Acceptability of Interlocking Soil Block Technology in Kenya's Construction Industry

Sanewu, Isaac Fundi[1], J.W. Kaluli[1], L.M. Ngunjiri[2] and J. Kinuthia[3]

Abstract—Interlocking stabilized soil block (ISSB) is a technology that encourages utilization of locally available building resources. Desirable features of the ISSB technology include; aesthetic value, ease of construction and non-use of mortar. This study sought to determine the social acceptability of ISSB technology in the Kenyan construction industry. The study adopted a descriptive design using semi-structured interviews on two target groups: technology users and non-technology users. Sixteen technology users were purposively selected from recorded users in the Ministry of Transport, Infrastructure and Urban Development (Kenya). Conversely, sixteen non-technology users were sampled using the snowballing technique. The ISSB technology was found to be most useful in the construction of residential houses, perimeter fencing walls and partition walls. The level of acceptability of ISSB technology to users was found satisfactory. Perceived low performance and inadequate demonstration projects amongst non-users limited their willingness to use the technology. In order to mitigate against the challenges of durability, ISSB walls should be constructed on foundations built with natural stones, be protected against wind driven rain and encourage use of earth-based rendering. Users should adopt a combined system of constructing columns and ISSB masonry to enable block connectivity with fresh concrete and achieve wall plumbness. This paper recommends a deliberate campaign in the building industry to shift negative perceptions about the ISSB technology. Furthermore, clear standards prescribing workmanship and construction guidelines must be provided to users and the construction industry.

Keywords—Interlocking soil block, Usability challenges, Standardization, Adoption index.

I. INTRODUCTION

Housing is universally acknowledged as one of the basic needs of humans. Unfortunately, because of low income levels in the country, many Kenyans are unable to own houses. The ownership of houses has largely eluded them because of the high cost of building materials. The value of new private buildings built with conventional materials has been reported to increase by 10.2 per cent from Kshs 77.7 billion in 2016 to Kshs 85.6 billion in 2017, mainly on account of a 9.7 per cent increase in the value of residential buildings [1]. According to Sessional Paper No.3 [2] on National Housing Policy for Kenya, it is estimated that urban housing needs stand at 150,000 units per year. It is also estimated that 20,000 – 30,000 units are constructed within the same period, giving a shortfall of over 120,000 units per annum. This shortfall in housing has been met through proliferation of squatter and informal settlements and overcrowding [3].

To meet the need for adequate housing of Kenya's population, Oyawa[4] proposes that sustainable investments and continued innovations have to be made on appropriate technologies that not only lower the cost of construction but also the cost to the environment. The Ministry of Housing and Urban Development, Kenya, established the Alternative Building Materials and Technology (ABMT) programme in 2006 to address high cost of building material by facilitating provision of affordable housing to low income earners. The ministry through collaboration with the Housing and Building Research Institute (HABRI) and other stakeholders led in dissemination of ABMT that culminated in partial revision of the Kenya Building Code [5]. This has encouraged selection of building materials and technologies that are both economically viable and sustainable. The Interlocking Stabilized Soil Block (ISSB) technology is one such technology that is gaining recognition. The provision of small-scale housing is therefore being achieved through use of this technology. The ISSB masonry is an assemblage of block units which are dry stacked. The interlocking nature of the blocks allows dry stacking, mortar less construction, which reduces the need for skilled labour and shortens construction time. Anand and Ramamurthy [6] found that the use of interlocking blocks lowers the cost of construction by 80%. On the other hand, Sanewu et al [7] examined the technical aspects of ISSB and found it to reliably perform in terms of structural integrity and durability. Compared with alternative fired bricks, stabilized soil blocks offer lower construction costs at comparable quality and are suitable for a wide range of environments [8].

The most important characteristic of interlocking block construction is its simplicity. Stacking interlocking blocks on each other is a simple though adequate technique. This technology has been proved viable in several pilot projects as exhibited by United nations centre for human settlement [9]. The technology has however received scepticism in its adoption due to shortage of its performance information. The objective of this study was therefore to determine the indicative social acceptability of interlocking stabilized soil block technology in Kenya. A clarification in the attractive attributes and on-site performance of this technology would aid in facilitating its acceptability and effective adoption in

1, Jomo Kenyatta University of Agriculture and Technology, JKUAT (corresponding author phone: +254721 331 375; e-mail: ifundi@jkuat.ac.ke).
2, Kenyatta University, Kenya
3, University of South Wales, UK

appropriate areas of application.

II. Methodology

Considering the objective of this study, a survey design was adopted in order to have an in-depth discussion and capture the respondent's reflections, knowledge and experience with the ISSB technology. This research adopted a qualitative research strategy. The qualitative strategy facilitated cross verification and extension of quantitative data collected through laboratory experiments. The survey study was guided by research questions which included; What type of houses are built using the ISSB technology? What qualities lead to consideration of the ISSB technology? What features of ISSB need improvement? and What is the occupational safety of ISSB buildings? In answering the research questions adequately, the study involved use of semi-structured interviews with research respondents.

The study was undertaken in Nairobi, Mombasa, Kiambu and Taita-Taveta counties. Two groups of respondents were considered: (1) Technology users (TU); and (2) Non-technology users (NTU). Technology users are those who have carried out construction using the ISSB technology while the Non-technology users have seen it being used on different projects but have had no opportunity to use it. The two target groups enabled a comparative approach in the study. Semi-structured interviews were preferred since they provided flexibility to modify the questions to the two target groups while still covering the same areas of data collection. The interview schedules included a set of key open-ended questions to define the areas to be explored.

Onwuebbuzie and Collins [10] suggests that in qualitative research the sample size should not be too small as to make it difficult to achieve data saturation, while at the same time it should not be so large that it is difficult to undertake deep case-oriented analysis. The study therefore targeted 32 respondents. Sixteen technology users (identified as TU1 to TU16) were purposively selected from the recorded users of ISSB technology in Kenya [11]. The selection criteria considered location (whether rural or urban) and availability of conventional wall materials. Sixteen non-technology users (NTU1 to NTU16) were sampled using the snowballing technique [12] considering the referrals from the technology users and their proximity to the constructed wall structures. The number of interviewees was majorly guided by the point of data collection when no new or relevant information emerged from the interviewees (saturation point). All interviews were face-to-face with participants. Before the interview, the respondents were informed about the study details and assured of their anonymity. The participant's consent to participate in the study was sought using a consent form. The interviews were audio-recorded and field notes made in order to re-transcribe the oral interviews. On average, the interviews took 30minutes to 45minutes per respondent.

III. RESULTS AND DISCUSSION

Interviews were guided by the indicative questions prepared based on the laboratory findings and research objectives. The Technology users and Non-technology users' views were organised under their preferred walling structures for ISSB technology, their evaluation of the technology performance and the factors that are inhibiting its adoption in the Kenya construction industry. The contribution of these themes to acceptability of ISSB technology has been discussed below.

A. *Preferred walling structures for ISSB technology*

There was a general agreement in both the TU and NTU that the technology can be best utilised in constructing residential houses including bungalows and maisonettes and non-load bearing walling structures (Fig.1). The technology was also argued to be adequate in acting as infill material in framed structures, but not as load bearing material. Some technology users however, contradicted this opinion by suggesting that the technology can be used in constructing recreational/entertainment and institutional centres. According to them, residential house walls requires plaster work which tend to increase the cost of construction. The ISSB technology was found least applicable in construction of storey structure (Fig. 1). Laboratory findings by Sanewu et al [7], found ISSB to have a compressive strength of 2.5 N/mm^2. In accordance to the specification of KS 02-1070 [13] this strength is adequate for non-load bearing masonry. This outcome affirms the application of ISSB technology in construction of non-load bearing structures as opposed to high rise structures. Nearly 13% of the respondents were of the view that since the technology is labour intensive it can be conveniently applied in rural set up where it can also create employment. In addition, the conviction of minority NTU was that this technology can be used in constructing decent and affordable short duration occupancy houses.

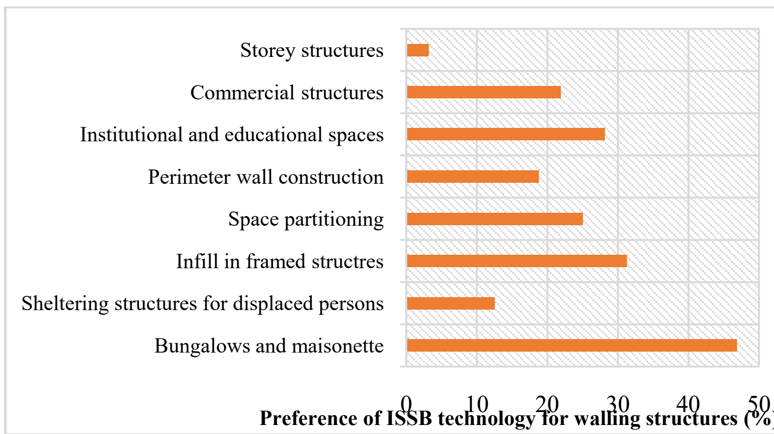


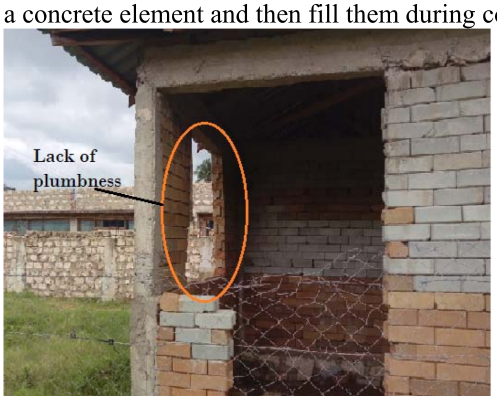
Fig. 1: Preferred walling structures for ISSB technology construction

B. *User evaluation of the performance of ISSB technology*

The theme of onsite performance was found to be very good since no visible physical deteriorating features were observed for the last 4-5 years of occupancy by the TU and the NTU. It was noted by 28% of TU that the interlocking nature of the blocks provides ease of construction and the regular nature of the blocks reduces amount of plaster works. It was observed that the masonry walls were created using running bond pattern. Since interlocking blocks are regular and smaller in size as compared to conventional blocks, the running bond pattern enabled them to interlock easily. According to Jaafar et al [14] failure of interlocking blocks occurs by splitting between the webs and the shells of the blocks depending on the type of bond pattern used. They argue that interlocking mechanism restrains the movements in horizontal and vertical directions. For load bearing construction of interlocking soil blocks, they recommended use of English running bond pattern where the performance of the walls was adequate. Their finding affirms the use of running bond in ISSB in constructing walls as practised by the technology users.

Wall plumbness and connectivity challenges

While 19% of respondents indicated block production workmanship to be the major challenge when using the ISSB technology, problem of wall plumbness was noted in the constructed houses (Fig.2a). Supporting this view, 38% of TU noted that columns need to be cast after constructing 10 courses high (approximately 1200 mm). This will encourage bonding of the concrete column with the blocks while also encouraging maintenance of wall plumbness. Where ISSB have been used as infill material, connectivity between the wall and other structural elements was noted by 9% of the respondents to be a challenge (Fig.3). This resulted to cracking along these zones (Fig. 2b). Such challenge can be averted by toothing the block wall at points where it is to be connected to a concrete element and then fill them during concreting.



(a) Challenges of wall plumbness

(b) Connectivity between blocks and column

Fig.2. Usability challenges of ISSB technology

Construction time, cost and quality

The three most preferred qualities of ISSB are non-use of joining mortar, ease of construction and natural aesthetic (Fig. 3). It was acknowledged by nearly all respondents that ISSB are regular hence not requiring cutting and dressing of the surfaces as compared to bush stones, thus reducing the time of construction. In addition, UNHABITAT [9] record that, mortar bonded masonry has mortar workmanship problems related to moving of units after mortar initial set and incompletely filing of mortar on head and bed joints. These challenges are however, averted when ISSB are used [4].

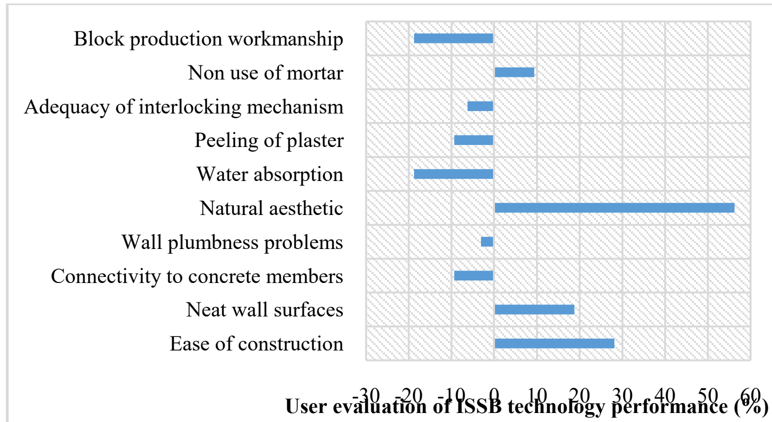


Fig. 3: Performance rating of the ISSB technology

The construction process has also been simplified by the interlocking nature of ISSB which allows them to be dry stacked without use of mortar. Mortar bonded blocks normally leave a rough surface which may necessitate plastering as compared to a good exterior décor presented by ISSB (Fig. 4a). The lean surfaces of ISSB and running bond pattern of the blocks creates a natural aesthetic appearance on the walls. The bevelled edges of the blocks allow them to generate a natural key on the wall (Fig.4b), adding to appealing appearance of the walls. This affirms Adewole [15] finding that an aesthetically pleasing look is achieved if the ISSB are properly constructed.

(a) Wall appearance of mortar bonded blocks and ISSB

(b) ISSB natural key on the surface

Fig.4.Natural wall appearance on mortar bonded blocks and ISSB walls

Durability of ISSB

The perception that earth materials are of less durability has contributed to low preference of the ISSB technology to developers. Durability was found to be contributed by poor workmanship observed during moulding of blocks. Since the blocks require mixing of the constituent materials, it was in view of some NTU that shortage of existing guidelines may lead developers to compromise on the ratios resulting into sub-standard blocks.

The study found that the first laid courses and those which were not protected against rain were susceptible to water absorption. 19% of the respondents associated water absorption with deterioration of the ISSB technology. The first courses were therefore done with natural stones or constructed on a well-drained and raised ground. In order to avoid erosion by wind driven rain, most respondents indicated that roof eaves should be made long enough to shield the blocks. Furthermore, where the blocks have been used in constructing fencing walls, a capping stone was placed at the top course to protect the blocks against rain.

Pealing of plaster was observed to occur where it had been applied on ISSB walls. Since the stiffness of cement-sand mortar is higher than that of ISSB, it may have resulted to inadequate adhesion causing the pealing of the plaster. However, to overcome this challenge, earth-based rendering materials should be applied on ISSB surfaces as recommended by ARSO:1333 [16].

Occupational safety

The theme on occupational safety was based on the question: 'How safe is it to live in houses built with ISSB?' While earlier laboratory observations indicate difficult in demolishing an ISSB wall, most of the interviewees confirmed that they felt safe while occupying the houses. Nonetheless, 6% of the respondents were suspicious of the adequacy of the interlocking mechanism. It was in their opinion that the ISSB walls may not be able to withstand small vibration or impact caused by intruders. It has been reported by Elvin and Uzoegbo [17] that earthquake damage to masonry walls constructed using interlocking soil blocks occurs in form of bricks shifting creating vertical gaps, splitting and cracking of a few bricks and spalling of plaster. Generally, they concluded that the structures are mildly damaged by earthquake vibrations and the houses still have structural integrity to allow occupants to exit safely. This finding asserts the view that the ISSB technology can sustain vibrations while assuring safety

C. Factors affecting adoption of ISSB technology

The level of adoption of ISSB technology was described by most interviewees as relatively low. It was emphasised (by TU and NTU) that the most contributing factors were: lack of awareness, missing or unknown standards of ISSB technology, fear of change from conventional materials and negative attitude towards earth material (Fig. 5).

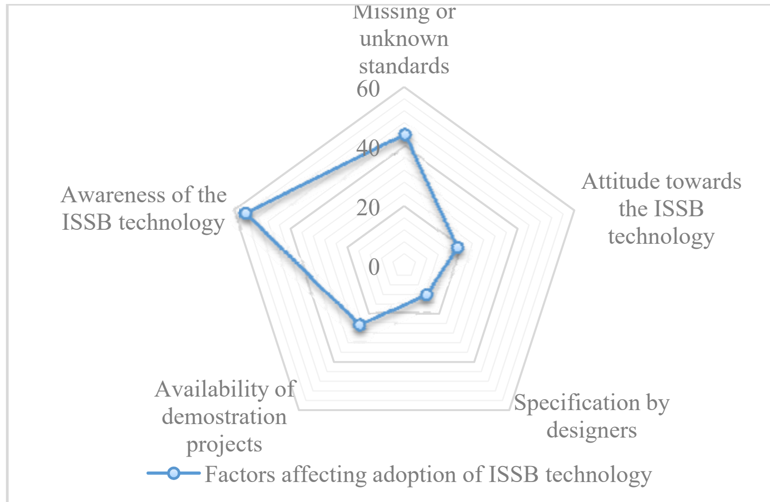


Fig. 5: ISSB technology adoption index

Awareness and attitude towards ISSB

There has been advocacy of conventional materials with aim of using stronger and prestigious material. Similarly, Tyrel [18] argues that pressure from modernization has contributed to neglection of promotion of vernacular construction methods and materials. Since the blocks are made of soil, some developers have a feeling that ISSB is reversing the progression of such trend. Awareness and exposure of the technology to developers has also been reported by Hadjri et al [19] to be lacking. As reported in Fig. 5. lack of awareness (56%) hinders the most to adoption of ISSB technology. The TU pointed out that deliberate campaign awareness should be carried out supported by construction of demonstration projects. Besides documentation of the ISSB technology advantages, there is need to develop a framework for its use on different construction sites so that home owners can be able to experience and see its performance. Conversely, the respondents opined that alternative stabilizers should be applied to enable the ISSB to be much cheaper and easily made in areas where pozzolanic cement is expensive. More so alternative target materials like crusher quarry dust and corral stone dust which are considered as waste material after quarrying activities to be used as substitute materials. This will encourage production of ISSB in regions where the existing soil is not ideal for the production of ISSB.

Clear construction standards and training

The training of construction designers in Kenya has majorly been towards use of conventional materials. However, in Nigeria it was Bobbo et al [20] recommendation that earth construction techniques should be incorporated into the educational curriculum. This was to facilitate training of designers and ultimate production of codes of designs. The lack of trained personnel coupled with unclear code of standard for the ISSB technology has led to its little specification by the designers for consideration by the clients (Fig.5). This finding concretized Burnet [21] observation that lack of standards has made earthen construction to be regarded as unapproved and un-regulated material. The present adoption has therefore been left to the premise of the current procedure based on experience, previous use and knowledge gained on site.

IV. Conclusion

This study sought to determine the social acceptability of ISSB technology in Kenya's construction industry. Based on interviews done in Kenya's construction industry, the following conclusions have been drawn:

1. The ISSB technology is best suited for construction of non-load bearing walling structures such as residential houses, perimeter fencing walls and partitioning of buildings.
2. The desirable features of ISSB technology include; non-use of mortar, ease of construction and good aesthetic value. A combined system of constructing columns and ISSB masonry should be adopted to enable blocks connectivity with fresh concrete and achieve wall plumbness. The ISSB walls should also be constructed on foundations built with natural stones and protected against wind driven rain.
3. For the ISSB technology to find a niche in the construction industry deliberate awareness, to designers through inclusion of ISSB technology in educational curriculums and to clients by constructing demonstration projects, should be enhanced. To aid specification of ISSB technology, clear codes of standards prescribing workmanship and construction guidelines should be developed.

The study recommends construction of demonstration projects in Kenya counties where sourcing of conventional walling materials is relatively expensive. In addition, home owners should be encouraged to have a perceptual shift through innovative sustainable architectural designs involving this technology in the Kenya construction industry.

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