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Technical Detailed Study on Hydraform Blocks Building Technology in Kigali City, Rwanda

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***Abstract**: This study provided an in-depth examination of hydraform block building technology in Kigali City, Rwanda, through comprehensive engagement with various construction industry stakeholders. The study employed convergent parallel design through mixed research approach, characterized by an impressive participation rate of 87% for questionnaires and 83% for interviews, captured diverse professional insights, including those of architects and quantity surveyors. The inclusion of individuals with varied educational backgrounds and experience levels further enriches the findings, offering a broad understanding of the technology's implications. Highlighting the potential benefits for lower to middle-class housing, the study also addressed challenges such as skilled labor shortages and the need for better awareness. Laboratory tests confirmed the superior strength and cost-effectiveness of hydraform blocks compared to traditional concrete cement blocks, although the study's scope was limited to Kigali.*

***Keywords:** Hydraform blocks, Building technology, Cost assessment, Compressive strength, Resistance, Residential construction*

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1. Introduction

Hydraform block building technology represents a significant advancement in sustainable construction practices, particularly in developing regions like Kigali, Rwanda. This technology utilizes a unique interlocking block system made from soil and cement, significantly reducing the need for conventional bricks and mortar (Assiamah, et al., 2022). The adoption of Hydraform blocks in Kigali addresses several key challenges, including the high cost of construction materials, environmental degradation caused by traditional brick-making processes, and the need for durable and affordable housing solutions. The innovative nature of Hydraform blocks not only enhances the efficiency of building processes but also supports the local economy by using locally sourced materials and labor (Ejidike, 2023).

Kigali, the rapidly growing capital city of Rwanda, presents a dynamic landscape for the implementation of Hydraform block building technology. The city's rapid urbanization and population growth demand sustainable and scalable housing solutions. Hydraform blocks offer an ideal alternative, providing strong, resilient structures capable of withstanding the region's climatic conditions (Egenti & Khatib, 2016). Furthermore, this technology aligns with Rwanda's commitment to green growth and climate resilience, as outlined in the country's Vision 2050 (Niyibizi, et al., 2024). By incorporating eco-friendly building methods, Kigali progress towards achieving its ambitious sustainability goals while improving the living standards of its residents.

The technical aspects of Hydraform block construction are central to its success in Kigali. The process involves compressing a mixture of soil, cement, and water into robust blocks using a hydraulic press (Kerali, 2001). These blocks interlock precisely, reducing the need for extensive mortar and thus accelerating construction timelines. Detailed study on the performance and durability of these blocks in Kigali's specific environmental conditions were crucial. The current studies provide insights into optimal soil compositions, block densities, and construction techniques that maximize the benefits of this technology. As Kigali continues to evolve, the integration of Hydraform blocks plays a pivotal role in shaping a sustainable urban future, fostering both economic growth and environmental stewardship.

The main objective of the study was likely to evaluate the effectiveness, efficiency, and sustainability of using Hydraform blocks as a building technology within the urban context of Kigali City.

2. Literature Review

Harikrishnan et al. (2021) indicated that practitioners recognized AR's value in enhancing communication between design and construction teams, leveraging experienced personnel's expertise effectively, and facilitating inspections, with adoption influenced by technological factors (e.g., cost of equipment) and non-technological factors (e.g., relationship building). Housing is one of the basic human needs and is usually ranked third after food and clothing (Filali, 2021). In most developing countries housing is inadequate and the housing backlog has been increasing rapidly. One key reason for housing inadequacy is the increase in population (Rakodi, 2015). It is estimated that the World's population is rising weekly by more than a million people, a rate that new construction does not match Earth from the air (Gu, Andreev, & Dupre, 2021). Due to the high pace of urbanisation and socio-economic factors that include the rise in prices of land and building materials, those classified as poor are the majority and they cannot afford proper housing McAuslan.

Hydraform interlocking blocks offer a viable alternative to conventional bricks, accompanied by additional intangible benefits (Surwade & Kamal, 2023). The provision of affordable housing for the poor needs to be facilitated through the development of innovative strategies (Chava & Newman, 2016). The persisting problem for urban housing authorities in Africa is the worsening condition of slums and squatter settlements due to the high rate of population growth, public provision of mass low-cost housing is always far below the actual demand (Makinde, 2012). The research findings demonstrated that environmental benefits accruing from adoption and use of Hydraform blocks in housing development outweighed the negative impacts the technology could pose to the surrounding environment, thereby providing an indication that the technology could be considered as an environmentally appropriate technology.

Adapting to technological advancements are crucial strategies for implementing innovative housing projects and policies to enhance the efficacy and versatility of Hydraform Blocks and broaden their adoption in diverse construction projects (Matamanda, et al., 2022). The study underscores the critical link between building technology, materials, and climate change, emphasizing the imperative to minimize embodied energy through energy-efficient technologies and low-embodied-energy walling materials to mitigate greenhouse gas emissions, highlighting the urgent need for policy initiatives to promote such practices in building codes and green regulations, thereby advancing sustainable environmental strategies and carbon sequestration efforts (Sangori, 2021).

In Rwanda, population increase has been tremendous over the years with the 2009 Census results estimated at 12,684,436 (RNIS, 2019). The continued increase in population size has led to increased housing demand for the low, middle, and high-income groups in the society. An effort of increasing access to high quality affordable housing therefore has a serious implementation, both for an individual and the society at large. If intended to improve lives, housing cannot be overlooked, especially as cities rapidly expand and the need for housing grows. Rwanda requires at least 25,000 housing units annually but developers say the cost of land, mortgages and building materials has made it difficult for more investment in the sector. The Hydraform blocks technology has been widely used in most parts of the World. In Rwanda, the technology was introduced in 2013.

3. Methodology

3.1. Description of the area of study

The area of study is located in Kigali city, Nyarugenge district,Gitega sector on the road . Where there is production plant of Hydraform blocks. Interviewed persons are people living in Kigali where the construction industry is more advanced.

Figure 1: Location of the area of study

Laterite soils are known to occur in humid tropical areas; however the precise combinations of environments under which they are formed have not fully defined. It was suggested (e.g. Harrison, 1933) that they are formed only over igneous rocks under wet tropical rain forests. However, later studies have shown that laterite soils may in fact be formed under very wide range of conditions.

3.2. Site selection criteria

A systematic approach was employed to ensure the relevance and richness of the study. Site selection was based on several key criteria aimed at providing a comprehensive view of Hydraform blocks in local construction. Diversity in projects, from residential to commercial and public buildings, was crucial, allowing for a detailed analysis of the blocks' adaptability across different types. Both ongoing and completed projects were included, enabling a comparative study of current practices and long-term performance. The scale of construction, from small residential buildings to larger public infrastructures, was also considered to understand the technology's scalability. Additionally, sites with varied construction materials, including different stabilizers and soil compositions, were chosen to assess their impact on structural integrity. Accessibility and willingness of stakeholders to cooperate were essential, ensuring effective data collection through observations and interviews. This meticulous site selection process aimed to provide a nuanced and thorough exploration of Hydraform Blocks Building Technology in Kigali, Rwanda, enriching the research with diverse real-world construction scenarios.

3.3. Population, sample, and sampling techniques

The target population for this sturdy were the professionals (architectural firm and quantity surveyors firms), and contactors who are based in Rwanda Country and are in either the private or the public sector. The two professionals above were selected since they give advice to the developer on the materials to use and those not to use. The number of the quantity surveyors selected was gotten from the IER, this is because they are the once that are fully registered and also their physical locations were stated making it easy to trace them and give them the questionnaires and even interview them. The number was 737 (IER, 2023). The number of the registered architects was also gotten from IER, and was found to be 109 (RIA, 2023). This brings the number of professionals to 846. The population of the registered contractors based in Kigali was gotten from Rwanda Development Board.

Due to short time available and also high cost of getting the whole population, the researcher had to take a sample of the population so as to represent the whole population. The characteristics of the sample to be chosen was taken to be the same as that of the whole population (Leedy, 2004) the researchers was very high confidence on his sample that it was a good representation of the whole population. There are a few known alternatives that can be used to determine the size of the sample, the one employed being to specify the precision of estimation desired and then determine the sample size necessary to insure it (Kothari, 2004) this method was adopted because it is simple and capable of giving a mathematical solution.

$$n = \frac{Z^2.P.q.N}{e^2.(N-1)+Z^2.P.q}$$

(Nachmias & Frankfort-Nachmias, 1996)
Where; n = Sample size, N = Size of the accessible population, P = the percentage likelihood that the sample population is estimated to have the characteristics being measured. This is taken as 95%, in which case the sample size “n” will be maximum and the sample will fall within the desired precision. This is the Confidence level, q = (1-P). This is the Significance level, e = Acceptable error, taken as 0.05. This represents sampling errors, which are errors which arise on account of sampling, Z = the standard normal deviate at the required confidence level. Confidence level (C) is 95%, therefore Z = ±1.95 (From

Statistical tables), (C) is 95%, therefore Z = ±1.95 (From Statistical tables). Therefore the sample size for respondents will be:

$$n = \frac{1.96^2 * 0.95 * (1-0.95) * 892}{0.05^2 * (892-1) + 1.96^2 * 0.95 * (1-0.95)} = 68$$

The sab sample size for the professionals (Quantity surveyors and Architects) ,contractors and developers was obtained by using ratios of which the professionals were 846 and the contractors 46

3.4. Data collection techniques

In conducting the research, a multifaceted approach to data collection was adopted to ensure a comprehensive analysis. Questionnaires were distributed to construction professionals, engineers, architects, and residents in Kigali, yielding valuable qualitative and quantitative insights into the perceptions, preferences, challenges, and user experiences related to hydraform block technology. Economic viability was assessed through detailed cost estimations for constructing a one-meter square wall using hydraform blocks, considering raw material costs, production expenses, transportation, and labor. Laboratory tests, including compressive strength assessments, water absorption tests, and sieve analysis, provided insights into the blocks' quality and durability. Site visits and observations at construction sites utilizing hydraform blocks offered practical insights into construction techniques, structural integrity, and overall performance. Additionally, in-depth interviews with experts in construction engineering and materials science enriched the study with specialized knowledge and qualitative data. This diverse data collection approach ensured a well-rounded analysis of hydraform block building technology in Kigali, Rwanda.

In an exhaustive evaluation of Hydraform block construction technology in Kigali, a diverse array of analytical methodologies was deployed to thoroughly scrutinize its technical dimensions. Integral to this investigation was the strategic deployment of questionnaires, meticulously crafted and disseminated among construction professionals, engineers, architects, and local residents. This method facilitated the collection of qualitative insights and quantitative data, illuminating perceptions, preferences, and real-world applications of Hydraform blocks. Additionally, a rigorous cost estimation analysis was conducted to evaluate the economic feasibility of constructing one-meter square walls using Hydraform blocks. This analytical tool involved meticulous calculations encompassing raw material costs, production expenditures, transportation logistics, and labor expenses. The study employed laboratory tests to assess the physical and mechanical properties of Hydraform blocks, including comprehensive compressive strength analyses to gauge their structural robustness under axial loads. Water absorption tests were employed to measure porosity and moisture resistance, crucial for evaluating durability. Concurrently, sieve analyses of raw materials like soil and stabilizers were conducted to assess particle distribution and material quality, pivotal in determining block strength and performance. Qualitative insights were gleaned through onsite visits and observations, offering firsthand assessments of construction techniques, workmanship, and structural integrity at active construction sites utilizing Hydraform blocks. This multifaceted approach, integrating questionnaires, cost analysis, laboratory tests, and field observations, ensured a comprehensive assessment of Hydraform block technology's technical viability and suitability within Kigali's construction landscape, enriching the depth and reliability of the study's findings.

Data collection tools of questionnaires and observation was used. The main tool of data collection was however the questionnaire. The questions were closed ended multiple choice questions as well as short answer questions for ease of analysis and interpretation. The researcher visited the groups and explained to the chairman/secretary of the groups the details of the study and what it entails and involves before administering the questionnaires.

3.5. Data analysis

The researchers systematically categorized the data and presented it in a more comprehensible format for the reader. To enhance clarity, the data was translated into narrative descriptions, tables, bar graphs, pie charts, and images. Narrative descriptions elucidated specific scenarios and relationships, while tables succinctly organized numerical data for easier interpretation. Graphs, charts, and maps, alongside pictures, not only condensed the data but also provided a visual appeal, facilitating easier comparison and understanding.

4. Results and Discussion

4.1. Introduction

The study aimed to evaluate the effectiveness, efficiency, and sustainability of using Hydraform blocks as a building technology within the urban context of Kigali City by surveying architects, quantity surveyors, and contractors. Structured questionnaires were employed to gather both quantitative and qualitative data from selected firms. The researchers analyzed the data through thematic discussions, organizing, summarizing, crosschecking, and providing explanations. Descriptive statistical methods were applied to interpret the qualitative data. The findings were presented using a combination of graphical and statistical techniques, including bar charts, pie charts, and frequency distribution tables, to effectively convey the respondents' perspectives on the subject matter.

4.2. Response from the Professionals

To assess the practical implications and acceptance of this technology, the researchers engaged with professionals in the field. A total of 24 professionals were identified, out of which 20 agreed to participate in the study. The response rate was notably high, with 87% of the identified professionals filling out the structured questionnaires. Additionally, 83% of the respondents willingly participated in interviews on the same subject matter. This high level of participation from the professionals indicates a strong interest and willingness within the industry to engage with and contribute to the study. The study likely benefited significantly from this enthusiastic response, as it allowed for a robust and diverse dataset. The responses collected through questionnaires and interviews likely provided valuable qualitative and quantitative insights, enriching the depth and comprehensiveness of the study findings. The willingness of 87% of the professionals to fill out questionnaires reflected a commendable level of engagement with the research topic. Moreover, the fact that 83% agreed to be interviewed demonstrates a keen interest in discussing their experiences and opinions regarding hydraform blocks building technology. This high response rate not only validates the relevance of the research topic within the professional community but also suggests a shared interest in advancing understanding and knowledge in the field. Therefore, the research paper's strong response rate from professionals underscores the relevance of the study within the construction industry in Kigali, Rwanda. The willingness of the professionals to actively participate in the research through questionnaires and interviews strengthens the credibility of the findings, making the study a valuable contribution to the understanding and application of Hydraform Blocks Building Technology in the region.

The current research aligns with Harikrishnan et al. (2021), highlighting the professionals acknowledge augmented reality's benefits in improving communication among design and construction teams, optimizing the use of expert knowledge, streamlining inspections, and adoption influenced by both technological (e.g., equipment costs) and non-technological factors (e.g., interpersonal relationships).

4.3. Response on the profession

To assess the professional outlook on this technology, the researchers distributed 20 questionnaires to industry experts, yielding responses that showcased a division in the respondents' professions.

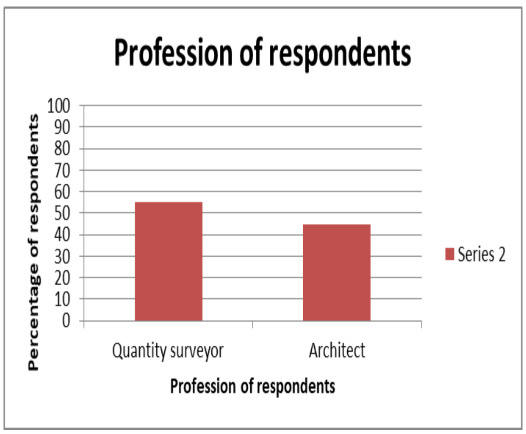


Figure 2 : Profession of respondents

20 respondents returned questionnaires, 11 were from architects and the remaining 9 from quantity surveyors. This distribution highlights the active engagement of these professionals, reflecting their collective interest in understanding and possibly integrating Hydraform Blocks building technology into their practices. Architects, primarily concerned with design and aesthetics, showed a significant interest in innovative construction techniques, as evidenced by their majority representation. Conversely, the involvement of quantity surveyors, who focus on cost estimation and project management, underscores the technology's relevance in budget-conscious construction contexts. This mix of responses illustrates the diverse perspectives within the architectural and surveying fields regarding Hydraform Blocks, suggesting an interdisciplinary interest. Architects might be driven by the potential for creative expression using new materials, while quantity surveyors could be motivated by the promise of cost-effective, sustainable building solutions. Thus, the findings from the research indicate balanced participation from both architects and quantity surveyors, highlighting a multifaceted interest in Hydraform Blocks technology within Kigali, Rwanda's professional community. This varied engagement enriches the study, offering a comprehensive view of the industry's interests and potential applications of the technology.

4.4. Response on education level

To enhance the depth of the research, a field survey involving 20 respondents was conducted. The survey results provided significant insights into the respondents' educational backgrounds. Among those surveyed, 80% had achieved a university-level education, indicating a substantial proportion of highly educated professionals engaged in the construction industry. This higher education level suggested a strong intellectual foundation and a potentially sophisticated understanding of construction technologies, including innovative methods like hydraform blocks building technology. Additionally, the survey revealed that 20% of the respondents had received education at the polytechnic level. This mix of educational backgrounds signifies a range of experiences, expertise, and viewpoints, enriching the study. The diversity in educational backgrounds among the respondents enhances the research by incorporating varied perspectives, reflecting the industry's broad spectrum of knowledge and skills. Consequently, the findings were more robust and representative of the construction industry's educational landscape in Kigali, contributing to a well-rounded understanding of hydraform blocks building technology and its implications for regional construction practices.

The current findings align with Surwade and Kamal (2023), suggesting that Hydraform interlocking blocks not only provide a viable alternative to conventional bricks but also offer additional intangible benefits.

4.5. Response on working experience

To enrich the study with practical insights, a field survey involving 20 respondents was conducted, focusing on the respondents' working experience within the construction industry. The survey results revealed a diverse range of experience among the respondents.

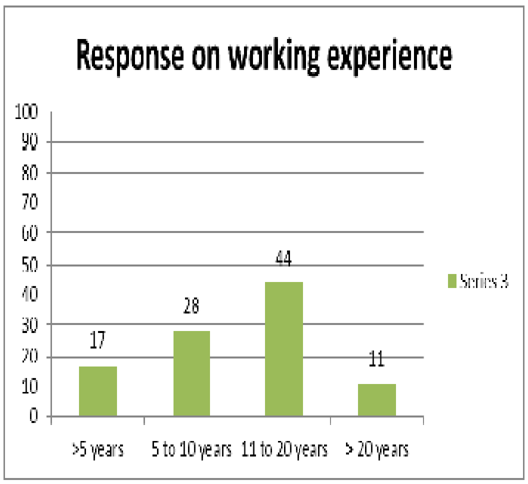


Figure 3: Working experience

Out of the 20 participants, three individuals had relatively limited experience, working in the construction industry for less than 5 years. This subgroup likely offered fresh perspectives and a contemporary understanding of emerging construction technologies, potentially bringing innovative viewpoints to the study. A slightly larger group, consisting of five respondents, had been working in the industry for 5 to 10 years. This mid-level experience likely provided a balanced perspective, incorporating both foundational knowledge and exposure to evolving construction methods. The majority of the respondents, numbering nine individuals, had accumulated substantial experience, ranging from 11 to 20 years in the construction field. This group likely contributed valuable insights based on years of practical exposure, offering a nuanced understanding of industry trends and technological advancements, including the challenges and opportunities associated with adopting innovative construction techniques. A smaller subset, comprising three respondents, had extensive experience, having worked in the construction industry for more than 20 years. This group likely brought a wealth of knowledge and expertise, offering historical context and a deep understanding of the evolution of construction practices, which would be invaluable in evaluating the long-term implications of technologies such as Hydraform Blocks Building Technology. Therefore, the research paper's findings highlighted a diverse spectrum of working experience among the respondents. This range, spanning from relatively novice professionals to seasoned veterans, provided a holistic perspective on the adoption and application of Hydraform Blocks within the construction industry in Kigali, Rwanda. The varied levels of experience enriched the study by incorporating different viewpoints, making the research findings comprehensive and reflective of the industry's collective expertise and understanding of innovative construction technologies.

4.6. Response on those who used hydraform blocks before

To gather practical insights, a field survey was conducted among 20 respondents, focusing on their prior experience with Hydraform blocks. The survey results revealed that a significant majority of the respondents, precisely 65 percent (13 individuals), had prior experience in constructing buildings using Hydraform blocks. This finding indicates a substantial level of familiarity and practical exposure to this technology within the construction community in Kigali.

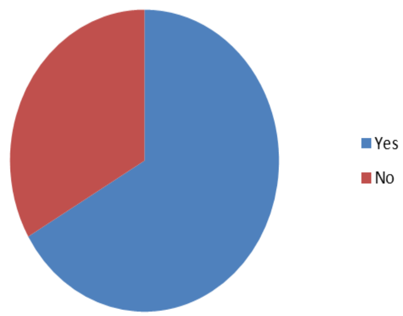


Figure 4: Hydraform blocks

The fact that a majority of respondents had hands-on experience with Hydraform blocks suggests a certain level of acceptance and adoption of this building material in the region. In contrast, 35 percent of the respondents (7 individuals) had not used Hydraform blocks before. This minority subset likely provided a valuable contrast, offering perspectives from individuals who were yet to adopt or work with this innovative construction material. Their responses would be crucial in understanding the barriers or reservations some professionals might have regarding the adoption of Hydraform blocks in their construction projects. The presence of both experienced users and those unfamiliar with Hydraform blocks likely enriched the research findings. Insights from the experienced users could provide practical feedback on the material's strengths and challenges in real-world applications. Conversely, the perspectives of those unfamiliar with the technology could shed light on potential concerns or misconceptions that might hinder its wider adoption within the industry. Therefore, the research paper benefited from the diverse experiences of the surveyed professionals regarding the use of Hydraform blocks. The substantial number of respondents who had utilized the material previously indicated a practical understanding of its application, while the responses from those without prior experience provided valuable insights into potential areas of improvement or education needed to encourage broader adoption. This diverse feedback likely contributed to a well-rounded and comprehensive analysis of Hydraform Blocks Building Technology in Kigali, Rwanda.

4.7. Response on building type

The study included a survey component aimed at understanding the types of buildings for which Hydraform blocks were being utilized. The survey results revealed a specific pattern among the respondents: all individuals who had used Hydraform blocks in their construction projects had employed the material exclusively for building residential houses. None of the respondents had utilized hydraform blocks in any other type of building apart from residential structures. This finding indicates a concentrated application of hydraform Blocks in the residential construction sector within Kigali. The exclusive use for residential houses suggests a niche preference for this technology in the housing market. The reasons behind this specialization could be varied, such as the suitability of Hydraform blocks for certain architectural styles, cost-effectiveness in residential projects, or specific structural advantages that align well with the requirements of residential buildings. The study's focus on residential construction signifies the importance of Hydraform Blocks in addressing the housing needs of the community in Kigali. By concentrating on residential applications, the research paper provides valuable insights into the specific challenges and advantages associated with using Hydraform blocks in this context. It also implies potential avenues for future research and development, encouraging exploration into expanding the use of Hydraform Blocks into other building types beyond residential housing. Therefore, the research paper sheds light on the specialized usage of Hydraform Blocks in residential construction within Kigali, Rwanda. The exclusive focus on residential houses among the surveyed professionals signifies a significant trend in the local construction industry. This focused application emphasizes the need for targeted strategies and innovations to further enhance the efficacy and versatility of Hydraform Blocks, potentially opening doors for its broader adoption in diverse types of construction projects in the future.

The current research aligns with Matamanda et al. (2022) by emphasizing the critical role of adapting to technological advancements in fostering innovative housing projects and policies, thereby enhancing the efficacy and versatility of Hydraform Blocks and expanding their integration across various construction initiatives.

4.8. Response on living standards of occupants

As part of the research, the living standards of occupants in areas where Hydraform blocks were used were investigated, offering valuable insights into the socio-economic aspects of the technology's implementation.

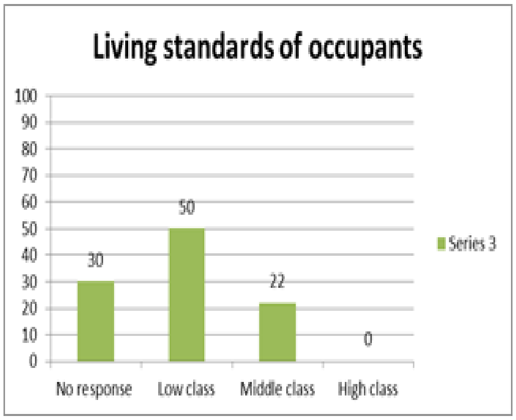


Figure 5: Living standards of occupants

Among the 20 respondents surveyed, 7 individuals who had not used Hydraform blocks did not respond to this question. However, among those who had utilized the material, 8 respondents indicated its application in areas populated by people with low socio-economic status. This suggests that Hydraform blocks were predominantly used in regions where residents belonged to the lower economic class. Additionally, 5 respondents reported using Hydraform blocks in areas inhabited by individuals from the middle-income bracket. Notably, none of the respondents had implemented the technology in areas predominantly occupied by individuals with a high socio-economic status. This distribution of responses implies a specific trend in the usage of Hydraform blocks, primarily catering to communities with lower to middle-income levels. The focus on areas with lower living standards potentially signifies the technology's affordability and suitability for economically disadvantaged communities. This targeted application could have significant implications for social housing initiatives and community development projects, indicating a potential avenue for further research and policy considerations in the realm of affordable housing.

Therefore, the research paper's findings underscore the targeted use of Hydraform Blocks Building Technology in areas characterized by lower to middle-class living standards. This specialized application aligns with the material's affordability and suitability for economically challenged communities, offering a potential solution for addressing housing needs in such areas. The study thus provided valuable data for policymakers, urban planners, and researchers aiming to enhance living standards and promote sustainable housing solutions in economically diverse communities within Kigali, Rwanda.

4.9. Response on problems faced during construction

The study aimed to understand the practical hurdles encountered by construction professionals, shedding light on the complexities of adopting innovative construction methods. Among the firms surveyed, a notable consensus emerged regarding the challenges faced during the construction process.

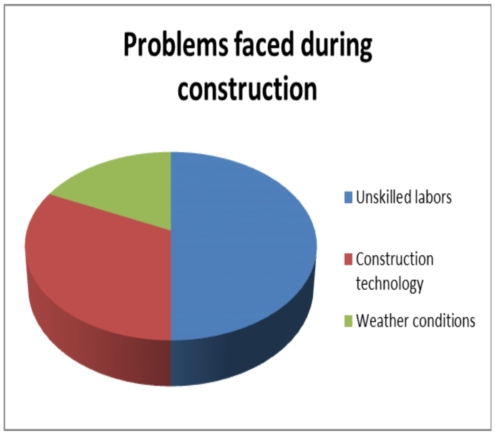


Figure 6: Problems faced during construction

Eight of the firms highlighted the difficulty in acquiring skilled labor as a significant problem. This shortage of skilled workers likely posed a hindrance to the efficient and effective utilization of Hydraform Blocks, indicating a potential gap in the local labor market's expertise in this specialized construction technology. Additionally, seven firms expressed the challenge of finding individuals who comprehended the intricacies of Hydraform Blocks technology. This issue likely pertained to a lack of awareness, training, or expertise among potential workers, suggesting a need for enhanced education and training programs to familiarize the workforce with the nuances of this innovative construction method. Furthermore, weather conditions emerged as a concern for three firms. Inclement weather can severely impact construction timelines and the quality of work, particularly in the case of construction methods sensitive to environmental conditions. This challenge emphasizes the importance of considering local climate factors when implementing construction technologies like Hydraform Blocks, highlighting the need for adaptable construction practices. Therefore, the research paper highlighted crucial challenges faced by construction firms during the implementation of Hydraform Blocks Building Technology in Kigali. The shortage of skilled labor, coupled with a lack of understanding about the technology among the workforce, posed significant obstacles. Additionally, adverse weather conditions further complicated the construction process. These findings underscore the necessity for targeted training programs, increased awareness initiatives, and weather-sensitive construction strategies to facilitate the smooth adoption of innovative construction technologies like Hydraform Blocks in the region. Addressing these challenges paves the way for more effective and widespread utilization of Hydraform blocks in the construction industry of Kigali, Rwanda.

The current research aligns with Sangori (2021) who emphasis on the crucial nexus between building technology, materials, and climate change, advocating for reduced embodied energy and the adoption of energy-efficient technologies and low-embodied-energy walling materials to mitigate greenhouse gas emissions, urging policy reforms to integrate these practices into building codes and environmental regulations, thereby promoting sustainable strategies and enhancing carbon sequestration efforts.

4.10 Response on if they can build their houses using hydraform

The firm representatives who answered the questioners gave their opinions on if they would use the material to build their own houses and 8 of them said they would but 4 said they would not.

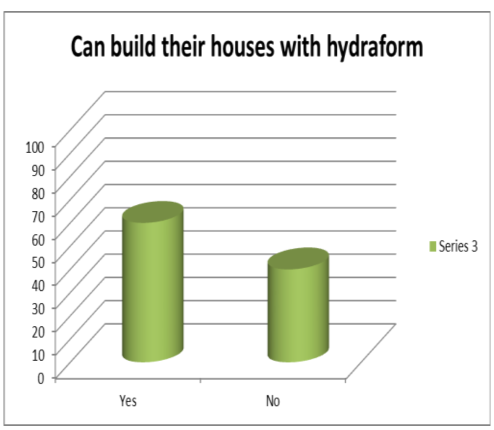
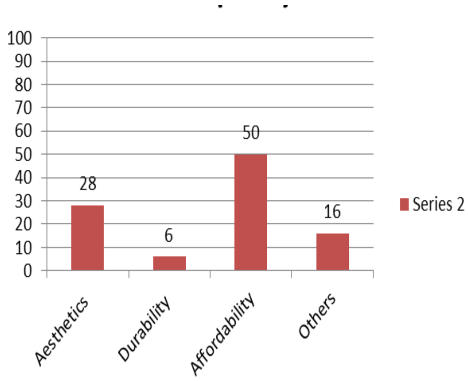


Figure 7: Building houses using hydraform

The perspectives highlighted the importance of integrating solar energy solutions in urban development. These divergent viewpoints likely stem from a blend of economic considerations, environmental advantages, technological familiarity, and regulatory uncertainties. A deeper exploration of these factors is crucial for gaining a holistic understanding of the underlying drivers shaping each stakeholder's position in this evolving discourse.



The survey findings offer a comprehensive perspective on the factors that contribute to the appeal of Hydraform blocks among construction firms in Kigali, Rwanda. Predominantly, respondents highlighted cost-effectiveness as the primary allure, emphasizing the affordability of these blocks. Furthermore, the aesthetic appeal of Hydraform blocks emerged as a significant factor, with many acknowledging their visually pleasing attributes. Moreover, durability was recognized by one respondent as a crucial feature enhancing the attractiveness of Hydraform blocks.

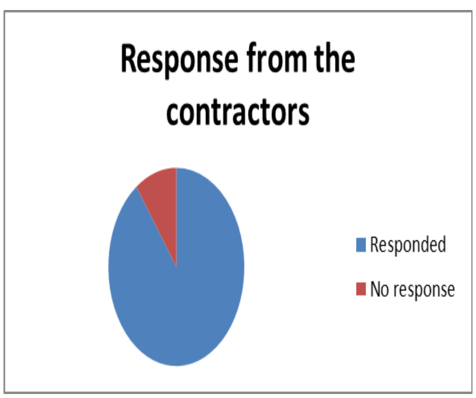


Figure 9: Response from the contractors

The enthusiastic participation of contractors, evident in their prompt completion of questionnaires and eagerness to engage in interviews, highlights their robust involvement and keen interest in the study. This heightened level of engagement not only underscores the research topic's relevance and significance but also underscoring contractors' readiness to contribute their valuable experiences and insights into the adoption and application of Hydraform blocks building technology in Kigali.

4.11 Response on attractive quality of hydraform

The firms were asked on some of the values that made the material attractive and 10 of them said it was cheap, 4 of them said it was affordable, and 5 said it has good aesthetics. While 1 supported the idea of it being durable.

Figure 8: Quality of Hydraform blocks

4.12 Response from the contractors

A total number of forty-two (42) respondents were identified but only twenty-nine (29) agreed to fill the questionnaires and were served with copies of the structured questionnaires. There was a 76% percentage level of response with twenty-nine (29) filling and returning the filled questionnaires. However, 92% agreed to be interviewed on the same subject.

4.13 Response on education level

Out of the 29 contractors who returned the questioners it was found that 8 of them had gone up to university level, 16 had gone up to college and 5 had gone to secondary school level with none of them reaching primary level.

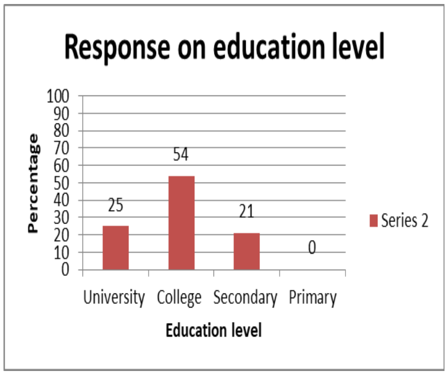


Figure 10: Response on education level

The diversity in educational backgrounds among respondents offers critical perspectives on the correlation between educational attainment and the uptake of Hydraform blocks building technology. The survey reveals a varied spectrum of educational achievements, predominantly showcasing participants with college-level qualifications or higher. This demographic composition underscores the potential influence of higher education on the familiarity and acceptance of innovative construction methods like Hydraform blocks within the community.

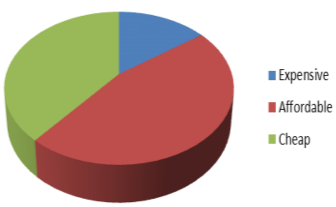
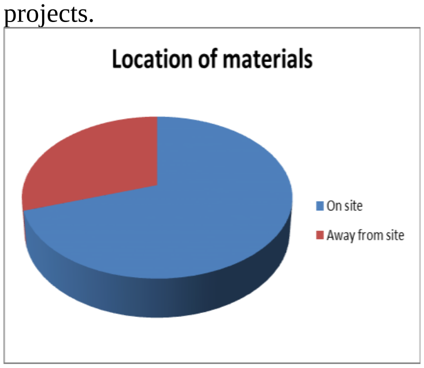


Figure 11: Cost of making Hydraform blocks

The varying perspectives on the cost of implementing green building materials underscore those financial considerations that differ among builders based on unique project conditions. Factors such as local material availability, the need for specialized equipment, and the size of the required workforce influenced cost perceptions. These insights emphasize the importance of evaluating diverse economic factors when determining the viability of green building materials in construction projects.



4.14. Response on opinion on cost of making Hydraform blocks

Being that the materials are to be made by the contractors they were asked on the cost of making them and 7 of the respondents said it was expensive as they were importing the soil away from the site location, 13 said it was affordable as they only used few people for the labor of making it and it was very fast and 9 said it was cheap since they had their own machines and the soil was not far from the site.

4.15 Response on the location of materials

Out of the 29 respondents who had used the Hydraform blocks 18 of them said they made them at site and 11 made them away from the site as there was no space at site and also the material was not readily available at the site.

Figure 12: Location of materials

The participants' feedback on material procurement offers critical perspectives on the practical considerations of using Hydraform blocks in Kigali, Rwanda. The decision to produce materials on-site or off-site is influenced by the unique conditions and availability of resources at each construction site. Gaining insight into these influencing factors is crucial for optimizing the application of Hydraform blocks and ensuring their successful integration into various construction projects.

4.16 Comparative study between hydraform block/Hydraform blocks and concrete cement block based on compressive strength test.

4.16.1 Standard used

During this project, compressive strength tests were conducted on both laterite cement blocks and sand concrete cement blocks to highlight their differences and inform the public about the superior choice of laterite cement blocks based on comparative results. Compressive strength is the ability of a material to withstand loads that tend to reduce its size, as opposed to tensile strength, which resists elongation. In material strength studies, tensile strength, compressive strength, and shear strength are independently analyzed. Compressive strength is measured by plotting applied force against deformation in a testing machine, such as a universal testing machine. Some materials fracture at their compressive strength limit, while others deform irreversibly, making a specific deformation threshold the limit for compressive load. This value is crucial for designing structures.

4.16.2 Age at test

Tests are done at recognized ages of the test specimens, usually being between 7 and 28 days. The ages are calculated from the time of the addition of water to the drying of ingredients. At least three specimens, preferably from different batches, are taken for testing at each selected age. In this project three specimens were taken. Compressive strength of the brick is calculated in the following way.

$$\text{Compressive strength} = \frac{N}{mm^2} = \frac{Maximum\ load\ at\ failure\ (N)}{Average\ area\ of\ bed\ faces\ (mm^2)}$$

The average of the 3 specimens has to be reported as the compressive strength of the bricks in the lot.

By considering the laboratory test results of compression test shows that the mixing ratio of 7% of stabilisation is economical. According to the tests performed during this project, the average strength of hollow concrete cement block is 3.12N/mm^2 while the one for laterite cement block is 12.43 N/mm^2 after 28 days. The study finally came up with that Hydraform blocks are strong and can resist to compression more than hollow concrete cement blocks and that concrete cement blocks are higher in price more than interlocking stabilized soil blocks.

4.17 Comparison between advantages offered by hydraform blocks over concrete cement blocks

Table 1: Comparison between advantages offered by hydraform blocks over concrete cement blocks

Aspect	Hydraform blocks	Concrete cement blocks
Compressive strength	Approximately 12.43 N/mm^2	Approximately 3.12 N/mm^2
Cost of labor	Comparable to concrete blocks	Comparable to hydraform blocks
Speed of Construction	Faster with better workability	Slower
Overall construction costs	Affordable for low-cost construction	Relatively higher for materials and labor
Local availability of materials	Utilizes locally abundant materials	Requires materials like cement which was locally abundant
Energy efficiency	Less energy required for production	Cement production was energy-intensive
Suitability for affordable housing	Economically attractive for affordable housing	Have higher costs, less suitable for affordable housing
Adaptability to local conditions	Suitable for areas with high deposits of laterite	Require imported materials in some regions
Strength and durability	Offers comparable strength to concrete blocks	Strength varies based on mix and curing processes

Table 1 shows that Hydraform blocks present a compelling option for construction due to their high compressive strength of approximately 12.43 N/mm², making them suitable for areas abundant in laterite deposits. They offer efficient use of locally available materials, requiring less energy in production compared to cement blocks. Their speed of construction is notable, enhancing workability and affordability, particularly for low-cost housing initiatives. In contrast, concrete cement blocks, with a compressive strength of around 3.12 N/mm², entail higher overall construction costs due to materials and labor, and their suitability for affordable housing is limited by their cost and energy-intensive production requirements.

The current findings align with several studies on Hydraform interlocking blocks. Assiamah et al. (2022) highlight their use of a unique interlocking block system, crafted from soil and cement, which notably reduces reliance on traditional bricks and mortar. This approach resonates with Kerali (2001), who emphasizes the method of compressing a blend of soil, cement, and water into durable blocks using hydraulic pressing. Surwade and Kamal (2023) further underscore Hydraform blocks as a sustainable alternative to conventional bricks, offering added intangible benefits. Additionally, Ejidike (2023) underscores the innovative potential of Hydraform blocks, not only streamlining construction processes but also bolstering local economies through the utilization of locally sourced materials and labor.

5. Conclusion and recommendations

5.1 Conclusion

The study has provided valuable insights into Hydraform Blocks Building Technology in Kigali, demonstrating a strong interest and participation from professionals in the construction industry. With an 87% questionnaire and 83% interview response rate, the study gathered a robust and diverse dataset, reflecting balanced participation from architects and quantity surveyors. This diversity, encompassing varied educational backgrounds and experience levels, has enriched the research, offering a comprehensive understanding of the technology's implications for construction practices. The study highlights the technology's affordability and suitability for economically diverse communities, addressing housing needs in lower to middle-class areas. It also identifies critical challenges, such as a shortage of skilled labor and cost complexities, underscoring the need for targeted training and awareness initiatives. Laboratory tests confirming the superior strength and cost-effectiveness of Hydraform blocks further support their economic advantages. Overall, this research enhances the understanding of Hydraform Blocks Building Technology, providing a foundation for its broader adoption and further studies in the field.

5.2. Recommendations

The study provides the following recommendations:

1. Educational institutions should collaborate with industry stakeholders to develop and implement specialized education and training programs on Hydraform Blocks building technology. These programs should target construction professionals, bridging knowledge and skills gaps for effective utilization of this innovative construction method.
2. Establishing industry standards and quality control measures is crucial to ensure consistent quality and safety in structures built with Hydraform Blocks.
3. Exploring diverse construction scenarios, including commercial and public buildings, will further enhance its application.
4. Continuous research and development efforts are needed to improve adaptability and effectiveness across different project types.
5. Collaboration among government agencies, NGOs, and community groups can effectively integrate Hydraform Blocks into projects benefiting economically diverse communities, particularly in Kigali.

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