An assessment of the usage and the improvement of interlocking stabilized soil block technology - A case of northern Uganda

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ABSTRACT

Northern Uganda is recovering from civil wars which have left communities without adequate housing. Attempts to introduce Interlocking stabilized soil blocks (ISSB) provide low cost housing haven't been very successful. The main purpose of the study was to find ways of encouraging use of ISSB. The study was both an experimental study and a survey. Tests were done on soil and block samples from projects selected from the region in the districts of Gulu, Amuru, Pader, Kole, Lira and Oyam. Questionnaires were also given to Engineers, Technicians and craftsmen from the same study location and data collected were analyzed using the Statistical Package for Social Sciences (SPSS) to test, rank and correlate them.

Tests on soil samples and block samples indicated that they are of generally acceptable quality and strength however, water absorption was generally high. Low incomes and low durability of the blocks were found to be the greatest barriers, whereas the greatest enablers are the fast speed of erection, and environmental friendliness. It is recommended that: UNBS commission ISSB standards; government provides more funding; policies are developed that promote the use of ISSBs: and more research is done on the durability of the ISSBs.

Keywords: *Factors; Adoption; Interlocking stabilized soil blocks; Appropriate Technology; Northern Uganda.*

1.0 INTRODUCTION

1.1 Background

According to the Uganda Bureau of Statistics (2006), 80% of housing in the rural areas is of temporary wall whereas nationally it is 70%. In Northern Uganda insurgencies displaced more than 1.8 million people into internally displaced persons camps for more than a decade (SPRING, 2010). Interlocking Stabilized Soil Block (ISSB) technology, an appropriate technology, was one of the methods introduced to help build houses to resettle the people. In June 2009, government of Uganda handed over several new Hydraform block making machines to 40 Northern Ugandan districts (Hydraform, 2009).

Interlocking means that the blocks/bricks are manufactured with special protrusions, dents and holes (Picture 1), that allows them to bond in wall construction without the use of mortar in construction.

Picture 1: Interlocking block work bonding

In 2009 in Uganda, with funding from the United Nations International Children's Education Fund (UNICEF), implemented a resettlement project to facilitate the sustainable return and re-integration (UN-HABITAT, 2009). The technology uses environmentally-friendly building materials and construction techniques that are more affordable to the poor while still meeting rigorous building standards. Similarly, the PRDP program, has distributed ISSB making machines to several districts in Northern Uganda for the construction of model houses to show case for the use of ISSB.

"Although these machines [hydraform] were meant to help the various vulnerable communities to afford reasonable housing at a low cost, it was noted that there was no evidence of work done using the machines …" (Office of the Auditor General, 2009). Even where attempts were made to construct low cost houses, it has been reported that some contractors carried out shoddy work. This increased the costs of supervision in the district …, while in some cases the works had to be demolished as was the case with the Staff House Construction at Aber Health Centre II in Aber Sub-County, (Northern Uganda Data Centre, 2010).

1.2 Problem Statement

Attempts to introduce the use of Interlocking Stabilized Soil Blocks (ISSBs), an appropriate technology in Northern Uganda, under the PRDP, has not yielded the expected outcomes in some of the districts like Oyam, Lira and Kole. In some districts like Oyam, ISSB technology is characterized by very low usage. Furthermore, projects that have been completed in the area do not seem to measure well with established standards and works accomplished in other areas. There has also been no attempt to analyze the reasons as to why the technology is not being easily adopted by the communities in this region.

1.3 Objectives

The general objective of this research was to establish ways of improving the use of ISSB technology in northern Uganda. The specific objectives of this research were to characterize current local materials and practices in ISSB technology in northern Uganda in comparison with standards and the machine manufacturers' recommendations and to assess the factors affecting adoption of ISSB technology.

1.4 Hypothesis

The hypotheses to study the characteristics of soil and block properties are summarized in the table below.

Table 1: Summary of Hypotheses

Property	Null Hypotheses	Alternate Hypotheses	Standard/ Recommendation
Clay content of soil	H_o: x > 30%	H_1: x ≤ 30%	Less than 30%
Plasticity index of soil	H_o: x ≠ 20%	H_1: x=20%	Average of 20%
Compressive strength of block	H_o: x < 2.5N/mm^2	H_1: x ≥ 2.5N/mm^2	At least 2.5N/mm^2
Dry density of block	H_o: x < 1600Kg/m^3	H_1: x ≥ 1600Kg/m^3	At least 1600Kg/m^3
Water absorption of block	H_o: x > 15%	H_1: x ≤ 15%	Not more Than 15%

2.0 METHODOLOGY

The research was quantitative and involved the use of both laboratory tests on soil and block samples and questionnaires that were given to engineers, technicians and craftsmen. The study was carried out in the districts of Gulu, Amuru, Pader, Kole, Lira and Oyam. Due to the large geographical area, purposive sampling was carried out in order to collect block and soil samples, and to distribute questionnaires. Soil samples used in the manufacture of blocks were taken from ten selected sites in the Northern Uganda sub-region. A minimum of five (5) block samples were also collected from each of the 10 project sites visited and taken to the laboratory in Gulu for tests. The number of five block samples is the minimum requirement for compressive strength testing (UNBS draft standard No. FDUS849). Tests on the soil samples were carried out according to methods for testing civil engineering soil (British Standards Institution, 1990) whereas for the blocks were according to Uganda National Bureau of standards methods (UNBS, 2009)

The reliability of factor ratings for the questionnaire was tested using Cronbrach's α Coefficient of Agreement which is a component within SPSS package. This provides a range from 0 to 1.0 which is used to determine how reliable the responses were with 0 being unreliable and 1.0 being reliable as the extremes of the continuum. Reliability of laboratory experiments on the other hand, was checked using t-tests and z-tests at 95% level of confidence for testing the hypotheses. Quantitative data gathered from the study were summarized and analyzed using Statistical Package for Social Scientists-(SPSS 12). One sample t-tests and z-tests were carried out on the results of the findings to test the research hypotheses.

The t-test was used for results with samples less than 30 whose population mean and standard deviation were unknown.

Where x: sample mean, µ: population mean, s: standard deviation, n: number of samples & df: degrees of freedom. For tests with more than 30 samples, z-tests were used

Where x: sample mean, µ: population mean, s: standard deviation & n: number of samples.

3.0 RESULTS

Table 2: Summary of Statistical Tests on Laboratory Tests

Property/ Test Statistic	Results			Hypotheses	Standard/Desired
Clay content of soil (t-Test)	x=24.40% n =10	μ =30% d.f = 9	s =2.91% t = -6.078	H_o: $x > 30\%$ H_1: $x \leq 30\%$	Less than 30% (Davis, 2003 & Ewan, 2003)
Plasticity index of soil (t-test)	x =19.70% n =10	μ =20% d.f = 9	s =5.85% t = $\pm$0.162	H_o: $x \neq 20\%$ H_1: x=20%	Average of 20% (Walker, 1995)
Compressive strength of blocks (z-Test)	x =3.586 N/mm^2 n =50	μ =2.5 N/mm^2 z = 6.19	s =1.24 N/mm^2	H_o: $x < 2.5N/mm2$ H_1: $x \geq 2.5N/mm2$	At least 2.5N/mm^2 (UNBS, 2009)
Dry density of block (z- Test)	x =1787kg/ m^3 n =50	μ=1600 kg/m^3 z = 7.64	s =172.98 kg/m^3	H_o: $x < 1600Kg/m3$ H_1: $x \geq 1600Kg/m3$	At least 1600Kg/m^3 (UNBS, 2009)
Water absorption of block (t-Test)	x=18.58% n =25	μ=15% d.f= 24	s = 4.63% t = 3.866	H_o: $x > 15\%$ H_1: $x \leq 15\%$	Not more Than 15% (UNBS, 2009)

3.1 Questionnaire

A total of 60 questionnaires were given to respondents and were returned giving an overall response rate of 88.33%. Responses from the questionnaires were analyzed using SPSS 12. To test the consistency of the ratings, a null hypothesis H_o was set as “there was no significant agreement among the respondents on the rating of factors”. The alternative hypothesis H_1 was set as “there was agreement among the respondents on the rating of factors”. The analysis aimed at establishing that the ratings had not been arrived at by chance but rather that there was true agreement in the ratings and therefore the results are reliable. To test the hypothesis, non-parametric tests using Cronbrach’s α Coefficient of Agreement was used (Salkind, 2008). The null hypothesis was rejected since the Cronbrach’s α Coefficient was 0.711 which shows that the results were reliable according to ratings by George & Mallery (2003).

3.2 Factors Affecting the Adoption of ISSB Technology

Findings on factors affecting the adoption of ISSB technology through questionnaires is shown in Table 4.7. The results were analyzed through SPSS and the factors were ranked using a five (5) point Likert scale with one (1) as barrier, three (3) as the neutral or no effect and five (5) as the enabler. The mean ratings, standard deviations and correlations were then determined as perceived by persons that have been actively involved in using this technology. Rankings of the factors according to their mean ratings are summarized in Table 4.7.

Bivariate correlation analysis was also performed on the mean ratings and standard deviations of the barriers and enablers shown in Table 4.10. The correlation analysis indicated significance for most of the factors at levels of 0.05 and 0.01 respectively.

From Table 4.8 it is seen that the speed of erection (C9) with mean rating of 4.40 is the greatest enabler. The next in ranking is the strength of blocks (C2) with a rating of 3.91. On the other end of the continuum as a barrier is income of users (C6) with a mean rating of 1.53. It is the greatest barrier followed by awareness (C7) with a mean rating of 1.70

Table 3: Ratings for Factors in the Questionnaire

Code	Factors	Mean	Std. Deviation
C9	Speed of erection	4.40	0.72
C2	Strength of blocks	3.91	0.97
C10	Suitability of soils	3.30	1.05
C1	Standardization of technology	2.98	0.99
C8	Design of buildings	2.81	0.62
C4	Skills and workmanship	2.62	0.88
C5	Tools and equipment	2.55	1.05
C3	Durability of blocks	2.45	1.19
C7	Awareness	1.70	0.58
C6	Incomes of users	1.53	1.03

Test t- statistics

The t-test was carried out on the significance of the ratings with the test value being set as 3 because the rating scale was form 1 to 5 with 3 as a neutral position. The two tailed test for level of significance shows that all the factors have a value less than 0.05 except for standardization of the technology, therefore ratings are significant. Also the 95% interval of difference shows that all factors have both the upper and lower limits either below or above zero except for standardization of technology meaning that they are all significant.

Table 4: Results of t-Tests Analysis

	Test Value = 3					
	t	d.f	Sig.(2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
1. Standardization of technology	-0.139	52	.890	-.019	-.29	.25
2. Strength of blocks	6.825	52	.000	.906	.64	1.17
3. Durability of blocks	-3.359	52	.001	-.547	-.87	-.22
4. Skills and workmanship	-3.115	52	.003	-.377	-.62	-.13
5. Tools and equipment	-3.145	52	.003	-.453	-.74	-.16
6. Incomes of users	-10.398	52	.000	-1.472	-1.76	-1.19
7. Awareness	-16.494	52	.000	-1.302	-1.46	-1.14
8. Design of buildings	-2.209	52	.032	-.189	-.36	-.02
9. Speed of erection	14.191	52	.000	1.396	1.20	1.59
10. Suitability of soils	2.096	52	.041	.30189	.0129	.5909

Correlation analysis was also done on the factors identified and some of the factors showed significant correlation at 0.05 level (two tailed) while others showed significance at 0.01 level (two tailed).

4.0 DISCUSSION

4.1 Laboratory tests

4.1.1 Silt and clay Content

ISSB technology is designed to use earth which is typically a sandy clay or lateritic soil, stabilized with between 5-7% cement (Browne, 2009). Montgomery (2002) observed that more cement is needed to counter the effect of high fines contents that result in high expansion. For contents of clay higher than 30% lime is recommended as a binder (Browne, 2009). Actually the best soils are those with sand contents of between 60-70% (Ewan, 2003). The silt and clay content in soils that were tested contained less than 30% of silt and clay [Fines] which is acceptable. In cases where the silt and clay content is high, sand is added to improve its grading other than using more cement.

4.1.2 Plasticity Index

Plasticity index (PI) of the clay soil is usually in the range of 15 to 25. However, according to Walker (1995), the best earth soils for stabilization are those with low plasticity index below 20%. He also adds that they are not suitable for manual compaction. Due to the variation in PI therefore, it's important to first of all, test soils in order to decide whether to use the manual machine or diesel operated one, and to establish whether or not to modify the soil grading as a way of improving the PI.

4.1.3 Compressive Strength

Tests on block samples indicated that they had average compressive strength of 3.58 N/mm^2. The draft UNBS standard FDUS849 (UNBS, 2009) that is based on the Kenya standard KS 02 -1070:1993P (KEBS, 1993) specifies a value of 2.5N/mm^2. This is in agreement with studies that strength of blocks is generally acceptable (Browne, 2009; Kerali, 2001). Also a typical internal cavity wall load-bearing block in the UK is manufactured to a compressive strength of 3.5 N/mm^2 (Browne, 2009). This result therefore means the block strength is acceptable.

4.1.4 Dry Density

Results of tests carried out on block samples indicated a mean strength of 1,787Kg/m^3which is higher than the allowable standard of 1,600 Kg/m^3 (FDUS 849). Since Montgomery (2002) classifies dry densities between 1900 and 2000 kg/m^3 as excellent, it may still be necessary to raise this property to 1,800 Kg/m^3.

4.1.5 Water Absorption

Water absorption of blocks is one of the indicators that can be used to determine its durability. Specifications by UNBS give a maximum value of 15%. Findings indicated an average of 18.78% which is high and unfavorable. Generally un-rendered low-cement (<6%) and low-density (<1800kg/m^3) ISSB exhibit an unacceptably low tolerance to humid conditions and will deteriorate during less than10 years (Montgomery, 2002). This could explain the low durability and it's also recommended that they should not be used in the foundations.

4.2 Questionnaire Results

4.2.1 Factors Affecting the Adoption of ISSB Technology

Speed of Erection

This was ranked as the greatest enabler with a mean of 4.40. Due to the interlocking mechanism of the blocks, wall construction is much easier and quicker (UN-HABITAT, 2009). This is achieved through mortar-less construction by dry stacking of blocks. In addition to the speedy construction process, the block production process is also generally shorter unlike clay bricks where the clay has got to be mixed large amounts of water and heaped into mounds and weathered for days. However, fast speed of erection can only be possible when all the resources needed for construction are ready including roof construction and covering to protect the blocks from rainfall.

Strength of Blocks

Strength of blocks came in second as an enabler and laboratory tests on samples from most sites showed compressive strengths over $2.5N/mm^2$ the minimum recommended by UNBS. Browne (2009) states that block strength should not be an issue as studies have generally yielded adequate strength of ISSB blocks. However, strength of the blocks is very dependent on the quality of materials used and workmanship. Although this is acceptable, as noted already, this strength may be acceptable as per draft standard of UNBS but may need to be raised to $3.5\ N/mm^2$.

Suitability of Soils

The suitability of soil came third with a mean rating of 3.30 which makes it an enabler. Parameters that were used in the laboratory experiments to determine soil suitability included silt & clay content and the plasticity. Silt and clay content was less than 30% recommended by Browne (2009). The plasticity index however varied from the recommended average of 20%. On the whole however, the soils were generally suitable. This implies that soil is not transported from far off borrow pits, no need to use lime (binder) that is not commonly found and for variations in silt and clay contents only sand can be added to improve the grading.

Standardization of Technology

This factor got a neutral position rating of 2.98; however there are important benefits that come with standardization of technology which can only be appreciated after long term use of the technology. These include: setting and enforcing the correct minimum standards; using accurate machines since mortar is not used and the buildings only depend on the shape and dimensions of the block. From the observations on the different blocks made by different machines, some had deeper interlock depressions than others. This factor can either undermine overall wall strength or improve it since the tolerance of the blocks determines how tightly they fit (UNBS, 2009).

Design of Buildings

Design of buildings also got a near to neutral rating of 2.81, however, in spite of the fact that most of the buildings to be made are simple in nature, its design plays a key role in strength and durability. Firstly, ISSBs are very prone to weather therefore larger roof overhangs protect the walls form rain and secondly length of straight walls is normally limited 4.5m. This also improves its stability especially when cross walls are introduced (Nasley *et al*, 2009). Therefore design features on a building go a long way in making it an enabler for adoption.

Tools and Equipment

Observations made on construction sites visited indicated that most of the works were being done with very few tools most of which were very basic. The assumption they seem to make is that these blocks are so precise that as long as the first course is level and plumbed, it's just a matter of piling subsequent courses on top. This however is not the case as the tools recommended by most machine manufacturers like Hydraform include dumpy levels and spirit levels up to 1.5m long.

Durability of Blocks

Browne (2009), Ewan (2003) and Kerali (2001) all agree that blocks made out of stabilized earth are generally not very durable. Generally, low-cement (<6%) and low-density (<1800kg/m^3) ISSBs with un-rendered surfaces exhibit an unacceptably low tolerance to humid conditions and will deteriorate during less than 10 years (Montgomery, 2002). Durability is a barrier that can be overcome with surface treatments like render, burnt oil application, use of more cement binder in ISSB manufacture or other coatings. This implies that costs become higher making the technology otherwise more unfavorable.

Skills and Workmanship

Skills and workmanship had a rating of 2.62. According to Alinatwe (2008), the knowledge and skills of the workers is a barrier to productivity. This technology is a little different from the conventional construction using mortar for bonding. It's not been included in the curriculum of most technical institutions and it has always been assumed that only intensive training is sufficient; however, some form of certification and testing is necessary. In the country as a whole the practice of licensing and certification of tradesmen is not in force except at professional levels of engineers, architects and surveyors. This is one of the factors that is difficult to overcome and can only effectively be dealt with if government policies are developed and enforced.

Incomes of Users

The biggest economic activity in the region is subsistence farming (Uganda Bureau of Statistics, 2006), which really does not bring in much income that can be saved for construction. The incomes of users is a major barrier and is indirectly linked to the speed of erection and the durability of the blocks that requires substantial funding that should at least go up to roofing. This is important in preventing the deterioration of walls by the effect of rainfall. The low incomes of the beneficiaries are indicated by the fact that the majority of projects are mainly funded by NGO's and government. The low incomes also affect the choice machines to be used which should be the manual type that is not only much more affordable but also easy to operate and maintain.

Awareness

Awareness of the potential users was rated as the greatest barrier. The common and effective ways of creation of awareness in order to decrease this problem as used in other places include; model projects, community education, training in schools and distribution of brochures (Good Earth Trust, 2008; U.N- HABITAT, 2009 & U.N., 1976). Some of these have been used but to a small extent and a lot can still be done even through the local leaders.

5.0 CONCLUSIONS

The properties of the soil used for making the blocks and the blocks themselves are generally of acceptable standards; however the water absorption of the finished block is high. This makes ISSB's less desirable for construction in these areas which are characterized by heavy rainfall. The machines commonly in use are diesel operated as opposed to the manual ones that are of much lower costs and easier to operate. Most the projects were the construction of houses implying that there is underuse use of the technology which could be very useful in the construction of rainwater storage tanks. The majority of projects are also funded by NGO's and Government implying that the poor are not able to afford.

Key factors that seem to favor the technology are fast speed of erection and environmental friendliness of the materials which avoid the destruction of forests for the production of burnt clay bricks. Despite the generally favorable materials and technology exhibited by ISSB technology, the predominant barriers include affordability for the poor, the stigma associated with the technology which is seen as mud and the generally low durability of the blocks. The other factors that were also identified and studied including; standardization of technology, design of buildings, skills and workmanship, tools and equipment, durability, awareness and incomes still feature predominantly as barriers which could explain the slow spread of this technology.

Recommendations

- Use of manual machines other than electric
- Stones and rocks should be used for the construction of foundations.
- sand should be added to soils with clay and silt fractions greater than 30%,
- The draft standards developed by UNBS should be commissioned.
- Design of buildings when using this technology be seriously considered
- Awareness in terms of publicity and sensitization.
- More Funding should be made in terms of grant schemes.
- The curriculum in technical schools should also include this technology(ISSB)

Areas for Further Research

Further studies should be made with regard to cost effective controls to enhance the durability of ISSB's. Studies should also be carried out to develop a simple and affordable tests on the block that can be used as an indicator of strength and durability.

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