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LOW COST CONSTRUCTION TECHNOLOGIES AND MATERIALS _CASE STUDY MOZAMBUIQUE

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Abstract: Low cost or affordable construction technologies and materials are often touted as a panacea in meeting the ever growing demand for rapid housing delivery in developing economies. Mozambique as with most of the developing world, from both historical perspectives and global trends in rural to urban migration, suffers an enormous service backlog and massive delivery challenges in addressing its millennium development goals in the provision of housing and shelter. It is generally acknowledged that there has recently been serious focus and growth towards the use of eco-materials and sustainable architecture in both developed and developing countries, drawn primarily as a response to global warming concerns. However the paradox of the third world remains; that the majority of populations remain steeped in traditional construction methods, which using today's modern scientific carbon 'footprint' analytic tools and relative to western comparisons qualify as low cost, green or ecological construction technologies . Ironically the biggest challenge facing the wide spread use of low-cost construction technologies in a modern economy today is primarily not sustainability but compliance with current norms in building standards and their ability to provide what we have come to currently socially characterize as reasonable shelter and comfort. This is often the basis of social acceptance and sustainable adoption of innovative low-cost solutions. This strategic perspective is often lost on advocacy groups or innovators. Regrettably this has led many innovative interventions to being stillborn. This paper explores the authors' experiences in carrying out a country survey of building materials, revision of building standards and lessons learnt on a Ministry of Science and Technology ,Mozambique in 2006 on the setting up of a pilot model Millennium Village and a national project on "Locally available materials for construction in Mozambique using appropriate technologies – (Low – Cost Construction)".

Keywords: *Low-Cost Construction Technologies, Eco-materials, Sustainable Habitats*

1. Introduction

Mozambique is characterized by plethora of types of housing ranging from conventional to no-conventional materials. Settlement patterns show concentration of populations mainly inhabiting coastal areas. The rural populations live largely under difficult conditions dominated by poverty and lack of access to knowledge on alternative, appropriate construction technologies that can exploit local resources leading to a low–cost construction. According to the Five Year Government's Program for 2005-2009

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(Resolution No. 16/2005 of May 11), the National Government set the following objectives for the broad construction sector i.e.:-

- Normalize patterns and construction models;
- Develop the national delivery capacity of construction;
- Improve the efficiency and quality of the construction works;
- Advocate and motivate the adoption of techniques and low cost technologies.

To achieve these strategic objectives, the Council of Ministers prioritized the Low-Cost Construction Technology Strategy as one of the key performance areas for implementation in 2006: registered Worksheet #198 (occupation 32/CM/2006 of 3/April), whose implementation was to commence in May 2006. The alternative technologies projects developed from this strategy were then basis of the implementation of the Appropriate, Affordable Construction Strategy, planned by the National Government.

2. Objectives

The investigation of the production of local materials and alternative technologies of "low - cost" construction houses in Mozambique was aimed:-

- To take advantage in a sustainable and ecologically acceptable way the local resources for the production of alternative construction materials;
- To promote the production of local construction materials and alternative constructive systems that are popularized and disseminated within Communities, Educational Institutions and in the Professional Training Centres;
- To contribute to the creation of regulations of alternative constructive systems and uniformity of the method and quality of the local production materials.

3. Justification

Mozambique has vast deposits of diversified natural resources, from which different kinds of construction materials can be produced. The existing methods are rudimentary and often result in precarious construction in the rural areas and high construction costs predominant in urban areas would be solved. It is a country frequented by flooding disasters and other natural disasters, making it imperative that proper action be taken on improving the housing quality (INE 2005). [9]. 62% of the population resides in the rural areas and suffers from poor service delivery and quality more than the urban dwellers.

Predominant materials are, 37,9% of the houses have pau-a-pic barked walls structures; 31,1% in adobe bricks; 75,8% have pavement(floor/foundation) of rammed earth and 74,3% have grass ceiling, stem, palm tree.[9] .The improvement of the living conditions and sanitation for the population is heavily linked with the form and adequacy of housing provision.

Figure 1: Typical Pau-a-Pic Stone, Pole Dagga hut, Boane, 2006

Figure 2: Typical Reed Hut, Estevel, Boane, 2006

Infrastructure development is the cornerstone of sustainable and harmonious growth of society in its various facets of social, economical and cultural dimensions. The initiative was cognizant that the existing legislation and antecedent building codes in force were last revised more than 45 years (REGEU, 1960). These building codes heavily propagated construction systems based on "concrete" which endear to high carbon-footprint and expensive construction costs, thereby putting a decent condign house beyond the reach of most of the population.

It was important for this project to effectively analyze the underlying problems and to demonstrate the viability of the alternative technologies for the up-scaling and promulgation of revised regulations to promote this new approach of construction. The subject of this presentation the study's initial focus was on stabilized soil bricks (SSB) masonry materials as a construction technology.

4. Methodology

For the accomplishment of this work the following methodology was used:

- Suitable representative locations for construction materials research were identified and selected from the Mozambican map. A desk-top survey was conducted to assess typical houses constructed in each area; the sites with raw material for construction materials production (soils clay and rocks); existence of materials factories; brick production and quarries. A project flow process is shown Figure 3:

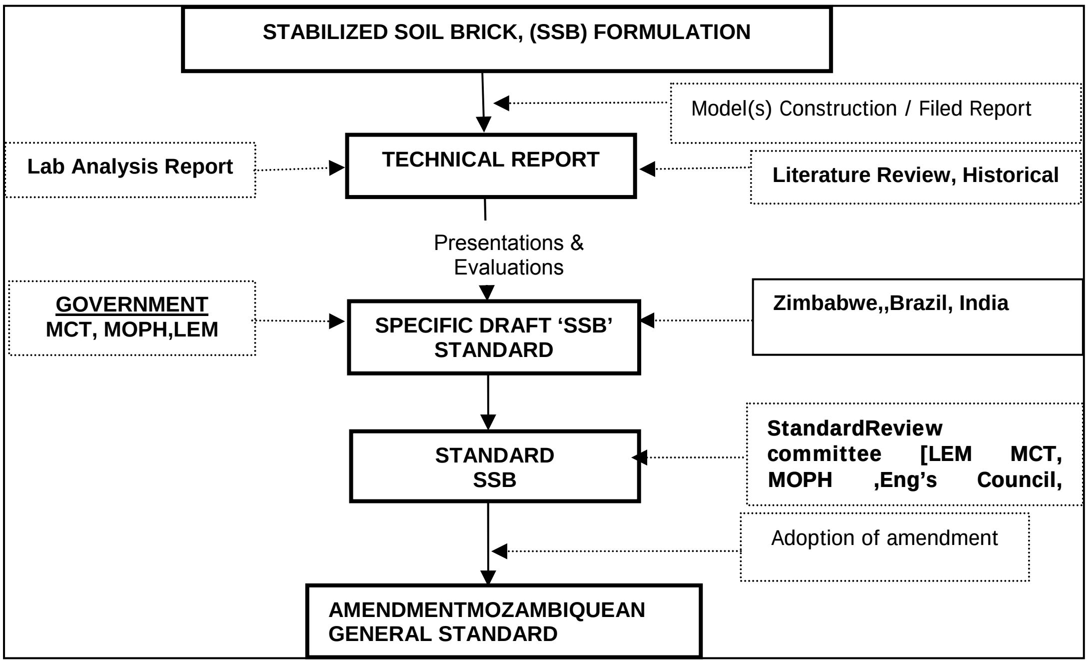

Figure 3: Flow diagram on the process to formulate SSB Standards for Mozambique

- Research visits were carried out to selected areas (Field study) where samples of soils, rocks and locally construction materials were collected to be subjected to test of characterization at Mozambique Engineering Laboratory;
- Experiences from other countries (Zimbabwe, Malaysia and India) were gained through consultation and, exchange dialogue;
- The building of masonry wall structures of Boane demonstration house models took place after a field and laboratory analyses and optimization of local soils and

imported materials for manufacturing of soil-cement blocks (SSB) by a manual Ceratec pressing machine on site.

5. Observations

- The average test results for compressive strength for the masonry units on the pilot project was 3,89MPa, which was satisfactory and above the minimum required value of 2,0 MPa (according Brazilian norms, NBR 8491 (see Tables 1 and 2):

Table 1: Criteria for evaluation of quality of blocks according to NBR 8491

Characteristic	***Dimension***	
Dimensional Variation	± 3 mm	
Compressive Strength	Average Value	≥ 2.0MPa
	Individual Value	≥ 1.7MPa
Water Absorption	Average Value	≤ 20%
	Individual Value	≤ 22%

Table 2: Compression tests results of CSB after 25 days

Formulation (4V+2R)				***Age (days)***	***Wt (Kg)***	***Area (mm^2)***	***Force of rupture (Kgf)***	***Density (g/cm^3)***	***Tensile Strength at ruptura (MPa)***
#	***Dimension (mm)***								
	L	**W**	**H**						
1	298	138	87	25	7.740	41124	145.9	2.16	3.55
2	298	138	87	25	7.400	41124	174.6	2.07	4.25
3	298	138	87	25	7.590	41124	159.3	2.12	3.87
							Average	**2.12**	**3.89**

- The rural and urban masonry demonstration model houses in Estevel and Boane main town Boane District, Maputo province were built under community participation.

Figure 4: Participation of women in block making, Estevel, Boane, Mozambique, 2006

- Calculations of the direct costs were made and compared with other types of conventional constructions;

Table 3: Direct Costs comparison for rural house model

Phase	***Costs (MTn) 26 MTn ≡ US$ 1***		
	Stabilised Soil Blocks	***Concrete Blocks***	***Industrial Clay Bricks***
Foundation	8,465.00	9,981.00	9,981.00
Walling	9,410.00	23,030.00	19,430.00
Windows, Doors	11,660.80	11,660.80	11,660.80
Roofing	11,852.00	11,852.00	11,852.00
Finishes	2,430.00	8,480.00	8,480.00
Total	***43,817.80***	***65,003.00***	***61,430.00***

It was observed that wall superstructure costs for SSB are about half the price of both the concrete and clay brick. *See Table 3*.

6. Building Codes and Design Standards Alternation

Based on the regional and international advancements status in the scientific and technological field of building materials and structural analysis, the following amendments to the building codes/regulations and standards have been made:

Foundation Designs:

- Foundations in all areas except earthquake prone areas e.g. Espungabeira District , "to be designed and constructed to transmit safely to the subsoil the total load without undue settlement and to suit existing local soil conditions."
- All designs subject to local building authority approval and or approved engineer, architect.

Wall Design and Construction – Slenderness:

- The wall design and construction is to be determined by minimum load – bearing capacity and the required minimum thickness of 100 mm, thereby fulfilling the health, safety and stability standards.
- Materials can be used for brick products and walling elements subject to local authority approval, based on approved local or international standards as verified by the local institutions such as LEM, MCT and MOPH.
- Lintels and Arches (Protection of Openings); the portion of a masonry or concrete wall above an opening shall be provided with a lintel or arch or brick – on – edge structure.

Roof:

- Any roofing material can be applied subject to a proper approved design and or the construction inspected by relevant local building authorities, engineers or architects. Any roofing material has to fulfil the health and safety requirements, to be also damp- and waterproof.

7. Way-forward on Standards and Regulations

On the basis of the results and findings of study, the following were the recommendations for consideration by the Mozambican government:-

- Immediate Adoption of the SSB Technology for delivery of houses and other structures by the government of Mozambique with the monitoring and quality control being effected by MCT/LEM Team, identified (MOPH)engineers and other experts until the specific SSB Standards/Guidelines for Mozambique are in place.

- Concurrent Amendment of the General Standards For Construction and Building Regulations in Mozambique be allowed for the continuous acceptance of identified new appropriate building materials and technologies as verified by MCT and LEM, and or witnessed by MOPH.

8. Technology Acceptance Assessment

The Ministry of Education and Health has built more SSB houses for its civil servants using this technology. The National Reconstruction Programme after Cyclone Flavio floods Relief 2006/7 along Zambezi, Buzi Rivers, saw the establishment of cooperatives for SSB production.

Figure 5: Teacher's house at 19 de Outubro, Estevel, Boane, Mozambique, 2007

In April 2008 Mozambique adopted of new National Building Regulations (MNBR) and standards with respect to the Compressed Stabilised Soil Blocks, based on the Brazilian (NBR 8491) and Zimbabwean standards. National survey investigations have indicated high spatial deposits of different raw materials whose exploitation and beneficiation necessitates adoption of respective appropriate standards. In brief it the main highlights were: -

- Southern Zone (Maputo, Namaacha, Inhambane): promotion of use of anthill soils/earth to make bricks is to be introduced and encouraged.
- Central Zone (Beira Sofala, Manhica, Tete, Inhambane): promotion of improved material extraction and furnace/kiln design for the burnt clay bricks. Also use of Stabilised Soil Blocks to be encouraged to minimize deforestation.
- Northern Zone (Nyasa, Zambezi, Nampula, Cape Delagado): promotion in the use of limestone as building material especially in Nacala. In Nyasa intensified training needs on SSB production and other earth building technologies.

9. Conclusion

The creation of low-energy ecological habitats is a key component to sustainable development. The design of the housing and the use of the materials have to correspond to local building traditions and to the user group's way of living. Religious and cultural traditions have a great influence on this and have to be included in the planning process. When introducing a new appropriate low-cost housing design it is important that it is not deemed as a type of houses only for low-income families. Social impact and effect of status is in this case very important. People with a low income do not want to live in houses labelled only for low-income people, because then everybody knows that the persons living in these houses are poor. The standardization of technology is imperative to such communities to manage perceptions. Lower income groups tend to copy the houses of the rich, which also is one of the reasons why it is important that adoption of sustainable technologies must be implemented at all levels.

As the developed world adopts low-carbon footprint housing systems this sets in motion a paradigm shift from the obsession of steel and concrete, towards a realization that communities are already endowed with natural resources it is the beneficiation knowledge systems which remain largely untapped.

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