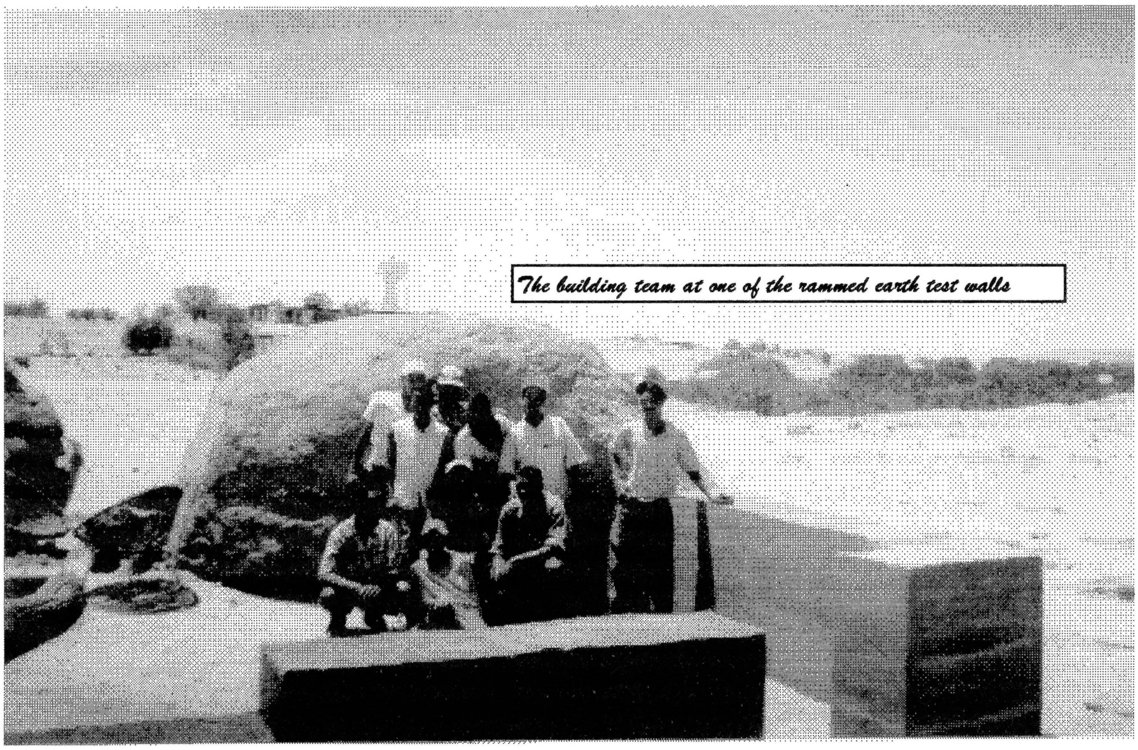
APPROPRIATE TECHNOLOGIES

Rammed earth and clay testing at Gobabeb

Abstract

The authors carried out preliminary investigations to determine the feasibility of clay and rammed earth construction at Gobabeb, and in Topnaar villages, all within the Namib Desert. Clay bricks were made from mud-cakes from the kuiseb river while soils from the gravel plains were used to make rammed earth test-blocks. Rammed earth blocks were reinforced with 0%, 2% and 5% portland cement, respectively. Clay building proved unsatisfactory. However, rammed earth construction was highly successful, particularly at 2% reinforcement. Two rammed earth test-walls were also erected with assistance from members of the local Topnaar communities. Indeed, several of the Topnaar community members plan to erect their own rammed earth dwellings within the next year.



The building team at one of the rammed earth test walls

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Rationale

Water is a scarce resource in arid lands such as Namibia and in particular, the Namib Desert where the study areas, Gobabeb and the Topnaar villages, are located. Consequently, forest resources are minimal. Being a proclaimed conservation area, the use of the few forest resources that are within the study areas, is restricted, if not totally forbidden. Still, most of the construction in the villages is done with tree barks and stems. Other buildings such as corrugated iron shacks and conventional cement buildings can also be also found.

The current use of tree barks and stems has a negative impact on the forest resources and violates existing park laws. Corrugated iron sheets provide poor indoor thermal comfort in these hot areas. Conventional cement buildings require huge amounts of cement and a lot of water for brick-making. Both cement and corrugated iron sheets are expensive and have to be bought and transported from towns further away from the villages. It is thus imperative that appropriate alternative building materials and techniques are sought and, where feasible, implemented.

1 INTRODUCTION

The Desert Research Foundation of Namibia (DRFN) and the Ministry of Environment and Tourism (MET) plan to establish a regional training and research centre at Gobabeb. The centre would support SADC's efforts at combatting desertification and would also act as a regional model for the use of appropriate technologies. As part of that effort, the authors conducted a baseline study in order to identify and evaluate the local resources, environmental opportunities and constrains that would be of concern to the planned centre. Among others (see Shanyengana, 1997), the authors also tested alternative building materials and techniques that could be of use to Gobabeb.

Clay and rammed earth tests were performed and two test structures erected. During this process, active participation of the local Topnaar communities was encouraged with the aim of transferring appropriate technologies and skills to the relevant communities. Here, appropriate technology being: "*technology that is essential, affordable, of low maintenance and, furthers the sustainable use and management of natural resources and opportunities in arid lands with due consideration of the local environmental, social, economic and political settings- conditions and values*" (Shanyengana, 1997).

This report discusses the findings of the clay and rammed earth construction experiments. The report does not serve the purpose of a scientific publication but rather, an in-house information document.

2 METHODS

2.1 Study sites

The study was conducted at Gobabeb and a neighbouring Topnaar settlement, namely Oswater. Soils for rammed earth construction tests were collected from the gravel plains at the respective sites. Clay deposits were identified and test sites selected within the Kuiseb riverbed, between the Homeb and Soutrivier villages. All the rammed earth test blocks were made and tested at Gobabeb while the clay bricks were all moulded and tested in-situ.

Figure 1: Daniel and Francisco at one of the clay testing sites within the Kuiseb riverbed. Note the 'caked' nature of the clay

2.2 Soil Analysis

A field analysis of the soil particle size distribution was performed as follows: soil was filled into a 10 ml test tube, water was added and the mixture was thoroughly shaken. After sedimentation, the ratio between sand, at the bottom of the tube, and fine material (silt and clay), on top, was determined. All the samples were later analysed, particle size distribution and salts, at the Agricultural Soils Lab in Windhoek (see appendices).

2.3 Construction equipment and techniques

Rammed earth test blocks were made in a form, measuring 30 cm x 40 cm x 21 cm (h x l x b) made from a 3 mm steel-plate. Successive layers of not-so-moist soil mixture were poured into the formwork and rammed-in with a wooden pole. The test walls were made in-situ. Again successive layers of earth were poured into a large formwork and ccmpacted with wooden and steel poles which were weighted at their ends. The test-blocks and walls were taken out of the formwork immediately. They were allowed a drying period of at least 2 weeks, even though some of them particularly the walls, only took about 5 days to dry.

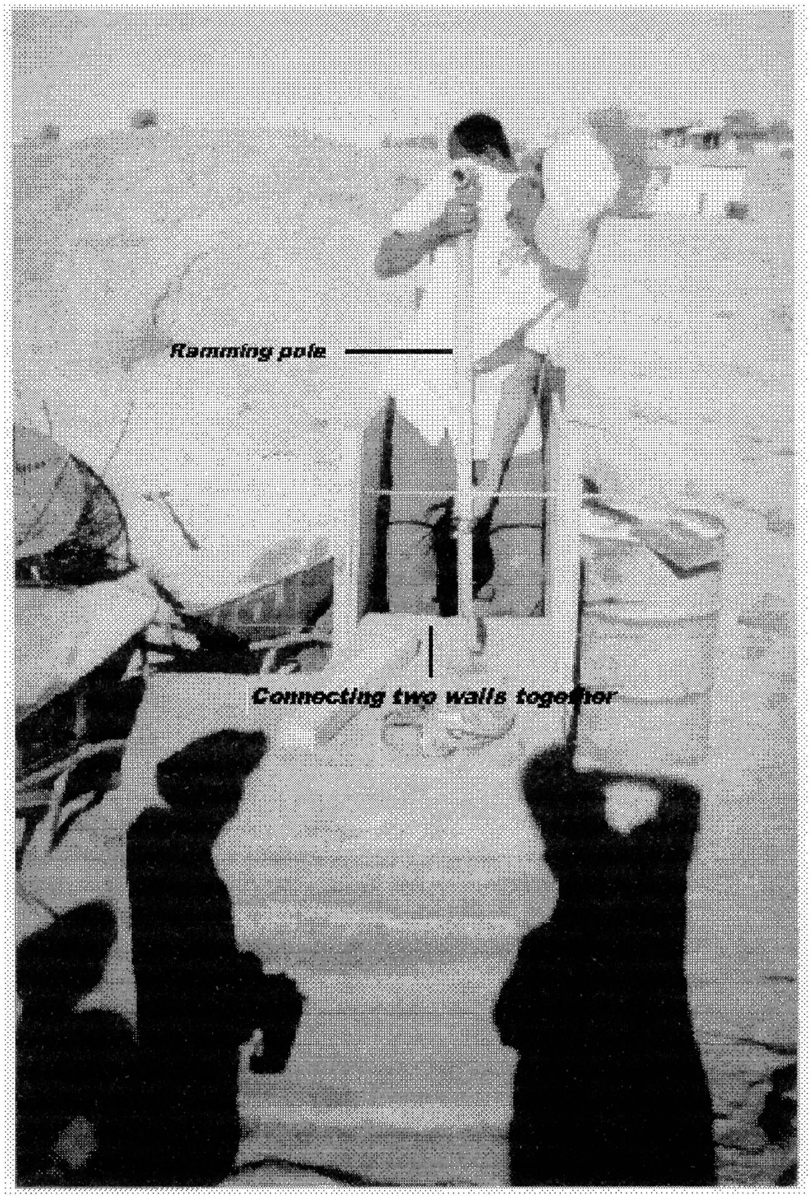

Figure 2: Constructing the test-wall, the ramming process

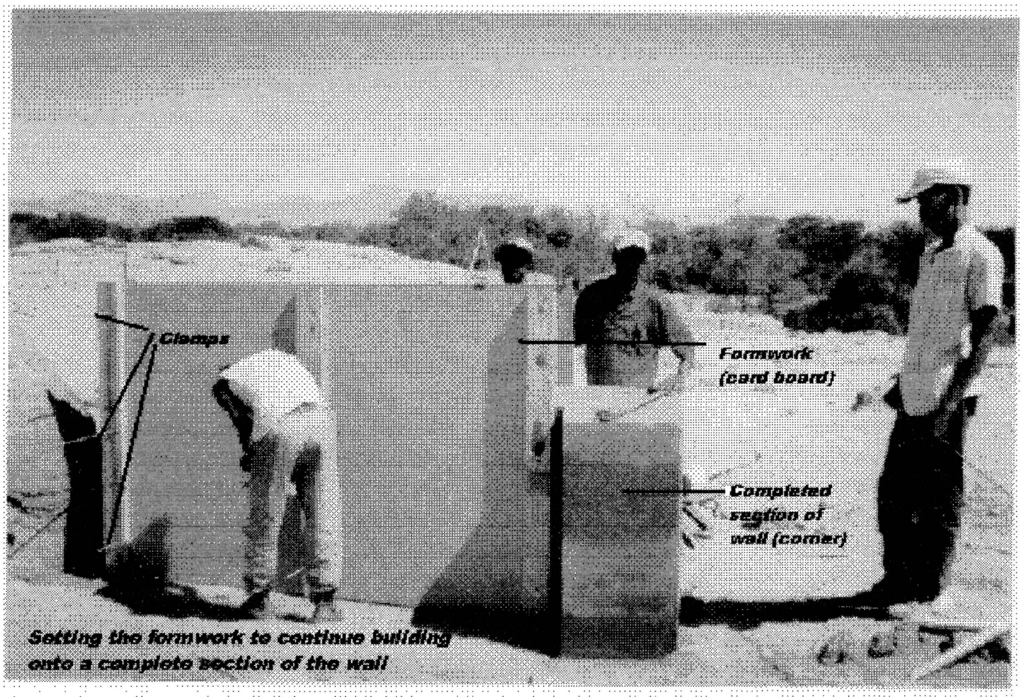

Figure 3: Connecting two sections of wall

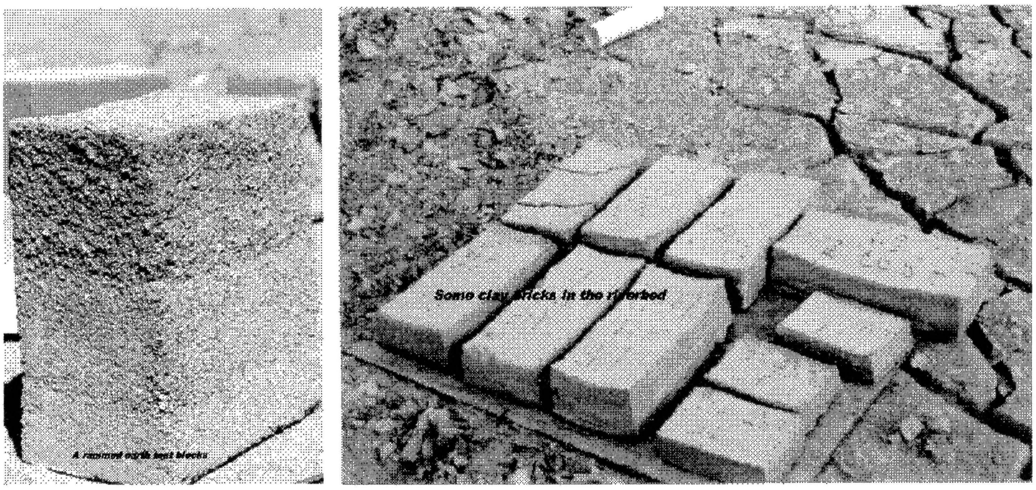

Figure 4: L - R: A rammed earth test-block and some of the clay bricks

Two standard clay bricklaying molds were used measuring 400 mm x 200 mm x 100 mm (l x b x h) and 220 mm x 160 mm x 60 mm (l x b x h) for the main blocks and the roof bricks, respectively. Clay blocks from the riverbed were reduced to powder and sieved through 500μm and 200μm sieves. About 3 parts of sand and gravel were added to 1 part of the fine material and mixed with about 4 litres of water. After throwing the mixture into the mold. The bricks were removed and allowed to dry for at least 48 hours prior to transportation. Tests were performed after at least 2 weeks.

2.4 Reinforcement with cement

For optimal rammed earth wall strength, soil with a particle size distribution of about 70% fine - coarse sand and 30% fine materials (clay and silts) is recommended. In such cases, no reinforcement is required except in earthquake risk areas and/or where reinforcement is required by a building act/policy (Easton 1996). However, soils from all the study sites lacked sufficient quantities of fine materials which then necessitated reinforcement. Portland cement was used for reinforcement. The rammed earth test blocks were build from soils with either 0%, 2% or 5% of cement added.

2.5 Testing

Altogether, 9 rammed earth test-blocks and more than 30 clay bricks were made and tested. The tests involved dropping both clay and rammed earth samples from hip height (about 1m) twice, once from breast height (about 1.5m) and once from above-head height (about 2m). All sample blocks and bricks were dropped on their 'bottoms' and then on their sides.

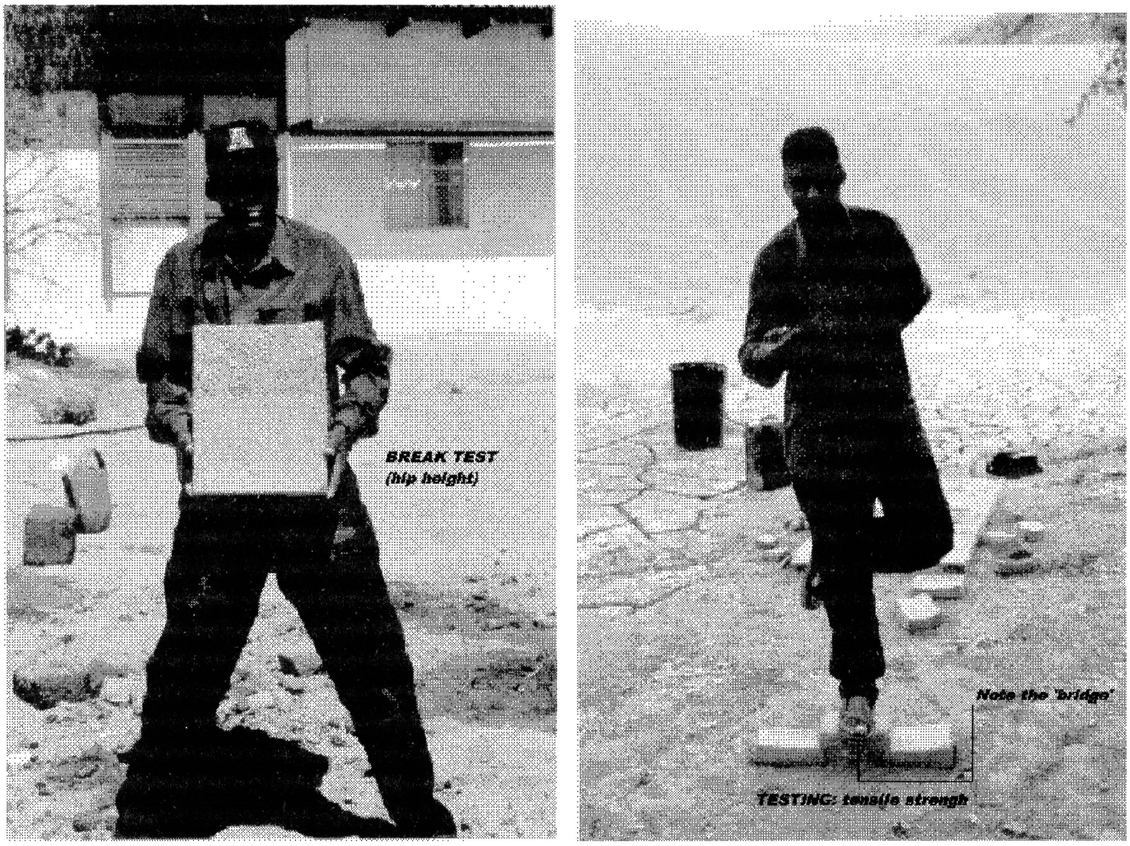

Figure 5: L - R: Break and tensile strengh tests

The surviving samples were wetted and the dropping test repeated. A few were wetted continuously, under a sprinkler, in order to simulate prolonged exposure to rain. The clay bricks were further subjected to a tensile test, as shown above. Here, a brick is placed at the ends of two other bricks, a bridge-like configuration, and a weight of about 70 kg applied to the overlying brick at increasing speed. First standing on the bridge on one leg, then applying force to it and finally jumping onto it. A good brick is one that does not break or if it does, it should not disintegrate into more than three whole segments.

Both rammed earth test-walls did not undergo a breaking test. However, they were constantly monitored and their drying process, reaction to fog and the sun's heat was noted. This monitoring is planned to continue for as long as the walls last.

3 RESULTS AND DISCUSSIONS

The results of the tests were as follows:

3.1 Rammed earth construction

3.1.1 Test blocks

Blocks that were reinforced with cement showed better resistance to fog and heat and, generally performed better during the breaking and wetting tests. The results of the breaking test were as follows:

	HEIGHT & TEST REMARKS						
Block w/ cement	**HIP** (1m)	**BREAST** (1.5 m)	**HEAD** (2m)	**SIDE HIP**	**BOTTOM FALL**	**SIDE FALL**	**WET**
0%	*Failed*						
2% w/ Gravel	*Failed*						
2% no Gravel a	*Passed*	*Failed**					
b	*Passed*	*Passed*	*Passed*	*Passed*	*Passed*	*Passed*	*Passed*
5%	*Passed*	*Passed*	*Passed*	*Passed*	*Passed*	*Passed*	*N/A*
2% clay	*Passed*	*Passed*	*Failed*				
Oswater mica	*Passed*	*Failed*					
Oswater gravel	*Passed*	*Passed*	*Passed*	*Passed*	*Crack*	*failed*	

Table 1: Results of the breaking test. *indicates that the block was still wet inside during the test

Results from the soil analysis indicate that there is a lower than required fraction of fine materials in the local soils and as such, reinforcement with cement or any binders such as lime is absolutely necessary. All the non-reinforced test-blocks failed the tests. The appropriate quantity of portland cement was found to be in the region of between 2 - 5 percent, for Gobabeb soils. This only holds for soil mixtures that have fewer coarse gravel particles. Coarser gravel particles, as indicated in the failed 2% reinforced blocks, seem to hinder proper compaction and allow water to go through the block. This would result in differentiated layers and create weak zones within the block, making it more susceptible to breaking.

All the blocks made with soils from Oswater, except one, acted differently. Even the one that was reinforced with 2% cement failed the tests. The high failure rate can be accounted for by the high content of mica, a silica-mineral, that was observed at this site. Mica is less compactible and where it occurs, within the block, it would most likely cause the block to shear or slide apart during testing, particularly when the block is dropped on its side, i.e., parallel to the ramming layers as seen in the test above.

3.1.2 Test walls and Participation by the local community

Members of the local Topnaar community, particularly builders, were informed of the clay and rammed earth testing. Initially, it was planned that the DRFN researchers and the Topnaars would build a little resource centre at a local school, Otoseb, as part of the test building. However, this did not happen due to other pressing commitments that the Topnaars had at the time. It was thus decided to build a test-wall and through this encourage technology and skills transfer.

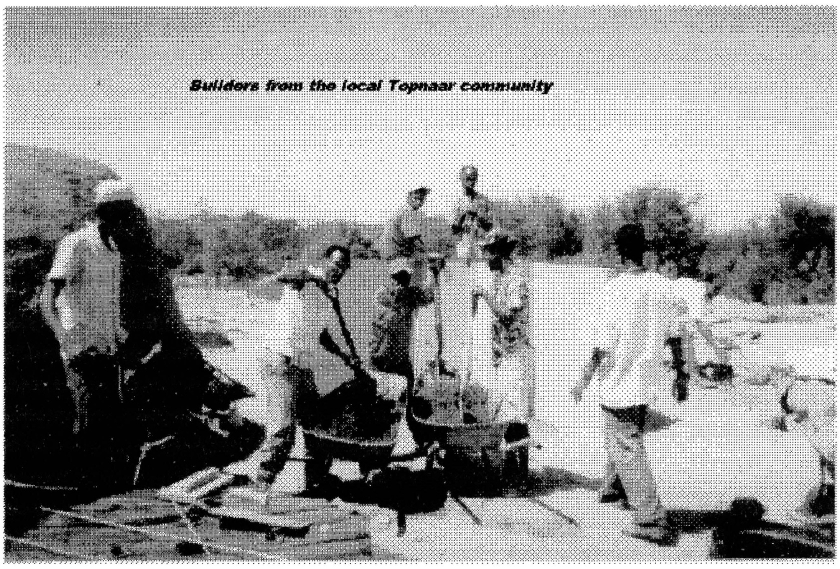

Figure 6: Builders from the local Topnaar community

Altogether, about 14 builders from Soutrivier, Natab and the 'Gobabeb village' partook in construction of the test wall. Their perceptions were most interesting. In the earlier phases of construction one builder summarised their views on the whole rammed earth building idea as follows: *'Well, Charlie, we really don't think this will work but we will help anyway'*, remarking something to do with *'sand castles'*. These perceptions changed drastically after the third and final day of construction. Indeed, the first section of the wall had started to dry and strengthen and, to everyone's astonishment or rather, objection, one of the authors was climbing onto the wall and using it as a ladder to hop into the formwork which was attached to the last section.

The wall had dried by the fifth day and was completely dry after about 2 weeks. This wall was latter plastered with cement, however, a smaller one was left un-plastered, for monitoring purposes. Plastering was deemed necessary because the wall is in the open and has no overhang roofs above it. Experiences elsewhere show that with overhang roofs and a good foundation the walls remain firm and solid for decades or, as my colleague Quentin Branch, a world authority on rammed earth, puts it: 'All that a good rammed earth building needs is a good pair of rain boots (foundation) and a rain hat (overhang roof)'.

3.2 Clay bricks

All the clay bricks appeared compact and strong. However, only less than a third of the total sample number made it through the tests. This could be explained by the high silt content, as seen from the results of the soil analysis. Unlike clays, silts are usually uncharged and have poor bonding properties. They also tend to repel each other and do not compact enough and, by so doing they weaken the brick and make it more susceptible to breaking. Trial clay bricks that were reinforced with 2% cement also failed the tests. In addition, the nature of the clay in the riverbed, hard-plate- or cake-like, and the lack of efficient pounding equipment made the process of brick-making very labour-intensive and time consuming. Indeed, under these circumstances, it is questionable wether the technique could be considered 'appropriate'.

4 RAMMED EARTH ELSEWHERE

The rammed earth technique has been in use for centuries, particularly among desert tribes of North Africa and the Middle East. There has been very little attempt at rammed earth building in Namibia. Indeed, the authors only know of one trial at a plot on the outskirts of Windhoek. Elsewhere, such as in Arizona (USA) and in Australia, rammed earth construction has scored a lot of success at both commercial and small-household levels.

Figure 7: A rammed earth house in Arizona, USA

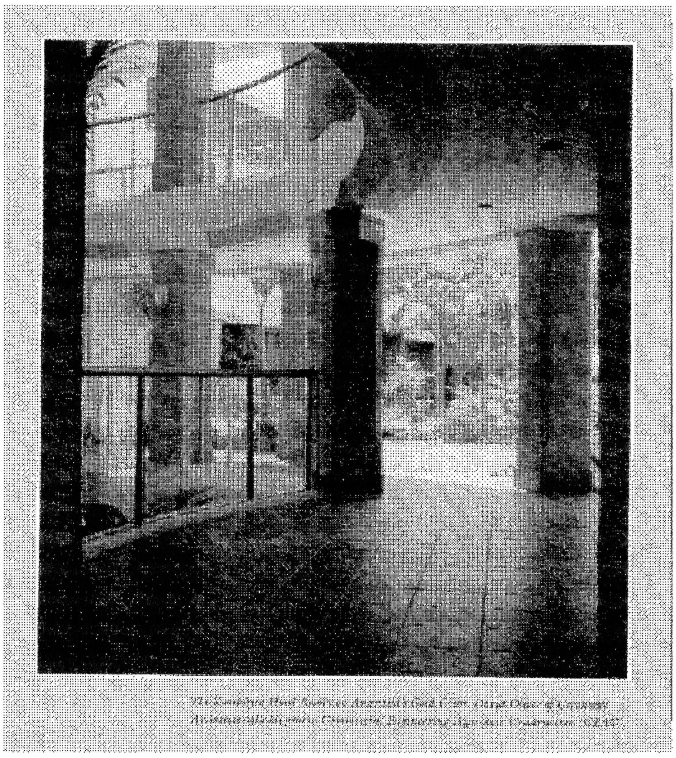

Figure 8: A rammed earth hotel in Australia

5 CONCLUSIONS

The results indicate that soils around the main station complex are feasible for rammed earth construction. Indeed, test blocks and walls built with soils reinforced with 2% of portland cement were most successful. Clay building proved 'inappropriate' owing mainly to: poor clay content (too high in silts) of the river deposits and the nature of the deposits, being cake-like, and thus requiring labour-intensive and time-consuming preparation prior to brick-making. However, overall the alternative building techniques, particularly rammed earth, received a lot of enthusiasm from the local communities. Currently, most community participants are planning on erecting their own rammed earth dwellings within the following year. They also plan to use the technique for building community-based tourist camps.

In conclusion, alternative building techniques, particularly rammed earth construction present opportunities for providing shelter and reducing the current destructive use of vegetation in remote areas such as Gobabeb and the neighbouring Topnaar villages. The technique is affordable, water-efficient, easy to master and makes use of freely-available materials and local labour. The thick walls also maintain comfortable indoor temperature. Indeed, an 'appropriate technology that is suited to conditions in arid areas such the Namib Desert.

6 REFERENCES AND SELECTED LITERATURE

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King, B., 1996. Buildings of Earth and Straw. Ecological Design Press, Sausalito, California.

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7 APPENDIX

SOIL ANALYSIS

LAB NO	SAMPLE ID	pH H2O	EC us/cm	P ppm	K ppm	Ca ppm	Mg ppm	Na ppm	Texture	Sand %	Silt %	Clay %	Sulphate-S	CaCO3
7784	Riverbed Site 1: River Sand	7.49	360	18	136	776	64	91	Sand	98	1	1	very low	none
7785	Riverbed Site 1: Clay/ Silt cake	7.54	1070	13	486	7780	506	148	Not	Enough	Sample		very low	none
7786	Sieved clay/silt from river	7.58	1184	37	404	9920	492	205	Silt Loam	23	52	25	very low	none
7787	Goabeb: Gob I sieved (no gravel)	7.55	1750	4	540	13720	456	17300	Sand	86	6	8	low	medium
7788	Oswater: gravel plain	7.94	1190	8	438	9140	552	800	Loamy Sand	82	11	7	high	low
7789	Gobabeb: unsieved (w/gravel)	7.49	1530	6	588	15080	530	12840	Sand	86	6	8	low	medium
7790	Oswater: (mica)	7.60	1110	5	498	10120	508	4668	Loamy Sand	84	10	6	high	none

Notes: EC measured in 2:5 soil:water extract….most results moderately high
2 samples have high sodium (& the highest Ecs)
However they are not high in sulphate
2 samples have high water soluble sulphate-S estimated >1000 ppm
this seems to be due to gypsum

Estimates of sulphate-S:		
	vlow	<10 ppm
	low	10-50ppm
	medium	50-500
	high	>500