EARTH CONSTRUCTION

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Cob, sod, pisé, (sandy soil) adobe, pisé blocks. Mud render, lime render
LOW STRENGTH RENDERS Continue maintenance.
Linseed oil coating is most successful.

GENERAL

Earth is one of the oldest building materials known to man. Historically the first reference to the use of soil as a construction material dates from the time of Hannibal, during the Second Punic War, when it was used to build watch towers for look-outs. Observers in recent years have vouched for the existence of these soil structures, twenty centuries old. Using many different techniques each building has been carried out in almost every country of the world. In many of the third world countries earth building in one form or another is still the major method of building domestic structures and throughout the world more people are housed in buildings constructed of earth than of all other materials.

The earliest buildings in Australia were built with rough bush-timber frames and mud, on the principle known as 'wattle and daub'[1]

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[1] G.F. Middleton, Earth Wall Construction, EBS Bulletin, No.5. Australian Government Publishing Service 1976.

Wattle and daub was mostly used for quick, cheap construction on the goldfields and for settlers first cottages as were other quick techniques such as cob construction, sod construction and slab and ricker. More substantial structures were built using Pisé or Adobe and the majority of surviving earth structures are of these two techniques.

In his search for other materials to suit his expanding requirements man has learned to hew stone and bake bricks, and, recently, commercialised materials and steel have been utilised in home building. However, with the cost of labour continually rising, the lack of building materials and an increased concern for the environment, more people are turning again to earth as a domestic building material, and with the greater interest in the retention of our heritage a larger number of old earth buildings are being considered for renovation.

SECTION I TECHNIQUES.

WATTLE & DAUB

This method began with the construction of a sturdy frame of bush timbers, sometimes used in their natural state, sometimes roughly squared. Next thin, straight withes, or saplings were interlaced with twigs or branches to make matlike screens called "wattles". These wattles were attached to the posts and studs, as both exterior cladding and interior lining and the spaces between filled with mud and straw. The exterior and interior surfaces were then 'daubed' with mud and invariably finished with whitewash.

COB

Cob was a practised building method used extensively in England but has been little used in Australia. Nevertheless, some examples still exist and Middleton refers to an example built as recently as 1946. Cob required the use of a very stiff mud mixture which was piled in thick layers on the wall without any forms or moulds. After the outline of the wall had been scored on the ground, a layer of the mixture was placed, by means of special long-tined forks, along the marked portions of the walls, and 'flayed', that is, beaten down and compacted. Successive layers were forked on and flayed until the walls were built to full height. A specially shaped cutting instrument called a paring iron was then used to trim the walls true and straight. Openings for doors and windows were cut out of the completed walls, first by cutting holes for the lintels and then for the actual door or window opening.

SOD

Sod walling is a building technique which in Australia was used even less than cob. There is, however, a settlement to the west of Sydney called Sodwalls where it is thought to have been used. Sodwalling is very simply a method of piling up lumps of turf into the form of a wall. It was a very poor building method and only used for temporary structures.

SLAB & RICKER

This is an early New Zealand variation on the English Cob method of building. The process was to place a mud mixture similar to that used for cob, down between a slab exterior wall and an interior wall of beach saplings or rickers.

PISÉ

Pisé was probably the most popular earth building technique used for the more substantial buildings of the earlier settlers and the majority of the old earth buildings still in existence especially in Western N.S.W. are built with the Pisé method. Pisé is an abbreviation of the French Pisé-de-terre meaning 'rammed earth'. In the Pisé method of construction, moist earth was manually rammed between temporary timber formwork in the final wall position. The forms were moved progressively along the wall length after each section had been rammed to form courses which varied in height from 300 mm to 900 mm maximum height. Successive courses were rammed until the final wall height was reached. Corners and partition junctions were usually rammed first in each course using special formwork and then the sections in between were rammed. Openings were created by inserting bulkheads in the forms at appropriate positions. Window and door frames were generally fixed to wooden plugs built into the walls during construction.

ADOBE

World-wide, adobe was and is, the most popular form of earth construction and although probably taking second place in Australia to Pisé, was used widely in early settlers times. The method has survived to present times much more than pise and is experiencing a considerable revival at the moment. Adobe is mud (puddled earth) or mud and straw which is moulded into blocks. After drying they are lain in bond in the walls in the manner of laying other masonary blocks.

PISÉ BLOCKS

Although not as widely used as Pisé, Pisé Blocks were used by the early settlers and examples can be found of whole buildings of Pisé Blocks (as at Trundele, N.S.W.) or of parts of Pisé buildings where Pisé blocks were used in less accessible parts of the building such as gables or upper parts of walls. Pisé blocks are a cross between Adobe and Pisé in that the earth is rammed as for Pisé but into small moulds, thus making blocks which are dried and then built into walls as with Adobe.

SECTION 2 RESTORATION & MAINTENANCE

GENERAL

Deterioration is inherent in the base material of which earth buildings are made and if initial construction and/or subsequent maintenance did not take this into consideration then significant remedial action may be necessary to restore a building to a stable and substainable condition. Because the earths used in earth buildings were not usually modified by firing or by the addition of stabilising materials the walls do not permanently harden, but remain unstable - they can shrink and swell with changing water content. Strength also fluctuates with water content: the higher the water content, the lower the strength.

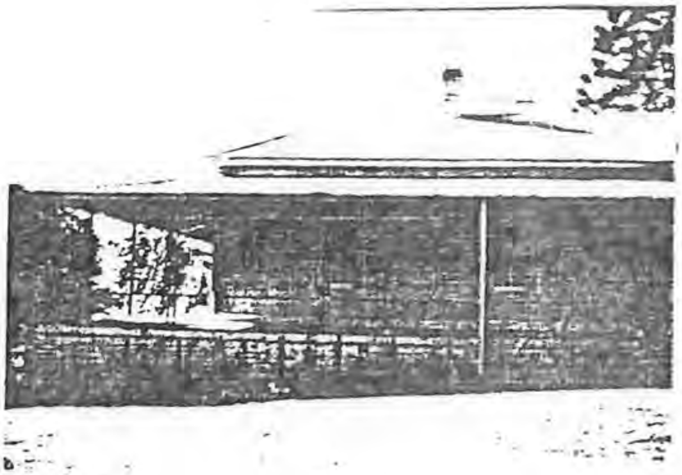
Earth will not permanently bond with metal, wood or stone because it exhibits much greater movement than these other materials, either separating, cracking or twisting where they interface. Yet, many more stable building materials such as stone, wood, and lime and cement motors and renders have been used in earth buildings, some during intial construction, some during subsequent maintenance. In earth buildings where these more stable materials have been used successfully they are generally held in place by their own weight or by the compressive weight of the wall above them. Also the preservation and restoration of a deteriorated earth building is most successful when the techniques and methods used for restoration and repairs are the same or as similar as possible to the techniques used in the original construction.

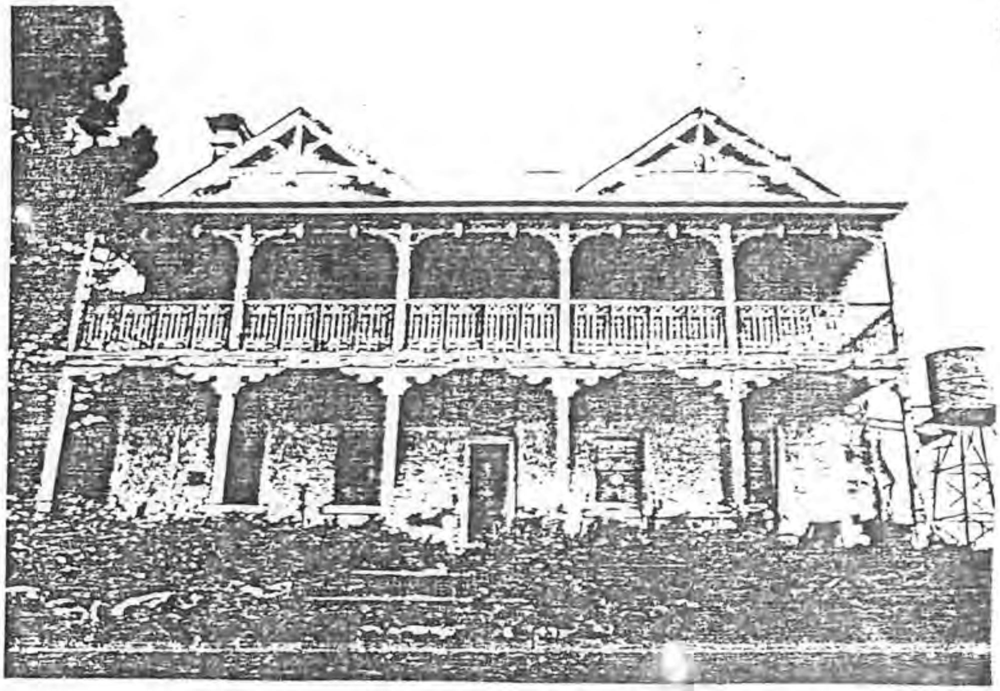
THE EARTH

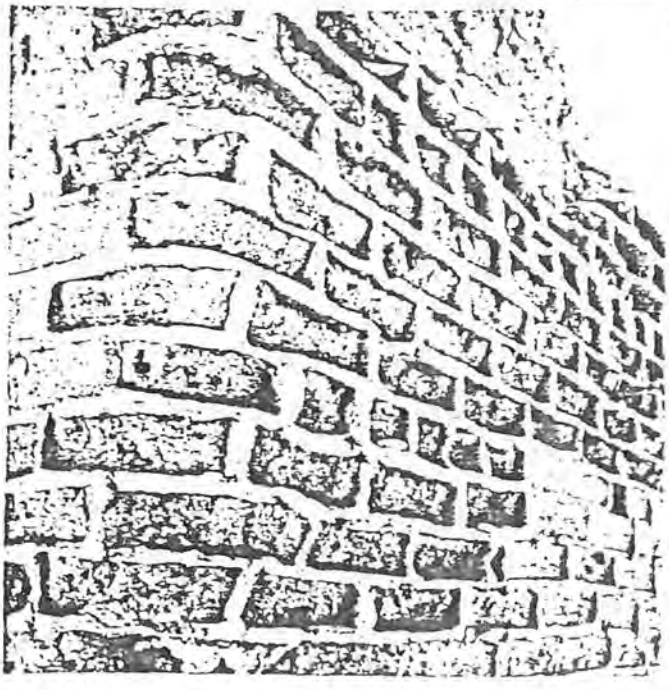
A large range of sub-soil earths are and were used for earth wall construction. Where the earths used for Pisé construction have a relatively low clay content and are inherently more susceptible to errosion, those used for Adobe tend to be more erosion resistant. Because of this Pisé walls were invariably protected by applied finishes and/or large roof projections or verandahs whereas these measures were not so common with Adobe although of course, the walls had to be protected from the top by short roof overhangs. As has already been said, the earth was normally not modified with additives. However, in a few examples lime was added in very small proportions (1 bag of lime to 1 dray load of earth) to Pisé earth, and quite a large proportion of Adobe blocks were made with straw added to the earth. The straw does not give added strength to the blocks but does help the blocks shrink more uniformly while they are drying.

MORTAR

Historically earth blocks were laid with a mortar made with the same earth as the blocks. Such mortars exhibit the same properties as the bricks: relatively weak and susceptible







to the same rate of hygroscopic swelling and shrinking, thermal expansion and contraction and deterioration.

Consequently, no other material has been as successful in bonding earth blocks. Where cement or lime mortars are used these stronger mortars accelerate the deterioration of the blocks.

FOOTINGS

Footings for earth walls varied because of differences in local building practices and availability of materials. While a few footings were large and substantially constructed, for most buildings they were usually non-existent. A change in the foundation conditions hether natural or artificial is a major cause of deterioration.

DAMP PROOF COURSES

Damp-proof courses were seldom if ever used during the time most old earth buildings were constructed. Very few, if any earth buildings, therefore, have damp-proof courses, and this fact, together with poor ground water drainage has led in many cases to serious damage.

SURFACE COATINGS

Traditionally most earth buildings had surface coatings internally and a large number especially Pisé buildings had external coatings too. Such finishes included mud plaster, lime plaster and whitewash and provided protection against deterioration, but relied on periodic replacement.

Mud Plaster has long been used as a surface finish and is sometimes mixed with cow dung to increase its durability. Because it is made of the same material it exhibits sympathetic characteristics to the wall. The mud plaster bonds to the earth wall because the two are made of the same material. Because mud plasters are made from earths with high clay content like the earths used for Adobe and because the Adobe walls have a rougher texture than Pisé, bonding is usually better to Adobe walls. Pisé walls may therefore, require the provision of a surface keying to facilitate bonding.

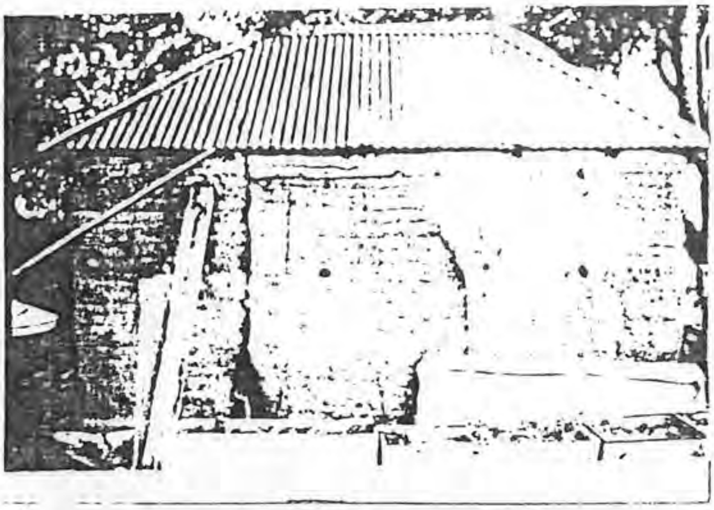
Whitewash has been used on earthern buildings since recorded history. There are as many recipes for whitewash as there are for bread, but all generally include ground gypsum rock, water, and usually a water-repellant such as tallow. Whitewash acts as a sealer, which can be either brushed on the wall or applied with large pieces of course fabric such as hessian.

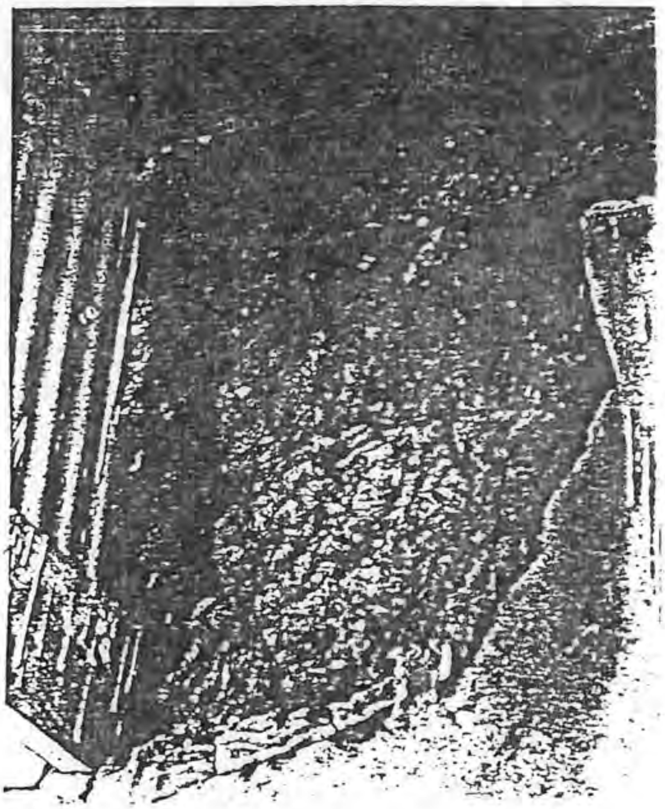
Lime plaster is much harder than mud plaster but less flexible and cracks easily. It consists of lime, sand and water and is applied in heavy coats with trowels or brushes. To aid bonding of lime plaster to walls a keyed surface is usually provided. This is achieved by racking out joints in blockwork or scoring diagonal lines in monotithic walls.

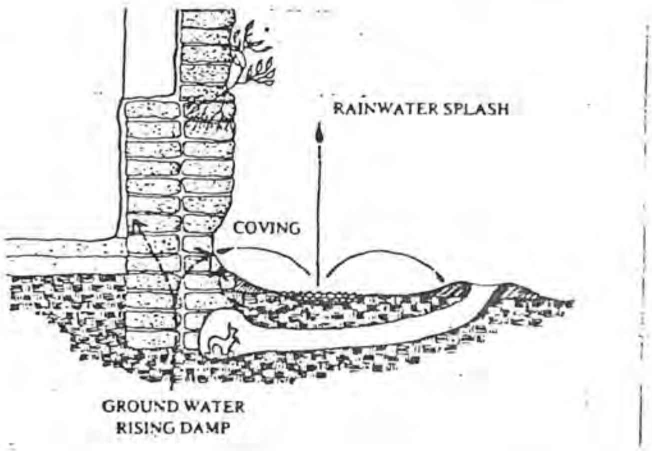
SOURCES OF DETERIORATION

Before restoration or repairs begin the problems that have been causing the deterioration of earth structure must be found, analyzed, and solved. It should be noted that deterioration is often the end-product of more than one of these problems. The remedying of only one of these will not necessarily arrest deterioration if others are left untreated.

Structural Damage: There are several common structural problems in earth buildings, and while the results of these problems are easy to see their causes are not. Many of






RAINWATER SPLASH
COVING
GROUND WATER
RISING DAMP

these problems originate from improper design or construction, insufficient footings, weak or inadequate materials or the effects of external forces such as wind or water. Solutions may involve repairing foundation conditions, realigning leaning and bulging walls, buttressing walls, inserting new window and door lintels, and repairing or replacing badly deteriorated roof structures. There are many tell-tale signs of structural problems in earth buildings, the most common being cracks in walls. Cracks are usually quite visible but their causes may be difficult to diagnose. Some cracking is normal, such as the short hairline cracks that are caused as the earth shrinks and continues to dry out. More extensive cracking, however, usually indicates serious structural problems.

Water Related Problems: The importance of keeping an earth building free from excessive moisture cannot be overestimated. The erosive action of rainwater and the subsequent drying of wall surfaces can cause furrows, cracks, deep fissures, and pitted surfaces. If left unattended, rainwater damage can eventually destroy earth walls, causing their continued deterioration and ultimate collapse. Standing rainwater that accumulates at foundation level and rain splash may cause 'coving' (the hollowing-out of the wall just above ground level).

Ground water may be present because of a spring, a high water table, improper drainage, seasonal water fluctuations, excessive plant watering, or changes in grade on either side of the wall. Ground water rises through capillary action into the wall due to the lack of a damp-proof course and causes the earth to erode or bulge. As the water rises from the ground, the bond between the clay particles in the wall breaks down. In addition, dissolved minerals or salts brought up by the water can be deposited on or near the surface of the wall as the moisture evaporates. If these deposits become heavily concentrated, they too can deteriorate the adobe fabric. Rainwater that has accumulated at earth wall foundations should be diverted away from the building. This may be done by regrading, by forming gravel-fitted trenches or brick, tile or stone drip gutters, or by any technique that will effectively remove the standing water. In repairing 'coving' the use of earth stabilized with cement might be considered if earth on its own proves unsuccessful. On the other hand, concrete patches, cement stucco, and curb like buttresses against the coving usually have a negative effect because moisture may be attracted and trapped behind the concrete.

Cement stucco and cement patches have the potential to cause specific kinds of water related earth wall deterioration. The thermal expansion coefficient of cement stucco is 3 to 10 times greater than that of earth walls resulting in cracking of the stucco. Cracks allow both liqued water and vapour to penetrate the earth wall beneath and the stucco prevents the wall from drying. If the earth becomes so wet that the clay reaches its plastic limit and slumps or if the earth is exposed to a freeze-thaw action, serious damage may result. Under the weight of the roof, and the dry wall above, the wet earth may deform or bulge. Since the deterioration is hidden from view by the cement stucco damage may go undetected for some time. Traditional earth walling construction techniques and materials should, therefore, be used to repair or rebuild parts of the walls.

The destructive efforts of moisture on earth buildings may be substantially halted by several remedies.

1. Shrubs, trees and other foundation planting may be causing physical damage. Their roots may be growing into the earth wall, and/or they may be trapping excessive moisture in their roots and conducting it into the walls. Their removal might be considered to halt this process.

2. Level ground immediately adjacent to the walls may be causing poor drainage. Regrading could be considered so that the ground slopes away from the building, eliminating rainwater pools. This may also include the removal of concrete or other hard surfaces adjacent to walls which may be diverting water to the base of the wall and preventing the evaporation of water from the ground surface.

3. The installation of footing drains may be considered. Trenches about 600 mm wide and a metre or more deep should be dug around the building a short distance from the base of the wall. If the soil is weak, it may be necessary to slope or shore up the sides of the trench to prevent cave in and subsequent damage to the walls. Drainage pipe should then be laid in the bottom of the trench. These pipes should drain to a sump or an open gutter below the level of the trench. The trench should then be backfilled with gravel to within 200 mm of ground level, the rest being filled porous soil.

Only after one or more of the above methods have been used to remove the cause of the damage should the coving be repaired using traditional materials and techniques.

<u>Wind Erosion</u> It is often difficult to isolate the effects of wind erosion as the results are similar to water erosion, although it is more often at the upper part of the wall. Maintenance is the key to protection against wind erosion, although in extreme cases wind brakes may be necessary.

<u>Vegetation, Insects, and Vermin</u> Examples of serious deterioration caused by vegetation, insects or vermin are unusual. It is usually in buildings which have been deserted for a long period of time. Termite attack of wooden elements of the building are the greatest problem as they are with any building in termite areas. All evidence of plant, animal and insect pests should be removed and

and measures taken to prevent their return. Pest control involving the use of chemicals should be examined carefully in order to assess the immediate and long lasting effects of the chemicals on the earth building and its inhabitants.

PREVIOUS REPAIR WORK

It is possible that repair work has already been carried out sometime during the life of the earth building. These repairs may have included cement renders, the replacement of timber lintels with steel ones and the spraying of plastic or latex surface coatings. The use of high strength cement renders has often caused the weaker earth walls to crack and crumble during the differential expansion of these incompatible materials. Steel lintels being more rigid than the timber they replace may cause the earth walls to twist when the building expands. Surfaces sprayed with latex or plastic coatings are prevented from expanding with the rest of the wall and subsequently portions of the surface may break away.

If possible, these incompatible materials should be removed from the building unless it appears that removal may cause more damage than to allow them to remain.

PATCHING & REPAIRING THE WALL

Adobe When repairing adobe bricks every effort should be made to use earth with a composition and colour as similar to the original fabric as possible. Bricks may be repaired or replaced. Fragments of the original adobe brick may be gound up, mixed with water and reused to remake bricks or patch the wall. However, the use of this material may be questionable as if it has spalled off the wall it frequently contains high concentrations of salts.

Pisé The selection of earth to repair pisé is more difficult than adobe. The technique of pisé relies on the ramming of the earth to achieve compaction. It is usually not possible in repairing pisé, to re-ram the wall unless a whole section of the wall is to be rebuilt, and of course, this will usually require the removal of the roof over that part to gain access from above. This is obviously not the case with wall sections below windows and in internal partitions. As re-ramming is not normally possible the repairs will have to be executed by the application of successive coats of earth render until the surface has been built up to its original position. The earth used in these render coats will most likely need to have a higher clay content than the original pisé earth to achieve cohesion between the earth particles. The clay content should not be too high however, as this will result in excessive shrinkage during drying which may cause the render to fall away from the wall.

Cracks and Joints

The repair of cracks and mortar joints in adobe uses the same procedure. As has already been said the cause of the cracks must be remedied before repair is carried out. The cracks or joints should be raked out to a depth of 2 or 3 times the width of the joint to obtain a good key of the mortar to the wall. Cracks and joints should never be repaired using cement mortars. It is a common error to assume that mortar hardness or strength is a measure of its suitability for repair. The use of this type of mortar, because of differing rates of thermal expansion, will cause the weaker earth material to crack, crumble and eventually disintegrate.

Bonding of Repair Work

With all forms of repair work it is important to achieve a good bond between the original and the new material. This needs not only careful consideration of the use of suitable materials but also preparation of the surfaces to which the repair is to be effected. Deteriorated material should be removed to give a firm base for the new material. The area to be repaired should be damped down by spraying with water immediately prior to application of the repair. Where severe damage must be repaired, successive layers of the repair material should be applied. Each layer should be allowed to partially, but not fully, dry. The moisture content of the repair material should be controlled to minimise cracking. Small cracks however, may be beneficial as these provide a key for the next layer.

MAINTENANCE

Cyclical maintenance has always been the key to successful earth building survival and it is usually the absence of periodic maintenance which necessitates major repairs. As soon as rehabilitation has been completed some program of continuing maintenance should be initiated. Surface coatings should be inspected frequently and repaired as soon as necessary. Mechanical systems, such as leaking water pipes must be monitored and repaired straight away. Observing earth buildings for subtle changes and performaing maintenance on a regular basis is a policy which cannot be over emphasized

CONCLUSION

An understanding of the characteristics of earth and earth construction techniques, as well as an awareness of the way they were used in the past is an essential basis for an appropriate choice of materials and techniques for their repair and rehabilitation. This understanding is also a basis for the appropriate use of earth as a modern and future constructional material for domestic and other small scale buildings.

Earth buildings hold many advantages for the modern, environmentally conscious owner builder: inexpensive, usually free material: low skilled labour oriented production of bricks and construction of walls; alternative flooring and roofing systems, also cheap or free; flexibility allowing for innumerable design criteria and varied choices of construction methods; passive regulation of the internal environment; harmony with the external natural environment; minimum expenditure of non-renewable resources, and eventual degrading and return to the natural state of the material when the building is no longer required.

It is mainly in these areas that the Earth Construction Research Unit is using the information from earth buildings of the past, together with our understanding of materials and good building practices to define appropriate earth building techniques for the future.

This sediment could be a terrace or creek bank deposit from the same creek system as the sand in the render (Aroona 1). The very coarse sand or gravel sized fraction is either an alluvial outwash or talus deposit which spreads thinly over the creek bank, or is a separate deposit deliberately added to the mud as a coarse aggregate.

Masking by mud prevents an optical estimate of the proportion of lime used but a ratio of 1 part lime to 3-5 parts sand is likely. Some natural lime (as calcium carbonate) may be present in the mortar.

CURNAMONA (render)

This render is composed of a poorly-sorted, rounded quartz sand, cemented by lime probably in the traditional proportion of 1 lime to 3 sand.

The sand, which ranges in grain size from .05 to 1 mm, has a reddish orange colour as a result of iron-oxide coatings on the quartz grains. Minor accesory minerals include micaceous siltstone, calcrete and magnetite. The sand is similar to the fluviatile deposits which form the extensive floodplain on which Curnamona stands and thus, this source is the most likely. The floodplain sand is often mantled by a thin calcareous soil.

A small amount of fibrous material has been added to the sand, presumably as a binder.

KANYAKA (pug mortar)

This pug mortar is composed of a very poorly sorted, mixed origin sediment to which lime has been added as a cementing material.

The sediment consists dominantly of fine sand, silt and mud and contains sub-rounded quartz grains up to coarse sand size though most are medium sized and smaller. Minor coarse grains of calcrete and possibly silcrete, and very fine grains of a dark mineral are also present.

The sediment is likely to be from a shallow surface deposit, possibly a creek-bank or terrace. Banks of the nearby Kanyaka creek and particularly of the tributary creek immediately south of the ruins are possible sources.

As with the Aroona mortar, masking by mud prevents an optical estimate of the proportions of lime used though the traditional 1 lime to 3 sand is possible.

SUMMARY

All of the mortars and renders examined consist of natural alluvial and colluvial sediments cemented by lime. Logic suggests that the builders of these homesteads would have obtained their raw materials from as close to the site as possible, and the geology of these mortars and renders confirms this reasoning.

David Young

David Young
SENIOR TECHNICAL OFFICER
18/2/83

VARIOUS MORTARS AND RENDERS

Samples of two renders and two pug mortars, that had been lightly crushed, screened, and tested by AMDEL, were examined using a binocular microscope.

AROONA 1 (render)

This render is composed of a fairly clean, poorly-sorted, creek sand that is cemented by lime, probably in the traditional proportion of 1 lime to 3 sand.

The sand consists of two elements; rounded grains of khaki, brown and red-brown micaceous siltstone which dominate the very coarse, coarse and medium fractions, and sub-rounded grains of quartz which dominate the medium, fine and very fine fractions. The geological map of the area shows the creek system immediately east of the Aroona homestead to drain both the Bunyeroo Formation (siltstone) and the ABC Range Quartzite (quartz sandstone), indicating that this is the likely source of the sand used.

AROONA 2 (pug mortar)

This pug mortar is composed of a very poorly sorted, mixed-origin sediment (diamicton) to which lime has been added as a cementing material.

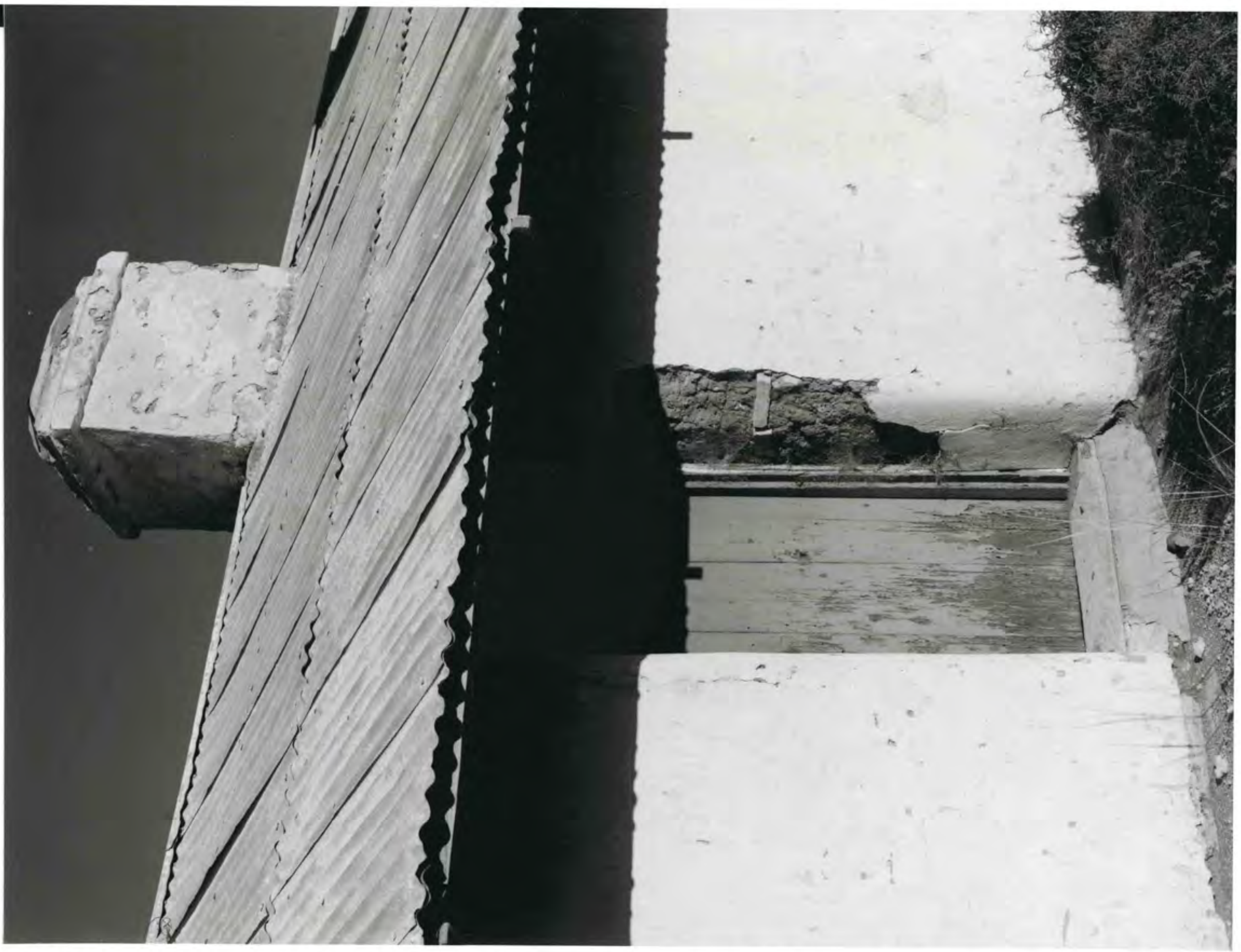
The sediment consists dominantly of mud and fine silts, but contains sub-rounded quartz grains in the very fine, fine and medium sand-sized fractions, sub-rounded to rounded grains of khaki, brown and red-brown micaceous siltstone in most size fractions, and very coarse sand to gravel sized angular fragments of grey-green, dolomitic (or slightly calcareous) siltstone and non-calcarous, grey, khaki, red and red-brown siltstone.

FILM 75 WEST WALL OLD HOMESTEAD CURNAMONA
NO 1 7-3-79

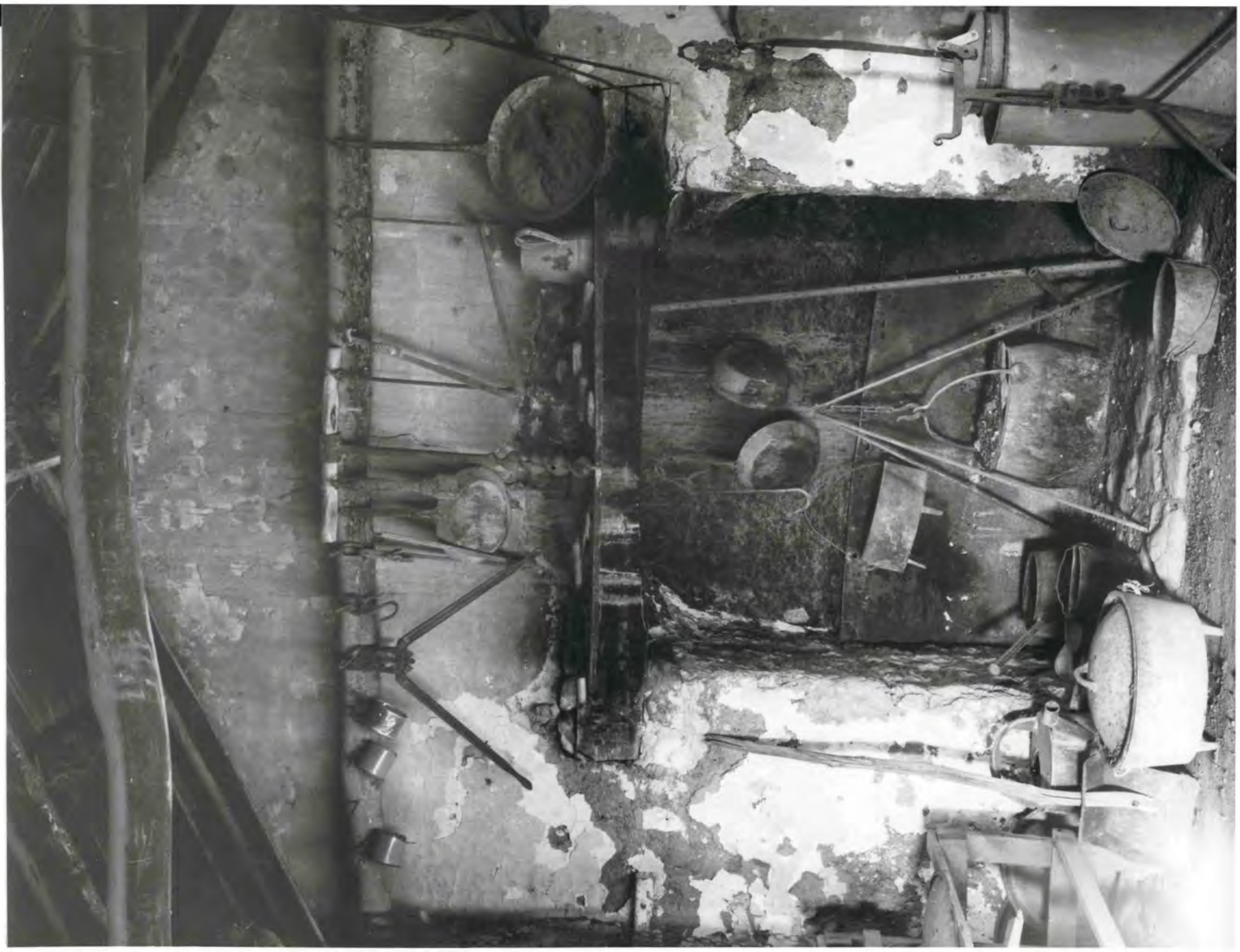
FILM 75 NO 4 WEST WALL OLD HOMESTEAD VIEW FROM SOUTH CURNAMONA 7-3-79

FILM 75 CHIMNEY NORTH EAST CORNER CURNAMONA
NO 8 ORIGINAL HOMESTEAD 7-3-79

FILM 75 WINDOW, NORTH WALL CURNAMONA
NO 9 ORIGINAL HOMESTEAD 7-3-79



FILM 75 WEST WALL, ORIGINAL HOMESTEAD CURNAMONA
NO 2 7-3-79



FILM 75 FIREPLACE NORTH EAST CORNER CURNAMONA
NO 10 ORIGINAL HOMESTEAD 7-3-79