only likely to cause problems - possibly cracking in the long term - if the pores are completely filled. Measurements of the thermal behaviour of selected polymer-adobe systems by thermomechanical analysis are being planned using the instrumentation at the GCI.
(x) It should not affect the natural color of the adobe, nor cause gloss or darkening.
(xi) Ideally it should be cheap, easy and safe to apply by easily trained labour using simple, available equipment.
(xii) If possible it should be reversible.

The surprising aspect of this apparently impossible list of requirements is that many of them can be met by existing systems. It is true that no perfect chemical cure-all for the ills of adobe has emerged, nor is a magic material likely to. The truth would appear to be that many of the shortcomings of preservatives, in the real world outside the laboratory, manifest themselves because of a combination of several reasons - inappropriate techniques in application, inadequate analysis of adobe composition and peculiarities of the site, such as weather patterns, ground water and so on. By proper attention to application methods and using the results of site analysis, together with site protection techniques, it is likely a number of preservative systems could be used quite satisfactorily. Our provisional findings are that polyisocyanates offer great promise in this regard.

Polyurethanes have hardly been used in stone and adobe conservation. For a while in the late 1960s a polyurethane resin (Pencapsula) was used [Steen, 1970, and Carter and Pagliero, 1969] on adobe sites. For various reasons a dislike was conceived for the material and it fell into disuse. More recently it is known that work in Uzbekistan involved use of a polyurethane based on a diisocyanate, but details of the type and co-reactants, if any, have not been published. Results and durability of the material are stated [Abdurazakov, 1985] to be excellent.

EXPANDED TEST WALL PROGRAM AT FORT SELDEN

Testing will start in early 1988. Construction of 30 test walls, each 1.52x1.52x0.25 m thick, is presently underway. The plan is to test, by accelerated outdoor weathering using an overhead spray to deliver twice daily 20 l of water over 15 mins. to the top of each wall, the effectiveness of the following materials and methods:
Chemical preservatives - Will concentrate on the polyisocyanates and silanes, by surface coating, bulk infiltration of the wall, basal infiltration of the footings and foundation areas, the tops of walls, and combinations of the above.
Shelters - Use of permeable knitted aerotextiles for assessment of their suitability for site preservation work. Shelter designs will be evaluated as will the durability of the shelters themselves. Tent, flat pitched-roof and barrel-arch scale model designs are planned.

The premise in examining permeable aerotextiles by field testing relates to their potential in conjunction with other protective measures especially partial chemical preservation. Thus, we think that a combination of the two measures, if necessary together with others, such as geotextile drains and wind-breaks, will likely be more effective in many instances and with minimal interference with the historic fabric of a site, than total reliance on either one alone. That is to say on either a solid roof or total enclosure - with the structural requirements these demand - or chemical preservation alone.

In shelter design [see for example: Stanley Price, 1986] the approach seems to have been 'anything goes' - from gross over-design to the backyard tent, with the limitations being set only by budget. We are planning in conjunction with Spacetech (an Australian based architectural design firm specialising in saddle-shaped tent structures) a modular shelter design capable of lateral add-ons using permeable aerotextiles which will require lighter anchorages and support structures than a solid roof. Transport costs to remote areas of these materials should be less than those of solid roof structures.

Drainage - Groundwater control by use of geotextile drains (Stripdrain and Cordrain), developed in the civil engineering field, which can easily be installed from rolls and with minimal excavation.

Geotextiles - Non-woven permeable fabric will be tested on a buried wall draped with the geotextile. The purpose will be to simulate reburial of an excavated site.

Reinforcing geobars - A double wall will be internally reinforced with geobars (ICI Paratie bars) and then destabilised by removal of basal adobe blocks. The purpose is to evaluate semi-rigid, non-corroding bars in structure reinforcement with a view to their use in earthquake areas and for structurally damaged adobe.

Control walls will be provided for all experiments. Photographic monitoring will be done by Fort Selden staff according to the procedure established for existing walls.

CONCLUSION

Results should begin to appear about a year from now when we will be planning a real-site trial. Our strategy is thus one of orderly evolution towards tested methods by progression from the laboratory through two stages of field trials.

No doubt the question will be raised of the cost of these 'high-tech' materials as an impediment to their eventual use on sites. Our purpose at this stage is first to evaluate them, and then if they fulfil their promise, consider and assess cost-effectiveness [See for example: Editorial: 'The Science of Cultural Materials', 1987]. The thesis of this work is to test and develop a range of optional measures for site preservation so that selection of appropriate materials and techniques, based on an analysis of the deteriorative factors operating, can be made.

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FORT SELDEN RUINS STABILIZATION

Thomas J. CAPERTON
New Mexico State Monuments
Museum of New Mexico
Box 2087
Santa Fe, New Mexico 87503
U.S.A.

ABSTRACT

The mud brick wall remnants at Fort Selden State Monument, New Mexico, USA were stabilized in 1972, 1974, and 1985. The techniques employed included the placement of caps on the wall tops, repair of coving at the wall bases, establishment of drainage slopes to prevent the accumulation of water next to walls, preservation landscaping, and construction of visitor trails. This report is a description and evaluation of that work.

LOCATION

Fort Selden is located in the semi-desert country of New Mexico in the southwestern United States, 53 miles (85 kilometers) north of the Mexican border on the Rio Grande.

HISTORIC BACKGROUND

The post was established to protect setters in the valley of the Rio Grande from Indian raids and bandits. The mud brick fort was constructed in the late 1860s by soldiers from the garrison, military prisoners, and some civilian employees.

The flat-roofed structures comprising Fort Selden were arranged about a rectangular parade ground, that included the Officer's Quarters, Company Quarters, Administration Building, and Post Hospital. Beyond the perimeter of the parade ground were the corrals, the Commanding Officer's Quarters, and the Trader's Store. Fort Selden was constructed to hold a complement of about 200 men, usually one company of infantry and one of cavalry.

The outer walls were two feet (.61 meters) thick and the inner walls, which did not support roof beams, were one foot (.30 meters) thick. The outer walls had rock foundations and the interior walls had mud brick foundations. The walls were ten feet (3.05 meters) high from floor to ceiling with a two foot parapet above the roof. The roofs consisted of peeled cottonwood logs overlayed with small cottonwood poles which were placed together. On top of these were a layer of willows placed crosswise, and on the willows a thick layer of hay and a 3 1/2 inch (8.9 centimeters) layer of mud mixed with cut straw. On top of this was a layer of tamped dry earth and, finally, a 3 1/2 inch layer of a mud. Most of the exterior walls were not rendered, while the interior of the buildings were coated with a lime plaster.

There were continual problems with the upkeep of the mud brick buildings. During one period of particularly heavy rain, tents were pitched inside the rooms to protect the inmates and their posssions. In 1871 the Post Commander commented: "The buildings and quarters are sufficient for the present garrison, and have been well built from the material afforded by the country (adobe) but that material ... disintegrates so fast during summer rains that constant repairs are needed to preserve the buildings from decay and ruin."

The post was abandoned in 1891. The roofs, windows, and other salvageable material were given to a contractor in payment for removing the bodies from the post cemetery.

ENVIRONMENTAL DATA

Fort Selden is located at an elevation of 3990 feet (1216 meters) above sea level. Temperature and precipitation has been recorded at a station 13 miles (20.9 kilometers) from the site since 1870.

The average annual maximum temperature (1870-1983) is 76.4 degrees F (24.7 degrees C), the average minimum temperature is 43.9 degrees F (6.6 degrees C). The highest recorded temperature is 109 degrees F (42.8 degrees C) and the lowest is -10 degrees F (-23.0 degrees C). There are an average of 97 days a year with temperatures over 90 degrees F (32.2 degrees C) and 100 days with temperatures at or below freezing (0 degrees C). The mean annual precipitation is 8.49 inches (21.60 centimeters). The highest recorded annual precipitation is 19.60 inches (49.8 centimeters). The rainy season is from July 1 through September 10. The months of July to September receive 54 percent of the annual rainfall.

PRESERVATION EFFORTS

The former fort was acquired by the New Mexico State Monuments, Museum of New Mexico, in 1972. There is a visitor center with a full time staff at the site. Preservation projects were instituted at the monument in 1972, 1974, and 1985.

Wall Caps: During the historic occupation of the post, lime plaster was used to form a simple cap on the walls. In some cases adobe bricks were layed in such a manner as to form a coping with a drip edge.

Erosional problems at another 19th century fort in New Mexico were dealt with by placing wide wooden planks on top of the walls to protect them and to form a drip edge. The planks were held in place by additional mud bricks.

During the 1972 stabilization effort at Fort Selden some of the wall remnants were capped with mud bricks which had been ammended with a synthetic resin (Pencapsula). The ammended bricks were relatively impermeable and this resulted in the accelerated erosion of the wall fabric immediately below the cap. The bricks were layed in line and flush with the walls with no drip edge. In addition to the cap failure, several courses of historic bricks were removed to form a base for the new material. The result of this work was a flat topped unnatural appearance to the walls. The amount of original fabric removed by this destructive technique would not have been lost to the natural weathering process for several decades.

The amended bricks were removed in 1974 and the walls were coated with a one inch (2.54 centimeter) cap of unamended mud.

The walls were capped with unamended mud again in 1985. This time narrow strips of red plastic sheeting were placed between the cap and original surface at three foot (0.9 meters) intervals to act as indicators when additional maintenance work is required.

The unammended cap lasts about one year. The rapid deterioration of the cap is the result of the flat wall top which exposes a relatively wide surface to rain and the effects of freezing and thawing. The walls which have not been capped have eroded to a characteristic rounded or pointed top which sheds water and on which snow does not accumulate. Like the soldiers that preceeded them, the monument staff is experiencing difficulties in finding time to keep up with the continual maintenance required for the mud wall caps. While this is a effective and aesthetically acceptable preservation technique, if well maintained, investigation should be made into the viability of amendments that would retard erosion without having adverse effects upon other portions of the wall remnants. The use of shelters to protect the exposed mud brick walls would obviously be a more effective preservation technique than capping. Careful consideration must be given to the design of the shelters so that they do not create adverse physical effects upon the wall remnants.

Wall Bases: Many of the wall bases at the monument exhibited typical basal erosion caused by rising damp, leaching of salts, wind borne abrasives, and to some extent, rodent infestation.

During the 1972 stabilization project the treatment of the wall bases was minimal.

In 1974 the walls that exhibited advanced basal deterioration were repaired by inserting new mud bricks into the base. The eroded areas were prepared by cutting them into a rectilinear form with a flat base to accept the new mud bricks which were set in unamended mud mortar. The square edges of the bricks were trimmed to match the contours of the historic walls. At one point in the project, used bricks became available from a building that was being razed in the community and they were used for repair of the resource. The bricks were so similar in appearance to the originals that careful recordation was required to distinguish the old from new materials. It was more cost effective to use the recycled bricks in comparison to manufacturing new ones on site.

During the 1985 stabilization work the wall bases were repaired using the same techniques of mud brick infill and plastering.

The walls which exhibited less basal erosion were repaired with successive layers of mud plaster.

Drainage Slopes: In 1974 slopes were established to prevent the accumulation of water next to the walls. This was accomplished by using hand labor and mechanized equipment. The exterior and interior ground surfaces of the rooms were, as practicable, brought to the same level by lowering or raising the fill. The ground surface was then sloped away from the walls to facilitate rapid water run off. This prevents problems associated with the transference of moisture through the wall from the area of greater to lesser fill.

In some cases where there was severe and extensive basal erosion, compacted earth berms were established against the walls to provide support and to prevent the accumulation of water next to them. Basal erosion occurs at the juncture of the wall and the top of the berm.

In 1985 limited sections of the slopes on the berms were recontoured to some extent.

Drainage within room blocks was generally facilitated by channeling the water through doorways to the exterior of the structure. In cases where this was not possible, the interior of the rooms were contoured to encourage the puddling of water in the center where it would evaporate.

The establishment of drainage slopes has retarded the erosional process and is acceptable in terms of aesthetics.

Wall Remnant Burial: Low lying walls that were not of salient visitor interest were draped with a permeable soil membrane and covered with earth. This is an effective technique which stabilizes the feature.

Preservation Landscaping: Several species of native grass, which do not require watering after establishment, were planted on the parade ground and the perimeters of the post. The grass reduces the amount of wind born particles that blast the wall remnants of the post during wind storms. No vegetation was planted in rooms for it was felt that it might retain moisture which would enter the walls. It is not known how effective this technique has been.

Visitor Trails: Distinct trails were established through the fort and visitors are requested to stay on them. This reduces damage from public use.

Architectural Cross Sections: In 1985 architectural cross sections were established through the site on a north-south and east-west axis. At points where the line intersected a wall, archaeological excavations were conducted to reveal the foundations and original wall thickness. Scale drawings were made of the wall sections in order to evaluate erosional patterns.

Soil Analysis: Fifty-two cores from mud bricks were taken from various locations in the fort, some areas represented different building periods and, in one case, a wall face was sampled extensively on a vertical and horizontal basis. This was done in order to determine whether or not differiental erosion rates could be correlated to the mud brick morphology. The tests which included particle size analysis, atterburg limits, and soluble salt content, revealed that the physical makeup of the sampled bricks throughout the site were very similar. The average particle size for the samples is 54.7 percent sand, 26.7 percent silt, and 18.9 percent clay.

DISCUSSION

The mud brick remains of Fort Selden are preserved by the State of New Mexico for their value as a public program. The walls and visual environment provide an intimacy and immediacy with the past that is impossible to achieve with the written or spoken word, or in a museum setting. Thus, the preservation design for the site has taken an approach which approximates 19th century romanticism. The dynamic process of deterioration is presented as a static condition.

This preservation philosophy is illustrated by the extensive multi-story mud and rock Indian sites in the southwestern United States. Archaeological excavation revealed substancial wall remnants which were stabilized and presented to the public as ruins. This has created a condition which did not, and could not, exist under natural circumstances. It has also created some perplexing preservation problems and interesting philosophical issues.

Public programming and preservation are, ironically, often in conflict. Stabilization techniques employed at Fort Selden, such as the removal of original wall fabric to install a mud brick cap, were detrimental to the resource. The archaeological excavation of portions of the fort created additional preservation problems. Other forms of intervention to include unamended mud brick caps, mud brick infill, and the establishment of drainage slopes were employed, in part, for their minimal visual impact. These techniques represent a band-aid approach which, at best, only retards the erosional process.

The preservation materials used are not readily distinguishable from the original. Some form of identification should be instituted in order not to create a fantasy historical environment for the visitor. Techniques such as the addition of small pieces of plastic, similar in form to straw, to the plaster and brick might be a solution to this problem. The plastic could be color coded to date its intervention.

There is a continual impact upon the site by vistors who touch, pick at, and walk or jump over walls. The trails were established about 2 feet (0.6 meters) from the walls. The resource would receive less impact if the trails were located out of reach of the walls.

Site or wall shelters may be a cost effective method of dealing with mud brick preservation. The designs should be such that they, at least, are compatible with resource, and preferably would enhance the overall public presentation of the site.

Preservation techniques, such as caps with drip edges, should be investigated and applied on a wall specific basis.

Perhaps the most effective preservation technique for earthen ruins is burial, which is antithetical to public programming. The site should be recorded prior to burial and copies of the data placed in time capsules at the site. The resource might remain covered for generations and the time capsules might insure the survival of the archival data.

Little is known of the mechanics and erosion rates of the walls at Fort Selden. If the process of degradation were better understood more effective preservation methods could be employed. It may be possible to develop a predictive erosional model by analysis of the original construction data, post occupational photographs, the morphology of the mud bricks, elevations and sections of the existing walls, and historic and predictive weather data.

In conclusion, the work at Fort Selden, and probably most other mud brick sites, has not been effective for their long term preservation. Philosophical issues regarding public programming at the site, specifically theatrical presentation versus treating the wall remnants as artifacts or collection items, must be addressed.

Analysis of the erosional process of the wall remnants should be conducted in order to come up with real solutions to the ruin's preservation. Any form of intervention should be tested, preferably not on the resource, before being employed on an extensive basis.

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FIG. NO.1 Fort Selden State Monument. View of the fort ruins after stabilization in 1974, looking west.

FIG. NO. 2 Preparing wall base for insertion of mud brick infill to repair damage caused by basal coving.

FIG. NO. 3 Wall base after correcting basal erosion with mud brick infill. Workman is filing down new brick to conform to historic wall profile.

FIG. NO. 4 Company Quarters before stabilization, 1974.

FIG. NO. 5 Company Quarters after stabilization. Note higher fill level and establishment of positive slope away from walls.

FIG. NO. 6 Officer's Quarters as it appeared during the occupation of the fort circa 1867.

FIG. NO. 7 Officer's Quarters in 1974 before stabilization. Taken from same point as FIG. NO. 6.

FIG. NO. 8 Officer's Quarters after stabilization in 1974. Note brick infill at base of walls and establishment of positive grade away from walls.

CONSOLIDATION OF ADOBE WITH ETHYL SILICATE : CONTROL OF LONG TERM EFFECTS USING SEM.

Giacomo CHIARI
Dipartimento di Scienze della Terra - Università di Torino
Via San Massimo 22
I - 10123 Torino To
Italie

ABSTRACT

Ethyl silicate has been used with good success in the consolidation of adobe surfaces in the past 20 years. Since the treatment is irreversible, some concern about its behaviour in time is justified. To control the modifications of the treatment, SEM pictures were taken at various time intervals, from one day to 16 months. These pictures show progressive reopening of the pores, with temporary formation of filaments of the polymer crossing the cavities. Globuli of silica gel progressively reduce their volume with completion of the reaction. This study will continue in the future.

INTRODUCTION.

The use of silicon esters, in particular of tetraethyl orthosilicate, for the conservation of decaying stone was first suggested in 1861 by A. v. Hofmann [Anon., 1861], but its application as a stone consolidant was patented in 1926 by Laurie. Later many conservators applied ethyl silicate particularly to the conservation of sandstone, limestone and marles, claiming satisfactory results. In the early '60s, though, especially in England, there were negative reports on the effectiveness of this treatment on stone, saying that if the stone was of good quality there were no apparent effects, and that if it was of poor quality, scaling of the treated surfaces followed [Bailey & Schaffer, 1964]. Since the ethyl silicate treatment involves a series of complex chemical reactions in which the medium to be consolidated plays an active role, it seems that the poor results quoted by Bailey could depend either upon an inadequate application technique or upon trying to consolidate the wrong type of stone. More recent reports [Bartusek, 1964; Lewin, 1971; Weber, 1975] on large scale field applications proclaim very good results, at least for some years.

Since 1969, ethyl silicate has been applied to the consolidation of mud-brick [Torraca & Chiari, 1972]. Clayish material, infact, contains a large quantity of free hydroxyl groups (-OH) capable of reacting with the consolidant during its polymerization. The reaction has been described in detail in many papers (see for example Lewin, 1983).

In preliminary laboratory studies many other consolidants were also tested, and ethyl silicate proved the most promising. Following this a large scale field test on archaeological walls in Seleucia (1969) was conducted, during which the application technique by spraying was refined. The method was applied with success in many other sites and countries, as well. Sicily (Mozia and Solunto, 1971); Peru (painted friezes in Garagay [Chiari, 1975];[Chiari, 1980]; mud friezes in Chan Chan); Jordan (a very ruined painted mud wall [Schwartzbaum, Silver and Wheatley, 1980]); Equador (laboratory tests on Chochasqui tuff [Chiari & Rossi Manaresi, 1980]); Saudi Arabia (Masmak, Riyadh [Albini, 1980]) are all examples of successful applications.

On many of these sites, (unfortunately not for all of them) there was the possibility of assessing the effectiveness of the treatment by examining them up to twelve years after exposure. In all cases the appearance of the treated parts was good, especially when compared with nearby non-treated parts, which suffered tremendous deterioration. Particularly successeful was the treatment of the mud frieze in Chan Chan which was left exposed to the sea aerosol for 10 years and was subjected to a severe flood in 1983.

This kind of overall examination, though, can be subjective, and therefore more thorough laboratory tests seem to be warranted. Lewin and Schwartzbaum, (1985), studied a specimen of the Teleilat Ghassul treatment to determine the degree of hydrolysis occurring after four years of normal indoor ageing. They pointed out that the reaction is very slow since there were still residual ethoxy groups. If, after curing, the chemical residue left in place continues to modify itself for several years, there may be doubts about a loss of the consolidating and strengthening effect. A new application of ethyl silicate to regain the required degree of consolidation can be done only if the material has regained its original porosity, to allow the penetration of the consolidant. Furthermore, it is known from in vitro tests that the hydrolysis reaction of the silica gel by itself produces a decrease in volume. This effect may be thought to take place also in the gel which is formed in the cavities of adobe in the early stages of curing. Whether this shrinking can cause stress in the material, in the long term as well, is a matter of debate.

The present study is aimed at obtaining more data on the kinetics of the reaction between ethyl silicate and adobe, both in the initial stages and over time, with the goal of answering at least some of the above questions. To determine what happens at the microscopic level to the treated material, Scanning Electron Microscope observations were performed at different time intervals after treatment. The results presented here are to be considered preliminary, since the time range is between one day and sixteen months only. It is the author's intention to continue these observations in the future.

TYPES OF ETHYL SILICATE COMMERCIALLY AVAILABLE AND THEIR BEHAVIOUR.

The silicon esters used in the treatments quoted above are of three different kinds: the monomer (tetraethyl orthosilicate (TEOS) produced by Union Carbide); the ethyl silicate 40 (Silester ZNS produced by Monsanto, which consists of a partially polymerized molecule containing an average of 40% in weight of Si atoms) and a mixture of methyl trietoxysilane and tetraethoxysilane in toluene solvent and catalyst (commercially known as Wacker H). The first two products are normally applied by diluting them in an equal amount of ethyl alcohol (96 % in volume), with or without the addition of 1% of hydrocloric acid as catalyst. A fourth product, Wacker OH, (basically TEOS plus solvent and catalyst) was not used in the above quoted treatments, but is investigated as well in this paper for comparison.

All the samples (with the exception of Figure 11 and 12) are from an adobe brick coming from the Huaca de la Luna in Trujillo, Peru, treated by complete impregnation with Monsanto Silester ZNS dispersed in alcohol; no catalyst was added.

Trials to follow the reaction in time by observing only one sample in exactely the same spot were jeopardized by the low conductivity of the material. The thin layer of gold coating necessary to obtain sharp images, interfered with the reaction, blocking the access to the water needed for the hydrolysis. Therefore we can compare "landscape" features only.

Figures 1 and 2 show the appearance of the original untreated material, in terms of grains, pores and clay particle arrangement. Figure 3 was taken one day after treatment. Only the large pore in the lower part is open, while the smaller pores (centre) are almost completely coated by the silica gel. This confirms the fact that for a few days after treatment the surface is water repellent and the measured porosity is greatly reduced. After seven days (Figure 4) the pores start opening; the silica gel coating over them is transformed into a net of filaments, which, by contraction, tend to break (Figure 5). Large blocks of gel that did not interact with the clay (Figure 6) evolve into empty round shaped vesicles, typical of highly polar polymers producing convex monomolecular membranes (Figure 7).

The number of filaments in the samples decreases with time. The filaments still present become longer as shown in Figures 8, 9 and 10. Although very spectacular, these filaments are not, in my opinion, the most important factor of adobe consolidation. The residual coating and the large number of bridges formed at atomic level between the clay particles is far more significant. These chemical bonds cannot, obviously, be seen.

A very important point stressed by these observations, is the fact that the material progressively regains its porosity and general appearance, retaining at the same time, the desired property of water resistance. After treatment, over time, the clay particles are no longer dispersed in water, thus giving cohesion to the adobe.

These observations, although limited to a time range of 16 months only, comfirm the slowness of the hydrolysis reaction. It does not seem likely that the completion of the reaction would induce in the material a stress greater than the one due to the shrinkage taking place in the first few months. The question of the long term (10-20 years) effectiveness of the treatment remains open. On the other hand, having proved that porosity is regained, and given the polar nature of the coating, a periodical treatment can certainly be planned, if needed. Evidence of the treatment progressively decreases with the contraction of the silica gel not directly involved in the reaction with the adobe. This compensates, in part, for the total irreversibility of the treatment. If the principle of reversibility cannot be attained (and in practice this is true for every treatment to some extent) at least the principle of "minimum intervention" should be sought.

Something more should be said about the use of Wacker H. This product has a methyl group directly attached to the Si atom (non polar and not hydrolyzable) which gives long lasting water repellent properties to the treated surface. Figures 11 and 12 show a sample from Teleilat Ghassul after 7 years of ageing. The landscape shown by the SEM pictures is that of a "pudding" like layer severely cracked, but basically stable in time (already evidenced in a sample of calcareous sandstone [Furlan & Pancella, 1983]. This phenomenon might be explained by the tendency of the silane groups to systematically arrange themselves toward the surface, since the polar part of the polymer is attracted toward the surface of the polar porous material. The hydrophobic layer on the outer part of the coating can inhibit the access of water, thus also explaining the excessively high content of non-hydrolyzed alcoholic groups found in the same sample by Lewin and Schwartzbaum, (1983). Since water repellency is not a truly desirable property for an adobe treatment, it is my contention that the other three products, based solely on TEOS without silane groups, are more suitable for adobe treatments.

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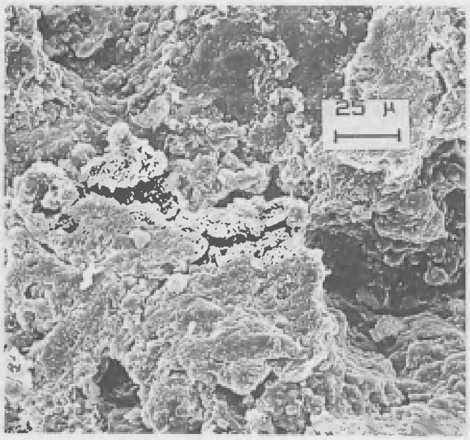


Figure 1

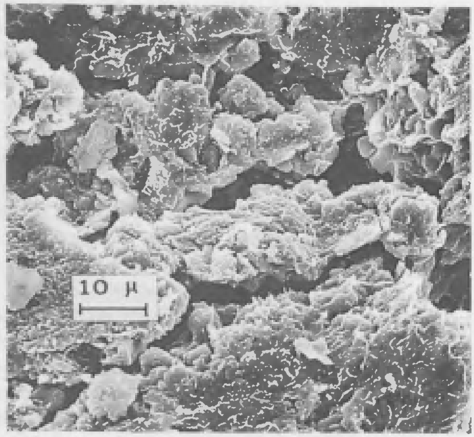


Figure 2.

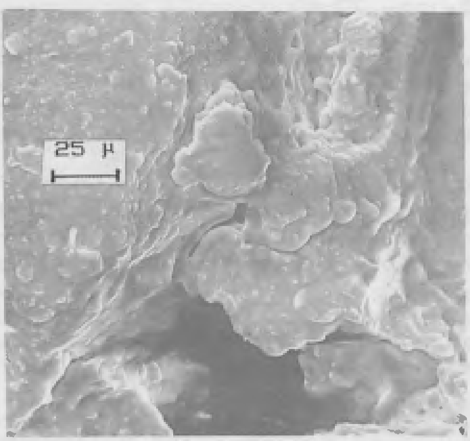


Figure 3.

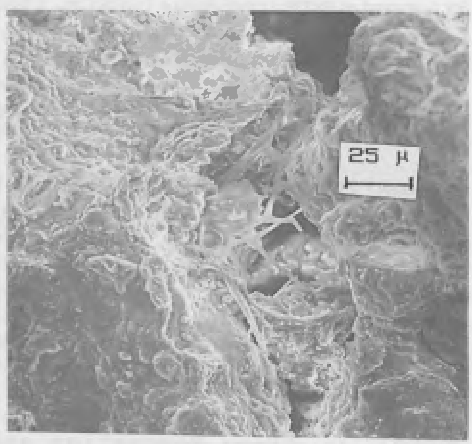


Figure 4.

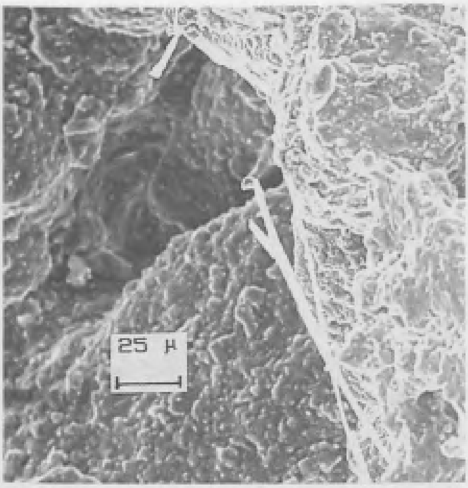
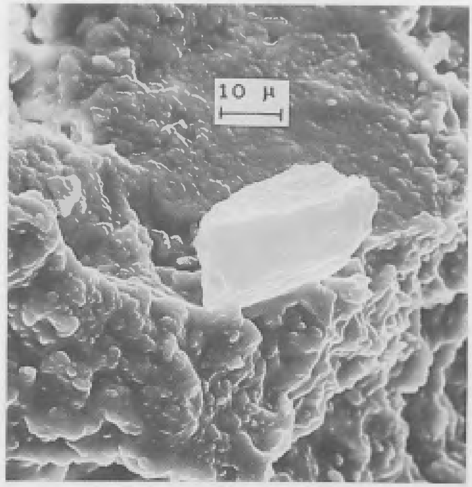


Figure 5.



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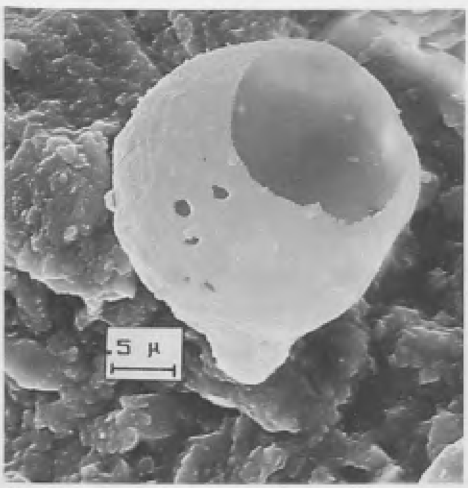


Figure 7.

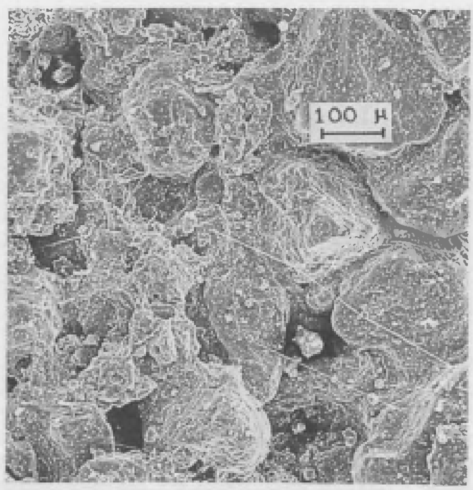
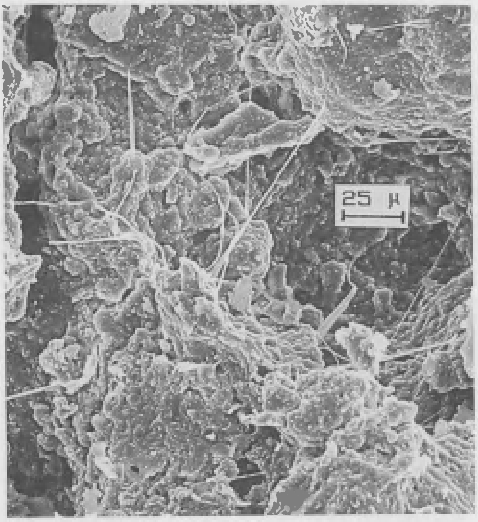


Figure 8.



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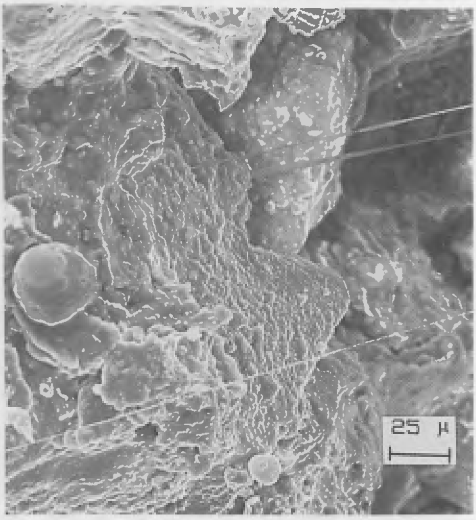

Figure 10.

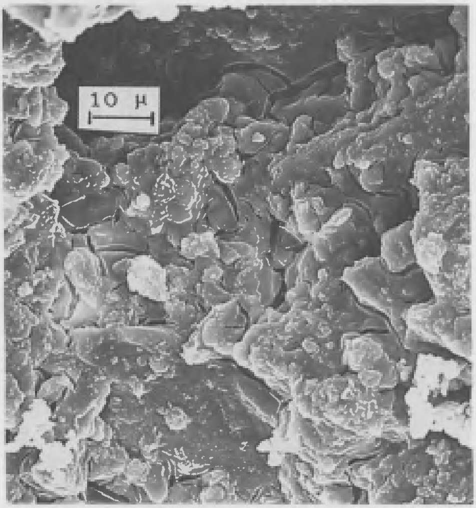

Figure 11.

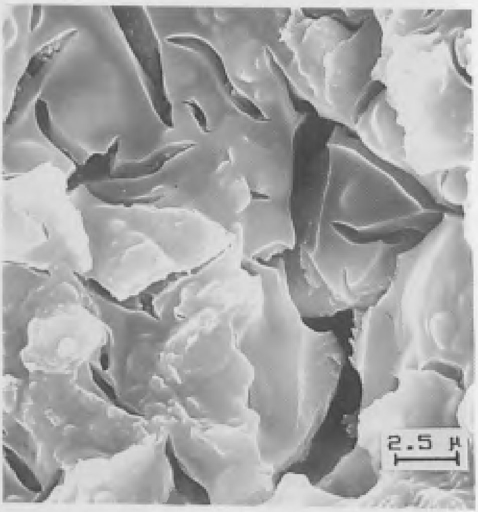

Figure 12.

THE CAUSES AND EFFECTS OF DECAY ON ADOBE STRUCTURES

Anthony CROSBY
National Park Service
PO Box 25287
Denver, Colorado 80225
U.S.A.

ABSTRACT

The complete understanding of the actual causes of deterioration, regardless of how simple or complex, is necessary before a comprehensive intervention program can be undertaken. Once the actual processes of decay are thoroughly understood, a logical approach will eventually result in the identification of the important cause-and-effect relationship. While most of the actual results of decay in adobe are often obvious, some causes and even some of the actual effects or results are not easily identified and may well require more indepth investigations.

EFFECTS OF MOISTURE

The most dramatic effect of moisture on an adobe structure is the collapse of the structure when the moisture content reaches an extreme level, reducing the compressive strength of the material below the actual loads subjected to it. The result is sudden and obvious. A wall or other primary feature can collapse completely. Figure No. 1 shows one example of this dramatic failure. The base of an unsupported portion of a 6-meter high adobe wall had absorbed moisture to the extent that the compressive strength was substantially reduced and the wall sheared along a classic compressive failure plane and simply slid off its base onto the ground below, while still remaining perfectly intact although somewhat lower and in another plane. Figure No. 2 is of a nearly saturated wall which failed completely soon after this photograph was taken.

Figure 1

Figure 2

The saturated condition in this case resulted from the important historic structure being located in the middle of an irrigated agricultural field. However, this is a relatively rare occurrence as moisture to that extent does not normally exist throughout the load bearing portions of a structure or structural feature. At Tumacacori National Monument, moisture as great as 28% existed in portions of 2 meters thick adobe walls. At this moisture content, the bearing capacity was reduced to less than 10 psi. However, the walls did not collapse or even develop structural cracks because other parts of the lower portions of the walls had much greater bearing capacity and because the wall was basically acting as a monolithic mass rather than as individual building units.

As it is more common to find only portions of an adobe wall or larger adobe mass with excessive moisture contents, much more common failure occurs under these conditions. In many of these cases, a series of events result in the wall not functioning as a monolithic mass, but rather as masonry segments. Failure then occurs in portions of a single structural feature. Lets look first at the case of a simple adobe wall. Moisture has accumulated along one side at the base of the wall. Rather than intermittent, the source is constant as could occur when snow has accumulated and then melts a little more each day. If the source is not constant, the moisture will not move to significant depths into the material and result in excess loss of compressive strength. As moisture moves deeper and deeper, less and less material is required to carry more and more of the loads. Stresses occur at logical planes, normally at the joints between courses or wythes of adobe. As the wetter mud begins to slump or compress slightly, the strains along the stress planes become greater until finally a portion of the adobe wall is acting independently. If the adobe material at the base of the wall begins to dry at this point, then there may be no additional failure, the movement may stop, and the cracks which have formed may not become larger. However, water in the form of rainfall or from an anticipated source may then gain access to the interior of the wall much more rapidly, and could then decrease the strength of the previously affected material. Failure could then occur even if the original problem of moisture entering at the base of the wall has been resolved.

The total collapse of an entire structure or even the collapse of a portion of that structure can obviously be termed "a failure." But what are some of the often subtle events which have weakened the material initially?

The actual effects of the free moisture which have resulted in this failure can probably be simply stated as the reduction of frictional quality of soil particles which resist movement of one particle in relationship to another. This occurs when the space between clay platelets is increased as moisture gains access. The important frictional quality is also reduced when natural cementing agents are effectively removed from the actual soil particles. The effects also result when certain soluble salts which have initially precipitated around particle junctions, effectively increasing the frictional surface and the resultant resistance to movement, are dissolved by water.

Some of these weathering factors of adobe brought on by internal moisture are complex and difficult to analyze. Generally, the disruptive action within an adobe mass is a result of one or a combination of factors. Some of these are: (1) the expansive action of soluble salts during hydration or dehydration, (2) the expansive action of the moisture as it is heated, (3) the differential thermal expansion of the salt crystals, and (4) the wet-dry cycles. Wet and dry cycles are actually not separate phenomenons but are probably based on a combination of some of the other disruptive actions.

Pressure is exerted by the salts on surrounding material by both hydration and dehydration, but apparently the hydration pressures are much greater. For example, hydration pressure of gypsum (CaSo4.2H2O) at 25 degrees Centigrade and 70 percent relative humidity is approximately 1,000 atmospheres or 14,000 psi.[1] Obviously, the actual effects on an adobe mass are dependent upon the concentrations of salts, the actual salt types, the location within the adobe mass, and the actual moisture conditions. The more obvious results of this phenomena occurs at the surface of adobe or immediately below the surface because moisture conditions change more dramatically and more quickly there. However, conditions can also exist in the interior mass which could also result in disruptive pressures.

Expanding moisture when heated from 0 degrees to 60 degrees Centigrade may develop pressures in pores as great as 7,500 psi. A temperature increase of 60 degrees Centigrade on the adobe material will probably not occur, but surface increases in the range of 20 to 30 degrees Centigrade are not at all uncommon. Based on the extremely low tensile strength of adobe, which is normally less than 100 psi, even this relatively small increase could have some disruptive effects.[2] However, this action would not occur significantly in an open pore situation. In that case, the water would simply move from one pore to another and eventually to the surface where it would evaporate. It is possible for the movement of ordinary moisture

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1 Winkler 1975, 123-34.

2 Eyre 1935, 17.

to be impeded by ordered water because of its higher density and electrostatic attraction to the material-water interface.[3] In this situation the expansive pressures could affect the material to some degree. However, the expanding water will probably only have an actual effect in combination with other factors. Surfaces exposed to the heating effects of the sun will probably not increase sufficiently in the relatively short time the material is subject to this action. Also, the evaporative effect of the higher temperatures will continue to effectively reduce the pressures.

The other disruptive effect of the temperature change in moisture within an adobe mass is the expansion of the moisture when it changes from a liquid to a solid. This, too, will normally affect the surface as the thermal mass of most adobe structures will prevent the temperatures in deep interior masses from actually reading freezing temperatures. In the 2 meter thick walls at Tumacacori, a continuous monitoring of internal wall temperatures over a 6 year period never indicated an internal temperature below 11 degrees Centigrade, even when actual ambient temperatures were below minus 10 degrees Centigrade. However, where adobe walls are exposed to lower temperatures, and especially when associated with strong winds, actual deterioration can be noted.

At adobe walls of an 18th-century Spanish Colonial complex in central New Mexico, severe erosion at the base of walls was long suspected to be the results of freezing. The actual decay was much more prominent on the north facing walls, the direction of the predominant winter winds. Even with winter temperatures in the area often less than minus 20 degrees Centigrade, little actual damage was obvious except in association with the winds. However, in association with the winds during the late winter of 1986-87, the results in several specific wall areas was disastrous. On thorough investigation of a portion of a wall which had recently collapsed, actual ice crystals were observed distributed throughout the collapsed mass. Extremely severe surface erosion on the north facing surfaces of large standing adobe walls nearby at Fort Union National Historic site is also attributed to some degree to extremely low effective temperatures in the material. And similar to the previously described conditions at Pecos National Monument, adobe walls have been literally split open by a combination of moisture lowering the bearing capacity of the adobe allowing access to the interior of the wall and the actual freezing of the moisture in the wall. In addition, on the surfaces of north facing walls in some areas particularly affected by strong wind

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3 Winkler 1975, 116 and 108.

anomalies have eroded at a rate up to 10 times those not effected by similar wind magnitudes.

The differential thermal expansion of salts present in the material probably also has some disruptive effects, but it is apparently not as important as some other factors.[4] Consequently, the actual effect again becomes significant only in combination with other disruptive actions or after these other actions have had their effect on significantly weakening the material.

The disruptive action caused by wetting-drying cycles is the most significant of the four mentioned. The specific causes are not well understood but have long been recognized as an important factor in adobe as well as in stone deterioration.[5] The same mechanisms are at work in adobe but probably to a much greater extent. This is especially true of adobes that have a significant amount of expansive clays. The results of the wetting-drying action are most dramatic during drying conditions when the most significant amounts of surface material become friable and fall from the walls at the slightest touch. The actual mount of friable material varies considerably, being most significant in the areas also affected by salt crystallization and hydration. In these areas, a depth of friable material of approximately 2 to 3 centimeters is not unusual.

The actual stresses resulting from wetting-drying cycles, as well as other internal forces, are certainly more obvious on the exposed surface of the adobe material. For most practical purposes, when not in the presence of excessive moisture, the deterioration caused by such factors as wetting-drying cycles are limited to the surface or to material near the surface. However, these cycles do reduce the strength of materials even within a wall mass and can result in traumatic failure at lower moisture contents. But even in these cases, before failure can occur, excessive amounts of moisture have to be present. As an example, material may fail when the moisture content is, for instance, 25% by weight. That same material, after being affected by the various internal forces, may fail at 20% instead. This difference may be critical in certain situations.

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4 Winkler 1975, 134.

5 Winkler 1975, 110.

DETERMINING MOISTURE CONDITIONS

Subtle changes in the cause-and-effect relationship may provide a much clearer picture of the actual migration of moisture through building fabric and the effect of that moisture on the material. In addition to what may appear to be capillary moisture intrusion, direct rainfall through the upper walls may also be suspected.

A subsurface investigation is often necessary to help determine soil conditions and whether or not a possible capillary moisture source exists. Typically, borings should extend to the water table if within ca. 15 meters below grade. Samples can be analyzed to determine properties such as moisture content, particle size, liquid and plastic limits, and amount and type of soluble salts. Conditions such as alternating layers of cobbles and hard pack may preclude the possibility of the water table being a capillary moisture source.

Free water has to be available before moisture can rise in the walls through capillary action. Free moisture will occur when the force of gravity pulls moisture through the material, normally at less than an actual saturated condition because a substantial amount of air pockets will still remain in the wetted material. Depending on the specific material, this could occur when the actual moisture content is as low as 15 percent.

It will also be important to check for historic responses to a moisture problem. At Tumacacori, various types of dataindicated that the church complex is in a natural drainage area. Extensions to the lower part of the walls along the west side of the church and campo santo walls were not part of the original construction but rather a historic response to a basal erosion problem. Since this historic period addition occurs only on the upstream side of the structures, the basal erosion that resulted in the addition was probably caused by flood water.

WALL MOISTURE CONDITIONS

From the outset it is important to determine the distribution of moisture in structural components and it is desirable that these conditions be determined nondestructively, if possible. After investigating the practical use of these nondestructive techniques, none of them seemed capable of providing the type of detailed information necessary at Tumacacori. However, critical information was determined by drilling holes into walls and taking material samples to determine the actual moisture content. Moisture profiles were then drawn of the moisture conditions at that one time.

Monitoring of the internal wall conditions can then proceed, if warranted. At Tumacacori, the internal wall moisture and temperature conditions were monitored for several years after the material sampling. In addition to the internal wall conditions, it may be important to periodically determine the surface moisture condition. These wall moisture conditions should be compared with results from comprehensive monitoring of conditions in the microenvironment.

The conditions in the microenvironment, whether rainfall, a surface moisture source, or ambient moisture, are the causes which result in deterioration. A thorough understanding of all causes and effects will result in an intervention program which is appropriate for the problems and the important features and overall values which should be preserved.

CONCLUSION

The actual mechanisms of decay are all dependent on the presence of moisture. Moisture has its most traumatic effect when it increases to such an extent that the mechanical strength of the adobe is reduced beyond the loads placed on it. Partial or total failure of an entire wall could result.

At Tumacacori, the primary source of moisture in the adobe walls was from capillary sources. Most of the east nave wall and two portions of the west nave wall were primarily affected. The damage had probably been occurring periodically since the building was constructed. The actual source for the capillary moisture was rain falling on and around the church, soaking into the soil near the wall foundations. A supplemental source upstream, which periodically moved moisture through the area just a few feet below grade, was also a distinct probability. The initial analysis of the actual wall conditions resulted in the elimination of conditions, primarily in appropriate drainage and impervious wall treatments, which could have resulted in the total collapse of a wall.

The continuing importance of monitoring and the development of an understanding of the reaction of adobe to various potentially deleterious conditions was important in providing a thorough understanding of one particular adobe structure. This understanding resulted in a comprehensive preservation project which actually required only minimal changes.

Any preservation project should be oriented to doing the least amount of work necessary to preserve the important building and site values. Minimal intervention should always be the overriding philosophy. Certainly, much more dramatic changes such as the total rebuilding of some walls and construction of new foundations under others could often be carried out based upon the most minimal of information with full confidence that such action would solve the problems. However, the more complete understanding of the cause and effect relationship often indicates that such drastic action is not really required.

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VERNACULAR ADOBE ARCHITECTURE IN TURKEY AND PROPOSALS FOR ITS RE-EVALUATION

Prof. Dr. Murat ERIC
Mimar Sinan University
Findikli Istanbul
Turkey

ABSTRACT

The vernacular adobe architecture in Turkey is widely observed in the Southeast,East and Central Anatolia.Adobe,which its historical background goes back to the 13 th century B.C. is still applied with various traditional techniques as a continuation of our old work of art. The techniques that are applied can be gathered in two groups as, massive and timber framed adobe systems. The vernacular adobe architecture which still exists has an architectural value of its own.Raising the quality standard of the material and adding various functions to the living texture should be seen as two important effects in preserving this value.

PREFACE

From the point of historical culture heritage and ruins,Turkey is a rich country.Different geographical characteristics of Anatolia which has the traces of various civilizations,effectected the selection of the material and the architectural formation accordingly.It's a great advantage for us to have the traditional methods and architectural plannings without too much change in the formation of the vernacular architecture in use,even today.Yet, the greatest danger we face today that will destroy the vernacular architecture,is the inclination today towards urbanization with yearning for the new technology and materials.The destruction as a result of this kind of change, is so great that it can not be compared with the long years of ware and natural destruction that the adobe material has to face. To find a solution to this problem will not only preserve our values but will also help them survive. It will be useful to go into the subject by examining the regional distrubition and the structural characteristics of the vernacular architecture in Turkey.

THE LOCATION AND THE STRUCTURAL CHARACTERISTICS OF THE ADOBE ARCHITECTURE

The examples of the vernacular adobe architecture in Turkey are observed geographically in the East,South east and the Central Anatolia especially on the dry and treeless land where dry climate regions. Lack of wood or stone materials in these regions plays a big role in using adobe material.Apart form this, from the point of preserving the heat,adobe has become a material which gives positive results in these regions where the summers and winters are tough. It is possible to signify here the excavations in Çatalhöyük, Hacılar, Beycesultan, Mersin belonging to the years 5900-4000 and excavations in Troy beloning to the years 2300-1200 and the remains of houses in Alişar and Boğazköy belonging to the years 1900-1200 and the urban areas excavated in Van, Çavuştepe and Adilcevaz which belong to Urartu civilization in the years 9-6 centuries B.C, as the oldest known examples. The massive adobe houses in Balaban, Van and Urfa and the adobe filled timber framed houses in Safranbolu, Osmaneli and various parts of the Central Anatolia which are 100-200 years old and show great structural similarities with these houses are the examples of the venacular architecture that should be preserved.

PIC.No.I. The structural technique of adobe whose past is old showing itself in the vernacular architecture. Van castle and an adobe house.

The adobe applications which were produced and used in structures in a similar way to the present vernacular architecture have generally been formed in two systems as with massive adobe walls and with timber framework adobe systems.

PIC.No.2.A beautiful example of the adobe vernacular architecture in Turkey,preserved and still existing. Balaban village between Kayseri and Malatya.

In the massive adobe walled buildings which has brought a horizontal siluette effect to architecture,used various techniques such as block, beating,keel and piling,but the most frequently applied one is the massive systems built by adobe blocks. In the application of adobe with timber framework, the general structure is formed with studs and braces and the gaps between the vertical studs which are placed every 50 cm. are filled with adobe blocks. These types were built in the regions of Anatolia where timber is in large quantity. The technique used in the production of the adobe material is almost the same everywhere although the clay shows regional differences. Definitely, this procedure used thousands of years ago had been no different form today's.The mud pile is placed in a hole and then pouring water on it the mixture is kneaded and afterwards filled in one or more rows of wet wooden molds. After being dried in the open air the material is ready for use. Although the colour of the clay differs in some regions great care has been taken in having high percentage of clay in the chosen soil and not having too much hay, choped fodder,sand and gravel in the adobe and not having them dried in the hot sun.

It is possible to come across one or two storeyed examples in the general architectural planning of the adobe houses. In the houses surrounded by a garden wall located in a courtyard there is a hall "sofa" around which I to 4rooms situated, used as living units.In the two storeyed examples, daily life

PIC.No.3. Producing of adobe blocks.

has moved upstairs while the ground floor is left for the service quaters like the kitchen, stable and storage. The flat soil roof which covers the building is also in use as a part of the house. The upper floors often have windows to the street or the courtyard with consoles. The streets are narrow and are in an organic formation which is created by the adobe houses with rounded corners. Some over the by the streets add a different beauty to the architectural texture. The material used here is tember which is thick with round crosscuts and in some examples reflecting an elite and pleasant culture. In the regions where trees are in large quantity, this type of architectural formation has developed and the wooden material gained importance on the living quarters and on the roof forming a beautiful composition with the adobe architecture.

There are no vertical wooden elements on the supporting walls of the massive adobe walled houses. They are supported with 1-3 rows of horizontal ribbons depending on the wooden materials. Ribbons placed on boht sides of wall are made from poplar or willow trees are 6-10 cm. in round diameter. As for the lintels, they are wooden pieces with small diameters. In some examples, apart from the wall system, it is useful to put vertical studs while making a construction. From the point of building differences massive adobe walls can be divided into there groups; first, walls made with the same size second, walls made with two different sizes called "mother" and "lamb"

PIC.No.4. An example of a house in which the massive adobe -and timber frame system used together.Old Malatya.

the latter being half size of the former and the last group thick walls which are built by adobe on both sides and filled in between. Adobe blocks are generally 30-40 cm. in length, 20-40 cm. in width and 8-15 cm. in thickness. The thickness of the walls are changeable according to the adobe sizes and applications which show similarities with I or I 1/2 and 2 brick masonry are made. Walls that are below the ground level and based on a stone foundation made of round stones is continiously plastered with mud. Compared to the adobe block more hay is added to the mud that will be used in plastering.

The flat soil roof which is an important characteristic of the vernacular adobe architecture consists of three parts; supporting joists,a floor made from reeds and branches to hold the soil and the pressed layer of soil above this. The supporting joists placed on the walls with a wooden base are generally with 15-25 cm. round crosscuts and made of poplar or willow trees . In some cases, indepentet post have been used to remove the weight of the roof on the walls. Posts are placed on the stone which is 15-20 cm. thick is pressed with a stone roller called "loğ",with the addition of mud,now and then.

The houses with wooden framed adobe walls which we come across mostly in Central and Western Anatolia, even though there are architectural planning similarities with the massive adobe systems but the number of floors have

PIC.No.5 . An example of a house in which adobe blocks are used in between the wooden frame. Osmaneli, a small town of Bilecik.

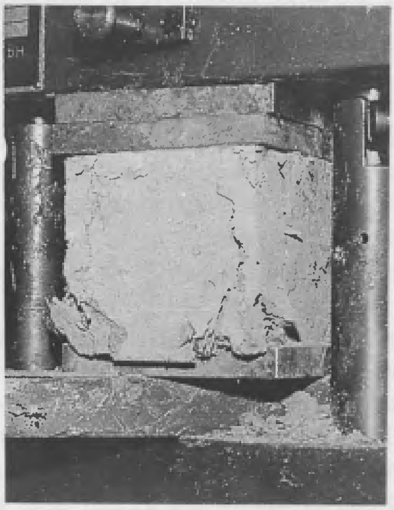
increased. Here, the wooden frame which is set up with vertical studs and braces are again devided by vertical intermediary studs placed in every 50-60 cm. and adobe blocks enter the wall formation as a filling material. In some with the wooden consoles second floors gain a different speciality and apart form this the wooden roof signifies an imporant characteristic of the vernacular architecture. In some examples it is possible to come across stone or massive adobe ground floors. The main supporter of the structure is now the wooden material and adobe is preferd because of its heat keeping characteristic. The adobe dimensions, plastering the wall with mud and building flat roofs, now and then show similarities with the massive adobe system. The adobe material in our vernacular architecture is some times used as plaster over bricks and sometimes as adobe blocks mixed with stone materials and it has been the traditional structural element which always chosen and admired in the structure system. Having viewed the location and the structural characteristics of the adobe architecture in Turkey, we can now carry on with our proposals on evaluation.

PROPOSALS ON RE-EVALUATION

As explained above,the vernacular adobe architecture is widely used in most inhabited regions as an extention of the historical heritage and culture of Anatolia.But,this valuable architectural texture as a result of strong desire for urbanization and for choosing new materials is in danger of vanishing without leaving healthy conditions behind.

We have two proposals here:

First,to raise the material characteristics up to the bricks or briquettes by developing its quality standard and therefore to obtain the preferance of this type in new usages.It is possible to observe this kind of expectation from the words of the inhabitants of these regions.They say,"Although we built our new houses with concrete and briquette,we miss our old adobe ones,our houses are no longer cool in summer and worm in winter". With this purpose, in 1980 some reseaches were done in the " Laboratory of the Building Materials" of our University and positive results were obtained. In our laboratory, the test results on the ordinary adobe materials obtained were 2-20 kg/cm^2 for the pressure resistance and 17-60 minutes for dissolving period. It is known by everybody that there are two most important reason in the destruction of the adobe,one of them being not enough resistant and the other the dissolving of the material in rain



PIC.No.6-7. The laboratory studies made to raise the quality standard of adobe materials.Mimar Sinan University,The Building Materials Laboratory.

water. Taking these into consideration,at the end of the extensive studies to raise the quality standard,lime and gypsum were added and the adobe was pressed as well. According to the test results,it has been observed that in the adobe blocks which had 15 % gypsum and pressed under 10 kg/cm2 ; the pressure resistance has increased up to 40-120 kg/cm2 while the other examples which were left unpressed and had 15 % lime,were not effected by water.

Taking advantage of the results obtained in our laboratory, we can say that using pressed and 15 % gypsum added adobe in the renovation of adobe blocks placed in the wooden frames as a filling and in the new massive wall applications and also starting 15 % lime added applications on plaster will be of much benefit.

The second prorosal concerning the protection of vernacular adobe architecture has a structural evaluation. We have to preserve our old but still existing works of art, which supplie the cultural communication between the past and the present and provide their use in our lives. The continous care of these preserved regions is a burden to the government budget, today. Therefore, it is a good solution to make protection plannings by renovation and to give them contemporary functions. These funtions, according to the characteristics of the old texture, can be renovated as residence, museum, touristic or cultural facilities. We want to give the Antalya harbour and Istanbul Soğukçeşme street restorations as an example in our country. In the first one social and touristic based plannings have been made, while some old stone houses being renovated, some new additions have been added. In the second one, a traditional street full of wooden houses, has been given function as pensions,have been renovated.

It is our greatest hope that, these applications be developed in a healthy way and the vernacular adobe architecture be a worthy texture to be protected and prospered.

LA BRIQUE CRUE EN ITALIE :

AVONS-NOUS UNE POLITIQUE DE CONSERVATION ?

Eugenio GALDIERI
12 via dell'Academia Platonica
I - 00147 Rome
Italie

ABSTRACT

The paper examines the present situation of the earth-built houses in Italy -particularly the cases of Sardinian and Piedmontese buildings- and deplores the failure of any peculiar conservation rule on this subject.

Permettez-moi avant tout, de vous porter le salut de l'Institut Italien pour le Moyen et Extrême Orient (IsMEO) et de l'Association LATER, pour la sauvegarde des habitations en terre.

Etant donné que la cinquième réunion d'experts dans laquelle nous sommes aujourd'hui engagés, se déroule en Italie ; on peut très facilement justifier qu'on commence justement par la situation de la brique crue dans notre pays. Et cela pour trois raisons principales : avant tout, parce que le problème des bâtiments en terre est à peu près inconnu chez nous, bien que l'Italie soit douée suffisamment d'une telle méthode de bâtiment ; en second lieu, à cause du manque absolu de lois de protection spécifique ; enfin, parce qu'il n'y a aucune sensibilité au regard de la conservation, au niveau populaire comme des autorités compétentes, centrales ou régionales qu'il soit. Et puisqu'il est déjà difficile -mais pas seulement en Italie- d'arriver à une définition correcte et épuisante de "bien culturel", il serait extrêmement plus difficile de persuader les autorités qu'une maison en terre est en tout cas un bien culturel à défendre ; et persuader en même temps, les gens communs que leur maison en terre est en tout cas un capital matériel à garder.

Par conséquent, faute d'une politique quelconque, dévouée à la préservation de ces bâtiments malheureux, ils sont destinés à disparaître en très peu de temps.
Mais voyons donc le problème dans ses aspects différents :
Comme je l'ai déjà affirmé plusieurs fois et en des lieux différents, si on demandait aujourd'hui à dix Italiens -non seulement aux habitants des grandes villes ou aux jeunes- si des maisons en terre existent dans notre pays, au moins six d'entre eux éclateraient de rire ; trois autres vous diraient qu'ils ont vu, sur les lacs du Nord et les deltas du Nord-Est, des cabanes faites de roseaux palustres et de la boue pressée, pour abriter les chasseurs ; un autre peut-être, tenterait de se souvenir dans quel village perdu de la Calabre, il a vu une petite et très pauvre maison rurale en terre pilonnée...

D'autre part, cette ignorance a des racines illustres : il y a soixante-dix ans, le géographe français Pierre Vidal de La Blache, dans son étude très approfondie et soignée sur les différentes typologies du bâtiment de l'homme dans le monde (1), avait ignoré justement la France et l'Italie pour ce qui concernait la présence en Europe d'habitations de terre.
D'accord, nous ne pouvons pas comparer les maisons en terre européennes à la millénaire tradition du Moyen Orient, de l'Asie ou bien de l'Afrique noire. Et, ça va sans dire, on ne peut pas comparer l'Italie, par exemple, à l'Espagne ou, si vous voulez, à certains lieux de la France ou de la Hongrie. Mais nous avons également des zones où la brique crue et le pisé sont (ou, mieux, ont été) la norme, la tradition et cela depuis longtemps.

Dans la plupart des régions italiennes -naturellement dans les plaines des bassins fluviaux- nous avons un très bon patrimoine, historique et moderne, de bâtiments en terre et il existe aujourd'hui un certain équilibre entre les exemples historiques ou très anciens et les bâtiments modernes : en effet, si durant les cinquante dernières années, il y a eu une destruction presque systématique d'édifices relativement récents ; d'autre part, on a commencé à prêter plus d'attention aux fouilles archéologiques et ainsi, on a mis à jour des complexes anciens dont on ignorait l'existence. Il ne faut pas oublier qu'autrefois les archéologues -ils avaient tous une formation "classique" ou "eurocentrique"-n'avaient pas l'habitude de considérer avec attention et respect ces matériaux pauvres, et souvent ils détruisaient presque tous les témoignages, non pas par aversion mais par simple ignorance d'une matière tant anormale. C'est ce qui arrivait encore, il n'y a pas longtemps, aux édifices civils étrusques dans la zone de Roselle, en Toscane (2).

Pour parler d'une période plus récente, il faut rappeler que chez nous, entre le XVe et XVIIe siècle, après une longue période pendant laquelle la technique des constructions en terre semble être tombée dans l'oubli, on utilise à nouveau cette méthode, et ceci à la suite de certaines influences étrangères : nous n'avons pas encore bien étudié et approfondi ce phénomène très singulier : de l'Est comme de l'Ouest, des populations étrangères viennent en contact avec notre pays et diffusent leurs méthodes de construction ; méthodes qui étaient bien connues chez nous depuis longtemps mais que désormais on utilisait seulement pour des bâtiments mineurs, pauvres ou provisoires comme, par exemple, les refuges de bergers. A l'Est, chassées par les invasions ottomanes dans les Balkans, des populations chrétiennes d'Albanie, de Yougoslavie et de Grèce se réfugient en Italie dans la partie Sud-orientale de la péninsule et y utilisent leur construction traditionnelle en terre, tandis que les Turcs eux-mêmes utilisaient à nouveau ce procédé dans les pays occupés.

A l'Ouest, des faits analogues se sont produits en Sardaigne : la longue domination espagnole et, en particulier, l'installation des Aragonais dans la région de Cagliari eurent une grande influence sur toute l'architecture en général ainsi que sur les matériaux de construction, en reprenant d'ailleurs une tradition ancienne.
Si nous nous référons à d'autres présences, nombreuses dans toute l'Italie (par exemple sur le cours oriental du Tessin, en Emilie-Romagne et surtout dans les Abruzzes, sur le versant oriental de la péninsule) nous pouvons admettre très aisément que le phénomène des maisons en terre présente, en Italie aussi, un panorama satisfaisant. Celui-ci repose sur une tradition très longue et assez continue, ainsi que sur l'absence presque totale de ce sentiment de honte et de retard social qui caractérise plusieurs pays du Tiers-Monde et qui est, en fin de compte, le principal ennemi des maisons en terre (3).

Examinons à présent, et plus précisément, les deux zones les plus significatives pour illustrer la situation actuelle en Italie. Il s'agit de deux régions assez distantes l'une de l'autre et dont les caractéristiques physiques, climatiques et sociales sont assez différentes : à savoir, la Sardaigne et le Piémont.
Pour ce qui concerne la Sardaigne, il faut dire que la qualité des constructions est assez bonne et la typologie présente les nombreuses variantes de l'habitation sarde, tout en concédant très peu aux modèles relativement étrangers à la culture insulaire.
Les influences espagnoles y sont évidentes, même dans la nomenclature technique : tout d'abord, cette dernière accuse une matrice classique-latine- et en même temps, elle révèle une technologie et une tradition castillane et aragonaise.
Aujourd'hui, quatre-vingt pour cent des presque vingt communes, petites ou grandes, qui s'étendent de Pula (l'ancienne Nora) au Sud de Cagliari, vers le Nord-Ouest, après Oristano, sont construites en brique crue ; il est intéressant de souligner qu'entre 1910 et 1925, les villages et les petites villes adoptèrent encore une fois les briques crues quand il fallait s'agrandir, alors que, dans les zones environnantes, l'habitude (et même la mode) voulait que l'on construise en brique cuite ou bien en béton armé.

En fin de compte, la Sardaigne a utilisé régulièrement la brique crue ou le pisé jusqu'en 1958, quand un signal d'alarme de nature hygiénique mais sans aucun fondement, poussa les autorités locales à interdire l'utilisation de la terre pour les nouvelles constructions et en particulier pour les dépôts de l'industrie alimentaire.

Pour ce qui concerne le Piémont, il faut préciser qu'il s'agit là aussi d'une vaste zone plane, entourée par trois cours d'eau, qui intéresse les villes de Novi Ligure, Marengo et Alessandria et une vingtaine de petites communes. Dans ce cas aussi, les maisons en terre ont une tradition ancienne (bien que mal étudiée) et une grande dignité formelle. Nous ne pouvons distinguer ces habitations bien soignées et entretenues -qui furent tout d'abord des habitations rurales- des toutes nouvelles villas pour une ou deux familles que l'on construit récemment avec des matériaux "résistants". La zone que nous avons choisi comme exemple présente un bon équilibre entre les constructions rurales et les édifices urbains ; plusieurs hôtels de ville et même un cimetière et une église y sont construits en terre (4).

Presque toutes les constructions piémontaises en terre ont été bâties selon la technique du pisé, avec une particularité, cependant : les murs périmétraux sont construits selon un procédé monolithique. Celui-ci, qui réduit au minimum l'utilisation de bois de charpente, consiste à élever des murs pleins, dans lesquels dès qu'ils sont secs, on pratique les ouvertures nécessaires. Dans cette région, la terre, en tant que matériau, est particulièrement riche d'alumine et devient donc très homogène et résistante, si bien qu'il est inutile de protéger les murs extérieurs des édifices par un enduit quelconque : l'effet chromatique de ces constructions d'un rouge corail très vif est particulièrement agréable. En dépit des sollicitations "modernistes" et des interdictions communales, beaucoup de paysans refusent d'utiliser tout autre matériau qui ne soit la terre rouge de leur région.

Du point de vue social, les qualités évidentes des maisons en terre -comme par exemple, les qualités cohabitantes ou l'élasticité des structures portantes en cas de tremblement de terre- retardent certainement la modernisation en cours dans toute l'Italie et favorisent d'autre part la continuité de la tradition. Tout cela pour ce qui concerne l'initiative et la position populaire. Mais... et les autorités ? Pouvons-nous dire qu'existe aujourd'hui en Italie, une politique quelconque vers la maison en terre ? La réponse est <u>non</u>, absolument <u>non</u>, désespérément <u>non</u>.

La position officielle vers ce problème -ou si vous voulez, la réaction des autorités aux mouvements d'opinion qui commencent à s'agiter à ce propos en Italie aussi (et admis qu'une telle réaction existe)- est sporadique et inégale d'une région à l'autre. Elle ne vise certainement pas la réhabilitation du système ou son étude sociale, économique et technique, mais plutôt la tutelle de l'objet en tant que "monument". D'une part, les Maires des différents sites, qui sont vraiment conscients des problèmes posés par les maisons de terre (5), ont tendance à solliciter des programmes unitaires et centralisés de sauvegarde. D'autre part, l'Administration centrale des Biens Culturels, engagée comme elle l'est avec des problèmes bien plus sérieux et urgents, est convaincue du fait que, dans le domaine général de la conservation, la politique la meilleure est celle du "mal mineur". Elle s'est dédiée jusqu'à présent à la sauvegarde des seuls éléments qui aient une importance architecturale ou historique particulière, en renonçant à priori à la tutelle de tout le contexte social et matériel qui, en lui-même, trouverait tous motifs d'auto-conservation. On peut citer, par exemple, le cas d'une construction en terre, dont la sauvegarde a été permise et favorisée par la Soprintendenza ai Reni Architettonici ed Ambientali di Cagliari en Sardaigne : celui de la Villa Serra, ex-Villa Tola, à San Sperate. Mais il s'agit là d'un cas tout particulier et significatif, à peu près unique : il s'agit d'une Villa d'été dont le projet a été signé en 1840 par un architecte sarde très connu, M. Gaetano Cima (6) ; c'est-à-dire une maison en terre... "griffée". En même temps, des centaines d'habitations, des dizaines de villages de 5.000 ou 10 000 habitants et presque entièrement bâtis avec la terre, sont destinés à une ruine lente mais sans cesse ni espoir.

Pour conclure : depuis quelques années, nous constatons qu'un certain intérêt pour cet argument se diffuse même parmi le grand public, mais dans l'indifférence totale des autorités : il nous reste donc à espérer que la politique de conservation change de manière radicale et positive. L'oeuvre de diffusion des données et la sensibilisation de l'opinion publique, en particulier grâce à la Faculté d'Architecture de Pescara (7), à l'Ecole Polytechnique d'Udine (8) et à l'Association LATER de Rome (9) (comme vous le voyez, aucune initiative n'a été prise dans les régions les plus riches de maisons en terre...), commence peu à peu à donner quelque bon résultat et à favoriser avant tout une mentalité et après, nous espérons, la création d'une loi spécifique de tutelle. Toutefois, nous sommes en mesure de donner notre contribution et d'accélérer le procès dont nous venons de parler, en remettant aux autorités scientifiques, administratives et politiques du pays, les résultats de nos recherches et expérimentations concrètes, dans le but de démontrer la validité actuelle d'un système millénaire.

NOTES

(1) Les études posthumes de M. De la Blache : Principes de Géographie humaine, Paris, 1948. Le plan récapitulatif est à la Pl. XVI, le texte est aux pages 150-4.

(2) Voir : Melani V., Vergari M., Roselle, Pistoia 1982, p. 80.

(3) Galdieri E., Le meraviglie dell'architettura in terra cruda, Roma, Bari 1982, chap. VIII, pp. 189-200 et figs. 1-18, pp. 244-253

(4) Galdieri E., "Arquitectura de tierra -historica y moderna- en Italia", Informus de la construcciòn, Consejo Superior de Investigaciones Cientificas, Madrid 1986, Vol. 37, n° 377, pp.51-53 et note n° 8.

(5) En 1986, l'Association LATER envoya un questionnaire (sur l'existence éventuelle de lois locales de conservation des maisons en terre) à quarante mairies de Sardaigne et Piémont ; pas plus que dix d'entre elles n'ont répondu (et elles étaient toutes de Sardaigne), en regrettant l'absence totale d'un quelconque règlement que ce soit dans ce domaine.

(6) Del Panta A., Un architetto e la sua città, Cagliari 1983, figs. 163-166.

(7) "Le case di terra : memoria e realtà", exibition et séminaire, Faculté d'Architecture, Pescara 1985.

(8) Bertagnin M., "L'architecture de terre en Italie : connaissance et réhabilitation d'un patrimoine typologique et technologique méconnu", Actes du Colloque international, "Le patrimoine européen contruit en terre et sa réhabilitation", Vaulx-en-Velin, 1987 ENTPE/Université de Lyon III, pp. 219-253.

(9) Galdieri E., "Etat et future des bâtiments italiens en terre", Actes du même Colloque, pp. 255-269.

A COMPUTER ANIMATED SIMULATION
"ETHYL SILICATE STABILIZATION"

Hugo HOUBEN
CRATerre/EAG
10 galerie des Baladins
F - 38100 Grenoble
France

Alejandro ALVA
ICCROM
13 via di S. Michele
I - 00153 ROME
Italie

RESUME

On présente ici une préversion de la simulation sur ordinateur de la réaction complexe de la stabilisation de la terre crue au silicate d'éthyle.

Depuis de nombreuses années, la stabilisation au silicate d'éthyle est pratiquée pour la préservation de l'Architecture de terre et son utilisation est enseignée à l'ICCROM.

Les responsables pédagogiques ont développé plusieurs systèmes afin de faire comprendre d'une façon simple et imagée aux architectes et conservateurs des cours, le mécanisme chimique complexe de cette réaction.

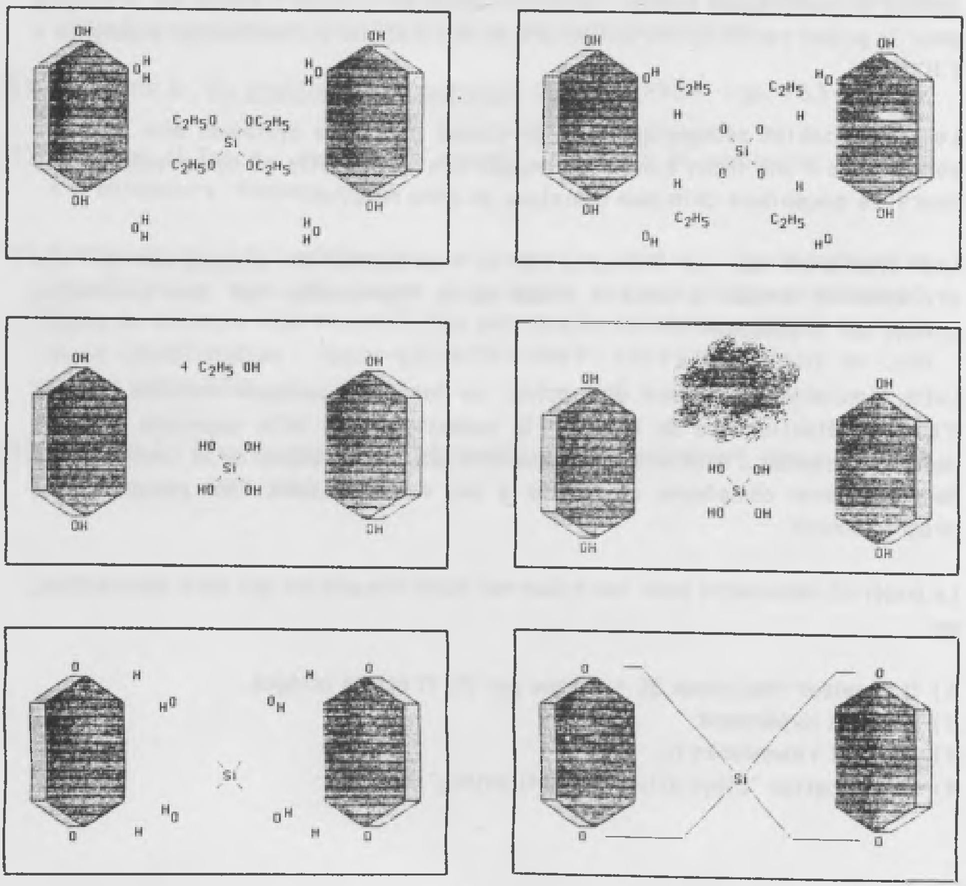
Une discussion sur la difficulté de la représentation pédagogique de tels processus chimiques a mené à l'idée de le représenter sur une simulation animée sur ordinateur.

Cette simulation, dans son état actuel ne dure que quelques minutes, et n'a d'autre prétention que de montrer le potentiel d'une telle approche. Il est destiné à susciter l'intérêt de ceux qui font face au problème de la transmission de phénomènes complexes chimiques à des non-chimistes, les pédagogues et programmeurs.

Le matériel nécessaire pour faire tourner cette simulation qui sera interactive, est :

1) Ordinateur Macintosh SE + disque dur 20 M octets intégré.
2) Logiciel Hypercard.
3) Logiciel Videoworks II.
4) L'application "Ethyl silicate stabilization".


A COMPUTER ANIMATED SIMULATION
© ICCROM & CRATerre
ETHYL SILICATE STABILIZATION
A COLLABORATION PROGRAMME OF
ICCROM - ARCHITECTURAL CONSERVATION COURSE - ARC 87
EAG - CERTIFICAT D'ETUDES APPROFONDIES EN ARCHITECTURE DE TERRE - CEAA TERRE 87 - 89


OH
C2H5O
OC2H5
Si
C2H5
+ C2H5 OH
HO
Si

PROBLEMS AND TECHNIQUES OF USING 'FRESH SOILS IN THE STRUCTURAL REPAIR OF DECAYED WALL FABRIC

Richard HUGHES
Consultant
Ove Arup & Partners
13 Fitzroy Street
GB - London W1P 6BQ
England

INTRODUCTION

1 "London Bridge is falling down,
Falling down, falling down,
London Bridge is falling down,
My fair lady.

2 How shall we build it up again?
Up again, up again,
How shall we build it up again?
My fair lady.

3 Build it up with wood and clay
Wood and clay, wood and clay,
Build it up with wood and clay
My fair lady.

4 Wood and clay will wash away,
Wash away, wash away,
Wood and clay will wash away,
My fair lady ...."
(Ref 1 English, Anon)

In these the first verses of England's most famous nursery rhyme there is a suggestion of an innate understanding, even by children, of structural soil's main weakness. The effect of water, or moisture, dramatically reduces strength and durability of a soil wall fabric so increasing the need for repair. Clearly a bridge structure partially made with 'clay' would require drastic remedial actions with the techniques such as those described further on in this paper.

However due to the ease of application the repair of a monolithic soil wall , by patching or thickening of a cavity, need not be a hard task. To the existing decayed or damaged fabric is applied a variously sized lump of a well worked 'mud' and this sticks in place. Large cavities can be filled in by building up the new material in horizontal layers or from front to back. The new surface can then be smoothed by hand, or palette, and then trimmed off or rendered. The method relies on the suction effect of the old dried soil removing moisture from the wet addition.

If the repair is to be no more than a cosmetic treatment then it is a simple quick and effective expedient. It certainly is an ideal method to slow down or stop further decay of the cavity. However, when the repair is to serve a structural purpose, and for a long time on an historic monument, this casual repair technique is of questionable value. An examination of soil structures that have been repaired by such methods often shows that the new material is incompatible with the old. In particular the joint surface between the old and new is prone to rapid decay. Furthermore, the patch can be stronger or softer and more or less durable than the existing material. Not uncommonly shallow patches and other additional soil layers fall off taking away some of the old material as well.

To understand the complex material and structural performance of the old and new material and particularly their interaction, it is necessary prior to conservation to, firstly, appreciate the working characteristics of a soil wall. It is then essential to know the processes by which the wall decays and, lastly, to be thoroughly versed in the geotechnical, physical and chemical behaviour of the old and new soils.

BACKGROUND TO WALL BUILDING TECHNIQUES

In the monolithic soil wall, whether it is "rammed" or "free built", and irrespective of its geotechnical properties, the fabric will have been formed to varying degrees of density: (i) The rammed wall will be characterised by layers of high and low density. The highest density is achieved where the rammer's compaction surface is in direct contact with the soil. The lowest density occurs at the bottom of each layer and near to the shuttering, both being places where less compactive energy is applied. (ii) The free built wall tends to have low density cores with higher density hand or palette compacted surfaces. Generally the density varies considerably due to a high moisture content, the uneven spread of organic material added to improve workability, and even as the result of the uneven puddling of people's feet being on the wall as it progressively built up. Even in an Adobe wall there is a great variation in density between bricks made by different workers and especially between the dried placed bricks and sloppy wet mortar.

The density of the soil determines its dry compressive strength, permeability and durability. The density that can be achieved is a product of the soil's physical and index properties (Atterberg Limits) and also the soil moisture related to the available compactive effort. These factors are also key items for determining soil workability. The measurement of density is clearly essential to understanding the capabilities of builders and the performance of a wall.

The importance of compacting a dense soil is not a new idea as this very interesting observation below shows:-

"....Then he summoned his Master of Works (Ssu Khung)
Then he summoned his Master of Lands (Ssu Thu)
And charged them with the building of houses.
Dead straight was the plumbline,
The planks were lashed to hold (the earth);
They made the Hall of Ancestors, very venerable.
They tilted in the earth with a rattling,
They pounded it with a dull thud,
They beat the walls with a loud clang,
They pared and chiselled them with a faint phing, phing;
Three hundred rod-lengths all rose up,
The drummers could not hold out ...." (Ref 2, Chinese)

This is a most unusual account of building a monolithic soil wall but is extremely accurate. The sounds made during the compaction of soil in the shutters has been recorded by the author in some experimental work. The change of noise from dull thud to a ringing musical note represented a critical change in compaction from a loose to dense state. The tests confirmed that this change of sound represented compaction to the 90% no air voids limit that was achievable with the moisture content and compactive effort available.

Interestingly, this concern with density has been utilised by the most recent of adobe making techniques where soil stabilisation is achieved by hydraulic compaction with a ten tonne piston pressure and a very low moisture content, often under 10%.

SOIL WALL DECAY

The processes that cause a new wall to decay, and the visual evidence of this, have been comprehensively described by the author (Ref 3). It is therefore only necessary here to stress the following points under the following interrelated subjects:

(i) Structural Movements
(ii) Shrinkage and Micro Fabric Cracking
(iii) Cyclic Moisture and Thermal Stressing
(iv) Soluble Salts
(v) Particle Wash Out and Pore Enlargement
(vi) 'Density Relaxation' and Load Redistribution

(i) The physical properties of dried soil makes it an extremely sensitive engineering material. At the best of times it has a low compressive strength, virtually no tensile strength and it progressively softens with increasing moisture content. The chemical and geotechnical properties continually change through the life of the structure. These characteristics alone mean that if new foundations settle differentially due to imposed loads, notably the superstructure, and this is a rather usual occurrence due to their often shallow founding depth, then the wall above cracks and render spalls off. Cracks will form in the soil fabric, when gradient changes in the foundations of as little as 1 in 5000 occur. Dishing, apparent hogging, and out of plane wall leaning characteristically occur. Shallow foundations founded in fine silty or clayey soils also move when saturated by water. This eventuality is not normally considered because many traditional areas of soil structures are located where heavy rain, floods and saturated soils are very exceptional events. Swelling soils typically cause wall hogging.

(ii) The low compactive effect by a hand rammer normally dictates that the desired moisture content is towards the upper limit of the soil's plastic state. This means that when the soil dries out it undergoes considerable volume change. Shrinkage is most noticeable with clayey soils particularly those containing Montmorillonite. Shrinkage cracking is often most obvious on the exposed wall surface where drying out is very rapid.

Interestingly, this feature has been exploited as a means of providing a keying mechanism for a finishing render. Shrinkage is also a feature between layers of soils, soils worked to varying degrees and those compacted to different densities. It is also very noticeable that shrinkage occurs around coarse inclusions such as stones and organic material leaving these loose within the wall fabric.

(iii) During the working life of a soil wall the moisture content is maintained at well below the soil's plastic limit (P.L.), and therefore overall volume stability is achieved. However, due to frequent fluctuations in humidity and periodic surface wetting local areas of soil wall can soften and therefore undergo volume changes, recognised as micro fabric cracking. The same occurs due to stress reversals, a result of daily cyclic heating and cooling. Thermal effects are also responsible for surface flaking and dusting, the latter being the result of the many mineral constituents expanding and contracting to different degrees. The thermal regime in the cracks is an important mechanism for their propogation. Also, it has been shown that the temperatures within cracks can be considerably higher and lower than on the wall surface and this leads to relatively faster rates of erosion.

(iv) Soluble salts are a major component of most soils and are as important as clay minerals for cementing the silt and sand sized particles. Cyclic moisture fluctuations derived from the surrounding environment can cause some of the salt minerals to swell, contract and reshape themselves while others can migrate and, when in a transient ionic state, form new mineral types. Leaching effects are very noticeable as salt efflorescence deposits on wall surfaces, that are incidentally licked off by animals. Where recrystalisation takes place in pore spaces on or below the wall surface large cavities are induced. Those forming at the base of walls usually progressively enlarge as the moisture trigger is provided by capillary rise of ground water. Some face spalling can be attributed to external surface salt enrichment. Enrichment of new salts in a wall come from bird droppings, animal urine, waste animal food, biodegredation of organic inclusions, and nesting materials. These can have a beneficial or detrimental effect on a wall's surface strength.

(v) Sand and silt particles are held in place by the bonding charges of clay minerals and the "jig-saw" like cementing action of the soluble salt deposits. Where the soil fabric is exposed the moisture and thermal regimes cause these relatively weak bonds to disintigrate with both coarse grains and the "fines" becoming detached. All soil walls show symptoms of this by surface dusting. Enlargement of surface pore spaces can also be recognised under the microscope at points where the larger particles are missing.

(vi) Surface cracks and areas of moisture-softened fabric cause live and dead loads to by pass the affected areas. Both surface load arching and differential stress paths across the wall thickness occur. Where a piece of fabric is softened by moisture ingress and then unloaded, a process occurs which I have termed "Density Relaxation". Here the soil swelling when wetted or heated, and accompanied by unloading, is not followed by a subsequent shrinkage back to the original volume. Basically, the particles readjust themselves and "set" in the new looser arrangement. There is a resultant increase of porosity and permeability and decrease of density and compressive strength. This also means that rarely does the original load distribution re-establish itself down through the now altered material; the loads continue to be transmitted through the wall as if the new work was not there.

Such changes in the stress-strain performance of a soil wall are common and should be borne in mind when designing new structures and rebuilding old ones. It is perhaps best to assume that imposed loads, through the expected life of the structure, will constantly be transmitted through only 4/5th of the wall's total thickness.

TRADITIONAL REPAIR METHODS AND THEIR PROBLEMS

It is these sorts of briefly described problems that require a wall to be repaired by thickening, patching and/or underpinning. These mending techniques as mentioned, are relatively easy to carry out. However the success of such actions should not be assessed by the initial appearance or quality of match. It is really only possible after some indeterminate period of time to see how well the new material behaves relative to the old and whether it has induced problems elsewhere. If successful, the new work can be indistinguishable from the original but more frequently there is a most noticeable difference. Commonly the new material stands out proud, as it is of much better quality than the old, but occasionally the new is eroded much faster. The joint between the new and old work is always a weak, and hence erodable, zone. Clearly, it is an important job of the conservator to understand the typical repair technique used to date and then be able to recognise good and bad practices, particularly bearing in mind structural compatibility and new-old soil interaction.

The new soil will be obtained from an immediately available source. This will often be the original borrow pit site, but occasionally not if extensive urban development has occurred. Another potential source is the weathered soil mass surrounding the monument. In all these cases the soil composition and geotechnical properties will not match precisely those found in the monument's upstanding walls.

The basic methods of applying new soil is as described in the introduction. If the building is old then the workmen will not know precisely the techniques used for the wall's original construction. Many "tricks of the trade" are lost even within the same traditional culture and new ones introduced. Normally the construction of the repair work will be done in a much cruder fashion. Hence we typically see little control over the moisture content added to achieve workability and minor additives may be left out. Almost certainly the original degree of compactive effort will not be matched. This means that the new soil particle distribution, composition, density and porosity will not match the original.

Significantly, the new soil is likely to be added directly to the decayed fabric that may be loose, powdery, salt enriched, clay or silt depleated. A good bond is therefore not achieved.

The adding of a wet soil mix to the old dried soil requires, as we have seen, a suction effect to obtain the necessary adhesion. This action has a two fold effect. Firstly, there is a migration of ions (forming salts) from the wet mix into the dried soil, and secondly, there is a reorientation of the clay mineral plates. Both reactions form a relatively weak zone between the two soils and this is a zone where, substantial shrinkage occurs.

Most importantly the patch, or major underpinning, is not done in such a way as to allow it to take up load that previously by passed the cavity or cracks. If a new structural movement occurs the load can be re-transmitted through the repair and it is often dramatically pushed out.

PROPOSED PRACTICAL GUIDELINES FOR REPAIRS

It is to be hoped that the building conservator can undertake repair work on a historic monument with skills and a thoroughness not available to local people with their limited time and resources. If the new work is to be anything better than a straight copy of a current local practice, the results will certainly undergo extreme scrutiny from a sceptical audience. Hopefully the results of the conservator's work will be much longer lasting than that of every day workmanship. It is therefore essential to be armed with a comprehensive schedule of work and to be thoroughly familiar with suitable practical techniques. It is not satisfactory to develop all the conservation skills during the course of the project. To this end the following guidelines are directed. It seems to the author that all too rarely are practical tips described in conservation reports.

(i) Before Starting Repair Work.

It is essential to examine all aspects of the soil building techniques of the area particularly those seemingly similar to ones used on the monument. Local craftsmen may also remember tricks of the trade no longer used, for example the use of additives principally applied for cultural reasons and the noise made by the soil when being compacted between the shutters.

Next, it is vitally important to define the areas of decay or defects and to study the decay mechanisms on the surface of the monument and on nearby structures. The recording of the decay is informative about building technique, structural performance, and past history of repair. It may be necessary to examine the core of a wall, a place where soil fabric decays is not apparent but can be rampant.

The local soils and the monument's soil fabric should be analysed in detail. Initially this must be done with laboratory tests but later simple hand field tests may suffice. The comprehensive range of tests available has previously been described by the author (Ref 4). The results of these tests will help explain the decay mechanisms previously recorded and also the success or failure of repair techniques.

It is appropriate to consider soil stabilisation for new fabric and indeed for the in situ old soil wall. Soil stabilisation with, for example lime, cement, bitumen, silicones, or low viscosity polymers will all cause the treated soil to change one or several of its properties, such as dry/wet strength, porosity, permeability, swelling, shrinkage, density relaxation and surface dusting. Such changes can be desirable but may also have long term effects that cannot be immediately assessed. Experience to date shows that surface applied protective coatings using the above referenced types of material have all failed. Basically the skins shear off from the low strength soil behind. Dried soil also appears from the author's research to be an effective filter for chemicals diluted with solvents. Chemical impregnation can cause the soluable salts to loose their cementing action. Special attention should also be given to cost, as treatment of large soil volumes can become exceptionally high using such methods.

(ii) Design of Future Works.

Prior to undertaking the site work, repair problems should also be assessed bearing in mind the future use of the structure and therefore the aims of conservation. For example, there can be a different approach between a structure that will be left as an empty shell and that having functional reuse. The ability to regularly maintain the fabric will dictate the severity of the patching exercise. Where there are to be new or altered loads, it is fundamentally important to know that the old or old and new fabric together can take and sustain these, particularly under adverse conditions that may not arise for many years. The insertion of modern facilities can also cause a new dynamic response to arise. The effect of undertaking the actual repair work on structural stability should be calculated and appropriate temporary works designed to maintain or improve structural stability. Where it is essential to undercut and build up replacement material, for example, in horizontal linear cavities at the base a wall, vertical strutting should be installed. "Acrow" props may not be available and fired brick columns with a concrete filled plastic bag (than can assume an irregular shape of the cavities upper surface) can be placed on top as a suitable substitute.

(iii) Practical Site Work.

The first step in the practical exercise is to take and test samples of the wall fabric, the decayed soil and new soil supply. The aims and techniques of this work have previously been described. With the obtained data experiments should occur to obtain the right soil mix, the right density and porosity, a good initial bond, and to achieve a re-produceability of finish expected of the workers.

At this time, before patching starts, causes of structural distress must be cured. Unless this is done the sensitivity of soil will mean further problems will continue to manifest themselves during or after the work.

Once the above tasks are completed patching can be done in something like the following way:-

(a) Remove loose soil, compacted basal debris, and local rubbish,

(b) Insert temporary works,

(c) Remove and dispose of decayed soil fabric in the area to be repaired.

(d) Cut back the cavity to be something approaching a rectangular prism. The flat upper and lower faces should be normal to the direction of load forces but this face is usually horizontal. The hole can be formed by using a flooring saw, a hammer pick, a hammer and chisel or drill. The faces are best left rough to increase the bonding surface area and "keying" effects. In this respect it is best, where feasible, to deepen the prism at the ends, so to increase the front to back friction surfaces.

(e) Before applying new material the excavation faces can be roughened with a wire brush and well and dusted.

(f) It is then necessary to wet the excavation sides and this is best done with a fine spray over a considerable period, so as not to induce the material into its plastic range of behaviour characteristics.

(g) The new material should be refined, mixed, and worked to a consistency previously determined with a moisture content related to the compactive effort required for the finished density. This should take into account the immediate moisture removal by the old soil, even though it has been dampened. Also, immediate moisture removal will cause an initial shrinkage that requires secondary compaction to eliminate.

(h) The excavated area is best filled in the same way as the original material was placed, normally horizontal layers from the bottom to top. It is often difficult here to apply an appropriate compactive effort. However, it must be noted that in old soil walls "free build" examples have a homogeneous character and in rammed walls each "lift" tends to be of a uniform character, but with the working conditions having modified the density. In other words large sections of the wall are isotropic with all three axial directions having the same strength, density, and durability parameters. This means that one can compact the infill soil from back to front. This also allows the soil next to the largest contact surface, that at the back, to be compacted and recompacted relatively easily and that the soil can be worked to the right density right up to the load bearing interface of old to new soil. If the excavation is to be horizontally compacted a hydraulic piston using the wall mass above as the reaction mass, may be suitable.

Where wall decay has caused extensive horizontal cavities these should be repaired in 'blocks' of roughly one metre lengths. The work should be done in a sequence such as 1-4-7-2-6-3-5 so that no two adjacent blocks are being worked on consecutively. This will provide time for a block to dry out and assume the working strength, when as necessary, it can then act as a prop. Where it is essential to reapply a wall load onto the patch it is possible, though no cases have been reported to the author, to uses jacks, acrow props, or other hydraulic systems, to apply a uplift pressure through the undermined cavity prior to placement of the new material.

(i) Structural cracks should in general only be infilled or repaired if the cause of failural distress has been rectified and if it can be shown that there will be no tendency for the wall to further readjust itself, so opening or closing the crack. Due to the problem of bonding, a repaired crack will never be a strong point. If the crack infill happens to become substantially stronger than the soil to either side, then with continued movement, cracking, will occur to either side or at the next weakest place. There are perhaps three ways of handling a crack once the structure has been stabilised:-

a. Clean out of the crack all loose soil and animal/insect nests and remains. Dampen the crack faces with a fine spray over a long period. Infill the crack with a rather muddy mix through a cake type icing bag with a long nozzle. After some moisture removal compact the soil with a tool able to penetrate the crack. Or the crack can be filled in with a powdered dry mix and water then added with the tool then working both the material and compacting it.

b. Cut back the crack sides to form a long rectangular prismatic cavity. Clean out and dampen the faces and compact new material within, as described in previous pages. The cutting and infilling can be done in various lifts and this can alternate with a similar patching on the other side of the wall.

c. The construction of "soft stitches" across the wall crack. Here the aim is to gently span the two crack sides with a soil tie. Where this method has been described to the author the rectangular prism forming the tie has been reinforced with a wire mesh. The problem with this method is the frailty of the bond if subsequent movements occur. Since this is potentially a problem with all such crack repairs the method can be made to give some degree of security but with less work than in method b., described above. The whole crack should also be infilled to reduce rendering problems, to eliminate heat gain or losses through the wall, and to slow down crack face erosion.

(j) After areas of decay and cracks have been repaired it is important to consider using a wall finish. On one hand this may be substantially changing the appearance and character of the monument, as found, but if there ever was a wall finish then its reinstatement can dramatically reduce future decay and the need for maintenance. Re-rendering is a not too difficult task and can be redone at frequent intervals whereas the methods noted above should only be done once.

In most cases the render is a modified version of the soil mass behind and its aim is transmit water, animals and wind blown material away. To some extent surface ornamentation has a similar role and can in particular dissipate the volume and velocity of water over the wall surface. Because it is a different material from that on which it is placed, bonding can be a problem and a keying mechanism may have to be installed during the wall repair. Cavities, ornamental bumps, embedded wood, bone, stones, and tiles have all be utilised for this. Modern equivalents are metal and plastic meshes and stainless steel pins.

(k) It is usually required of the conservator to reduce the need for future maintenance. Often after a building is conserved it is left for the same decay processes to recommence. While most attention should be given to the structure it is possible to change and control the micro conditions surrounding the structure. Attention can be given to topography, drainage, exposure, vegetation, animal and adjacent land use. (Ref 5.)

CONCLUSIONS

The practical approach adopted above for conserving a monolithic soil wall may appear somewhat an "overkill" for what is a relatively easy task. There may be some truth in this for those specialists familiar with soil structure conservation, but, these I think are very few in number. A lack of documentation, reporting and lecturing on the practical aspects, which there clearly is by those specialists, stands as a testament to failings within a subject reaching crisis point. A scientific understanding, not expensive to acquire, directed to simple site repair methods of high quality workmanship, offers at present much more than unproved sophisticated technology that is exorbitantly expensive.

This paper has stressed to this end:-

1. The complex physical and chemical character of soil
2. The importance of soil density and soluble salt cementing agents
3. Complex and rapid decay where "Density Relaxation" and load by passing have been discussed for the first time
4. The nature of traditional repairs
5. The difficulties of matching new soils to the old
6. Practical guidelines for repairing monolithic soil walls.

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5. The [illegible] ties of matching new soils to the old
6. [illegible] guidelines for repairing monolithic soil walls.

CONSERVATION OF MEDIEVAL STRUCTURES OF MUDBRICK AND OF FIRED BRICK LAID IN CLAY

Roberto NARDI
Centro di Conservazione Archeologica - CCA
Via Zanardelli 16
I - 00186 Rome
Italie

ABSTRACT

This report arises from a conservation intervention on two walls - one of mudbrick and one of fired brick - laid in clay. The work was carried out in situ during the excavation campaigns for the Crypta Balbi in Rome*.

To explain something of the background: the Crypta Balbi excavation involves an urban area in the center of Rome**, in a zone that over the past two millennia has experienced a continuous superimposition of human activity. Thus today it presents an exceptionally interesting historical stratification.

* This work has also been reported at the conference on Preventive Measures During Excavation and Site Protection, held 6-8 November 1985 at Ghent, Belgium, and at the 8th Triennial Meeting of the ICOM Conservation Committee, 3-10 September, 1987, Sydney, Australia.

** This corresponds to the city block formed by Via Caetani, Via delle Botteghe Oscure, Via dei Polacchi, and Via dei Delfini. The work began in November 1981, and is directed by M.L. Conforto of the Archaeological Superintendency of Rome and by Prof. D. Manacorda of the University of Siena. To date, a variable number of archaeologists -- researchers, graduates, students -- from various Italian universities have participated in the excavation, up to a maximum of 70 per campaign. There have been six campaigns interspersed with laboratory research activities. The results of the work are published contemporaneously with the excavation: three volumes are already available, and three others are in preparation. The intervention was carried out by M. Anastasi, A. Costanzi Cobau, L. Demitry, R. Nardi, T. Roby, C. Tavazzi, M. Van Molle, of the Centro di Conservazione Archeologica (C.C.A.), Rome.

1) MUDBRICK WALL

The wall is a semi-circular structure, 4.20 m in diameter and 0.80 m thick, which rises 3.70 m above the present excavation level. Without getting involved in speculation as to the dating and significance of such a structure, I might mention one hypothesis among many that it was a large kiln for materials, prepared and never used, and therefore never fired. This is a rare type of structure in the urban Roman context, considering its material, shape, and the construction techniques used: the reason for its rarity is, naturally, the material's own susceptibility to atmospheric agents.

We were given proof of the latter at the expense of the structure itself, when there were no conservators on site. The wall was a quarter excavated in plan and 1 m in elevation, and left exposed to the elements. Rain, wind, sun and algae immediately took their toll, dissolving most of the external facing, and leaving a shapeless, unrecognizable nucleus.

Due to this initial "sacrifice", the conservators were asked to extend their laboratory activity to include direct intervention on site, working alongside the archaeologists. It was thus possible to excavate the structure after first organizing some preventive measures that would limit damage and the need for later restoration.

Preventive measures

The causes of deterioration were identified as follows: rain, wind, plants and algae, sun. The rain, beating and running on the structure, dissolved the unfired clay; the wind exercised mechanical pressure and abrasion, which were particularly damaging to surfaces already weakened by rainwater; the plants and algae caused chemico-physical damage due to their growth and metabolism products; the sun heated and dehydrated the damp structure, causing the material to contract, crack and break away, as well as crystallization of soluble salts.

We therefore decided to intervene with arrangements that would permit the regular excavation process to continue without threatening the integrity of the remaining structure. A rigid roof of metal tubing and corrugated plastic was erected to keep off rainwater and limit the effect of the wind, which, thanks to adjacent structures, came primarily from above. Algae were controlled by spraying a biocide Lito 3 (Ciba-Geigy) before the spring campaign. As to the plants, a distinction was made between those growing superficially on the wall, which were cut at the roots and removed, and those growing partially within the clay structure. For these, we decided to cut off the accessible parts and leave the rest in place -- first because total removal would have caused serious damage; second, because the plants play, nonetheless, a useful role as static reinforcement.

The problem of the clay's dehydration from insolation required specific measures, because the overall schedule of the dig called for the structure to be excavated during the summer.

As we know, structures and artifacts, once buried, tend to reach a thermo-hygrometric equilibrium in relation to the surrounding environment. This, after an initial "expense" in terms of deterioration, corresponds to a stable phase during which the material does not deteriorate any further. Then along comes the archaeologist, who by excavating, alters the material's hard-won equilibrium and sets off a new, dramatic phase of "acclimatization" to the new environmental values, as the material seeks to reach a new stable phase. At this point the equation is simple: the slower the new acclimatization phase, the lesser the damage to the structure.(2)

In our case, uncontrolled dehydration would have led to the contraction of the material, with the formation of micro/macroscopic cracks, spalling and surface loss; breakage and structural damage that might compromise the wall's static performance; surface migration and crystallization of dissolved salts; interference with in-depth consolidation with hydraulic grouts.

The first simple solution was to shade the structure all day with bamboo screening fastened over the corrugated plastic roof. Then we devised a humidifying system that delivered water "drop by drop" and was fed from a water tank that refilled itself automatically, without any use of electric power (sold for gardening and modified to obtain a minimum but continuous dosage).

This kept the structure damp for the total time necessary for excavation (even when the yard was closed for holidays) and conservation. Tests on samples made it possible to set the water dosage so that the quantity emitted was entirely absorbed deep into the structure without any puddling or overflow (1 lt/h divided into 72 outlets along the entire circumference).

The intervention

To carry out the intervention, we deliberately chose to use simple materials and techniques, as close as possible to the original. This was to avoid denaturing the character of the wall itself with the addition of extraneous products. We were perfectly aware that this decision could mean less "solidity" of the wall once it was restored, but we preferred to deal with this problem by planning for future roofing and protection (and thus take a risk) rather than immediately sacrificing the appearance and the "precarious" but "genuine" character of this kind of structure, perhaps by flooding it with synthetic materials. For this we decided, insofar as possible, to use the sole material of which the wall is made - clay - with a minimal addition of hydraulic lime (10% Lafarge hydraulic lime, low in salt content)(3);

A brief inquiry among some former brick makers, who had gone out of business more than 25 years ago, enabled us to locate a clay pit in the city that contained material similar to the clay in the wall (consistency, color, purity); thus we had the necessary access to raw material for the intervention.

The intervention was divided into two parts: one involved internal consolidation of the structure, with repair of cracks and reinsertion of detached blocks; the other involved integration of zones of external facing to meet static requirements, and surface protection.

The humidification plant was progressively de-activated during the in-depth consolidation; the flow of water was reduced each day until the tank was finally shut off and the plant dismantled.

For the internal consolidation we carried out infiltrations of a solution of 9 parts sifted clay, 1 part hydraulic lime, and water as needed. (The solution was considered suitable after sampling for fluidity, color and resistance. The resistance could not be excessive in relation to the original material or it would have meant inserting a rigid element into a fragile structure and upsetting the static equilibrium.) The mixture was then injected into the cracks and detached areas, which were first treated with water and alcohol. For this operation we used plastic syringes, replacing the needles (which were too fine) with either rigid metal tubes (internal diameter 3 mm) or flexible polyurethane ones (Festo Pneumatic PU3, internal diameter 3 mm), varying in length from 10-50 cm. Different injection tubes were used in accordance with the internal formation of the cracks being filled and the depth of the consolidation. Holes to inspect and/or facilitate the filling of the cavities were occasionally drilled with a hand drill, using bits 2-3 mm in diameter.

Where necessary the larger detached zones were re-positioned against the body of the structure by means of expanding braces, which were removed once the mixture dried. As an indication, the consolidation of about 19 m^3 of wall required 60 kg of grout, equal to 3 kg/m^3.

The consolidation terminated with microstuccoing and stuccoing of all surface cracks. This was done with a spatula and the same clay-lime mix as before, prepared in denser form.

For the second type of intervention (repair for static purposes where the external mudbrick facing had fallen away) we adopted the compromise of inserting "half-baked" bricks. For this, another sampling was done, this time with a potter's kiln. Progressive tests of firing were made in increments of 100°C (from 100° to 900°C) on clay samples with different amounts of sand added to the mix, in order to study their behavior on cooling, color changes, and resistance.

The samples thus obtained were subsequently tested for resistance to artificial rain. The desired result was to obtain bricks that were as similar as possible to the original mudbrick (in size, shape and color) but resistant to water, and to use graphic documentation in order to avoid the risk of falsification.

This was in order to make statically solid integrations (as they had to serve as supporting ribs on the sides of the structure) which would also eventually act as an impermeable outer protective barrier.

Unfortunately, the results were not exactly what we had hoped, due to the relatively high firing temperature required to make the clay impermeable (above 400°C), which produced a color distinctly different from that of the mudbrick. At least the areas of integration will now be easy to distinguish from the original structure.

For surface protection we also decided to use a "light" approach that would permit consolidation of surface areas with a "dusting", which was not expected to act as a water repellant. We therefore used a very liquid solution of lime milk and sifted clay, sprayed on.

This solution, as mentioned above, functions solely as a surface consolidation and a sacrificial layer, being a front for contact with the environment and a new location for crystallization of soluble salts; the question of protection from rainwater was ultimately to be resolved by roofing.

Finally, we decided not to attempt to extract the soluble salts. In the first place, the wall is built on ground that could potentially furnish an inexhaustible supply of new salts. Thus our efforts would serve only to stimulate the circulation of dissolved salts up to the surface, creating a risk of damage to no avail. Second, after the intervention and the drying of the structure, and after 24 monthly inspections, the phenomenon of crystallization has not appeared in any significant way.

2) WALL OF FIRED BRICK LAID IN CLAY

Not far from the preceding structure, inside the large exedra which lies east of the Roman monument, a calcara (lime kiln) was brought to light. This was abandoned at a moment of full activity (in medieval times) and has thus survived intact. It is composed of a circular wall, 3 m in diameter, 0.25 m thick, 2.80 high, divided into two parts: the upper was for loading the marble, which was found heaped at the side, the lower for the wood fuel, found as charcoal in situ; between the two are remains of an air space found covered with a molten glassy material. The entire structure was originally excavated in the strata produced by the collapse of the Roman monument, and looks the same today, still in phase with the surrounding medieval stratum. Only the irregular slope of the ground made it necessary in some areas to excavate the wall from both inside and outside, leaving it isolated for a maximum height of about 1 m. The wall is composed of re-used Roman bricks laid in clay, then partially and irregularly fired when the kiln was used.

Preventive measures

In this case the conservation intervention was facilitated by the fact that the entire exedra area is protected by very high perimeter walls and also because, for excavation purposes, it has roofing to protect it from rainwater.

The preventive measures adopted were thus limited to planning a preliminary consolidation intervention, to be carried out during the excavation phase, and to the installation of a "humidifying" plant for the structure, similar to that described above.

The intervention

The consolidation intervention was greatly facilitated by the type of structure itself, by the colour and consistency of the bricks and fired clay setting bed: in fact it was possible to use, as a consolidant by infiltration, the mixture of hydraulic lime and brick dust developed by the ICCROM Research Team under G. Torraca (grout based on hydraulic lime and brick dust added to a fluidifier and a small anount of acrylic emulsion).

The application of the consolidant, which was carried out immediately after the humidifying system was dismantled, took place on a damp structure; nevertheless, all cracks and areas under treatment were further dampened with water and alcohol prior to every infiltration (carried out with the same methods and instruments as for the structure already described).

The intervention concluded with a biocide treatment, using Lito 3, and partial back-filling of the exterior of the wall, which had been exposed by the excavation. The latter operation was necessary for static purposes, in order to balance the weight of the earth which had once been there and had now been removed. This weight maintained an equilibrium and contributed to the support of the wall. For this purpose, an artificial slope was created, with a filling of expanded clay (LEKA) and yellow river sand. These materials were chosen because the two products do not bind to each other and thus do not pack down, forming a rigid mass that would be difficult to remove; the expanded clay permits the creation of volume with little weight; the yellow river sand fills the interstices of the clay, does not permit the growth of plants, and blends chromatically with the structure and the environment.

The consolidation naturally involved the entire structure, including the vitrified parts, in order to ensure the presentation of the complete functional entity on completion of the excavation.

Conclusion

As we have seen, the intervention was carried out with simple preventive measures and with generic materials, relying on operations that are closer to normal maintenance practice than to extraordinary restoration. Twenty-four months have passed since the structures were excavated and they are still in a good state of conservation. Naturally, this is not a very long time, and the structures still require inspection and occasional attention, but the result is still significant in view of the vulnerability of a material such as mudbrick in a climate such as Rome's.

This work has been presented in order to emphasize how a "light" approach in conservation can produce "heavy" results, without the use of tons of synthetic products. We deliberately chose to move away from the now almost "traditional" type of conservation intervention that calls for massive use of synthetic products, applied to incompatible substrates. This approach signals the mutation of our profession as "conservators" (of form and materials) into that of "transformers" (of original artifacts into "healthy objects").

While attributing to research laboratories the fundamental role of support in borderline cases, for which light interventions would be inadequate, we also wanted to re-claim for "field" conservation a role of research in the context of the material feasibility of interventions that use simple techniques and products, compatible with the original materials and technology.

This line of work, apart from its obvious theoretical value, has important practical implications. The "official world of conservation", composed of the few countries and institutions that benefit from advanced technology and that are viewed as models, are rapidly outdistancing the others, thus dramatically increasing the gap between this elite and the rest of those responsible for cultural property. The price is paid, not only by the heritage itself, but also by the "followers", who suffer in the form of professional frustration, for not being "technologists", and who often, as a result, abandon trying to work with the means at hand and, worse still, abandon the traditional manuals of care and maintenance that are themselves part of the world cultural heritage.

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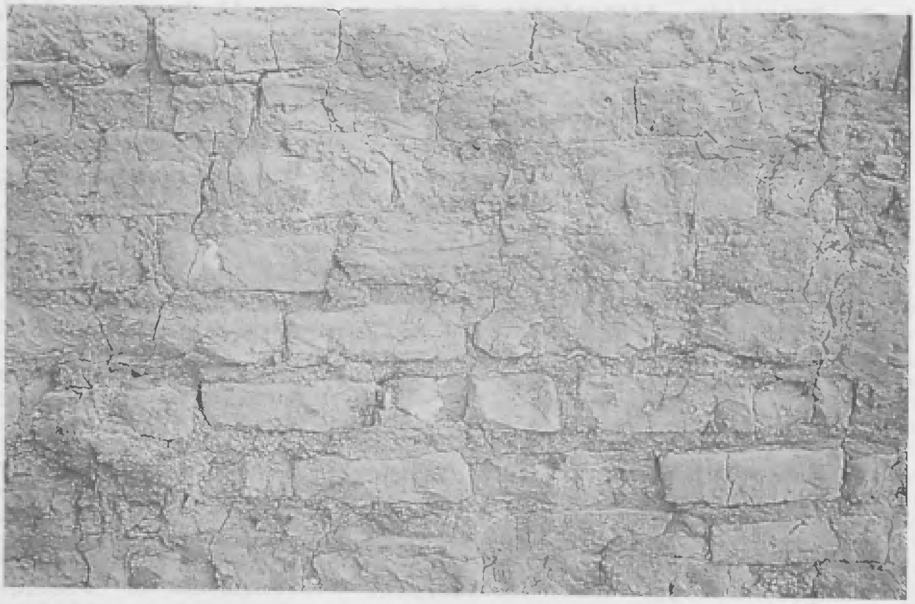
General view of the wall during excavation. The structure is already protected from rainwater and sun.



Detail of the sun-dried brick wall upon excavation, before any type of protection.

Previous detail after brief exposure to atmospheric agents.

Part of the humidifying system for the structure.

Detail of consolidation

LES "CASAS DE HACIENDAS" DES ANDES EQUATORIENNES

André F.A. STEVENS
Consultant international, Ir. architecte
Brusselsesteenweg 138
B - 3009 Winksele
Belgique

ABSTRACT

Late in 1984, the author got a three-months assignment from the Belgian Ministry of Cooperation to the Ecuadorian National Institute of Cultural Heritage, Quito. The main aim being to train local students in the inventory techniques suitable to the architectural heritage. Thanks to special authorizations, seven 'casas de haciendas' (country farmhouses) were the subject of this first survey. This unknown adobe architecture -colonial rural heritage stretching over three centuries- proves evidence of high quality in building techniques and architectural design, as the expression of the well-being of privileged people. The complete report will be published in 1988 by Unesco, Division of human settlements (70 pages highlighted by plans, elevations and photos). On the other hand, the best and most colorfull photos will be printed in a glamorous photographic album entitled 'TERRA INCOGNITA' dealing with the history of monumental earth architecture through the great past civilizations.

ORIGINES ET OBJECTIFS DU PROJET

C'est en 1982 que le Secrétaire d'Etat à la coopération belge décida d'envoyer l'auteur pour une mission de trois mois en Equateur. L'objectif était de former les fonctionnaires du département 'inventaire' de l'Institut national du patrimoine culturel aux techniques élémentaires d'inventorisation du patrimoine architectural. Ce n'est que fin 1984 que l'administration compétente autorisa ce séjour exceptionnel.

Grâce aux facilités du responsable de ce département, l'équipe de travail eut accès à sept 'casas de haciendas' où elle se livra en toute quiétude aux premiers travaux d'inventorisation. La tâche consistait en la réalisation d'un plan du niveau principal avec les mesures essentielles, les prises de vue photographiques -noir et blanc + couleurs-, l'enquête historique, l'établissement de croquis et l'élaboration des descriptions circonstanciées. Des activités multiples que se partageait une équipe de cinq personnes environ. D'autre part, à l'occasion de ces déplacements parfois lointains, il nous fut possible de faire le tour d'autres haciendas, sans pour cela pouvoir y pénétrer.

La documentation recueillie se révèle aujourd'hui inédite à plus d'un titre. Mais à l'heure actuelle, il semblerait que d'autres priorités aient amené les autorités équatoriennes à identifier le patrimoine culturel de la ville de Quito, et plus précisément ses couvents. Aussi la publication de cette étude par l'Unesco en 1988 -Division de la population et des établissements humains- pourra-t'elle contribuer à la poursuite du projet d'inventaire des 'haciendas'.

Il ne sera question ici que d'un bref compte rendu, donnant une large place aux illustrations inédites, un modeste apport à l'étude typologique des constructions en terre crue. On mettra en valeur autant les qualités de la construction que celles de cette architecture de terre qui n'en a pas l'air. Tous les murs porteurs sont en effet élevés en terre -pisé ou adobe-, dans un climat tempéré à quelque 3000 mètres d'altitude, ce qui fait de ces demeures coloniales à multiples fonctions une architecture parfaitement adaptée au milieu ambiant.

DESCRIPTION SOMMAIRE

Situées à environ 3000 mètres dans le couloir interandin (1) -et plus précisément dans la province de Pichincha en ce qui nous concerne-, les 'casas de haciendas' s'intègrent harmonieusement dans une campagne verdoyante -douze mois par an-, faite de prés, de champs et de bois -eucalyptus, palmier, cyprès, avocatier, etc-, mais aussi d'une riche variété de fleurs colorées. Etangs, fontaines, parcs, murs de clôture en terre, haies de taxus, allées d'arbres centenaires, terres de culture (2), collines et volcans agrémentent les vastes perspectives d'un environnement naturel subtropical de toute beauté, tour à tour délicat et grandiose. Il y a une dizaine d'années, on recensait dans la province de Pichincha (environs de Quito) quelque trois cents cinquante 'haciendas' ou domaines terriens, toutes ne possédant pas nécessairement une habitation doublée d'une ferme (3).

Ayant, pour les plus anciennes, appartenu à des ordres religieux -les Jésuites, la 'Mercedaria', etc-, ces vastes habitations sont aujourd'hui bien souvent des propriétés privées, certaines toujours entourées de leurs terres de culture, d'autres ayant été transformées en résidences secondaires par leur propriétaire, des gens privilégiés de la capitale (4). D'autres encore font ou ont fait l'objet d'une totale reconversion: centre culturel ou de séminaire à Tilipulo, infirmerie pour les habitants d'un vaste lotissement sur l'hac. 'Ibarra' (5) , hôtel-restaurant en ce qui concerne les haciendas 'Ciennega' et 'Charlavi'. A propos de l'hacienda 'Cochicarangui', on n'a pas hésité à construire une nouvelle habitation de facture résolument contemporaire à côté des anciens bâtiments. Par contre, d'autres 'casas' comme 'La Merced' (1643) n'ont subi que des transformations mineures, conservant leur caractère d'authenticité. A Quito, l'hacienda 'La Delicia', après de nombreuses années d'abandon total, fait l'objet d'une restauration minutieuse avec le concours de l'Institut national du patrimoine culturel. L'hacienda 'San Agustin de callo' se singularise, quant à elle, par la présence de deux constructions d'époque Inca (2ème moitié du XVe) ou pré-Inca parmi les mieux conservées de l'Equateur, autour desquelles l'habitation s'est développée, transformant l'une en chapelle et l'autre en salle à manger, sans altération aucune des vestiges d'origine.

Une caractéristique commune à la plupart d'entre elles est l'existence d'un ou plusieurs patios empierrés, vaste cour d'entrée et de distribution de forme proche du carré (parfois plus de 50 m. de côté), autour duquel s'articulent les différents corps de la ferme. L'entrée proprement dite se fait à partir de galeries couvertes, formant en quelque sorte le prolongement abrité du patio, mais à un niveau supérieur, et faisant office de couloir extérieur à l'habitation.

Les ailes abritent en général l'habitation privée du propriétaire -chambres, séjour, bibliothèque-musée (6), salle à manger, cuisine en communication avec les services-, la chapelle et le grenier à blé, tandis que les communs -logement du personnel, étables, écuries, blanchisserie, etc- occupent une situation quelque peu à l'écart. Pour la plupart à un seul niveau, -Ibarra fait exception-, elles s'étendent sur une aire variable, allant de

2000 mètres carrés pour les plus petites jusqu'à plus d' un hectare pour les plus vastes -Zuleta-, constructions, cours et patios compris. Néanmoins il reste difficile de se faire une idée de la grandeur de l'exploitation elle-même, mais on dit qu'à Zuleta plus de trois cents personnes seraient encore au service de l'hacienda.

Dans la mesure du possible, et suivant l'orientation retenue, une grande attention est donnée à la qualité de la perception du paysage depuis les lieux de séjour de l'habitation, soit que la vue porte sur un jardin aménagé en contrebas, soit qu'elle porte sur de vastes étendues de nature entre vallées et montagnes, un panorama qu'anime, suivant les saisons, le cortège de lourds nuages défilant au 'fil de la terre'. Un spectacle lentement découvert suivant les séquences visuelles que ménage la disposition des espaces comme des ouvertures.

Construite en terre crue (adobe ou pisé) pour ce qui concerne les murs porteurs, comme la plupart des anciens bâtiments de Quito (7), la 'casa de hacienda' n'en utilise pas moins d'autres matériaux locaux dans une parfaite harmonie de structure et de texture: pierre de taille pour les soubassements et les colonnes, bois pour les châssis, les portes, les balustrades, les charpentes, brique cuite pour les structures plus récentes, tuiles pour les toitures à large débord (8). Il n'est pas rare de trouver une note de couleur vive sous la forme de châssis peints en bleu ou rouge, se détachant sur des murs chaulés. Elle se présente ainsi comme une vaste entreprise où chaque matériau a trouvé son meilleur champ d'application, la terre crue étant bien-entendu mise à l'abri de toute intempérie.

En guise de première conclusion, la construction comme l'architecture y est de grande qualité, préservant autant le confort esthétique que le bien-être matériel, et tirant le meilleur parti des ressources naturelles aussi nombreuses que variées, une manifestation d'un authentique art colonial.

Notes:

(1) Les Andes équatoriennes entourent et protègent une longue série de près de quinze petits bassins, dont les plus fertiles sont celui de Quito et celui de Cuenca. Tout ce couloir, dont la largeur maximale est de 100 km, se situe en général entre 2 600 et 3 200 m. d'altitude.

(2) On estime que 50 à 60% de la population de l'Equateur vit, directement ou indirectement, des activités agricoles, allant des cultures primitives réalisées par les communautés indiennes des montagnes jusqu'aux grandes exploitations du littoral. Dans les Andes, la surexploitation des terres, parallèlement au déboisement provoqué par les Espagnols et à la perte des structures sociales et culturelles correspondant aux modes traditionnels de conservation des sols, a entraîné un extraordinaire appauvrissement de la productivité. On considère actuellement que la plupart des terrains cultivés dans les Andes équatoriennes sont plus ou moins largement érodés et beaucoup devraient cesser d'être exploités pour essayer de les régénérer.

(3) Suite à la colonisation, la nouvelle société -organisée autour de l' Audience de Quito, qui acquit progressivement une indépendance presque complète- vécut en fonction de l''encomienda', de la 'mita', des 'obrajes'; elle facilita l'établissement des grands domaines fonciers (latifundio) avec leurs formes de servage, l'élimination d'une grande partie de la population, l'imposition souvent superficielle de nouvelles valeurs et habitudes. Cette prospérité favorisa la prolifération d'une architecture coloniale plus fidèle aux normes et modèles de la métropole, contrairement à

ce qui s'est passé au Pérou et en Bolivie, lesquels développèrent de plus en plus des formes métissées. Quant à l'économie des haciendas, les réformes agraires de ces vingt dernières années ont réussi à éliminer pratiquement les traditionnels rapports féodaux qui asservissaient l'Indien à son maître. Mais avec la disparition de la main-d'oeuvre bon marché, tout le système économique a changé. Les haciendas se sont reconverties à l'élevage et à la production laitière qui exigent moins de salariés.

(4) Dans les grandes lignes, la distribution de la population par 'races' est la suivante: Blancs (10%), Indiens (39%), Métis (41%), Mulâtres (5%), autres ethnies (5%). De tous les pays d'Amérique du Sud, l'Equateur possède le plus grand pourcentage d'Indiens.

(5) Caractéristiques du projet de lotissement sur l'hacienda 'Ibarra' proche de Quito: 200 hectares, 6 380 lots, 12 700 habitants, 65 000 logements. En 1984, M. Raul Diaz, professeur à l'Université d'Ibarra, proposa un programme d'habitat en blocs de terre crue, lequel a reçu l'aval du Président et de la Banco popular. Selon ses calculs, le mètre carré bâti en blocs de ciment armé revient à 16 000 Sucres, tandis que celui en blocs de terre crue revient à 4 500 Sucres, soit plus ou moins quatre fois moins cher. Prix du bloc: adobe: 2,9 S.; brique: 5 S.; adobe stabilisée au ciment: 3,9 Sucres. (Oct. 84: 1 USD = 100 Sucres = 60 FrB.)

(6) Au 17ème siècle, l'école quiténienne marque l'apogée de l'occupation espagnole. Il n'est pas rare de rencontrer dans l'une de ces 'casas de haciendas' un véritable musée privé que les responsables de l'Institut national tentent tant bien que mal d'inventorier.

(7) Construit entre autres à des fins anti-sismiques, le mur porteur en terre crue peut atteindre 1M20 d'épaisseur (Hacienda 'La Merced': forte épaisseur des murs, petites ouvertures, peu de lumière, le port du 'poncho' supplée les lacunes de tout système de chauffage). Le dernier tremblement de terre eut lieu en février 1987 dans les provinces d'Imbabura et de Napo. Précédemment, en 1797, un extraordinaire mouvement tellurique (tremblements de terre et éruptions volcaniques) dura un mois et provoqua un affaissement des Andes centrales équatoriennes.

(8) Un proverbe anglais -archi-connu des spécialistes- veut qu'une maison élevée en terre défie les temps si elle porte de bonnes bottes et un bon chapeau. L'un des murs de clôture de l'hacienda 'La Merced', élevé en briques crues et en pisé, est surplombé par le massif débordant d'une haie de taxus plantée à l'intérieur de la propriété. Il s'agit là d'un exemple rarissime de mise en valeur d'une enceinte, combinant le végétal avec la terre crue.

Remerciements.
La réalisation de ce premier inventaire des 'haciendas' des Andes équatoriennes ne fut possible que grâce à la collaboration de Ximena Escudero de Teran et Rosario Arregui de Morales, responsables du département 'Inventaire', et des étudiants particulièrement motivés: Patricio Andrade Onofre, Cecilia Azanza Cruz, Cecilia Ordonez de Andrade, José Arce Arboleda, José Maria Velasco Coronel, Maria Fernanda Espinosa Garcès, Sylvia Mera Ponce, ainsi que l'expert belge Patrick De Sutter.

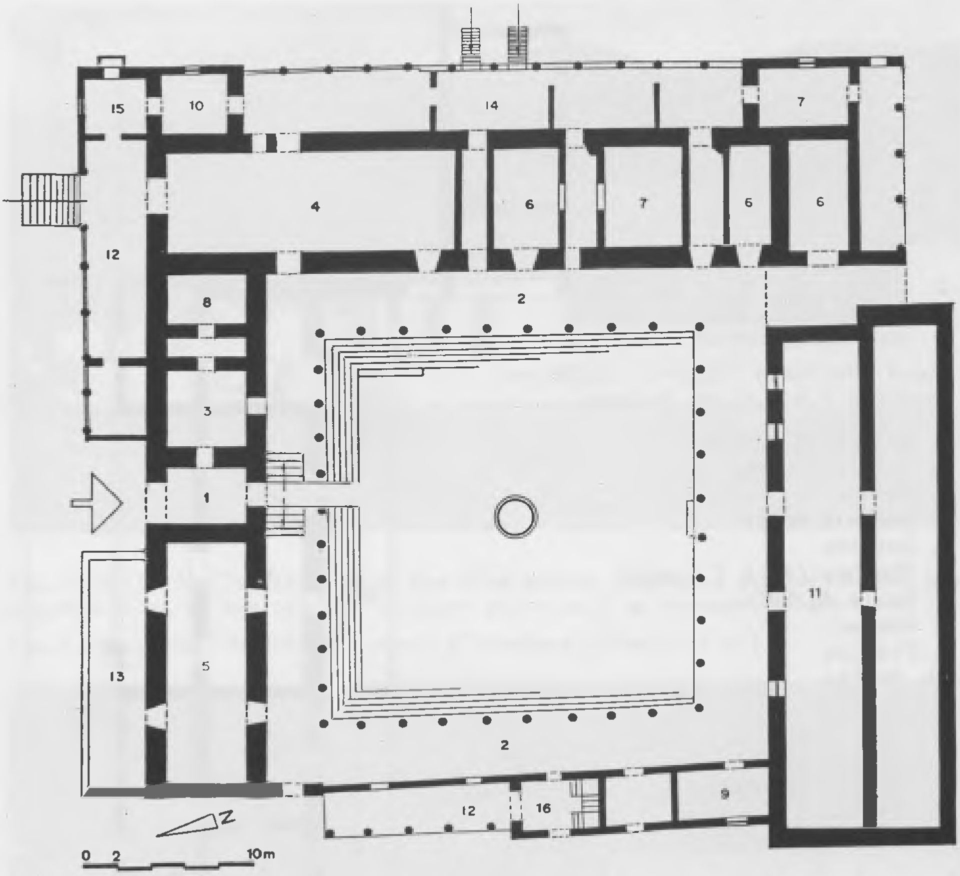


Fig.1. Hacienda 'La Merced' (Equateur). 1643. L'une des plus typiques et des mieux conservées des Andes équatoriennes. Noter la forte épaisseur des murs d'adobe (1M20) et la petitesse des ouvertures dont certaines coupent le mur de biais. Un remarquable témoignage d'un authentique art colonial. (Source: I.N.P.C. et Stevens)

1. Entrée
2. Galerie ouverte
3. Cuisine
4. Salle à manger
5. Bibliothèque
6. Chambre
7. Salle de bain
8. Remise
9. Chapelle
10. Séjour
11. Grenier
12. Terrasse couverte
13. Terrasse sur remise
14. Couloir, séjour
15. Bureau
16. Mirador

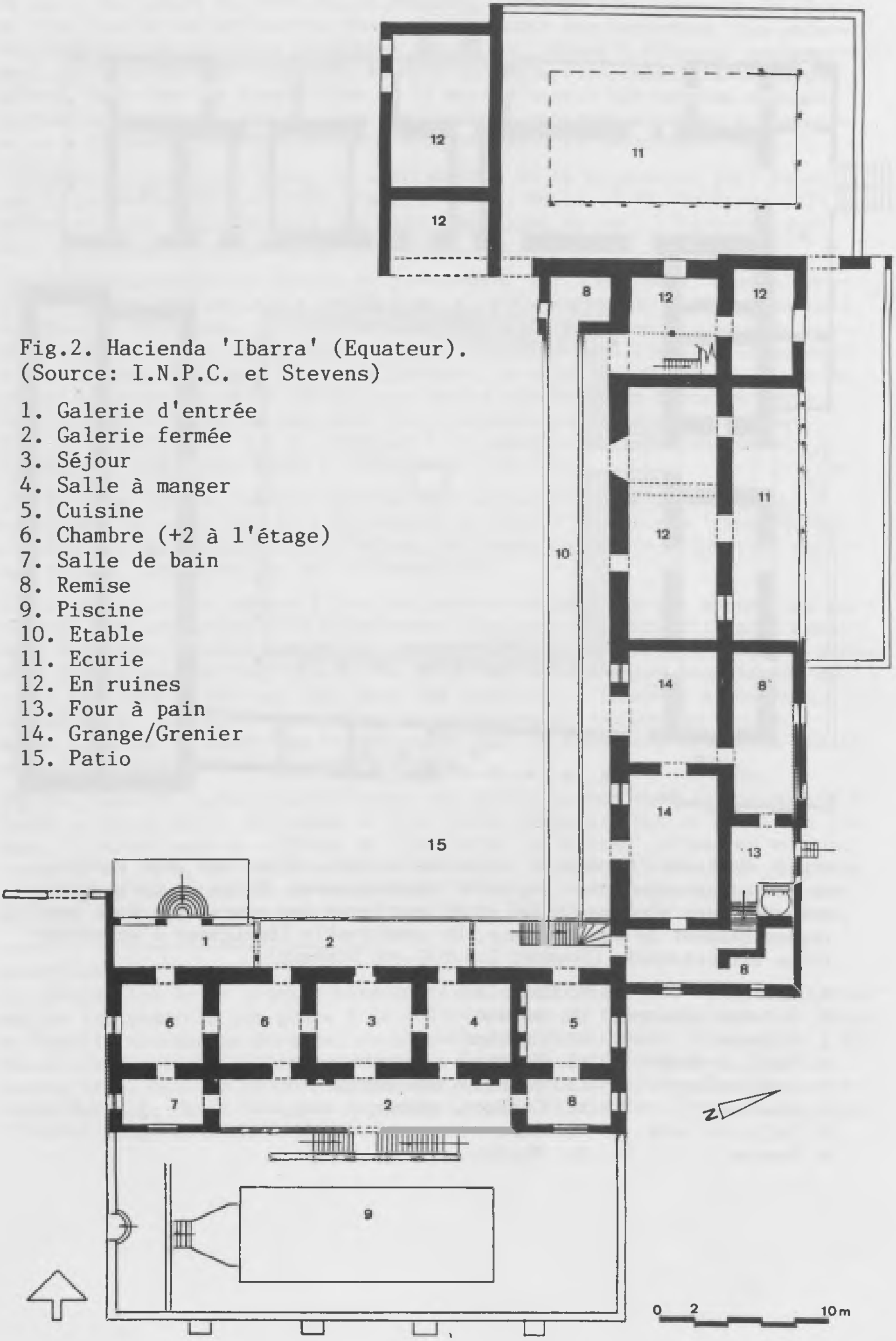


Fig.2. Hacienda 'Ibarra' (Equateur).
(Source: I.N.P.C. et Stevens)

1. Galerie d'entrée
2. Galerie fermée
3. Séjour
4. Salle à manger
5. Cuisine
6. Chambre (+2 à l'étage)
7. Salle de bain
8. Remise
9. Piscine
10. Etable
11. Ecurie
12. En ruines
13. Four à pain
14. Grange/Grenier
15. Patio

Fig.3. Hacienda 'Zuleta'. L'une des plus vastes des Andes équatoriennes, Les constructions et les cours s'étendent sur plus d'un hectare. (Photo: A.S.)

Fig.4. Hacienda 'Magdalena', prov. d'Imbabura. (Photo: A.S.)

Fig. 5. Hacienda 'Ibarra' (Equateur). (Photo: A.S.)

Fig. 6. Hacienda 'La Merced', la galerie entourant le patio (Photo: A.S.)

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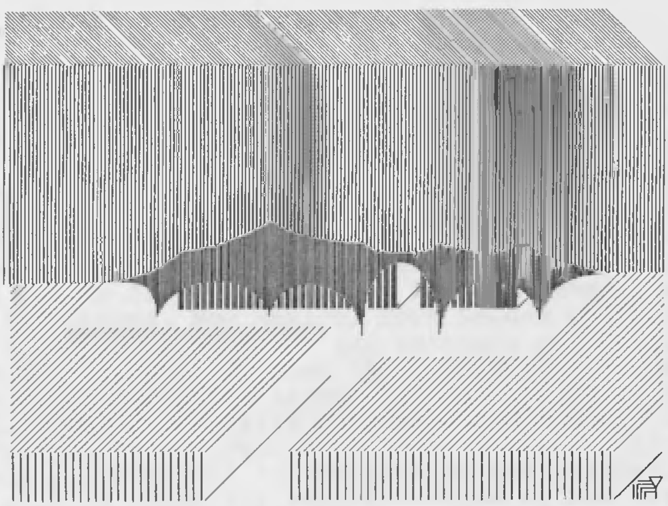

Structure textile de protection. Temple d'Ihtar, Babylone. Projet A.STEVENS

FORT SELDEN TEST WALL STATUS REPORT

Michael Romero TAYLOR
New Mexico State Monuments
Museum of New Mexico
PO Box 2087
Santa Fe, New Mexico 87503
U.S.A.

ABSTRACT

Mud brick test walls were constructed at Fort Selden State Monument, New Mexico, USA in 1985 in order to monitor the erosional rates of various amendments to mud plaster, the capillary rise in selected wall bases, and the impact of precipitation on wall caps. These experiments will yield insights into the long term preservation requirements of historic and contemporary earthen architecture. This status report describes the effects of weathering on the experimental walls after twenty two months of exposure. The project will continue for a period of ten years.

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1. INTRODUCTION

The test walls at Fort Selden State Monument in southern New Mexico (USA), were constructed in November, 1985 to monitor the erosional rates of selected experimental mud brick preservation techniques. The experiments include the feasability of utilization of chemically amended mud plaster, the relationship of different wall bases to capillary rise, and the evaluation of various capping techniques used to protect the upper portion of walls.

Fort Selden State Monument is located seventeen miles north of Las Cruces, New Mexico. Fort Selden was established in 1865 to provide protection for settlers of the area from Indian raids and bandits. When the fort was abandoned in 1891, the roofs and other salvagable material were removed. As a result, the adobe walls have remained exposed to the weather for nearly 100 years. The test walls are located approximately 150 meters to the east of the historic ruins.

The site is under the administration of New Mexico State Monuments, Museum of New Mexico, Office of Cultural Affairs. There is a museum, with full time staff, at the site.

Fort Selden is situated on a gravel bench adjacent to the Rio Grande floodplain. The mean average precipitation is 8.49 inches (21.6 cm). Rainfall pattern is seasonal with 54% of the moisture occurring in late summer. Winter moisture is in the form of rain, and occasional snow fall. Winds, which occur year around, can reach 100 kilometers per hour during springtime. The average annual maximum temperature is 74.4 degrees F (23.5 C) and the average minimum temperature is 43.9 degrees F (6.6 C). The fort site is in a semi-arid region at an elevation of 3990 feet (1,216 meters) above sea level. Flood plain irrigation and the proximity of the Rio Grande account for relative high humidity at the former fort site.

The mud brick test wall experiments may yield insights into the long-term preservation requirements of the the wall remnants at Fort Selden, as well as historic and contemporary earthen architecture. In this early phase of the experiment, it is not felt that New Mexico State Monuments can endorse or recommend any of the techniques or chemicals being used in this test wall project. A number of the methods and chemicals used are ones which are of dubious value in mud brick preservation, but which are used to some extent throughout the Southwestern United States. They have been incorporated into the experiment in order to determine their efficacy, one way or the other.

2. AMENDED PANELS

Two walls were constructed of unamended mud brick and mortar. The first two courses of the walls were set below the ground surface. Each wall is sixty five feet long (19.81 meters), five feet high (1.52 meters), and 10 inches wide (25.4 cm). One wall was set on a north/south axis and the other on an east/west axis. Each wall face is divided into 13 panels, five feet wide. There are twelve amended panels on each wall face with one panel of unamended mud which serves as a control. The four wall faces are the same. The ammendments are applied to both sides of the wall, opposite each other, including the wall top. Each amendment and control panel have a north, south, east, and west exposure. Thus, the effect of climatological conditions, to include storm patterns and solar orientation, for each panel can be assessed.

The amendments were either mixed in with the mud plaster, sprayed on the wall surface, or applied with a paint roller.

2.1 AMENDED MUD PLASTER MIXES

Experiments with various amendments mixed with mud plaster are being conducted to assess the efficacy of renderings which would be compatible with unamended mud brick and retard the erosional rates of plaster. The amended mud plaster was applied in three coats to a total thickness of one inch (2.54 cm). Each of the amended panels was divided in half on a vertical axis. One half of the panel was treated with a 5 percent solution and the other a 10 percent solution of the chemical amendments. The different solutions of the same amendment will be used to determine the minimal amount needed to be cost effective when used for retarding erosional rates of plaster. The amendments used are two copolymer acyrlics (El Rey Superior 200 and Soil Seal Concentrate), a resin emulsion (Daraweld-C), an asphalt emulsion, agave juice extract, and straw.

2.2 AMENDED MUD PLASTER DESCRIPTIONS

The following is a description of each amended mix panel to include the type, application procedure, and condition twenty two months after construction. The described conditions of the panels are subjectively based on visual inspections. The four description conditions used are: very little erosion, little erosion, moderate erosion, and serious erosion.

The copolymer acyrlics applied to the walls are El Rey Superior 200 and Soil Seal Concentrate.

El Rey Superior 200 is an acrylic modifier that is used commercially in cementitious applications. It is a methyl methacrylate/acrylate resin at 47% solids in water. Other acyrlic modifiers that have been used in preservation applications in the the southwestern United States have included Rhoplex MC-76 and Rhoplex E 330. Rhoplex MC-76 is identical to El Rey Superior 200 with the exception that a de-bubbling agent has been added to it. Rhoplex E-330, a slightly modified version of Rhoplex MC76, has been used as an amendment to mud mortar in stone masonry cultural resources at Chaco Canyon, Aztec, and Wupatki National Monuments. Applications at some of these monuments have been in service for a period of ten years. Both Rhoplex MC-76 and E330 have been used in 10% solution on a test wall experiment at Bents Old Fort National Monument. After three years of exposure, the walls showed little erosion.

El Rey Superior 200 has experienced very little erosion in this test wall experiment. The portions of the panels with the five percent solutions exhibit slightly more erosion than the panels with the ten percent solutions.

Soil Seal Concentrate is a soil stabilizer used commercially for soil surface erosion control. It is composed primarily of latex acrylic balanced copolymers prepared in emulsion form. Soil Seal is usually mixed with water and used as a spray. Soil Seal consists of 40 percent methacrylates and acrylates, 1 percent poly ethoxylated ethanol, and 3.5 percent silicates. It is 46% solids in water. Soil Seal has intermittently been used as a soil stabilizer in adobe bricks, mortar, and re-pointing of masonry walls at Pecos National Monument in New Mexico since 1973. Soil Seal was also used as an amendment to mud plaster in Bent's Old Fort experiment where, after three years of exposure, it exhibited little erosion in 5% and 10%

solutions.

Soil Seal is experiencing little erosion in the Fort Selden experiment. The portions of the panels with the five percent solutions exhibit slightly more erosion than the ten percent solutions.

Daraweld-C is a high polymer resin emulsion at 51% solids in water which is used commercially as a bonding agent for concrete. Daraweld-C has been used as a preservative by the National Park Service since the early 1970's in mud brick preservation. However, it is not in as widespread use as it was previously because of its relatively impermeable nature.

Daraweld-C has experienced very little erosion in this test wall experiment. The portions of the panels with the five percent solutions exhibit slightly more erosion than the panels with the ten percent solutions.

Asphalt Emulsion is a petroleum based product. It has been used in earthen construction in the Near East for thousands of years. In the United States, asphalt emulsion gained widespread use as early as the 1950's and continues to be a popular amendment for stabilized brick used in construction. Asphalt emulsion has been used to some extent as an amendment to mud plaster on unamended mud brick walls. Its use in preservation has been criticized for it makes the plaster much darker than the original material. It also creates a relatively impermeable coating over unamended mud brick walls which inhibits the evaporation of moisture. Since asphalt emulsion is used to some extent in the Southwest as an amendment to mud plaster over unamended mud brick walls, it was selected to be monitored in this project.

Asphalt Emulsion has experienced little erosion in this test wall experiment. The portions of the panels with the five and ten percent solutions exhibit similar erosional rates.

Agave (Agave) juice was extracted from leaves by boiling and pounding the pulp. The undiluted extract was steeped for approximately two to three weeks before application. Cactus juice has been used by some cultures in the desert regions as an amendment to adobe plaster.

This experiment with agave extract differed from the other applications in that the first two coats on the panels were unamended mud plaster. Only the third coat contained the amendment. The agave juice was mixed undiluted with mud plaster on one half of the panels and mixed in a one to one solution with water on the other half of the panels. A slurry of adobe plaster and undiluted cactus juice was then applied to all surfaces.

Agave juice extract has experienced moderate erosion in this experiment with no difference between the two mixes.

Straw is used as an amendment to mud plaster on an almost universal basis. It has been claimed that it acts as a binder which reduces cracking on wall surfaces and thus extends the life of the plaster application. Its use is criticized by some preservationists who claim that it encourages penetration of moisture and that insects follow the straw as a food source into the wall.

In the Fort Selden experiment four one-pound coffee cans of straw, cut into two inch lengths, were mixed with one wheel barrow of mud. Like the agave juice, this amendment was only mixed with the final coat of plaster.

These amended panels are experiencing moderate erosion.

2.3 OBSERVATIONS

The chemically amended mixes have already graphically shown individual rates of erosion. The amended mixes generally have eroded much less than the spray and roll on applications. The five percent solutions have eroded slightly more than the ten percent solutions. The long term erosional rates of the five and ten percent solutions will be monitored during the project term to determime if the use of five percent solutions is
cost effective.

El Rey Superior 200 and Daraweld-C, have eroded very little since they were applied twenty two months ago. It is possible, however, that significant amounts of moisture are trapped behind the ammended plaster. This will be a crucial factor in determining the longevity of the plaster panels and of the mud brick wall.

Soil Seal Concentrate and asphalt emulsion have experienced little erosion since application. These mixes have eroded, however, more than El Rey Superior 200 and Daraweld-C, although they are still performing well.

Agave juice extract has eroded much more than the above mentioned four amendments.

The panels amended with straw, and with agave juice extract, have eroded to a greater degree than all the other amendments.

All the amended mud mixes, with the exception of the agave juice extract and the straw, darkened the unamended mud to varying degrees.

2.4 AMENDED SPRAY AND ROLL ON APPLICATIONS

Like the amended mud plaster panels, the panels used for the spray and roll on experiments were divided in half on a vertical axis. One half of each panel was plastered with three coats of unamended mud and the other half was left unplastered. These panels will be used to assess the effectiveness of spray applications on mud plastered and unplastered mud brick ruins, such as the ones at the fort.

Chemical amendments were either rolled or sprayed on both halves of the panel at equal strength. The amendments used for spray application were: a cement-base finish (Super Quickseal), inorganic mineral salt solution (K and E Penetrating and Hardening Mineral Sealer), linseed oil, a silicone resin (Silicote), and an acrylic emulsion (Seal-Krete). The rolled on application is an acrylic emulsion (Thorocoat).

2.5 AMENDED SPRAY AND ROLL ON DESCRIPTIONS

In one portion of the experiment two different chemical amendments were sprayed on the same test panels. The base coat was Acryl 60 and the finish coat Superquickseal. The manufacturer recommended that Acryl 60 be applied to the wall before Super Quickseal.

Acryl 60 is a formulation of acrylic polymers and modifiers, designed for use as an additive for Portland cement to improve adhesion and mechanical properties. Acryl 60 was used in amended mud plaster in the test wall experiment at Bent's Old Fort National Historic Site. It performed well in the three years that the walls were monitored.

Super Quickseal is a cement-base coating used commercially as a finish coat for concrete and masonry. It has not been used in any known preservation applications for mud brick walls. It was recommended by the manufacturer for experimentation.

The Super Quickseal and Acryl 60 combination has experienced moderate erosion.

K & E Penetrating and Hardening Mineral Sealer is a solution of inorganic mineral salts at 30% solids in water. It was sprayed on mud plaster in the Bent's Old Fort experiment where it experienced little erosion after three years of exposure. It is not known if this product has been used in other applications on mud brick walls.

K & E Penetrating and Hardening Mineral Sealer is experiencing serious erosion.

One part commercial grade boiled linseed oil was mixed with five parts mineral spirits and sprayed on a panel. Linseed oil has been used to some extent to preserve adobe plaster either by spray or brush application. It has also been used in a limited degree in mud floor consolidation. Linseed oil was mixed with mineral spirits in a 1:2 solution in the Bents Old Fort experiment. After three years of exposure it exhibited very little erosion.

Linseed oil has experienced serious erosion in the Fort Selden experiment.

Silicote is a modified silicone resin spray at 9.9 percent solids in xylene. It is not known if Silicote has

been used in any attempts to preserve mud brick walls.
The Silicote panels are experiencing moderate to serious erosion.

Seal-Krete is an acyrlic manufactured commercially for waterproofing stucco, masonry, cement and mud brick. The manufacturer claims it is a deep penetrating sealer. It is not known if it has been used as a spray on mud brick or mud plaster.
Seal-Krete spray is experiencing serious erosion.

Thorocoat was applied to the test panels with a paint roller. It is a ready mixed non-cementitious 100% acrylic textured coating specifically designed to protect and decorate a wide variety of exterior and interior surfaces. Thorocoat has a heavy resin-base texture. The manufacturer claims that it is thicker than paint which permits cracks and pores to be water resistant and allows the release of moisture. It is not known if Thorocoat has previously been tested on mud brick walls.
Thorocoat has experienced moderate erosion.

2.6 OBSERVATIONS

The five spray applications have generally performed poorly. Large spalls are occurring in the plastered surfaces of the sprayed panels. At these weak points, water is directed into the wall, causing more deterioration than if it had not been sprayed in the first place. Penetration of the sprays into the walls appears to be limited, and since the weaker interior core of the wall has no place to release moisture except through the sprayed surface, exfoliation and eventual failure occurs. The roll on application is peeling off where small cracks have allowed moisture to enter.
It appears that, at least in this experiment, unamended mud plaster withstands erosion as well, if not better than, the spray applications.

2.7 CONTROL PANEL

Unamended mud plaster was applied to serve as control panels for comparison to the amended panels.
The use of unamended mud plaster has been used to preserve earthen architecture ever since mud bricks began to be used as a building medium thousands of years ago. Unamended mud plaster is the most compatible plaster material available for mud brick walls. Its only drawback is the need for frequent, cyclical maintenance if left unsheltered.
The unamended mud plaster panels are experiencing moderate to serious erosion.

3. WALL BASE EXPERIMENTS

Twelve walls, each with a different type base, were constructed to determine the extent of capillary rise. Each wall is 5 feet (1.52 meters) high, 5 feet long, and 10 inches (25.4 cm) wide. Experiments were selected upon the basis of modern and historic practices, as well as myths, facts, arguments, and fantasies.

Eight electrical resistance sensors, which provide data on relative moisture content of the walls, were placed in the center of each wall at various heights. A sensor was placed beneath the wall base and the others on regular intervals up to one-half the wall height. Three sensors were placed below the ground surface as controls.

Relative moisture readings are taken with a resistance meter.

3.1 WALL BASE DESCRIPTIONS

Standard concrete foundation with stem wall, and a cement stucco over wall surface.

Rock foundation with mud mortar and exposed mud brick wall surface.

Base course (a varied grade of rock and soil used for highway underlayment) foundation with exposed mud brick wall surface.

Unammended mud brick foundation with exposed mud brick wall surface.

Unammended mud brick foundation surrounded with sub-surface polyethylene sheeting sloping away from the wall to provide a drainage gradient. The wall has an exposed mud brick surface.

Unammended mud brick foundation surrounded with a sub-surface layer of mud ammended with Union Carbide R-274 (a silicon base water repellent) sloping away from the wall to provide a drainage gradient. The wall has an exposed mud brick surface.

Unammended mud brick foundation with perforated plastic pipes set on each side of it in gravel which drain into a rock filled sump. The wall has an exposed mud brick wall surface.

Unammended mud brick foundation with cement stucco over the wall surface.

Unstabilized mud brick foundation with a poured and formed concrete wainscot, exposed mud brick wall surface.

Rock foundation with mud mortar and a poured and formed concrete wainscot, exposed mud brick wall surface.

Unammended mud brick foundation with unammended mud plaster on the wall surface.

Unammended mud brick foundation coated with parge plaster and asphalt vapor barrier, exposed mud brick wall surface.

3.2 OBSERVATIONS

The resistance meters have yielded less information than anticipated. With the exception of the walls which are surrounded by the concrete wainscots, virtually no data is being obtained from the sensors which are located above the ground surface.

There is no obvious coving occurring at the bases of any of the walls.

4. WALL CAP EXPERIMENT

Four different wall caps, each five feet long (1.52 meters), were applied to an unammended adobe wall which is twenty feet long (6.10 meters) and five feet high. The types of capping materials selected are in fairly common use in New Mexico. The erosional patterns of the capped walls will be compared to uncapped walls at the experimental site.

4.1 WALL CAP DESCRIPTIONS

One course of commercially manufactured mud bricks which are ammended with asphalt emulsion were placed on top of, and flush with, the wall.

One course of commercially manufactured mud bricks which are ammended with asphalt emulsion were placed on top of and perpendicular to the wall and on a slope to facilate water runoff. This also establishes a two inch overhang or drip edge on each side of the all.

A rounded cement cap was troweled on to the top of the wall and feathered into the top mud brick course.

Three courses of fired brick were applied to the top of the wall to form a denticulated cap.

4.2 OBSERVATIONS

The unamended mud brick cap placed on top of and perpendicular to the wall is performing most satisfactorily of the four wall caps. The other three caps, which have no drip edge, are all experiencing approximately the same patterns of erosion at the point where the caps meet the walls.

5. TEST WALL MONITORING PROGRAM

All test walls are photographically documented on a bimonthly basis using color slides and black and white film. In addition, video documentation of the erosional rates is conducted bi-annually.

Erosional profiles of the chemically amended wall panels will be recorded in 1990 and 1995. Aluminum rods were inserted perpendicular to, and flush with, the panel surfaces. The rod ends will serve as datums for the recordation of the erosional profiles.

Soil moisture sensor data is recorded after each occurance of precipitation.

A weather station at the site monitors temperature, precipitation, and wind speed and direction, on a continual basis. This information will be used in the final report to analyze the effects of the microclimate upon the experimental walls.

Munsell Soil Color analysis of amended wall panels is conducted on a bi-annual basis.

6. SUMMARY

In this early stage of the test wall project at Fort Selden State Monument it is evident that preservation techniques employed exhibit a wide and varied range of erosional patterns.

The experimental panels in which the amendments were mixed directly in with the mud plaster are experiencing much less erosion than the panels on which the amendments were applied by spray or rolled on. Techniques need to be developed in order to determine the amount of moisture retention taking place behind the amended plaster before any recommendations can be made.

The moisture sensors utilized in the wall base experiment are providing little information on the rate of capillary rise given the amount of precipitation at the site. The wall bases will be monitored for occurrence of coving. The walls may be cored to determine the amounts of moisture in them and accelerated weather testing by flooding the bases may be conducted.

The cap with a drip edge and drainage slope is protecting the wall top more than the other techniques used and much more than if the wall was left uncapped. Judgements must be made in relation to the aesthetic value of this technique, as compared to the value and significance of the wall.

Unamended mud plaster and mud bricks are, as far as known, the only materials compatible with historic earthen architecture. Some of the techniques employed in this experiment may prove applicable to the preservation of cultural resources at Fort Selden and mud brick structures in general.

This phase of the mud brick test wall project at Fort Selden is scheduled for completion in 1995 at which time a comprehensive report will be prepared on results of the experiment. The research program will hopefully be expanded during this period and in the future. New Mexico State Monuments welcomes comments and suggestions regarding this project and future mud brick research. Correspondence may be directed to New Mexico State Monuments, Museum of New Mexico, Box 2087, Santa Fe, New Mexico, 87053, USA.

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FIG. NO. 1 Fort Selden Test Wall Project, overall looking west. Visitor's center and historic fort ruins are in the background.

FIG. NO.2 Fort Selden Test Wall Project, chemically amended wall, south face.

PRESERVATION OF ADOBE CONSTRUCTIONS IN RAINY AREAS

Julio VARGAS NEUMANN
Ernesto A. HEREDIA ZAVONI
Juan J. BARIOLA BERNALES
Pontificia Universidad Catolica del Peru
Apto. 1761
Lima 100
Peru

Povindar K. MEHTA
University of California
Berkeley
721 Davis Hall
California
Berkeley, CA 94720
U.S.A.

ABSTRACT

This study presents the results of a durability test program on mud plasters subjected to simulated rain. Different stabilizers were used as extracts from tuna leaves, a variety of cactus plants, banana leaves and stalks, and locust beam tree pods. Results of mud plasters stabilized with asphalt RC-250 are presented for comparison. Experimental results showed that shrinkage cracking is one of the most important factors that affect the disintegration of soil stuccos. A procedure was developed to obtain cracking resistant stucco composed of natural soil, coarse sand, straw and a stabilizer extracted from the cactus plant. The stucco was also water resistant.

INTRODUCTION

It is a general experience that adobe buildings do not stand up well the destructive action of rain. Protection against water usually requires expensive industrial materials as cement, lime or asphalt. However, some extracts from plants, including locust beam tree, banana and cactus, have been traditionally used for protection against water. In the region of Nankansi (Ghana) the mud stucco is polished with stones, which apparently reduces permeability. There not exist however, studies that evaluate scientifically the techniques and materials describes above.

The objectives of this investigation were:

(a) To study in the laboratory the different techniques and natural products used traditionally for protection of adobe constructions against rain.

(b) To evaluate the different techniques and natural products mentioned above by means of a simulated rain test.

EVALUATION OF STABILIZERS AND TECHNIQUES FOR IMPROVEMENT OF STUCCO WATER RESISTANCE

A series of tests was planned to evaluate the effectiveness of various natural stabilizers and techniques for improvement of the durability of stucco. Evaluation was in terms of erosion caused by a laboratory-controlled rain. All plasters were fabricated using soil from the campus of the

Catholic University (PUC soil).

The following substances were selected to study their stabilizing properties:

a) Cactus stabilizer (Opuntia Ficus Indica), (see Fig. 1)
b) Banana stabilizer (Musa Paradisiaca)
c) Locust beam tree stabilizer (Ceratonia Silicua)
d) Liquid Asphalt

Photographs of the locust beam tree, banana and cactus plants are shown in Figures 1, 2 and 3. In the case of natural stabilizers, each substance required a different fabrication process. Cactus stabilizer was obtained by soaking the chopped plant in water (equal weight proportions of cactus and water) for 5 days. Banana and algarrobo stabilizers require boiling of the vegetal substances in water. Boiling of banana stalk and leaves did not result on a viscous residue as mentioned in the literature {Schreckenbach, 1984}. Apparently the banana species selected in this research (Musa Paradisiaca) is not appropriate for stabilizing purposes.

Locust beam tree stabilizer did result on a thick residue, however produced fungus and attracted insects to such an extent that its study was discontinued.

Preliminary tests were conducted on specimens referred to as "stucco specimens" consisted on a layer of mud cast in a wooden form of dimensions 20 x 400 x 400 mm.

Stucco consisted on a mix of soil, straw and water and stabilizer. Straw type was grass added in a percentage of 2% by weight for all specimens. Water or stabilizer was added in enough amount to obtain a "standard consistency" of the mix. Consistency was controlled with a modified Vicat neddle {Vargas et al, 1984}.

The effect of asphalt stabilizer was investigated in two percentages 2 and 4% with respect of weight of dry soil. Additionally, for comparative purposes, specimens of plain soil (without stabilizer) and specimens of plain-polished soil were fabricated. Polishing was performed with a trowel at 7 days of age.

The specimens were subjected to several cycles of simulated rain produced by a hydraulic system and the eroded material during each cycle was collected. Figure 2 shows the experiment setup.

The specimens were subjected to 20 cycles of 3 hours (each one) of simulated rain. Damage suffered by the specimens was visually rated as light, moderate or severe. Table I indicates the test results.

The main conclusions can be summarized as follows:

(a) Simulated rain test on specimens S1 (plain soil) caused damage that could be clearly observed after only 30 minutes of exposure. At the end of the third cycle damage was visually rated as severe.

(b) In the case of specimens S2 (plain soil with stone-polishing) polishing of the surface showed to be effective only during approximately the first four cycles. For the following cycles erosion damaged the stucco similarly as in the case of S1 specimens.

(c) Simulated rain tests performed on stucco specimens indicated that shrinkage cracks originate weak zones where damage concentrates. From this point of view, shrinkage cracking control is critically important.

(d) Test results indicated that stabilization to a level comparable to asphalt can be obtained by using cactus stabilizer. The washed material was only 28 grams against 650 for S1 specimens. Fabrication of cactus stabilizer should be studied in order to determine its optimum composition.

ADDITIONAL STUDIES FOR IMPROVEMENT OF DURABILITY OF STUCCO

(a) Tests for Determination of Optimum Composition of Cactus Stabilizer.-

The objective of these tests was to study the influence of soaking time during fabrication on the effectiveness of the stabilizer evaluated through the rain test.

Figure 4 shows the variation of weight of eroded material versus soaking time during fabrication.

As can be seen in Figure 4 soaking time of cactus stabilizer is an important factor for adequate behavior of the stabilizer. Best results were obtained for soaking time between 14 and 25 days. At this age the stabilizer is characterized by a green color and strong odor of decomposed organic matter. Soaking times seem to depend, however, on the environment temperature.

(b) Tests of Shrinkage Cracking Control.-

Shrinkage cracking control of soil stucco was studied through (1) restrain of drying shrinkage by addition of coarse sand, (2) control of growth of cracks by straw addition, (3) cracking control by simultaneous addition of sand and straw.

Studies of cracking were performed on small walls (0.60 x 0.60 x 0.15 m). Stucco mix contained PUC soil, coarse sand, straw and water.

Particles sizes of coarse sand were limited to ASTM meshes #4 and #40. Amounts of sand considered were 50, 100 and 200% of weight of dry PUC soil.

Straw type was ichu from Cusco (Stipa ichu). It was cut in 100 mm-length pieces and used dry. The amount of straw was 2% of total weight of dry material (soil plus sand).

Optimum results were obtained for simultaneous addition of sand and straw. Amounts of sand and straw shall be proportioned so as to obtain adequate workability. For PUC soil best results were for amounts of 50% and 2% straw.

FINAL TEST OF DURABILITY OF STUCCO USING THE OPTIMUM COMPOSITIÓN

The conclusions from previous tests were applied in the fabrication of stucco applied to small walls of dimensions 0.60 x 0.60 x 0.15 m. These stuccoed small walls were subjected to simulated rain to study its resistance to erosion.

Stucco consisted on two layers: (1) a first layer of coarse stucco of 12 mm of thickness and (2) a second layer of fine stucco of 3 mm of thickness.

Coarse stucco was composed of PUC soil, coarse sand, cactus stabilizer and straw. The proportion of soil and sand was 1:0.5 and straw was added in a quantity of 2% of the total dry material. These proportions yielded optimum results in regard of shrinkage control. Straw was cut in 100 mm-length pieces.

Fine stucco consisted on PUC soil, straw and cactus stabilizer. Fifty-milimeter-length straw was used in this case and coarse sand was not included because it make it difficult to obtain an adequate finishing.

For all cases cactus of optimum composition was used, which corresponds to 18-day-soaking time.

Stucco surface was polished with stones. The procedure used followed the literature {Schreckenbach, 1984} recommendations: (1) rub the surface of stucco with a granitic stone (coarse surface) and (2) most and rub the surface with a basaltic stone (smooth surface).

Specimens of PUC soil and straw (2%), without cactus stabilizer and without polishing were also fabricated for comparison purposes.

The specimens were subjected to 2 hours per day of continuous simulated rain during 15 days. Three specimens were tested for every stucco type. Figure 5 shows the obtained results.

The obtained results (Fig. 5) indicated that the stucco fabricated with soil, coarse sand, straw and cactus stabilizer is considerable more resistant to erosion. Apparently this is because (1) shrinkage is adequately controlled by using straw and sand and, (2) cactus stabilizer improves the resistance to erosion.

CONCLUSIONS

(1) Shrinkage cracking is one of the most important factors that affects the disintegration of stuccos made from natural soils.

(2) A procedure has been developed to obtain a cracking-resistant stucco composed of natural soil, coarse sand, straw, and a stabilizer extracted from the cactus plant. The stucco is also water resistant.

(3) Satisfactory results were obtained on durability of stuccos of an optimum composition when applied to adobe masonry. Specimens were subjected to simulated wetting and drying cycles of rain.

(4) A study showed that the ėffectiveness of the cactus extract as a stabilizer depended greatly on its composition, which is controlled by the age and temperature of the cactus-water mixture. Other stabilizers, such as banana-stem extract and locust beam extract, were not found effective; this may be due to the lack of data on their optimum compositions.

RECOMMENDATIONS

A technology was developed which consist on plastering the walls with a mud stucco stabilized with cactus.

The main recommendations for plastering adobe walls with this type of stucco are to:

(1) Prepare the cactus stabilizer soaking cactus chopped pieces until the soft (inside) part dissolves completely leaving the skin only as residue. The obtained product is characterized by gluey consistency, green color and strong smell of decomposed organic matter.

(2) Remove dust from the wall surface.

(3) Apply the stucco in two layers, a first layer of 12-mm thickness and a second very thin layer (approximately 3 mm). The first layer contains straw and coarse sand in amounts that allow an adequate workability. The second layer contains straw in small pieces (approximately 50 mm) and should not contain coarse sand. The second layer covers the cracks of the first layer and provides a surface adequate to be polished. Both layers are mixed with cactus stabilizer (not water is used).

(4) Rub the stucco surface with a "coarse" stone (granitic). Thereafter, moist the surface with the stabilizer and polish it with a smooth stone (basaltic stone).

(5) Paint the finished surface with the cactus stabilizer.

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Table I Results of Rain Tests on Stucco Specimens

Stucco	Number of Cycles	Weight of Eroded Material (gr)	Damage
S1 (Plain Soil)	9	613	Severe
S2 (Polished Soil)	10	653	Severe
S3 (Soil with Banana Stabilizer)	20	288	Moderate
S4 (Soil with Cactus Stabilizer)	20	28	Light
S5 (Soil with Asphalt (2%))	20	60	Light
S6 (Soil with Asphalt (4%))	20	15	Light

FIG. No. 1 Photograph of Cactus Plant

FIG. No. 2 Test Setup

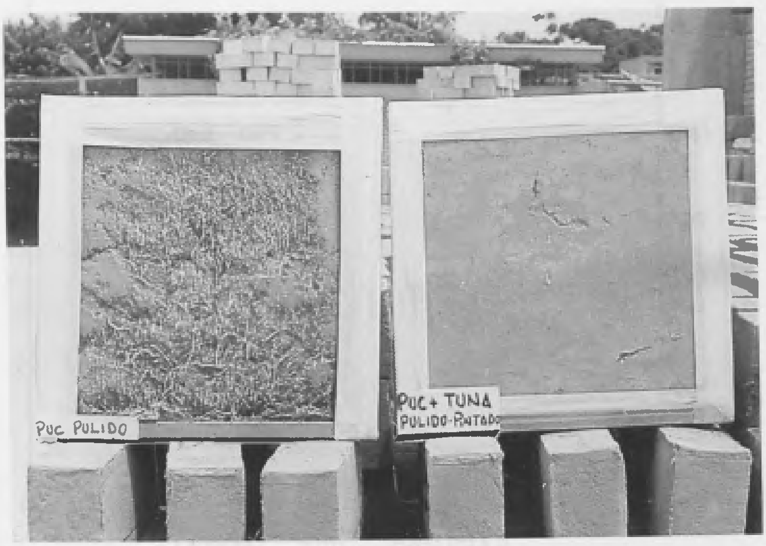

FIG. No. 3 Photograph of Specimens S2 and S4 after Testing

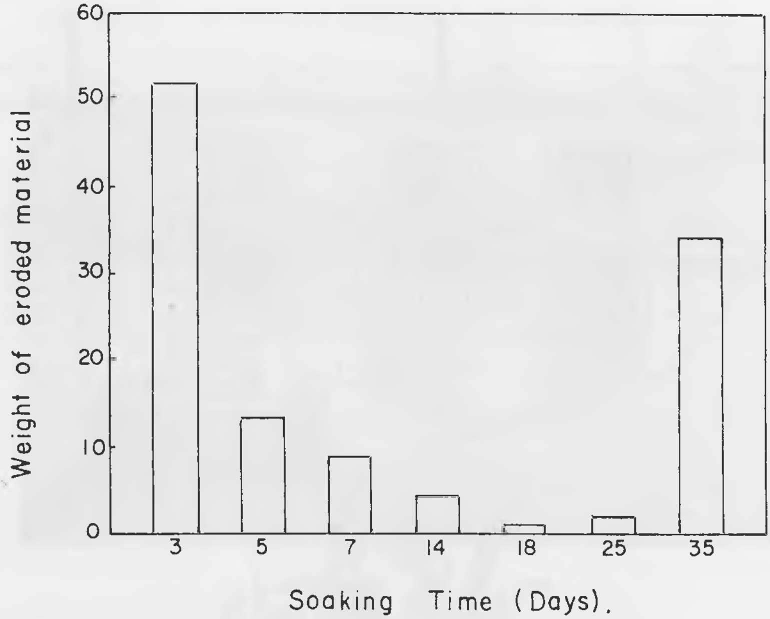

FIG. No. 4 Effect of Soaking Time During Fabrication on Stabilizer Effectiveness (Stucco Specimens)

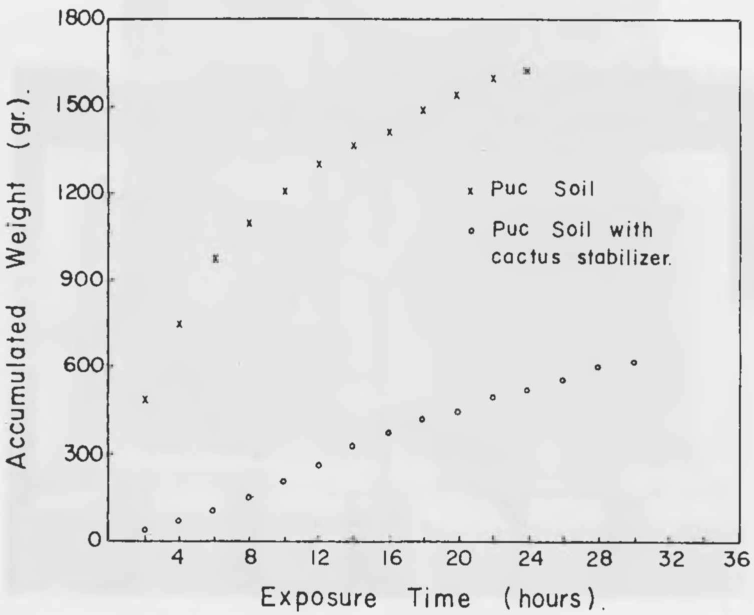

FIG. No. 5 Weight of Eroded Material by Rain vs. Exposure Time (Small Wall Specimens)

ICCROM
VIA DI SAN MICHELE 13 I-00153 ROME RM, ITALY

CRATerre
CENTRE SIMONE SIGNORET / BP 53 / F-38090 VILLEFONTAINE (FRANCE)
TÉLÉPHONE : (33) 74 96 60 56
ÉCOLE D'ARCHITECTURE DE GRENOBLE
10, GALERIE DES BALADINS / F-38100 GRENOBLE (FRANCE)
TÉLÉPHONE : (33) 76 40 66 25
TÉLEX : 308 658 F CRATERE
TÉLÉCOPIE : (33) 76 22 72 56
TÉLÉTEL INFOTERRE : 3615 CODE "ANICK"

MELATT DIRECTION DE L'ARCHITECTURE ET DE L'URBANISME