The ‘Conservation and Design Guidelines’ are intended for anyone planning or undertaking building works in the historic Stone Town of Zanzibar. The Stone Town is a unique cultural asset, but badly designed modern buildings and ill-conceived repairs using incorrect techniques or materials are threatening its survival. The Guidelines explain how to protect the Stone Town. They include an explanation of how to design new buildings in compliance with the law, an analysis of traditional stone structures and common causes of failure, detailed descriptions of traditional building technologies and up-to-date conservation techniques, and advice on how to plan and execute repairs to traditional buildings.

The Guidelines draw upon the experience gained during the rehabilitation of the Old Dispensary building funded by the Aga Khan Trust for Culture (AKTC), a UNESCO funded training project at the Old Customs House, and more recently, the Community-Based Rehabilitation Programme co-funded by AKTC and the Swedish International Development and Co-operation Agency (SIDA) and carried out by AKTC’s Historic Cities Support Programme (HCSP). The Guidelines are part of an on-going effort to provide inhabitants of the Stone Town with the tools to maintain their built environment, and to engage the community as a whole in conservation. In particular, the Conservation and Design Guidelines provides detailed information about appropriate construction techniques in Swahili for the first time. Particular thanks are due UNESCO, who co-funded the production of the Guidelines.

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GOOD PRACTICE GUIDELINES FOR ALTERATIONS, EXTENSIONS, AND NEW BUILDINGS
These Guidelines have been drawn up to protect the traditional character of the Stone Town.

The Stone Town is very special. There is nowhere else in the world like Zanzibar Stone Town. Visitors come from all over the world to see it. There is nothing like the Stone Town in the rest of Tanzania. It is one of the things that makes Zanzibar different from the Mainland, and special. It is an important part of the island’s unique cultural identity.

Zanzibar should be proud of its Stone Town. The Stone Town is the embodiment of Zanzibar’s long and great history. It is proof that the island was once the greatest power in Africa, and a great Islamic state.

But the Stone Town is delicate. As times change, people wish to change their buildings, or need to carry out repairs. But these changes, unless properly guided, can destroy the Stone Town’s special character. Like a shell on the beach, slowly eroded by the waves, each change takes something away, and soon the Stone Town will lose its beauty and fineness, and become like a pebble. If the Stone Town is destroyed, visitors will no longer come to Zanzibar, and the economy will suffer.

The best way to preserve the special character of the Stone Town is to repair and maintain buildings using the correct methods, but otherwise to leave them as they are. If changes cannot be avoided, then the changes must be influenced by these Guidelines.

The law requires anyone wanting to do building work in the Stone Town to first ask permission from the STCDA. The STCDA’s job is to guide people wishing to do building work so that the changes they make and the building methods they use do not destroy the special character of the Stone Town. The STCDA will judge the building application according to these Guidelines.

If the building application follows the Good Practice Guidelines, approval by the STCDA will be quicker and easier.
1. It is mandatory to get permission from the STCDA before carrying out any building work in the Stone Town.

The law says:

« No person shall build, alter, remove or demolish a building, part of a building, an architectural or streetscape feature without first making a building application to the STCDA for written permission. »

This means ALL building work.

2. The STCDA will judge all applications for building permission according to the Good Practice Guidelines.

All building work in the Stone Town must follow the Good Practice Guidelines.

When thinking about or planning building work, FIRST look at the Good Practice Guidelines. DO NOT START any building work before obtaining written permission from the STCDA.
When carrying out repairs or alterations to existing buildings, always follow these key points:

1. **First Restore**
   When repairing existing buildings, always try to restore the existing fabric, rather than replace with new. This saves money and protects the special character of the Stone Town.

2. **Like with Like**
   When carrying out repairs or alterations, ALWAYS use the same materials as the original for the repairs. The repair is more likely to be successful if the materials used for the repairs are the same as the original. In the long term, this saves money and buildings.
   
   In particular, NEVER use cement to repair lime plaster.

3. **Quality Control**
   Poor quality materials will not work. The repair will fail and the work will have to be done again. ALWAYS check that materials have been prepared and stored properly.
   
   This is particularly important with lime. ALWAYS check:
   - That the lime is fresh; if it has not been stored as putty, it should be no older than a week.
   - Store lime under water as putty. The longer it is kept as putty, the better it will be.
   - Remove unburnt lime particles.

4. **Use Skilled Craftsmen**
   Always check that the craftsmen are skilled. Bad workmanship will fail, costing more money and endangering the building.
   Always ask for references, proof of experience, or the names of other people for whom the craftsmen have worked.

5. **Always Consult the Conservation Guidelines**
   The Conservation Guidelines describe repair and restoration techniques. By using this information, the building work will be better, last longer, and cost less.
   Applications for Building Permission to the STCDA that refer to the Conservation Guidelines will be processed more easily and quickly.
Original crenalations  
Do not change or remove

First restore  
Original mouldings are protected  
Do not change or remove

Original timber windows  
FIRST restore. Do not change or remove

Original Mouldings  
Do not change or remove

Like with Like  
Repair original lime plaster with lime plaster

Use skilled craftsmen  
To carry out repairs

Carved timber door  
Do not change or remove
Inappropriate alterations

DO NOT use cement plaster

DO NOT use textured finishes to repair plaster

DO NOT add modern features to the front of the building

DO NOT create textured finishes. These are not appropriate to the Stone Town

DO NOT add modern window openings
Inappropriate new building

- Perforated concrete blocks
- Pre-cast balusters on balconies
- Security bars
- Textured finishes
Important Architectural Features both inside and outside are protected by the law.

Examples of Protected Architectural Features are:

- original doors
- covered passageways (wikios)
- decorative plaster
- decorative tilework
- entry porches
- fascia boards on roofs and canopies
- original windows
- niches and arches
- balconies and teahouses
- timber stairs, etc.
EXAMPLES OF PROTECTED ARCHITECTURAL FEATURES

- Original windows
- Decorative timberwork
- Decorative tilework
- Original doors
- Decorative plaster
- Fascia Boards

DO NOT change or alter protected architectural features, other than to preserve or restore.
It is not permitted to change architectural features other than to preserve or restore them.

**EXAMPLES OF PROTECTED ARCHITECTURAL FEATURES**

- Decorative plaster moulding
- Niches
- Decorative timber
- Decorative tilework

**DO NOT**
- Alter or damage decorative plaster mouldings
- Cut new openings in walls
- Damage or block original niches
- Damage original tilework
- Repair lime-plaster with cement
1. All materials used to preserve or restore architectural features must be the same as the original. This means using lime to repair lime plaster, and timber to repair timber.

2. All changes or alterations either inside or outside must be reversible. This means that changes can be removed or reversed without causing permanent damage or alterations to the original building.

3. New door opening is not reversible and can cause structural damage.

4. DO NOT leave block-work unplastered.

5. DO NOT add extra floors. Extra floors can cause structural damage.

6. Modern window does not match original windows.

7. DO NOT use cement to repair original lime plaster.

8. DO NOT alter or destroy decorative plaster mouldings.
THE LAW STATES:
Part V, 38 (2)

« Details and fittings for new buildings and additions shall be compatible, in appearance and proportion, with the traditional character of the Stone Town. »

DOORS, WINDOWS, BALCONIES

The buildings of the Stone Town were built using traditional designs for doors, windows, balconies, and other architectural features. These features are an important part of the town’s special character, and must be preserved.

DO NOT use architectural features that are modern in design or out of keeping with traditional buildings.

DO NOT replace original doors and windows with modern ones. First try and repair the originals. If they are beyond repair, replace with copies of the originals made of the same materials.

DO NOT alter, remove or damage balconies or teahouses.
Traditional windows

The shape and design of the modern window is not compatible with the traditional character of the Stone Town

Proportions and design of new windows are not like traditional windows

DO NOT use pre-cast concrete railings on balconies or teahouses

Traditional door

The shape and design of a modern door is not compatible with the traditional character of the Stone Town

Proportions and the size of modern doors are not like traditional doors
DO NOT alter, remove or damage balconies or teahouses. If the original balcony is damaged, FIRST try and repair it. If this is not possible, replace with replica of original.

DO NOT replace original timber balcony with new concrete balcony.

DO NOT use pre-cast concrete balcony railings.
GOOD PRACTICE GUIDELINES

COLOURS

THE LAW STATES:
Part V, 38 (3)

« Colours: Used on the outside of the building must blend with the range of tones and colours found in the Stone Town. »

First
match original finishes and colours

Acceptable Colors

Roof paint colour
Red oxide
White

Wall finish colours
Light blue
White
Light yellow

Joinery finish colours
Green
Blue
Clear

DO NOT use oil paint on plastered surfaces

Use limewash on plaster surfaces, or paints that can breath
THE LAW STATES:
Part IV, 34 (2)

« Changes to protected streetscape features are not allowed except to preserve and/or restore the original design. »

Streetscape features are protected by Law.

Streetscape features are both natural and constructed. They contribute to the character of the street and urban environment. This category includes specific features such as:

- façades
- fountains
- gateways
- external stairways
- tombs
- trees and vistas

EXAMPLES OF PROTECTED STREETSCAPE FEATURES
Streetscape features are protected by Law.

**DO NOT** alter or destroy Streetscape features.

**EXAMPLES OF PROTECTED STREETSCAPE FEATURES**

For a full map of protected streetscape features refer to STCDA.
Some of the buildings in the Stone Town are given extra protection by the law through ‘listing’. There are Grade 1 listed buildings and Grade 2 listed buildings in the Stone Town.

Grade 1 listed buildings are shown in the plan opposite.

Grade 2 listed buildings are listed with the STCDA, see the map inside the STCDA. Allocate a place, best is just inside the door of the STCDA.

The level of protection is different for Grade 1 and 2 buildings. This means that building work that might normally be acceptable is not allowed on Grade 1 or 2 listed buildings.

First check whether your building has been listed Grade 1 or 2.

IF YOUR BUILDING IS
GRADE 1 LISTED

THE LAW STATES:
Part 1V, 32 (2)

1. No alterations or additions to the building are allowed, either inside or outside.

2. In very exceptional circumstances, the STCDA may allow minor changes, but any building work must preserve and/or renovate the original.

3. This means using traditional materials and techniques (See Construction Guidelines). Always follow the Good Practice Guidelines.

IF YOUR BUILDING IS
GRADE 2 LISTED

THE LAW STATES:
Part 1V, 32 (3)

Inside
1. Changes may be permitted by the STCDA as long as they conform to the Good Practice Guidelines. Where alterations are made, they must be done in such a way that if removed, they do not alter the original design of the building in any way.

Outside
2. No alterations or additions to the structure of the exterior walls will be allowed. In exceptional circumstances, the STCDA may allow minor changes.

3. Any work carried out must involve preserving or renovating the original fabric of the building. The Good Practice Guidelines must be followed at all times.
**Grade 1**
Listed buildings are:

**Grade 2**
THE LAW STATES:
Part V, 37 (2 a)

« Balconies, canopies, roof overhangs, and gutters may be built beyond the building lines to a maximum of one third of the width of the street, or in any case not more than one metre. Barazas and steps may be built beyond the building line to a maximum of 0.4m and sign boards to a maximum of 0.5m. »
THE LAW STATES:
Part V, 37 (2 a)

« Any new building or addition shall be sited so that walls and façades facing onto streets are in line with adjacent building lines. This applies to the ground floor and all storeys above. »

Modern building breaks the original building lines in the street
Modern windows and doors are not compatible with traditional character of the Stone Town

It is not permitted to set the front of the building back from the original street-line
THE LAW STATES:
Part V, 37 (4)

"The height of any permanent addition to an existing building, or of any new building, may not exceed the maximum height of the adjacent buildings, and in any case, may not exceed three storeys. The Authority may limit the height of a building to protect a Grade I or Grade II listed building or a protected architectural streetscape feature. Penthouses, teahouses, and other such roof-top additions may be permitted subject to the discretion of the Authority."
THE LAW STATES:
Part VII, 58 (1) (2)

« The use of large projecting signboards, signs made of plastic materials or illuminated signs, as well as any other form of advertising considered inappropriate in character, form or scale for the Stone Town will not be permitted. »

The erection of signs and other forms of advertising are subject to the approval of the STCDA

Signs or advertisements will be rejected if they are:

• Too big
• In the wrong place, e.g., in a Protected Streetscape
• Too bright or dominant
• Illuminated

This sign is not acceptable. It is too big and ruins the streetscape.
THE LAW STATES:
Part V, 37(5)

« Scale and massing:
New buildings, alterations, and additions shall be compatible in scale and massing with the character of the Stone Town. »

Scale of the new building is too small
Massing – the shape of the new building is *not compatible* with the Stone Town and breaks the building lines of the street.

Scale of the new building is **too big**.
ALTERATIONS AND EXTENSIONS

**Note:** Alterations and extensions can harm the comfort of neighbours or other inhabitants of the Stone Town.

**Always consider the following points when designing:**

**Privacy**
Alterations, extensions or additions must not intrude on another’s privacy. In particular, the location of new window openings should be carefully considered so as not to affect the visual privacy of another.

**Ventilation**
Many houses in the Stone Town rely on the wind for cooling. Alterations, extensions, and additions must not block the wind reaching another.

**Noise**
Alterations, extensions or additions must not increase the level of noise reaching another, for instance by locating an open restaurant area next to another’s bedroom.

**Access**
It is not permitted to block or impair access to another property.

**Views**
Alterations, extensions or additions must not block the views of another, for instance of the harbour or the street.
New building or extension

New building blocks
the wind reaching
next door building

Noise from new
building is disturbing
for neighbours

Windows in new
building allow views
into next door
building

New building
blocks views

New building
blocks breeze

Loss of
privacy
NATURAL CONDITIONS

The old buildings of the Stone Town were designed to cope with the environmental conditions of Zanzibar without resorting to mechanical systems of environmental control, such as air conditioning. They do this by maximising the beneficial aspects of the natural conditions, such as the prevailing wind and night time cool, and minimising those aspects that lead to discomfort, such as direct sunlight.

Old buildings regulate the environment cheaply and without using electricity. There are many lessons that can be learnt from old buildings that can reduce energy consumption and save money.
Windows open to the prevailing wind. Through breeze cools the interior.

Breeze ventilates roof void helping to keep the interior cool.

The courtyard is like a cup, filling with cool air at night, which slowly empties into the rest of the building by day. The air in the courtyard only warms up when the sun is directly overhead at midday.

Tile or iron-sheet roof over the flat roof protects the building from hot sunlight.

Thick walls protect the interior from heat. Sunlight is reflected by white limewash.

Courtyard increases ventilation.

Interior is shaded from direct sunlight.

High ceilings allow air to circulate more freely cooling the interior.
CHECK LIST

When designing new buildings for the Stone Town, always follow these key points.

Respect the Special Character of the Stone Town

When designing a new building, first look at the buildings and the street around. Treat these old buildings with respect. Try to blend in with the character of the street. Do not be intrusive.

Fill the Plot

New buildings must always fill the plot and not leave space around. In particular, the front of the building must be in line with the front of the buildings on either side.

Respect Streetscape and Building Lines

New buildings must respect the building lines of the original buildings in the street. New buildings must follow the lines of adjacent roofs, mouldings, windows, and canopies. Always treat the old buildings with respect.

Do Not Exceed the Height of Adjacent Buildings

New building must not be higher than the adjacent buildings in the street, and in any event, may not exceed three storeys.

Use Traditional Fixtures and Fittings

Always use traditional designs of windows, doors, balconies, roof details, porches, and canopies, etc. Look in the street around and copy.

Where Possible, use Traditional Methods of Construction

Use coral-stone walls and lime-plaster finishes. These often cost less, and the building will use less energy when finished.

Do Not Use Textured Wall Finishes

It is not permitted to use textured wall finishes. Walls must be smooth.

Use Appropriate Colours

It is not permitted to use bright colours on walls or joinery. The colours on new buildings must be the same or similar to those on adjacent traditional buildings.

Always Seek the Permission of the STCDA

The law requires anybody wishing to carry out building work in the Stone Town to first seek permission from the STCDA.

If the Building Application follows these key points, approval by the STCDA will be quicker and easier.
2.

REPAIR OF STONE HOUSES

THE AGA KHAN TRUST FOR CULTURE
The foundation is a part of the building that is never seen. It is the job of the foundation to support the weight of the house, so foundations are the first thing to be built and are buried underground. In Zanzibar, foundations are the same as walls except they are a little wider and perhaps made of bigger stones. It is their job to make sure that the building does not sink into the ground or that heavier parts of the house do not sink faster or further than lighter parts. They work by forming a continuous wall beneath the thinner walls of the house and spread their weight over a wider area.

If you stand on very wet sand you will sink slowly into it. If you stand on a flat piece of wood only slightly wider than your feet you will not. This is because your weight has been spread over a wider area. If most of Stone Town is built on firm sand. If it remains dry it is strong and will carry a lot of weight but if it has water running through it, it will soon wash away, leaving foundations unsupported and weak. If this happens the unsupported part of the foundation will break and the wall above will sink and perhaps begin to lean. In most cases, the foundations under houses in the Stone Town are good and only cause trouble if drains, sewers or water-supply pipes break, causing water to wash out sand from around them. Occasionally foundations are damaged if ditches are dug too close to them or a dry toilet pit collapses.

In old houses local movement caused by this type of damage is dangerous. If one part of the building moves it will cause more strain to be imposed on other old and tired walls. They too may begin to move and the building may become unstable.
Bricks Coursed and Bonded

Brick walls are bonded, and can resist pulling forces.

With bricks or long stones it is possible to arrange them so that they overlap and hold each other down. It is also possible to arrange them in orderly lines or COURSES. Walls like this are called Coursed and Bonded and they can resist pulling forces better because of the extra strength provided by the bonding. Bonding also distributes the weight imposed on the wall more evenly.

The rounded shape of coral rag prevents efficient bonding and can easily distribute the imposed load badly, leading to localised stress. Walls that are coursed and bonded are also much better at resisting BENDING. Rubble walls are more BRITTLE and will break if bent. Another important problem in building with rounded corals is seen in corners and in the junctions of walls. To be strong, buildings must have good corners with alternate stones from each elevation interlocking and fastening elevations firmly together. In the coral rubble walls of Zanzibar it is not possible to make such corners. Walls simply meet in flat BUTT-joints and there is no interlocking of elevations. Houses built with corners like this are weak.

Coral-rubble walls are not bonded and do not resist pulling forces effectively.

Cracks may form at corners.
Arches work because all the stones in them are in Compression. The weight above squeezes them hard together, keeping them in place. For maximum strength it is better if the stones are big and flat. This gives a larger area for the weight to pass through. If the stones are small the mortar between must be relied on to transmit much of the weight.

In order to stand, arches also need Abutment. If the arch is not to collapse, the weight pushing sideways through its stones must press on something solid, this is called Abutment. In the middle, an arcade abutment is provided by the columns and the pushing force from the next arch. At the ends of an arcade there is no abutment and because of this a potential weakness occurs.

For maximum strength, it is better to use big, flat, stones.

Large mortar joints weaken the arch.
Roof and floor slabs are made of boritis (mangrove poles) and lime concrete. The boritis support the slab and help to keep walls upright. This is very important as rooms are tall and walls relatively thin. The poles are needed to stop walls from bending or leaning. This is called RESTRAINT.

In order to understand how the slabs work and the problems that can arise, it is important to know how they were made in the first place. As walls reached full room height, construction would stop. Boritis were placed at close centre across wall heads and over the rooms below. In most cases boritis were seated on about 3/4 the width of the wall. The gaps between boritis were bridged by placing small sections of marine coral between them. On top of this, lime concrete was cast. When the new slab was firm enough construction would continue on top of the floor slabs until the next floor was needed, and so on. Constructing floors in this way means that walls are not continuous from foundation to roof. **At each floor level the majority of the new wall rests on the slab below.**
Boritis bend under the weight of the slab. As the slab bends it may crack down the centre of its underside, parallel to the wall. When this happens, the walls may be pushed slightly apart and, if pushed far enough, they will tear along the holes left by decayed boritis.

All the old houses in the Stone Town suffer to some extent from the defects mentioned above. Most of them have twisted out of shape, with bent walls, sagging floor slabs, and big holes eaten into outside render. They have deformed because weaker parts of the buildings have given way to the forces described, and other parts have been required to do more work than intended. In due course, it may be that they too will break or at least bend and crack until they have distributed the extra load.

**Equilibrium**

When buildings deform in this way and adjust to changed loadings, it is said that they have found equilibrium. Equilibrium, once established, will remain until another change in loading imposes new stress in other parts of the building and stability is lost. It is possible that the extra stress will cause these parts to break or deform also. When this happens, equilibrium has been lost and damage will continue until the load is again shared and equilibrium returns. Dependent on the quality of the building and the materials used, there may come a time when there are not enough strong parts left to do the work required. That is when part of the building will fall down.
PLANNING REPAIRS

The Real Cause

When considering repairs, it is important to first establish the cause of the problem. If the repair does not deal with the REAL cause or causes of the trouble, all the money spent will be wasted and your house may still fall down.

Structural and Cosmetic

Repairs can be divided into two types, STRUCTURAL and COSMETIC. In most cases both types of repair are needed, the structural repair takes place first and SOLVES THE PROBLEM. This is followed by the cosmetic repair that hides the structural repair and makes the walls look as though nothing has ever happened.

In the Stone Town, many builders carry out ONLY cosmetic repairs thinking that they are solving the problem. Most of these repairs consist of filling cracks with cement and then rendering over them. If a repair is needed because part of a building has started to crack, it is no good simply filling the crack for a cosmetic repair. The cracks are caused by a change in the work carried out by different parts of the building. If the repair is to last, it must be directed at the cause of the changes. It is sometimes not easy to find what the real cause of the problem. In order to do this, the building and its surroundings must be closely observed in search of clues.

Survey

Looking at the building and site for clues to the problems is called a SURVEY, and must precede ALL repair work. The effectiveness, cost, and quality of repair work will only be as good as the survey that preceded it. All damage and symptoms of damage, should be recorded on a scale drawing. While compiling the survey you will begin to understand the causes of damage and start to formulate approaches to repair. When complete, the survey will

FINDING THE CAUSE OF THE PROBLEM

LOOK FOR THE OBVIOUS

1. Has anyone in an adjoining house taken out window frames or removed timber lintels?
2. Has anyone in a flat underneath or next to yours removed a wall or cut a new opening or door through a wall?
3. Have any of the neighbours begun to replace boritis or perhaps an entire floor slab?
4. Have any ditches or pits been dug close to walls?
5. Have any big pieces of render fallen off recently and has it rained heavily, (have the walls been wetted more than usual).
6. Could the drains or mains water supply be leaking underground?
7. Does your house have a toilet pit? Even if your toilet is canalised, find and inspect the old pit if it has not been filled. Collapsing pits cause very serious damage in the walls above.

All of these things are very common causes of damage to old buildings.
2.15

Cracks forming long horizontal lines are caused by some distant part of the building sinking or perhaps starting to lean.

Horizontal cracks can form when walls tear along boriti holes.

When looking for clues indicating the cause of trouble, it is also a good idea to look for parts of the wall or floor that have become miss-shaped or bent. Swellings or bulges within walls indicate the wall is over stressed and being crushed, particularly if vertical cracks are to be seen nearby. If a floor slab bends and falls away from a crack, it may show there is a problem with the foundation and that the wall is sinking or that a part of the wall supporting the slab is moving down, perhaps caused by a bending lintel. In both of these cases, the damage will be accompanied by angled cracks in walls nearby.

Clues may also be found in the shape of doorways and window openings. They will have been built square and plumb so that if they start to change shape it is a sign that something is wrong. Only by plotting the location and extent of actual damage and the symptoms of ongoing damage on a drawing, is it possible to truly understand its causes.

Angled cracks will form above a new opening with a lintel that is weak and starting to bend.
Structural repairs involve a small number of techniques. Sometimes these are used on their own, but in many cases some or all may be used together.

Stitching strengthens buildings by connecting elevations and interior cross walls (remember they are built with butt joints). This repair option is used to repair vertical cracks developing as a result of lack of bond between elevations. The form of construction will determine the materials used and method of repair involved. If the walls are plain sheet masonry, as sometimes used in small townhouses and utilitarian rooms in larger houses, it is possible to make connections by inserting packs of roofing tiles alternately into each elevation. This technique is not suitable for arcades, as there is not sufficient mass in the columns to permit the required cutting away. Stitching involves fastening elevations together by introducing large corals or packs of tiles alternately into each elevation such that they interlock in the way resembling brickwork. Although using corals to form stitches is the best option in terms of similarity of material, they are seldom found in large enough sizes and need to be quarried especially for the purpose. Much work is also required to shape them into fairly regular blocks. An alternative to coral is Mangalore roofing tiles. Ceramic tiles are very similar to corals in expansion and contraction, and are available in town.
manner described until interlocking packs of tile are installed up the interior of the junction.

4. **Vertical tile stitches:** Tile stitches can also be used vertically across horizontal cracks. This process provides gentle support to walls fractured along voided boriti holes. Although a very effective technique, it must be stressed that vertical tile stitches must not be used if structural movement remains active. In many of the larger houses featuring interior arcades, there is insufficient bulk in the masonry of the end piers to permit the type of excavation required to install effective stitches safely. In these situations, the cracks must first be grouted as previously but the physical connection between elevations is made by alternately stitching with steel rod grouted into pre-drilled holes.
2.21

oughly flushed free of debris and
saturated by pouring in water. It
is important that flushing is
thorough as small fragments of
mortar can easily block access
to smaller parts of the void.
Grout is poured through a
simple piece of equipment made
from a large funnel and piece of
hosepipe.

3. Pouring
Pouring begins in the second lift
of holes and ideally continues in
the one site until grout comes
out from the hole beneath. In
reality, void systems can be
complicated such that grout may
begin to flow from a site many
metres from the point of entry.
It is essential that entry points
are kept open and do not be-
come obstructed, preventing the
ingress of further material.

4. Sealing
To keep the grouting hole open
it is necessary to pour only small
amounts of grout followed
immediately by an almost equal
amount of water. Pouring should
not be continuous, short pauses
are taken to allow air to escape
and allow grout to spread. If the
weight of liquid grout within the
wall becomes too great there is
a danger of damage. Grouting
should continue from each site
until refusal, at which time the
hole is sealed and work begun on
the next. Occasionally a slightly
higher pressure is required to
force grout into fine or remote
cracks. Sufficient pressure will
be generated by erecting a
scaffold and pouring the grout
from a height of four or five
metres.

Once the wall is grouted it
should be left to cure for two
weeks.
INSERTING NEEDLES

A 'needle' is the name given to any long thin section of material placed through a wall and at 90° to its face. By inserting sections of carefully cut coral through walls cracked vertically within their thickness, it is possible to tie the parts together across the cracks and void systems thereby strengthening it.

METHOD

1. Mark out a 1m square grid on the wall. Starting at one end of the bottom line in the grid, begin to cut a neat rectangular hole approx. 300mm square. The hole must pass right through the wall.

If the wall is very thick, needles can be placed slightly more than halfway through from either side. In this case, the excavations on each side must be off-set slightly to produce a bonding effect. It is best to begin cutting the socket by drilling a number of 20mm or 25mm holes as close together as possible over the site of the intended socket. Long sharp chisels are then used to finally excavate the hole. Before placing the needle, a bed of 1:3 lime mortar is laid along the bottom and the needle firmly bedded into it with a rocking action.

When in place, a very dry mix of 1:3 mortar is tightly packed around the needle along with small stones. Long thin pieces of wood or steel are used together with a hammer to beat home the mortar. It is very important that this work is properly done and that no empty spaces are left. When one site is complete the next needle to be placed should be as far from the first site as possible, and so on until the work is complete.

Needles should be approx. 250 mm square and cut from the toughest corals. An electric angle grinder or disc cutter will help in roughing them out.

Precautions

Before placing needles, walls should be relieved of as much weight as possible. This can be done erecting dead shores to support the floor slab above, and by firmly strutting any openings.
Deep tamping is a procedure designed to place mortar at depth within the outer masonry of walls. It is used to repair badly scarred walls severely eroded by salt activity and abrasion. Although a simple activity if correctly executed, the strength of walls and their resistance to water penetration will be much improved.

**METHOD**

The site is flushed free from debris using large amounts of clean water, this will also serve to saturate the masonry. A quantity of very dry 1:3 mortar is prepared and a number of small stones in different sizes are placed in a bucket of water to soak. Using a trowel, a small amount of mortar should be placed in the void between stones, and a long thin section of timber or steel used to compact it firmly against the substrate. Compaction must be firm and a hammer used in conjunction with the timber to drive it home. One or two further sections of mortar are laid in the same way and the small wet stones beaten into it.

The procedure is repeated until the cavity is filled.

The effectiveness of this repair depends on the degree of compaction and a good selection of stones.
plumb bob and line is also required.

3. The batten, plumb bob, and square will all be used to maintain the line of the building. This is necessary because each excavation is completed and backfilled before the next is begun, and some means are therefore required to ensure alignment of the sections. Measurements taken from the suspended plumb bob to the face of the workings below will ensure that when finally connected the various sections will be in alignment.

4. Excavation work should begin by carefully opening the first 1m section. It will be necessary to continue digging until reliable, undisturbed strata is found. If the excavation exceeds 1.5m in depth, simple timbering must be installed to prevent the possibility of the trench collapsing. Depending on ground conditions, it may also be necessary to install shuttering to the rear of the excavation. If this is required concrete slabs should be used as these can be abandoned as work proceeds. Should timber be used in this location it must be removed as work advances, if abandoned the work will become voided as it decays.

5. As soon as reliable strata is found, a very dry mix of 1:2 concrete is laid as a bed for successive courses of large flat corals. The stone used must be the rough, hard variety laid in a 1:3 sand/cement mortar. Small thin stones are introduced into the bed joint as required to fill cavities. It is important that courses are laid with care from the rear of the excavation, and the ground beyond carefully compacted to exclude the possibility of voids. Each end of the construction is left 'toothed' to enable bonding with the neighbouring section. The new foundation is brought up to a point 75mm inches below the original work. The remaining gap is packed with a very dry mix of 1:2 cement/sand mortar. This mortar must be beaten into place with suitable pieces of timber and hammers. No voids must be left and the whole must be packed solid. The site is now back filled and firmly compacted.
3. SHORING AND TEMPORARY SUPPORT

THE AGA KHAN TRUST FOR CULTURE
This section provides information on how to make safe buildings to parts that are dangerous. Details are also given of the support system needed before any attempt is made to cut new openings in existing walls.

| RAKING SHORES         | Parts of the Raking Shore  
|                       | Raking Shore for Tall Buildings  
|                       | Setting up the Shore  
|                       | Locating the Needle and the Cleat Assay  
| EMERGENCY RERAINT     | Parts of the Emergency Restraint  
| HORIZONTAL OR FLYING SHORES | Parts of the Horizontal Shore  
|                       | Positioning Horizontal Shores with Reference to Floor Levels  
|                       | Special Flying Shores  
| DEAD OR VERTICAL SHORES | Dead Shoring to Failed Floor Slabs  
|                       | Details of Floor Slab Support  
|                       | Dead Shores with Needles  

**Note:** The procedures described in this section are guidelines only. Before undertaking substantial structural repairs or tackling serious structural problems, consult a building professional.
Shoring is the name given to the provision of temporary support to buildings that are not safe or need to be supported while work is carried out. It is very important that some types of repair are not attempted without first supporting the building.

These repairs are:
1. Cutting new openings in walls for doors and windows
2. Replacing lintels above openings

If this work is undertaken without the use of suitable support there is a danger that the building may be seriously damaged or even collapse.

There are three main types of shore:
- **Raking Shore** for walls that have begun to lean or bulge
- **Flying Shore** for buildings that are part of a terrace
- **Dead Shore or Needles** for support of roof or floor slabs
Raking shores consist of inclined boritis called rakers. One end of the raker is placed against the wall whilst the other sits on the ground. They are used to support walls that have begun to lean or bulge. The most effective support is given if the raker meets the wall at an angle of 60 to 70 degrees. In tightly packed areas like the Stone Town, this angle will be determined by the space available, and the width of the footway.

When providing support to an unsafe building, it is often necessary to use both raking and dead shores together.
On tall buildings raking shores are installed in systems with one or more inclined rakers placed against the wall in the same vertical plane. Each raker slopes at a different angle so as to support the wall at each floor level. To support small townhouses only two rakers will be needed but to reach the top of the larger palaces a third raker will be needed. This need not go right down to the ground but can spring from the back of the top raker. Rakers used in this way are called riding shores. To support riding shores properly it is best to use two top rakers side by side.
To prevent the bottom ends of the rakers sinking into the ground they sit on a large wooden SOLE PLATE, this spreads the thrust of the wall over a wide area of soil.

If the top ends of rakers were simply to rest against the wall they would slide up it and be useless if it continued to lean. To prevent this, the tops of rakers are located against short NEEDLES, which are stout lengths of timber set into pockets cut in the wall to provide a firm grip. In addition to seating around needles, the heads of the rakers also rest against a timber WALL PLATE, spreading their thrust over a large area of wall.

1. **Detail of the Sole Plate**

Rakers are tied together with steel dogs

Bottoms of rakers are recessed to house folding wedges

The plate must be firmly bedded on solid ground

Rakers are tightened into position with folding wedges
2. Details at the Head of Each Raker

Rakers locate around the needle and press against the wall plate. To keep the needle rigid it is locked in place with a cleat.

Cleat 100mm x 100 mm

The needle must measure at least 100mm x 100mm and a minimum of 200mm must pass into the wall.

Shoulder to head of rakers must not be less than 90mm deep.
3. Detail of the Wall Plate

To fix the wall plate it should be secured to the face of the building by steel wall hooks. The hooks are easily made from re-bars and are driven into mortar joints.

The wall plate should be as wide as possible but at least 400mm.

If it is necessary to joint planks in order to obtain a plate of sufficient length, a bevelled halving joint should be used.

The length of joint must be at least seven times the width of the plank.
RAKING SHORE FOR TALLER HOUSES

Top rakers have to be doubled to support the riding shore. This detail shows how to join the two and support the needle.

The riding shore must spring from a sturdy bracket bolted across both top rakers.
SETTING UP THE SHORE

It is very important that raking shores are set against the wall in the correct place. They must only rest against solid masonry and never against the thin sections of in-fill between piers. It is also important that the raker heads and needles are placed where the wall is strong enough to resist their thrust. These should be inserted slightly below each floor level. If the heads and needles are placed against plain un-braced walls there is a risk that the wall may be caused to bulge inwards or crack. If the top raker in the system is placed too close to the top of the wall, there is a danger that there may not be sufficient weight above to prevent its thrust pushing off the wall head.

In order to provide maximum support with least danger of damage, needles and the heads of rakers must be set up so that an imaginary line extended along the bottom of the boritis meets both the vertical centre line within the wall and the centre lines of the rakers.
LOCATING THE NEEDLE AND CLEAT ASSAY

Folding wedges must not be driven home with sledge hammers in order to tighten rakers into position against the needle. Doing so would create dangerous vibrations that may damage the wall.

Rakers should be jacked into position with a crowbar or a car jack and the wedges then tightened.
Although the raking shore lends the best support to leaning walls, in an emergency support can be quickly provided by installing temporary wall ties. This involves tying back leaning walls to stable walls in another part of the building with large diameter nylon rope. In order to do this, it may be necessary to cut holes through other walls in order to provide anchor points. This type of support is very useful on the tall palaces.

In an emergency, restraint can be provided by tying back the wall with ropes and stout timbers as illustrated.
**Slowing down movement**

To provide maximum restraint, horizontal timbers should be attached to long vertical wall plates working on the outside of piers. Neither this technique nor the use of raking horses will pull walls back to vertical. They are only used to prevent or slow down further development.
PARTS OF THE EMERGENCY RESTRAINT

To connect the rope special steel clamps must be made as illustrated.
Tightening the nylon rope

Nylon rope will stretch, so arrangements must be made to tighten it. This can be done by making a special fitting, using a steel rod and washer as illustrated.

**Detail 1**

**Detail 2**

15mm threaded steel rod

Threaded section must be 500mm long to allow adjustment

10mm steel washer
Flying shores are simply flat boriti struts used to provide temporary support to two parallel walls where one or both show signs of failure. The most common use for this kind of support in the Stone Town is where one house in a terrace has collapsed and some support has been lost to the houses on either side.

For distances between walls of up to 9m or less, a single shore may be used. For distances up to 15m, a compound or double flying shore is needed.

A single flying shore consists of a horizontal length of boritis set between the walls in need of support. The ends rest on needles set into the wall and are stiffened by inclined struts above and below at either end. The struts also provide added support to the walls and must be set to coincide with floors. As with the raking shore, timbers must be placed with care in order to avoid damage.
Details of a Single Flying Shore

Joint A

Joint B

Joint C

Steel Dogs

Folding Wedges

Needle & Cleat
POSITION OF FLYING SHORES WITH REFERENCE TO FLOOR LEVELS

A. Runs of boriti joists are the same on both sides and floors are at same level.

B. Runs of boriti joists are the same on both sides but floors are at different levels.

C. Runs of boriti joists are different on each side and the floors are at different levels. The wall with joists parallel to it has less restraint, the shore is placed against the wall.
SPECIAL FLYING SHORES

**The Angle Shore**
To provide maximum support where floors are at different levels the angled shore should be used.

**The Double Flying Shore**
For distances of more than 15m. use a double flying shore. Spans of this width will require the use of timber rather than boriti.

**Note:** refer back to joints on previous page.
Stout boritis placed vertically are used to support floor and roof slabs weakened by rotting boritis. They also form part of the support system needed before new openings can be cut through existing walls. Additionally, dead shores should be used to relieve damaged walls of much of the weight of floor slabs set into them. When used to support floors whilst new openings are cut through the walls the props support needles.

Needles are very strong timbers or sections of steel placed right through the wall and at 90° to its face. The needle supports the weight of the work above and transmits it to the dead shore. When using dead shores to support a failing floor or roof slab it is very important that all of the slabs to the rooms beneath are supported in the same way. This will ensure that the weight of the slab in need of support is carried right through the building and down to the ground. Any cellars or rooms below ground level must also be strutted.

Shores are placed on sole plates of timber planking laid parallel to the walls and set about 1/3 of the width of the room in. The purpose of this is to spread the weight transmitted through each of the props over a wider area of slab and make it easier for the props in the rooms beneath to continue the load down to the ground.

Directly above the sole plates, heading boards must be nailed to the underside of the boritis of the slab above. The shores themselves are placed between the two sets of horizontal planks and firmly tightened into position by driving home sets of folding wedges placed between the tops of the shores and the heading boards. The props, when in position, can be further strengthened by nailing planks diagonally across them, reducing any tendency to bend.
DEAD SHORING TO FAILED FLOOR SLABS

Section through supported slab

- Shoring system to slab above
- Boriti joists
- Note that support is provided clear of rotten boriti ends

Floor Slab  Horizontal Bracing

Elevation of Support System

- Sole Plate
- Boriti Shore
- Heading Board
- Diagonal Bracing
DEATILS TO FLOOR SLAB SUPPORT SYSTEM

**Head of Each Shore**
- Heading board
- Locating lath nailed to heading board
- Slender folding wedges tighten boriti shore against sofit of slab over

**Foot of Each Shore**
- Boriti shore
- Foot of boriti shore is located in simple timber frame, screwed to sole plate
- Sole plate
In order to remove a section of a wall, to make a new entrance or window opening, it is essential that the weight of the wall above is supported until the new lintel is fitted.

**Providing Support**

1. To provide support in these situations it is first necessary to cut a series of holes about 1.5m apart, a short distance above the site of the intended opening. Baulks of timber or steel beams are then passed through the holes, their ends being carried on the dead shores.

2. The foot of the shore is placed on a timber sole plate. Pairs of hard wood wedges are placed between dead shores and the needles. Before the wedges are driven home securing the needle against the wall above, a bed of very dry cement mortar must be placed on top of the needle at the point where it passes through the wall. This will ensure a solid bearing for the needle through the wall. Once the wedges are finally driven home the whole must be left for five days to set.

3. Shores should be further strengthened and prevented from possible overturning by nailing planks diagonally across them. It is essential that both needles and dead shores have an ample margin of strength to avoid any settlement of the wall through bending of the needle.

Note: To avoid damage to the building it is essential that needles are strong enough to bear the weight above. Always use the thickest timbers or steel beams that are available. The maximum distance between needles is 1 metre.
INSTALLING DEAD SHORES AND NEEDLES

**Stage 1**
Carefully mark onto the wall the full width and height of the opening. The height should be measured to the top of the lintel.

**Stage 2**
A short distance above the line representing the top of the lintel, cut holes to receive the needles.

**Stage 3**
Insert the needles and shores as described in the text. Ensure that the shore firmly braces the needle against the top of the hole. Pack the gap between the needle and the wall with a very dry mix of sand and cement.
4. LIME AND LIME MORTARS
4.2

LIME & LIME MORTARS

INTRODUCTION

MORTARS
What are Mortars?

AGGREGATES
The Shape and Size of Particles
Cleanliness

BINDERS
What Materials Can Be Used as Binders
Which Binder is Best

LIME MORTAR
Lime
Slaking & Sieving
Mixing Lime Mortars
The Setting of Lime Mortars
In building, the word MORTAR is applied to any mixture of solid particles that bonds larger materials such as stone or bricks together, forming a solid mass. Mortars are very important, and are used for many purposes in construction and restoration work.

**Render and Plaster**
Mortar used to hold stones or bricks together, forming walls and arches, coat walls inside and out with a smooth surface, is called render or plaster.

**Stucco**
In the past, plaster was also used to decorate walls with intricate patterns and designs. When used in this way mortar is called stucco.

**Grout**
A special mortar is also sometimes needed in repair work, to help strengthen walls by filling cracks and open spaces that may have developed between the stones deep within the wall. This type of mortar is called grout.

In most cases mortars are made of two parts; solid particles or AGGREGATES and the material that holds them together, the BINDER. Sometimes extra pigments are added. Pigment provide colour; set additives make mortar more weather resistant and harden more quickly.
Aggregates do a number of important jobs. They act as fillers, giving the mortar much of its compressive strength and help the wall to breathe by allowing moisture to escape through it. The smallest particles in the aggregate will also decide the colour of the mortar. The correct choice of aggregate is very important when preparing mortar. The characteristics of aggregates used will affect the quality and performance a great deal.

The most important characteristics of aggregates are:

- SHAPE
- SIZE
- CLEANLINESS
PARTICLE SHAPES

It is best if particles are rough, jagged, and angular. This will help them interlock and fit together, held firmly by the binder. Aggregates like this are called SHARP.

Aggregates that are smooth and rounded are called SOFT and will make weaker mortars because the binder will not be able to grip them so tightly.

Sharp Aggregates

BEST

Soft Aggregates

NOT SO GOOD
SIZE OF PARTICLES

It is very important that the aggregate is made up of particles of different sizes. Smaller particles should fill the spaces between the larger ones. Try to imagine a pile of footballs; between the balls will be quite big spaces, we could fill those with tennis balls. Even with tennis balls filling the big spaces there will be smaller spaces between the footballs and the tennis balls, these could be filled with table tennis balls. Even with all the spaces filled in this way there will still be lots of very small spaces left between the balls. It is these small spaces that the binder will occupy when the aggregate is mixed.

If mortar is made with only big particles it will be very weak and porous. If made with only small particles it will be very difficult to mix with the binder and will crack and fracture easily. The strongest mortars will have a good range of particle sizes and an aggregate to binder ratio of approximately 1 part binder to 3 parts of aggregate, (1:3). This ratio is called the void ratio and is determined by both the size and shape of particles.
DISTRIBUTION OF PARTICLES

Follow these steps to determine the size and distribution of particles in aggregates:

1. Find a deep, flat sided, glass or clear plastic bottle. Certain types of water bottle will work well, but you will need to cut off the top.

2. Fill the bottle to about 1/3 with a sample of aggregate.

3. Top up the bottle with water, hold a cloth tightly over the top with the flat of your hand and shake very hard. Make sure all the aggregate has been taken up and swirled around in the water.

4. Place the container on a flat level surface and leave undisturbed for one day so that the particles can settle out of the water. As the particles settle to the bottom of the container, the larger and heavier pieces will settle first. On top of these will be the middle-sized particles and on top of those will be arranged the finest of the particles.

5. You should now look very carefully at the aggregate in the container. In your mind’s eye divide the contents into four equal parts. If the bottom 1/4 is more or less all big pieces, the top 1/4 more or less all fine pieces and the 1/2 in the middle mostly medium sized pieces, the aggregate will have a good range of sizes.

VOID RATIO OF PARTICLES

Follow these steps to estimate the void ratio of aggregates:

1. Find two clear flat-sided containers: water bottles with the top cut off will do.

2. Fill one to about two thirds with aggregate.

3. Fill the second to the same depth with water and mark the level.

4. Gently pour water from the second container into the first container containing the aggregate. Take care not to disturb the contents.

5. Continue to pour until the water level in the second container is level with the top of the aggregate.

6. Place the water container on a flat surface and observe the new level.

7. Ideally, approximately one third of the water should have been absorbed amongst the aggregate.

If a lot of water was needed to fill the spaces, the aggregate contains too many large particles and mortar mixed with it will be prone to cracking and be very porous. If only a little water is required, there may be too many fine particles and the mortar will be poorly bound and therefore physically weak.
PARTICLE CLEANLINESS

It is very important that aggregates, particularly those consisting of soils, are free from root and leaf fragments. It is also not good if the soil contains too much clay. To remove root fragments etc., the soil must be put through a course sieve.

To find out if there is too much clay in the soil, follow the steps below:

1. Find a flat-sided container like the one used previously. Place some soil in it and mix with water just as before.

2. When the soil settles to the bottom of the container, if the layer of clay on top is deeper than one tenth of the depth of sand, it is too dirty to use.

If the aggregate stains heavily or forms sticky balls in the fingers it should also not be used.

To obtain the best possible results from an aggregate you MUST:

1. Select a well-graded material, ranging in size from fine to coarse. (In order to achieve this, it may be necessary to mix aggregates from different locations. Although potentially expensive, such mixing is recommended for aggregates intended to form an exterior render in an exposed position. Renders exposed to the full heat of the sun will contract very rapidly in a rain shower. This will produce stresses in the surface that could lead to early failure.)

2. Avoid a high percentage of clay.

3. Wash the aggregate in clean water if there is any danger of contamination by seawater.
**WHAT MATERIALS CAN BE USED AS BINDERS?**

The binder is the part of the mortar that holds all the different sized particles of aggregate together. Without a binder the aggregate would simply be a pile of sand.

**Kimbada cha makuta**
In Zanzibar three types of binder are used. In the simple ‘kimbada cha makuta’ of the shamba, heavy clay soil is often used to bind together pieces of coral to make infill between the sticks of the frame. This kind of clay binder and mortar is not very good as it will easily wash out in the rains, although it is simple enough to mix up more and replace the loss. Simple clay bound soil mortars in Zanzibar are suitable only for crude buildings.

**Portland Cement**
Another kind of binder very widely used is Portland Cement. Cement is supplied as a grey, dry, and very fine powder. It is added to the aggregate dry and then mixed in with water to produce a wet mass, CEMENT MORTAR. These mortars are now used with coral stone, concrete block, bricks and as renders.

**Lime**
To build the higher quality coral stone Swahili house, and many years ago to build the Stone Town, a third kind of binder was used, lime. Lime is today supplied as a fine white powder called HYDRATED LIME or as a thick white paste called PUTTY. Hydrated lime is generally only used as a component of cement/sand/lime mortars and is not of sufficiently high quality to specify for use as a traditional lime mortar. Lime putty is the binder originally used in the construction of the Stone Town. Lime in this form has been used to make mortar for thousands of years in many parts of the world.
WHICH BINDER IS BEST?

Before looking at the very different mortars produced by cement and lime binders, it is important to understand how crucial mortars and renders are in the life of a stone building.

When used in a building, stones are encased in mortar. The mortar fills the spaces between the stones and is often applied to their faces as a plaster or render. Mortar makes the environment in which stones must live. If stones, and the buildings made from them, are to remain healthy, mortars and renders MUST be as similar as possible to the stones they live with.

Many old houses were built with poor foundations. This often leads to cracks forming in the walls as heavier parts of the house start to sink. Mortar made with a lime binder remains slightly flexible even when set and will let walls move without cracking too much. Furthermore, lime mortars repair fine cracks themselves as rainwater slowly deposits fresh calcium carbonate taken into solution from the surrounding mortar.
LIME PLASTER

Old buildings were built without damp proof courses which stop rising damp inside the walls and it is very important that mortars are porous so moisture can pass through them and evaporate. This helps to keep houses dry and makes a healthy atmosphere inside.

CEMENT MORTARS

Cement mortars are very useful to modern builders but potentially disastrous when used for traditional construction and restoration work. When cement sets it is strong, hard, waterproof and can be used in almost any circumstances. Cement is also very easy to use and of known quality and reliability. All of this makes them ideal for many MODERN building processes but not recommended for use in old buildings.

When preparing a mortar for use with historic masonry, it is important to think of the building not as a rigid structure, with all of its parts set fast as though cast in steel, but as a living animal that MUST move and breathe. Cement-based mortars do not have the ELASTICITY to allow the building to move without cracking.
The waterproof nature of the cement mortar inhibits evaporation of rising moisture and often helps to encourage a damp and humid atmosphere in the house. Damp walls that have been rendered in waterproof cement in an attempt to cure the problem will become wetter because moisture trapped behind the render will naturally rise to new and higher levels within the wall. This action can also damage and weaken walls as a result of salt, dissolved in rising moisture, crystallising in the mortar behind the render and breaking it up.
It is common practice in the Stone Town to replace lime renders with cement because it is thought to be stronger and less likely to suffer damage in the future. Areas of cement patching can often be seen surrounded by scars eaten deep into the wall. Cement mortars will also expand and contract up to twice as much as limestone or brick. This means that stones and bricks are constantly fighting against the mortar that surrounds them, which eventually leads to the formation of many small cracks that allow more rainwater into the wall.

Moisture and salts are concentrated at the edge of cement, causing the plaster to fail.
LIME MORTAR

Lime mortars are always to be preferred for use with stone or brick and especially in old houses built with lime mortar originally. If it is possible during the course of repair work, it is good to remove as much cement repair as possible and replace it with lime mortar. This will allow the stones to breath and move. Cement renders in particular should be removed and replaced with lime-based plaster. It is always better to use lime based mortars with coral stone, because lime is made from coral stone and remains chemically compatible. Lime and coral stone will bond together better. In order to understand this, we must look at the way lime is made and how it works as a binder.
THE LIME CYCLE

Building

Mixing Mortar

Stone Town

Lime Stone

Lime Burning

Carbon Dioxide

Calcium Carbonate

Calcium Oxide

Carbon Hydroxide

Lime Putty

Slaking

Water
1. The raw material of lime is limestone, which must first be burnt in a KILN or CLAMP. In Zanzibar it does not matter which kind of limestone is used, the procedure is the same.

2. As limestone is burnt, water and CARBON DIOXIDE are driven off, which changes the stone into QUICKLIME which still looks very much the same as limestone but is lighter in both colour and weight.
3. When cool, the quicklime is put in a tank and covered with water. As soon as it comes into contact with the water it will expand very quickly and get very hot, occasionally the water may boil. This process is called SLAKING and the mixture of slaked lime and water is called PUTTY.

4. To make mortar it is necessary to mix the putty, which will become the binder, with suitable aggregates.

5. Once the mortar is used in the wall or as a render, the water will start to evaporate and CARBON DIOXIDE, from the air, will be absorbed. This process is very slow and is called CARBONATION. As the lime in the mortar takes in carbon dioxide, it replaces that lost when the stone was burnt and slowly turns the putty back into a form limestone.

6. So lime mortars, when CARBONATED, are chemically the same as limestone and will act in a very similar way. Although the manufacture of lime and lime bound mortar is very simple, to get the best quality product and good working results great skill and detailed knowledge is needed.
The use of lime as a binder is very ancient and has been practiced worldwide. There are many different methods of making quicklime from limestone. In Zanzibar the most common way of making quicklime involves the use of a CLAMP (in Swahili, ‘tanu’). This is the oldest and most basic way of burning limestone.

**Burning Limestone**

Several layers of coconut logs are arranged on the ground in a large circle. On top of these are stacked coral stones, followed by more logs and more stones, the stones becoming smaller towards the top of the dome shaped heap. The logs are then set alight and will burn for many hours. Although some of the lime produced in this way will be of excellent quality, there will be much that is UNDER-BURNT and a little that may be OVER-BURNT. This is because a great deal of the heat produced by the burning logs is lost and many of the corals never actually get hot enough to be fully converted into quicklime. For this change to take place a minimum temperature of 880°C is needed. To ensure that stones are burnt right through a slightly higher temperature is best. The very best quality and most reactive quicklime is produced in the lower temperature range. The higher the temperature the more the lime is OVERBURNT and the quality decreases. Fortunately, the temperature at which coconut burns is just about that which is needed to produce good quality lime so there is not too much danger of over-burning.

**Difficulties using the Clamp**

The biggest problem with the clamp is that so much fuel is needed to produce a small amount of quicklime. Under-burnt lime, which has not quite reached the minimum temperature, will contain a core of unchanged limestone and only the outer skin will be of any value. Over-burnt lime is often wizened and shrunken in appearance and it is also very slow to SLAKE, taking weeks. If lime like this is used to make plaster before it has fully slaked, the process will continue on the wall, resulting in fragments peeling off as the particles slowly expand.
Improving Kilns and Better Lime
The clamp is such an ancient and crude method of production that it is not difficult to improve. The most important thing is to retain much more of the heat and so change more coral into quicklime and use the fuel more efficiently. A very simple way of doing this is to cover the outside of the clamp with a thick layer of wet mud containing palm leaves or reeds as reinforcement. Holes should be left in the mud at various points to provide ventilation. Although the clay covered clamp is more efficient, eventually the heat of combustion causes the clay to fall away and the advantage is lost.

The Shaft Kiln
The next step up from the clamp or the clay-covered clamp is the simple shaft kiln. The shaft kiln resembles a short fat tower. The outside is often made of concrete, although coralstone and lime mortar will do just as well. To stop the heat inside burning the walls, the kiln is lined with fired clay bricks set in earth mortar and, to retain as much heat as possible, an insulating layer of 15mm to 20mm coral aggregate is provided between the brick-lining and stone walls. Ventilation is provided by brick covered channels in the kiln floor and ports through the walls.

Suitable Fuel
Although timber burns at about the correct temperature to produce first quality lime, it is expensive and damaging to the environment. It is a good policy to reduce the amount of timber required by adding coconut husks and setting aside areas of land on which to plant new coconut. Coconut logs burn quickly and produce a long flame; this is very useful within the shaft kiln as it helps to produce a good even calcination. Because coconut burns quickly it can be used to encourage other, slower burning fuels such as dung.

Filling the Kiln
It is very important that the stones within the kiln are more or less the same size, about the size of a fist or a little larger. This ensures that the charge is filled with small gaps or voids, enabling air to enter the mass and flames to work up through it. If it is necessary to burn two or more sizes of stone at the same time they should not be mixed. Each size should be packed together, isolated by fuel layers. The base of the kiln is stacked with logs so as to form a tunnel, which is filled with brushwood. Above are arranged alternate layers of fuel and stone. To fire the kiln it is necessary to ignite the brushwood. If flames come out of the top of the kiln there is too much air getting in and the ventilation holes must be blocked with clay or brick. Should black smoke come out, more air is needed and ventilation holes should be enlarged. When the kiln is operating at its most efficient temperature, a very small amount of smoke should be visible. The air above the kiln should ‘shimmer’ slightly. A rough indication of the temperature inside the kiln can be gained by observing the colour of the combustion through a ventilation hole:

- 500°C: slightly visible red glow
- 700°C: dark red
- 800°C: mellow cherry red
- 1000°C: bright red
- 1200°C: bright orange

With practice it is possible to judge the working temperature and regulate the firing conditions.
SLAKING & SIEVING

In order to obtain the best results it is very important that the quicklime is slaked as soon as it is cool enough to move, no time must be lost in submerging it in water. The longer quicklime is exposed to the air, the more the quality of mortar made from it will decrease. This is because moisture contained in the air will very soon begin to slake the lime. The problem with this is that as well as water, air contains carbon dioxide. If left out the quicklime will both slake and carbonate at the same time. This is called AIR SLAKING and means that the quicklime is turned back into limestone dust before it has been used in a mortar. This will make it quite useless as a binder.

Slaking

Always put the lime into the water, never pour water over the lime.
During slaking there must be sufficient water to completely cover the lime. It is important to remember that as slaking proceeds the lumps will swell and get much bigger, so enough room must be left in the tank or pit to allow for this. If possible it is best to slake in a large concrete tank, but if this is not possible slaking can just as easily be carried out in a shallow soil pit. To make such a pit it is necessary to select an area of flat ground about 5m square. It is best if the ground is slightly higher than the land around; this will help stop possible contamination of the lime with salts possibly contained in the soil. A strong earth bank about 1m high is next built around the site. The soil must be well compacted and beaten down with a shovel.

Once the bank is completed the pit is lined with palm leaves and plastic bags to prevent the lime becoming contaminated with soil. When all of this work is done, the pit should be filled with water to depth of about 500mm and the quicklime shovelled in. Always put the lime into the water, never pour the water over the lime. As the lime starts to expand, be ready to add more water should it show above the surface. After two or three hours the heat and bubbling caused by slaking will stop but that does not mean slaking is over. The lime will continue to swell and slake for at least two days. It must therefore stay under water, in the pit, for at least four days, during which time it must be hoed and turned frequently.

Making Lime Putty

Make sure that the lime putty stays in the pit for a **minimum of 4 days**, or as long as possible.

It is best to slake lime in a large concrete-block tank.

Water must always cover limestone.

Hoe and turn putty frequently.

Always put the lime into the water, never pour the water over the lime.
After at least four days under water the QUICKLIME has become LIME PUTTY and is now ready for REFINING. This is a simple task involving picking out all the remaining unburned limestone and any other large impurities, followed by sieving. It is best if the sieve has a mesh size of between 1 mm and 2 mm. As with every other part of lime technology, refining is simple but if it is not done well the quality of the putty will suffer. After refining, the putty must again be stored under water until it is required. It is possible to store putty in a number of small pits dug into the ground. The pits must, of course, be lined as before and their tops covered with palm leaves to reduce evaporation and exclude unwanted material.

FOR WELL-SLAKED PUTTY FOLLOW THE STEPS BELOW:

1. Quicklime must be slaked as soon as it is cool enough to move and must never be left for long periods in the open air.

2. It must be slaked in clean pits or tanks free of soil or vegetable matter.

3. The quicklime must be completely covered by clean water during slaking and sufficient water must be kept on hand to top up the tank when necessary.

4. The quicklime must remain in the tank and fully covered by water for a period of at least 48 hours. This will ensure that all the lime is slaked.

5. Whilst in the slaking tank the mass must be stirred and agitated at regular intervals. This will make sure that water penetrates through the mass and the whole is completely slaked.

6. When slaking is complete the putty must be transferred to clean storage tanks where it must remain under water for as long as possible before use and for a minimum period of six weeks.

7. During in the transfer from slaking to storage tanks, the putty must be refined and unburned fragments of stone and larger pieces of fuel debris removed. The putty must then be forced through a sieve with a mesh size of 1mm to 2mm.
MIXING LIME MORTARS

It is not possible to mix lime mortar in the same way as cement mortars, which are simply turned over and over, with occasional chopping. To make a strong lime mortar it is essential to coat each particle of aggregate with lime paste, this means that the pile of mortar, after initially mixing in the aggregates with a shovel, must be beaten with pick axe handles in addition to chopping and turning. The longer mixing and beating can be prolonged the better and more efficient the mortar will be.

It is also important that only the smallest amount of extra water is added during mixing. The temptation to pour on lots of water in order to make mixing easier must be resisted. Additional water will severely weaken the mix and cause a great deal of shrinkage and cracking on drying.

In addition to all of the above it is also very important that the correct ratio of aggregate to binder is maintained. Once mixed, the mortar should be stored for as long as possible before use. This enables the lime to thoroughly coat every particle of aggregate, ensuring an efficient and well-bound mortar. Lime mortars that have not matured for long enough will not bond well with the aggregate. Lime particles become smaller as they mature and develop closer contact with the aggregate. If lime mortars are used soon after mixing, the lime does not have time to develop a close contact with aggregates that may already be coated with a film of water.
FOR THE BEST QUALITY MORTAR FOLLOW THESE STEPS:

**Note:** Throughout the whole mixing process, no extra water should be added. However, if some of the aggregate is composed of a very dry and porous stone dust it may be necessary to add a small amount. If this is required a hand held spray should be used in order to avoid swamping the mix.

1. Metering is easy to achieve by regarding a suitable bucket as one whole unit of measure. A one to three mix would consist of one bucket of lime to three of aggregate.

2. Using the same bucket, measure out the correct amount of aggregate which should be as dry as possible.

3. Using a shovel, divide the lime into a number of small parts spread evenly over the mixing area. Using the same bucket measure out the correct amount of aggregate, adding small quantities to each of the piles of lime.
4. Using a shovel, fold and shop the aggregate into each of the piles of lime.

5. Each pile must next be firmly beaten with timber paddles and occasionally chopped with a shovel. The longer this process can be maintained the better the quality of mortar will be.

6. When each of the small piles is thoroughly mixed they should be shovelled together to form a single large pile which should again be chopped and beaten.

7. Once mixed, the mortar should be stored for as long as possible before use and for a minimum period of three months. It should be stored in a clean pit or in a number of plastic or galvanised steel bins. Whilst in storage air must be excluded from the bins or pit. This can be done by covering them with damp sacking and palm leaves.
Carbonation
Lime mortars set very slowly, as the water required for mixing and preparation evaporates and carbon dioxide from the atmosphere is absorbed. Carbon dioxide works with the lime producing a growth of tiny interlocking limestone crystals, which bond with the aggregates binding them together. Although this reaction may take place quite quickly on the surface, it can take years to spread through the mortar in a thick wall. This slow process of setting as a result of contact with carbon dioxide contained in the atmosphere alone is called carbonation.

Carbonation is helped if the mortar is encouraged to dry very slowly, making it much easier for carbon dioxide to enter if it is slightly moist. This can be done by gently spraying the surface with a garden spray. A rendered wall must also be protected from direct sunlight by hanging sheets of wet sacking in front of it. If renders are allowed to dry very quickly they will crack and will not bond properly with the masonry.

Setting with Additives
Adding other materials to lime mortar that react chemically, can speed up the setting process. Set additives are essential if the mortar is to be used in a situation that is constantly wet, as carbonation will not take place if the mortar remains saturated. Lime mortar alone will not set under water, so if the mortar must have an effective set additive mixed with it. The materials that will work in this way are called pozzolanas and contain silicates or aluminates or both. A very common building material that makes an excellent pozzolana is brick. To be used in this way, the bricks must first be broken into small pieces and then reduced to dust by sieving through a fine flour screen. The brick dust is added to the mix of lime and aggregate just before use. To one part of lime and three parts of aggregate should be added 1/4 of a part of brick dust. Although it is not best practice, if no other pozzolana is available, a small amount of cement can be added to the mix. This should not exceed 1/2 of a part.
5. REPAIRS TO HISTORIC RENDER
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**Note:** The procedures described in this section are guidelines only. Before undertaking substantial structural repairs or tackling serious structural problems, consult a building professional.
An undamaged and well maintained lime render is essential if walls are to remain strong and the atmosphere inside houses is not to grow dank and humid. Repairing broken or missing rendering should not be seen as a luxury but as a vital step in the repair process that can be guaranteed to deliver important benefits and offer real value for money.

Renders, both interior and exterior, are very easily damaged by:

- salt action
- abrasion
- water penetration
- neglect
- rusting nails
- iron
- steel fittings

If the roof of a house is compared to an umbrella, the render is an overcoat keeping out the rain. Lime renders are not waterproof like cement, but porous. They work by absorbing rain and holding it in the surface. This prevents the rain from soaking right through and wetting the masonry beneath. When the rain stops and the sun begins to shine again, the rainwater soon evaporates and the render dries.
Cement Render
Cement renders work in a different way. They ARE waterproof and do not allow any water to enter. This sounds like a good idea but if the render is cracked or damaged and rain gets in it cannot escape. The wall will remain wet, even if the sun shines all day, water will be trapped inside, evaporating only very slowly. Eventually this causes damage in the form of deep scarring and pitting of the surface. The damage is caused by salt taken up in rainwater as it moves over and through contaminated masonry. As it slowly evaporates out of the small cracks and holes through which it entered, salt crystals are left behind. These grow and begin to push against the stone or mortar around them. Eventually this action will break the mortar and pitting will develop.

Lime Render
Salts will damage lime render in the same way as a cement render but in this case it is in the face of the RENDER not the wall. So lime renders protect walls by becoming damaged themselves. To safeguard the wall, all that need be done is remove the damaged render from the lower section of wall and replace it with a fresh one and so on.

Because cement render is waterproof, escaping water cannot pass through it and all the damage takes place in the wall BEHIND the render.

The porous nature of lime render allows water to evaporate freely through it.
THE CAUSES OF FAILURE

It is not sensible to begin a large programme of rendering without first finding out why the render failed in the first place.

If the cause of the damage is simple abrasion, the result of years of scratching and rubbing by carts and cars, etc., rerendering is straightforward. However, it is likely that the wall will be contaminated with salts of one type or another, in which case rerendering without other supporting treatments would be a terrible waste of money as the new work would quickly fail. To re-render externally without first renewing or repairing gutters and downpipes etc., would also be a mistake. Just as render protects the wall, gutters and down pipes protect the render.

In the same way as structural repairs, re-rendering and repairs to rendering require careful planning and thought. The first task is to test the surface of the remaining render as it may be that a lot can be stabilised and kept, reducing the amount of new work needed, this has advantages from a conservation point of view also as more valuable original material will remain.

Testing Existing Plaster and Render

Testing is a very simple matter. The surface is lightly tapped with a small section of iron rod. If the sound produced is hollow the bonding between coats is poor. If there are only isolated areas that sound like this, the render is in good condition and can be kept. If, on the other hand it sounds hollow all over, it would be best to replace it.

If the wall surface is very badly eaten away, it will need more than just re-rendering; some attempt must be made to DESALINATE it as it will be contaminated with salt.
When looking for the cause of plaster failure on the ground floor, the first thing to look for is RISING DAMP. This simply means are the bottoms of walls and ground floors wet or damp? If they are it is necessary to find out WHY. If your house is in the Stone Town, unless it is very close to the sea, it is unlikely that rising ground-water will be the cause of the problem. Ground-water is water that is naturally contained in the earth and in the Stone Town will result from rain fall. If you live close to the sea, wall there is a chance that sea water that has permeated through holes in it whilst the tide was high is soaking through the soil and up into your house.

The depth at which ground-water is found below the surface is determined by the type of soil and strata. If the soil is not very porous, like clay, ground-water can be close to the surface and cause walls to be damp. The Stone Town is built on sand which is very porous so ground-water should not be a problem. However, walls can seem to suffer from serious rising moisture problems caused not by ground-water but by LOCALISED PONDING of rain water. This is caused by water draining through broken street covers and collecting against walls, saturating the wall below the street. Before re-rendering, this type of problem must be cured by carefully filling holes in the street covers and, if possible, making gentle gradients AWAY from the building and into the street.

Desalination is the name given to the removal of salts from stone, bricks, and renders, etc.
DESALINATION

A great deal of the salt contaminating buildings in the Stone Town comes from the use of beach-sand and other aggregates with high salt contents. It is also possible that sea water was used in construction and for slaking lime. Masonry walls are therefore often contaminated to their full height and thickness, a situation making complete desalination impossible.

However, if salt content is reduced or eliminated in the outer 150mm of the wall surface before new render is applied, it is likely that the new render will survive. This is because if the salt is removed from deeper than from where the rain penetrates, the salts within the wall will not turn into a solution and migrate, damaging the surface.

The only sure way to remove salt is to remove as much as possible of the material that contains it.

1. The first step is to cut away all the damaged render right back to the large corals forming the walls. If the mortar between the corals is not firm and solid, this should also be removed.

2. The surface of the wall is next saturated with clean drinking water and apply a ROUGH RENDER whilst the wall is still wet. A rough render consists of a coarsely broken porous aggregate mixed with a lime binder. The traditional mix of 1:3 is normally used. It is not necessary to use expensive good quality lime, ordinary HYDRATED LIME from the building merchants will do. The aggregate can be any broken up coral with a good range of particle sizes. The mix is quite wet and should be THROWN against the wall to ensure contact.
3. It is the job of the rough render to draw salts out of the masonry. The water applied to the wall will soak into it and on its way, dissolve much of the salt in its path. Eventually, it will begin to return to the surface for evaporation. As it does so, it will carry its charge of salts along with it. The rough render will act as an extension to the wall and the water and salt will move on through it to the surface. There, the salts will be concentrated.

4. When quite dry, the salt infested render is removed and cleared away from the site. It is important that the rough render does not get wet after it has dried and before it is removed. If rainfall is allowed to saturate it, there is a danger that salts contained in it will be washed back into the wall.

5. When the process is completed the salt content within the masonry should be much reduced. If rising moisture is not present the treatment should be a permanent cure, assuming the rerendering is well done and when complete is maintained! However, if the house is close to the sea wall or still suffers from rising damp due to ponding, the new render may be damaged again quite quickly.
If after desalination the wall is still obviously contaminated, it will be necessary to isolate the salts from the new work. This simply means that a WATER-PROOF BARRIER has to be set up between the wall and the new render.

The work should begin by vigorously brushing the wall with wire brushes to remove more of the contaminated surface material without digging too deep into the mortar between corals. The wall is then brushed with soft brushes to remove dust. The edges of adjoining intact render should be pointed and secured. In order to make the isolating barrier between wall and render, the entire affected area is painted with a layer of bituminous paint. Once dry, re-rendering may proceed.

For the new render to adhere to the paint, a number of short hardwood skewers approx. 100 mm long should be prepared and hammered through the bitumen and into convenient mortar joints beneath at about 300 mm centred vertically and horizontally. Rough coconut string is tied around and between each of the skewers to make a strong net effect. The net will hold the render firmly against the wall.
REPAIRS TO HISTORIC RENDERING

WALL PREPARATION

The wall is first thoroughly wetted with clean water; this helps the new render to stick. If the wall is not wetted, the dry stones and mortar quickly suck much of the moisture out of the render and it will not bond with the wall. In all plaster work, it is important to remember that the various coats are not glued together. All that causes them to stick is friction and, for this to work, the new render must contact every part of the face of the wall or render. If the wall is not wetted and the render dries very quickly, it does not have time to take hold of the rough surface and the bond will be weak.

DUBBING OUT

This is the name given to filling the deeper holes and scars. Dubbing out brings the wall surface to a rough average flatness. Following wetting, a 1:3 mix of lime and red laterite soil is thrown off the end of a trowel into the hole. It should be about 40mm thick.

Small stones are then pressed into it. The stones are first immersed in water to saturate them. Using stones in this way will reduce shrinkage and the water contained in them will help control drying and reduce cracking. If the work is in direct sunlight, it must be protected by hanging sections of wet Asian cloth in front of it. Direct sunlight will cause it to dry too quickly and crack.

If the holes are very deep, dubbing out should take place in two or three coats. Each must be allowed to dry, and all cracking and shrinkage must have ceased before the next is applied.

MIX RATIOS

<table>
<thead>
<tr>
<th></th>
<th>SOIL</th>
<th>SAND</th>
<th>DUST 1*</th>
<th>DUST 2**</th>
<th>LIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filling deep holes</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>&amp; dubbing out</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Render coat</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Setting coat</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

* Dust 1 is crusher dust
** Dust 2 is finely crushed soft white coralstone.
This is the name given to the first coat (closest to the wall). It is very important that the way it is applied reflects the character of the room.

**REMEMBER, WE ARE NOT BUILDING NEW HOUSES, WE ARE CONSERVING OLD ONES. THIS MEANS THE WORK CARRIED OUT MUST NOT BE BETTER OR WORSE THAN THE ORIGINAL. IT HAS TO BE THE SAME.** So the rendering must be carried out with the old work in mind.

Remember that although the render coat is not the top coat, it **DICTATES** the look of the finished work. The top coat is only 3 to 5mm thick so it simply follows the line of the render beneath. If the render coat is not correct the top coat will also be incorrect. This is especially true of mouldings and arches.

1. **The wall and dubbing out are saturated.** A line is stretched along the top of one of the walls a little below the boritis. It is stretched between hardwood pins driven into mortar joints. The line is about 40mm above the wall surface and represents the thickness of the plaster.

2. **Pieces of line are then cut to about the same length as the height of the room.** A bent nail or small stone is tied to one end of each line. The lines are now suspended at about 1.5m from the horizontal line already set up. The lines act as plumb lines and control the verticality of the work.

3. **Small dabs of plaster with a stone pressed into each are formed beneath the vertical lines at about 1.5m or 2m centres.** When the dabs are set, the lines are removed, the wall saturated and plaster applied between dabs. A straight edge is used to control the level between dabs.

4. **It is very important that the surface of the render is well keyed before it sets.** To do this the surface has to be scored. Steel trowels must not be used for this purpose as the scoring is too thin, it is better to use a stick about 5mm or 10mm wide.
When the render coat is fully dried and all shrinkage and cracking has ceased, the wall can be dampened and setting coat applied. It is essential that the mortar is applied quickly, whilst still plastic.

It is best to apply setting coat with a flat wooden or plastic float. Plaster is placed on the float and very quickly smeared with an upwards action onto the wall. A small rounded steel trowel is used to 'iron' it firmly down onto the render coat. During this process the plaster is wetted as necessary so an average flat but undulating surface results.

**Note:** Examination of patination and texture on much of Zanzibar’s historic render indicates that setting coat was originally applied with small rounded steel trowels. In order to maintain this texture similar tools or should be used.

Keying must be taken seriously and carried out with thought, it is particularly important that areas around doors and windows are well keyed as these are subject to vibration. REMEMBER IT IS ONLY FRICTION THAT HOLDS THE RENDERS IN PLACE.

Stick for scouring to produce key
This type of repair is used for small areas of damage within larger areas of intact render. As the surrounding render is not damaged, salt is not likely to be the cause of localised damage of this kind. Patches are often required to improve the quality of surface, following the removal of cement mortar that may have been used to fill in following the introduction of an electric wire or to make good places damaged by rusting iron fittings, etc.

REMOVAL OF RUSTING IRON, ETC.
The size and extent of the metalwork will dictate the precise details of removal but regardless of size, the principles will remain the same.

As far as possible, the fitting should be drilled out using a non-percussion drill so as to avoid vibration damage to the delicate bond between coats of render and masonry substrate. Holes are drilled at close centres around the outside of the metal, it is then gently tapped with a light hammer and gradually worked free. Should the feature be set deeply, it may be necessary to continue excavating the holes begun with the drill by hand. For this purpose a special chisel called a QUIRK is useful. The special 'fish tail' shape of the tool will permit very deep excavations with no damage to surrounding work. Once the metalwork is removed, the cavity in the wall is filled with mortar and small stones to the wall surface. When all shrinkage has ceased, the patch repair may proceed.
Before placing a patch of new render the site must be prepared. It is important that the joint between new work and old is crisp and regular, the joint should not be jagged and crude. A very sharp scalpel or craft knife is used to clean up ripped and broken edges around the site. The patch follows the line of the break but, avoid sharp and jagged angles. The edge is slightly undercut so as to help make a good key between old and new work.

**Flush the site**
The site is flushed free of all debris and dust. Flushing continues until the site is saturated and will accept no more water. Particular attention must be paid to wetting the various joints between layers of render and the masonry. It is important to pay attention to these joints, as capillary attraction along them is very strong and will rapidly suck water from the new render, leading to fine cracks parallel to the joint and a very poor bond.

**Applying new render**
During application, it is important that the work is compacted and that slightly more plaster is applied, ensuring that the patch does not become lower than surrounding work. When applying small patches within areas of vigorously textured original work, it is important that the repair should replicate the rhythm of the existing. If required, craftsmen should practice the required surface before final application.
**Note:** To ensure good bonding between new work and old, the repair site must be painted with a slurry of lime paste and boiled seaweed water. This mixture works as a binder and will secure the new work. If seaweed is not available, a dilute mixture of PVA and water can be used.

**To prepare the slurry:**

1. Take a small amount PVA woodworking adhesive and dissolve it at the ratio of 1:20 in clean warm water.
2. Take a small amount of setting coat and add 1/10 of a part of the PVA water, mixing the lime into a thin paste.
3. Take the slurry and using a small firm brush, vigorously work it well into the wetted substrate, ensuring as far as possible that some has been drawn up along the joint lines.
4. The new base coat should be applied immediately onto the slurry, ensuring that it is very firmly ironed down and compacted with some pressure against both substrate and all joint surfaces.
5. When fully dry and all cracking and shrinkage has ceased, the setting coat may be applied. Before applying the setting coat the entire site must once again be saturated and treated with slurry as described below.

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**Diagram:**

1. The site must be flushed free of all debris.
2. Apply PVA/lime slurry to help bond between new and old.
3. New base coat firmly ironed down and compacted.
4. Top coat applied slightly proud of surrounding plaster.
REPAIRS TO MIHRABS

A slight variation on the patching procedure is required to repair the pointed cusps to mihrabs. These features are damaged very easily and are frequently broken off. Because they are pointed, it is not possible to mend them in the same way as holes in flat plaster.

To make the repair, and assist the plaster to stick, it is necessary to make an ARMATURE. This is simply a frame to hold plaster in place.

1. The first step is to remove all the damaged plaster and dust. A wheel brace and 5mm tungsten tipped bit are used to drill a number of holes in the widest parts of the repair site. The holes are flushed free of dust and the site saturated.

2. Small hardwood pegs are cut and set into the holes with sieved lime mortar (1:3) with the addition of a little PVA water or boiled seaweed water. Rough local coconut string is bound around and between the pegs forming a framework. The length of peg and general form of the frame is dictated by the nature of the individual repair and judgement will be required to make sure the frame is buried below the plaster. At no point should the frame come closer than 15mm to the surface.

3. The framework and site are again wetted and the lime slurry worked well into the surface. This is followed immediately by render coat which is firmly ironed down against the surface and around the peg and string framework. Once set the render coat is rubbed down with sand paper so that it more accurately follows the shape of the cusp. When all shrinkage has stopped the render coat is again wetted and setting coat applied in the normal way.
The method described above can also be used to repair mouldings. If the damage is severe and the mouldings are heavy, wooden pegs can be replaced with sections of ceramic tile.

**To strike a vertical line across a moulding**

1. Place a flat board against the moulding.

2. Ensure the flat face of the board is at $90^\circ$ to the wall by holding a square between both.

3. Ensure the board intersects the moulding at $90^\circ$ by placing a spirit level against it.

4. To strike the line, tie a pencil to a piece of dowel and holding it tight against the board, strike the line.

**To record the section**

1. Cut carefully along the line with a sharp hack-saw blade.

2. Insert card into the slot and draw the section.
To construct sections of mouldings

1. Place full-size plywood sections at regular intervals along the length of the repair.

2. Reform the stones backing the moulding. Those that remain well embedded in the wall should be left. Loose stones must be removed and replaced with tile. Missing stones should also be replaced with tile inserts.

3. Accurate placing of the base coat is essential, the setting coat simply follows its line.
5.19 REPAIRS TO HISTORIC RENDER

GROUTING AND PINNING

Areas of original render that have lost adhesion and are in danger of falling from the wall, may be reattached by injecting a liquid grout into the space between render and wall. If the area of detachment is large, pinning may also be needed to secure the plaster. Grouting is an expensive and labour-intensive procedure and should be reserved for the conservation of valuable and interesting examples of plaster. In the Stone Town grouting is of value in the conservation of column heads, mihrabs, mouldings and stucco ornament.

WORKS SHOULD PROCEED AS FOLLOWS

1. The first requirement is to locate the full extent of the areas of detachment, some of which will be obvious while others will not. To find them, simply tap the surface with the blunt end of a pencil. Detached areas will sound hollow. As these are located, a soft pencil is used to mark their outline on the wall.

2. A number of 2mm holes are drilled at the lowest point along the bottom of each area of detachment so as to form a continuous slot about 10 to 15mm long. A single 3mm hole is drilled at the highest point in each detachment.

3. Using a large veterinary hypodermic syringe (with a blunt needle) inject clean water into the top hole in the detachment. As it enters, the water will flush out debris and plaster fragments from within the void and dampen the interior.

When fully wetted, a mixture of PVA wood-working adhesive and water must be rinsed through the detachment, causing the inside to become very slightly sticky and helps in re-attaching the render. The flush should be prepared in the following manner. A small amount of PVA adhesive must be dissolved in clean warm water in the ratio of 1:20.
4. As soon as flushing is complete, the lower slit in the detachment is plugged with cotton wool and grout introduced through the top hole. To counteract the weight of grout causing the detachment to bulge, a piece of wood may be leant against the wall.

**Grout should consist of the following:**

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lime</td>
<td>2 parts</td>
</tr>
<tr>
<td>Very fine brick dust</td>
<td>8 parts</td>
</tr>
<tr>
<td>PVA water</td>
<td>as required</td>
</tr>
</tbody>
</table>

Grout should consist of the following:

It is very important that grout is well mixed. Mixing should continue for at least 20 minutes prior to pouring. Thorough mixing can only be achieved with the use of an electric drill fitted with a bent wire mixing device. When grouting is complete the cotton wool plugs should be removed and replaced with a little setting coat.

**PINNING**

If the areas of detachment are large, it may be necessary to pin through the plaster layers and into the masonry beneath, in addition to grouting. Pins will help support the weight of the plaster and make the hole more stable.

Before pinning, it is best to allow one week after grouting. 3mm holes are drilled with a non-percussion drill in the middle of the larger areas of detachment. The pins themselves do not require great strength and it is more important that they are compatible with stone and plaster. In Zanzibar, a very suitable material from which to make pins is well dried bone. Before inserting the pin into the hole, it is filled with a mixture of setting coat and a little PVA water. The pin is then pressed home and the hole sealed with more setting coat.
6. FLOOR SLABS & OPENINGS
INTRODUCTION

This section provides guidelines for replacing traditional boriti-pole and lime-concrete floor slabs, replacing individual boriti-poles in a floor-slab, and for forming new openings in walls. It also provides guidelines for the construction of brick relieving arches.

REPLACING FLOOR SLABS

- Floor Slabs
  - Procedure for Replacing Floor Slabs
- Exceptional Circumstances

REPLACING BORITI AND BANAA

- Boriti and Banaa
  - Replacement Procedure

NEW OPENINGS AND LINTELS

- New Openings
  - Procedure for Installing a New Reinforced Concrete Lintel
- Replacing Boriti Lintels
- Relieving Arches

**Note:** The procedures described in this section are guidelines only. Before undertaking substantial structural repairs or tackling serious structural problems, consult a building professional.
In the buildings of the Stone Town, floor slabs were traditionally made of boriti-poles with a lime-concrete cover laid over to form the floor above. Roof and floor slabs should be replaced if they begin to sag to the extent that cracks develop along the underside, parallel to the walls. If this situation develops the slab will be entirely dependent on the boriti for support. Even if all of the boriti are renewed this type of loading will rapidly cause them to bend.

Where most of the boritis in a floor slab have decayed and are due to be replaced, the lime-concrete floor should be carefully inspected for signs of failure (e.g., cracks parallel to the wall as described above). If the floor shows signs of failure, the slab should be replaced along with the boriti.
It is not safe to remove a complete slab at one time. If an entire slab is removed, the walls in that area will lose significant restraint and may begin to bend or bulge under the weight.

Slabs must be removed in short sections of about 2.5m. Each new section should have a male or female dovetailed key cast into it so that it locks into the next section when it is cast. It is best if sections are not removed and replaced one after another all along the floor, instead replace them on a rotational basis. This will allow freshly cast sections to cure slightly before the one next to it is removed. This approach will avoid areas of weakness developing.

It is a good idea to replace all of the boriti along with the slab, since removing the slab makes it possible to fit much longer poles. If this is too expensive, at least one long pole should be inserted into each section of repair. This will improve restraint.
**Removal of existing floor slab**

1. Work should begin by dividing the floor into a number of sections about 2.5m wide. Divisions should be drawn on the floor with chalk.

2. Next, decide in which order they will be cut out and replaced. Cutting out must start against an end wall with the opening of a channel about 300mm wide to separate the slab from the wall. This work must NOT be done with a mechanical demolition hammer as the high frequency vibration made will travel a long way through the wall and may cause damage, even if it is not seen at once. It is best to use a 2lb hammer and sharp punch, although an electric drill fitted with a small diameter bit may be used to help. The section of slab should then be un-picked on a piecemeal basis. Large sledge hammers MUST NOT be used to break up the slab!!!

3. If the slab is very thick or the room is very long, it may pay to use specially made wedges as illustrated. They can easily be made by a local smith and consist of three parts. To use them, it is first necessary to drill a series of holes about 300mm apart along the front edge of the section to be removed. The three parts of the wedges are assembled in the holes with the middle part sticking up.

4. A 2lb hammer is then used to gently drive the wedge home. Each wedge must be tightened in turn, a little at a time until the sections fracture off. At least five sets of wedges should be used together. When cutting away the small pieces of light coral used to bridge the spaces between boritis, remember to save the coral for reuse in the new construction.
Construction of new floor slab

Reconstruction should begin by replacing the boriti with new longer poles. If banaa were originally used, they should again be used in the new construction. If this is too expensive and you can only afford plain boriti, try at least to fit one or two banaa to the original pattern as an indication of the original appearance. If you cannot afford to replace all the boriti, try at least to fit one good long pole every 1.5m.

Once the boriti are fitted, coral salvaged during demolition must be replaced to close the gaps between poles. 25mm thick boards must be arranged as shuttering to contain the lime concrete when it is cast. If the walls are in good condition and the slab is not thicker than 400mm, the replacement slab should be the same thickness. However, if the slab is very thick, or the wall is showing signs of over stressing, the slab must be reduced to 300mm.

A suitable mix for the concrete is:

- \( \frac{1}{4} \) part cement
- 2 parts lime
- 2 parts sand
- 3 parts broken brick, fines up to 18mm (\( \frac{3}{4} \)" gauge)

Lime and aggregates are mixed as long as possible before needed and the cement added immediately prior to use. The mix should be dry and vigorously compacted on laying.

When casting is complete and at least four weeks allowed for curing, a thin cement screed should be run over the surface to produce a flat, smooth finish. To do this, it is necessary to set up levels.
Water level

A simple way of making a water level is to use two water bottles and a length of hose pipe as illustrated.

1. To use the level, make two simple tripods from sticks or small boritis tied with string and suspend one of the bottles from each. Position one tripod and bottle (bottle 1) over the highest point in the newly cast slab. This site is the DATUM and must not be moved.

2. The second tripod, with bottle 2, can be moved freely about the slab. Bottle 2 should be positioned at the furthest point from the datum. In order to transfer the datum to this point, bottle 2 should be laid on the slab and water poured into bottle 1 (at the datum). When a clear stream of water, free from air bubbles, comes out of bottle 2, it is slowly lifted until the water level in both bottles is steady and the same.

3. The bottle should then be tied in place and accurate measurements taken from the top of the water in the bottle at the datum to a point, about 15mm above the slab and a dab of concrete laid to that height.

4. The same measurement must be repeated from the top of the water in the second bottle and another dab of concrete placed. This process should be repeated at regular intervals over the face of the slab. It is then possible to float a fine, flat layer of concrete over the slab.
EXCEPTIONAL CIRCUMSTANCES

In some situations, walls may be so weakened and damaged that an especially light slab should be used.

To make such a slab, boritis are laid in the normal manner but the coral used to bridge the gaps between the boritis are replaced with two layers of rough hessian (sack cloth). The cloth is purchased in long wide rolls and spread over the top surface of the boritis. It is secured by nailing along the back of each boriti at 300mm centres. Small sections of aluminium are cut from drink cans and used as washers to prevent the cloth pulling through the nails. The cloth must be stretched as tightly as possible. Soaking in water before it is fixed can assist this.

A 100mm thick layer of concrete, mixed as previously specified, is laid over the cloth. Empty aluminium drinks cans, orientated vertically, are pressed into its surface at centres of approximately 150mm. This allows the concrete to be firmly packed between.

Cast another 100mm layer of concrete over the cans. The finished slab will provide good insulation and be 40% lighter than a conventional slab of similar thickness.
**BORITI AND BANAA**

**Boriti** are the round mangrove poles on the underside of floor slabs. In larger houses or in important rooms, the mangrove is often square and these are called **banaa**.

Both boriti an banaa have the same functions; they stop the slab above from bending, tie walls together, and during construction, they work as a shuttering for casting the slab.

Tying walls together requires poles to be as long as possible because **friction** is required to keep them in place. The deeper poles are embedded in the wall, the greater the friction. Embedding much of the pole in the wall also helps to distribute the weight of the slab more evenly throughout the wall. During construction boriti should be placed to more than half the thickness of the wall.

Unfortunately embedded boriti rot, and it is occasionally necessary to replace them.
**Shorter poles = loss of structural strength**

The task of replacement is a difficult one as it is necessary to fit the pole between its two neighbours. To obtain the maximum length, the pole is offered up diagonally between the ones either side. It is then straightened into a position parallel with its neighbours and a small amount at each end located in the wall. Replacing poles in this way inevitably causes the new poles to be significantly shorter than the originals. As more poles are replaced so the quality of available restraint diminishes.

It is very important that as more boriti are replaced restraint is not lost. Although it is not possible to fit poles any longer than the diagonal between the ones on each side, it is possible to artificially increase the quality of restraint afforded by short poles. This is done by fitting specially manufactured brackets to the ends of replacement boriti.
REPLACEMENT PROCEDURE

1. Following removal of the old boriti, work carefully on the empty socket with a sharp chisel and wooden mallet to form a slight cone shape extending the full depth of the space left by the original poles. The wider base of the cone is to the back of the excavation. The mouth of the socket, where the new pole will rest, is also made a little deeper and a flat base cut, to allow a pad stone to be fitted below the pole, spreading its weight and avoiding point loadings.

2. Before fitting replacement poles, drill one small hole in the side about 100mm from each end to fix the bracket as illustrated.

3. Lay a suitable coral pad stone on a bed of 1:3 lime mortar. Apply a bed of the same mortar to the top of the pad stones and lift the pole into position. Working around the pole and in the socket, slide the bracket into position and hammer the end into the hole in the boriti.

4. The hole is now carefully packed with a very dry mortar and small stones. This must be done with great care, making sure the socket and bracket are tightly packed. The mortar is compacted with a hammer and long thin piece of wood or steel. To complete the repair, re-render the area.
New Openings & Lintels

New Openings

Openings not formed under arches need long stones or timbers placed over them to support the wall above. These are called lintels. It is common in traditional construction to use boriti poles as lintels, and boriti lintels are sometimes put inside the wall and hidden, or left exposed. In modern construction or alterations, it is common to use reinforced concrete lintels to form new openings. Whilst this may have some advantages, the workmanship is often poor which can have potentially serious consequences. This section provides guidelines for the construction of reinforced concrete lintels and other more appropriate forms of support over openings.

Important note:
Although the method of cutting new openings is described in the text, it is potentially dangerous. In general, it is NOT recommended to form new openings in historic buildings. When replacing lintels or cutting new openings, it is essential that the masonry above the work site is well supported before the work begins. If this is not done, very serious damage can result. (See section 3 of the Guidelines, Shoring & Temporary Support.)
Cutting a new opening

1. Begin the work by carefully installing a needle and dead shore system to support the building during construction work, as described in Section 3 of the Guidelines (Shoring and Temporary Support).

2. If a new opening is to be cut, it is important to make as little vibration as possible and it is ALWAYS good to work as neatly and cleanly as possible. It is best to begin by drilling a few holes in the centre of the area to be removed with a big electric drill (not a percussion drill).

3. Stones can then be quickly unpicked with a good sharp punch and hammer. As far as possible, cut away the mortar between stones as this will cause less vibration. The sides should be unpicked as cleanly as possible to form neat reveals. An electric angle grinder can help in this. It is important that the top of the opening is cut to form slots wider than the intended opening so as to provide support for the lintel.
PADSTONES

If a pre-cast concrete lintel is to be used it is first necessary to cast concrete padstones on top of the slots to either side. This ties the top of the wall together and makes a good firm base for the lintel to sit on.

A suitable mix for padstones is:
1 cement to 4 coral aggregate up to 7mm (¼ inch).

After a period of 28 days the padstones will have cured and a bed of mortar consisting of 1 part cement, 2 parts lime, and 8 parts of aggregate is laid on top of each padstone and the lintel firmly bedded into it.

Following a period of two to three days, to allow the mortar to become firm, a very dry mix of 1 part cement, and 3 parts of aggregate is beaten into the gap between the top of the lintel and the wall above. It is very important that the work is carried out well and that the mortar is firmly packed into the space. To do this, hammers and short pieces of wood are used to drive the mortar home, two people must work together, one each side of the wall.

If the concrete lintel is to be cast in place (in situ), there is no need to cast padstones on the wall as these can be a part of the lintel but slots must still be cut to support it.
**PRE-CAST CONCRETE LINTELS**

Lintels must never be less than 75mm in thickness. As a rough guide for larger openings the lintel should not be less than one twelfth (1/12) of the span.

Although concrete is very tough it is surprisingly weak in tension. When used as a lintel, concrete will easily bend and may snap. To prevent this 18mm (¾ inch) steel bars must be cast into the bottom. The bars bend up at the end to provide more support and are about 25mm up from the bottom bed. To make sure the lintel is fixed the correct way up (with the bars to the bottom) the word TOP is clearly scratched into the wet concrete.

To make the lintel, it is first necessary to make a mould into which to pour the concrete. This must be robust and made from 18mm (¾ inch) planking. It is a good idea to make it so that it bolts together. This will make it much easier to remove the lintel once it is set. Before pouring the concrete into the mould, the inside is lubricated with soap to help in removing it.

**A suitable concrete mix for lintels is:**

1 part Portland cement
2 parts sand
4 parts broken brick or coral aggregate up to 18mm (¾ inch) gauge.

**Note:** These specifications are guidelines only. ALWAYS consult a structural engineer.

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**Casting lintels in-situ**

Although this is often done in the Stone Town it is not recommended to cast lintels in-situ. Lintels must be very strong and to make concrete strong it must be well compacted and cured. Curing takes 28 days, if the supports are removed before this time the lintel will not be at full strength and will easily bend under the weight of the wall.

**Badly cast lintels have caused buildings in the Stone Town to collapse.** It is MUCH safer to use a PRE CAST lintel, which can be fully cured before it is fixed and the opening used almost as soon as the work is done.

**Mould made from 35mm planking**

Steel bars must be cast 25mm from the bottom bed

- Use bolts to make removing the lintel easier
- Lubricate mould with soap to help when removing lintel
REPLACING BORITI LINTELS

Boriti lintels are weak and prone to rot and bend. As this occurs, the masonry in the wall above subsides and cracks. This type of action can give rise to knock-on effects in neighbouring parts of the building. It is important that rotted boriti lintels are replaced as soon as possible.

In the smaller houses of the Stone Town, boriti lintels over doors and windows are often left exposed. These features are very important and must be preserved. They must NOT be replaced in concrete because they add a great deal of character to rooms and are part of the historic structural system. Like must replace like and new boriti MUST be used.
To protect the replacement boriti from bending due to over-stressing, it is possible to construct very simple arches over them. This is called a relieving arch and it will carry much of the weight of the wall above the opening. Relieving arches can also be inserted to protect door and window cases where lintels were not employed in the first place.

Work should begin with the introduction of needles and dead shores to support the building during construction, as described in Section 3 of the Guidelines (Shoring and Temporary Support). However, in many cases labour and expense can be reduced by utilising the boriti in the soffit of the slab above as support for the masonry. This will only work if boritis enter the wall at 90° degrees to the opening and they are in good condition. If they are parallel to the wall or badly rotted they will not provide support of any kind and needles should be used. When using boriti for support in this way it is STILL necessary to install dead shores beneath them. The boriti support the wall above but the boriti must be supported by shoring.

In the majority of cases it will be necessary to remove and replace not only rotted lintels but also the masonry above, as it will be shattered and much weakened.
PLACING BORITI AND BUILDING THE ARCH

With the wall supported, and defective masonry and rotted boriti removed, reconstruction and installation of the arch can begin.

1. New boriti should be selected and fitted in the same location as the originals. They should match as closely as possible in terms of size and general shape. New boritis should be firmly bedded on a 1:3 lime mortar and the spaces between bridged with small pieces of coral and mortar in the traditional way. Allow two or three days for the mortar to harden and construct a simple centring immediately on top of the boriti.

2. The centring is the formwork around which the arch is constructed. It is required because the arch will not stand until it is in compression and at least one ring or layer of stones or bricks is completed.

3. The cheapest and simplest way to form the centre is to use pieces of very light white coral to form a segmental shape. This should resemble the top of a very large circle. For an opening 2m wide the hump should be about 400mm tall in the middle. The centring is constructed along the full length of the lintels. It is important that the stones or bricks in the arch are not seated on the boritis. The arch, when complete must rest at either end on masonry. If it sits on the timber it will fail if the timber rots.
4. Once the centre is in place the arch is built around it. Although it is possible to build the arch in coral it is easier and will involve less labour to use fired brick. The bricks or coral, should be arranged around the centre by adding a course to each side alternately. They are laid in a bed of 1:3 lime mortar and the last bricks to go in should be in the middle and the joint vertical.

If bricks are used they should be arranged as headers set on their sides, as this will minimise joint thickness. A minimum of four rings is required to protect a two-metre opening.

When complete, the arch must be left for as long as is practical before continuing construction above it. The centring remains in place and forms an in-fill between the timber lintel and arch. When the arch is complete it will carry all of the weight of the wall above the opening.
7. LIMEWASH
INTRODUCTION

Limewash is the material traditionally applied to walls as a decorative and protective coating. Originally all the buildings in the Stone Town were limewashed regularly as part of their maintenance programme. This section provides guidelines for preparation and application of limewash.

PREPARATION

Mixing
Pigments
Preventing mould growth

APPLICATION

Preparation of wall surfaces
Painting

Note: The procedures described in this section are guidelines only. Before undertaking substantial structural repairs or tackling serious structural problems, consult a building professional.
At its simplest, limewash is very finely sieved lime putty in an excess of water. The basic wash, however, is not durable and will dust off easily. To prevent this, it is possible to add a variety of materials or binders. Unfortunately, most of them are proteins and very quickly encourage mould growth in the wash, especially on exterior walls. In colder climates, it is possible to add animal and milk fats to the mix, both of which work very well and also help in waterproofing. In tropical climates like Zanzibar, it is not easy to recommend an additive that will prevent dusting and not encourage mould growth.

**Binders**

A very effective binder for use indoors is water in which seaweed has been boiled. The liquid is allowed to cool and form a sticky gelatinous mass. Before use, it is thinned with boiling water and put through a fine sieve. Approximately half a litre of liquid is added to 20 litres of wash.

For use outside, common salt is perhaps the best choice although this must not be used if the render is of significant historic value. Approximately half a kilo of salt is added to four gallons of wash.

**Eucheuma Denticulatum**

commonly grows along the coast of Zanzibar
**Lime must mature**

Like other aspects of lime technology, limewash will be at its most effective if it is carefully prepared. The lime should be well matured putty made from good quality quicklime.

Before use, the putty is sieved through a very fine muslin. The finer the particulate size the better the protection it will give. This is because the binding power within limewash is weak and large particles are simply too heavy to be held in place. Very often coarse unsieved putty is used. This makes a rough surface which will quickly attract dust and brush off easily.
Limewash can carry a small amount of pigmentation, but the more that is added the weaker and more prone to dusting the wash will become. Vivid colours cannot be achieved with a limewash and only delicate shades are possible. The best pigments are called earth pigments and they are metal oxides, prepared from natural earths by firing. Copper sulphate can also be added to make a delicate blue.

Many artificial pigments are damaged by lime and the combination of lime, sunlight, and oxygen can cause them to lose their colour. These pigments are not lime fast.

Yellow ochre, golden ochre, burnt ochre, raw sienna, raw umber, and burnt umber are all lime fast earth pigments.

To put the colour into the wash it is first necessary to mix the pigment into a thin paste with a little water. The paste is then stirred into the wash.

It is very difficult to prevent the development of unsightly black algal slimes. The best solution is to scrub or sand-paper off the slime and re-apply limewash. Commercially manufactured mould inhibitors are available (e.g., Robbialac/Berger Fungicide Wash, available in Dar es Salaam), and these should be liberally applied after the old mould has been removed and just before the application of the new coat of limewash. Mould inhibitors will not last for more than about a year and must be re-applied.

The cheapest and most convenient method is to rinse walls with Carbolic acid. The effect of this will not last more than one year and re-application should be made after the monsoon rains.
It is important that wall surfaces are well prepared before application.

1. Remove loose flaky material with a stiff brush and dampen the wall.

2. Dampering is best achieved by puncturing a hole through the top of a mineral water bottle. This can then be used to thoroughly wet the wall and direct water accurately into cracks and crevices. Before application the surface is saturated but not ‘running wet’.

3. **Painting**
   - For exterior work, wash is applied with a soft wide brush. Work quickly and apply very thin coats. Each should be no thicker than milk.

   If plain wash is being applied the first coat should be invisible until it is dry. As subsequent coats are applied the previous layers may also become transparent. This tendency will lessen as more coats are added. Each coat is allowed to dry before the next is applied.

   Do not apply limewash to exterior walls whilst it is raining.

   - For interior work application should be carried out with a soft wide brush, but a much better quality finish will result if the wash is sprayed on. A ten litre hand pumped spray is adequate for this work. Several very thin coats are applied in the same way as described above.
This section provides guidelines on recommended procedures of repair and maintenance of both structural and non-structural timber elements.

**CAUSES OF DECAY**
- Diagnosis

**IMPORTANT PRINCIPLES OF TIMBER REPAIR**
- Key Points
- Glue

**REPAIRS TO JOINERY**
- Plug Repair
- Repair to Mortice and Tenon
- Repair Around a Hinge
- Replacement of Broken Louver Without Opening the Frame
- Repair of Rat Damage

**REPAIRS TO STRUCTURAL MEMBERS**
- Scarf Joints
- Halved Scarf
- Repair of Carpentry Joints
- Beam End Repair - Steel Flitch System
- Base of Timber Post

**Note:** The procedures described in this section are guidelines only. Before undertaking substantial structural repairs or tackling serious structural problems, consult a building professional.
Timber elements of buildings in the Stone Town

All buildings in the Stone Town include elements made from timber. These might be doors, windows, balconies, teahouses, verge boards, roofs, canopies, etc. The timber elements perform important jobs: doors and windows provide security and privacy, roofs keep out the rain, and balconies increase ventilation. In order to continue functioning correctly, it is important that they are maintained and repaired properly.

But, apart from the practical tasks they perform, the timber parts of buildings are an important aspect of the historical character of the Stone Town. Many of the timber elements such as doors and balconies are very old, and are often elaborately carved. These pieces are valuable because they were made by skilled craftsmen and demonstrate the richness of Zanzibar's history. When they are allowed to disintegrate through neglect, or are destroyed or removed by bad repair work, the Stone Town is diminished.
Most problems with timber in the Stone Town can be traced back to the presence of water. Timber elements were originally made from hardwood such as teak, mninga or mvule. As the name implies, hardwoods are far denser and heavier than softwoods such as cypress, and are therefore much more durable and resistant to the harsh environment of the tropics.

But even hardwoods become vulnerable to decay caused by insect attack or mould growth when saturated for long periods. Occasional saturation will not normally cause problems, so long as the timber dries in between, but when moisture remains in the timber for long periods, it breaks down the natural resistance of the hardwoods, quickly leading to decay.

Well-detailed and maintained timber should not become saturated. Water ingress is often caused by the failure of other building parts immediately adjacent to the timber or even some distance from it. For instance, a cracked plaster window sill can allow water to collect around the bottom of a window frame causing it to rot; or, a damaged roof can allow water to collect around the buried ends of timber beams leading to decay.

When considering a repair, it is important that the cause of the damage is diagnosed and dealt with, as well as the actual damage to the timber part. If the causes are ignored, the repaired piece will quickly become like the original damaged section. In most cases, it should be enough to repair the original detail (e.g., re-plaster the sill or repair the roof), but in some cases, the original detail may have been at fault (e.g., the sill may have sloped inwards instead of outwards allowing water to collect under the sill). In these cases, the fault must be corrected or the timber given extra protection to help it cope with the effects.
Common problem areas found in timber elements

Water in the ceiling
Check the roof for leaks and repair the roof.

Decay caused by water
First check joint between roof and wall. If this is open, it may be a sign of serious structural subsidence.

Signs of rot in beam set into wall
First check for serious structural subsidence, using a spirit level and plumb bob. Check extent of damage by tapping with a metal object or drill small holes with a hand-held drill. Decaying timber sounds hollow and will be soft.
If deck or balcony are damaged, consider how to prevent water from collecting here. Repair with boards and plugs.

Decorative Verge Board
Check for rot and possible cause from roof damage.

Open joints
Check for structural subsidence. First check if the balcony is leaning with a spirit level and plumb bob. If there is a problem, support the balcony with temporary support, (see Section 3 of Design Guidelines).
Important: Check all structural timber for signs of decay, e.g., beams, posts, joints, etc. Where possible, repair timber, or if decayed, replace with identical piece.

Broken planks
Use a plug to repair.

Water collecting around timber
First consider how to prevent water damage and decay caused when timber is set into the wall.

Open joints
Check that the structure is not subsiding or falling apart.

Decaying window frame
Check plaster. Cracks may allow water into the frame.

Open joint
Check for signs of movement in the wall above. Subsidence can create structural load on the window frame.

Cracks around hinges
Use hook and eye to fix shutters back in the wind.

Damaged plaster
Allows water into window frame.

Decayed sill top
Check joint between metal rails and sill. Rust and decay may mean water is collecting in the joint.

Decayed sill bottom
Check plaster adjacent to sill for damage.

Holes in frame
Rats gnaw through the timber frame.

Posts set in the ground
Check for decay. Ensure the base is clear of debris and check timber in the base, frequently very vulnerable, and replace bottom part if required.

Broken louver
Shear wear and tear cause damage.
PRINCIPLES OF TIMBER REPAIR

In historic buildings, it is always better to retain as much of the original historic timber as possible. Where the original is covered in fine carvings, the reason for this is obvious. But even if the timber piece is quite plain, it will have a character that comes from age, which is impossible to reproduce. It is this character that makes the Stone Town unique.

Always try to repair a timber element in a building rather than replace it.

Often decay or structural damage affects only a part of a timber element. For instance, timber beams may only be rotten where the timber is buried in the wall; the rest of the beam may be perfectly sound. In such cases, it is sometimes enough to cut away and repair the section of timber that has failed or is rotten, whilst retaining most of the original piece.

When carrying out repairs to timber elements, always consider these key points:

1. Assess the condition: Fitness for the job

As timber ages, it often becomes rough in texture as the grain is exposed, and wear and tear leaves marks and scars across its surface. But this texture of age is not in itself a reason to replace old timber. In fact, the texture or ‘patina’ of age is what gives old timber its character.

When considering repairs to timber, it is important to try and keep as much of the original timber as possible. The judgement about whether to retain or replace a timber section should not be made on the basis of appearance alone, but rather on the fitness of the timber piece or element to do the job it was designed for. In other words, a rough grained louver on a window does not need to be replaced if it is strong enough to hinge properly, will continue to stand-up to daily use and keeps the elements out, whereas a badly decayed beam that can no longer support any weight, must be replaced in its entirety.
2. **Like with Like**

As a living tree, wood is composed of millions of small cells filled with moisture. When a tree is made into timber, it is dried and most of the moisture in the cells evaporates. The timber shrinks, but the cellular structure remains, and because of this, timber will continue to respond to its environment, expanding or shrinking according to the dampness of the air.

It is important to bear this in mind when carrying out repairs to old timber. For the repair to be effective, the damaged part must be cut out and a new piece of timber fixed in its place with glue or a joint. The new section is fixed tightly against the old, but both the new timber and the old will continue to move according to the environment. If the new timber is very different from the old in density or age, it will move at a different rate. The joint between the two is put under pressure and may eventually fail.

*When carrying out repairs, always use timber identical or similar to the original!*

**Moisture content:** Typically, new hardwoods will have a moisture content of between 15% and 18%, whereas old hardwood may have a moisture content as low as 7%. For this reason, whenever possible, patching repairs to old joinery items should be made using old timber of approximately the same age, taken from another old timber piece that has been discarded. Where, for instance, an entire member of a frame is to be replaced, new hardwood can be used, but the joint between old and new must allow for movement.

**Similar timbers:** It is best to determine the species of the timber to be repaired and to use the same species for the replacement piece. Never use softwoods such as cypress to repair hardwoods. The repair will always fail.

**Appearance:** If the timber element is to be finished with a clear finish such as teak or linseed oil, an effort should be made to match the appearance of the new timber piece (e.g. colour, grain pattern, etc.) with the original.
3. Grain
When carrying out repairs by plugging, or repairs that in any other way involve letting-in and mating pieces of new timber to original joinery items, it is essential that the direction of the grain of the repair is the same as the direction of the grain of the surrounding original timber. When making new members for joinery items, the grain direction of the new member must be the same as the original member.

4. Strength
The strength or rigidity of a joint must not be altered in any way as a result of a repair. Where joints have originally been left open to allow for movement, or fixed without glue or mechanical fastening, these must not be ‘strengthened’ during the course of the repair by the addition of glue, mechanical fixings such as screws, or by any other method. Generally, care should be taken to make joints that are not too rigid or strong, as movement is inevitable, and if a joint is inflexible, the stresses will be transferred to the timber, which, if old and brittle, may crack.

5. Repair in-situ
It is generally better to carry out repairs to timber in situ, or in other words, whilst the timber element remains in its original position. This is because removal usually results in more unnecessary damage both to the timber and to the buildings around, and if an element is disassembled for repair, reassembly once the repair is complete is very difficult and usually shows.

When carrying out structural repairs, the same principle applies, although great care must be taken to ensure that the structure is properly supported and prevented from collapse before repairs begin (see Guidelines, Section 3, Shoring and Temporary Support).
GLUES

During the course of the restoration project on the Old Dispensary, several different glues or adhesives were tested. Whilst the results of this research is presented below, it should be noted that the manufacturer's instructions on use should be followed at all times.

The choice of adhesives will be determined by the expected structural performance of the glue joint, the location of the piece to be glued (e.g., whether or not it is exposed to rain and moisture), and cost.

Urea-formaldehyde glues are both strong and highly resistant to moisture, but they are also expensive, and so it is recommended that they be only used where a joint is load bearing or is likely to be in contact with moisture, and lower specification glue used elsewhere.

- It should be noted that Urea-formaldehyde glues are usually two-pack, which means that the two ingredients must be mixed up on site in order to make the adhesive. Once mixed, two-pack adhesives must be used immediately, and cannot be stored in its mixed state.

Note:
We do not recommend the use of organic wood glues (e.g., casein glue which is milky-white in colour), as these tend to quickly deteriorate when exposed to moisture. A wood glue called 'Woodfix' is commonly used in Zanzibar; however, our tests showed that this glue failed when saturated. In particular, NEVER use casein glues such as Woodfix for structural repairs.

### 1. ADHESIVES FOR JOINERY WORK

<table>
<thead>
<tr>
<th>External (Joinery exposed to moisture)</th>
<th>Aerolite 306, manufactured by The Kenya Swiss Chemical Company, E.Africa (Nairobi).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal</td>
<td>Ponal-3, manufactured by Heinkel, E.Africa (Nairobi).</td>
</tr>
</tbody>
</table>

### 2. ADHESIVES FOR STRUCTURAL TIMBER

<table>
<thead>
<tr>
<th>External &amp; Internal</th>
<th>All adhesives used for load-bearing structural timber work, to be Urea-formaldehyde type, to BS 1204 PART 1; Aerolite 306, manufactured by The Kenya Swiss Chemical Company, E.Africa (Nairobi) Resorcincol, available in Nairobi Aerodux 185 by Ciba-Geigy (Novartis)</th>
</tr>
</thead>
</table>
Note: the grain of the timber of the plug must run in the same direction as the surrounding timber, and the moisture content and species must be the same as the piece being repaired.

1. Cut rebate with a chisel. The plug should be proud of the surrounding timber.

2. Glue and plain to finish.
REPAIR OF MORTICE & TENON

1. Patch incorporating tenon

2. Face patch

3. Slip tenon

4. Half scarf incorporating slip tenon
REPAIR AROUND A HINGE

Damage around hinge

Dovetailed plug repair

Note: ensure grain direction is the same

REPLACEMENT OF BROKEN LOUVERS WITHOUT OPENING THE FRAME

1. Cut off old pivot to remove louver

2. Drill hole in shutter end for pivot dowel

3. Deepen pivot hole

4. Push the loose pivot in the deep hole until it is flush then position louver

5. Use saw cuts in dowel to assist positioning of dowel

New shutter

Saw cuts

Dowel

Detail 2

Detail 3
REPAIR OF RAT DAMAGE

Problem:
rat damage at base of doors

Detail 4

1. Cut inside damage to depth of 10mm
2. Original timber underneath
3. Original timber may be tenon
4. Principle: maximise surface area for gluing
8.15

TIMBER CONSERVATION

STRUCTURAL REPAIRS

SCARF JOINTS

Detail 1

Spayed scarf eg., for members subject to bending stresses such as beams

Halved scarf eg., in wall plate
HALVED SCARF

Use in compression members such as posts.

REPAIRS OF CARPENTRY JOINTS

Repair of carpentry joints

- patch incorporating tenon
- face patch
- slip tenon
- halved scarf incorporating slip tenon
BEAM END REPAIR
WITH STEEL
FLITCH SYSTEM

Detail 4

Bearing plate of flitch rests in wall

Timber inserts concealing flitch

Steel Flitch detail

Decayed end of beam cut away

Top plate

Bottom plate

Bearing plate

Steel Flitch

Timber inserts conceal bottom and edge of flitch on soffit of beam

New timber 'cheeks' bolted through flitch

Bolts recessed and concealed by pellets
**BASE OF TIMBER POST**

**Detail 5**

- **Wood post**
- **Steel anchor**
- **Concrete footing** for small loads
- **Steel anchor. Galvanise to protect from corrosion.**

- **Wood post repaired with halved scarf joint**
- **Steel anchor**
- **Minimum 150 mm from base of timber post to ground level**
- **Concrete pier**
- **Concrete pierfooting width and depth depends on pier load and bearing capacity of soil.**

Concrete pierfooting width and depth depends on pier load and bearing capacity of soil.
CASE STUDY:
HOUSE NO. 1287, KIPONDA
This section describes the major works undertaken as part of the conservation of a badly decayed house in the Kiponda district of Zanzibar Stone Town (House 1287, or the so-called ‘Indian Ladies House’). The works were carried out as part of a training exercise for the Conservation Building Brigade and others involved in construction in the Stone Town, between January and April 1999. On top of the structural and masonry repairs described in this chapter, other works were undertaken at the house; much of the joinery was restored or replaced, a new toilet was installed and the building was completely re-wired. Detailed information about construction costs is available upon request.
House No. 1287 is a very simple two-story building. Accommodation on the ground floor consists of three interconnected rectangular rooms. Principal access is via a simple small door set in the west elevation. This provides direct access to a narrow entrance room, which at its far end contains a crude dog-leg staircase leading to the first floor. The entrance room provides access in the west to a small kitchen and wash room. This is the only room in the house with a water supply. A manhole in the east gives access to a toilet-pit beneath. A door in the north of the entrance room gives access to a bed/sitting room, a corner of which is crudely partitioned to form a changing and washing area. To the north of this room is a pair of handsome double doors providing access to a small rear lane. Currently the doors are sealed closed. The floor plan established on the ground floor is repeated in the first floor. The head of the dog-leg staircase gives access to a narrow landing. To the south is a toilet room and store. Sewage disposal is via a vertical cast iron pipe feeding directly into the toilet pit under the room below. North of the landing is a bedroom. Access to the flat roof is via a simple open stair rising from the west of the landing.
HISTORY

The building dates from the end of the 19th Century, C1886/90 and is part of a small terrace, originally constructed as shops or workshops with living accommodation attached. The shop sold food stuffs and is known to have dealt in cooking oil. The area of Kiponda in which the building is located, is one of the older districts of the Stone Town and became noted for a range of small-scale commercial activities. House1287 is a fine example of a utilitarian form of architecture motivated by low profit margin trade.

The current occupants and their relatives have lived in the house for 80 years, during which time they have witnessed minor but significant changes. The house retains many original features including much of the original fenestration, and a dry earth closet, which is still in regular use. The most significant interventions the building has witnessed comprise the removal of a small interior wall that once divided the commercial premises from living space, the introduction of electricity and plumbing and the complete re-rendering of the interior in cement mortar. The floor to the toilet/store room on the first floor was also removed and replaced in cast concrete. It is likely that the ad hoc pitched roof and parapet walls were also added at this time.

MATERIALS

Roof and First Floor Slabs
Originally a slab of lime concrete approx. 600mm thick acted as a roof for the building, supported on undressed mangrove poles set at 400mm centres (boriti). The mangrove acts both as shuttering to allow construction of the slab, and as reinforcement to the soffit of the completed slab, resisting the development of tensile forces. The spaces between boriti are bridged by small sections of coral. In an attempt to increase the water resistance and general durability of the slab, this construction was modified by the addition of cement based render. Finally, a simple pitched roof of corrugated iron and crude mangrove joinery was constructed some distance above the slab, an alteration seen throughout the Stone Town.
Walls
In common with the vast majority of buildings in the Stone Town all the walls are constructed from rounded nodules of coral rag laid in the form of random rubble, bound by a mortar composed of yellow laterite soil, and locally burnt lime. The proportion of lime to aggregate is typically 1:3. If bound by good quality mortar, such walls can have a high compressive strength.

Regardless of the quality of mortar, walls composed of rounded coral rubble are weak in tension, a characteristic resulting from the inability of rounded building units to overlap and create a bond. Such walls will easily tear vertically if subjected to modest tensile forces. The absence of bonding also reduces the elasticity of the wall, reducing its ability to bend and deform in response to high compressive loading, point loading and minimal restraint. Walls are therefore brittle and prone to rupture horizontally or develop vertical cracks within their thickness together with bulges.

A further problem encountered in walls composed of rounded rag is seen in the junctions of elevations and cross walls, where the nature of the material prevents effective interpenetration and tying in. As a result of these factors, walls and buildings are very sensitive.

The exterior and interior of the masonry structure were originally rendered in a two-coat lime plaster. The first or render coat typically consists of a 1:3 mix of yellow laterite soil and lime. The top or setting coat in almost all cases consists of a 1:1 mix of lime and finely ground soft white coral stone dust. Currently, the entire interior of the building is re-rendered in a cement and sand composition.
CONDITION ASSESSMENT

General Condition
The exterior lime render is heavily patched with unsightly cement mortar. It is extensively employed in all elevations and gives the building a shabby and derelict appearance. Many open cracks can be seen in all the elevations. Salt crystallisation and abrasion scar the lower 3m to 4m of exterior elevations. Inside the building, numerous open cracks are visible. The southerly sections of the ground floor, first floor, and roof slab are all badly cracked and inclined towards the south east corner. The south wall leans out significantly.

Roof Slab
The roof is divided by a large crack running diagonally from the mid point of the west elevation to the east wall. Boritis in the soffit are rotted above the toilet room and landing. Above the bedroom, 50% of the boriti are rotten.

First Floor Slab
In the first floor slab, significant cracks can be seen in all rooms. Above the kitchen/store the cast concrete slab has cracked diagonally from the door to the south east corner and exhibits a significant deflection to the south east. In the landing, a crack extends diagonally in continuation of that in the toilet. The crack continues diagonally across the bedroom floor. In both the bedroom and landing, a slight deflection to the south east can be observed.

Synopsis of problems

Failure of openings
East elevation sinking
Failure if part of south wall
Large vertical cracks
First floor
Ground floor
Roof
Ground Floor Slabs
The floor to the kitchen and store area is badly damaged and scarred by many attempts at repair. Many large cracks divide it diagonally from west to south east. In the south east corner, the concrete sounds hollow and is clearly unsupported. A deflection is noted to the south east. In the entrance room and bed/sitting room, a single large diagonal crack is evident in replication of the pattern in the rooms above.

West Elevation
From the middle of the elevation to its junction with the south wall, three distinct crack systems are visible, running vertically down the full height of the building. They range in width from 3mm to 35mm. In all cases they have been filled with cement render and have subsequently reopened, indicating an active and ongoing settlement. The wider cracks in the systems extend through the full thickness of the wall and a number of smaller cracks appear to be actively developing in their vicinity. This is particularly in evidence in the brittle cement render of the interior. Salt damage is much in evidence throughout the lower part of the entire elevation. The inner cross wall in the south of the entrance room, is badly cracked above the door into the kitchen. The opening appears to have been constructed without an effective lintel. The full weight of the work above is carried on the door case, which has developed a significant deflection. In the south wall of the landing (immediately above), a similar condition exists above the door into the toilet room.

South Elevation
From ground level to the first floor the entire elevation exhibits a rotation of about 70mm. From first floor level to the roof, the elevation is 40mm out of plumb. A scale plot of the distortion, in relationship to the thickness of the wall, shows that the centre of gravity of the wall, remains within the central 1/3. It can therefore be assumed that the wall is currently stable but lacks effective restraint, and is subject to ongoing progressive rotation. The wall is further weakened by a number of horizontal and shear cracks, effectively dividing it into three sheets of rubble masonry. The lower south east corner is particularly badly shattered.

North Elevation
The elevation is scarred with cement repairs and numerous crack patterns, probably the result of long-term settlement and knock on effects generated by the developing instability in the south elevation.

Analysis of Damage and Conclusions
Examination of crack patterns, deflections in the floor slabs, and deformed door jambs and lintels, etc., suggest an active differential settlement in the south east corner of the building. The most likely cause of this is a collapse of the pit associated with the earth closet, which is located in the extreme south east corner of the building. It is also probable that traffic vibration has played a part in inducing the collapse and furthering ongoing damage. Although the collapse of the toilet pit is responsible for the bulk of the damage observed, it must be borne in mind that the failure has disturbed the delicate equilibrium existing between various elements of the structure and has given rise to significant ‘knock-on’ effects that will exploit intrinsic structural and material weaknesses elsewhere in the building. If the current rate of rotation in the south elevation and growing instability is maintained, the south elevation will shortly be in danger of collapse.
By far the easiest solution to the structural problems of house 1287 would have been to demolish the south elevation and a section of the west elevation, back fill the toilet pit, dig new foundations, and rebuild.

However, the nature of the exercise was not simply to produce a restored house, but to train local craftsmen and building professionals in the methodology of sensitive structural repair. With this goal in mind, works to the house were divided into the following phases.

Works began with the installation of temporary support systems to prevent further rotation of the south elevation and relieve weak walls, and the failing foundation in the south. The dead shoring systems required to secure the floor and roof slabs transmitted the load from floor to floor, directly to the ground. For maximum safety and efficiency, ranks of shores were erected one above the other. Shores were positioned with some care to avoid denying access to walls and sections of the ground floor required for repairs. All windows and door openings were also firmly strutted and cross braced.
Local tradesmen fabricated the timber components and steel fittings that are not stock items. Shores were erected as follows:

1. Needle holes were marked on the wall and cut. This work was carried out as neatly as possible and with as little vibration as possible.

2. The two wall plates were positioned either side of the socket holes. The wall hooks supporting these were driven into convenient mortar joints.
3. The position of the foot was established. To do this, a length of string was prepared the same length as the long boriti rakers.

Holding one end of the string in the top needle hole, an assistant was asked to take the other and move away from the wall until the string became tight and in contact with the ground. A pick and shovel were then used to cut an accurately shaped rectangle to accommodate the foot.

4. The lower needle, needle-brace, and raker were installed by inserting the needle into its socket and held hard against the top of the cavity.
The needle brace was then positioned across the wall plates so as to fit firmly above and behind the needle. The position of the needle brace was then marked with a scribed line along its lower edge, across the wall plates.

The needle was then lifted away and the brace securely bolted into position. A dry mix of 1:2 cement, sand was placed in the needle cavity, and a medium hammer used to drive the needle into its socket and against the brace, compacting the mortar around it and consolidating its position against the top of the cavity and the brace.
The raker was then lifted into position beneath the needle, with its lower end resting on the foot. Using a stout steel crowbar between the foot and the bottom of the raker, the raker was levered up until hard against the needle. It was secured in this position by driving home folding wedges.

Rakers must never be tightened into position by beating home the wedges with sledge-hammers, as the vibration created will damage the wall.

Note: Should it have proved difficult to lever rakers sufficiently tight against the needle, two hydraulic lorry jacks would be used in the following way:
Dead Shores
It is important that all loads are transmitted through the building and to the ground as efficiently as possible. To do this, shores must make close contact with the floor surfaces and the boritis of the slabs overhead. This requires the use of sole and heading boards.

To Fit the Heading Board

• The boards must consist of 20mm x 200mm soft wood planks nailed to the underside of the boritis.

Initially, attachment should only be made to boritis of common height. Folding wedges must be used to pack the spaces between poles of smaller radius. To secure the wedges, holes should be drilled through boards and wedges, into boritis, and suitable nails introduced.

40mm square battens were then nailed down the centre of each heading board to locate positively the heads of boriti used as shores.

• To locate these accurately a plumb line was used. The boards must be at least 200mm x 20mm.

• Dead shores between sole and heading boards consisted of boriti with a minimum diameter of 150mm set at 1.5m centres. The head of each shore was accurately notched, so as to locate around the batten nailed to the heading boards. The shores were tightened by inserting folding wedges between notch and batten.

Drill a 35mm hole through the base of the raker and introduce a short section of 30mm steel rod. Holes must be sufficiently far above the foot to allow the introduction of one lorry jack under each side of the bar. When in position gently jack the raker into position.

5. The above procedure was repeated to position the lower raker, and when in place the side bracing was added.
General Principles of the Structural Repairs

The objective of repair work is to remove both the CAUSE of damage and to stabilise its RESULTS, preventing further damage developing.

As the CAUSE of the problem was the collapse of the toilet pit, an important part of the repair was the provision of new foundations to support the south and east of the building (UNDERPINNING). Following this, the damage in the remainder of the building was stabilised.

This meant that walls were to remain bent but would not move any further. Stabilisation would ‘freeze’ them where they were. To achieve this the south wall was strengthened (increased in load bearing capacity) and restrained with the provision of wall ties.

Repairs began with the demolition of the southern section of the roof slab and parapet to the head of the south wall. This action was taken to reduce further the loading on the weak south wall. Although much of the load was now carried on the dead shore system, the slab was badly cracked and all of the boritis in that section required renewing. Removal of the slab would enable long new boritis to be installed, enhancing restraint of the south wall.

A suitable mix for this kind of work is:

- 1 part Portland cement
- 2 parts sand
- 4 parts broken brick or coral aggregate up to 18mm (¾ inch) gauge.

Before pouring the concrete, the contents of the toilet pit were removed. Most of the old sewage was found to have broken down into a spongy black mass which proved to be very compressible.

In addition to filling the pit, the dead mass of concrete was used to support a 300x500mm ground beam and needle, penetrating and supporting the east of the south exterior wall and the east of the entrance room wall. Concrete was shot into the pit by the bucket-full and roughly compacted with timber rams. In order to pre-stress the wall and avoid residual settlement, the concrete was cast to within one foot of the underside of the existing foundation. It was then allowed to set for one day, and three lorry jacks placed on top of it, directly below the original foundation. The jacks were tightened to stress the wall. Concrete pouring continued to a slightly higher level than the bottom of the original foundation in order that it could be compacted under it. The jacks were lost.

In preparation of the works to strengthen the south wall, a strip foundation was also constructed parallel to that of the interior south wall. This work extended the same depth below ground as the original construction and was attached to it at numerous points by coral ties.

FOUNDATIONS

Works began with the demolition of the concrete floor to the kitchen. Once removed, the full extent of the failure in the toilet pit was visible.

The pit was found to be extensive and shared with the house next door. Its failure had undermined and left entirely unsupported the whole of the south east section of the party wall between the two buildings. Provision of new foundations under this side of the building would require the toilet-pit to be filled with concrete and hardcore.
The severely weakened south wall was strengthened by ‘grafting’ onto it a second wall, constructed to the interior and to the full height of the kitchen. In the east of the elevation, the new wall entirely assimilated the existing work. To the more stable centre and west, a large blind arch was formed in the new work to maximise the space available in the kitchen. The two walls were firmly married by the insertion of wall ties. Below 1.5m above ground level coral ties were employed. Above that level, 17mm steel reinforcement bars protected by two coats of Alkyd paint were used. In addition to the steel ties, coral needles were also used to help transfer and share the load of the existing wall. In the extreme south of the elevation the two walls merge.

The construction used large flat coral in a mortar of the following composition:

<table>
<thead>
<tr>
<th>Cement</th>
<th>Lime</th>
<th>Stone Dust</th>
</tr>
</thead>
<tbody>
<tr>
<td>½</td>
<td>2</td>
<td>8</td>
</tr>
</tbody>
</table>

All cracks and lacunae were grouted with a well-matured mix of:

<table>
<thead>
<tr>
<th>Cement</th>
<th>Lime</th>
<th>Silica Sand</th>
</tr>
</thead>
<tbody>
<tr>
<td>¼</td>
<td>2</td>
<td>14</td>
</tr>
</tbody>
</table>

All shattered masonry above the entrances to the kitchen and toilet was removed and fired brick relieving arches inserted. Traditional boriti lintols were then installed.
Placing Boriti and Building the Arch

Following removal of the defective masonry and rotted boriti, reconstruction of the openings and installation of the arches began. New boriti were selected and fitted in the same location as the originals. They matched the originals as closely as possible in size and general shape. New boriti are firmly bedded on a 1:3 lime mortar and the spaces between bridged with small pieces of coral and mortar in the traditional way. Following two or three days for the mortar to harden, a simple centring was constructed immediately on top of them.

The centring is the formwork around which the arch is built. It is required because the arch will not stand until it is in compression and at least one RING or layer of stones or bricks is completed. The cheapest and simplest way to make a centre is to arrange empty drinks cans so as to form a segmental shape. This should resemble the top of a circle. For an opening 2m wide, the hump of cans should be about 350mm tall in the middle. The cans should be set across the full width of the boritis and bedded in lime mortar or gypsum plaster. Once the centre is in place, it is possible to build the arch around it.

It is much easier and will involve less labour to do this in fired brick, although it can easily be made in coral if preferred. The bricks or coral should be arranged around the centre by adding a course to each side alternately. They should be separated by a bed of 1:3 lime mortar and the last bricks to go in should be in the middle and the joint vertical. If bricks are being used they should be arranged as stretchers, set on their sides. This will minimise joint thickness. A minimum of four rings is required. When all the bricks are in place the arch must be left for as long as is practical for the mortar to harden.

The wall above is next rebuilt in ordinary 1:3 mortar, care being taken to pack stones tightly around the boriti. To complete the job, all that remains is remove the drink cans and pack the underside of the arch with light coral stone followed by re-rendering.
THE PROVISION OF RESTRAINT

Repair of the foundations solved the problem of ongoing rotation in the south elevation, but the weakness of the wall and the extent of rotation suggested the need for additional restraint. The need was met by installing five steel wall ties and restraining bars. The ties were secured to various points on the exterior of the south wall and anchored to points up to six metres away, in the north (stable) part of the house. Additionally, the new masonry to the ground floor interior will apply an eccentric loading to the elevation, which will also serve in stabilisation.
FLOOR SLABS AND ROOF

The southerly section of the roof slab was rebuilt to the traditional design but to a depth of only 300mm. Cracks in the first floor slabs were grouted with the mix specified above.