

Adoption of appropriate technology in construction: A pilot study of compressed earth blocks uptake in Kamuli District – Uganda

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The use of compressed soil blocks (CSB) in the construction of housing in Uganda can be traced back to the slum upgrading projects of the early 1990's (DCDM, 2003a; 2003b). 25 years on, the propagation of a technology that has seen improved supply of housing in India, South America and Southern Africa has had little impact on the supply of housing in Uganda. Basing itself in the diffusion theory, this study provides insights into how failure of adoption can be managed or reduced.

In an effort to better understand how current and future innovations may be better conceived and rolled out, the level to which the perception of critical adoption dimensions affect diffusion are queried in the propagation of compressed earth block as a building material. The study was undertaken based on the innovation decision model, querying identified opinion leaders in communities where CEB technology has been utilised about their opinion on the technology.

The study found that perceived economic advantage of a technology is a decisive factor for its adoption in spite of awareness of promising alternatives. The study identified that while interpersonal communication channels are important in the formulation of opinions, these present a limited opportunity for awareness of a critical number for adoption to gain momentum. The study having tested methods of identifying opinion leaders, forwards the notion that awareness drives focused on these individuals, emphasising the lifecycle cost benefits of CEB has the potential to lead to an increase in demand and adoption. Furthermore increase in demand can lead to a reduction in price of CEB through a greater sharing of fixed overhead costs.

Key words: Appropriate Technology, Compressed Earth Block, Adoption

1. INTRODUCTION

Access to housing the world over is a particular challenge for all income groups. In the global south however, it continues to be a stark problem due to low incomes, lack of access to housing finance facilities and supply bottlenecks from centralised institutions.

Building materials purchase, transportation and handling presents a major percentage of overall financial, social and environmental construction costs in the procurement of conventional tropical housing. In Uganda, various innovations have been fronted to overcome these challenges and make appropriate housing more accessible. Of particular interest to this research is the Compressed Earth Block (CEB) and its variants. Earth is a familiar construction material in the region and has been in use for generations; it would then seem that Compressed

Earth Blocks would very quickly become the material of choice for housing construction, especially within the low income groups. However, this is not the case.

Traditional housing construction entailed the use of earth, wattle and wooden poles with a covering of thatch roof; today, these methods are stigmatised as being backward as the population adopts “modern” materials. The situation at hand has been augmented by adopted building codes that shun traditional materials, labelling them as temporary and therefore unfit for urban construction (UN-Habitat, 2010), serving to increase the cost of housing supply.

It has to be noted that fired clay brick, which is the predominant building material today (UBOS, 2010; Hashemi et al., 2015) has a number of detrimental short and long-term impacts. These include: cutting of virgin non renewable forests for wood fuel; inefficient firing that leads to energy wastage and a high associated embodied energy; smoke pollution and associated respiratory health problems, and destruction of wetlands during clay excavation (Oteng'i and Neyole, 2007, UN Habitat, 1991). To alleviate these challenges, CEB has been fronted, aimed at not only improving traditional earth masonry and reducing the demand supply gap of quality construction materials, but also counter the negative environmental impacts that are associated with the production of fired clay brick.

Compressed Earth Block (CEB) or Compressed Soil Block (CSB) is the modern descendent of the moulded earth block, more commonly known as the adobe block. The idea of compacting earth to improve the quality and performance of moulded earth blocks is, however, far from new, it was with wooden tamps that the first compressed earth blocks were produced, and this process is still used in some parts of the world. The turning point in the use of presses and in the way in which compressed earth blocks were used for building and architectural purposes came in 1952, following the invention of the CINVA-RAM press, designed by Raul Ramirez at the Inter American Housing Centre (CINVA) centre in Bogota, Columbia (UN-Habitat, 2009; Titan Brick, 2013.) Since then, a number of technologies have been implemented for the production of CEBs with varying success.

The use of CEBs in the construction of walling in housing was introduced by the Uganda government financed slum-upgrading projects in the early 90s with varying degrees of success. Since then, a number of private and public institutions have utilised the technology, bringing public awareness up. However, the reach of these institutions has remained limited, so much so that in the Uganda National Household Survey 2012/2013, CEB is not listed among the major construction materials in use.

This has been attributed to a variety of factors; according to UN-Habitat (2009) technologies such as Interlocking Stabilised Soil Blocks (ISSB) – a CEB variant - have not been integrated into the educational curricula of secondary vocational institutions and tertiary engineering and architectural institutions, and thus adoption has been slow. Further still, *ibid* suggests that a key challenge affecting the propagation of the technology is changing the mentality of the companies and individuals already manufacturing and using conventional methods of construction such as burned bricks and concrete blocks. In addition, UN-Habitat (2010) indicates that a lack of official recognition and incorporation in the building regulations of emerging technologies affects their acceptance negatively. While the arguments presented are valid, the study at identifies the fact that the grounds presented are limited to the implementing side and takes little note of the prevailing attitudes of the would be users of the technology.

The study at hand investigates the recipients of innovative technology, querying the social-technical systems within which diffusion of innovations occurs by investigating perception of would be adopters towards CEB; furthermore, the study analyses factors that influence adoption from opinion leaders perspectives with empirical insights.

2. DIFFUSION THEORY AS A FRAMEWORK FOR RESEARCH

The diffusion theory provides an excellent platform to decipher how practices in construction go from innovation to standard industry practices. Diffusion in general is the process by which an innovation is communicated through certain channels over time among the members of a social system. Rogers (1983) states that communication is a process in which participants create and share information with one another in order to reach a mutual understanding or convergence. When a change agent seeks to persuade, and approaches a client to adopt an innovation, it can be realised that such an event is only one part of a total process in which information is exchanged; with more deliberate observation it can be seen that their interaction continues through several cycles, and is a process of information exchange.

Further still, (Rogers, 1983) designates diffusion as a special type of communication because it involves the propagation of an innovation. An innovation is an idea, practice or object that is perceived as new by an adoption unit, which might be an individual or society. This newness implies that there is a degree of uncertainty - here meaning a lack of: predictability and performance information in the minds of potential adopters owing to no prior application.

Various literature (Rogers, 1983; Robinson, 2009; University of Twente, 2015) infer that there are a number of close knit and often interrelated factors that influence the rate of diffusion or adoption of new technologies, these are: the characteristics of innovation itself; communication channels used to propagate information about and the innovation; the effect of time and consequences; and the context or social system within which the innovation is spreading.

The factors presented are complex social constructs and it is therefore important to examine the frameworks within which they interact. Theoretical models help to explain, predict, and understand phenomena and, in some cases, to challenge and extend existing knowledge within the limits of critical bounding assumptions. According to Koebel et al. (2004) diffusion is modelled extensively as either the diffusion process or the adoption process with the difference being that diffusion models focus on the overall rate and timing of the diffusion of an innovation within a specific industrial sector, while adoption models focus on the characteristics of the person, firm or society adopting an innovation and the decision to adopt. Currently, there is very little evidence to suggest that CEB is being taken up as a construction material in Uganda; therefore, of particular interest to this study is the innovation adoption model, to identify why this state of affairs exists. Key to adoption models is the innovation - decision process defined as a mental process where a would be adopter seeks information at various stages in order to decrease uncertainty about an innovation's expected consequences.

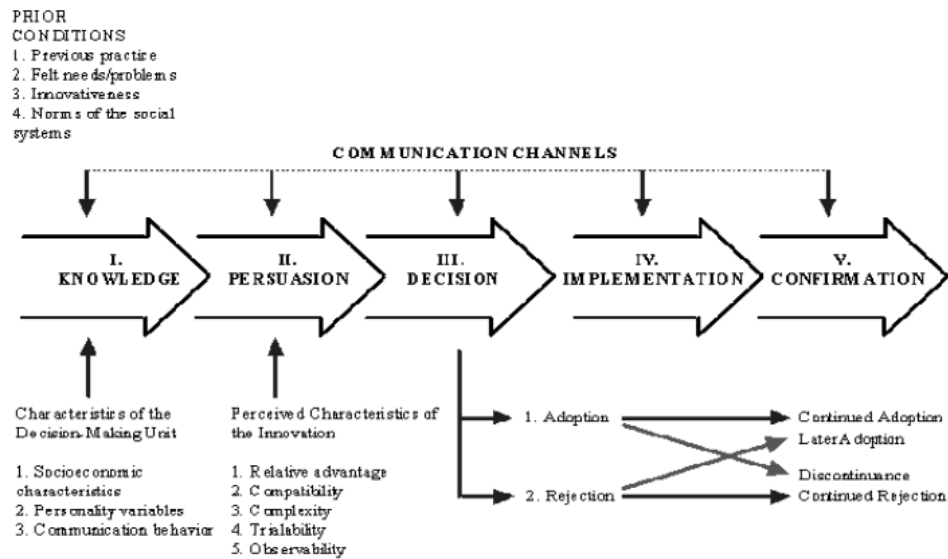


Figure 1: Innovation decision model adapted from Rogers in Mustapha (2006)

Mustapha (2006) expounds on the notion presented by Kobe et al. (2003) presenting four theories common to diffusion studies: Innovation decision process, individual innovativeness, rate of adoption, and perceived attributes. The author states that among these, the most widely used theoretical approach is the innovation decision model. This process, has four key stages: Knowledge - a person becomes aware of an innovation and has some idea of how it functions; persuasion – a person forms a favourable or unfavourable attitude toward the innovation; decision – a person engages in activities that lead to a choice to adopt or reject the innovation; implementation – a person puts an innovation into use; confirmation – a person evaluates the results of an innovation-decision already made.

In order for a population or an individual to adopt an innovation, there must be awareness of the innovation. The drivers for initial awareness are debatable with arguments suggesting that information can either be sought out by potential adopters or furnished by a change agent (Koebel et al., 2004.) However, there is consensus that awareness is a key driver for adoption. According to Robinson (2009) and Rogers (1983), mass media and interpersonal communication, are the key channels of dissemination with regard to the spread of innovations. However, Robinson (2009) suggests that mass media are more effective in creating knowledge of innovations, whereas interpersonal channels are more effective in forming and changing attitudes toward a new idea, and thus influencing the decision to adopt or reject a new idea.

The study by approaching various actors in the construction industry and utilising a cross-referencing methodology identified Haileybury Youth Trust (HYT) Uganda, a community based NGO involved in CEB propagation as a possible partner in the study exercise. HYT Uganda is funded by various charities from the United Kingdom and trains local youth volunteers for a one-year period in soil selection, mix preparation, CEB manufacture and construction techniques. The aim of the HYT is to increase the use of low-cost carbon saving techniques, specifically CEB, impart necessary skills to meet the growing demand for infrastructure and improve livelihoods (HYT Uganda, 2014.)

HYT being engaged in the construction of a 4-classroom block, 2 staff houses and a kitchen in 8 schools in Kamuli district, Eastern Uganda plays the role of change agent, creating awareness and disseminating information through various channels about CEB. The construction of the

aforementioned school infrastructure over several sites represents a large application of CEB in an accessible area for research study.

The degree to which an adoption unit is relatively earlier in taking on new ideas than other members of a social system is referred to as innovativeness. Adoption models that expound on the innovative nature of individuals within a society are largely based on the work of Everett Rogers, who categorizes the innovative character of adopters as a function of time and as a probability distribution (Koebel et al., 2004; Eder et al., 2015). Here, it is suggested that different types of adopters have distinctive individual profiles in terms of age, education, income, risk tolerance, and these affect the individuals propensity to take on a new technology. There are 6 distinct groups of people: innovators, early adopters, early majority, late majority, laggards and non-adopters.

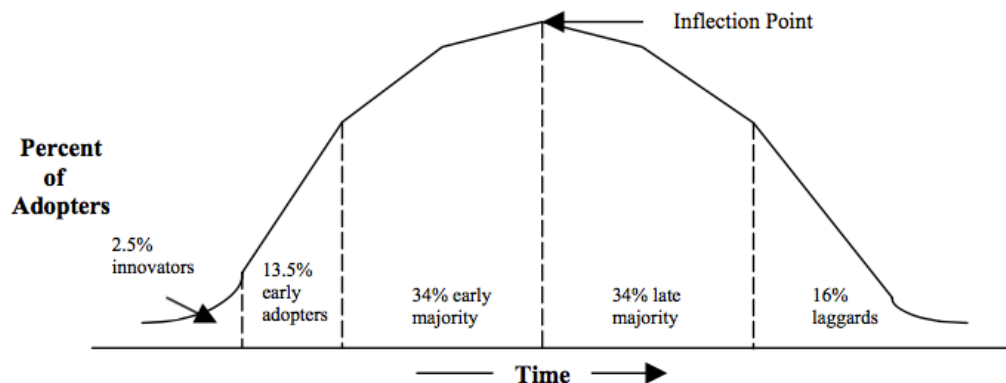


Figure 2: Adoption curve (Koebel et al., 2004)

Innovators are those who want a certain product as soon as it becomes available. Innovators are willing to take risks, and have financial capabilities. Early adopters are a larger group who also seek new products but may look more into functionality and are more integrated in the local system than are the innovators. The early majority is the first mass of people to adopt a product. The early majority interact frequently with their peers but rarely hold positions of opinion leadership within the social system (Eder et al., 2015; Robinson, 2009.) The late majority adopts when the majority of the market is already familiar with the product. According to Robinson (2009) the relative scarcity of resources within this group means that most of the uncertainty about a new idea must be removed before this group of people feel the need to adopt. The final group to adopt an innovation are the laggards, with the non-adopters not taking up the innovation.

In order to determine adoption trends and the underlying reasons for adoption, the study sought out opinion leaders within HYT's area of operation; opinion leaders are individuals who are influential within the social system and who spread information about an innovation. These individuals are often local and generally are to be found among the early adopters (Eder et al., 2015; Feder and Savastano, 2006.) Furthermore, Valente and Davis (1999) state that the diffusion network relies on opinion leaders to initiate the diffusion of a new idea or practice. They can function as champions for the new practice and accelerate the diffusion process and will often function as the theoretical underpinning to peer education programmes.

The study at hand utilised network analysis, a set of methods that enables researchers to locate individuals who are more central to a community and thus perhaps more influential to identify the appropriate opinion leaders to query. Chatman (1987) expounds on the concept of network analysis stating that there are three main methods to measure the existence of opinion leaders:

sociometric, designation by key informants, and self-designation. While the sociometric method has the greatest degree of objectivity – here all members of a social environment are tasked to identify opinion leaders and the networks between individuals are analysed, the study utilised designation by key informants. This method was chosen for over the sociometric method for two reasons; first, sociometric analysis requires considerable time and financial resources, both of which were constrained, and second not all members of the environment were accessible. Furthermore, self-designation was considered inappropriate because the considerable bias augmented by the fact that the study had little information on the society in question. The designation by key informants process identified 20 opinion leaders, 5 each from 4 different sites, accessible to the study: Nakibungulya, Kisege, Bugonda Butaga, and Makanda, in HYT's area of operations.

To capture the diffusion mechanisms important to homebuilders, we developed a questionnaire to measure the variables that were identified in the literature review as influencing technology adoption, and these were filled out during structured interviews. In an area where literacy is low, the method allowed the research team to consistently probe respondents for in depth opinions and the reasoning behind these opinions through conversation with the aid of an interpreter.

The survey tool was divided into two distinct parts. The first section collected background information such as the respondents' age, sex, employment status and position in the community. This information provides a qualitative background enabling researchers to ascertain the position and context of the views presented by the respondent.

The second part of the questionnaire queried the innovation decision process: First, the communication channels through which the respondent learnt about the technology, and the length of time that has elapsed since first learning about the technology. Following on, having learnt about CEB, the research tool gathered information about the amount of knowledge an individual has on CEB, whether they have formed a favourable or unfavourable attitude towards the use of CEB as a construction material; this being a result of , the adopter's perception of the inherent qualities of CEB. Here questions pertaining to the innovation's consistency with the populations' values and relative advantage in terms of: economic advantage, social prestige, and convenience / satisfaction were asked. Having developed an opinion; the study participant was queried on the course of action taken. The research tool collected this data by employing a 3-point scale, whose responses were backed by 5 secondary questions. The use of multiple interrelated scales enables response verification.

The survey tool rounded off by asking respondents to comment on issues that they felt were pertinent but had not been touched upon by the research team.

3. RESULTS AND DISCUSSION

The study collected information from a total of 19 respondents who included technical personnel involved in the training of youth, locals and administrators in the schools where HYT was active. In common was the fact that the majority of individuals identified as opinion leaders had positions in local leadership at various levels; 4 of the respondents are formal leaders in the local council system, while 7 are informal leaders within the community structure. The importance of formal leaders is highlighted by Nypan (1970) whose study in East Africa concludes that the involvement of formal leadership in the diffusion of innovations has a positive impact as they occupy a central position within their communities. The author notes that often, formal leaders' influence often extends beyond their official duties. The role of formal leadership

versus informal leadership in the adoption of appropriate construction technology in the global south is an area worthy of investigation.

The identified opinion leaders were comprised of 4 females and 15 males. The average age of the group was found to be 43 years. The average age of male opinion leaders was slightly less, at 41 years, than their female counterparts whose average age was found to be 49 years. It should also be noted that the female members of the opinion leadership group were more highly educated than their male counterparts with 3 out of the 4 having a tertiary education. This in the studies view indicates a bias towards male opinion leaders with women being judged on more stringent measures to be accepted as opinion leaders.

Table 1: Education level of selected opinion leaders

	No formal education	Primary education	Secondary education	Tertiary education
Male	1	3	5	6
Female	0	0	1	3

3.1. Communication channels

There are two main communication channels through which an innovation can be spread, that is, mass communication channels and interpersonal communication channels. Results collected show that the majority of respondents 18/19 learnt about CEB from interpersonal modes of communication that included friends 7/19, and site visits 11/19 organised by a contact in the peddling organisation, benefiting institution or personal initiative after work started on site. Only 1 individual noted receiving information through what may be deemed as a mass communication method, and this was an announcement made by the local council chairperson.

It should be noted that while interpersonal communication is important for changing attitudes amongst peers, mass communication plays a major role in creating knowledge of innovations (Robinson, 2009; Rogers 1983.) From the data collected, one may form the opinion that failure to utilise mass media as a communication has limited public awareness about the opportunity presented by CEB as a construction material. Extending beyond the area of the study, the research teams experience in Uganda suggests that there is little mass media coverage of CEB on communication channels such as TV, radio and social media, thereby extending the phenomenon of lack of awareness to a country level. However, this theory remains to be proven. Also worth investigating is the potential of localised information sources such as: an announcer, a leaflet, the school principal, a government official, the mayor, a teacher as a distinct category who according to Lin and Burt (1975) are capable of customizing a message for either an individual, a small group of individuals, or a rural village.

3.2. Knowledge

From the data collected, it was determined that the majority of respondents 12/19 have known CEB between 1 to 5 years, 5/12 respondents have known about CEB for between 5 and 7 years, while 2 have known about CEB for over 7 years. With this information, the study proceeded to query the respondents' amount of knowledge on CEB. It was found that the majority of respondents have practical knowledge on CEB, that is, they have been involved in

the production process (14/19), acknowledge interlock (16/19), and can identify the material mixture (16/19). This can be attributed to the high number of respondents who have learnt about CEB from interpersonal communication and site visits. It was not surprising that only 3 respondents were able to quote facts about CEB from literature, these also being individuals who have known about CEB the longest.

In the innovation diffusion model, it has been shown that early adopters have generally outstanding social economic characteristics (Chatman, 1987, Cosmas and Sheth, 1980, Eder et al., 2015, Feder and Savastano, 2006) However, owing to the fact that the pilot survey did not collect information from the wider community, the existing data set is insufficient to draw conclusions on the social economic characteristics of the selected group as compared to the wider community. This however is an important consideration for future research.

3.3. Persuasion

In the innovation decision model, the inherent characteristics of the innovation play a major role in persuading individuals in a society to adopt an innovation. The inherent characteristics determine the innovations relative advantage; determine whether an innovation is consistent with the existing norms and values; determine the complexity or ease of use of the innovation; and also govern whether an innovation can be easily applied at a favourable scale for benefits to be judged before adoption (Robinson, 2009).

While it has already been determined that CEB is easy to use, and earth construction is consistent with the values of the population in the area of study as per the discussion presented earlier (Gooding and Thomas 1995; UN-Habitat. 2009; Nambatya, 2015), the study sought respondents' opinions with regards to the modernity of CEB construction. The purpose of this line of questioning was to determine whether CEB in construction is currently desirable and will remain so in the near future. 17/19 respondents viewed ISSB as being a modern construction material. 2 individuals responded viewing CEB as a conventional material, with 1 individual adding that while the material has been in use for a while its employment in the region is not commonplace, highlighting the possibility of gaps in communication and demonstration methods. None of the respondents considered CEB a primitive material indicating overall, a positive view of CEB, currently and in the near future.

3.3.1. Relative advantage

Relative advantage is the degree to which an innovation is perceived as better than the idea it supersedes by a particular group of users, measured in terms that matter to those users, like: economic advantage, social prestige obtained from construction, and convenience or satisfaction. It should be noted that there are no absolute rules for what constitutes "relative advantage," but rather it depends on the particular perceptions and needs of the user group (Robinson, 2009.) Participants in the study were required to first, rank the fore mentioned criteria according importance, note down any additional parameters for consideration. They were then tasked to follow this up by scoring the major walling construction materials: CEB, concrete block and brick in the agreed upon criteria. Results show that convenience/satisfaction is an important sub parameter for relative advantage, with 61% (11/18) respondents saying this is the biggest consideration when faced with constructing a dwelling. Economic advantage had 24% (4/17) respondents saying that it was the most important consideration, while social prestige had 22% (4/18). However, it must be noted that many more people responded in favour of economic advantage 70% (12/17) as being the second most important consideration. 22% (4/18) respondents had convenience as the second most important consideration, while 6% (1/18) had social prestige as the second most important consideration. In scoring 1 was the

most important consideration, while 3 was the least important, and averaging the scores: convenience scored 1.5, economic advantage 1.8 and social prestige scored 2.8 making it the least important consideration. The results also show that economic advantage and convenience/ satisfaction are nearly equal considerations in the choice of building materials consistent with the findings of Greenhalgh et al. (2004) who suggest that economic benefit is oftentimes the most important measure of relative advantage.

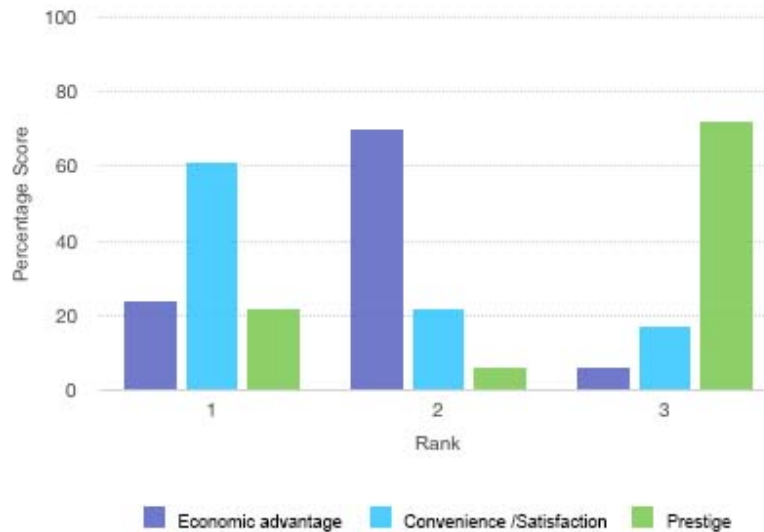


Figure 3: Comparison of drivers for material selection

In order to compare the relative advantage of key walling materials (CEB, burnt brick, and concrete blocks) respondents were asked to rank them against each other in terms of perceived cost of construction, perceived prestige form society when utilised in construction and the perceived convenience/ satisfaction obtained when a specific material is utilised.

Economic advantage

The collected results indicate that burnt brick is considered cheaper to use in construction than CEB or concrete blocks. It must however be noted that the perceived difference in savings made during construction between CEB and brick is very small – 47.5% (9/19) think that savings will be made when burnt brick is utilised as opposed to 42% (8/19) who consider CEB the cheaper option. The major disparity between the two materials arises from the 32% (6/19) who perceive CEB to be the most expensive as compared to the 5% (1/19) who suggest that brick is the most expensive. Overall, respondents deem concrete block as the most expensive option 75% (12/16.) This state of affairs may be due to the following reasons as deduced during the survey

- Addition of cement to soil is viewed as wastage; respondents fail to quantitatively comprehend material wastage in mortar joints due to poor construction techniques common in Uganda
- Due to the informal nature of residential construction, the time cost of construction is rarely considered.

- The lump sum required for production of CEB, for machine hire and cement purchase is often viewed as very high. This is especially brought into focus when one considers that there is no evidence of lifecycle cost comparisons by construction practitioners and homeowners.
- Bricks are considered cheap because they do not require specialised training to make. In the area of the study, brick clumps of varying size and quality were observed at numerous homesteads.

Satisfaction/ Convenience

In considering the criterion satisfaction/ convenience, 95% (18/19) of the participants indicated that the most satisfaction would be attained from the use of CEB with none indicating satisfaction from the use of brick. Respondents identified the higher speed of construction and pleasing aesthetic of the smooth CEB blocks compared to brick as the major considerations for their responses – these indicate that observable results have helped form a positive perception towards CEB. 56% (9/16) indicated that brick would provide the least satisfaction. However a lack of reliable data on time and associated cost savings accrued by use of CEB means that only individuals who have seen CEB construction being undertaken, as is the case with the respondents of the study, hold this opinion.

Prestige

When queried about the prestige obtained from use of a material for construction, CEB was ranked highest with 74% (14/19), No participant indicated that social prestige would be obtained by use of brick. This can be attributed to the fact that brick is a common and easily obtainable material.

3.3.2. Decision

Having determined factors important to adoption and the perception of the sample group towards CEB, the study investigated whether the identified opinion leaders had engaged in activities that affirm adoption or rejection. The data collected indicates that while respondents have acted as middlemen for the application of CEB (5/19), participated in awareness drives (9/19), influenced attitudes at workplace or social circle (10/19), only 2 respondents are actively involved in personal construction using CEB. This state of affairs may be attributed to the fact that brick, the common building material is perceived to have a greater economic advantage over CEB – analysis of data collected indicated that economic advantage is a key consideration in choice of building material.

4. Conclusion

This study provides a benchmark from which the adoption and diffusion of sustainable construction practices, materials and technologies can be investigated and improved. The adoption of sustainable practices is key in an age where demand for infrastructure in the global south is increasing, in the shadow of a growing awareness of the earth's finite resources. The study at hand highlights the fact that in low-income societies, such as those found in the rural Uganda context where the pilot study was carried out, the actions of opinion leaders absent of focused awareness campaigns and financial support is not sufficient to overcome the barriers to adoption – mainly economic, even for a technology perceived as more satisfying, convenient and prestigious.

The study having tested methods of identifying opinion leaders, forwards the notion that

awareness drives focused on these individuals, emphasising the lifecycle cost benefits of CEB has the potential to lead to an increase in demand and adoption. Furthermore increase in demand can lead to a reduction in price of CEB through a greater sharing of fixed overhead costs. Also, as material use becomes more common, the fallacy that CEB is for use by well-funded foreign NGOs will be disproved, further reducing bias.

It is important to note that during the formulation of the study, interaction with stakeholders in the production and use of CEB indicated that in urban settings, the adoption of the technology is further undermined material failure and poor observable results resulting from substandard workmanship. It is envisioned that a comprehensive study can be carried out in both a rural and urban setting to ensure that the existing dichotomy is captured leading to the construction of an appropriate diffusion and adoption strategy.

In the Ugandan context, the relative absence of large-scale developers implies that the relationship between building infrastructure owners and small-scale contractors (builders) is key in the process of material and technology selection, and application. Unfortunately, little is known about the communication channels and social networks builders use to learn about innovations or influence their adoption practices. Similarly, there are numerous questions about how builders assess relative advantage; how they estimate the consumer's reaction; existing information gaps between builders and consumers and the importance of word-of-mouth among builders. This should be considered as a key area of study, as the end users, who are the main focus of this investigation, cannot be considered as independent actors.

Acknowledgements

This study was undertaken with support from the project: Energy and Low Income Tropical Housing (ELITH), funded by EPSRC/ DFID/ DECC as part of the energy and international development programme.

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