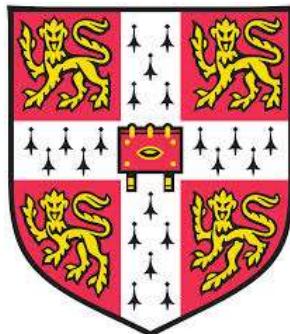


**INVESTIGATING THE RATIONALE FOR MATERIAL SELECTION IN
TROPICAL HOUSING PROJECTS IN UGANDA – A Case for
Interlocking Stabilised Soil Blocks (ISSB) Technology**



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**This dissertation is submitted for the degree of Master of Philosophy in
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Supervisor: Prof. PETER GUTHRIE

DECLARATION

This dissertation is the result of my original work and includes nothing which is the outcome of work done in collaboration except where specifically indicated in the text.

The word count is 14,187. Hence the dissertation does not exceed the word limit of 15,000 words.

Signature:

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ABSTRACT

Behind Uganda's housing construction industry are conventional practices in the choice of building materials, particularly burned bricks (BBs) bonded together with thick mortar of up to 30 mm to erect walls for housing. Due to the growing population, the demand for houses in Uganda has increased in the recent years, increasing the demand for building materials. However, meeting this increased demand can speed up deforestation and worsen the effects of climate change since the firing of bricks in Uganda takes 5.7 times more energy than that recorded in the ICE database of general baked clay bricks in the UK.

The use of Interlocking Stabilised Soil Blocks (ISSB) technology where cement is added to soil and compressed in a block press is an environmentally friendly and appropriate building technology alternative. The blocks are air-cured rather than fired. They are more durable with 80 % higher compressive strength than BB and even more cost-effective per square metre with up to 40 % cost savings accruing from dry stacking and less mortar for plastering and rendering. ISSB block presses are also now more available than in the past with Makiga and Hydraform Uganda as local suppliers.

Despite the ISSB benefits, the technology has not been fully integrated in urban housing. This research set out to investigate the current barriers to more widespread adoption of ISSB technology in relation to the rationale for building material selection. Such a research was intended to identify the specific areas that the promoters of sustainable tropical housing should focus on when disseminating the use of ISSBs.

Through a case study of ISSB construction operations by HYT Uganda (NGO) and Technology for Tomorrow T4T (Innovator) that involved unstructured field interviews, observations as well as documentary evidence, this research provided a holistic view into the problem of slow adoption of ISSBs as industry continues to use BBs and the findings were analysed by triangulation.

The study found that cost, durability, availability and acceptability by clients were the common reasons for material choice. However acceptability by clients was governed by their perceptions towards stabilised soil. From the field interviews, it was established that social attitudes point to stabilised soil as an inferior technology meant for rural settings while adding cement to soil is viewed as wastage. Hence the technology is perceived expensive and unaffordable.

The study concluded that, it is crucial for promoters to understand the local perception towards the ISSB technology and should therefore focus on educating clients as a first step. Client understanding of the ISSB technology as a sustainable and cost effective technology for building construction will go a long way in the adoption of this technology.

The implications for further research include (i) How ISSB promoters can best communicate ISSB technology to clients and (ii) The role of policy, legislation and government in promoting environmentally friendly building materials in Uganda.

Key words: Material selection, Tropical housing, Sustainability, Climate Change, ISSBs

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ACRONYMS

- BB Burned Bricks
- CEB Compressed Earth Blocks
- CSEB Compressed Stabilised Earth Blocks
- FCPF Forest Carbon Partnership Facility
- HYT Haileybury Youth Trust
- ICE Inventory of Carbon and Energy
- ISSB Interlocking Stabilised Soil Blocks
- MDG Millennium Development Goal
- MFPED Ministry of Finance, Planning and Economic Development
- NEMA National Environment Management Authority
- NGO Non-Governmental Organisations
- NHCC National Housing and Construction Company
- NPA National Planning Authority
- NFA National Forestry Authority
- T4T Technology for Tomorrow
- UBOS Uganda Bureau of Statistics
- UK United Kingdom
- UNBS Uganda National Bureau of Standards
- US Uganda Standard
- USD United States Dollars
- Ush Uganda Shillings

GLOSSARY: TERMS AND DEFINITIONS

Stabilised soil blocks

Compressed building blocks made by a mixture of soil with a portion of cement and/or lime as a stabiliser. They are also known as compressed stabilised earth blocks (CSEBs) and in some literature are also referred to as CEBs. The soil used is taken from below the topsoil, with any organic material and particles larger than 5 mm–6 mm removed.

Interlocking Stabilised Soil Blocks (ISSBs)

These are formed in presses that form grooves within the blocks such that the blocks interlock vertically and/ or horizontally.

Compressive strength

The average compressive strength at failure when five blocks have been crushed in a compression test machine at a loading rate of 150 kN per minute.

Modulus of Rupture

This is the nominal transverse breaking strength of the blocks.

Plasticity

Plasticity is the ability of a soil to submit to deformation without elastic failure characterised by cracking. A well-hydrated cohesive soil is able to deform without cracking after reaching its elastic limit.

Plasticity Index (PI)

Plasticity Index is the difference between Liquid Limit and Plastic Limit ($PI = LL - PL$). LL and PL are Atterberg limits. A high Plasticity Index (PI) means high clay content.

CHAPTER 1: INTRODUCTION

1.1 Background and Justification of the Study

Like food and water, shelter is a basic need that protects humans from the harsh climatic conditions. For countries that are challenged with provision of adequate affordable housing, low-cost building materials especially soil-based materials have been extensively researched. Although suitability of soil composition for construction is not readily standardised due to its inherent natural variability, research over the last 20 years provides quality control assessment of strength, durability and stability. Uganda is highlighted as one of the countries with suitable soil that can be optimised as a building material and its material suitability is also judged through observing its local vernacular architecture.

In Uganda, adobe Burned Bricks (BBs) are the most common earth building material bonded together with thick mortar of up to 30 mm (Hashemi et al. 2015). However, since firewood is the fuel used for the kilns, firing of the adobe bricks has a direct impact on the environment through deforestation and in turn contributes to the global climate change effects. Interlocking Stabilised Soil Blocks (ISSBs) made from a mix of cement with soil and compressed in a block press are air-cured rather than fired. ISSBs are a further development of compressed earth blocks with both horizontal and vertical in and out-of-plane grooves. These have been introduced in Uganda over the past 20 years as an alternative environmentally friendly building materials technology to BBs (Pérez-Peña, 2009). Although low-cost and more sustainable, ISSBs have not been fully integrated in the housing construction industry in the urban areas.

This research therefore uses a case study approach into the operations of two ISSB promoting companies, Technology for tomorrow in Kampala and Haileybury Youth Trust in Jinja with the following objectives.

1.2 General Objective

The research set out to investigate the current barriers to more widespread adoption of ISSB technology in relation to the rationale for building material selection. Such research

is intended to identify the specific areas that the promoters of sustainable tropical housing should focus on when disseminating the use of ISSBs in Uganda.

1.3 Specific Objectives

- (i) Determine the common baseline reasons for the choice of building materials in Uganda's housing construction industry,
- (ii) Determine the barriers to widespread adoption of ISSBs, and
- (iii) Recommend areas of special concern that promoters of ISSB technology in tropical housing should focus on.

1.4 Justification of the Study

Climate change is a global concern and the building sector contributes up to 30 % of global annual greenhouse gas emissions and consumes up to 40 % of all energy (UNEP, 2009). The high embodied carbon of modern construction materials has led to a revival in earth construction even in the developed world (White, 2013). Given Uganda's population currently at 34.9 million people increasing at an annual growth rate of 3.03 % according to UBOS (2014), the demand for housing and in turn building materials has increased. Use of BBs in Uganda's housing industry has led to increased wetland degradation as well as deforestation due to the need for wood fuel as shown in fig. 1 and 2 below.



Fig. 1: Wetland degradation



Fig. 2: Firing of bricks using wood fuel

Building materials that ensure reduced environmental impact of housing on the degradation of wetlands and deforestation will enable realisation of full economic, social and environmental value of wetlands and natural forests. According to the 2011 NEMA

Forests Valuation Study, the estimated total monetary value of forest products and services in Uganda, including carbon stocks is USD 1,276.95 million (World Bank, 2013 Uganda - Forest Carbon Partnership Facility (FCPF)). In a study to investigate the nature and extent of environmental degradation associated with brick making in the Lake Victoria region, Oteng'i *et al.* (2007) observed that a kiln stack of 10,000 bricks on average required 14 tonnes of wood which translated to 3 mature trees of 1 and 1/2 ft basal diameter. With more kilns burnt, the resultant tree cover loss is significant. The removal of tree cover exposes the soil surface to high radiation loads, erosive rains and desiccating winds, high atmospheric evaporative demands and high temperatures. Hashemi *et al.* (2015) described the current construction methods and materials in Uganda as low quality, high waste, energy-intensive production methods, associated with excessive soil extraction and deforestation.

With a boost in the construction industry, more people have joined the brick making business, using the arable land and encroaching on the wetlands. Wetlands cover approximately 26,600 km² of Uganda's total area of 241,500 km², including water bodies. With coverage of 11 % of the total land area, wetland resources represent one of the country's vital ecological and economic natural resources. Wetland degradation affects the functions and costs of other sectors (Kaggwa *et al.* 2009). For example, degradation of wetlands reduces their capacity to contain storm run-off from roads, resulting in flooding and unplanned road repairs. The convicted encroachers of wetlands are liable to imprisonment for a term not exceeding 18 months or a fine ranging from Ush 108,000 to Ush 18 million or both, according to section 98 of National Environmental Act, Chapter 153 (NEMA, 1995). However, there is laxity in enforcement as evident from the increasing wetland degradation associated with brick making activities in the wetlands in and around major towns.

There is a need for a fundamental shift from adobe technology as shown in fig.3 where a wooden mould is used to make mud sun-dried and burned bricks to ISSB technology where different types of manual or motor-driven press machines compress construction blocks from a mixture of soil and a stabilising agent. The stabiliser can be cement or lime. The soils used for the manufacture of stabilized soil blocks have to be free of deleterious and organic materials and particles larger than 5 mm–6 mm removed (UNBS, 2011).

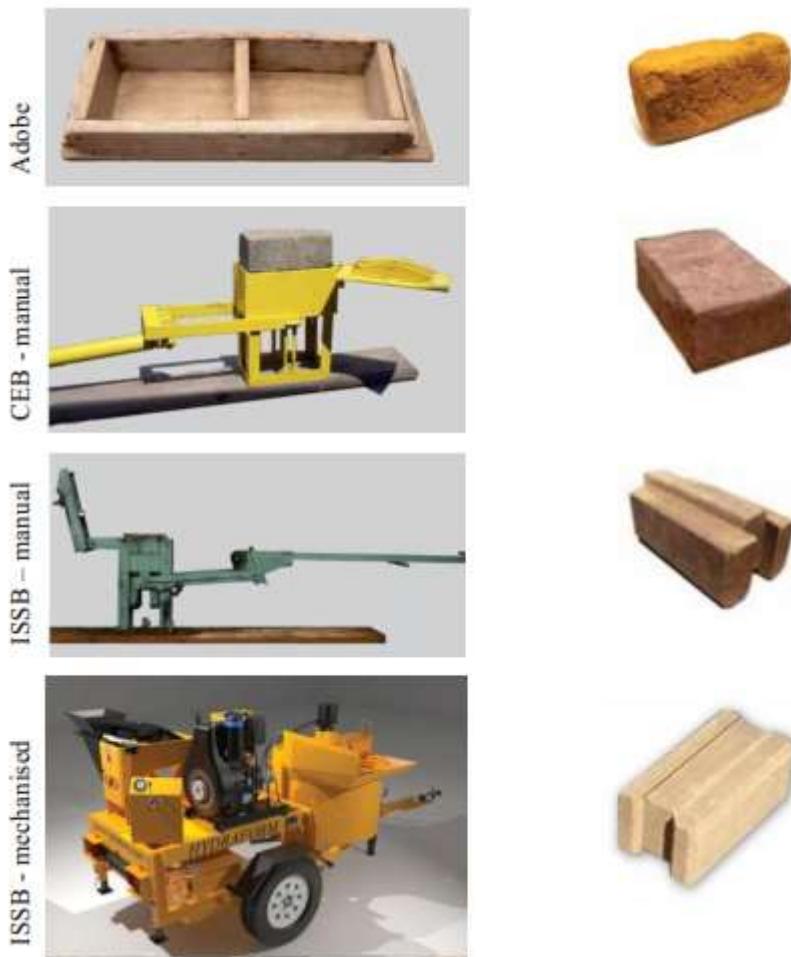


Fig. 3: Various Earth blocks and their respective presses

The ISSB press mould is standard and depending on the machine, the blocks are (i) Straight Double Interlocking Blocks, (ii) Curved Double Interlocking Blocks, and (iii) Straight Single Interlocking Blocks. The block sizes/ dimensions are specified in the US 849 (UNBS, 2011). The distinguishing feature of ISSBs from Compressed Stabilised Earth Blocks (CSEB) is the interlock that allows for dry stacking. However, this technology has both costs and benefits.

1.5 Costs and Benefits of ISSBs

The ISSB production costs include (i) procurement of the block making machine, (ii) training brick makers and builders in block production and wall construction and (iii) purchasing cement and sand. The unit price of a straight machine is USD 1,640 and curved machine is USD 1,800 inclusive of training within Kampala. Additional costs are incurred outside Kampala (T4T, 2015). On average, one 50 kg bag of cement costs Ush

29,000 equivalent to USD 8.07 at factory price (Mugenyi, 2015). From one bag of cement, 100 to 150 ISSBs can be produced and it takes two to four workers in an 8 hour work day to produce 400 to 600 blocks (Pérez-Peña, 2009). The benefits of ISSBs are beyond technical performance to include aesthetic, environmental, economic, social, health and safety, innovative research (education) and versatility (water and Sanitation projects) as elaborated in subsections 1.5.1 to 1.5.7 below.

1.5.1 Technical performance

ISSBs have better technical performance than BBs making the former a potential substitute. Appendix 1 gives a comparative analysis of ISSBs, the key parameters of which are highlighted in Table 1. According to Walker (2007), tests on CEB and BB specimens from Kenya conducted at the BRE centre for innovative construction materials confirmed that the dry compressive strength of ISSBs is over 80 % higher than BBs. The thermal conductivity for ISSBs is slightly higher than for burned bricks (Pérez-Peña, 2009). And according to the ICE database on embodied energy and carbon in construction materials, cement stabilised soil block at 5 % cement have lower values than burned clay bricks (Hammond et al. 2008). Studies in India by Venkatarama et al. (2001) also prove that the soil – cement block is the most energy-efficient among the alternative materials for walling, consuming only one-fourth of the energy of burned clay brick.

Table 1: Technical performance of ISSBs vs BBs

Parameter	ISSBs	BBs	Remarks	Source
Wet Compressive Strength (N/mm ²)	1.5	0.5	Minimum values	PÉREZ-PEÑA (2009) and US 849
Dry Compressive Strength (N/mm ²)	2.5 – 6.7	0.27 – 2.2	ISSB 80% stronger than BB	WALKER (2007) and ODONGO (2008)
Thermal Conductivity (W/m°C)	0.8 – 1.4	0.7 – 1.3	ISSB higher slightly	PÉREZ-PEÑA (2009)
Density (kg/m ³)	1700 – 2200	1400-2400		PÉREZ-PEÑA (2009)
Embodied Energy of material (MJ/kg)	0.68 @ 5 % cement	3.00	ISSB lower. 3.00 is for general clay brick. In Uganda, it is 17.136 for BB	HAMMOND et al. (2008) HASHEMI et al. (2015)

According to UNBS (2011), the US 849 technical considerations for ISSBs include;

- (i) water absorption: at max 15 % of original mass,
- (ii) density: at min 1600 kg/m³,
- (iii) shrinkage cracks: at max 0.5 mm wide and 70 mm long,
- (iv) dry and wet compressive strengths: at min 2.5 and 1.5 N/mm² respectively,
- (v) modulus of rapture: at min 0.5 N/mm², and
- (vi) weathering (% loss in mass): at max 15 %. Visually, there should be no broken edges or honey comb effect.

1.5.2 Aesthetic appearance

When compared with the current BB construction method, ISSBs wall construction has better aesthetics as shown in Table 2 below that compares various walling blocks.

Table 2: Visual appearance of various building materials

Properties	Interlocking Stabilised Soil Block	Sun-dried Mud Block	Burned Clay Brick	Stabilised Soil Blockb	Concrete Masonry Unit
GENERAL INFO					
Block Appearance					
Wall Appearance (not rendered)					

Source: PÉREZ-PEÑA (2009). Human Settlements in Crisis, Interlocking Stabilised Soil Blocks, Appropriate Earth Technologies in Uganda.

1.5.3 Environmental

ISSBs are cured over 28 days and not fired thus saving the fragile ecosystems specifically wetlands and forests. The deforestation rate of 1.8 % per year in Uganda is remarkably high and as such the Uganda - Forest Carbon Partnership Facility (FCPF) notes that there is a risk of losing the entire forest cover in the next 40 years (World Bank, 2013). As of 2005, the total area of Uganda's forests was 3,594,550 ha however between 1990 and 2005, the annual forest loss was estimated at 88,638 ha/ years (NFA, 2009). Using ISSBs reduces the wood demand thus reducing embodied energy and greenhouse gas emissions.

1.5.4 Economic

In projects where communities were mobilised and engaged as a local labour force to construct schools and teachers' housing, the overall construction costs with ISBBs use realised 40 % savings (Pérez-Peña, 2009). More generally, 20-40% savings with CSEB use have been quoted even against concrete block work (Webb, 1994). Since the blocks are weather proof with good aesthetic qualities, the entire building exterior does not have to be plastered. It may be varnished or painted to one's preference. According to HYT

practice, only about 60 % of the ISSB building is plastered with 1 cm thick plaster compared to BB building that plasters nearly 100 % with about 2 cm mortar due to uneven brick face. Also, due to its interlocking feature, little mortar (equivalent to 1/10 in BB courses) is needed between the ISSB block joints and wall construction is faster allowing for labour savings in man hours.

On-site production of the blocks implies no transport (both fuel and cost of vehicle hire) or handling costs needed. There are no losses associated especially with breakage of non-uniformly burnt bricks during transit on roads with potholes.

The block presses are currently more readily available within Uganda than in the past. Makiga and Hydraform are the current local suppliers. For community projects, manual machines are preferable to motor-driven because of cheaper labour costs and provision of more employment opportunities. Although motor-driven presses are more efficient in block production, diesel is an extra cost and associated emissions add to the carbon footprint. The block presses also requires basic maintenance skills which are transferable and any repairs can be made locally through use of scrap material and welding thus minimal maintenance costs.

1.5.5 Social

According to World Bank (2014), Uganda has experienced two decades of strong economic growth and poverty has decreased significantly in recent years from 31% in 2005-06 to 22% by 2012-13, thus surpassing the 2015 MDG target of halving the 56% poverty rate recorded in 1992-93. However, despite declining poverty rates, the absolute number of the poor has decreased relatively little due to high population growth with Uganda's population doubling since 1990. The Uganda National Household survey 2012/2013 showed unemployment rate of 9 % representing a total of 814,000 persons in the working age group 14 - 64 years (UBOS, 2014). It can be argued that the ISSB technology can tackle poverty by providing business opportunities for the block making machine companies and enhance employment of skilled local labour in block production and construction.

1.5.6 Health and safety

Without kiln burning, the brick makers live a healthier life free from air pollution effects and safe from potential fire accidents. According to Rau et al. (1980), if clay borrow pits are improperly managed, they become safety hazards (Oteng'i and Neyole, 2007). With ISSB use, safety hazards due to abandoned and degraded landscape with large open holes that get filled with water in the rainy season are avoided. These could become death traps for children who turn them into swimming areas. Kobusingye et al. (2001) noted that drowning comprises a large, mostly neglected problem in Uganda. Households that are far off from clean water sources also tend to resort to such places as water collection points posing a safety risk to the community especially women and children who fetch water. The abandoned brick making areas also become breeding zones for mosquitoes increasing the spread of malaria and thus increased health costs. The onsite excavated areas during ISSB production on the other hand are closely monitored and have in the case studies been turned into below-ground water tanks and/or pit latrines, soak pits, septic tanks or manholes.

1.5.7 Education research in sustainable practices

As an appropriate and sustainable technology, the use of ISSBs has the potential to stimulate educational dialogue regarding sustainable housing and reducing embodied energy in building materials. Good practices could lead to collaborative research between the industry and education centres into more innovative solutions for sustainable design and building materials thus improving energy efficiency even in the built environment.

1.5.8 Water and sanitation projects

Since ISSBs can be curved using a special mould, they have also been used in implementing water and sanitation projects. Curved Double Interlocking Blocks have been used in constructing underground and above the ground water tanks and curved architectural house designs. Over 600 water tanks have been constructed by CARITAS Kasana Luwero using the ISSB technology under the self-developed home financing pilot program (Pérez-Peña, 2009).

1.6 Scope and Limitations of the Study

The research is a cross-sectional study in two study areas within Uganda; one in rural Jinja and the other in Urban Kampala. The sites are 86 km apart and below in fig. 4 is a map showing their locations.

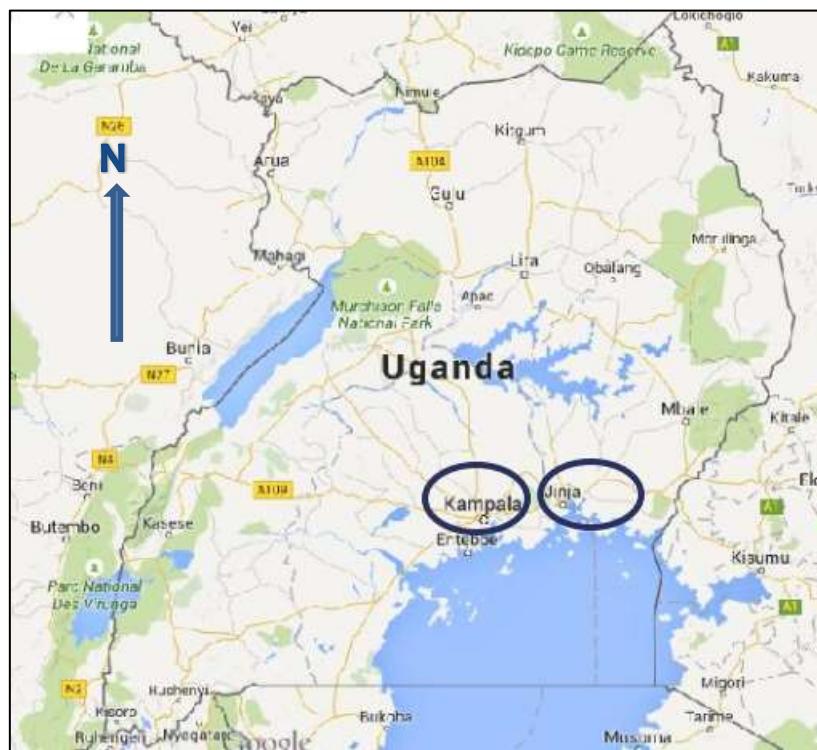


Fig. 4: Location Map of Uganda highlighting the two districts; Kampala and Jinja

1.7 Conclusion

The introduction chapter has given a background to the study focusing on the current construction practices in Uganda's housing industry with use of BBs that are environmentally damaging. It has made a case as to why ISSB technology is an appropriate and sustainable technology that needs to be adopted widely in urban housing. The study objectives are therefore fitting to identify specific areas that have caused the technology to remain on a small scale. To answer the objectives, a study was taken with two ISSB promoting companies within the scope of Kampala and Jinja.

CHAPTER 2: REVIEW OF THE LITERATURE

2.1 Introduction

This chapter is a review of various research conducted on affordable housing in tropics and in informal settlements with specific consideration of the demands tropical climate places on construction and the building materials used in tropic housing. The history of the ISSB technology in the region is also reviewed in this chapter.

2.2 Tropical Housing in Uganda

Several studies in the building sector have focused on reducing the energy usage of buildings. Some have concentrated on building design while others on the embodied energy of building materials. In the tropics, energy usage is not dominated by winter heating therefore studies focus on how building design and building materials affect indoor thermal comfort. Tropical climates are those in which heat is the dominant problem, and where, at least for a substantial part of the year, buildings serve to keep the occupants cool, rather than warm, and the annual mean temperature is not less than 20°C (Clark, 2006). The American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) define thermal comfort as that condition of mind which expresses satisfaction with the thermal environment (Webb, 1994).

Uganda is located in East Africa at latitudes of 2°S to 5°N, on the East African Plateau. Uganda's climate is tropical, but is moderated by its high altitude. Temperatures vary little throughout the year, but the average temperatures increase in the north of the country as the elevation decreases towards the Sudanese plain. Average temperatures in the coolest regions of the south-west remain below 20°C, and reach 25°C in the warmest, northernmost parts. According to the UNDP climate change profiles for Uganda, the recent climate change trends show an increase of 1.3°C in the mean annual temperature since 1960, an average rate of 0.28°C per decade (McSweeney *et al.* 2003). Daily temperature observations also show increasing trend in the number of hot days and hot nights per year. The average number of 'hot' days per year in Uganda has increased by 74 (an additional 20.4 % of days) and by 130 hot nights (an additional 37.4 % of nights) between 1960 and 2003 (McSweeney *et al.* 2003). Such climate poses demands on

construction in terms of the building design, construction methods and properties of building materials used.

In Uganda, the informal sector supplies the huge demand for housing including self-built houses, many of them illegal and mostly lacking infrastructure (UNEP, 2006). The large majority of the people cannot afford properly designed houses provided by the private sector housing developers. For instance, in Kampala, 70 % of the households live in rented tenements, while about 12 % live in stores and garages (UBOS, 2010). The housing standards are generally low, with an additional 2.6 million urban housing units required between 2000 and 2025 (MFPED, 2008). The informal settlements in Uganda are characterised by slums with more than 60 % of the population in Kampala living in slums (UNHABITAT, 2007). In both urban and rural areas, adobe burned earth bricks constitute the most widely used walling materials.

Earth construction in a tropical climate is desirable and suitable due to thermal properties of the earth building materials that allow for thermal comfort. However the current construction methods and materials in Uganda are unsustainable and involve firing of bricks whose embodied energy is 5.7 times more than general clay bricks (Hashemi et al. 2015). Moreover, in the same study, Hashemi et al. (2015) found that the bricks are bonded together with up to 30 mm of mortar which exceeds 10 mm joint thickness for normal brick work. New methods of construction that involve neither firing of the blocks nor use of excessive mortar have been introduced.

2.3 History of ISSBs in Uganda

Interlocking stabilised soil blocks (ISSBs) are earth building materials stabilised physically by compaction in a block press and chemically by addition of cement. Stabilisation helps to achieve (i) improved cohesion, (ii) improved compressive, tensile or shear strength, (iii) reduced porosity and in turn susceptibility to shrinkage and swell, and (iv) improved waterproofing, resistance to erosion or abrasion (White, 2013).

In early 1990s, Dr. Moses Musaazi of Makerere University, Kampala in Uganda who was keen on appropriate technology in the region particularly in Kenya developed a type of double interlocking system to make the construction method of blocks interlock without or with much less mortar. His innovation of the interlock is a modification of the existing

manual block press, CINVA –RAM that was developed after World War II. Dr. Musaazi's office at Makerere, built in 1994 is the first ISSB building in Uganda. UNHABITAT together with Good Earth Trust have promoted the technology in an effort to provide shelter for all especially vulnerable communities in Northern Uganda by building schools and teachers' housing. Examples of the case studies are attached in Appendix 2. In 2006, HYT Uganda started promoting ISSBs in rural communities in eastern Uganda (Jinja) and has since then built classroom blocks, rainwater storage tanks and toilet facilities in schools.

2.4 Material Suitability

Selection of building materials should involve establishing an inventory of building materials available on site and therefore the building form (Morel *et al.* 2001). However, it is common practice that pre-selection of the building form influences the choice of building materials. For earth construction, the soil used must be suitable. According to Webb (1994), a suitable soil should have a proportion of clay mineral, silica or sand and a small proportion of silt. Both saturated strength and durability of CSEBs are improved by increased cement content and impaired by clay content. The most ideal soils for cement soil block production have a plasticity index between 5 and 15 (Walker, 1995). Soils with a plasticity index above 20-25 are not suited to cement stabilisation using manual presses, due to problems with excessive drying shrinkage, inadequate durability and low compressive strength. Walker (1995) cautions that due to the inherent variability of soils, recommendations can only provide basic guidelines for cement requirements. It is unlikely that constitutive relationships for stabilised soil blocks will ever be as well defined as those, for example, of concrete and mortar. According to the study by Venkatarama *et al.* (2007) on optimum soil grading for maximum strength of soil-cement blocks, the optimum clay content is in the range 14-16 %. Also, optimal water content should always be sought to get higher strength and higher durability (Bahar *et al.* 2004).

2.5 Manufacture of ISSBs

The process of making ISSBs in Uganda involves mixing the excavated soil with 5 % Portland cement i.e. one 50 kg bag of cement added to five wheel barrows of soil. To improve the soil properties, one wheel barrow of sand is normally added. After mixing with the optimal water content, the mix is then introduced into the machine mould and compressed. The compressed blocks are stacked in layers of five and covered with

polythene to attain full curing in 28 days. Below in fig. 5 and fig. 6 is an illustration of the manufacturing process for cement-stabilised blocks.

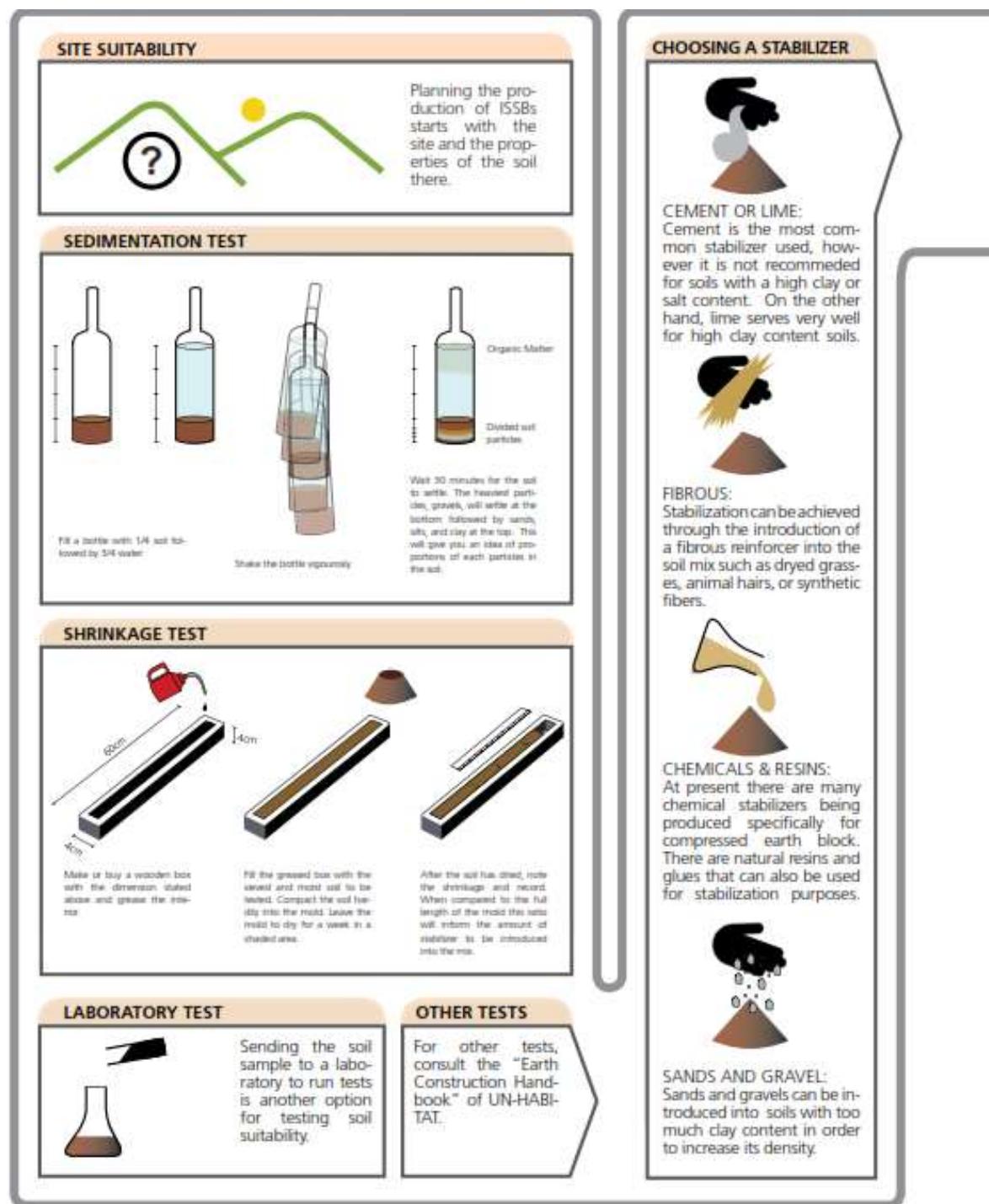


Fig. 5: Process for Cement-Stabilised Blocks

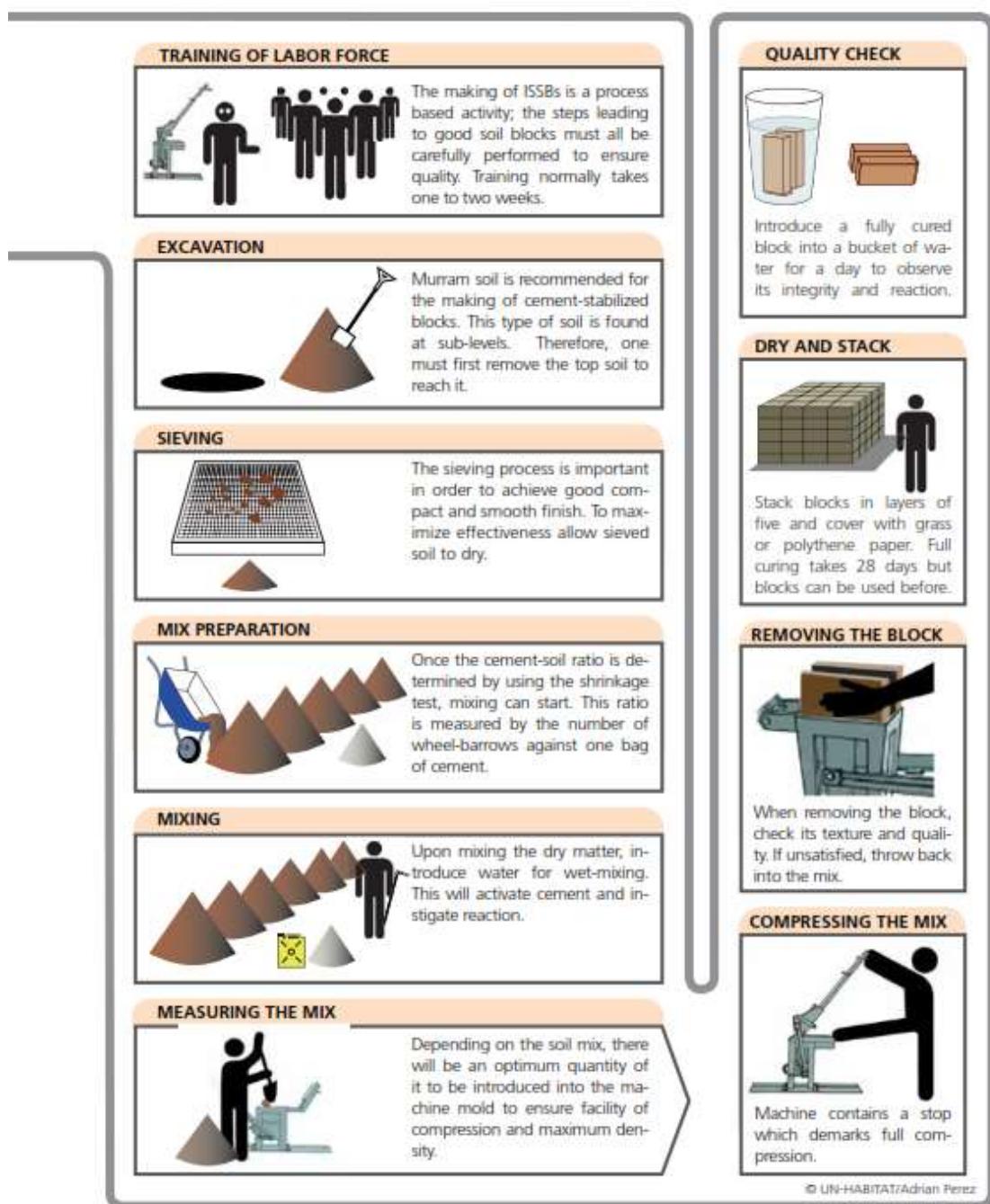


Fig. 6 (Cont'd): Process for Cement-Stabilised Blocks

Source: PÉREZ-PEÑA (2009). Human Settlements in Crisis, Interlocking Stabilised Soil Blocks, Appropriate Earth Technologies in Uganda.

2.6 Conclusion

The literature reviewed in this chapter has highlighted the demands that a tropical climate places on the building materials. Although earth construction is suitable in tropical climates, particularly in Uganda, the use of BBs is environmentally damaging.

Hence, literature on ISSBs highlighting its history in Uganda and the suitability of stabilised soil for construction has been covered in the same chapter.

CHAPTER 3: MATERIALS AND METHODS

3.1 Introduction

The activities and methods undertaken to realise the study objectives are the subject of this chapter. It suffices to mention that the research study was approved by the Centre for Sustainable Development and the travel to Uganda funded by St. Edmund's Tutorial award. Additional funding for site visits was provided by the host organisation, Haileybury Youth Trust, HYT Uganda.

3.2 Activities

Site visits were conducted to on-going ISSB construction sites to meet and interview builders and artisans on site. The researcher on one occasion got involved in the block making process as shown in fig. 7 and fig. 8, observing and also interactively conducting interviews around the ISSB subject. Although not part of the objectives for study, the researcher had to get acquainted with the ISSB building process as summarised below from fig. 7 to fig.12. The researcher was able to keenly make observations and got the interviewees to freely talk about ISSBs.



Fig. 7: Onsite ISSB production



Fig. 8: Stacking and curing of the blocks



Fig. 9: Dry stacking to save mortar



Fig. 10: Mortar applied in columns



Fig. 11: ISSB house (60 % plaster)



Fig. 12: ISSB wall finish (varnished)

A total of seven completed sites were also visited to interact and interview the beneficiaries especially head teachers and staff living in completed buildings. The focus was on finding out if they were comfortable living in ISSB built school buildings and teachers' houses. Photographic surveys were conducted to enhance the key observations during the site visits.

Appointments were also made to meet with architects and project managers/contractors at their offices and these gave key information as they were considered to be more knowledgeable in the construction methods and materials they promoted.

3.3 Methods

The method adopted was a case study approach into the viability of ISSBs in a wider context including environmental, social, economic, political and legal aspects in addition to technological considerations. Firstly, a critical review of documented case studies for use of ISSB technology was done. The findings backing ISSBs as a sustainable building material, form part of the justification for the study carried out. Secondly, a field trip to conduct site surveys on construction sites for both field based observations and interviews with the key stakeholders in the housing construction industry was done. The research targeted to gather both qualitative and available quantitative information. Although the study is more qualitative in nature, the quantitative data gathered was in the form of documentary evidence. For the purpose of this study, the documentary evidence provides a more compete, un-biased and evidence-based picture for use of ISSB technology as a sustainable low-cost alternative to BBs in Uganda's housing Industry.

The case study methodology used was a suitable approach to meeting the research objectives and the method is justifiable according to Fellows and Liu (2003) who

recommend application of the case study approach to topics that are experimental in nature such as construction (Knight and Ruddock, 2008). The ISSB topic required different combinations of data collection including interviews further discussed in subsection 3.3.1, observations in 3.3.2 and documentary evidence in 3.3.3. With these three sources of evidence methods, the results were analysed in Chapter 4, sub section 4.4 using triangulation which allows each particular concern/concept to be tested such that a consensus of the findings yields robust results.

Due to the limited time available for the investigation (14th April to 15th May 2015), the research was a cross-sectional study capturing the situation at the moment in time. This study therefore is not a longitudinal study that investigates a subject to identify change or development over a period of time.

3.3.1 Interviews

According to Yin (2003a), interviews are one of the most important sources of case study information (Knight and Ruddock, 2008). The interviews were designed to target people directly involved with ISSB housing construction which is the case of concern for this research. The focus of this case study research was not the performance of the organisations or companies that used ISSBs, rather the ISSB phenomenon itself in Uganda's housing industry.

Two cases were chosen to establish any distinct characteristics or similarities and differences of ISSB use in construction. One case was with HYT Uganda, a UK-based internal NGO that operates in rural Kamuli, Jinja district and promotes sustainable housing through training locals in the manufacture and building practice using ISSBs. They construct schools, water tanks and sanitation facilities specifically latrines and bathrooms. The second case was with Technology for Tomorrow (T4T), a company that was started by the ISSB technology innovator; Dr. Moses Musaazi and has its major operations based in urban Kampala, the capital of Uganda. T4T constructs schools, water tanks and a few residential buildings using ISSBs. As recommended by Stake (1995), the major consideration of the selected cases was to maximise what could be learnt from both rural and urban practice in the application of the ISSB technology. Both HYT and T4T also provided quantitative data on ISSBs as the basic factual information about the

technical performance of ISSBs that supports evidence from other sources. Other documentary information was obtained from HYT and T4T websites. However, it was treated objectively with due care and caution given the fact that websites are primarily advertising platforms rather than for providing unbiased information. Only informative and evidence-based data was selected for use in this report.

Interviewees from these two organisations; HYT and T4T are referred to as promoters. Open-ended questions to promoters were in such format as; (i) Share with me about your experience with ISSBs, (ii) Why ISSBs (iii) What challenges do you experience with making and using ISSBs, (iv) How is the marketing done?

As a control to the research, other key players in the housing industry that are not directly promoting the use of ISSBs in construction were also interviewed. One key informant from NHCC; a company that uses concrete blocks and one from Akright Projects Ltd; a private company that uses BBs were selected. NHCC is a renowned construction and real estate management company partly owned by the Uganda government and uses concrete blocks in construction. The Head of Technical Services, NHCC who is also an Architect was interviewed as a key informant. Akright Projects Ltd on the other hand is a leading private real estate company that uses BBs and the company's Project Manager was also interviewed. Both NHCC and Akright are located in Kampala and are a vibrant private sector in housing construction that operates on commercial principles by constructing houses for sale (UN-HABITAT, 2007). These stakeholders are herein referred to as non-promoters. They were interviewed on why they used the construction materials that they used and also asked about the possibility of using ISSBs in commercial housing for low-cost housing. They provided insights into uptake of new innovations and why they were currently not using ISSBs.

Table 3 below summarises the various stakeholders that were interviewed and the sectors they belonged to.

Table 3: Interviewees and their sectors

Stakeholders	Sector	Organisation	Interviewees	Remarks
Promoters	Non-government organisation	Haileybury Youth Trust, HYT Uganda	Trainers (3), artisans (6), builders (3), beneficiaries (4)	Build with ISSBs
	Small – Medium Enterprise	Technology for Tomorrow, T4T	Innovator (1), architect (1) contractor (1)	Build with ISSBs
Non- Promoters	Private Real Estate developers	Akright Projects (U) Ltd	Project Manager (1)	Build with BBs
	Public- partly owned by Uganda government	National Housing and Construction Company, NHCC	Head technical services; Architect (1)	Build with Concrete Blocks

The interviewees were readily accessible and included end users, trainers and trainees in ISSB production and wall construction, architects and contractors. The conducted interviews allowed a detailed insight into the ISSB subject being developed. The interviews were semi-structured so as to fully understand the impressions or experiences of the interviewees, and also to learn more about their answers to the questions. The questions were open-ended and flexible enough to probe and delve into issues as they arose. A full range and depth of information was obtained and more importantly relationships were built that were useful later in the study where there was missing information that they could provide.

3.3.2 Participant/ field observations

Field observations involved visiting and spending time on different ISSB construction sites in rural parts of Jinja and also getting involved in the ISSB production with the block makers. Observing the workers was in a similar way to that as an employee engaged on the construction project under investigation. Observed was the use of the construction technology; the process of soil-cement mixing, operating the block making machine for block production and stacking the blocks. This method of data collection took into account what was actually done rather than what the textbooks/ specification/ people

said they did. Photographs and videos were taken as supportive evidence. The insights drawn reflect people's actions and practices and these have been integrated in the discussion chapter.

3.3.3 Documentary evidence

Any published and unpublished document that the two organisations had to support ISSBs as a satisfactory building material was obtained. Such documents included UNBS certification of the ISSBs attached in Appendix 4, compressive strength tests conducted on ISSBs and BBs attached in Appendix 5, and also the Uganda Standard for ISSBs, US 849 (cover page provided in appendix 6).

3.4 Conclusion

The Materials and Methods chapter has discussed the case study method of approach to the research and has described the three sources of evidence including (i) the nature of interviews conducted with various stakeholders, (ii) the field observations and (iii) the documentary evidence.

3.5 Commentary

The next chapter presents the findings from the field study and the analysis of the results.

CHAPTER 4: RESULTS AND ANALYSIS

4.1 Introduction

This chapter first lists the steps followed in the case study method and materials employed in the study. Followed by the research findings including field observations in the order of the research objectives and finally provides the analysis of the results against the criteria established from the findings of the first specific objective.

4.2 Case study Procedure

The steps followed to collect data presented as findings in this chapter included;

- (i) **Planning the interviews:** Most topics covered on the ISSB subject were designed in advance with a set of unstructured questions that were reviewed prior to field research. The companies in the housing industry in Uganda were then identified and possible contacts made. Two of those contacted were directly involved with ISSBs and prior to embarking on the field study were given a brief overview and background to the project research but not the details of the research questions. The non-promoters mentioned in this study were only contacted on appointment after getting to the field and to avoid biased responses, they were only briefed at the time of the appointment.
- (ii) **Conducting interviews:** The interviewees were carefully selected after liaising with the company managers who identified those that were knowledgeable and had hands-on experience with ISSBs. The interviewer took cautious care to ensure that as much as possible her views did not affect the responses from the interviewees. The interviews were recorded on an audio device and later transcribed. Any observations made were noted in a book and photographs taken.
- (iii) **Presentation of the interview data:** The responses on barriers to widespread adoption of ISSBs were varied. However, while checking the suitable presentation method of the qualitative data, the coverage of the responses was found to converge along particular themes including technical, economic, social and environmental. The order of the research questions guides the chronology of presentation of the collected data in section 4.3.

- (iv) **Analysis of the results:** The documentary evidence gathered was used to develop table 4 showing the ISSBs vs BBs against the criteria for material selection using triangulation. The analysis follows what Mangen (1999) stresses that by using the obtained quantitative data, the qualitative primary data is reinforced (Knight and Ruddock, 2008).

4.3 Results/ Research Findings and Observations

Although the researcher anticipated interviewing all the companies on the developed list of companies in the housing construction sector, it was found that most of the non-promoters had little to no information on ISSBs. Therefore, only two interviewees were selected from non-promoting companies, NHCC and Akright. The findings presented herein are largely from interviewees in companies that use ISSBs (i.e. HYT and T4T) unless otherwise stated.

The findings in the subsequent sub-section 4.3.1 answer the research objective on the rationale for material selection while 4.3.2 and 4.3.3 answer the second objective on the barriers to use of ISSBs in Uganda's housing construction.

4.3.1 Criteria for material selection

There were four major and common responses to the research question on choice of material selection from both promoters and non-promoters. These as stated below are not in any order of importance.

- a) **Cost:** Both promoters and non-promoters alike agree that cost is one of the key considerations for material selection. The non-promoters using BBs find the unit price of BBs lower than for most other walling materials. The promoters on the other hand preferred to consider the overall cost of construction per square metre of walling and argued from that angle.
- b) **Durability:** Strength of the material and evidence of long standing houses were another key consideration. The non-promoters using concrete blocks acknowledged the higher price of concrete walling against most other walling materials. However, they concentrated on the strength and durability of houses built with concrete blocks as the selling point of the housing estates they develop. Their target clients are middle to high income earners. The promoters on the

other hand provided proof of the compressive strength tests of the ISSBs and certification of ISSBs by UNBS (2011). ISSBs have a high compressive strength compared to BBs. A standard for specification of ISSBs was also developed and it is available as the Uganda Standard US 849.

- c) **Acceptability:** Attitudes of the clients/end-users towards the built ISSB house were a driving factor. The non-promoters who construct houses for sale are mostly afraid to risk building say 100 ISSB low-cost houses for sale and they get no clients. From the experience of the Head of Technical services, NHCC, he mentioned that even after considering the option of low-cost building, they were hesitant about low-income earners being able to afford the houses unless there was a government subsidy.
- d) **Availability:** This was with respect both to raw materials and skilled personnel/workmanship. The non-promoters who use BBs could easily access them from local manufacturers and artisans even without prior commitment of an order. The promoters focused on the potential to train the local communities in ISSB production given that presses are currently available on the Ugandan market.

4.3.2 Barriers to use of ISSBs

Although the interviews were unstructured to gain insights around the experiences of interviewees with use and promotion of ISSBs in housing, the research findings on barriers converged under the four (4) categories shown in fig.13 below.

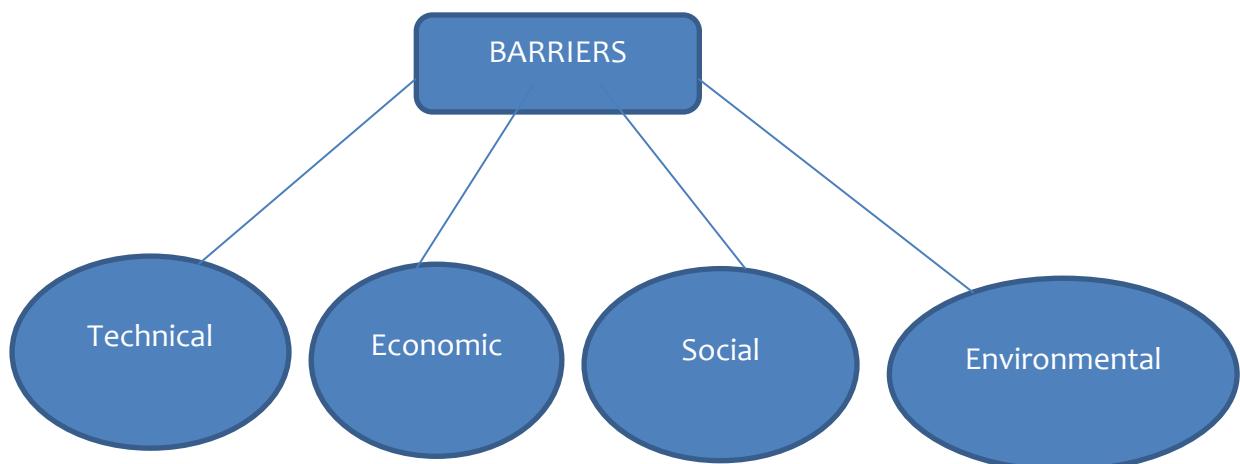


Fig. 13: Categories of the barriers to ISSB use

Under each of the categories as presented below from subsection 4.3.2.1 to 4.3.2.4 is a summary table of the barriers and the specific concerns. These are then elaborated on

with a narrative as to why the interviewees identified them as barriers to ISSB technology in Uganda's tropical housing. Some barriers were identified and perceived by the researcher based on observations made.

4.3.2.1 Technical

A summary of the specific concerns - barriers under the technical category

CATEGORY OF BARRIER	Specific Concerns
TECHNICAL: Non-uniform practice, Quality Control and Regulations 	<ul style="list-style-type: none"> i. Some practitioners used BB in foundation while others used ISSBs ii. Some dry stack the blocks while others use mortar for bonding iii. Some make only 100 ISSBs per 50 kg of cement while others make up to 150 blocks iv. Quality and strength of block v. Training required for both good block work and construction vi. Local authorities were hesitant to approve building plans that use unburned earth building blocks
<p>Architect Interviewee: “Those that appreciate the technology buy the block press and ask their expert builders inexperienced with ISSB to build as a way of avoiding training costs. Their shoddy works lead to bad publicity for stabilised soil blocks.”</p> <p>NO CLEAR REGULATIONS THUS NO ENFORCEMENT OF BUILDING STANDARDS</p>	

Explanations of why the above technical concerns are barriers.

- i. Concerns (i) to (iii) show non-uniform practice between the practitioners in the application of ISSB technology. HYT is an NGO that encourages community participation. When constructing schools, communities are mobilised to contribute to the building of foundations and they provide BBs. This practice is

intended to instil a sense of ownership. However, it could be interpreted to mean that ISSBs cannot be used in the foundation and yet T4T does use ISSBs in foundations. When making ISSBs for use in foundation, T4T add two parts of sand to the cement-soil mix rather than one part used for the walling blocks.

Typically, unfired earth blocks should only be used for foundations in very dry climates on well-drained sites (White, 2013). The use of BBs in foundations may also imply that ISSBs are not a stand-alone technology making it the more difficult to advocate against the environmentally damaging BBs.

- ii. Likewise, while HYT dry stack when erecting walls and use mortar when building columns, T4T use mortar throughout the walling. The mortar used is only a tenth of that commonly used in BB walls. Choosing to dry stack depends largely on both workmanship and the quality of blocks. Those who use a little mortar in the entire walling do so to guard against the risk of unsatisfactory workmanship.
- iii. Number of blocks per 50 kg bag of Portland cement varies from 100 – 150 blocks depending on the clay content in each soil type. This variation may leave a potential client unsure of the exact number of blocks to consider. However, soils with more coarse particles do make up to 150 blocks whereas those with finer particles make 100 blocks from a 50 kg bag of cement.
- iv. Quality control remains an issue of suitability of soil, experience of the artisans and strict supervision. The supervisor needs to have experience working with different soils on different sites. Moistening of the cement – soil mix depends on the original moisture content of the soil and often on site, the right moisture is judged from how the mix feels between the fingers. Also, when the block is made, it is checked and if found unsatisfactory, it is thrown back into the mix.
- v. Training is therefore required for a good block and also to build a straight wall. However, training becomes a barrier to those who do not have the experience and yet are unwilling to spend time in training for at least two weeks. Even when they buy the press to do it themselves, they do not get the standard quality of block desired.

- vi. Local authorities would not approve drawings specifying ISSBs as the building material. This is because there are no clear building standards and laxity in enforcement of building regulations yet without challenging orthodoxy; most local authorities believe that all earth bricks or blocks should be burned.

4.3.2.2 Economic

A summary of the specific concerns - barriers under the economic category

CATEGORY OF BARRIER	Specific Concerns
ECONOMIC: Perceived expensive and unaffordable 	<ul style="list-style-type: none"> i. Cost of cement (USD 8.07 per 50 kg bag) ii. Cost of the block press (USD 1,800 training inclusive) iii. Catering needs for artisans on site iv. Marketing Strategy; currently word of mouth and/ or grant-funded projects in the HYT case
ISSB Trainee Interviewee: “Adding cement to soil is viewed as wastage and therefore perceived expensive.”	COSTS ARE VIEWED IN ISOLATION

Explanations of why the above economic concerns are barriers.

- i. Concerns (i) to (iii) are reasonable however they are perceived in isolation rather than the life cycle cost of building. A major concern is the lump sum required upfront for purchasing cement for making ISSBs. One has to afford to buy and stock the required number of bags of cement to allow for building works to run smoothly. Hence, reducing the time artisans stay on site and the number of days the block press is hired. However, low income earners are most times unable to afford such a cost for all the required cement. This is not an issue for NGO projects because their funding is usually guaranteed and readily available from grants. Moreover although the locals in the rural communities where the NGOs operate

admired the exposed ISSB block work on completed toilet facilities in schools, they viewed addition of cement to soil as wastage. They wished to have used ISSBs for their own residential houses but perceived ISSBs as an expensive technology to employ and were afraid that they could not afford it.

- ii. Cost of buying the block making machine is USD 1,800 training inclusive. If one wants to build one residential house, they find it quite costly to buy their own machine. However, if the benefits of owning one outweigh the cost of purchase, then it is worth investing in one especially for commercial housing business.
- iii. Catering needs of the employed labour on site is viewed as an added cost to the clients. Clients believe that if the blocks are made away from site as is the norm with BBs, then they have fewer costs to consider.
- iv. Marketing of the technology is still a challenge. For example, most projects that T4T has executed have been by word of mouth with clients (mainly friends and relatives) who wish to save on building costs. A few environmental conservation enthusiasts have also used the technology. But the projects remain few, on a small scale even though they are gradually increasing in number. Also HYT that promotes carbon saving practices in housing is currently looking into possibilities of helping the ISSB trainees to start businesses of their own. The challenge is that unless told that a particular house was built with ISSBs, many people may not notice the building material especially if they are unfamiliar with the block. The interviewees mentioned that the government and building authorities in Uganda have not yet fully recognised and embraced ISSBs in their projects.

4.3.2.3 Social

A summary of the specific concerns - barriers under the social category

CATEGORY OF BARRIER	Specific Concerns
SOCIAL: Attitudes and Perception 	<ul style="list-style-type: none"> i. Associated with low-income class building of mud and wattle ii. In Jinja, it is associated with international people iii. Youth remain reluctant to attend ISSB training iv. It is difficult to steal construction materials v. Health and safety; accidents when operating the press <p>Architect Interviewee: “Clients in Kampala are hesitant to use compressed earth blocks for their housing; they associate it with a low social status and doubt durability.” “LOW-COST” is misinterpreted to mean “POOR QUALITY”</p>

Explanations of why the above social concerns are barriers.

- i. In urban areas, ISSB housing is associated with low-income building with mud and wattle in rural villages. This view is common mostly among the medium to high income earners.

Yet again, branding the technology as “low-cost” is interpreted by a large majority as “poor quality”. Such is a long-held perception and it is not surprising given the famous quote, “The bitterness of poor quality remains long after the sweetness of low price is forgotten.” The promoters of ISSBs therefore find it challenging to re-educate people that use of cement in soil blocks leads to the desired strength and durability of house.

- ii. In rural Jinja, ISSB technology is associated with “Bazungu” –international people whose expertise is highly regarded. It is believed within the communities that international organisations have money and can afford to build with the ISSB technology. Hence some people fear its affordability and perceive ISSBs as an expensive technology because of that ideology.
- iii. The reluctance of some youth to get involved in ISSB training is increased by tourists who offer them hand outs (free money). This was reported as the case in Jinja which is a tourist area by the source of the Nile. Some other youth are simply discouraged when they observe their colleagues operating the manual block press as the process does appear tedious until one tries it. To the participating trainees, operating the press is a skill they have acquired with training and practice.
- iv. Corrupt practices and theft of construction materials is common in the housing industry. Contractors tend to misreport the exact total number of bricks delivered to site especially since some BBs break during transit to site. With ISSBs, such practices are curbed with onsite production, supervision and the pre-established number of blocks per 50 kg bag of cement. This was identified as a barrier to adopting use of ISSBs as dishonest workers want to continue their corrupt practice of material theft and cheating. Hence clients need to be aware of this.
- v. Health and safety controls to guard against accidents from the press once not operated carefully. Some parents in Jinja believe that once misunderstandings arise, one may intentionally hurt another when operating the press. They thus stop their children (youth) from going for ISSB training. Also related, is the safety concern for children where there is an open excavated hole on site. With ISSB practice, the concern is taken into consideration by digging up subsoil leaving the ground in the shape of a crater. A child could walk in and out with minimal danger.

4.3.2.4 Environmental

A summary of the specific concerns - barriers under the environmental category

CATEGORY OF BARRIER	Specific Concerns
ENVIRONMENTAL 	<ul style="list-style-type: none"> i. Ultimate use for the onsite open excavation ii. Rarely is the technology sold on the emphasis of environmental advantage but on cost saving
<p>Cement remains a highly energy intensive stabiliser MORE RESEARCH INTO ALTERNATIVE STABILISERS</p>	

Explanations of why the above environmental concerns are barriers.

- i. The non-promoters were concerned about the ultimate use for the large excavated hole in case of a large commercial or real estate housing development. However, the promoters plan for the open excavations for underground water tanks, soak pits, utilities and for single residential buildings, they can use them as compost pits.
- ii. ISSBs are environmentally friendly carbon “saving” not “zero” carbon building blocks. Cement is highly energy intensive and also, in absence of suitable soil onsite, it has to be imported from another site. The carbon emissions from transporting the soil often avoided with onsite production would then have to be included in the embodied carbon of the blocks. Those sensitized about sustainability would care about sourcing of materials. However most people who are keen on the technology are driven first by the cost saving benefit, and then environmental conservation.

Anonymous view: “The end-user wouldn’t lose their sleep over the environment; only authorities do”. Such is the attitude of those who are not sensitized and/ or have not

yet understood the very essence of living in the earth's finite resources and being generational stewards.

4.3.3 Observations

- (i) There were more public structures than privately owned residential homes. This is partly because the NGO (HYT) is focused on schools in rural parts of Jinja constructing school buildings, sanitation facilities (toilets), perimeter walls, and water tanks. It is also difficult to know all the ISSB built residential projects due to privacy considerations. Hence non-promoters usually only get to know about public projects in schools and may be perimeter walls. However, because such structures are public and not privately owned, sceptics biasedly affirm that it is so because no individual would want to own a stabilised soil built house. This is not true as there are a few examples of well-built residential homes as shown in fig. 14 and hotel in fig. 15 below.



Fig. 14: Residential home



Fig. 15: Hotel Kigo in Kampala

- (ii) Structures with good quality ISSB block work were aesthetically pleasing and the varnished ones appeared newly built. Varnish was primarily applied on the outer walls to protect the blocks from rain water as water simply slips off. As well, there were some examples of unpleasant ISSB structures that were built much earlier around 2007. The latest buildings as observed in 2015 show improvement and mastery of the production of ISSBs and construction over time.
- (iii) BBs were used in the foundation. This poses a question as whether ISSBs can or cannot be used in foundations.

- (iv) Women were not involved. The construction sector remains largely male dominated. In the UNHABITAT documentation of human settlements in crisis, some women were involved in activities such as fetching water required in the cement-soil mix.

4.4 Analysis of the Results

The analysis presented in Table 4 below is an interpretation of the documentary evidence against the four criteria for material selection while taking into consideration the barriers to ISSB use. It is the result of the triangulation process and should be regarded as an initial guiding tool to help the client make a macro level decision when selecting between the two earth construction materials.

Table 4: Status of material selection criteria of ISSBs vs BBs by triangulation

Criteria	ISSBs vs BBs	Remarks
Cost	Unit cost of ISSB is Ush 300 and BB is Ush 150 [1] ISSB cost per sq. m is Ush 35000 and BB is Ush 55000 [1]	ISSB more cost-effective [1] PÉREZ-PEÑA (2009)
Durability	ISSB compressive strength higher than BB by 80 % [2]	ISSB more durable [2] WALKER (2007)
Availability	ISSB depends on block press, cement and trained personnel	BB more readily available
Client acceptability	Stabilised soil considered inferior	Industry goes business-as-usual with BB

Following the above analysis, the discussion below in section 4.5 focuses on what the results mean to the researcher and why.

4.5 Discussion

Promoters of the technology have different perspectives of ISSBs from those non-promoters held. This is likely to be the case since every organisation/ company wants to promote the product they believe in or have built their businesses with.

With respect to the rationale for material selection, cost, durability and availability are easier to demonstrate to parties willing to take on the technology. Client acceptability on the other hand, is influenced by intrinsic attitudes and most times, the lack of exposure. It takes time to instil a mind-set change and yet to the researcher, the perceptions held about ISSBs appear to be insufficiently informed. Only those people who are keen to innovation take the time to study a particular new product. The documentary evidence on ISSBs particularly the compressive strength tests of ISSBs vs BBs and the UNBS certification of ISSBs appear to remain unknown to the public. It could be an issue of no interest for people to find out or reluctance to change. Organisations or companies in the same industry should readily access such documents. The non-promoters in commercial housing business remained doubtful of the strength and durability of the cement-soil blocks.

The practicality of dealing away with BBs will only be but a gradual process. Rather than condemn the act of firing bricks, the focus should be on clearing the perceptions about ISSBs and having more buildings built with ISSBs.

With the current global focus on climate change and the push for sustainability, ISSBs are well placed as a sustainable and environmentally friendly product whose adoption will increase when more people are sensitized and restrictions are made on and regulations enforced on environmentally damaging building materials.

Overall, the findings are summarised below.

4.6 Summary of Findings

- (i) Cost, durability, availability and client acceptability were the major criteria for material selection.
- (ii) There is available information on the technical performance of stabilised soil blocks in various literature sources including UNBS certification, tests done by independent bodies at University of Bath, UK, at the Central Materials Laboratory and at the materials laboratory at Makerere University Kampala. There is a Ugandan manual for Interlocking Stabilised Soil Blocks, US 849 and comparative

analyses on ISSBs vs BBs intended to clear technical uncertainty around use of ISSBs.

- (iii) The barriers to wide spread adoption of ISSBs range from technical, economic, social to environmental. The fact that the housing industry has no clear regulations and the laxity in enforcement of laws, policies and regulations is a glaring challenge to get new innovations on board. The major economic challenge lies in judging the cost of the ISSB technology based on the unit cost of the block rather than per square metre of walling whereas socially, attitudes and perceptions towards stabilised soil as an inferior technology remain a challenge. The environmental barriers are not such roadblocks to the ISSB technology which as agreeable has been classified as environmentally friendly compared to existing methods and materials.

CHAPTER 5: INTERPRETATION AND GENERAL DISCUSSION OF RESULTS

5.1 Introduction

The aim of the research was to investigate the current barriers to wide spread adoption of ISSB technology in relation to the rationale for material selection in tropical housing industry in Uganda. BBs are the most common building material in Uganda and although ISSBs are more environmentally friendly and a cost effective building material, its adoption remains low and on a small scale. In this research, the rationale for material choice and the barriers to widespread adoption of ISSBs in tropical housing projects were established from a case study carried out in Jinja and Kampala. Based on the insights drawn from the interviews, observations and documentary evidence, the critical areas that need to be a focus for a way forward are presented as the eventual outcome of the study. It is hoped that this report provides all potential clients and developers with information enough to make macro level decision on the building material to use and for the promoters to gain useful insights for a way forward for the technology.

The discussion in this chapter focuses on what the results mean and how they fit into the existing body of knowledge. Also, insights drawn from synthesizing the results in the analysis table are included in the discussion.

5.2 Discussion

With respect to cost, the unit price of ISSBs is higher than that of BBs and it would increase with increase in the price of inputs particularly cement. However, the price is also affected by the number of blocks (productivity) made per employed labour. It follows therefore that most of the promoters of the ISSB technology encourage clients to consider the overall cost of walling rather than per unit block. From the analysis table, the cost per square meter of ISSB walling is lower than BB walling by approximately 36 %. Building with ISSBs being cheaper than using BBs is a fact that remains and fits well within the available body of knowledge including Webb (1994) who mentions a 20 – 40 % savings. Good Earth Trust reported that the calculation done by Uganda's education sector after stringent cost benefit analysis of construction using ISSBs rather than fired bricks revealed short-term financial savings of around 20 % overall in the construction of classrooms, teacher housing, latrines and kitchens. Irrespective of addition of cement in

the soil blocks, HYT calculation in Appendix 3 shows that ISSB housing uses only 25 % of the cement a BB house built with the current construction methods would use. In conclusion, it ceases to be a question of actual cost of the ISSB technology rather the perceived cost. It can be deduced that some people view addition of cement to soil as wastage and perceive the technology as expensive since cement is the more expensive ingredient in making mortar and/ or concrete. The increase in price of cement directly affects the cost of construction.

Although strength and durability of materials was a concern, the compressive strength of ISSBs is higher than BBs. Venkatarama *et al.* (2007) confirms that soil-cement blocks are used for load bearing masonry of 2-3 storey buildings. Webb (1994) affirms that stabilisation (by compaction and addition of cement) is meant to address strength and durability of soil as a construction material reducing shrinkage cracks and increasing strength. It is the quality of the block that remains an issue of quality control from sourcing of materials, mixing cement and soil in the correct ratio to using trained labour to produce the blocks. However as noted by Rigassi (1985), having good quality of blocks does not guarantee good construction which in turn would also affect durability. In the case study, both promoters, HYT and T4T offer a full package including training and construction with the blocks and do not produce blocks for sale. It should not however be interpreted to mean that entrepreneurs cannot venture into production of ISSBs for sale, rather that they need to support their clients by recommending to them experienced engineers, architects and builders to ensure good construction. At the building stage, Morel *et al.* (2001) recommends that both professionals and artisans (masons) unfamiliar with the technology must be appropriately informed especially of (i) material quality (ii) building methods (iii) protection of the structure against erosion, and (iv) quality control.

Availability of the materials was another concern. BBs are readily available due to the wide spread brick making activities. It is easy to make a wooden mould. Locals have resorted to using arable soil and/ or wetlands and without stringent regulations; many illegally access forests and cut trees for wood to use in firing the bricks. On the other hand particularly in the case study, production and therefore availability of ISSBs depends on first getting a new client interested in building using ISSBs. The practise with

ISSB technology involves onsite production and then construction. The manual block presses that used to be transported from Kenya are currently available in Uganda. It has been a practice with NGOs to give the machine to their trainees if they got a construction project. The availability of ISSBs is currently dependant of the demand for the cost-saving housing construction. Such a demand has only increased on a person-to-person basis by word of mouth.

The client needs and financial standing often dictate the choice of materials. Most clients introduced to ISSBs by word of mouth will not accept to use a stabilised soil material especially if they have not seen it used on previous buildings. Some architects have recommended use of stabilised soil to clients but most clients only get convinced after a field visit to see, touch and feel the already built ISSB houses. The block work on houses should be aesthetically pleasing, appear durable and strongly recommended by their architects, engineers and/ or contractors. However, even after recommendation by architects, some clients are not entirely satisfied and prefer to go the traditional and conventional way with BB. The clients that have been exposed to ISSBs through their colleagues rather than promoting companies are not surprisingly better persuaded to build with ISSBs because they know their colleagues do not expect a profit.

The fact that the promoters have built houses from ISSBs which are standing and inhabited is a mark of good progress towards disseminating the technology to the communities. Actually, the first ISSB building in Uganda is the office that the innovator (Dr. Moses Musaazi) occupies on day-to-day official business. In Jinja, the inhabitants including head teachers and teachers (beneficiaries of HYT work) mentioned that they were comfortable living in ISSB built houses. Low acceptability amongst most social groups was highlighted by Webb (1994) since earth is characterised as being the “Poor Man’s Building Material”. From this research, slow adoption appears to be an issue of insufficient sensitization on the innovative methods hence social attitudes and low client acceptability with a perceived risk of poor quality construction and low durability of unfired earth construction. The developers therefore are keen on client acceptability of the built houses. Fortunately, the promoters do train local communities although not necessarily the existing local manufacturers and artisans in ISSB production and wall construction. The trained personnel however end up not fitting into the existing job

market and those without business acumen end up as redundant skilled labour in ISSB production and construction. The challenge expands to the need for an enabling environment in which a technology innovation must run. This is where the government and building authorities have to play a major role through enabling policies, building regulations and enforcement of environmental regulations.

Although the ISSB technology is certified by the UNBS, the 2011 – 2015 National Development Plan document highlights the country's failure to adopt low-cost building technologies in development projects such as upgrading of slums (NPA, 2010). The country also suffers high levels of corruption and although it appears feasible to use ISSB technology to train local labour and provide employment opportunities, most efforts are sabotaged by politics. Any housing initiative including upgrading of slums with low cost sustainable building materials will have to design in-built safe-guards to avoid the effects of politics and corruption.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary of Major Findings and Resulting Conclusions

Material selection for housing construction was dependent on cost, durability of building materials, their availability as well as acceptability by the clients. The promoters focused on the cost effectiveness and environmental benefits of ISSBs. The non-promoters that used BBs focused on the low unit cost of BBs and the ready availability thereof. Those that used concrete blocks focused more on strength and durability of the concrete and although open to low-cost housing, feared the uncertainty of client acceptance of stabilised soil in construction and therefore anticipated that the sale of such completed houses would be low.

The barriers to wide spread adoption of ISSB technology converged along particular themes and were categorised into technical, economic, social and environmental barriers. The environmental concerns with respect to ISSB technology were minimal since the block production and construction method associated with ISSB use is more environmentally friendly. Production of ISSBs is done onsite with the blocks air cured rather than fired and a complete house uses only approximately 25 % of the highly energy-intensive cement that a conventional BB building would require.

The economic barrier was the unit price of ISSBs vs BBs. With consideration of the cost of equipment, cement and labour, the unit price of ISSBs is higher than the unit cost of BBs. However, based on per square metre of walling after construction, the cost of ISSB walling was less than BB. If one is to realise the financial savings, it is therefore advisable to consider the overall cost of construction with ISSBs rather than cost of block before construction. Savings result from reduced labour costs in man hours, no transportation and associated fuel costs and less mortar used in construction, plastering and rendering.

Technical barriers centred on quality control. However, the promoters of ISBBs have tested the compressive strength of the blocks, obtained UNBS certification and have developed a manual for production of ISSBs (US 849) to close in the gap on the technical barriers to the technology. It was noted however that the promoters have no control

over anyone that decides to use the technology without training and yet shoddy ISSB works reflect badly on the technology.

Client acceptability of the ISSB technology was identified as a major social hindrance that cannot be ignored. At the same time, non-promoters used that as reason to continue with business as usual. Hence user satisfaction is critical to marketing and adoption of ISSBs and promoters need to be aware of this as they execute any projects.

Even with all the various barriers as summarised above, the fact that some people buy machines and try to build on their own is an indication that the technology is appropriate and desirable. Training in ISSB production and construction is an absolute must before adopting the technology even though one is an expert in building with other materials.

6.2 Recommendations (focus area)

- (i) Promoters need to understand **the local perception towards the ISSB technology and focus on educating clients as a first step.**
- (ii) **Client understanding of the ISSB technology as a sustainable and cost effective technology** for building construction will go a long way in the adoption of this technology. Clients ought to know that ISSBs are not only for low income earners but also high income earners that wish to save on building costs while saving the environment.

6.3 Contribution to Knowledge

The perceptions of the society in which the promoters of new appropriate technologies operate have to be understood. Some perceptions such as adding of cement to soil being seen as wastage are very misleading as communities believe cement should only be added to sand for mortar or concrete. Understanding such perceptions helps the promoters to identify focus areas to discuss with potential clients when educating them about the new innovations.

6.4 Implications of Work and Future Research

It is hoped that the research will inform stakeholders on the biases around the technical, economic, social and environmental barriers to use of ISSBs and cause a mind-set change so as to select and adopt environmentally friendly building materials in tropical housing.

Future research should focus on;

- (1) How promoters can best communicate ISSB technology to clients with specialised ISSB training course content for various stakeholders.
- (2) How the new innovations in building materials especially ISSBs are incorporated in the Buildings Control Act, 2013 under PART VI – CONTROL OF BUILDING OPERATIONS particularly section 34: Building operations without permit prohibited and section 42: Prohibition of building methods and materials. Also inclusion in PART VII, section 46: National Building Code.
- (3) The role of policy, legislation and government in promoting environmentally friendly building materials in Uganda. A typical suggestion would be;
 - (i) To enforce a higher tax rate on burned brick housing construction aimed at getting all BB housing developers to alternatively use ISSBs.
 - (ii) Provision of an incentive for low-cost housing using ISSBs such as low to no ground rent for ISSB built houses. The government could then take up compensation of the freehold owners.
 - (iii) Carbon trading commitments and funding credits can provide an incentive to change from BB production to more ISSBs.

6.5 Limitations

- (i) As highlighted by Flick (2006), the quality of this qualitative research lies beyond what one can assess by applying specific criteria. The use of triangulation only helps to generate additional insights about the quality of qualitative research.
- (ii) There is no generalisation in qualitative research. Therefore the researcher paid careful attention to understand which social entities to generalise or transfer the findings to. For example, the two interviewees referred to as non-promoters, although were key informants, their contribution is not fully representative of the views of the entire commercial sector. Some private companies could embrace ISSBs and revolutionise the housing industry by providing affordable low-cost and sustainable housing.

6.6 Lessons Learnt

- (i) Although the technical performance of ISSB building material is certified, its adoption is a journey that promoters have to continue to take by focusing on the client satisfaction for the projects they develop.
- (ii) The focus should not necessarily be to eliminate use of BBs but to reduce its preference.

And as stated in the Stabilised Soil and the Built Environment journal article,

“Here the problem is an educational one which future strategy administrators must face up to because with the largest population growth in history many people fear that today's housing crisis could become tomorrow's global catastrophe. Soil scientists and architects have demonstrated how soil can be used efficiently and effectively to provide good quality **low income** housing. It is therefore the responsibility of the governments of the world to make use of the soil stabilisation techniques we offer.” Webb, 1994.

“Rather than being for just low income housing, ISSBs are for **low-cost** housing; both high and low income earners alike can embrace it.” Nambatya, 2015.

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APPENDICES

Appendix 1: Comparative Analysis and Advantages of ISSBs

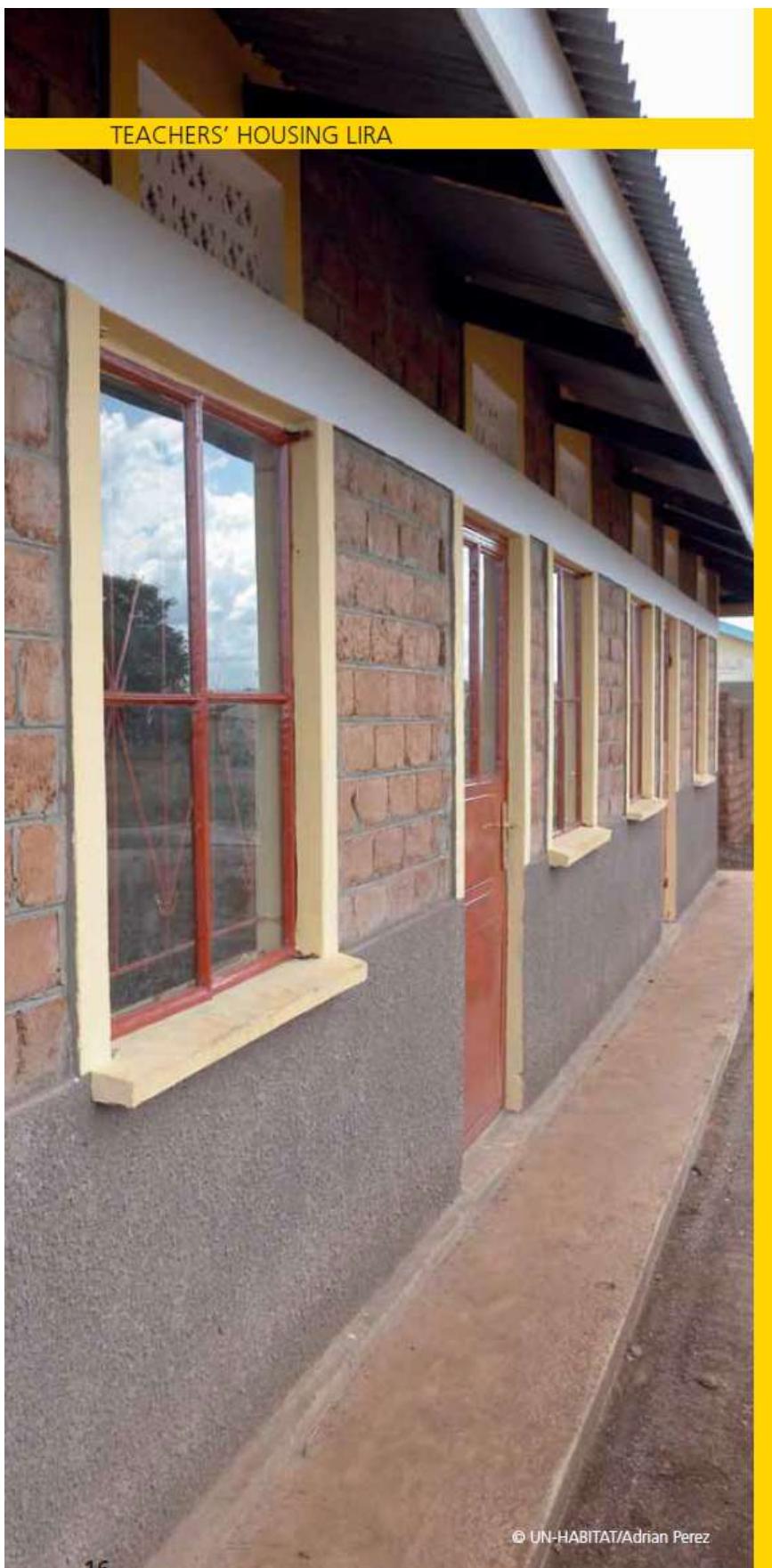
COMPARATIVE ANALYSIS and ADVANTAGES OF ISSB

The advantages of ISSB technology are many and even when compared to other technologies; it is affordable, environmentally sound, user friendly, performs well, versatile in use, among others. However, like with any other construction technology, care must be taken to ensure quality. The quality of ISSB's depends on good and locally available soil selection, a stabilizer to compliment the type of soil, and good practices during production and implementation.

Properties	Interlocking Stabilised Soil Block	Sun-dried Mud Block	Burned Clay Brick	Stabilised Soil Blockb	Concrete Masonry Unit
GENERAL INFO					
Block Appearance					
Wall Appearance (not rendered)					
Dimension (L x W x H) (cm)	26.5 x 14 x 10 cm	25 x 15 x 7 cm to 40 x 20 x 15	20 x 10 x 10 cm	29 x 14 x 11.5 cm	40 x 20 x 20 cm
Weight (kg)	8-10 kg	5-18 kg	4-5 kg	8-10 kg	12-14 kg
Texture	Smooth and flat	rough and powdery	rough and powdery	smooth and flat	coarse and flat
Blocks needed to make up a sq.m.	35	10 to 30	30	21	10
PERFORMANCE					
Wet Compressive Strength (mps)	1 - 4	0 - 5	0.5 - 6	1 - 4	0.7 - 5
Thermal Insulation (W/m C)	0.8 - 1.4	0.4 - 0.8	0.7 - 1.3	0.8 - 1.4	1 - 1.7
Density (kg/m3)	1700 - 2200	1200 - 1700	1400 - 2400	1700 - 2200	1700 - 2200
AVG. PRICE (2009)					
Per Block (UgS)	350	50	150	400	3000
Per Sq Meter	35000	10000	55000	45000	75000

Information for this chart gathered from Craterre publication: "Compressed Earth Blocks :Manual of Production" and GET

Appendix 2: Case Studies in Uganda



UN HABITAT
FOR A BETTER URBAN FUTURE

UN-HABITAT:

The mission of UN-HABITAT is to promote socially and environmentally sustainable human settlements and to work towards adequate shelter for all.

Project Abstract:

UN-HABITAT, with funding from UNICEF, implemented this project to facilitate the sustainable return and reintegration processes in Northern Uganda. Through the use of alternative environmentally-sensitive building technology, 64 teacher's housing units in 16 schools and three ISSB demo buildings were constructed in the area.

Structure:

- » 16 ISSB buildings each containing four unit housing blocks
- » 16 ISSB two unit VIP-Toilet blocks
- » 32 unit kitchens made by the benefiting community
- » 3 demo offices, one containing an ISSB water tank

Type of Block Used:

- » Single Interlock
- » Double Interlock
- » Grooved Double Interlock

Contextual Innovations

- » The use of ISSBs at foundation level in form of a double wall.



ARUP

ARUP

This consulting engineering firm is one of Ireland's largest. Their work is characterized by innovative and sustainable design solutions, and value-engineering projects. Through the Arup Partnership Worldwide, there are over 10,000 staff working in more than 90 offices in 37 countries.

Project Abstract

The school is located near Pajule town in Pader, Uganda. This area currently houses one of the largest IDP camps in the country. The purpose of the project is to provide a school building and a campus for the Pajule Secondary School which currently shares its premises with the primary school. The new school campus will decongest the existing situation and provide the students with a quality environment conducive to learning.

Structures:

Phase I:

- » Two classroom blocks
- » Two Latrine blocks

Upcoming Phases:

- » Classroom blocks
- » Library
- » Admin Building

Type of Blocks Used:

- » Wide Format Double Inter-lock



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Connect Africa:

Connect Africa is a Ugandan faith-based organization promoting and providing local residents with appropriate technologies and training to create sustainable communities.

Project Abstract:

Connect Africa's activities revolve around "Connect Africa Resource Centers" (CARCs) that serve as a base for training and technological dissemination. At these ISSB community-constructed centers, Connect Africa teams teach local leaders how to use sustainable technologies that in turn help raise the local residents' quality of life. Currently there are four CARCs, all located in strategic areas in Northern Uganda including Kigumba, Opit, and Atiak; the recently constructed 'hub' located near Kampala.

Structures:

- » Each CARC holds a conference room and living quarters for volunteers
- » ISSB water tank(s) & water filters
- » ISSB production unit
- » ISSB Ecological Sanitation toilet (Eco-San)

Type of Blocks Used:

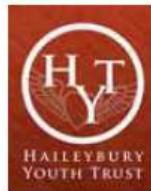
- » Double Interlock
- » Curved Double Interlock

Contextual Innovations

- » The CARC built in Opit four years ago was made of dry-stacked ISSB blocks and has proven sound so far and cost effective.
- » The left-over and unusable ISSB blocks have been used for the creation of a 'Rocket Stove'.



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Haileybury Youth Trust:

HYT works with communities to improve quality of life by meeting humanitarian needs, such as housing, education, and access to clean water in an environmentally friendly manner. HYT provides training programs and advocates ISSB technologies. HYT has been involved in over 20 ISSB projects in the Jinja area building water tanks, affordable teachers' housing, classrooms, perimeter walls, dormitories, and schools.

Project Abstract:

The most comprehensive project taken upon by this organization is the development and expansion of Lord's Meade Vocational School containing within its campus samples of all the previously mentioned structures.

Structures:

- » Water Tanks
- » Dormitory building
- » Teachers' housing (bottom left)
- » Double Classroom Block
- » Store
- » Bench (top left)

Type of Blocks Used:

- » Double Interlock
- » Grooved Interlock
- » Curved Double Interlock



Presidential Initiative to Support Appropriate Technology PISAT- under Uganda National Council of Science and Technology UNCST:

The UNCST Vision is "to be the centre of excellence for the management and integration of science and technology into the national development process.

The UNCST Mission is "to provide effective and innovative leadership in the development, promotion and application of science and technology and its integration in sustainable national development".

Project Abstract

The project objective was to use ISSB Technology to help transform the Rugby pitch into a quality field site, complete with toilets, seating area (stands) and a club house with locker rooms, dining area and VIP area.

Structures:

- » Toilets
- » Stands- seating area
- » Retaining Wall- Perimeter wall
- » ISSB Water tank

Type of Blocks Used:

- » Double Interlock
- » Curved double interlock

Appendix 3: GHG emission data for ISSB vs Burned Bricks (BB)



Haileybury Youth Trust



GHG emission data for ISSB Vs Burned Bricks (BB)

ISSB Technical Data:

Block Mass: 7-8kg.
Of which cement: 0.5kg (one 50kg bag/100 blocks)
Percentage Cement: 6-7%
Embodied Carbon: 0.084 kg.CO₂e / kgⁱ

BB Technical Data:

Block Mass: 2-5kg but there is no standardⁱⁱ.
Of which cement: 0 kg
Embodied Carbon: 0.24 kg.CO₂e / kgⁱⁱⁱ

Mortar Data:

ISSB – no mortar in walls, only in pillars. Pillars appear every 2 m in a straight wall. HYT estimates that this means we only mortar about 20% of the blocks in a building with a small amount, ca 1 cm, of mortar every time.

BB are frequently mortared with over 2 cm of mortar between every course.

Embodied carbon^{iv} depends on the cement-to-sand ratio used, with values varying proportionally.

For 1:6 Cement: Sand ratio: 0.136 kg.CO₂e / kg
For 1:3 Cement: Sand ratio: 0.221 kg.CO₂e / kg

Plaster Data:

ISSB – Plastered with 1 cm of plaster. HYT usually plasters 60 % of its buildings, leaving 40 % of the surface area as exposed blockwork.

BB – Plastered with 2.5 cm of plaster (thanks to uneven face) over 100 % of the building (if being built by the government, other NGOs etc).

Embodied carbon: 0.24 kg.CO₂e / kg^v

Calculation:

Thanks to thickness of plaster differences HYT only used 40% of the plaster that a BB building would use – even if plastering 100% of the building.

UK Registered Charity Number: 303244
Uganda Registered NGO ref: 7790 S.5914/8295



However if you take into account that HYT only plasters 60 % of the building we use $40\% * 60\% = 25\%$ of the cement that BB buildings would use.

References

Estimated values for the equivalent embodied carbon (CO₂e) of the construction materials in question have been taken from the Inventory of Carbon and Energy (ICE). This is a database that gives estimates of the embodied energy and embodied carbon of common construction materials. The ICE was produced by University of Bath researchers, and last updated in 2011.

The values provided in this database are based on a comprehensive number of sources. Although strong preference was given to UK data, sources were not restricted to just the UK^v. The ICE is a widely used and respected source for embodied carbon estimates, and has been used around the world. In the absence of any known bespoke embodied carbon studies on ISSB and BB in Uganda, ICE values are used as a reasonable starting estimate.

^v Value is for "Cement Stabilised Soil @8%", from JONES, C. and HAMMOND, G. (2011) *Inventory of Carbon and Energy*. Emissions scope boundary is cradle-to-site. The authors note that of the 8% stabilisation, it is assumed that 6% is cement and 2% is quicklime.

^w Pg.10 from PEREZ, A. (2009) *Interlocking Stabilised Soil Blocks - Appropriate earth technologies in Uganda*. Nairobi: UN-HABITAT

^x Value is for "General clay bricks" from JONES, C. and HAMMOND, G. (2011) *Inventory of Carbon and Energy*. Emissions scope boundary is cradle-to-gate.

^y Values are for "Mortar" with varying cement: sand ratios from JONES, C. and HAMMOND, G. (2011) *Inventory of Carbon and Energy*. Authors state that values are estimated from the ICE Cement, Mortar and Concrete model.

^z Value is for "General plaster" from JONES, C. and HAMMOND, G. (2011) *Inventory of Carbon and Energy*. Emissions scope boundary is cradle-to-gate. It is noted by the authors that there is poor background data for embodied carbon of plaster.

^{vii} CIRCULAR ECOLOGY. (2014) *Embodied energy and carbon - The ICE database*. [Online] Available from: <http://www.circularecology.com/embodied-energy-and-carbon-footprint-database.html#.VVk1Y7dYe7> [Accessed: 18th May 2015]

Appendix 4: UNBS certified results on technical performance of ISSBs

	UGANDA NATIONAL BUREAU OF STANDARDS CERTIFICATE OF ANALYSIS		
<p>Certificate No: CM/2013/0831</p> <p>Name of Client: Technology for Tomorrow Limited</p> <p>Description of Sample: Interlocking stabilized soil blocks</p> <p>Sample No: 0537/2013E Lot Size: NA Quantity of Sample: Six stabilized soil blocks</p> <p>Manufacturer: Technology for Tomorrow Limited</p> <p>State of Sample(s): Six stabilized soil blocks were delivered to the lab.</p> <p>Sampling Report No: NA Date of Testing: 2013-08-13 Receipt/Sampling date: 2013-05-10</p> <p>Test Method(s): US 849:2011, Specification for stabilized soil blocks</p>			
Test Parameters:	Results:	Specification:	Status of Results:
1. Dimensions (mm)			
i) Length	285	283 - 287	Pass
ii) Width	140	139 - 142	Pass
iii) Thickness	95	92-96	Pass
2. Water absorption (%)	8.6	15 (maximum)	Pass
3. Density (kg/cub.m)	1910	1600 (minimum)	Pass
4. Shrinkage cracks	None	Not more than 0.5mm wide 70mm long	Pass
5. Dry compressive strength (N/sq.mm)	3.9	2.5 (minimum)	Pass
6. Wet compressive strength (N/sq.mm)	2.0	1.5 (minimum)	Pass
7. Modulus of rapture (N/sq.mm)	0.52	0.5 (minimum)	Pass
8. Weathering - loss of mass (%)	2.3	15 (maximum)	Pass
<p>Analysed By: John Okumu</p> <p>Technical Signatory: <i>John Okumu</i> Date: <i>13th August 2013</i></p> <p>Executive Director UNBS: <i>[Signature]</i> Date: <i>2013/08/15</i></p>			
<i>290830</i> This Certificate of Analysis is only valid if it bears an authorized signature and official seal. This certificate has been issued without alteration and may not be reproduced other than in full except with written approval from the Executive Director, Uganda National Bureau of Standards.			
Office Address: Plot M217 Nakawa Industrial Area.	Postal Address: P.O. Box 6329, KAMPALA	Telephone: Executive Director: +256 - 414 - 286 123 General Line: +256 - 414 - 222 367	E-mail: unbs@infocom.co.ug Website: www.unbs.go.ug Fax: +256 - 414 - 286 123

Certificate No: CM/2013/0831

Name of Client: Technology for Tomorrow Limited

Description of Sample: Interlocking stabilized soil blocks

Sample No: 0537/2013E

Lot Size: NA

Field No: Straight double plain interlocking block

Address: P.O.Box 70640, Kampala, Uganda

Quantity of Sample: Six stabilized soil blocks

Manufacturer: Technology for Tomorrow Limited

State of Sample(s): Six stabilized soil blocks were delivered to the lab.

Sampling Report No: NA

Date of Testing: 2013-08-13

Receipt/Sampling date: 2013-05-10

Test Method(s): US 849:2011, Specification for stabilized soil blocks

Test Parameters:

Results:

Specification:

Status of Results:

9. Visual inspection

Were free from broken edges and honey combing

Shall be free from broken edges and honey combing

Pass

Remarks:

1. The sample was analysed according to the above mentioned International Standard.
2. The sample analysed above meet the requirement as specified in the standard.
3. This certificate of analysis (CM/2013/0831) is valid for the sample number 0537/2013E. SAMPLING WAS NOT INDEPENDENTLY CARRIED OUT BY THIS OFFICE.

Note:

NA means "Not Applicable"

Attachment(s) to the Certificate: Nil

Analysed By: John Okumu

Technical Signatory:

Executive Director UNBS:


John Okumu

Date:

12th August 2013

Date:

2013-1815

Page 2 of 2



UGANDA NATIONAL BUREAU OF STANDARDS

CERTIFICATE OF ANALYSIS

Certificate No: CM/2013/0832

Field No: Straight double grooved interlocking block

Name of Client: Technology for Tomorrow Limited

Address: P.O Box 70640, Kampala, Uganda

Description of Sample: Interlocking stabilized soil blocks

Sample No: 0538/2013E Lot Size: NA

Quantity of Sample: Six stabilized soil blocks

Manufacturer: Technology for Tomorrow Limited

State of Sample(s): Six stabilized soil blocks were delivered to the lab.

Sampling Report No: NA

Date of Testing: 2013-08-13

Receipt/Sampling date: 2013-05-10

Test Method(s): US 849:2011, Specification for stabilized soil blocks

Test Parameters:**Results:****Specification:****Status of Results:**

1. Dimensions (mm)

i) Length 263 263 -267 Pass

ii) Width 141 139 -142 Pass

iii) Thickness 95 92-98 Pass

2. Water absorption (%) 8.4 15 (maximum) Pass

3. Density (kg/cub.m) 2000 1600 (minimum) Pass

4. Shrinkage cracks None Not more than 0.5mm wide 70mm long Pass

5. Dry compressive strength (N/sq.mm) 3.3 2.5 (minimum) Pass

6. Wet compressive strength (N/sq.mm) 1.5 1.5 (minimum) Pass

7. Modulus of rapture (N/sq.mm) 0.54 0.5 (minimum) Pass

8. Weathering - loss of mass (%) 3.1 15 (maximum) Pass

Analysed By: John Okumu

Technical Signatory:

Date: 13th August 2013

Executive Director UNBS:

Date: 20/3/2015

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29083
Serial No.

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E-mail: unbs@infocom.co.ug
Website: www.unbs.go.ug
Fax: +256 - 414 - 286 123

Certificate No: CM/2013/0832

Name of Client: Technology for Tomorrow Limited

Description of Sample: Interlocking stabilized soil blocks

Sample No: 0538/2013E

Lot Size: NA

Field No: Straight double grooved interlocking block

Address: P.O.Box 70640, Kampala, Uganda

Quantity of Sample: Six stabilized soil blocks

Manufacturer: Technology for Tomorrow Limited

State of Sample(s): Six stabilized soil blocks were delivered to the lab.

Sampling Report No: NA

Date of Testing: 2013-08-13

Receipt/Sampling date: 2013-05-10

Test Method(s): US 849-2011, Specification for stabilized soil blocks

Test Parameters:Results:Specification:Status of Results:

9. Visual inspection

Were free from broken edges and honey combing

Shall be free from broken edges and honey combing

Pass

Remarks:

1. The sample was analysed according to the above mentioned International Standard.
2. The sample analysed above meet the requirement as specified in the standard.
3. This certificate of analysis (CM/2013/0832) is valid for the sample number 0538/2013E, SAMPLING WAS NOT INDEPENDENTLY CARRIED OUT BY THIS OFFICE.

Note:

NA means "Not Applicable"

Attachment(s) to the Certificate: Nil

Analysed By: John Okumu

Technical Signatory:

Executive Director UNBS:



Date:

13th August 2013
203-4815

Date:

Page 2 of 2

Appendix 5: Compressive strengths test on ISSBs vs BBs



DEPARTMENT OF CIVIL ENGINEERING
STRUCTURAL MECHANICS/MATERIALS LABORATORY
EARTH BRICKS

JOB: Fired Bricks

SAMPLE LOCATION: Pajule Secondary School Site, Pader District

CLIENT: Arup

YOUR REF:

Ref No.	Date Cast	Date Tested	Age (Days)	Dimensions (mm)			Mass Kgs	Density Kg/m³	Load, KN	Ult. Compressive Strength (Mpa)
				L	X	B	X	H		
Sample 1	Not known	20/12/07	N/A	215	135	90	4.770	1826	17.7	0.61
Sample 2		20/12/07		215	135	90	5.105	1954	31.4	1.08
Sample 3		20/12/07		215	135	90	4.715	1805	9.8	0.34
Sample 4		20/12/07		215	135	90	4.905	1878	7.8	0.27
Sample 5		20/12/07		215	135	90	4.465	1709	98.1	0.34
Sample 6		20/12/07		215	135	90	4.223	1617	7.8	0.27

Tested by: Mr. Fred Mukasa

Checked by: Dr. Umar Bagamia
CIVIL ENGINEERING DEPARTMENT
FACULTY OF TECHNOLOGY
MAKERERE UNIVERSITY
P.O.BOX 7062, KAMPALA - UGANDA



DEPARTMENT OF CIVIL ENGINEERING
STRUCTURAL MECHANICS/MATERIALS LABORATORY
EARTH BLOCKS

JOB: Testing of Stabilized Compressed Earth Blocks

SAMPLE LOCATION: Pajule Secondary School Site, Pader District

CLIENT: Arup

YOUR REF:

Ref No.	Date Cast	Date Tested	Age (Days)	Dimensions (mm)			Mass Kgs	Density Kg/m³	Load, KN	Ult. Compressive Strength (Mpa)
				L	X	B	X	H		
Sample A	14/12/07	20/12/07	6	265	140	120	8.600	1,932	137.3	3.70
Sample A	14/12/07	20/12/07	6	265	140	120	8.587	1,929	149.1	4.02
Sample B	14/12/07	20/12/07	6	265	140	120	7.600	1,707	92.2	2.49
Sample B	14/12/07	20/12/07	6	265	140	120	8.195	1,814	137.3	3.70
Sample C	14/12/07	20/12/07	6	265	140	120	7.700	1,730	98.1	2.64
Sample C	14/12/07	20/12/07	6	265	140	120	7.680	1,680	117.7	3.17

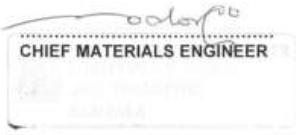
Tested by: Mr. Fred Mukasa

Checked by: Dr. Umar Bagamia
CIVIL ENGINEERING DEPARTMENT
FACULTY OF TECHNOLOGY
MAKERERE UNIVERSITY
P.O.BOX 7062, KAMPALA - UGANDA

CENTRAL MATERIALS LABORATORY

CLIENT: M/S Norwegian Refugee Council PROJECT: Alaa Primary Sch.-Pedida East Subcounty
 Kitgum District
 TEST RESULTS FOR: Fired Clay Bricks DATE: 17.10.2008

DATE MADE	DATE TESTED	DIMENSIONS (mm)	WEIGHT (Kg)	DENSITY (Kg/m³)	CRUSHING LOAD (kN)	ULTIMATE COMP. STRENGTH (MPa)
Not indicated	16.10.2008	230x100x90	3.9	1884	50	2.2
"	"	"	4.1	1981	50	2.2

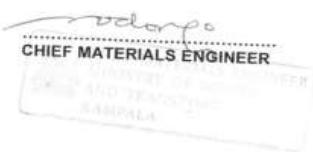


CHIEF MATERIALS ENGINEER

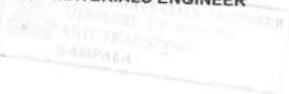
CENTRAL MATERIALS LABORATORY

CLIENT: M/S Norwegian Refugee Council PROJECT: Alaa Primary Sch.-Pedida East Subcounty
 Kitgum District
 TEST RESULTS FOR: Interlocking Blocks DATE: 17.10.2008

DATE MADE	DATE TESTED	DIMENSIONS (mm)	WEIGHT (Kg)	DENSITY (Kg/m³)	CRUSHING LOAD (kN)	ULTIMATE COMP. STRENGTH (MPa)
Stabilised soil A	16.10.2008	300x140x120	10.8	2143	185	4.4
"	"	"	10.7	2123	175	4.2
"	"	"	10.6	2103	195	4.6
B	"	"	10.8	2143	215	5.1
"	"	"	11.0	2183	210	5.0
C	"	"	11.1	2202	240	5.7
"	"	"	10.9	2163	240	5.7
"	"	"	11.0	2183	280	6.7
"	"	"	10.6	2103	260	6.2



CHIEF MATERIALS ENGINEER





BRE Centre for Innovative Construction Materials
Dept. Architecture & Civil Engineering
University of Bath
Bath BA2 7AY
UK

Sam Gordon
Good Earth Trust
164 Vauxhall Bridge Rd
London SW1V 2RA

12 September 2007

Dear Sam

RE: Tests on compressed earth block and fired clay brick specimens from Kenya

Following receipt of the Kenyan compressed earth block (CEB) and fired brick specimens from the Good Earth Trust, they were initially prepared for testing by oven drying and then cooled under ambient laboratory conditions. Due to the damage sustained by the brick en route, a 75 mm (nominally) cube specimen for testing was obtained by cutting up the broken fragments.

The specimens were tested in uni-axial compression to failure, in accordance with recognised procedures for masonry units. The CEB specimen was capped top and bottom with 3mm thick plywood sheets. The fired clay brick specimen was capped with 3 mm thick dental plaster (figure 1). The following results were obtained:

Property	Compressed earth block	Clay brick cube
Average dimensions		
Length (mm)	264	76
Width (mm)	144	70
Height (mm)	124	83
Dry density (kg/m ³)	1840	1640
Maximum compression load (kN)	230.3	15.3
Unconfined compressive strength (N/mm ²)*	4.0	2.2

* Aspect ratio correction in accordance the Australian Earth Building Handbook.

The dry compressive strength of the CEB is therefore 82% higher than the fired brick specimen supplied.

Appendix 6: Cover page of Uganda Standard, US 849

