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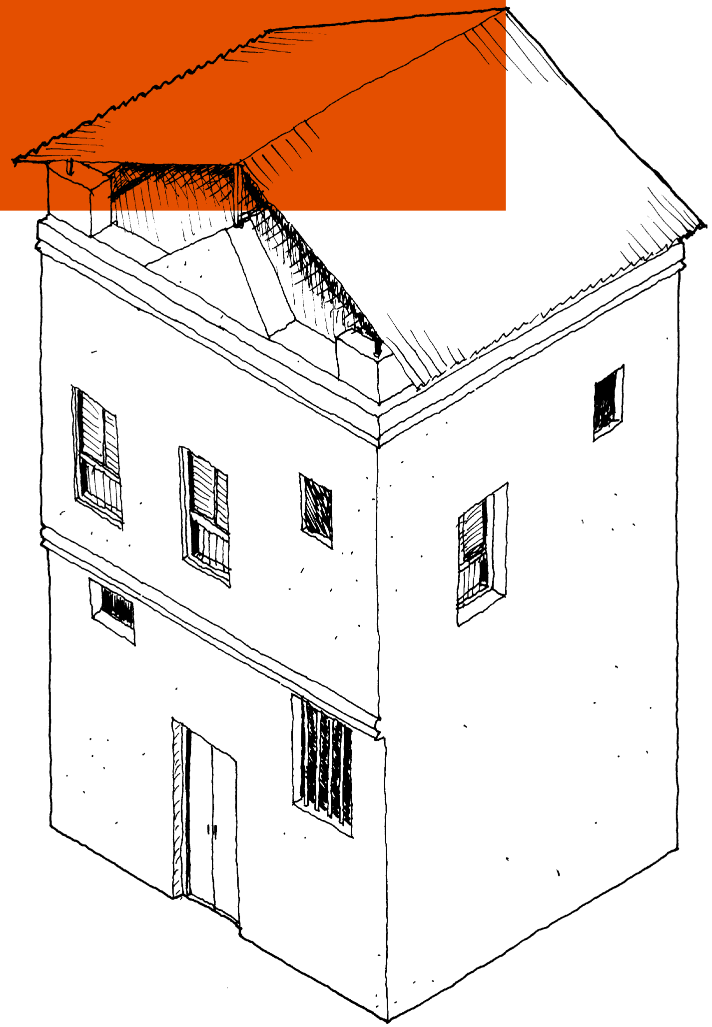
CASE STUDY:
HOUSE NO. 1287, KIPONDA



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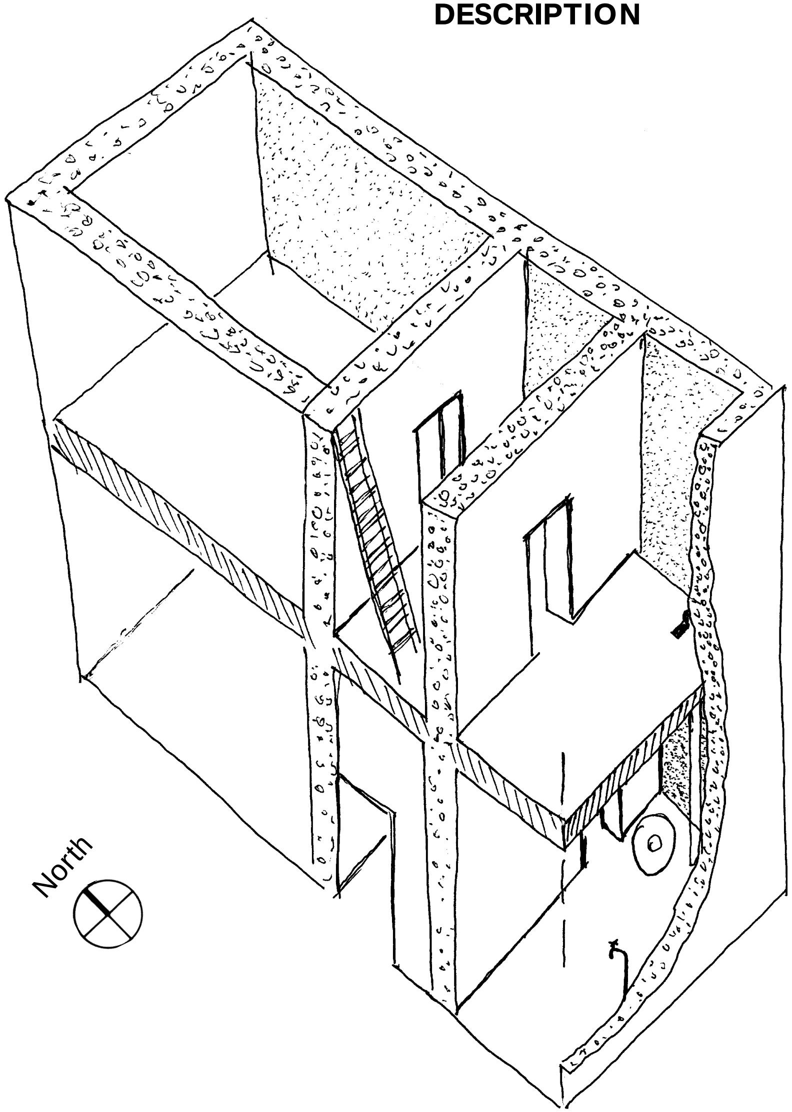
INTRODUCTION

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.

CASE STUDY NO. 1287

BACKGROUND

DESCRIPTION

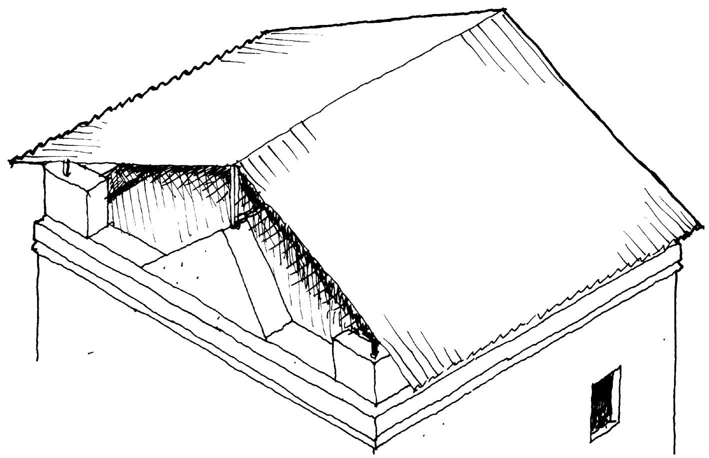


House No. 1287 is a very simple two-story building. Accommodation on the ground floor consists of three interconnected rectangular rooms. Principal access is via a simple small door set in the west elevation. This provides direct access to a narrow entrance room, which at its far end contains a crude 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.

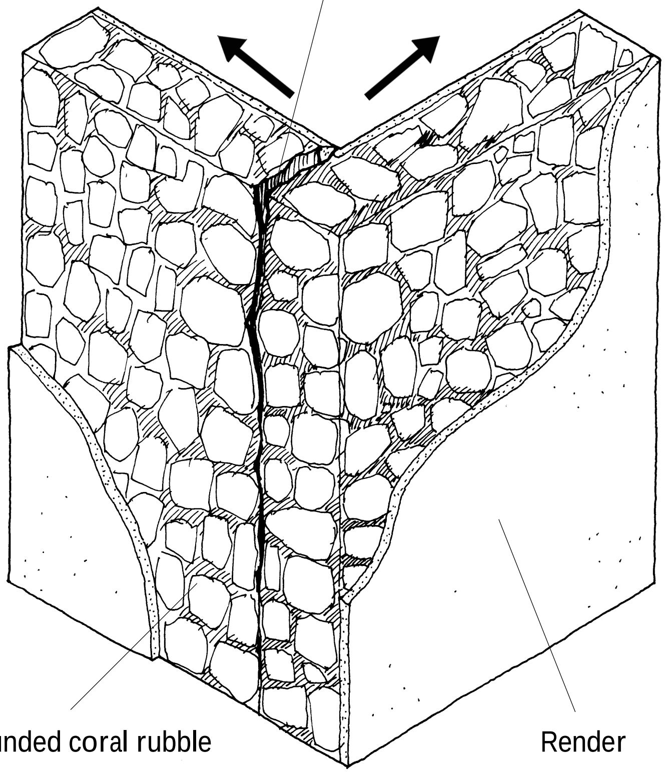
The current occupants and their relatives have lived in the house for 80 years, during which time they have witnessed minor but significant changes. The house retains many original features including much of the original fenestration, and a dry earth closet, which is still in regular use. The most significant 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.

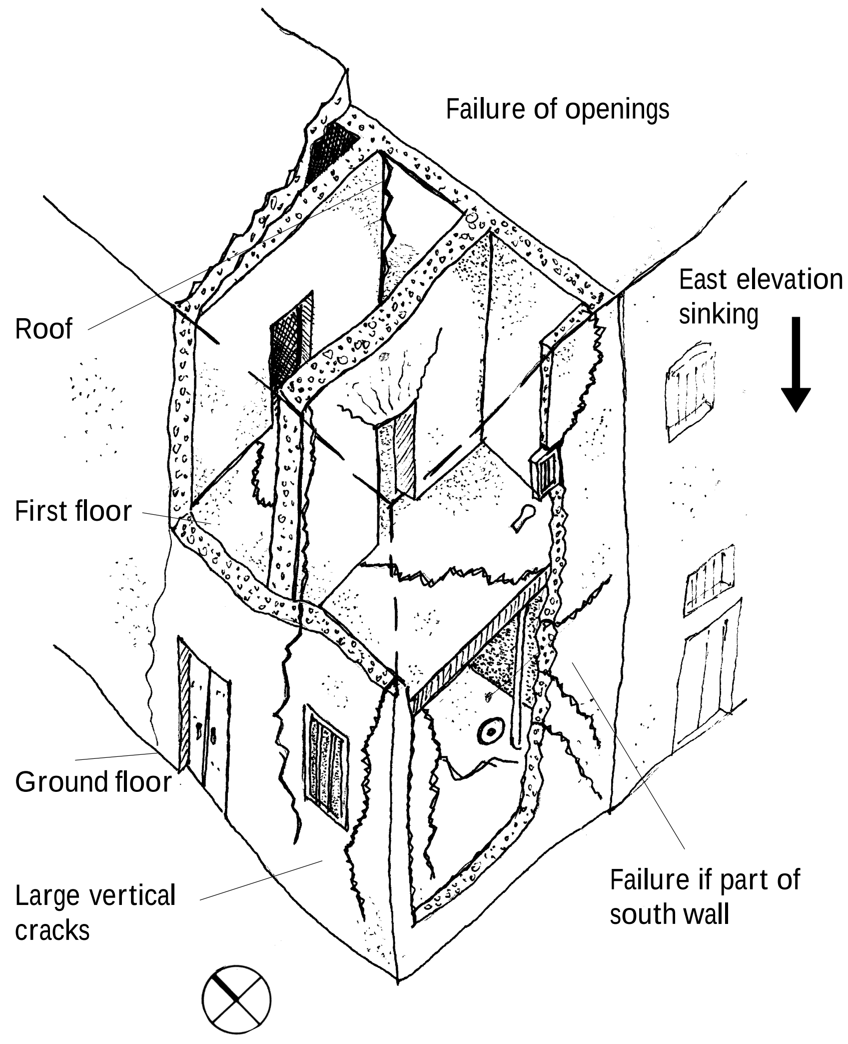
CONDITION ASSESSMENT

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



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

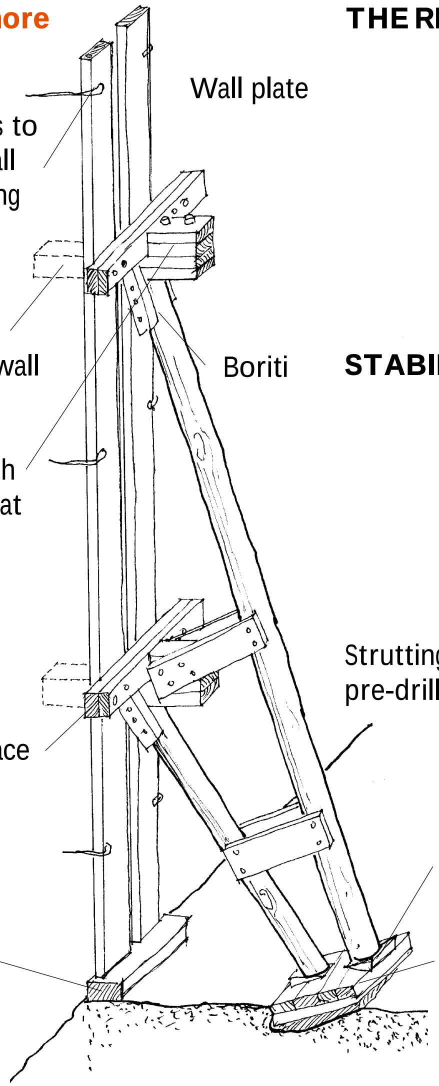
The elevation is scarred with cement repairs and numerous crack patterns, probably the result of long-term settlement and knock on effects generated by the developing instability in the south elevation.

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.

REPAIRS

Raking Shore



THE REPAIR PROCESS

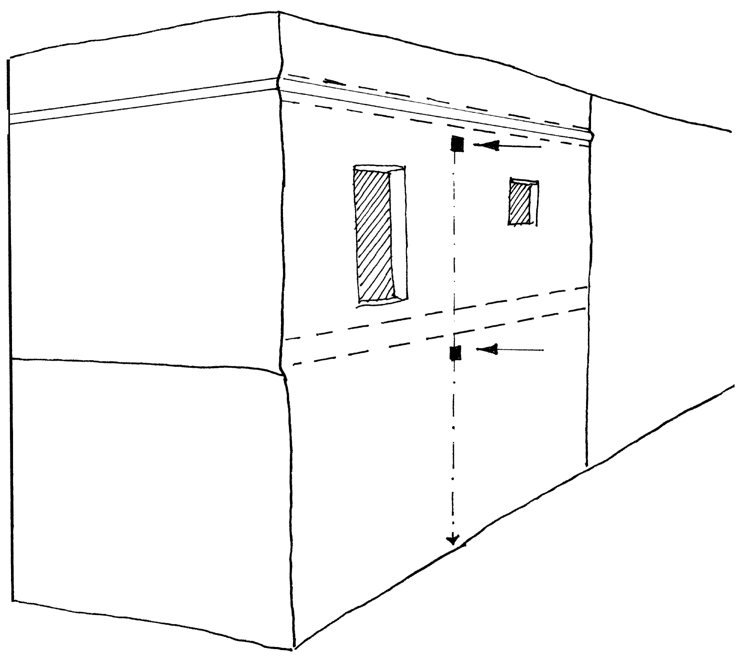
By far the easiest solution to the structural problems of house 1287 would have been to demolish the south elevation and a section of the west elevation, back fill the toilet pit, dig new foundations, and rebuild.

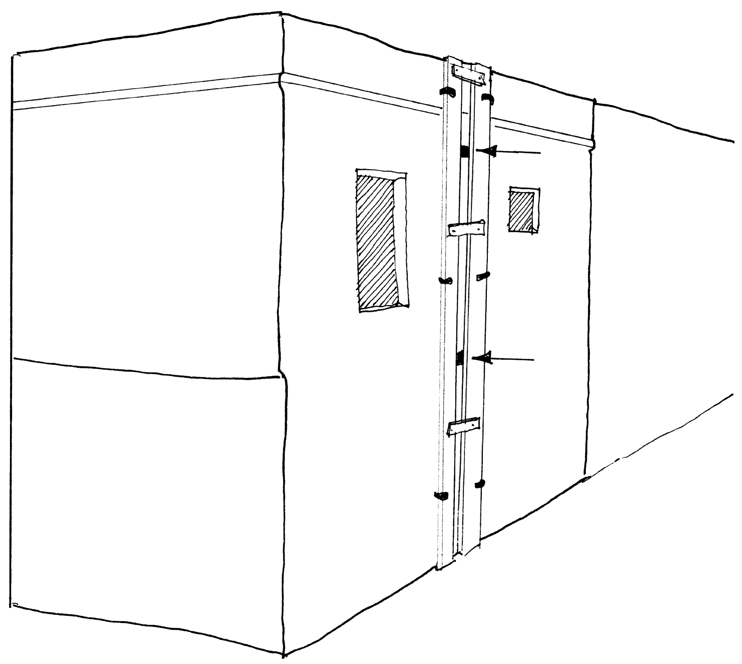
However, the nature of the exercise was not simply to produce a restored house, but to train local craftsmen and building professionals in the methodology of sensitive structural repair. With this goal in mind, works to the house were divided into the following phases.

STABILISATION

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.

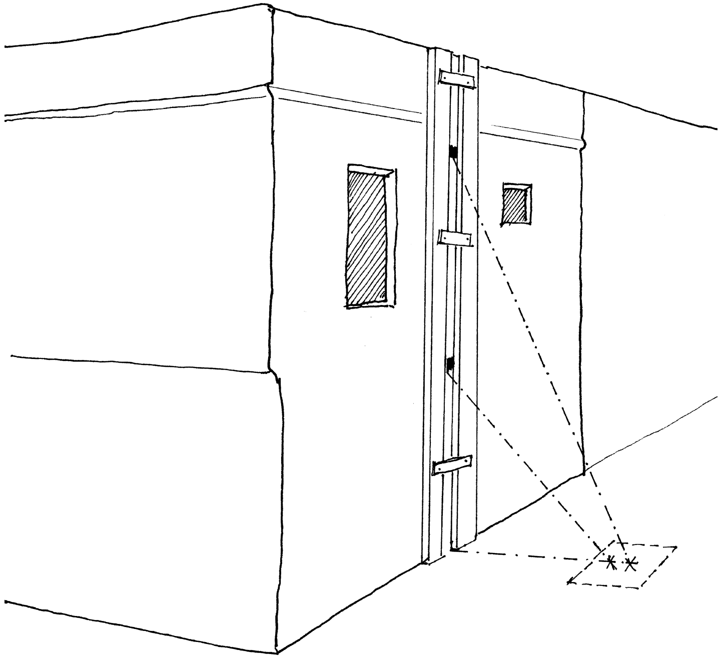
Local tradesmen fabricated the timber components and steel fittings that are not stock items. Shores were erected as follows:

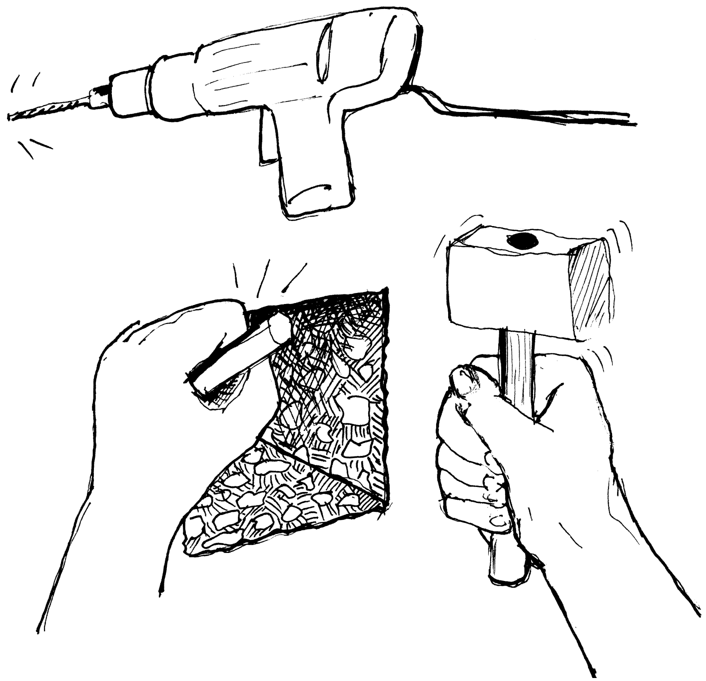




1. Needle holes were marked on the wall and cut. This work was carried out as neatly as possible and with as little vibration as possible.

2. The two wall plates were positioned either side of the socket holes. The wall hooks supporting these were driven into convenient mortar joints.

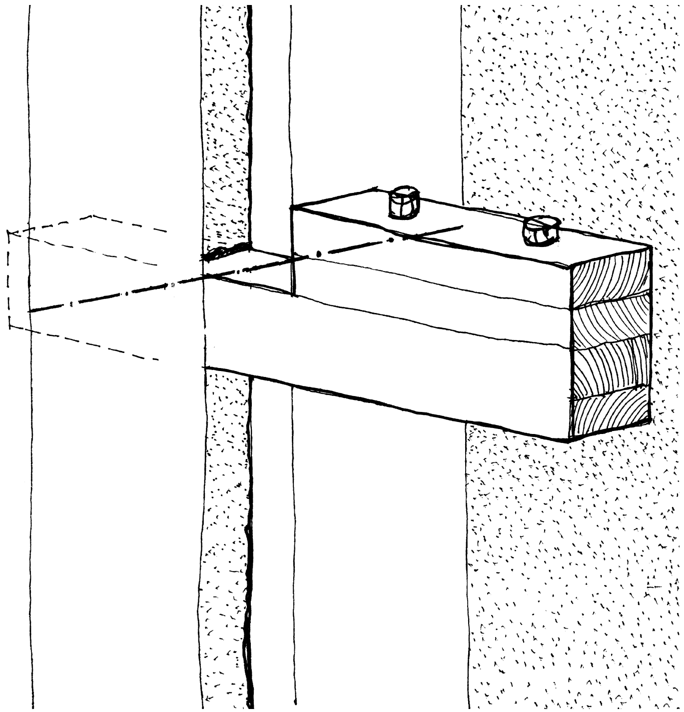




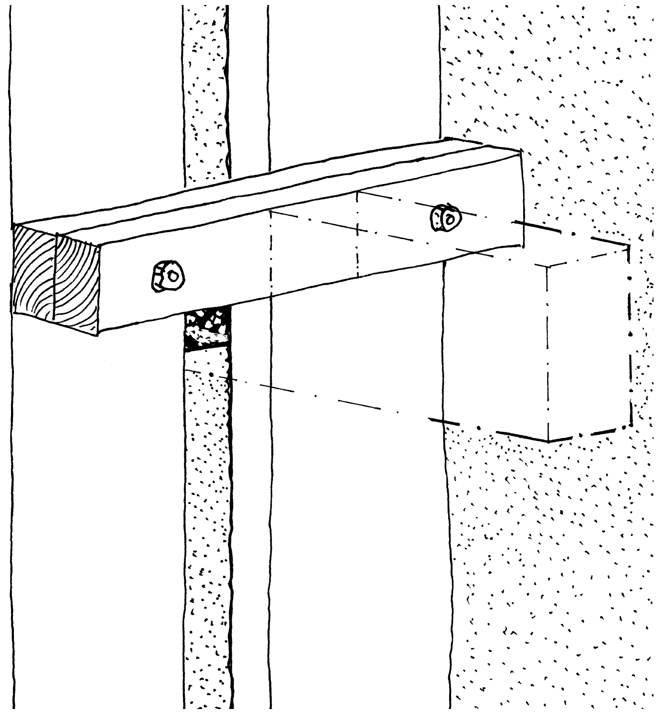
3. The position of the foot was established. To do this, a length of string was prepared the same length as the long boriti rakers.

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.

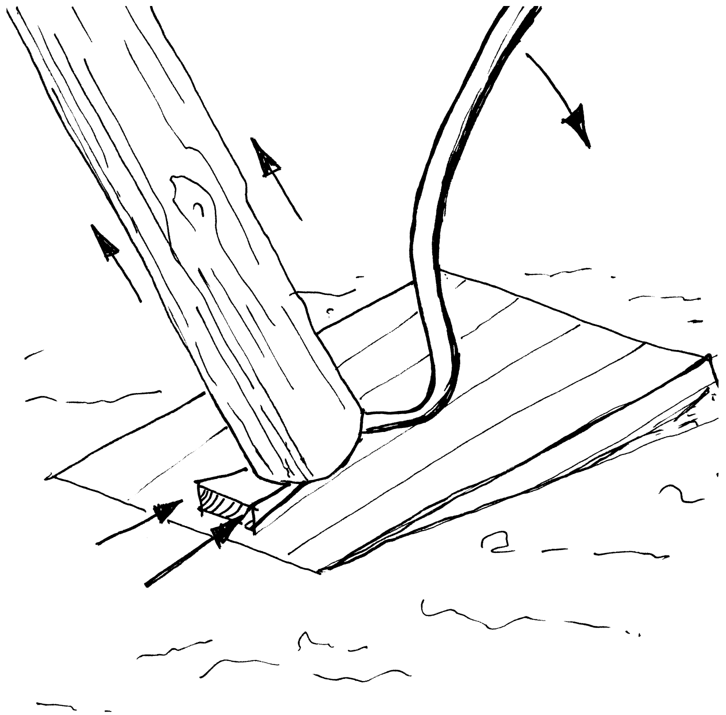
4. The lower needle, needle-brace, and raker were installed by inserting the needle into its socket and held hard against the top of the cavity.

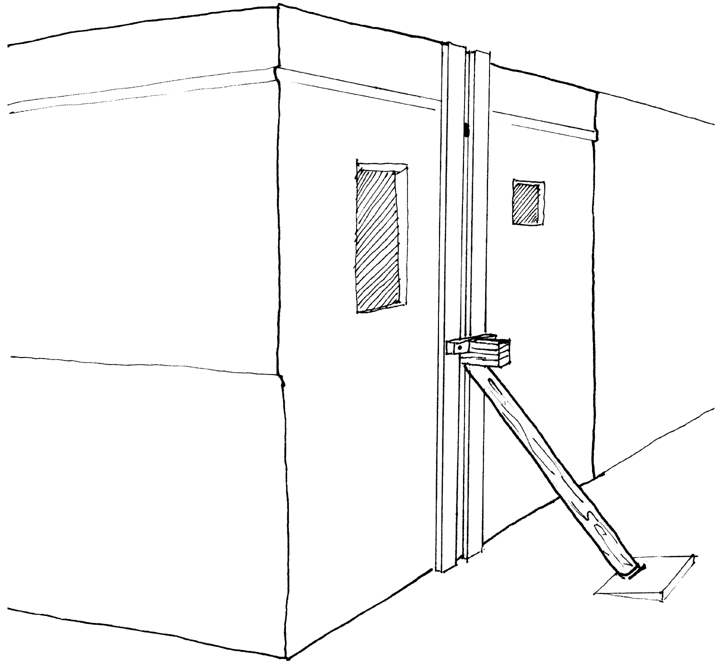


The needle brace was then positioned across the wall plates so as to fit firmly above and behind the needle.The position of the needle brace was then marked with a scribed line along its lower edge, across the wall plates.



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.

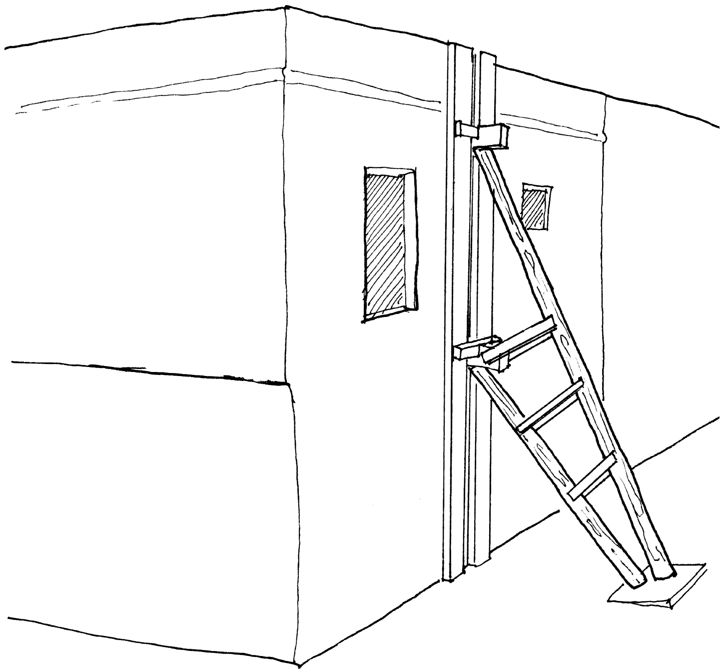




The raker was then lifted into position beneath the needle, with its lower end resting on the foot. Using a stout steel crowbar between the foot and the bottom of the raker, the raker was levered up until hard against the needle. It was secured in this position by driving home folding wedges.

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:



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.

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.

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.

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.

A suitable mix for this kind of work is:

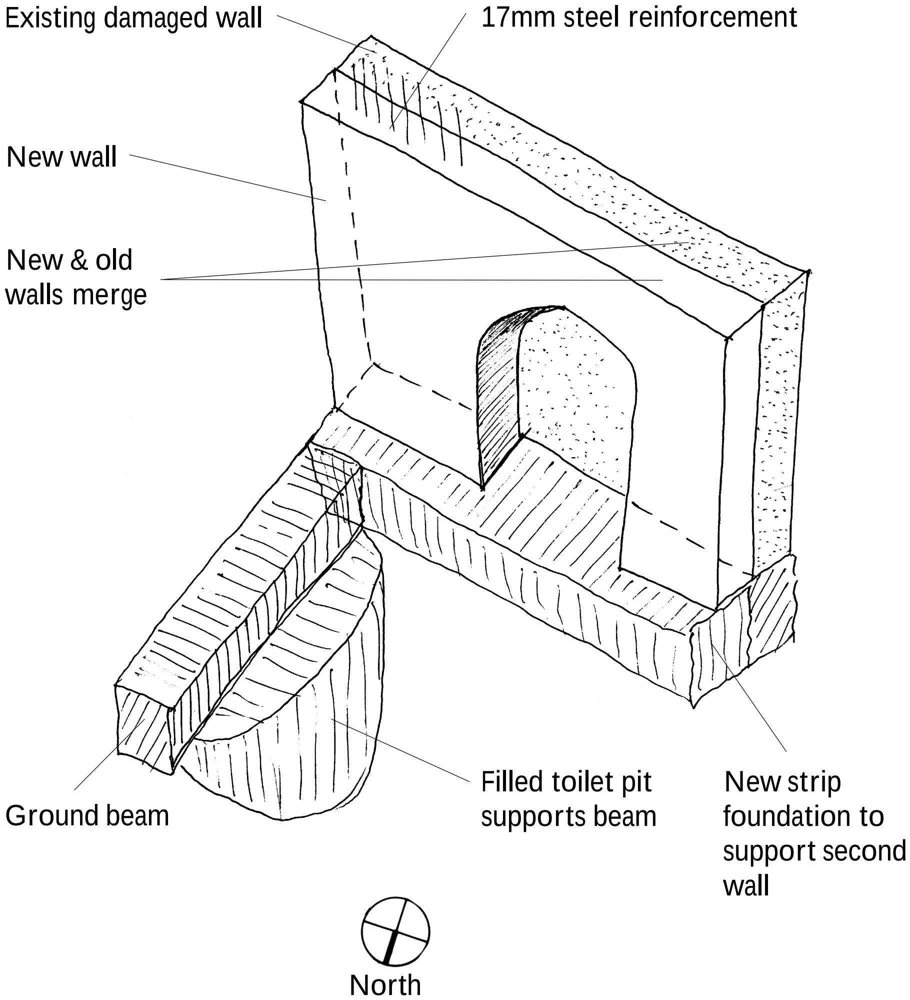
1 part Portland cement
2 parts sand
4 parts broken brick or coral aggregate up to 18mm (¾inch) gauge.

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.

Foundation and Wall Repairs



WALLS

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:

Cement	Lime	Stone Dust
½	2	8

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

Cement	Lime	Silica Sand
¼	2	14

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.

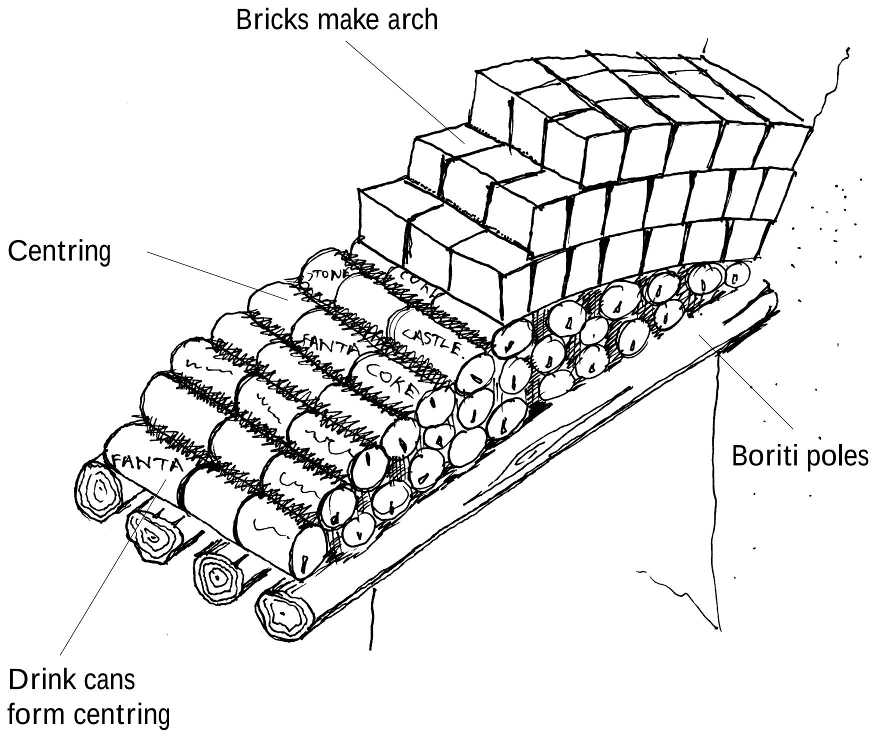
Placing Boriti and Building the Arch

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.

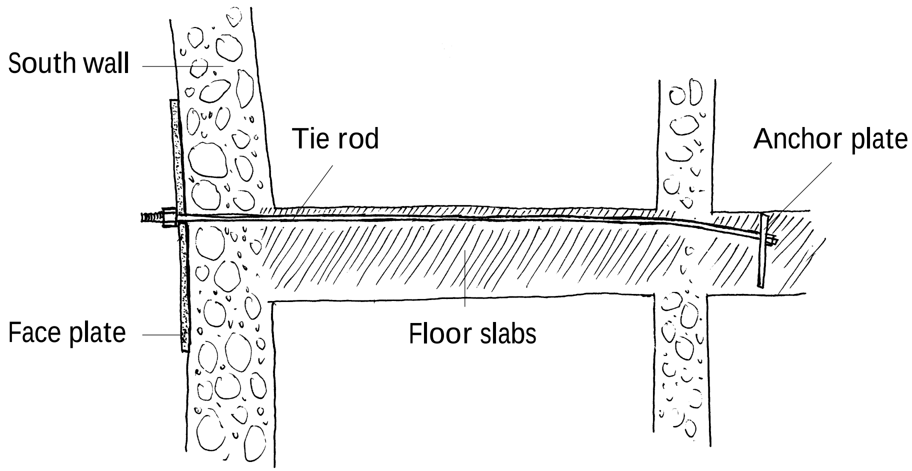
It is much easier and will involve less labour to do this in fired brick, although it can easily be made in coral if preferred. The bricks or coral should be arranged around the centre by adding a course to each side alternately. They should be separated by a bed of 1:3 lime mortar and the last bricks 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.

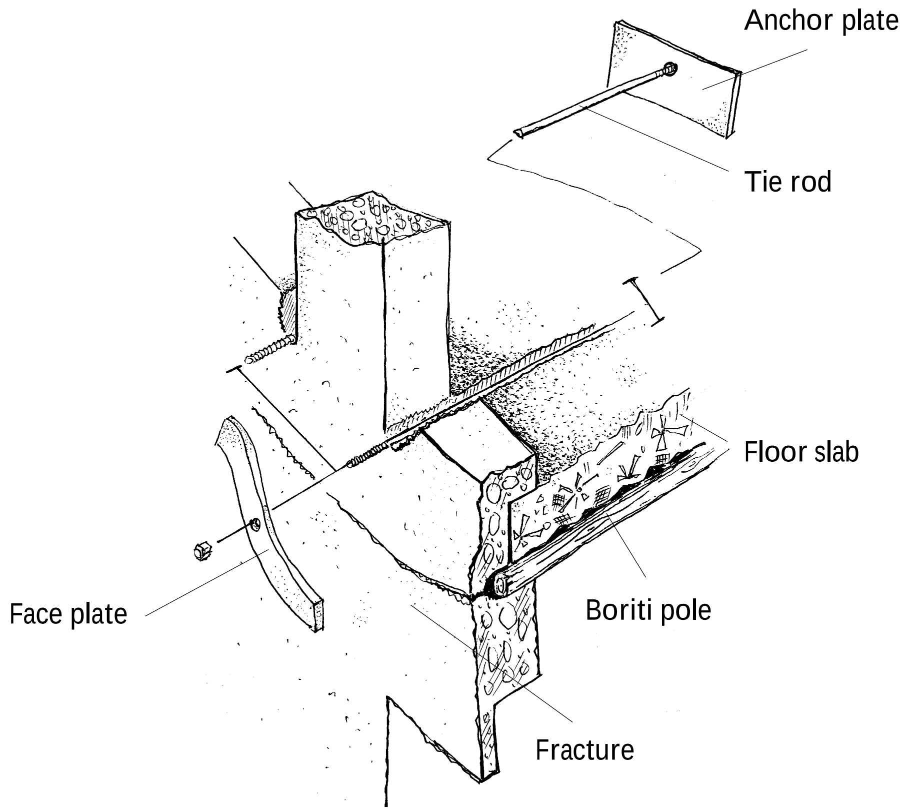
The wall above is next rebuilt in ordinary 1:3 mortar, care being taken to pack stones tightly around the boriti. To complete the job, all that remains is remove the drink cans and pack the underside of the arch with light coral stone followed by re-rendering.



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 sixmetres 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.

Synopsis of Repairs