International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Exploring the Potential of Lightweight Construction Materials as a Sustainable Solution for Ghana's Agricultural Industry.

Caleb Fosu[1], Opoku Bernard Sowah[2], Sefah Samuel Amoateng,[3]

[1,2,3] *Department of Architecture, Kwame Nkrumah University of Science and Technology, Kumasi AK384,Ghana..*
Email: fosucaleb.arc@gmail.com

A B S T R A C T

Lightweight construction materials have the potential to transform sustainable development practices; however, their adoption in Ghana remains limited, particularly within the agricultural sector. This study aims to Explore the Potential of Lightweight Construction Materials as a Sustainable Solution for Ghana's Agricultural Industry Three specific objectives are set: (1) to identify the CSFs of lightweight construction and determine which can be applied in the Ghanaian context; (2) to explore the sustainability of lightweight construction materials in Ghana's agricultural sector; and (3) to provide recommendations for enhancing their adoption in agricultural practices. A structured questionnaire was distributed to 126 agriculture and design professionals such as architects, engineers, and contractors. The data were analyzed using descriptive analysis. The findings reveal that key CSFs for lightweight construction in Ghana include material recyclability, resource efficiency, cost-effectiveness, thermal performance, and energy efficiency. However, the level of awareness and knowledge about lightweight construction materials among professionals is critically low, leading to limited adoption within agricultural applications. Key barriers identified include the lack of professional training, minimal integration of lightweight construction into university curricula, and negative perceptions within the agricultural sector. This study underscores the need for targeted interventions, such as specialized training programs, academic modules, and comprehensive manuals detailing practical applications of lightweight construction materials in agriculture. The findings provide a roadmap for promoting the adoption of lightweight construction materials as sustainable alternatives, with potential long-term environmental and economic benefits for Ghana's agricultural sector.

Keywords: Lightweight construction material, Sustainability, Agric industry, Sustainable materials, Modular Construction.

1. Introduction.

People, the earth, and wealth are all affected by our built environment. It depletes natural resources, generates employment and property values, and provides us with a safe place to live. We face the same capacity-building challenge around the world in order to mainstream sustainability as a core building principle (Shijie,2017).

Sustainability has several connotations. What it most commonly refers to as asking is "What effect will this new development have on the planet's ability to maintain life?" Development that is sustainable is one which satisfies existing demands without jeopardizing the capacity of future generations to satisfy their own needs (Rankin, 2014). Although this is an ambiguous, open-ended statement, it has proven to be enduring and offers a target to which many people aspire. However, it offers no instructions on how to get there or how to gauge progress toward sustainable development (Rankin, 2014).

Material is a significant part of building costs, and lowering material costs can lower overall costs. A move to the use of local resources in construction projects is one of the most effective ways to reduce the cost of materials for affordable housing (Sarr, 1988).

Lightweight construction uses timber or light gauge steel framing as the structural support system for non-structural cladding and linings (eg. fibre cement, plywood and colour bond steel) (Alexander, 2019). Depending on the region and environment they are built in, lightweight construction materials have the potential to increase affordability and sustainability. Both at the level of the individual residence and at a higher density level, this is.

Sustainable lightweight building materials have greater overall performance when measured against the predetermined criteria (Pierre, 2019). The following standards will be used:

- Materials sourced and produced locally
- Transportation expenses and the environment impact
- Material thermal efficiency
- Economic viability

- Building material recyclability
- Pollution and waste produced during the production of materials
- Energy needed for the production process

This study aims to investigate the perceptions of construction and agricultural professionals regarding the viability of lightweight construction materials as a sustainable option for the agricultural industry in Ghana. The study is guided by three main objectives:

1. To identify the critical success factors of lightweight construction and determine which of these can be applied in the Ghanaian context.
2. To explore the sustainability of lightweight construction materials within the agricultural sector in Ghana.
3. To provide recommendations for enhancing the adoption and use of lightweight construction materials in the agricultural industry in Ghana.

According to Prof. Dr.-Ing, Jochen Dörr (2018), lightweight architecture is possible described as trying to adjust the design so the proportions make sense. Increased weight up to tare without affecting function derived from this change. As Werner Sobek (2016) states: 'Lightweight architecture seeks to minimize structure and reduce weight as much as possible. Also, all stressful situations should be carefully documented, structural behavior can be predicted and characterized as accurately as possible. By reducing the specific gravity of industrialized construction'

Materials and systems, the use of prefabricated modular systems that do not require cranes or other heavy machinery for assembly, have low energy costs for transport, and even the building materials themselves help reduce environmental costs. The main problem is that lightweight buildings have low thermal inertia and large diurnal variations in thermal temperatures. As a result, they are rarely included in bioclimatic techniques in temperate regions.

Lightweight construction is a broad phrase with different definitions depending on geography and even department. Non-structural cladding and linings are supported by lightweight construction using wooden or light gauge steel framing (eg. fibre cement, plywood and colourbond steel). As we face the social concerns of climate change, increased urbanization, and rapid demographic shift, lightweight construction is increasingly considered as a more responsible construction option as an alternative to all-concrete construction. This trend is really the globalization of local traditional construction methods, rather than a fashion statement (Plessis, 2002).

Lightweight Construction:

- Generally, has lower embodied energy than heavyweight construction.
- Can yield lower total life cycle energy use, particularly where the diurnal range is low.
- Responds rapidly to temperature changes and can provide significant benefits in warmer climates by cooling rapidly at night.
- Is preferred on remote sites with high materials transportation component.
- Usually requires more heating and cooling energy in cold to warm climates (where solar access is achievable) when compared to heavyweight construction with similar levels of insulation and passive design.
- Can have low production impact (eg sustainably sourced timber) or high impact (unsustainably sourced timber or metal frame).
- Typically requires more maintenance and is less durable than heavyweight construction.

The following are few advantages of lightweight construction materials (Rhys, 2022)

- Lower construction costs.
- Construction is much faster.
- Flexibility in design, especially on difficult sites.
- Lower transportation expenses.
- Lower labor and handling costs on-site.
- It's better for sites with restricted access.
- Excellent environmental, acoustic, and thermal performance.
- Energy efficiency is number eight.

There are ways to reduce the environmental impact of buildings. Not only the building itself, but also the materials can be recycled and reused. The proposed technology is based on weight loss and how it can be achieved by improving architecture and building systems (Braganca, 2005). Optimizing the total primary energy consumption (PEC) of building materials and their transport and maximizing passive solar gains wherever possible while minimizing operational energy consumption and maintaining thermal comfort, we focus on two aspects of utilization. Measurements were collected to assess the relative impact of these parameters (Mendoca, 2005).

1.1 Modular Construction

Modular construction is categorized as an offsite construction technique or a Modern Method of Construction (MMC). Another name for it is volumetric construction. The evidence received indicates that modular construction meets every requirement outlined in the CIMP 2006-2015 and the IBS Roadmap 2011-2015.

The utilization of modular buildings has increased significantly during the past few decades (Choi, 2017) When this tactic is properly applied, projects gain in terms of cost, time, and safety, among other factors. According to experts, modularization will significantly boost the building industry's efficiency over the next 20 years.

However, in some situations, different issues and obstacles to proper execution limit its application, according to National Research Council (2009). (Enshassi, 2009). Over the past few decades, researchers have studied a variety of modular building characteristics. Pasquire and Gibb (2002) found that experience plays the most important role in selecting whether to employ modular or traditional construction in their analysis of the advantages and disadvantages of off-site building component manufacture. A tool was also created by Song et al. (2005) to assist decision-makers in determining whether modularization is practical for their projects. The relationship between project productivity and the factors that could affect a modular building project's success was also explored by Choi (2020), and he discovered a plausible linkage. The biggest problems were long lead times, excess production, and delays in component assembly. Throughout the preceding 15 years, modular building has become a staple in a variety of construction-related businesses. Modular construction is today used in a variety of buildings, including high-rise residential complexes, offices, hospitals, and supermarkets. Previously, it was exclusively used for temporary or movable structures. This demand has been spurred by the construction process' off-site component, which offers significant economic and environmental advantages. Rethinking Construction developed its goals and increased the use of off-site production, leading to the phrase "modern method of construction" (MMC) being created (OSM). As a result, many customers viewed OSM's long-term growth as essential to their strategic business operations in terms of constructing quickly, accurately, and consistently. With a manufacturing environment accounting for the majority (up to 70%) of the value of the building job, modular construction is arguably the most advanced OSM technology.

When constructing a building or large portions of one, modular construction uses prefabricated three-dimensional or volumetric modules that are essentially fully produced under factory conditions before being connected on site. The first big modular building to get architectural honours was Murray Grove, which opened in 1999 in Hackney, north London. The 80 modules are arranged in an L-shape throughout the five-story building, which has courtyard balconies and outdoor access points. This building uses standard-sized modules in an eye-catching manner to meet the demands of the occupants and the Peabody Trust, a social housing provider.

Building with prefabricated modular modules is a cutting-edge strategy that has numerous advantages for sustainability and construction. The financial advantages of investing in the long-term infrastructure and manufacturing process of a particular place are instead driven by economies of scale. To maximize the repeated use of manufactured components and to optimize the integrated design, supply delivery, installation, and commissioning process, modular building necessitates discipline from all members of the design and construction team. To assist potential users in better understanding how to design structures using this relatively new technology, this guide covers the design, production, and construction of a variety of building types using modular components, as well as the fundamentals of the offsite manufacturing process.

1.2 Types of modular construction

1.2.1 Steel.

Steel construction, which includes skeleton frames, beams, and columns, is well-known in the multistorey commercial building industry. I and H sections that have been hot-rolled serve as the end connections. Bolts and, in certain cases, welding are used to assemble the ends on-site. Steel-based modules use cold-rolled C sections made from galvanized steel strip that are then assembled into floor, wall, and ceiling panels. Depending on the load, C sections used in walls range in depth from 70 to 100 mm, with steel thicknesses from 1.2 to 2.4 mm. These C pieces are placed at intervals of 300 to 600 mm to accommodate plasterboard dimensions.

For floors, 1.5 mm thick steel sections that are 150 or 200 mm deep are used, depending on the span. The Steel Building Institute's (SCI Publications) P272 (Lawson, et al., 1999), P302 (Gorgolewski, 2001), and P348 (Gorgolewski, 2001) publications explain the method of employing steel in modular building (Lawson, 2007). BS EN 10346 specifies that the total thickness of zinc used in the galvanized coating is equivalent to 275 g/ m2, or around 20 microns on each side (British Standards Institution, 2009). The zinc oxidizes in a self-sacrificing manner when exposed to air or water, shielding the steel even from scraping. The building envelope's light steel components have a design life of more than 100 years, based on measurements taken on site (supplied by SCI P262) (Lawson, 2009). Corner posts may be constructed from square hollow sections or hot-rolled steel angle sections, depending on the modular system (SHSs). Open-sided modules can be built using steel edge beams, which typically have a depth of 300 to 400 mm and span over corner columns.

1.2.2 Concrete

The fabrication of hollow-core slabs, structural beams, and columns, among other items, is accomplished by the well-established and effective precast concrete industry. Precast 2D wall, floor, and ceiling panels or 3D modular parts with an open foundation are the two different types of concrete modules that are available. Concrete modules are widely used in high-security applications because they have a very high level of damage resistance (Gorgolewski, 2001).

In general, the reinforced ceiling slab is 150 mm thick and the reinforced walls of the module are typically 125 mm thick. When the modules are constructed with open bases, the floor of one becomes the ceiling of the one above, reducing structural depth and weight. Under-floor heating is another invention, which uses pipes buried in the slab that covers the ceiling. Concrete modular modules with two or three rooms within one module are regularly constructed to increase efficiency (Lawson, 1999). Modules can be linked with other planar precast concrete pieces to create areas with greater spans. Additionally, multipurpose rooms and modular restrooms are available. L- and T-shaped precast wall panels are frequently used in core areas of buildings to ensure the integrity of the structure overall.

1.3 Factors That Influence the use of Modular Construction

Statistical information from the US Census Bureau on population increase and the demand for affordable housing The United States' population will have increased from 300 million to over 350 million by the end of 2025, according to projections from the Census. Based on the average home size, 19.3 million houses will be needed to house the extra 50 million people (2.59 persons). Housing concerns have an effect on urbanization, according to numerous research. The divide between the rich and the poor is getting wider as cities do not grow in lockstep with the economy (Nixon, 2022).

This area focuses on cutting-edge building technologies and materials that can be applied to creating suitable housing for all socioeconomic classes, including environments where people can live in a healthy, manageable, and sustainable way. Infuriating and filthy living circumstances are reported by one-third of city dwellers, according to a 2005 survey. The fatality rate in conventional construction is substantial. Compared to other industries, the construction sector has a higher rate of fatalities. 20% of all deaths in the US are attributed to construction (Osha, 2005). Since most accidents happen on the construction site, Klakegg contends that employment involving construction in off-site factories are safer than those involving construction on-site. All aspects of residential construction, including modular and mobile homes, are covered in the documentary safety hazards to workers in modular construction. The Occupational Safety and Health Administration database contains 125 events involving the construction of modular buildings, the majority of which happened during installation operations and were brought on by roof collapses. It is estimated that modular construction causes 80% fewer injuries than conventional construction. A Becker study found that 50% of participants thought modularization was safer than conventional building.

1.4 Benefits and Barriers to the use of Modular Construction

1.4.1 Quick Mode of Construction

The modularization strategy offers two major advantages: multiple operations can be completed at once, and the weather has little bearing on the schedule (Kawecki, 2010). (Ferdous, 2019) Because of this, a modular construction project typically takes 40% less time to complete than a traditional construction project (Ferdous et al., 2019), which is crucial for projects that need to be completed quickly (Kamali, 2016), like hospitals and other post-disaster infrastructure reconstruction (Kermanshachi, 2019). According to Ramaji and Memari, the complexity of a project has a significant impact on the modularization's ability to save time because it necessitates more communication and on-site work (2015).

1.4.2 Cost Efficiency

The CII predicts a 10% to 25% decrease in project building costs when modularization is adopted. A number of factors contribute to cheaper costs, including lack of sensitivity to weather extremes, relatively quick installation of off-site building components, and less material transportation for on-site workers (Al-Bizri, 2017). (Goulding, 2017). Since the design technique is standardized and involves less time and engineering than the conventional design procedure, Cartwright (2011) underlined that modular construction results in lower costs.

1.4.3 Safety of Materials.

On-site work frequently entails tasks that endanger workers' lives (Namian , 2020), and the rising incidence of fatalities and non-fatal injuries has spurred a flurry of study to discover answers (Liyung, 2015). Numerous studies have examined the impact of modularization on worker safety and found that it dramatically lowers the frequency of safety concerns (Shin, 2016). The usage of the modular construction method reduces accident risk in construction projects by 80%. The year 2019 (Penaloza, 2019) Despite the fact that modularization lowers mortality on construction sites, safety frameworks must be created for this method (Pealoza, 2019). As a result, safety regulations were developed for personnel working on modular construction projects by the Occupational Safety and Health Administration (OSHA), which keeps track of workplace incidents in the United States (U.S Department of labour 2014).

1.4.3 Eco-Friendly

The amount of waste generated by conventional construction methods has long been a subject of environmental worry for project managers and stakeholders (Jiang, et al., 2018). Modular construction generates less waste in comparison to conventional construction (Kawecki, 2010). The products are simple to recycle and reuse, and the garbage is straightforward to get rid of. The parts may be detached after their useful lives are over. On-site, they don't create any noise, dust, or greenhouse gases (Korman, 2010). Therefore, using modular construction to save waste volume is a good idea. (Illankhoon, 2020; Wang et al., 2014).

1.5 Sustainable Building Materials

Sustainable building materials are those that are made utilizing resource-efficient techniques, such as choosing materials with a low embodied energy content, using locally available and renewable energy sources, and selecting materials that emit fewer GHGs into the atmosphere. They must be extremely long-lasting and capable of incorporating a variety of technologies, such as capturing energy and capturing CO2 while removing pollution. They are utilized when they have a lower long-term environmental cost than natural materials (Bainbridge, 2004).

Sustainable construction materials: Timber has the lowest environmental impact during its manufacturing and life cycle, and it must be certified to ensure that its production and origin are both sustainable.

Isolation renewable materials: These include cellulose, which may be obtained from waste newspapers or paper and is totally recyclable and compostable (Hewage, 2016). They can't produce waste and need to be as efficient as possible when it comes to temperature control.

All waste does not need to be landfilled.

1.6 Examples of Sustainable Building Materials

1.6.1 Hemp Wool

Made of fibers from the inner of hemp plant which is mixed with binder.

- Need little water to grow hemp plants and does not need pesticide or insecticide during its growth period.
- Easy to harvest where its growth period from seed to harvest is between 90 – 120 days
- Serves as a sponge for carbon dioxide during its growth cycle
- Holds class A fire ratings due to its high silica content.
- Vapor permeable which means moisture can flow through it and regulate indoor temperature

Figure 2.1 Showing Hemp Wool

1.6.2 Hempcrete

A composite insulation material by mixing hemp with lime and silica to produce a natural concrete that retain thermal mass.

- It is fireproof material
- Hempcrete regulate moisture
- Easily transported and can also be mixed on site
- Low dust rate

Figure 2.2 Showing Hempcrete

1.6.2 Bamboo

Combination of lightweight, tensile strength and renewability make it an ideal replacement for expensive imported materials.

Figure 2.3 Showing Bamboo

1.6.2 Recycled Plastic

Concrete made from ground-up trash and recycle plastics. This practice reduces greenhouse gas emissions and provides positive new use for plastic waste that would otherwise be clogging landfills

Figure 2.4 Showing Recycled Plastic

1.6.3 Timber

A tried-and-true construction mainstay retains many advantages over concrete, steel and other industrial building materials. Trees absorb carbon dioxide as they grow and don't need to undergo energy-intensive procedures to be converted into a construction product. There's no denying that in terms of carbon footprint, timber is a strong performer. By trapping CO2 throughout its growing life, this eco-material offers significant benefits in terms of reducing greenhouse gas emissions. The fact that it is a natural resource is another strength, because it is easily recycled and contributes to sustainable forest management. “That’s the other great advantage of timber!”, continues Gilles Leva. “Prefabricating timber frames facilitates rapid construction, and equally simple demolition. So, from this point of view, timber is fully consistent with eco-responsible construction”. But timber does not have the answer to everything because this resource is not unlimited and requires a reasoned exploitation. In order for timber construction to establish itself in the long term in places where it is not a traditional method, it will have to rely on the establishment of a professionalized timber industry and networks of dedicated prefabricators and installers to guarantee competitiveness and quality (Rwelamila,2008).

Figure 2.5 Showing Timber

2. Methodology

This study employed a comprehensive research methodology to explore the effectiveness of lightweight construction materials as sustainable options for agricultural industrial facilities. The methodology included a mixed-methods approach, encompassing both qualitative and quantitative research strategies.

2.1 Research Approach .

The adopted research approach is both the qualitative and quantitative approach. Qualitative research is defined as a market research method that focuses on obtaining data through open-ended and conversational communication. This method is not only about “what” people think but also “why” they think so. Systematic review, which is a type of literature review, includes specific criteria for search method and selecting publications for inclusion in the review and this is the approach that was employed in the study

The study involved collecting quantitative information through closed-ended questionnaires and open-ended questionnaires as well as qualitative information through in-person interviews. To answer the research questions, the advantages of different approaches were merged.

2.2 Research Design

The research design combined personal interviews, open-ended questionnaires, and closed-ended questionnaires to gather primary data. A non-experimental survey strategy was employed**.**

2.3 Sampling Design

The study applied a non-probability purposive sampling method, specifically homogeneous purposive sampling, to target respondents knowledgeable about lightweight construction materials. The sample was drawn from a population within Juaben and the KNUST community, with 96 respondents included in the study. Sampling ensured efficient data collection and relevance to the research objectives.

2.4 Data Collection Instruments

Primary data were collected through interviews and questionnaires, while secondary data were sourced from books, journals, and online resources. Techniques included photography, sketching, and digital surveys (e.g., Google Forms) to enhance data diversity.

2.5 Data Analysis

Data analysis is a technique for gathering information or data, organizing it, structuring it, and giving it significance so that inferences can be made. Statistics, such as tables with frequency and percentages, were used to present the analysis' findings. Graphs were also used to convey data where suitable.

2.6 Ethical Considerations

The department of architecture's permission to conduct the study was requested in order to allay any ethical worries about it. This request was backed by a letter of authorization. In order to secure approval from the proper authorities to carry out the research, the authorization letter was delivered to the study area. The researcher introduced himself to the participants, explained the goal of the study, and got their consent before handing out the surveys or conducting the interview. Participants could choose to remain anonymous or not, and all were guaranteed their privacy if they so choose.

3. Results

The results of this study are presented under four subsections to include the respondents' demographic profile, Lightweight Construction Materials and Establishing its Critical Success Factors, Utilization of Lightweight Construction Materials Efficiently, and Challenges Affecting Lightweight Construction Materials.

3.1 Demography of Respondents

The respondents were asked to provide demographic information, including their gender, highest level of education, professional role, and years of professional experience. According to Research Optimus, frequency analysis of demographic data offers valuable insights into the characteristics of study participants. The results, summarized in Table 1, revealed that the majority of respondents were male (56.19%), while females constituted 43.8%. In terms of education, most participants held a Bachelor's degree (38.01%), followed by those with Master's degrees or equivalent (20.66%), and a smaller percentage had Senior High (28.09%) or Junior High (12.20%) education.

The professional backgrounds of the respondents spanned across key sectors relevant to the study, with farmers (27.27%) and architects (19.00%) making up the largest groups, followed by agribusiness owners (18.18%), agricultural extension officers (13.22%), structural engineers (12.39%), and construction managers (9.91%).Regarding years of professional experience, the majority of respondents were in the 31–50 years age bracket (39.02%), followed by those aged 18–30 (27.27%), 51–60 (18.90%), and 61 years and above (15.85%).

Table 3.1 Summary on respondent's demographic

Demographic	Frequency	Percentage
Gender		
Male	72	56.19
Female	54	43.8
T0TAL	**126**	**100**
Level of Education		
Junior High	21	12.20
Senior High	34	28.09
BSc	46	38.01
MSc/M.Arch	25	20.66
TOTAL	**126**	**100**
Professional Background		
Farmer	38	**27.27**
Agribusiness Owners	22	**18.18**
Agricultural Extension Officers	16	**13.22**
Architects	23	**19.00**
Structural Engineers	15	**12.39**

Construction Managers	12	**9.91**
TOTAL	**126**	**100**
Years of Experience		
18-30	49	27.27
31-50	63	39.02
51-60	31	18.90
61 and above	26	15.85
TOTAL	**126**	**100**

Table 3.2 Below is a Table of Critical Success Factors (CSFs) of Lightweight Construction Materials

CSF	Publications															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Resource Efficiency	x			x	x	x	x	x	x		x	x	x	x	x	12
Material Efficiency	x	x	x	x	x		x	x	x	x	x		x	x		12
Sustainability	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	15
Material Recyclability	x	x	x	x	x	x		x		x		x	x	x		11
Cost Efficiency	x		x		x			x	x	x		x		x	x	9
Thermal Efficiency	x	x		x	x	x	x	x		x	x		x		x	11
Energy Efficiency	x		x	x	x	x			x		x	x		x		9

15 publications in total were examined to get to the aforementioned CSFs. The most common CSFs cited in the analysis of the various articles are represented in the table above. This illustrates a few key CSFs used in lightweight construction to help under-stand what to take into account or what the most crucial aspect of utilizing light-weight construction materials is.

4.1.2 Applicable CSFS and Materials Employed as Sustainable Choice

Professionals in the built environment were questioned about which of the factors established do they consider is applicable in Ghana in order to further research and determine which of the variables can be applied locally.

Table 3.3 Resource Efficiency

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	16	12.7	12.7	12.7
	Medium	36	28.6	28.6	60.3
	High	60	47.6	47.6	88.9
	Very High	14	11.1	11.1	100.0
	Total	126	100.0	100.0	

(Source: Author’s Field Study, 2024)

Out of the 126 respondents, 60 said that "resource efficiency" was a major factor that could be applied locally as they chose high for an answer, shown in table 4.27. 11% of respondents deemed this factor to be crucial.

Table 3.4 Thermal Efficiency

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	6	4.8	4.8	4.8
	Medium	10	7.9	7.9	12.7
	High	94	74.6	74.6	87.3
	Very High	16	12.7	12.7	100.0
	Total	126	100.0	100.0	

(Source: Author's Field Study, 2024)

By selecting "high," 74.6% of answers concluded that thermal efficiency was essential for the success of lightweight construction. 12.7% of those agreed or strongly agreed that this factor is very crucial, given the response "very high." 16 more out of the 126 respondents give the factor medium and low ratings

- ***Table 3.5 Thermal Efficiency***

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	6	4.8	4.8	4.8
	Medium	10	7.9	7.9	12.7
	High	94	74.6	74.6	87.3
	Very High	16	12.7	12.7	100.0
	Total	126	100.0	100.0	

(Source: Author's Field Study, 2024)

By selecting "high," 74.6% of answers concluded that thermal efficiency was essential for the success of lightweight construction. 12.7% of those agreed or strongly agreed that this factor is very crucial, given the response "very high." 16 more out of the 126 respondents give the factor medium and low ratings.

- ***Table 3.6 Cost Efficiency***

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	4	3.2	3.2	3.2
	Medium	4	3.2	3.2	6.3
	High	80	63.5	63.5	69.8
	Very High	38	30.2	30.2	100.0
	Total	126	100.0	100.0	

- **(Source: Author's Field Study, 2022)**

With high as the chosen response, 63.5% of respondents agree that cost efficiency is essential for the success of lightweight construction. A very high response from 30.2% of respondents indicates that they view this factor to be critical. The factor is rated as medium and low by the remaining 6.4% of respondents.

- ***Table 3.7 Energy Efficiency***

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	10	7.9	7.9	7.9
	Medium	12	9.5	9.5	17.5
	High	84	66.7	66.7	84.1
	Very High	20	15.9	15.9	100.0
	Total	126	100.0	100.0	

(Source: Author's Field Study, 2024)

66.7% of respondents, who chose 'high' as their preferred response, concur that energy efficiency is critical to the success of lightweight construction. 15.9% of those polled gave 'very high' as a response, indicating that they thought this factor was key. Ac-cording to table 4.30, the remaining 17.4% of respondents gave the factor medium and low ratings

Table 3.8 Material Recyclability

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	10	7.9	7.9	7.9
	Medium	10	7.9	7.9	15.9
	High	68	54.0	54.0	69.8
	Very High	38	30.2	30.2	100.0
	Total	126	100.0	100.0	

The significant majority of the 126 respondents—68—who selected "high" as their preferred option agree that "material recyclability" is essential to the success of light-weight construction. According to table 4.31 above, 30.2% of those surveyed responded "very high," indicating they regarded this factor to be crucial.

Table 3.9 Material Efficiency

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	10	7.9	7.9	7.9
	Medium	4	3.2	3.2	11.1
	High	76	60.3	60.3	71.4
	Very High	36	28.6	28.6	100.0
	Total	126	100.0	100.0	

(Source: Author's Field Study, 2024)

The vast majority of the 126 respondents, or 76 of them, who chose "high" as their pre-ferred option concur that "material efficiency" is crucial to the success of lightweight construction. Table 4.32 above shows that 28.6% of respondents rated this factor as "very high," suggesting that they thought it was critical.

Table 3.10 Sustainability

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	8	6.3	6.3	6.3
	Medium	6	4.8	4.8	11.1
	High	86	68.3	68.3	79.4
	Very High	26	20.6	20.6	100.0
	Total	126	100.0	100.0	

(Source: Author's Field Study, 2024)

Out of the 126 respondents, 86 indicated that "sustainability" was a significant factor that could be applied locally by selecting "high" for an answer, as shown in table 4.33, and 20.6% indicated that they thought this factor was extremely important by select-ing "very high".

4.2 Utilization of Lightweight Construction Materials Efficiently

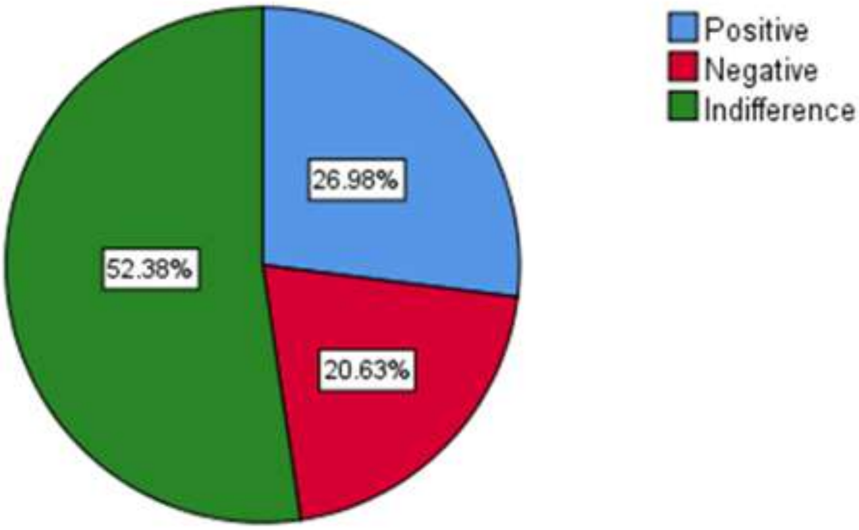
Table 3.11 Frequency of Proposing Lightweight Construction Materials to Clients

	Frequency	Percent	Valid Percent	Cumulative Percent
Not Often	12	9.5	9.5	9.5
Less Often	66	52.4	52.4	87.3

Often	32	25.4	25.4	34.9
Quite Often	14	11.1	11.1	98.4
Very Often	2	1.6	1.6	100.0
Total	126	100.0	100.0	

(Source: Author's Field Study, 2024)

Figure 3.1 Clients' Response to Lightweight Construction Material Recommendation



According to table 4.20, respondents in the built environment "often" recommended clients to choose lightweight construction materials. According to figure 4.1, Most of clients are neither positive nor negative when lightweight construction materials are suggested to them. It follows that most clients are unfamiliar or lack of expertise on lightweight construction materials. Nevertheless, when lightweight construction materials were suggested to clients, some of them responded favorably.

Table 3.12 Value Satisfaction Level

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Medium	14	11.1	11.1	11.1
	High	18	14.3	14.3	25.4
	Very High	94	74.6	74.6	100.0
	Total	126	100.0	100.0	

(Source: Author's Field Study, 2024)

Table 3.13 Usage Experience Satisfactory Level

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	66	52.4	52.4	52.4
	Medium	26	20.6	20.6	73.0
	High	22	17.5	17.5	90.5
	Very High	12	9.5	9.5	100.0
	Total	126	100.0	100.0	

(Source: Author's Field Study, 2024)

Table 3.14 Purchase Experience Satisfactory Level

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	8	6.3	6.3	6.3
	Medium	70	55.6	55.6	61.9
	High	32	25.4	25.4	87.3
	Very High	16	12.7	12.7	100.0
	Total	126	100.0	100.0	

(Source: Author's Field Study, 2024))

According to table 4.21, the value of lightweight was very important to 74% of the respondents from the built environments. On the other end, 52.4% of the respondents expressed dissatisfaction with usage experience with lightweight construction materials, indicating a lack of knowledge on usage in this area as shown in table 4.22.

Additionally, the vast majority of respondents select "medium" when asked about their purchase experience, indicating that they are neither positive nor negative in table 4.23.

4.2.2 Challenges Affecting Lightweight Construction Materials

Table 3.15 Poor Knowledge Awareness

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	6	4.8	4.8	4.8
	Medium	8	6.3	6.3	11.1
	High	22	17.5	17.5	28.6
	Very High	90	71.4	71.4	100.0
	Total	126	100.0	100.0	

(Source: Author's Field Study, 2024)

Table 3.16 Inexperience Manufacturers

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	4	3.2	3.2	3.2
	Medium	38	30.2	30.2	33.3
	High	56	44.4	44.4	77.8
	Very High	28	22.2	22.2	100.0
	Total	126	100.0	100.0	

(Source: Author's Field Study, 2024)

Table 3.17 Poor Product Awareness among Consumers

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	8	6.3	6.3	6.3
	Medium	10	7.9	7.9	14.3
	High	58	46.0	46.0	60.3
	Very High	50	39.7	39.7	100.0
	Total	126	100.0	100.0	

(Source: Author's Field Study, 2024)

Table 3.18 Quality Product Challenges

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	76	60.3	60.3	60.3
	Medium	18	14.3	14.3	74.6
	High	16	12.7	12.7	87.3
	Very High	16	12.7	12.7	100.0
	Total	126	100.0	100.0	

(Source: Author's Field Study, 2024)

According to table 4.24, 71.4% of participants stated that a lack of knowledge about employing lightweight construction materials was a major barrier to buying a product.

Additionally, as seen in table 4.25, 56 out of the 126 respondents viewed inexperienced manufacturers as a concern.

Clients' poor product awareness, which accounted for 46% of the responses, was directly impacted by lack of expertise.

Finally, the majority of respondents did not consider that the quality of the product is a significant barrier to hindering lightweight construction materials. This indicates that respondents thought lightweight construction materials had high quality standards

Table 3.19 Structural Stability

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	28	60.9	60.9	60.9
	Medium	12	26.1	26.1	87.0
	High	5	10.9	10.9	97.8
	Very High	1	2.2	2.2	100.0
	Total	46	100.0	100.0	

(Source: Author's Field Study, 2024)

Table 3.20 Aesthetic and Functional

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	2	4.3	4.3	4.3
	Medium	24	52.2	52.2	56.5
	High	19	41.3	41.3	97.8
	Very High	1	2.2	2.2	100.0
	Total	46	100.0	100.0	

(Source: Author's Field Study, 2024)

Table 3.21 High Cost and Difficulty in Repairs and Maintenance

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	24	52.2	52.2	52.2
	Medium	18	39.1	39.1	91.3
	High	3	6.5	6.5	97.8
	Very High	1	2.2	2.2	100.0
	Total	46	100.0	100.0	

(Source: Author's Field Study, 2024)

Respondents were questioned regarding the structural integrity of lightweight con-struction materials. using data from table 4.28, Low was selected as the response by 60.9% of respondents. Respondents apparently believe that lightweight construction materials are unstable structurally.

Additionally, when asked if lightweight materials are aesthetically pleasing and functional, the majority of respondents chose "medium," indicating that they had neither a good nor a negative opinion, as seen in table 4.29.

When asked if lightweight construction materials are expensive and difficult to repair and maintain, respondents provided a middling response. In conclusion, respondents be-lieved that lightweight construction materials are structurally unstable but economical and simple to maintain

4.Findings, Conclusions and Recommendations.

4.1.1 Establishing the critical success factors of lightweight construction, and which of these factors can be adopted in Ghana

The research revealed that many professionals in the built environment had limited knowledge of how to effectively incorporate lightweight construction materials into their designs. Despite this knowledge gap, the study identified several critical success factors (CSFs) that could be relevant for adopting lightweight construction in Ghana. These factors include resource efficiency, material efficiency, sustainability, recyclability of materials, thermal efficiency, cost-effectiveness, and energy efficiency. These CSFs have the potential to guide the successful implementation of lightweight construction materials within the Ghanaian context, supporting both the construction and agricultural sectors.

4.1.2 Exploring Sustainability of Lightweight Construction in Ghana's Agric Sector

The research also explored the level of awareness among professionals regarding the availability of information on lightweight construction materials. It was found that many respondents, particularly within the built environment, are not well-informed about these materials. Some experts in the field are hesitant to seek out information on sustainable, lightweight construction options. Additionally, professionals in the agricultural sector in Ghana tend to hold negative perceptions of lightweight construction as a viable alternative for their industry, largely due to the limited literature and awareness on the subject. This lack of information and understanding contributes to a general reluctance to adopt lightweight construction materials within the sector, despite their potential sustainability benefits.

4.1.3 Recommendations for Improving Lightweight Construction in Ghana's Agric Industry

The research highlights the significant positive impact of lightweight construction materials on sustainability and sustainable development globally. Despite the opportunities and challenges associated with their use in Ghana, it is evident that these materials can play a crucial role in advancing long-term sustainability in the agricultural sector.

To fully leverage this potential, there is a clear need for a comprehensive manual detailing the viability of lightweight construction materials and their practical applications in agriculture. Such a guide would be invaluable in supporting the adoption of these materials as a sustainable solution for the agricultural industry in Ghana.

Professionals both in the region and worldwide share an optimistic view that lightweight construction materials can serve as a practical tool for promoting the sustainability of the agricultural sector. By addressing the unique challenges posed by these materials in Ghana, this initiative can contribute to the development of more sustainable agricultural practices, ensuring long-term environmental and economic benefits.

4.2 Conclusion

In order to suggest solutions that would aid in sustainable development, the research's primary objective is to evaluate and establish the viability of lightweight construction materials as a sustainable option for the agricultural sector. The study's overall conclusions are given below. To start, it was discovered that most built environment experts at KNUST are not conversant with lightweight construction materials and structures. The study's findings also indicate that the agricultural industry in Juaben rarely addresses lightweight construction materials. In Juaben, heavyweight construction is typically taken into consideration when constructing structures for the agricultural sector.

Additionally, this research discovered that individuals have a poor expertise of the availability of knowledge when it comes to the information about lightweight construction and its materials. According to the respondents' responses, Juaben and KNUST have limited knowledge of lightweight construction, which has discouraged them from applying it. Some experts in the built environment are reluctant to research information on lightweight construction. Again, there is a dearth of literature in Ghana on lightweight construction materials. The implementation of lightweight construction in Ghana's agricultural sector has been impeded by the scarcity of information on the subject. The research also identified several significant opportunities and difficulties for lightweight construction. It is clear that lightweight construction materials contribute to sustainability worldwide despite the opportunities and difficulties they present. Professionals from Ghana and around the world are positive that lightweight construction materials can be a useful tool for increasing sustainability in Ghana

4.3 Recommendation

The research's primary objective is to evaluate and determine the viability of lightweight construction materials as a sustainable option for the agricultural sector in order to make recommendations for solutions that will promote sustainability and maximize the use of lightweight construction materials. Due to a lack of expertise and information on the topic under discussion, the study's findings showed that lightweight construction is typically not taken into account when building structures specifically for the agricultural industry. But certainly, the situation may shift in the future. The primary issues mentioned in the earlier chapters are what the proposals are aimed to address. The key recommendations are as follows:

- According to the findings of this study, professional and industry-specific training, seminars, and workshops on a range of lightweight construction-related issues need to be greatly improved.

- University curricula should incorporate courses or modules on lightweight construction and materials, and professionals in the agricultural sector should consider how effective lightweight construction materials are to maximize use.

References

1. Adebayo, A A. (2002). Sustainable Construction in Africa, Agenda 21 for Sustainable Construction in Developing Countries, Africa Position paper: 1-10.
2. Ahmed K., Hatira, L. & Valva, P. (2014). The Construction Industry in Ghana, West Africa “How can the construction industry in Ghana become sustainable?” Master’s Thesis, Department of Strategic Sustainable Development Blekinge Institute of Technology Karlskrona, Sweden
3. Bainbridge D.A. (2004). Sustainable building as appropriate technology. In Building without Borders: Sustainable Construction for the Global Village; Kennedy, J., Ed.; New Society Publishers, Gabriola Island, Canada, 55–84.
4. Batcbelder, D., Caiola, R.E. & Davenport, S.W. (1985). A Sourcebook for the Use of Local Materials in Construction. The Experiment in International Living, Brattleboro, Vermont, USA.
5. Bay J. Ong (2006). Tropical sustainable architecture. Social and environmental dimensions, Architectural Press.
6. Braganca, L. & Mendonca, P., (2005). Functional asssessment of lightweight construction solutions in view of sustainabilty. In: Improvement of Building's Structural Quality by New Technologies. Innsbruck: CRC Press, pp. 555-565.
7. Cartwright, J. T., (2011). Zoning and Designing for Affordability Using Modular Housing.Iowa, Iowa State University.
8. Danso, Henry (2018). Identification of Key Indicators for Sustainable Construction Materials. Advances in Materials Science and Engineering.
9. Djokoto S.D., Dadzie, J. & Ohemeng-Ababio, E. (2014). Barriers to Sustainable Construction in the Ghanaian Construction Industry: Consultants Perspectives. Journal of Sustainable Development
10. Djokoto, Susan, John Dadzie and Eric Ohemeng-Ababio (2014). Barriers to sustainable construction in the Ghanaian construction industry: consultants’ perspective. Journal of Sustainable Development. 7 (January): 134-143.
11. Ebohon, O.J. and Rwelamila, P.D. (2001). Sustainable construction in Sub-Saharan Africa: relevance, rhetoric and reality. Position paper for Agenda 21 for sustainable construction in developing countries: 1-16.
12. Enshassi, A., Mohamed, S. & Abushaban, S., (2009). Factors affecting the performance of construction projects in the Gaza strip. Journal of Civil Engineering and Management, 15(3), pp. 269-280.
13. Ferdous, W., Bai, Y., Ngo, T. D. & Manalo, A., (2019). New advancements, challenges and opportunities of multi-storey modular buildings – A state-of-the-art review. Engineering Structures, Volume 183, pp. 883-893.
14. Generalitat de Catalunya, Sustainable Building, Vol.2, Design Manual: Sustainable Building Design Practices, ICAEN (Institut Català d’Energia), (2004).
15. Jiang, L., Li, Z., Li, L. & Gao, Y., (2018). Constraints on the Promotion of Prefabricated Construction in China. Sustainability, 10(7), p. 2516.
16. Kamali, M. & Hewage, K., (2016). Life cycle performance of modular buildings: A critical review. Renewable and Sustainable Energy Reviews, 62(C), pp. 1171-1183
17. Kim J. J. & Rigdon, B. (1998). Sustainable Architecture Module: Introduction to Sustainable Design. Michigan: National Pollution Prevention Center for Higher Education.
18. Kwaku Ahmed, Lamia Hatira, Paul Valva (2014) The Construction Industry in Ghana, West Africa “How can the construction industry in Ghana become sustainable?”, pp. 1-10.
19. Lawson, R. M., Grubb, P. J., Prewer, J. & Trebilcock, P. J., (1999). Modular Construction Using Light Steel Framing: An Architect's Guide. 1st ed. Berkshire: The Steel Construction Institute.

20. National Research Council, (2009). Advancing the Competitiveness and Efficiency of the U.S. Construction Industry. Washington DC: National Academy Press.

21. Ortiz O., Castells F. and Sonnemann G. (2009). Sustainability in the construction industry: A review of recent developments based on LCA. Construction and Building Materials, 23(1), 28–39

22. Plessis C. du, (2002).Agenda 21 for Sustainable Construction in Developing Countries, CSIR Building and Construction Technology.

23. Williams D.E. (2007). Sustainable Design: Ecology, Architecture, and Planning, John Wiley & Sons.