THE POTENTIAL OF COMPRESSED STABILISED SOIL TECHNOLOGY IN LOW-COST HOUSING IN SUDAN

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Aims and Objectives of the Study

The study explored the Sudanese experience in the use of stabilised soil technology in low-cost housing projects for limited-income groups in the capital Khartoum. The techniques investigated are employed in prototype buildings in the form of: compressed cement-stabilised soil building blocks, ferro-cement roofs and fibre-reinforced cement roofs.

The aim of the study was to assess the performance of these buildings, both from a structural and a social perspective, and to use the lessons gained from this experience to propose recommendations to achieve improved, more sustainable and socially acceptable future low-cost housing. In order to achieve this aim, three case studies at four sites in Khartoum, where the technology has been adopted since the last fifty years, were investigated and assessed.

Thus, the objectives of the study were:

- To assess the technical performance and durability of compressed stabilised soil techniques employed in low-cost building projects in Khartoum.
- To assess the social acceptability of the techniques by the residents of the houses.
- To use the lessons gained from the structural performance of elements in the earlier designs and the shortcomings in the manufacturing processes and site practices, to propose recommendations to achieve improved, more sustainable and socially acceptable buildings in the future.

Background to the study area

Sudan is the largest country in Africa, with an area almost 1,000,000 square miles (2,590,000 km^2) constituting 8.3% of Africa's land area. In the 2003 census, the population of Sudan was 35 million people and the annual population growth was 2.8%. Urban population constitutes 38% of the total population and the unemployment rate is 30%. The current population density is 17 persons per km^2, i.e. 43 persons per square mile. The GDP per capita in 2002 was equivalent to USD 410. The percentage of population below the national poverty line in 2000 was 26%

Khartoum (20,736 square km in area) is the capital of Sudan and one of the famous colonial cities in Africa. It is composed of three towns: central Khartoum, Khartoum North and Omdurman. In the past two decades Khartoum has witnessed an increasing number of rural-urban migrants. Figures show that in 1993 it has received an estimated 1,400,000 (42%) of the total migrant population in Sudan. The 2003 estimated population of Khartoum was 5,352,000 people. The housing demand in Khartoum is estimated as 103,000 units per year, i.e. roughly about eleven housing unit for every 1000 people. The majority of households (85%) in Khartoum are on low (145,000 – 165,000 SDP/month)* to limited incomes (165,000 – 300,000 SDP/month).

Due to its increasing population numbers and very high demand for low-cost housing, Khartoum has been chosen as the target area for this study. Two of the case studies were in central Khartoum, one in Omdurman and another in Khartoum North.

Low-Cost Housing in Sudan

Sudan is faced with an ever-increasing problem of providing adequate, yet reasonably affordable housing in both urban and rural areas. Hence, low-cost housing is one of the basic needs of limited and low-income groups. In a typical housing project in Sudan, the land and services costs represent only 15% of the total housing cost. The other 85% is construction costs mainly in the form of disbursements, which are costs physically attributed to the work to be realised such as materials purchasing costs, labour costs and sub-contracting costs. For instance, the cost of building materials constitutes 60% of the total housing construction cost.

Due to the limited financial means of the majority of households in the country, in order to provide reasonably affordable housing in sufficient numbers at both the urban and rural areas, a need arises for locally available, low-cost construction materials with good structural and thermal performance, yet not requiring special skills or sophisticated machines for their fabrication. Due to its low input (15%), the land building and services promotion does not provide a possible source of savings.

Appropriate Building Materials

For any shelter programme to be successful, the cost of construction materials needs be as low as possible and the materials as durable as possible. This is true in the case of Khartoum, where the majority of people (85%) are from the low to limited income groups, who can only afford locally available traditional materials. In addition to being durable and low-cost, the selection of building materials needs to provide the most desirable levels of climatic comfort. This is due to the harsh weather conditions in the country.

Soil is the primary material used in constructing traditional low-cost dwellings in Sudan. It is considered the most appropriate construction material due to its sustainability of supply, low processing cost, ease of use and desirable thermal characteristics. It is also well suited to the local weather conditions and the indigenous occupancy patterns in the country. Soil construction methods are used in 80% of urban buildings in the country and this figure exceeds 90% in rural areas. Good quality clayey soils fit for construction purposes are widely available all over the country. The problem with conventional materials such as steel and cement is their high costs rather than their supply.

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* 1 Sudanese Pound (SDP) = 0.0002014 British Pound (GBP), i.e. 1 GBP = 4,965 SDP as in 2004.

The main drawback of soil construction, however, is its lack of durability, which demands the need for regular maintenance, frequent repairs or re-erection of the whole structure. The main causes of deterioration of soil buildings are: shrinkage cracking, erosion, underscouring, and mechanical damages due to direct or indirect water action and poor resistance of soil structures to environmental agents, especially water.

Literature has shown that better mechanical properties, improved durability and enhanced resistance to weather conditions could be achieved through compressed stabilised soil technology. Recently in Sudan, the use of Compressed Stabilised Soil Blocks (CSSBs) technology has been considered an appropriate low-cost improvement to traditional soil constructions. The technology of CSSBs has a variety of applications in the construction of aesthetic, efficient and easy to build low-cost buildings in Khartoum and is considered a viable alternative to other more expensive and less durable building materials. In using CSSBs for house construction, home ownership to limited-income groups could be delivered at comparatively low prices, as they allow the use of a wide range of locally available soil types. In addition, as the basic raw material in the production of CSSBs is soil, its source will remain abundant, thus lowering acquisition, transportation and production costs.

Methodology

To achieve the objectives of the study, three case studies at four sites in Khartoum, where the technology has been employed, were visually investigated and assessed. Case I presented an example of the compressed soil technology represented in the form of cement-stabilised soil blocks for wall construction, which have been adopted in a low-cost housing project of 92 houses in the early 1950s. Case II presented a recent experience of the CSSBs technology adopted at two sites using the same construction techniques. The buildings at both sites (Figure 2) have been constructed in 2003 using compressed cement-stabilised soil blocks for wall construction and ferro-cement vault roofs. Case III presented a past experience of the above technology of cement-stabilised soil blocks and ferro-cement roofs and fibre-reinforced cement roofs implemented in a school constructed twenty years ago (Figures 1 and 4). The current condition of all the buildings and their structural performance were examined and assessed. The social aspects were assessed by conducting face-to-face interviews with randomly selected households, using a pre-structured questionnaire. Laboratory tests on some collected blocks and roof samples have also been conducted.

Discussion of Findings

The study found that there were common issues in regards to: types of defects and deterioration modes associated with the compressed stabilised soil blocks and roofs, the probable causes of deterioration and shortcomings in the production processes. There were also common social aspects that could be drawn from the experience of the residents in terms of their acceptability and satisfaction with the improved technology implemented in their houses. These are presented in the following sections.

Summary of Technical Issues

The overall structural condition of all the buildings was good. However, visual inspection of exposed block surfaces showed some defect types, mainly in the form of surface erosion, cracks, and easily disintegrating loose material residues from blocks corners.

Other encountered defects were: cracks on the plaster skin of interior walls, peeling and falling of render from exterior walls, cracking at arch apexes, and cracks in ferro-cement vault roofs and fibre-reinforced cement roofs. Conducted compressive strength and water absorption tests on randomly selected block samples revealed that the blocks were below the identified standards in the country. The study attributed the above defects and the poor quality of blocks to the following reasons:
Low cement percentages; poor choice or inaccurate percentages of soil; poor quality of mixing water; shortcomings in the production processes; thermal expansion; lack of flexibility to accommodate structural movement; direct action or combined effect of rainfall, wind, rainwater and water spray; improper curing of the blocks; the use of unusually thick or non-uniform mortars; site related reasons - such as swelling clays leading to heave and cracks in the walls; lack of experienced workforce and prolonged lack of maintenance.

Crack measurements revealed that the majority of cracks encountered on the CSSBs were slight or negligible. Laboratory tests found that an increase in cement content results in an increase in the wet compressive strength of a CSSB and a reduction in its water absorption. The main defect types encountered on the buildings, leading to their premature deterioration, were attributed to failings in the manufacturing and processing methods and improperly counteracting the effects of exposure to the environment. Shortcomings in the processing methods arose due to lack of set specifications, quality assurance measures and site supervision, in addition to poor site practices. Prolonged lack of maintenance of CSSB structures could have also lead to their deterioration. The study found that whatever cause within or outside the block that might be responsible for initiating a crack in the wall, the subsequent development and propagation of this crack could have been easily accelerated by late, insufficient or non-existent maintenance and repairs. The lack of understanding by the relevant authorities of the need for subsequent maintenance budgets, in addition to shortages of trained experts in this form of construction, made the problem even worse.

<u>Summary of Social Aspects</u>

The majority of respondents were generally happy with the compressed soil techniques implemented in their houses, both from an aesthetic and performance points of view. Most houses were still owned by the original buyers and/or their siblings. Nearly all the respondents thought the CSSBs were an appropriate building material and preferred them to traditional fired clay bricks. The majority of respondents thought their houses were in a good state when they were constructed and are still in an acceptable condition with some basic maintenance carried out as needs arise.

The main criticism from respondents focused on the small size of plots (200 – 300m^2), which were declared inadequate by many households. However, this was not an issue when the houses were initially acquired, but due to the complex interfamily relationships in Sudan, which increase households above the original family size, the need for more space subsequently became apparent. When asked about their views, nearly all respondents wished they could expand, either horizontally or vertically. However, due to the small plot areas, horizontal expansion was not viable and some ended up expanding on land from the front road. Vertical expansion, on the other hand, was not financially feasible to many households due to the expensive construction work that would be involved to implement such a change. These issues highlight the need for considering low-cost multi-storey options in future low-cost housing projects.

All respondents had no major worries in regards to the houses structures or other serviceability problems and were happy to continue living in the houses. The main defect types observed by the occupants were: minor surface cracks in the CSSB walls and ferro-cement roofs and peeling of surface render and plaster from external CSSB walls. The main complaint from the majority of residents was the extreme heat in summer, which they all related to the poor thermal performance of the CSSBs. Fewer respondents related the reason to the thin ferro-cement roofs.

Conclusion

The thesis concludes that the overall structural condition, performance and social acceptance of the technology were good. Although the cement-stabilised soil production process is a simple one, it relies heavily on quality assurance measures. It is the improved durability of the CSSB, rather than any other property, that is likely to ensure its widespread acceptance.

The study highlighted that it is feasible to substantially improve the blocks quality without significantly increasing their cost. This can be achieved by taking into account factors affecting the blocks performance and durability and trying to improve them. If such improvements are successfully implemented then the blocks will become more acceptable and accessible to more people from the low-income groups in both urban and rural areas. However, without proper standards and codes, even skilled supervisors and workmen would not be able to appreciate the consequences of bad methods of work. This could be an important factor likely to hinder the widespread adoption of the compressed stabilised soil technology.

Finally, the study recommended the need for set standards and specifications, appropriate practical guidance and check lists for both CSSBs production processes and stabilised soil roof construction. In addition, it highlighted the need for qualified labour and workmanship. It also recommended the need for considering the social needs, desires and aspirations of residents in future designs of low-cost housing and the provision of adequate infrastructural services.

Figure 1 – A prototype school building constructed with compressed cement stabilised blocks (CSSBs) and vault ferro-cement roof.


Figure 2 – A housing complex with CSSB walls and vault ferro-cement roofs.


Figure 3 – A close look at a CSSB wall.


Figure 4 – A school building constructed with CSSB walls and fibre-reinforced cement roofs.


Figure 5 – Fibre reinforced roofing sheets supported by bearers.