An investigation of structural stability and causes of deterioration in rough dry stone monuments at Ziwa, NE Zimbabwe

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Abstract

Ziwa National Monuments are found in the Nyanga district, north eastern Zimbabwe. This agricultural landscape is part of the impressive and extensive Nyanga archaeological agricultural landscape consisting of stone terracing, livestock pits, enclosures and other intricate dry stone structures. Despite the archaeological importance of these structures there are no established systems for monitoring of deterioration and conservation. While Zimbabwe has well established methods of conserving dry stone walling that have been disseminated to other countries in eastern and southern Africa, these techniques are not applicable at Ziwa. The Ziwa structures are categorised as rough (R-style), without dressed stones or coursing. Previous studies have established that it is not possible to apply precise monitoring techniques like the demec gauge and triangulation. Therefore other stone conservation capabilities need to be explored for the vast R-style architectural heritage of the eco-region. This study looked at the construction techniques at Ziwa and how these may influence structural stability, the behaviour of the walls and monitoring methods that are being or can be applied. It also studied modern terracing in Nyanga and how the construction methods and monitoring techniques may inform structural conservation at Ziwa.
1. Background and introduction

1.1 The Ziwa cultural landscape

Ziwa National Monument (No 53) is located on an estate about 20km north west of Nyanga village (Latitude 18°00′S, Longitude 32°38′E), on the lowlands of the northern part of the Eastern Highlands. The estate consists of some 3 337 hectares which are declared a National Monument under the National Museums and Monuments Act, Chapter 25:11 of 1997. The site was declared a National Monument through a Government Gazette Number 236 of 3 May 1946. The National Monument boundary is marked by the Nyan’ombe River in the west and the Ziwa mountain in the east (Figure 1). To the north and north west the estate shares a boundary with Matongo and SaNyangare villages respectively.

Ziwa is part of the most impressive and extensive Nyanga archaeological agricultural landscape. The archaeological property on the estate consists of stone terraces, enclosures, pit enclosures, hill forts, passages, smelting furnaces, grinding places, clearance cairns and other important remains from the past. Terraces and enclosures are the most dominant in the landscape. Terrace farming in this area and the district in general appears to have been a means of adaptation to an environment with a generally steep terrain, thus exhibiting technological innovativeness on the part of the later farming communities that settled in the area during the 17th to the early 20th centuries AD.

Early perceptions of travellers and antiquarians were that better quality walls such as those at Great Zimbabwe type sites were earlier and built by a superior race. Poor walls or the rough (R) walls such as those found in Nyanga were built by later arrivals, so called decadent Kaffirs of Bantu societies (see example Hall 1905). This has been dismissed by modern research and dating has shown that the two communities were broadly contemporary. The Ziwa ruins complex belongs to what are called Later Farming Communities in Southern Africa and dates to between 1600 and 1900 AD. Terracing agricultural systems were common in many parts of Sub-saharan Africa from east Africa to South Africa (Summers 1958). Nyanga is therefore not an isolated development, but probably it is one of the largest manifestations of this agricultural technology innovation.

There is site museum at Ziwa which has been open for the past 18 years and currently there are efforts to put the estate onto the World Heritage
List as an organically evolved relict landscape. It is on the World Heritage Tentative List (1996) under the following criteria:

(iii) bear a unique or at least exceptional testimony to a cultural tradition or to a civilization which is living or which has disappeared;

(iv) an outstanding example of a type of building, architectural or technological ensemble or landscape which illustrates (a) significant stage(s) in human history;

(v) an outstanding example of a traditional human settlement, land-use, or sea-use which is representative of a culture (or cultures), or human interaction with the environment especially when it has become vulnerable under the impact of irreversible change.

It therefore has immense archaeological significance and its proper management will benefit the global community.

Figure 1. Ziwa National Monuments estate, showing some sites mentioned in the text.
1.2 Problem statement and aims of the research project
In Zimbabwe the methods of conserving dry stone walling are only well developed and tested for monuments of the Zimbabwe Culture with coursing. At the moment it is not possible to apply precise monitoring techniques like the demec gauge and triangulation measurements on rough un-coursed dry stone walls at Ziwa and others that cover vast expanses of the Nyanga District. There are thus no tools to measure and monitor in-plane and out-plane movements in this type of architecture. This is necessary if the conservation of the monuments is to be approached systematically and in a proactive manner so as to sustain the authenticity and integrity of the cultural landscape.

The long term objective of this investigation is to develop a rough dry stone walling monitoring system and explore stone conservation capability for the same architectural heritage. The methods will include experimentation using both scientific and indigenous knowledge systems. This data will be used to propose and experiment with various techniques of wall monitoring. This investigation used Ziwa as a case study given that this is the largest National Monument in Zimbabwe with the protected rough (R-style) stone structures and is also of international significance regarding the evolution of ancient agricultural systems.

1.3 Methods used
Literature on previous research at Ziwa and Nyanga was studied to get an overview on the architectural traits of the dry stone structures and previous conservation studies. The study revealed that the engineering aspects of the dry stones walls have not been addressed in detail in the past and there has been little work done to prevent deterioration of the stone structures. A few non-systematic restorations were conducted between 1992 and 1996 but these are poorly documented and their effectiveness has not been monitored. A lot of photographic documentation of the walls exists but most of it is poorly labelled and not useful for structural monitoring of the walls.

A two week field work at Ziwa between 19 October and 2 November 2010 was conducted. Two recording forms were designed to ensure speedy documentation of the required details in the field. The fieldwork consisted of a detailed examination of the structure of the dry stone walls at Ziwa, structural failures and their causes and photographic documentation. The survey sampled the different categories of dry stone structures, namely terraces, enclosures and forts. One minor excavation to test the foundation of a field wall was conducted.
Observations and study of traditional rough stone structures in use around Ziwa were carried out in communities to the north east of Ziwa. Four places in the Chitsanza and Bende Gap areas were visited and interviews conducted with community members. The interviews investigated how modern terraces and enclosures were constructed and conserved. This data could assist future conservation of the ancient structures at Ziwa.
2. General description of Ziwa dry stone structures

This section gives detailed descriptions of the main features of the agricultural landscape at Ziwa. Specific details of wall and construction styles and how they may influence structural stability in the stone walls are also given.

2.1 The terraces

The terraces are the most obvious and outstanding feature of the agricultural landscape. These are well preserved in many parts of the district and form a seamless web of maze-like terrace landscape extending about 100km north of Nyanga township. In all the terracing covers an estimated 8 000km² of Nyanga, but is by no means restricted to the district boundaries. To the east it continues into Mozambique and to the west into Makoni district, while to the north it tails off towards Mutoko district. The terracing is more pronounced in the low-lying areas and lesser in the plateau. In parts of Nyanga, especially the northern half of the district, whole landscapes are terraced with massive dry stone walls.

The ground in most parts of the estate is covered with stones. Therefore stone clearance and hence terracing was an indispensable technique to enable successful cultivation. Large quantities of rocks were carefully piled to form clearance cairns, walls, or terraces. The terraces were carefully constructed mainly using dry undressed dolerite and granite rocks. Areal mapping of slope angles at Ziwa disclosed that most slopes range from 5% to 40% gradient, but most commonly between 5% and 25%. The terraces closely follow the contours of the hills and mountains, and in some cases they cover whole slopes from base to top. On some clearance cairns some very tiny stones less than 10mm in maximum diameter shows that the clearance was done meticulously.

Terraces form a remarkable uniformity in design and construction style, manifesting great engineering skill as well (Brand1970). Two main variations in terrace construction which occur consistently at Ziwa and throughout the district can be recognized. On gentle ground free-standing clearance walls are common, while on the slopes bench terraces are the
norm. The terraces are generally discontinuous although some run for several scores of metres unbroken. Stone-lined pathways or passages used to move through the field systems often run at right angles to the slope, breaking the continuity of some terraces.

2.1.1 Free standing field walls
In relatively flat areas free standing double-faced field walls are common. These have been formed by the construction of two outer faces of carefully stacked uncoursed blocks infilled with core stones of varying shapes and sizes (Figure 2). The type of face blocks depends on the parent rock which varies between dolerite and granite at Ziwa. Occasionally both rock types are used in a single wall. Face block shapes are very irregular and wall faces are built of stones of varying sizes including some massive immovable boulders. The largest ones have face measurements of up to 1m. Fitting the various stone blocks securely together must have required considerable skill. The long axis of some stones is parallel or vertical to the wall face and in rare cases laid into the wall to give good stability. However, no instances of through or tie stones that run the entire width of the walls have been observed so far. These effectively tie the two outer faces of the wall together thereby enhancing structural stability (Walker & Dickens, 1992: 62).

![Figure 2. Free standing terrace wall profile.](image)

Core material fill is generally of poor quality consisting of different types of stones in admixture laid as random rubble. Interlocking between core and face stones is rare. Core material varies from very tiny stones, 0.01cm to large, 60cm, though most range between 10-40cm. Tightly packing the core with small stones reduces the number of voids hence producing a more compact core and enhancing wall stability. Wall tops are usually flat and where wall construction is complete, neatly packed with stones of 20-40cm.
Wall width at the bottom surface of the terraces ranges from 40cm to 1.60 and at the top from 35cm to 1.25m, averaging 1.16m and 86cm respectively. This shows that the walls have a somewhat inconsistent batter that may however be sufficient to provide stability for a rubble random core in short walled structures at Ziwa. Height varies from about 20cm to 1.8m above the terrace surface depending on the amount of excess stones to be removed. It is clear that the main objective in free standing field walls was to remove the excess stones and disposing them on carefully built terraces to create clear soil surfaces for cultivation. The field walls often form wide (5m) terraces. Terrace alignments are overall continuous stretching 15-60m long, though discontinuity may occur when terraces abut to boulders, enclosures or cross passages.

Most of the field walls are constructed on soil with no foundation trenching, but some have rock or bedrock foundations depending on the terrain. Because of the generally thin soils firmer ground is reached at depths of 10-15cm below the ground surface. This could reduce bearing capacity and settlement problems and minimise the possible seasonal heave/shrinkage movements that result from soil moisture variation.

2.1.2 Bench terraces
Bench terraces constructed from dolerite or granite, depending on the parent rock, are more prevalent than free standing field walls at Ziwa due to the nature of the terrain dominated by ridges, small hills and mountains. Two types of bench terraces are found at Ziwa (Figure 3). The first type (revetment walls) comprise of a carefully placed skin of blocks with the core stones stacked behind, forming a single faced terrace. The core blocks may be stacked into the backfill in order to stabilise soil. Terrace surfaces flush with the tops of the walls. The other more prevalent type (gravity earth retaining walls) is constructed in the same way but is double faced, with large stones forming the outer wall faces, while the fill consists of small stones. The upper wall face is raised above ground by a single course to 1.m high presumably to impound rain water and allow its infiltration. Some terraces slope laterally a design meant to dispose safely of surplus water during exceptional rainstorms. With time this will result in erosion at the base of the terraces potentially leading to foundation block disturbance.

When constructing bench terraces the slope was cut back and stones were removed, with the larger ones being used to construct the wall faces and smaller ones being used to make the fill. The lower face of the terraces was
built on the natural often stony subsoil. The placement of core material behind a single face effectively removed any lateral pressure from the outer face hence soil stabilisation or reinforcement. According to Soper (2002), the surface beneath the wall was left sloping and the soil salvaged before construction. Loose stones would have been used to start the lowest wall then the soil scrapped down behind, removing contained stones to build the wall faces and core (Soper 2002). The walls of the bench terraces generally vary in height with slope. On the relatively gentle slopes the walls are between 30cm to 80cm high and on steep gradients this increases to between 1m-1.5m on the lower side. The width of the field systems varies with slope as well. They are usually wider (5-10m) at the lower slopes and narrower (up to 1m or slightly less) as gradient becomes steeper.

![Figure 3. Bench terrace profiles. a) Revetment bench terrace, b) earth retaining terrace.](image)

As with free standing terraces the faces of the walls in bench terrace have some extremely large blocks. The long axis of some stones is also parallel to the wall face but others are laid into the wall giving good stability. The core has much small rubble but also larger stones up to 70cm cm thrown at random occur (Soper 2002: 39).

Bench terraces are more susceptible to vegetation growth and have to support the backfill pressure, which is likely to increase during the rainy season. At Ziwa soils behind the terraces are however generally shallow (Soper 2002). Comparatively, free standing walls are inherently more stable as the only forces acting are the walls’ own self weight on the foundations (Walker & Dickens 1992: 25).

2.2 Enclosures
Also found among the terraces are stone enclosures of diverse forms. In the Ziwa area three types can be recognised: the simple enclosures, pit enclosures and forts.
2.2.1 Pit enclosures

The most common type is the pit enclosure consisting of a pit roughly in the centre of an enclosure (Figure 4). The pit enclosures appear to have been built to a preconceived plan as there is unmistakable uniformity in their design. The pit (Figure 4b) can be constructed by creating an artificial soil and rubble platform built out from a slope or partially dug into the slope. The wall of the pit appears to have been built up first and the platform later as backfill. Excavations during restorations at the nearby Nyahokwe National Monument revealed some layering in the rubble fill.

The pit walls are built with no batter using irregular stones (occasionally neatly) fitted together and wedged to form vertical faces. The pit diameters range between 2-10m, averaging 4m and 1-1.5m deep. In the absence of a batter wall stability appears to be achieved by the compression of the solid platform fill of the earth and rubble. There is evidence of coping at the top in some of the pits. The floor of the pit slopes away from the entrance and where the structure is not on bedrock it is paved with flat stones. The pit stone facing is susceptible to lateral pressures exerted by the platform fill. Most of the pits are silted and covered with clumps of trees usually the *ficus* species that cause structural instability.

Directly opposite the inner side of the pit entrance is a drain hole running outwards under the platform (Figure a). The drain tunnel should have been built and lintelled using stone slabs before being loaded with platform back fill about 1-1.5m high. Drain hole inlet and outlet dimensions vary and sample measurements are given below:
Drain holes sizes (m) | H   | W   | L   | Comments
---|-----|-----|-----|-----
MW34 Inner | 0.25 | 0.17 | 5.41 |
       Outer | 0.38 | 0.53 | 5.41 |
Ruin 1 Outer | 0.30 | 0.27 | 2.00  | inner collapsed
Ruin 16 Drain 1, outer | 0.36 | 0.34 | 2.19  | inner collapsed
       Drain 2, inner | 0.10 | 0.32 | 1.58  | outer collapsed

The lengths of the drains depend on the size of the enclosure and the placement of the pit within the enclosure. A number of enclosure walls have collapsed over the drain holes showing that the feature is a source of structural instability.

A tunnelled or untunnelled passage entrance leads into the pit. The passages into the pit are walled with stone blocks on either side. Where the pit passage is roofed stone slabs are used to close the gap above the tunnel and occasionally the slabs are covered with soil, giving an impression that it runs under the platform. The tunnel entrances usually have a batter with the top being slightly wider than the bottom. Top entrance widths range from 50cm-1.2m while bottom widths are 40-80cm, with internal heights of around 1m-1.4m. Sample measurements are given below:

Lintelled pit enclosure entrances sizes (M) | H   | W-T | W-B | L   | Comments
---|-----|-----|-----|-----|-----
MW34 | 1.10 | 0.67 | 0.74 | 2.35 | reconstructed
Ziwa 614933 | 0.73 | 0.58 | 0.50 | 3.00 |
Ziwa 61579520 | 1.20 | 0.70 | 0.61 | 3.50 |
Ziwa 61749528 | 1.32 | 0.55 | 0.56 | 3.00 |
Ziwa 61759529 | 0.85 | 0.64 | 0.54 | 1.80 |
Ziwa 61619473 | 1.00 | 0.50 | 1.00 | 3.00 |
Ziwa 61379313 | 1.24 | 0.84 | 0.72 | 3.00 |
Ziwa 61329325 | 1.40 | 0.63 | 0.60 | 2.74 |
Ziwa 61269312 | 1.13 | 0.81 | 0.77 | ?   | L not measured|
Ziwa 61279315 | 0.56 | 0.56 | 0.62 | 3.40 |

The outward inclination of the entrance increases their stability and reduces incidences of wall toppling. In some instances the pit tunnel entrances are augmented by building a wall above the lintel slabs such that the maximum wall height at the pit entrance is 70cm-1.8m. The extension of the wall above the lintel creates substantial loading that my
lead to structural failure in lintelled pit entrances. The lintel slabs are about 15-25cm in thickness.

Pit enclosure entrances sometimes have drawbar holes on either side in the middle of the side walls. The measurements show that one socket is longer than the other. In the longer holes wooden drawbars were placed into the socket during construction as provisions for locking the entrance. The top of the holes was covered with stone slabs and stone core material placed above them. The drawbar could be slid across to engage in a shorter socket on the opposite side to prevent animals from coming out of the enclosures. Similar locking sockets are also found on pit tunnels entries and other types of enclosures. There may be a hole in the top of the wall above the long socket in which a stone locking pin could be dropped to secure the drawbar in the closed position (Soper 2002). The horizontal locking slots vary in size with the few measured giving the following measurements:

<table>
<thead>
<tr>
<th>Locking slots size (M)</th>
<th>H-rt side</th>
<th>W-rt side</th>
<th>L-rt side</th>
<th>H-lt side</th>
<th>W-lt side</th>
<th>L-lt side</th>
</tr>
</thead>
<tbody>
<tr>
<td>MW34 Enclosure</td>
<td>0.15</td>
<td>0.24</td>
<td>1.45</td>
<td>0.20</td>
<td>0.26</td>
<td>0.49</td>
</tr>
<tr>
<td>Pit</td>
<td>0.17</td>
<td>0.26</td>
<td>0.70</td>
<td>0.18</td>
<td>0.25</td>
<td>0.26</td>
</tr>
<tr>
<td>Ruin 1 Western entrance outer</td>
<td>0.27</td>
<td>0.40</td>
<td>0.42</td>
<td>0.25</td>
<td>0.30</td>
<td>2.24</td>
</tr>
<tr>
<td>Western entrance inner</td>
<td>0.12</td>
<td>0.21</td>
<td>0.30</td>
<td>0.21</td>
<td>0.37</td>
<td>0.65</td>
</tr>
<tr>
<td>Eastern entrance outer</td>
<td>0.31</td>
<td>0.31</td>
<td>1.45 collapse</td>
<td>collapse</td>
<td>collapse collapse</td>
<td>collapse</td>
</tr>
<tr>
<td>Eastern entrance inner</td>
<td>0.17</td>
<td>0.19</td>
<td>1.14</td>
<td>0.30</td>
<td>0.15</td>
<td>0.40</td>
</tr>
<tr>
<td>Ruin 16 Outer enclosure entrance 2</td>
<td>0.31</td>
<td>0.19</td>
<td>?</td>
<td>0.29</td>
<td>0.19</td>
<td>1.70</td>
</tr>
<tr>
<td>Inner enclosure entrance 3</td>
<td>0.22</td>
<td>0.20</td>
<td>0.55</td>
<td>0.18</td>
<td>0.28</td>
<td>2.40</td>
</tr>
<tr>
<td>Inner enclosure entrance 4</td>
<td>0.36</td>
<td>0.34</td>
<td>0.25</td>
<td>0.34</td>
<td>0.34</td>
<td>0.36</td>
</tr>
</tbody>
</table>

The slots act likes huge voids and are a source of structural instability in the stone walls. The instability is higher when the loading above the slots increases.

The enclosures enclosing the pits are typically oval and built on gently sloping ground or bedrock. They are constructed using stone blocks of available material either dolerite or granite or in rare cases both types. The blocks have varying sizes with some of them very massive (with face dimensions of 1m by 80cm) and irregular in shape. It would have required several men to place some of the blocks. The blocks are neatly fitted together and voids between blocks are closed using numerous wedges. The enclosures usually have short free standing walls on either side of the entrance that graduate into retaining walls for the rest of the circumference because of the backfill platform described earlier. The retaining walls are typically double faced (gravity retaining) although in
some cases they flush with the platform surfaces and may be single faced (revetment). In the gravity retaining walls bulk mass and weight of the wall help to resist lateral overturning pressure of the backfill.

The free standing walls at the entrances are sometimes thickened, up to 5m thick and are around 1-1.2m high on the outer side. The rest of the outer walls range between 1.10-1.8m the highest sections being at the back of the enclosure that is on a slope. Inner sections are normally higher at the entrance 1-1.8m and lower in the retaining sections 0-80cm. It is not clear whether the inner faces of the retention wall are built from the same foundation as the outer faces. On examining some collapsed sections it would appear that they are not.

As in the pit the enclosure entrances may be lintelled with stone slabs or open. The enclosure entrances often have inbuilt draw bar holes with similar dimensions to those of the pits. Some of the lintelled entrances have walls running over them but in most cases the stone slabs are not loaded. The entrances are longer where the walls have been thickened.

The platform between the enclosure and the pit was provided to accommodate pole and *dhaka* houses. The perimeter wall sections usually have bays that accommodated houses and in some cases the wall is interrupted by the houses and raised platforms. It is common to find *dhaka* pieces deposited in the core material.

The core material is the same as in free standing terrace field walls and bench terraces. Collapsed sections show a lot of soil ingestion, evidence of lateral pressure from platform backfill loading. The foundations of the pit enclosures are mostly a combination of shallow soil and stone boulder foundations though bedrock foundations can also be found.

### 2.2.2 Simple enclosures

Apart from the absence of the central pit simple enclosures at Ziwa have almost the same characteristics as the pit enclosure. They have rather high and thick walls around the entrance getting lower and less wide either side and in sloping areas the lower side turns into a retaining wall. The walls rarely run the entire perimeter being occasionally interrupted by *dhaka* houses.
In rare cases the enclosure outline consists of short stretches of low free standing (10cm-75cm high and up to 1m thick) or revetment walls (up to 1m high) with gaps between where housing structures once stood. These enclosures have the most extensive observable housing consisting of circular raised platforms being remnants of grain storage huts and stone outlines of houses.

The free standing walls built as division walls between the dhaka houses must have abutted to the house walls (Figure 5). The subsequent collapse of the houses could have caused some of the collapses noticeable in some enclosures. Dhaka fragments are observable on or in the enclosure walls. It has already been indicated how this may be a source of structural instability in dry stonewalls.
Not so familiar are the enclosures which do not show any conclusive evidence of function as they lack occupation deposits. These were probably used as stock pens.

2.2.3 Forts

Less common than the terraces and pit enclosures in the Ziwa area are the forts. These are usually found in fine commanding situations on hills and promontories with views over a large segment of the surrounding country. Generally the forts are not well constructed and MacIver (1906: 4) described them as carelessly constructed of large and small pieces of unworked stone piled one upon the other without mortar. Their main features include thick (1.5-2.5m), high outer walls (1.5-3m). The walls are thickened at the base to provide a banquette, which runs round on the inside, a little below the top of the outer half of the wall (raised parapet) (Figure 6a).

![Figure 6. a) Ruin 16, banquette and parapet. b) lintelled inner enclosure entrance.](image)

At Ziwa few of the forts have squarish loopholes while all have at least two lintelled outer entrances. The loopholes are placed about 1-2m from the ground but their function is uncertain as they are not splayed and so give such a restricted view or field of fire that no weapon could be discharged effectively through them. The sizes range from 25-50m² and the top is laid with stone slabs as in drain holes.

The sizes of the entrances are similar to those found in enclosures averaging 1.2m by 50cm. The entrances also have horizontal drawbar holes and sometimes a locking slot in the roof through the banquette above. At least two of the forts at Ziwa like Mujinga Fort and Ruin 16 have
an inner enclosure of similarly massively constructed walls and lintelled entrances (Figure 6b). At Mujinga the inner enclosure is also loopholed. Ruin 16 has at least two drain holes on the southern outer wall. The foundations are usually on bedrock as well as boulders, thereby providing a good base for bearing capacity.

It has already been indicated how the lintelled entrances, draw bar wholes and drains can be sources of structural instability in stone structures. The square loopholes that penetrate the thick walls at varying heights and intervals are a further cause of instability as often there is substantial stone blocks loading above them. Indeed at other sites like Nyangwe Fort in Nyanga National Park which has about fifty four loopholes the walls are badly ruined over these features. The poorness of the stonework in the forts (for example a number of gaping voids and poorly fitting blocks in Ruin 16) has contributed to the ruining of some forts.

However, the thickening at the base provided by the banquette helps to stabilise the wall as there is sufficient cross section to resist overturning moments. Compared to enclosures and pit enclosures which are generally built on gentle bedrock foundations, forts are usually built on rock outcrops and boulders sloping downwards away from the wall face which may be substantially inclined (up to $45^0$ from the horizontal). Thus in a number of cases there is the natural tendency for the walls to slip along the base.

The above is a simplified broad outline of the types of dry stone structures found at Ziwa. It is clear however that there are many internal factors in the construction of the Ziwa structures that may contribute to instability. These factors will be discussed in the next chapter.
3. Mechanisms of structural instability and failure at Ziwa

Structural instability in dry stone walls of the Great Zimbabwe type monuments has been comprehensively studied since the 1970s. This has resulted in fairly detailed determinations of the mechanisms and causes of structural failure. The most recent work is that of Walker and Dickens (1992) that established five broad categories of modes of failure in stone structures of the Great Zimbabwe type. The modes of failure are bulging, settlement, splitting, toppling and progressive wall collapse. Despite the difference in construction styles between madzimbabwe and Nyanga stone structures these modes of failure appear to be applicable in both cases. Therefore Walker and Dickens’ (1992) descriptions of the mechanisms of failure will be followed in this case study.

Altogether forty enclosures and pit structures were recorded. 75% of the structures had some structural problems. The main problems identified for stone structures were bulging and toppling.

3.1 Bulging
In bulging, a section of stone blocks in the face project outwards to form a convex profile in a previously plane face (Walker & Dickens 1992: 64). At Ziwa bulging is prevalent in both free standing and retaining walls. However it may be difficult to recognise because the wall outlines are usually wavy, unsymmetrical and adapt themselves to the irregularity of the ground surface dominated by rocks and boulders.

In the majority of cases at Ziwa bulging failure is recognised through manifestations such as deformed wall profile, fracture of blocks due to excessive stress, tilting of base blocks, voids behind walls and numerous openings between or missing blocks (Figure 7). In rare cases bulging can be detected from soil ingression into the base of the wall.
The main causes of bulging failure include mostly a combination of bearing capacity failure, disturbance of core material, slippage of base blocks in walls built on bedrock, excessive lateral earth pressure, and vegetation growth within the wall structure (Figure 8). Core disturbance in the retaining walls seems to arise from the effects of lateral earth and backfill pressure. It was observed that core disturbance could also arise where base blocks have slipped in inclined bedrock or boulder foundations. In all types of walls vegetation growth within the wall structure has caused significant core material disturbance.
3.2 Toppling

Toppling can be in two forms, viz block toppling - which is the displacement of the upper blocks in the wall away from their initial position and wall toppling – the overturning of a retaining wall due to excessive lateral pressure (Walker & Dickens 1992: 67-8).

Evidence of block toppling at Ziwa is prevalent. In the majority of cases loose blocks can be seen balanced on the edge of the wall and many have fallen and can be observed at the base of walls (Figure 9a).

![Figure 9. a) Ruin 16, block toppling. b) Ruin 1, the decay of the roots could lead to the previously supported blocks toppling.](image)

Block toppling is usually caused by the vegetation growing on most structures as the root system, sprouting shrubs and tree trunks disturb blocks. The annual cycles of clearing of vegetation growing on top of walls may also result in block toppling if not carefully executed. The removal of vegetation and subsequent decay of tree roots or trunk could lead to block toppling as the blocks try to resettle. Further humans, including staff members and tourists climb and move along stone walls. Animals such as baboons and grazing cattle are also a major cause of block toppling, the former occasionally intentionally in search of insects. In many instances, for example Ruin 16 fort at Ziwa, most top blocks do not have sufficient restraint and any disturbance will result in toppling (see Figure 6).

Wall toppling is also common in many of the retaining terrace and enclosure walls. According to Walker and Dickens (1992), this mode of failure results from negative eccentricity of the resultant thrust line at the base of the wall and so the wall rotates about its toe. This kind of mechanism is difficult to establish at Ziwa as of now as studies are still at a preliminary stage. However, the rotation of a wall at its toe could be impossible in the type of walls at Ziwa which lack block bonding on the face and between the core and the face. It is evident that a significant
number of wall sections have collapsed throughout the estate (Figure 10), however it cannot be ascertained whether this is a result of wall toppling.

In sections that have not yet collapsed wall toppling can be predicted by the presence of outward/inward leaning wall profiles (Figure 11), loose or missing blocks and vegetation growing within the wall structure. Excessive lateral earth pressure in retaining terrace and enclosure walls appears to be a cause of wall toppling at Ziwa. Lateral earth pressure tends to fluctuate throughout the year and usually increases during the rainy season due to rainfall ingression into core and backfill. This is exacerbated by the absence of drains on most platforms and terraces, the latter being originally built partly as water retention structures. In addition vegetation, including falling trees may also cause wall toppling.

Figure 10. Ruin 1 terracing, fresh wall collapse

Figure 11. a) MSE6 enclosure, outward leaning wall. b) Ruin 1, inward leaning wall.
3.3 Progressive wall collapse
Progressive wall collapse is another mode of structural failure observed at Ziwa. When a section of a wall has collapsed the zone of instability will spread progressively along the wall length (Walker & Dickens 1992). When a section of a wall collapses blocks in the adjacent wall length will be disturbed. Core movement and lateral forces may cause the wall faces and blocks to topple as a result of the lack of restraint. The poor bonding in R style walls at Ziwa increases the rate and extent of progressive wall collapse. The lack of support for wall ends that originally leaned against houses could cause progressive wall collapse as well. The problem may be accelerated by vegetation growth, cattle walking across collapsed sections and baboons searching for insects (Figure 12). Humans also aide the problem by creating unauthorised paths across terraces. The animal and human paths contribute to the formation of water channels that may result in erosion and washing away of soil or backfill in retaining walls during the rainy season.

Figure 12. MSE6, progressive wall collapse. Old collapse is to the right and new collapse to the left. Fresh collapse is suspected to be caused by baboons.

3.4 Splitting
Splitting is defined as vertical separation of block bonding through the height of the wall. The problems of vertical splitting appear to be rare at Ziwa. Openings of vertical joints between adjacent wall sections have been identified in a few instances and these may result from lack of bonding between adjacent blocks as well vegetation growing within the wall structure (Figure 13).
3.5 Wall settlement
Wall settlement is a ground failure beneath the foundation stones that results in a downward movement, which is often accompanied by a forward rotation including a bulge above (Walker & Dickens 1992). Excessive settlement or bearing failure is restricted to walls built onto soil strata. According to Walker and Dickens settlement failures are restricted to either free standing or buttress walls as foundation failure of retaining walls is inevitably accompanied by bulging.

This problem occurs at Ziwa and results in vertical settlement and tilting and rotation of face blocks at the base of the affected wall face and bulging above settlement. Differential movements and load redistribution results in the tilting, loosening as well as openings between blocks.

The cause of wall settlement in most cases is bearing capacity failure of the foundation material. At Ziwa this is aided by burrowing animals and occasionally hunters digging out animals from burrows. As in other modes of failure vegetation influences wall settlement as tree roots disturb foundation material.

3.6 Internal and external factors influencing deterioration at Ziwa
Walls may deteriorate due to internal or external factors. According to Walker and Dickens (1992) internal factors relate to problems inherent with the form of construction adopted, and without maintenance and/or altering the structure may be a continual cause of further deterioration.
Thus the inherent weaknesses of the construction technique are generally the primary causes of wall instability.

3.6.1 Internal factors influencing deterioration

As seen at the beginning most of the walls at Ziwa are about 100 to 300 years old. The fact that the majority of them have remained standing in a sound condition for this long time suggests the structural strength of the form of wall construction. However, there are certain construction techniques in the structures that contribute to low factor of safety.

It has been observed that deformation may arise from material failure of the blocks. At Ziwa a number of walls have fractured blocks indicating failure that could cause or abate deformation. Flexural fracture has also occurred in some of the many lintelled entrances in the stone structures. The fracture which is noted in bulges (Figure 9a) could be a result of load redistribution. However, in other cases the poor quality of the blocks could be the cause (Figure 9a).

Block fracture has also been observed in blocks spanning the gap in the horizontal locking slots. This has been observed in heavily built up entrances, suggesting that the blocks may be fracturing due to excessive loading (Figure 14). Structural failures are common on entrances where there are lintelled entrances as well as locking slots. For example the two entrances in MW34 and three entrances in Ruin 16 have been and restored after some collapses.

![Figure 14. Ruin 1, a) lintelled entrance with block fracture in horizontal locking slots b).](image)

Frequently the walls above the drains in enclosures, especially pit enclosures have collapsed. Although the cause of this failure has not been investigated it is suspected that this could be a result of fracture failure of the blocks spanning the drain gap caused by excessive loading from the
walls above and the backfill. Disturbance of the backfill by lateral pressures could also lead to displacement of the blocks spanning the drain gap.

In both granite and dolerite structures there is poor contact between adjacent blocks due to their rough surfaces and curved and irregular profiles. Hence there is excessive use of wedges and poor linkage or bonding in the construction of the walls (Figure 15). Excessive wedging reduces the inherent stability of the wall if movement occurs after construction. Because the stones do not always fit together there is often a high voids ratio in the core as well as the face. The high voids ratio in retaining walls has resulted in soil being gradually washed into the wall interstices. With time this soil ingression has increased the lateral pressure onto the outer faces leading to wall disturbance or collapse. This is aggravated by poor drainage in pit enclosures where there is usually only one drain hole that runs from the pit.

![Figure 15. a) Hamba West and b) Ruin 16; excessive wedging and voids due to irregular blocks in granite and dolerite structures respectively.](image)

In enclosures and free standing walls there is no bonding between the core and the face blocks as the general construction technique is to have two rows of large blocks forming the outer faces with rubble infill. These stacks of granite or dolerite blocks will only remain stable if there is no further disturbance after construction. Lack of horizontal structural integrity, normally provided by through stones or tie stones also significantly lowers the factor of safety as lateral forces within the core will be easily transferred to the face of the walls causing them to deform (Figure 16).
Figure 16. a) Hamba West granite terrace and b) Campsite dolerite terrace, showing the construction form of the face and core.

The construction of structures on inclined rock outcrops or incorporating sloping boulders sometimes contributes to wall disturbance. At Ziwa wall or block slippage along the base is common (Figure 17).

Ancient passages used to move through the field systems often run at right angles to the slope, breaking the continuity of some terraces. Without maintenance the passages can heavily be affected by water erosion during the rainy season. This removes away soil from the base of the passage walls thereby inducing ground movement.

Figure 17. Ruin 1, wall and block slippage.

There are many intentionally blocked pit enclosures at Ziwa. These are assumed to have been closed by the original inhabitants being rendered unusable presumably due to structural failure.
3.6.2 External factors influencing deterioration

External factors contribute to the deterioration of the condition of the walls and may arise from influences such as rainfall, vegetation growth, and animals. The influences of these factors have already been alluded to when discussing the different modes of failure and few additional details here will suffice.

At Ziwa it has been discerned that occasionally some walls have collapsed during the rainy season. The average annual rainfall at Ziwa for the past ten years is about 900mm. Studies have shown that rainfall can influence the behaviour of the walls by reducing the shear strength of joints in retaining walls; increasing backfill pressure and inducing ground movements. All these forces may be the cause of structural deformation and failure in the dry stone walls.

Vegetation growth against or within the wall structure is prevalent at Ziwa. Most stone walls are crumbling from the effects of uncontrolled vegetation. The roots of shrubs and large trees easily penetrate the wall structure due to the high voids ratio. This leads to displacement of blocks (see Figures 8 & 9) and causes a lot of deformation. As already seen the core material in most retaining walls tends to be loose small stones with lots of soil. This encourages the growth of vegetation within the wall structure. In many cases trees have fallen of walls causing collapses. If left unmaintained, vegetation will establish itself within the crevices of dry laid masonry and can be well-established within a year with root systems wedged between stones (Figure 17).

![Figure 17. a) Ruin 1 and b) Camping site terracing vegetation proliferation within and against walls.](image-url)
Ziwa provides vital grazing to cattle from surrounding villages. Grazing in the commons is very poor for most parts of the year. As there is no protective fence most villagers release their cattle into the monuments area in the morning and round them up at the end of the day or sometimes leave them there for days. There is concern from the NMMZ that livestock cause a lot of damage as they move about on the estate. Cattle tend to move along ancient track ways but sometimes create new paths across terracing, especially on low walled and collapsed sections. The highly unstable top blocks may be dislodged and progressive wall collapse may occur as a result of cattle movement.

Incidences of baboons dislodging blocks and destroying wall sections in search of insects are quite common as has already been cited. Burrowing by animals such as springhares and ant bears is also common in enclosures. While this may not affect the walls directly, the burrows maybe dug out by hunters in search of these or other animals that would have entered them during hunting expeditions. The hunters sometimes destroy walls the catch the animals.

In related cases the lintelled pit tunnels may be used as refuge places by animals running away from hunters and have often been destroyed as the hunters try to catch the animals. The local villagers sometimes dismantle walls and use the stones to build houses. In several places at Ziwa national monuments heaps of stones from destroyed terracing ready for collection was common in the 1990s. For example a prominent politician from Sanyangare Village attempted to forcibly build his homestead inside the monument on a hill to the north west of Ziwa. Although he was eventually stopped a lot of damage had been caused as several enclosures and tiers of terraces were destroyed.

In the 1990s the District Administrator’s office constructed a dam on Tsanga River inside the Ziwa national monuments northern boundary (Figure 18). The dam construction resulted in the destruction of about 100 terraces, with lengths of up to 30m per wall being removed. The rocks were used to build a wall about 60m long, 1.50m thick and a height of about 4.50m.

In 1994 a group of women collecting firewood on Ziwa national monuments and was later interviewed had deliberately dismantled scores of a flight of terraces to create a path uphill. The incidences of intentional destruction by the locals have subsided due to improved security and policing.

Ziwa is a source of firewood and construction timber for the surrounding communities. Indiscriminate cutting down of trees occurs frequently.
Some of the trees are felled onto walls and disturb or damage them. Villagers sometimes use ox-drawn sledges to carry the firewood and timber. This has destroyed some terraces and is triggering some extreme erosion problems.

![Image](image1.jpg)  ![Image](image2.jpg)

*Figure 18. a) Dam on Tsanga River constructed using blocks from destroyed terraces (b).*

The army battle school located to the south of Nyangombe River has been carrying out some military exercises on Ziwa farm. On certain occasions their activities have been damaging to the fabric of the stone walls, to the extent that NMMZ has lodged several written complaints. The trail of their activities is evidenced by heavy truck tyre impressions off road; debris of mock battles which include smoke cans and spent cartridges, dug-out bankers, and decoys; fire places and empty food cans in enclosures etc. These exercises are bound to result in some disturbances to wall structure although this could be minor and restricted to block toppling or intentional removal.

In rare cases termite activities at Ziwa have been identified as influencing wall deterioration. Termites may develop mounds against walls and establish their soil channels within walls causing bulging (Figure 19).

![Image](image3.jpg)

*Figure 19. Pit structure MW34, bulging from termite activity.*
3.7 Structural monitoring at Ziwa

Little monitoring has been undertaken at Ziwa although there is now a better maintenance programme than in the pre-1990s period. Structural monitoring at Ziwa was attempted in the 1990s following the detailed studies at Great Zimbabwe. However it was discovered that the precise monitoring techniques used at Great Zimbabwe such as the demec gauge and triangulation measurements were largely inapplicable at Ziwa because of the architectural style of the walls. As at other stone walled sites a monitoring system at Ziwa would enable identification of areas with structural problems and causes of deterioration, quantification of the movements and the levels and extent of corrective measures required. The data obtained from these two processes helps in understanding the structural behaviour of the walls and determine the safety thresholds.

At the moment there is no monitoring scheme that has been officially adopted for the site, although there has been experimentation with some of the less precise techniques. One of the techniques that have been tried at Ziwa to detect in-plane movement is that which uses glass tell-tales. This involves fixing a glass drawn wire across an area where movement is suspected. The presence or absence of a broken wire can then be used to evaluate the structural stability status of a wall.

A broken wire would be interpreted as indicating movement, hence potential instability and unbroken wire a stable wall. The method is simple to use and does not require much skill to implement. There is no documentation on the performance of this method or why it was abandoned at Ziwa. In this technique it is very difficult to quantify the magnitude of the movement. Further animals and visitors can easily break the glass wire thereby giving a false impression.

The other method that has been tried is photography. Comparison of old and new photographs of stone structures has been shown to be a very useful monitoring mechanism in Zimbabwe. A sequence of photographs may enable one to estimate problems, distinguish between old and recent problems and determine progressive deterioration. Ziwa has some old and recent photographs but this record is patchy. However a more detailed record was constructed in the 1990s. In 1993 a number of structures were systematically photographed with the assistance of the conservation team at Great Zimbabwe. The purpose of the exercise was to create a collection of photographs that could be used for comparative structural monitoring and interventive work. The exercise produced a comprehensive photographic record of sections of walling in enclosures around the site.
museum. However, due to the vastness of the monument only the core area between the site museum and Ruin 16 was covered. A comparative analysis of two sets of photos taken in 1993 and during this research reveals deterioration in some structures, for example MW34 and Ruin 16. This shows that photography can be an effective monitoring tool.

The record was re-examined and shows that since 1993 it has not been used to monitor the structures. It is now almost twenty years since this record was created; ideally a new comparative set of photographs should have been taken. Further there is no proper archive and photographs are not being properly stored and could deteriorate making the record difficult to use with time. The method is not sufficiently suitable for accurate structural monitoring to record wall movements and further understanding of wall behaviour.

If photography will continue to be employed there is need to work in a systematic way. The standard practice when using photography as a monitoring tool is that the sets of photographs should be as similar as possible regarding sectioning and positioning in order to have comparable documentation. The baseline photo documentation must illustrate all the aspects being considered important, including threats, on-going changes and instability. The camera positions must be identical from visit to visit and this can be ensured by taking precise measurements and marking the positions on a site map.

Photography is becoming cheaper with the development of digital technology and NMMZ should be able to afford and sustain a photographic documentation programme at Ziwa. The site now has the post of a resident Site Administrator who with minimum orientation could spearhead a continuous photography programme. There is electricity and it is possible to set up equipment such as a PC, a printer and photographic accessories. In addition video filming could also be tried.

Techniques such as Demec strain gauge and triangulation survey are currently considered to be the most reliable and accurate in measuring in-plane and out-plane movements and understanding wall behaviour. However, engineering studies have shown that these methods are not suitable at Ziwa where the low height of the walls and the random construction techniques do not lend themselves to these monitoring strategies (Walker & Dickens 1992). Further triangulation would be difficult to apply at Ziwa due to the complex terrain and the closeness of most structures that would make setting up of survey stations difficult. Walker and Dickens (1992) proposed that regular inspection, maintenance and vegetation control would be the best suitable courses of action.
4. Contemporary dry stone construction and monitoring

A survey of modern dry stone wall construction in Nyanga was also conducted. It was hoped that this could shed light on construction techniques and how these affect wall stability as well as establishing indigenous knowledge and methods of conservation. Four places in the Chitsanza and Bende Gap areas were visited and interviews conducted with community members.

Although extensive terrace construction ended in the early 1900s, there are historical records of isolated continuing terracing. The local community in Nyanga has largely abandoned terrace construction but still build dry stone structures of various types. The death of terracing could be partly linked to the Native land Husbandry Act of 1951 that prohibited cultivation of slopes above 10% gradient. However, the post independence (1980) era has seen a resurgence of slope cultivation as a result of land shortages and non-observance of restrictions.

It was noted that new contemporary rough terrace structures were emerging in a number of places. In most fields stones removed from top soil have been dumped along the contour and the field. No attempts have been made in most instances to build a wall facing in the structures. Where such an attempt has been made the series is single-faced. There are however some homesteads that are surrounded by systematically constructed modern dolerite terracing (Figure 20). These are mainly retaining walls sometimes double faced and similar in construction style to ancient terracing, though the workmanship appears to be poor.
Modern dry stone enclosures and field and/or home barriers are common as well (Figures 21 & 22). Enclosures are normally used as livestock pens and homestead courts (*dare*). The construction style is again usually inferior compared to ancient enclosures and many of them are highly unstable. However one exception was noted at Magombedze Homestead where the quality of the wall is impressive (Figure 20a). The walls are free standing with two outer faces and core infill but do not have trenched foundations. The outer face blocks are irregular and the type depends on available material around the homestead. The core material consists mostly of small stones randomly placed. Wall heights range from 1m to 1.2m and about 80cm to 1m thick.

Field and homestead barriers conform to the same construction style as in enclosures, though in one case some of the walls seemed to be double faced but with no core material. Wall heights in barrier walls range from 90cm to 1.46m and thicknesses of about 36cm to 1m. Field barriers could be very expensive as they fence off several acres of cultivated areas. These barriers are meant to protect crops from both domestic and wild animals.

The choice of blocks used in the construction is said to be influenced by the shape of the stones. At Magombedze Homestead those blocks with a more or less regular shape were preferred for the outer faces. The blocks are undressed. The selection of blocks with the right shape is considered to be critical for wall stability. On the other hand at Mashenu Homestead any block could be used whether regular or not, as long as it could be placed without falling over.
The stone barriers do not have trenched foundations. Two outer lines of stones are placed first on ground surface without levelling. The core is then filled with small stones (*matsanza*) that are removed from the surrounding fields. Some outline stones also sit on the core material. Small stones are preferred for the core material because they close all voids. It would appear that the face blocks are of a sufficient size to resist lateral pressure that this random core would exert. The closure of core voids prevents small animals from getting into the walls and generally contributes to wall stability. The thin faced walls with no core material at Mashenu Homestead appeared to be very unstable. The builders also revealed that proper placement and fitting of blocks to avoid any large gaps or spaces and few or no use of pins/wedges are critical in building a stable wall. Good base stones and good core make a stable structure.

Some of the factors influencing deterioration are similar to those in ancient structures. For example the thin stacks of blocks in some of the walls will remain stable only if they are not disturbed as there is an inherently low factor of safety in such structures. The interviewees cited poor fitting in core material as a contributing factor to deterioration. Movement is likely to occur in walls built on soil strata without formal foundations.

Children climbing on walls may cause deterioration; therefore they are monitored and forbidden from doing so. At Mashenu Homestead vegetation cleared from the fields was placed on top of some of the walls to augment the height and this may disturb blocks resulting in toppling (Figure 23b). Goats can cause deterioration or collapses if allowed to walk on the walls. An ox-drawn cart accident caused minor damage at Magombedze Homestead. In livestock enclosures cattle may disturb walls by rubbing against them.
Vegetation growth is another factor that influences deterioration (Figure 23a). At one of the homesteads existing trees were not removed when the barrier wall was being constructed (Figure 22). In future the root system may affect the walls. However, in one example vegetation growing against the barrier walls is encouraged as this helps in creating a hedge around the fields.

Figure 23. a) Motosi Homestead, trees growing on walls. b) Mashenu Homestead, cut shrubs placed on top of a wall.

It was found out that once constructed little care of the walls and maintenance was carried out. No monitoring techniques are being applied. The dry stone structures are never built to last forever. Instead they are built to serve the current needs and can be abandoned or altered or destroyed depending on the dynamics of socio-economic contexts. The primary reason of constructing terraces is to remove excess stones to create cultivable land. In sloppy areas terracing serves a dual purpose of removing excess stones as well as soil conservation.

Terraces may be left to lie fallow after three or four years of cultivation or are abandoned altogether after five to ten years where people still have adequate land to create new fields. When lying fallow the terraces are not monitored or maintained. There can however be some structural repairs when the families return to old terrace fields. Further north on the escarpment in the Kumbu River valley abandoned modern terraces have been observed. These were cultivated by people from Chirimanyimo in the 1980s but by 1993 this had stopped because the soils were no longer fertile. Hence there is little concern about maintenance or monitoring as the life span of the terraces is very short. In functional agricultural terracing there could be an annual cycle of routine maintenance and augmentation of the risers when stones which appear on the surface have to be removed and placed on existing walls.
4.1 Implications of observations on conservation of ancient structures

Though the study of modern dry stone walling was not detailed enough, certain observations made may be useful when stabilising walls in ancient structures. Although the modern structures are overall less elaborate and of poor quality compared to the ancient ones, it is apparent that the masons are familiar with the basic requirements of a sound structure. According to the indigenous masons careful selection of blocks and a good foundation are the basis of a sound structure. Good workmanship in utilising available materials is also important. The core material largely made of small stones (matsanza) though random rubble seems to be of an insufficient size to exert much lateral pressure on the bigger face blocks. This factor, together with the commonly short heights could explain the generally remarkable stable conditions of most ancient terracing and enclosures.

It has already been suggested by many authors (Summers 1959; Sutton 1984; Soper 2002) that although the terracing covers expansive square miles of the Nyanga landscape, a small population consisting of a few families practicing some form of shifting cultivation could have lived in the area, continually constructing new terraces as old ones became infertile and lost soil due to erosion. The temporary nature of some of the structures like terraces may mean that in the past there could have been less concern with long term stability that bothers us today. This means that as our primary concern is long term conservation interventive stabilisation must consider a wide range of structural strengthening techniques, both traditional and modern.

The proliferation of self-taught stone masons in Nyanga provides an opportunity to NMMZ to utilize existing skills within the surrounding communities in stabilisation and restoration works. This has already been attempted when Mr Matosi of Nyahokwe Village was invited to attend a workshop for traditional stone masons at Great Zimbabwe in 2001. The idea was to build a pool of traditional stone masons that the organisation could depend on in its dry stone conservation programmes nationwide. Both parties would learn from each other through the exchange of scientific and indigenous knowledge systems. However there were no follow up programmes and the development of traditional skills seems to be no longer a priority.

Few major restorations have been undertaken at National Monuments like Ziwa, Nyahokwe and Nyangwe Fort in the 1990s. As no monitoring mechanism is in place the success of these restorations can only be measured visually - the restored walls look authentic and have not collapsed. However, there are signs that some movements may have taken
place in some of the restored sections. There is need to research further on appropriate monitoring methods so that the conservation processes can be approached and documented more systematically. This requires a lot of experimentation using both scientific and indigenous knowledge.

4.2 Conclusions and recommendations

There is currently very little understanding of wall behaviour at Ziwa and the stone buildings have several structural problems that are not being documented systematically. This research has not succeeded in developing alternative structural monitoring techniques partly due to the limited time frame and budget of the project. The testing of other techniques was not possible as the engineering and surveying methods require interdisciplinary collaboration. Although, approaches had been made to the Department of Agricultural Engineering at Africa University near Mutare the fieldwork could not be undertaken due to the resource limitations already cited.

For comprehensive evaluation of the stability and deterioration of the Ziwa structures transdisciplinary cooperation between archaeologists, engineers, surveyors and traditional stone masons is required. This should be achieved in future studies. However, it is recommended that photography be considered as the main monitoring technique until other sophisticated methods are developed. Current work should be sustained until the whole estate is covered and the overall condition of the archaeological monuments is known. Detailed recording and systematic photography should be instituted in order to build an archive for use in case of any future interventive work that may be necessary. Where the need for intervention is immediate the recommended course of action should be taken as soon as possible.

Interventive work has been somewhat ad hoc. As no proper documentation of previous work and monitoring mechanism are in place the success of restorations and reconstructions cannot be measured accurately. In order to institute some systematic monitoring the site requires a technically minded Site Administrator. He should be assisted by a team of experienced stone masons able to attend to minor problems immediately. When the structural instability of a stone feature is noted, basic stabilisation efforts can go a long way in maintaining its structural and historic integrity.
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