

EXPLORING THE CHALLENGES OF HYDRAFORM BLOCKS AS A SUSTAINABLE BUILDING MATERIAL: THE EXPERTS VIEW

Iruka Chijindu Anugwo¹, Williams Miller Appau², Frederick Simpeh³ and Elvis Attakora-Amaniampong⁴

^{1&2} *Department of Construction Management and Quantity Surveying, Durban University of Technology, South Africa*

^{2&4} *SD Dombo University for Business and Integrated Development Studies, Department of Real Estate, Wa, Ghana*

³ *Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, Department of Construction and Wood Technology Education, Ghana*

Hydraform blocks form an innovative medium for construction in low-income countries. Despite its contribution towards sustainability, its adaptation in developing countries has been low. Studies so far have focused on the chemical composition of hydraform block but have limitedly established the challenges of its usage. This study aims to assess the challenges of the adaptation of hydraform blocks in Northern Ghana. Fusing the study in the context of frugal innovation theory, Delphi technique among 11 senior contractors and 7 principal contractors were selected to work on Ghana Government Agenda 111 hospital projects in Northern Ghana. The findings revealed a strong consensus that the lack of expertise in processing and the cost of purchasing hydraform machines at the pre-construction stage was high. Aside, lack of maintenance and breakages of blocks were established as a critical challenge at the post-use stage. Along with the findings, the study points out that increasing the localisation of developing hydraform block machines and training in the developing world will facilitate sustainable building construction.

Keywords: Delphi method; frugal innovation; hydraform blocks; sustainability; Ghana

INTRODUCTION

Globally, construction investments are rising due to an increase in human population and settlement. This change has led to rising building materials, construction safety, decrease in project implementation and efficiency, among others. Consequently, the use of sustainable materials in building construction has been a huge task towards sustainable development goals. In Africa, the dependency on sandcrete blocks in construction has a multi-dimensional problem comprising cost and performance, and sustainable development challenges (Sojobi *et al.*, 2021). The rising cost of cement, high mortar walling due to temperature, minimal reinforcement, and wall rendering

¹ IrukaA@dut.ac.za

are typical challenges facing the use of sandcrete blocks in Africa (Ekong *et al.*, 2022). This has led to the development of innovative blocks such as the hydraform blocks for construction. Although the hydraform block has emerged in other developing countries, its composition has been different. In Africa, large development of hydraform blocks composed of less cement and more soil (Uzoegbo, 2020).

However, since the emergence of hydraform blocks, studies have largely focused on assessing their mechanical properties, and seismic capabilities (Gul *et al.*, 2022). Studies have neglected the assessment of the perception of construction managers on the use of hydraform towards sustainable construction. This is a frugal innovative approach that needs to be studied. Frugal innovation concept has been an emerging concept in recent times towards sustainable development goals. It refers to the assessment of innovative strategies that largely reduce the total cost of material usage while ensuring quality standards (Ebolor *et al.*, 2022). Other scholars describe Frugal Innovation (FI) as an innovation that provides affordability excellence, offers good value, resource efficiency, and sustainability for inclusive consumption (Dabić *et al.*, 2022; Levänen *et al.*, 2022). The government of Ghana to build the agenda 111 hospitals in Ghana, hydraform blocks was adopted for projects in Northern Ghana. However, preliminary investigation shows that there is slow progress in project execution which is not largely attributed to financial constraints but also due to challenges in the use and methods of hydraform blocks. Aside, there appears to be a disconnect between the hydraform block design and implementation processes. This is an empirical gap that this study seeks to fill. Based on that the study aim to assess the perception of construction managers towards the understanding of frugal innovation in hydraform block usage in construction in Ghana. Situating the emergence of hydraform blocks in the context of this study aims to inform policy decisions related to housing, construction, and sustainable development, and holds expectations for addressing both environmental and socioeconomic challenges, particularly in Northern Ghana where resources are constrained. To an extent, this study paves the way for more inclusive and sustainable development through empowering other sectors aside health to build better housing in Northern Ghana.

LITERATURE REVIEW

Frugal Innovation: Its Emergence in Construction Management So Far

Globally, urgent transitions from unsustainable ways of doing things to more sustainable development require a new set of policies, vision, and innovations. Studies have indicated that sustainable development can only be achievable through the design and implementation of integrated methods that tackle environmental sustainability while addressing the institutional, social, and economic dimensions of sustainability. Historically, Frugal Innovation (FI) is overestimated as a new model inspiring the shift from traditional innovative solutions to more sustainable innovations through affordability, limited resources use, and inclusivity (Schumpeter, 1934). The term frugal innovation is a new concept in construction management with few conceptual frameworks. Whilst Schumpeter's (1934) is of the view that challenges of frugal innovations can be described into three-set dimensions. These includes institutional voids, resources to enhance technology use, and social challenges that deals with affordability constraints.

On the contrary, other scholars have indicated that even though FI aims to ensure affordability, it does not ensure complete reduction of cost. However, Dabić *et al.*, (2022) are of the view that FI its aims are driven ultimately by the sustainability

outcome of the model rather than the innovations of the technology. That implies that other social, institutional, environmental, and economic circumstances can influence the frugal models intended purposes. Literature on theories on resource dependency, institutional innovation, resource-based view, and competitive advantage have shown that understanding the how sustainable the construction sector may be influenced by social barriers, institutional and resources.

Challenges of adopting frugal innovation have also been describes by Dabić *et al.*, (2022) as both firm-level reach and grassroot movements. According to their study, identify and developing the capabilities needed to set up frugal innovations at the firm level. They further grouped these capabilities as shared sustainable engagement, core functionalities, and substantial cost reduction. Rossetto *et al.*, (2023) also characterised frugal innovation as optimisation of performance level, substantial cost reductions, and concentration on core functionalities. In Ebolor *et al.*, (2022a) view, understanding the main capabilities that supports frugal innovations offers meaningful contribution to the construction sector. They premised their argument on first, focusing on frugality-based ideas and operationalisation of frugal innovation. Second, identify, developing, and managing the innovation at the firm level. According to Sousa (2023), activities in the construction industry are responsible for high anthropogenic emissions, large demand and use of cement, and non-renewable energy sources. Environmental sustainability challenges to the use of cement are that it contributes about 97% of emissions and 8% of anthropogenic emissions in the construction sector.

Empirically, studies have shown the potentials for adopting frugal innovation in block design and manufacturing. Sojobi *et al.*, (2021) assessed the shift in the partial replacement of cement to produce hollow sandcrete blocks. Thus, potential utilisation of calcined clay, laterite, and calcite as quaternary blends to substitute quarry dust and cement. Their study showed that the utilisation of high binder-to-aggregate ratio, appropriate water-to-cement ratio, and optimal combination of the components produced eco-friendly and durable sandcrete blocks. Bapat *et al.* (2023) assessed the understanding of frugal innovation in design of homeless individual. Their study found that a successful prototype design led to successful fabrications of construction materials. This led to efficacy and in terms of strength and weight of materials. The study failed to assess the social conscious aspect of users. Al-Awsh *et al.*, (2021) conducted an experiment to understand the mechanical and thermal performance of insulated blocks. According to their study, the use of optimal dosage of vermiculite, polystyrene, and low-density polyethylene reduced thermal conductivity in concrete blocks. The results further showed a vermiculite block produces cheap cost compared to other insulated blocks. Zengfeng *et al.*, (2020) assessed the use recycled concrete components from precast block to construct new building. Their study showed that introducing recycled concrete aggregates slightly shrinks the compressive strength and weakens the durability of concrete blocks. Nadeem *et al.*, (2023) also evaluated the cost implication and mechanical properties of using interlocking blocks towards affordable masonry in Nigeria. Their study found that it is less expensive to apply finishes to hydraform block when compared to sandcrete block wall.

METHOD

The study was qualitative based on Delphi technique. The Delphi technique is widely used to determine a reliable understanding and credible inputs of the opinion of a field of study among group of experts (Drumm *et. al.*, 2022). In this study, the techniques

were used to assess the drivers and challenges of adaptation of hydraform blocks in sustainable residential building in Ghana. Four critical processes were through the Delphi technique. First, questions were formulated to connote the perception that the use of hydraform blocks as less expensive and saves time. These questions were also defined to capture the critical challenges confronting the use of hydraform blocks in construction, considering their knowledge gained on its usage over the years. Second, this section involved the selection of experts in managing residential housing construction projects. Senior contractors were selected as experts based on about 10 years of working with hydraform blocks and principal contractors were selected as panelist. The principal contractors were selected based on 3 critical approaches. First, more than 10 years of experience with the use of hydraform blocks. Second, experience related to application of sustainable building materials in construction. Third, knowledge on frugal innovation as an emerging concept in sustainable construction. Regarding the selection, the study sent a request to the ministry of health for consent letter to ascertain the contacts of contractors working on the projects. Phone calls and emails were used to request for their curriculum vitae and certificates of operation to determine their expertise and qualification. Among them, 11 senior contractors and 7 principal contractors met the criteria. Both senior and principal contractors were selected from 5 regions that forms the Northern Ghana working on Ghana governments agender 111 hospitals projects. All these experts were willing to participate in the study, which seems adequate when conducting a Delphi study as suggested by (Hallowell and Gambatese, 2010). Interviews were conducted using two rounds. The first round of interviews was conducted among the senior contractors on the challenges of the use of hydraform block on sustainability. The second round of interviews was conducted among the principal contractors to confirm the impact of hydraform blocks from the senior contractor's perspective. At this stage, principal contractors were further asked to express their concerns on the impact of hydraform blocks on sustainable construction. The purpose of the round two is to avoid redundancy of information provided by senior contractors. To determine consensus among principal contractors, the study used frequencies. These includes responses $\geq 80\%$ as strong consensus, $\geq 60 \leq 79\%$ as good consensus, and $\leq 59\%$ as weak consensus.

FINDINGS

Identification of Frugality-Based Ideas of Hydraform Blocks

Evolution and rationale

The evolution of hydraform blocks in supporting the governments of Ghana's agenda 111 hospital projects in the Northern Ghana was litmus test conducted by the Ministry of water resources, works and housing, when developing rural housing. Prior to the adaptation of hydraform machine, experts are of the view that the department of housing under the ministry, used a manual machine called the 'Tec-machine'. Due to the delays and manual use of the Tec-Machine, the department of rural housing discovered the hydraform machine in South Africa with the help of the Ministry of Water Resources Works and Housing. Later, the Ghana government established a collaboration with the South African government to train staff on the operation, maintenance, and use of the hydraform machine (see figure 1). According to experts, the rationale for adopting the hydraform blocks was based not bases on reducing cost but also on its light weight compared to traditional construction material like concrete block, excellent thermal and sound insulation properties, high level of fire resistance, energy efficiency, and its environmental friendliness.



Figure 1: Nature of hydraform machine. (Source: field work, 2024)



Figure 2: Nature of hydaform block (Source: field work, 2024)

Composition and manufacturing process

The hydra form block is produced from a sandy -loam soil and a cement mixture. The soil stacked contain more sand than clay and silt. The soil must be sieved with minimum lead -time of 1m³ per 1000block or 15m³ sieved soil for one day production. An eight-man team (excluding sieving and curing) can produce 1500 block per a day. However, experts show that only 4 workers were deployed to control the machine. These include the operator, the server, and two other workers who assist in hydraform packing. The processes involved mixing the concentrates by hand or mixture, checking moisture content. Third, use sieving and stock the block 5 high and 7 wide (depending on the width of the plastic). Cover the block, as they are stacked. Uncover blocks when sade plastics are used and water the block twice a day -once in the morning and evening and cover again immediately. The block is finally cured for 7-14 days. The longer the curing, the stronger the block

Operationalisation and Challenges of Hydraform Blocks on Construction Management from Experts' Perspectives

Experts and panelist discussions resulted in two broad challenges confronting the use of hydraform block in hospital building construction in Northern Ghana. Experts categorised the challenges under pre-usage stage to include quality of block processing, lack of expertise in block processing, Environmental conditions, and Cost of machine purchase. Post-usage challenges of hydraform blocks include lack of maintenance, delays, and breakages. At the first round of interviews among senior contractors, the study found that the lack of expertise in molding the blocks was largely agreed by experts as the most influencing determinant facing the successful use of hydraform innovation in Ghana. This is supported by an expert that:

“I have observed that the operators add more water to the sand and clay when moulding the bricks. This results to a lot of cracks within the blocks when it dries”

The study further found that the environmental condition is also largely accepted by experts as the second key determinant. Aside, it was also observed that most expert's respondent to a defect in the quality of block processing which is perceived to have an impact on construction management. According to one panelist:

“I keep putting the challenge on the level of training the operators gained in handling and installation of the hydraform machine. Because the compressed nature of the blocks is not well done which affects the quality of the block and hence influences the durability and integrity of the project”

Lastly, the cost of machine was also agreed as a determinant of construction management. According to one expert:

“The amount used to purchase the machine or rent if possible and acquiring the necessary training for proper block production can be a significant investment”

Considering the post hydraform usage stage, three indicators were themed from the interviews. Among the indicators, experts bemoaned the levels of breakages and lack of maintenance as critical to sustainable construction management in the project. Despite the levels of breakages and machine maintenance challenges, experts did not agree that the use of hydraform blocks affects construction management in the project.

Table 1: challenges of hydraform block from the expert perspective

| Indicators | Number of times it appears in the interview | Frequency (%) | Decision |
|---------------------------------------|---|---------------|------------------|
| Pre-usage stage | | | |
| Quality of block processing | 7 | 64 | good consensus |
| Lack of expertise in block processing | 9 | 81 | strong consensus |
| Environmental conditions | 7 | 64 | good consensus |
| Cost of machine purchase | 8 | 73 | good consensus |
| Post usage stage | | | |
| Lack of maintenance | 7 | 64 | weak consensus |
| Project delays | 2 | 18 | weak consensus |
| Breakages | 8 | 73 | good consensus |

Operationalisation and Challenges of Hydraform Blocks on Construction Management from Experts’ Perspectives

The panelist consensus on the challenges of hydraform blocks showed similar results to the expert’s concerns. According to the study, panelists unanimously agreed that lack of expertise in block processing and the cost of machines influences construction management in the project. According to one panelist:

“Every project has been assigned to one machine because it’s expensive to import into the country. The cost is also associated with inadequate skills to operate, and so we need to invest in some junior contractors to learn its operations”.

Aside, the environmental condition was largely agreed as critical to affect construction management. These are related to the soil structure, dry winds, and salty water table. This was supported by a panelist that:

“Also, because the project is conducted at different sites, they have different soil structure and environmental conditions, so they struggle to get the qualities. This is usually related to the salt content in the soil and clay”

One striking result that emerged in the study among the panelist was the quality of processing block. The study observed that the normal practice of processing the

blocks requires that the soil is mixed with clay by hand or mixer, water and moisture content, workers cover the blocks as they are stacked, keep the blocks in a shady environment, uncover the block and water the block twice daily and cured for 7-14 days.

According to one panelist:

“I see that because the block does not involve much cost, we do remove the spoilt ones out and use the correct ones. We agree that the processing should be checked even though that is not a great concern”

“It appears because the project supervisors are instructed by the government to complete the hospital within a certain stipulated time, the curing of the blocks do not reach 7-14 and packed for laying”

Table 2: Challenges of hydraform block challenges towards construction management from a panellist perspective

| Indicators | Number of times it appears in the interview | Frequency (%) | Decision |
|---------------------------------------|---|---------------|------------------|
| Pre-usage stage | | | |
| Quality of block processing | 4 | 57 | weak consensus |
| Lack of expertise in block processing | 7 | 100 | strong consensus |
| Environmental conditions | 5 | 71 | good consensus |
| Cost of machine purchase | 7 | 100 | strong consensus |
| Post usage stage | | | |
| Lack of maintenance | 5 | 71 | good consensus |
| Project delays | 4 | 57 | weak consensus |
| Breakages | 6 | 86 | strong consensus |

DISCUSSION

Frugal innovation is known as a new revolution that inspires the drift in traditional innovation to sustainable innovation. Following the premises of frugal innovation aimed to achieve, affordability, inclusivity, and limited use of resources, this study showcased the challenges of adopting hydraform blocks as a frugal innovation in hospital building construction in Northern Ghana. The study in the context of frugal innovation showed that the idea of using hydraform blocks was well conceived at the government level. However, it appeared that the technology is new which was likely to show some potential challenges. According to Schumpeter’s (1934) developing the capabilities needed to set up frugal innovations required a shared sustainable engagement, core functionalities, and substantial cost reduction. In this study, experts are of the view that the development of collaboration with South Africa government to train selected experts on the use of hydraform machine served as the first point of engagement. Overall, the notion of adopting the use of hydraform blocks was purposely designed to ensure sustainable hospital building at a reduced cost. However, the study identifies challenges associated to the three-dimensional challenges of using frugal innovation indicated by Schumpeter’s (1934). Two critical challenges were observed differently in this study. First, a strong consensus was established that the rush in implementing the technology at the local level provided a knowledge gap among the local Masons. This was not surprising to observe that construction was moving slow across the study locations. Situating this within the

context of frugal innovation, there appears to be a challenge with knowledge transfer and capacity building which supports earlier findings of Ebolor *et al.*, (2022a). This raises important implications on how knowledge transfer initiatives can be strengthened to ensure that local masons have the necessary skills and expertise to effectively implement frugal innovations. At worst, the lack of inclusivity and local participation in the hydraform implementation process has a ripple effect on ownership and sustainability of the project in the study context.

Second, the high cost of hydraform machine had implications on the project delays, considering the fact only one hydraform machine was procured at the study locations to mold the blocks. Notwithstanding, cost associated to hiring professionals' construction experts to assist in managing the sites was high. Ideally, it can be contested that the rationale for using local Maison were limited which attracted high cost to successfully complete the project. In support of the findings, Schumpeter's (1934) is of the view that the lack of inclusivity in pre and post implementation stage of innovations affects productivity. This can perhaps be explained as the true reflection of lack of quality of the blocks due to breakages as ascribe by experts and panelist. This is quality assurance challenge that is likely to have safety concerns particularly in critical hospital infrastructure projects. Indeed, Nadeem *et. al.* (2023) and Zengfeng *et al.*, (2020) also found similar challenges when adopting hydraform interlocking blocks. Different from Sojobi *et al.*, (2021) and Al-Awsh *et al.*, (2021) who found cost as major challenged, this study further found that environmental conditions and lack of expertise in processing the blocks are critical challenges for adopting the hydraform machine. Expression of environmental conditions was associated to high temperatures and weather in Northern Ghana which has implications on hydraform block cracking during curing. Practically, implementing shading techniques during the curing process of hydraform processing would help to protect the blocks from direct extreme temperatures in Northern Ghana. Aside, enhancing the mixing formula of the clay, water, and cement, and implementing proper drainage systems to prevent water accumulation in the blocks will have the capacity to check moisture and prevent breakages. Moreover, ensuring capacity building and training of local maisons and laborers in hydraform block installation and production technique would mitigate the challenges of bad handing of blocks.

CONCLUSIONS

The purpose of the study is to establish a consensus on the challenges influencing the adaptation of hydraform blocks in construction of hospitals in Northern Ghana. This was conducted using experts and panelist view, conceptualised into frugal innovations, and analyzed thematically. The challenges were attributed to lack of capacity building and knowledge transfer between government officials and local masons, neglect of quality assurance standards, lack of local participation and inclusivity, and to a large extent, cost management and resources constraints. More broadly, the study revealed that idealisation of hydraform block design and implementations was conceptualised at the government level with limited local inclusiveness. Experts and panelist shared similar views regarding the challenges at both the pre-stage and post-usage stage of the hydraform blocks. At the pre-stage level, the study showed that lack of expertise and cost of machine purchase was a major challenge. Increasing breakages of blocks and lack of maintenance of hydraform machine were post-usage challenges. Situating these results in the frugal innovation premises, the study can deduce that the conceptualisation approach of using the top-down method of implementing the project is a gap which could affects

the core functionality and intended aim of ensuring sustainable hospital building. Theoretically, the study can conclude that the frugality of adopting hydraform blocks was more limited shared sustainable engagement which affected the core functionalities and increased additional cost of maintenance. Practically, following the premise of frugal innovation has been a game changer in other sectors. To achieve that, the study will recommend that using a bottom-up approach which require studying the environmental conditions, and extensive training and localisation of the use hydraform machine will ensure a shared sustainable engagement and achieve sustainable hospital buildings. At best, it will be prudent to conduct a pilot study in different locations to understand and predict the challenges that should be expected.

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