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Appropriate Technology and Design: A Solution for Sustainable and Affordable Housing Delivery in Major Cities of Ghana

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Authors' contributions

This work was carried out in collaboration among all authors. Author ET designed the study, performed the statistical analysis, and wrote the first draft of the manuscript. Authors SKA and BAB managed the analyses of the study, wrote the protocol, and managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Appropriate technology and design for housing delivery undoubtedly has abundant cost benefit and other advantages. However, the acceptance of its usage and application for sustainable and affordable housing delivery is rare. Appropriate technology supports and enhances good life without compromising the earth's ecosystem and the prospects of later generations. It is energy efficient, environmentally sound, and it is been controlled by the local community with local available materials. Appropriate housing design on other hand, focuses on the engineering and architectural perspective of a structure that supports sustainable construction and development. The paper aimed at determining the extent to which appropriate technologies and designs are currently employed in addressing housing sustainability and affordability in Ghana. Questionnaire survey was used for the data collection. The study was conducted in Accra, Takoradi and Cape Coast of Ghana within the period of 5 Months. In total, 110 questionnaires were distributed among Building and Construction Professionals and Self- Built House Owners. Out of the number distributed, 56 were retrieved for analysis. Data was analyzed using descriptive statistics. The findings of the study established that, hydrafoam, adobe bricks technology, timber homes technology, and wattle and daub technology were considered the most used and acceptable appropriate technologies for sustainable and affordable housing delivering. The findings of the

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study also revealed that, the extent to which appropriate technologies and designs have been adopted in major cities in Ghana is low. This implies that less emphasis is placed on the use of appropriate technology and design in resolving sustainable and affordable housing issues in major cities. It is therefore, suggested that, government and stakeholders mainstream the use of appropriate designs and technologies for sustainable and affordable delivery. Consequently, stakeholders should help change the perception of Ghanaians towards the adoption of appropriate technologies and designs for sustainable and affordable housing delivery.

Keywords: Affordable; housing; appropriate technology; appropriate designs; sustainable.

1. INTRODUCTION

The rising concerns of the negative impacts of construction related activities on the environment have called for sustainable building development [1,2]. This however, can be achieved by adopting appropriate technology and design practices. Appropriate technology and design is simple and energy efficient. It greatly relies on local or community base expertise for its delivery. Tracey [3] opined that, the continued use of appropriate technology is a fundamental solution to addressing the concerns of standards of living of people and environmental issues. Science-based technology, has since its inception offered a better world through material and techniques improvements [4]. According to [5] the idea of sustainable development began to take shape since the beginning of the industrial revolution which marked the beginning of change in human behavior towards the environment. Sustainable building construction, which involve the use of appropriate technology and simple design, is not entirely new. It has its trace from vernacular buildings that use locally based materials and technologies [6]. Fernandes et al. [7] stated that, the use of locally based technologies, and innovative designs for housing was widespread until the industrialized revolution which saw the increased use of new industrially produced and standardized building materials. This has led to the homogenization of the use of different construction approaches for housing delivery. In Ghana, the rate of housing delivery has been erratic and often fallen short of the demand [8]. Amoa-Mensah et al. [9] revealed that, the country's housing deficit is projected to be around 2 million housing units as against an annual purported delivery of 37,000 housing units which is dominated by individual self-house projects. The 2021 Ghana population and housing census revealed that out of the 10.7 million houses in Ghana, 2.1 million of them were containers, kiosks and wooden structures. It is further revealed that 6.2 million of the 30.8 million of the population live in uncompleted buildings. The issues regarding housing needs pragmatic measures to alleviate the country's housing deficit. Hence, there is the need to be much more focused on technologies and approaches that can deliver housing at lower cost, in order to bridge the huge housing deficit gap facing the country [10]. According to [11], the construction industry has strong interaction with global energy and environmental problems and out of that building structures are responsible for more than 40% and over a third of the total greenhouse gas emissions. This effect was obviously due to the techniques and materials which have been adopted over the years for executing building structures around the globe. The problem, require both public and the private sector acceptance to improve the usage of appropriate technologies and designs for housing delivery. Such a work would reduce the massive consumption of the global energy. It should however be noted that, appropriate design and technology is simple and apply little or no impacts to the environment. It also supports sustainable development. The cities (Accra, Takoradi and Cape Coast) selected for the research can be found in the southern part of Ghana. These locations were chosen among the cities in Ghana because they are highly industrial cities (specially Accra and Takoradi) and most building and construction professionals are based in these cities. There are numerous studies conducted on appropriate technologies and designs, for achieving sustainable and affordable housing, however, pragmatic studies establishing how appropriate technologies and designs are being employed for sustainable and affordable housing delivery, is lacking. This study therefore aimed at determining the extent to which appropriate technologies and designs are currently adopted in addressing housing sustainability and affordability in Ghana.

2. HOUSING AFFORDABILITY AND SUSTAINABILITY CONCEPT

Housing affordability is a concept which involves the ability of households to consume other basic necessities of life such as food and clothing in

addition to accessing adequate housing. In other words, housing affordability is the ability of mortgagors to effectively meet mortgage obligations, and households' access to adequate standard of housing without denying them access to other basic necessities of life [12]. Housing sustainability on the other hand, seeks to meet the needs of the present without compromising the ability of future generation to meet their own needs regarding housing [13]. It originated from the concept of sustainable construction which is the application of sustainable development to the construction industry. Housing sustainability could therefore, be best described as a subset of sustainable development, which encompasses issues such as tendering, site planning and organization, material selection, recycling, and waste minimization [14]. It is worth nothing that affordable houses cannot be considered sustainable if they create negative impacts on the environment, or on social life. Hence, the need to marry housing affordability with sustainability, to provide practical solutions for their implementation.

2.1 Appropriate Technology and Design Concept

Appropriate technology, is a technology that support and enhances good life for all of its citizens, in both rich and poor countries, without compromising the earth's ecosystem and the prospects of later generations. It is energy efficient, environmentally sound, and controlled by the local community, and usually with local available materials. It is more productive and less expensive compared to high technology of industrialized societies [15]. In contrast to the areas of high-tech innovation and development that has been considered so far, there is an aspect of technology, often called appropriate technology [16]. At present, these are found primarily in the rural third world, "but also in pockets of the developed" countries [4]. Vergragt [4] further emphasized that appropriate technology has been advocated as a solution for rural developmental problem but has also gained support as a direction for sustainable technologies. However, it has often been identified as "cheap", "second hand", or second best to that of high technological innovations. The issues with the adoption of this concept is that, going forward building practitioners have to learn from our past mistakes, and to either combine elements of appropriate technology with some aspects of high technology into a moderate technology or to adapt appropriate technology solely where necessary to ensure sustainable technology, with the aspect of sustainable construction [4]. Appropriate design on the other hand, is an engineering perspective (structural designing, loading, stability, strength and durability), styles, sizes, shapes-plans (thus the architectural perspective) of a structure to be build, that supports sustainable construction and development [17,18]. It greatly relies on local or community base expertise for its delivery. Houses constructed with appropriate designs are environmentally friendly, socially and economic sustainable for both present and future generations. Both the structural designing (thus loading sizing of members) and architectural designing (drawings-plans, styles, sizes, shapes) are made to reduce construction cost greatly for average people to afford [16]. Therefore, appropriate designs, should be regarded as a way through which countries in the developing world like Ghana can accept to use after addressing the relevant issues associated with it, in order to close the gap of huge housing deficit facing this part of the world. According to [19,20] designs impact the delivery of housing in a variety of ways. For example, the choice of design type, materials and their applications have a significant environmental impact, depending on the sources of materials, their durability, and potential reuse. Malik [21] explained that, for designs to be appropriate, it must possess some specific qualities, among these qualities include: encouragement of cyclic construction process, maximization of resources reuse, consideration for low energy design, avoidance of potential health hazards, economically and socially sustainable, must harvest rain water and conserve it for reuse.

2.2 Forms of Appropriate Technology and Designs for Housing Delivery in Ghana

In Ghana, there are various forms of appropriate technology and design for housing delivery. Discussed below are some of the appropriate technologies and designs proposed to resolve housing issues in the major cities.

2.2.1 Hydrafoam technology (The use of interlocking masonry blocks and bricks)

Interlocking or hydrafoam masonry bricks technology is very efficient, easy to handle, very compact and yet versatile blocks. While they are

made of laterite, they can also be made of cement and sand content only, with ratio of 1:20, indicating one part of cement and twenty part of sand or laterite. This means that for one bag of cement you will need about 10 wheelbarrows of soil. This mix yields or produces about 75 blocks with engineering standards which is acceptable for wall construction [22]. According to [23], embodied energy in traditional building materials like hydrafoam blocks can be reduced by approximately 10-15%. The usage of interlocking block of any type in place of conventional fired ones can significantly reduce the energy use and also cut down Co2 emissions by reducing the environmental degradation of the environment but ensure low cost housing to developing societies. Adedeji [22,23] reviewed some important benefits with solid interlocking blocks over conventional blocks, among them were, its substantial cost savings due to elimination of bedding mortar in the superstructure, except in ring beams and high gables, it accelerates and speeds up construction thereby reducing workmanship and cost. Hydrafoam blocks are as efficient as concrete and almost twice as efficient as fired clay bricks in terms of the thermal insulation they offer. They have attractive face bricks finish in variety of colours. The production of interlocking blocks such as solid interlocking blocks (SIB) does not require firing as in the case of burnt bricks/blocks nor are expensive factory processes associated with cement products required. Hence, energy consumption is reduced considerably, besides, the cost of using interlocking blocks in construction, is lower than that of conventional blocks as its operation does not require special skilled labour as it is in the case of conventional blocks. Above all the labour gang output of 1 mason +1 labour for laying interlocking blocks is three times higher than I mason +1 labour for laying conventional masonry block. The blocks/bricks can also be used for both internal and external wall construction, they are used as external wall elements without rendering and plastering. It is lighter in weight and easy to work with, it is environmentally friendly and supports sustainable construction and development. It is a low embodied energy material, and uses simple methods and processes in manufacturing, and above all reduce about 85% of cement contents which is use for making conventional blocks.

2.2.2 Adobe brick technology

Adobes are sun-dried mud bricks bonded with mud mortar to create thick-walled structures [24]. Kennedy [24] further stated that, adobe bricks can also be derived from yellow silt or clay deposits in soil and by rivers. These thick earthen walls provide what is known as “thermal mass” which helps to modulate interior temperatures by absorbing excess heat during the day and slowly releasing it at night. Adobe is also referred to as earth construction. According to [25] adobe construction has been in existence for a good number of years, and it was among one of the most ancient and widely used building materials by humans. Following the series of studies undertaken on this kind of construction, it has been concluded that there is currently about 30% of the world’s population that live in buildings constructed with adobe or earth [25]. Houses that are constructed with adobe brick technology are still being built in either multi-storey buildings or smaller single-storey homes. Adobe homes have been used in both North America, South America and in Africa for thousands of years. Bui et al. [26] stated that the cost associated with this method of construction is less because of the use of materials available within the specific community. Costa et al. [25] also stated that the material and technology employed, makes this kind of construction very beneficial to the environment because there are no refined processes involved. Agyekum [1] opined that in Ghana there are some quite a number of homes that were constructed with adobe technology or bricks. The challenge now is how to improve upon their durability, water resistance abilities and appearances to be accepted as sustainable and affordable housing solutions.

2.2.3 Wattle and daub technology

The technique of weaving branches (wattle) as a support for mud plaster (daub) is perhaps the oldest of earth building techniques and is still used for traditional architecture in many parts of the world [24]. Essienyi [27] revealed that, in Ghana the Wattle and Daub method of constructing walls is highly associated with indigenes living in the southern part of the country. In some other parts of the world, wattle and daub technology is constructed by placing fresh earth on support [25]. Agyekum [1] stated that the approach of this construction technique in Ghana is quite different, first setting out of the base are carried out, and at regular interval pits to receive the timber poles are excavated following the setting out. The vertical pole of timbers is firmly held at the base with stones rammed around the base, then other framing systems or members are carried out in the horizontal direction to form a

complete structure and occupied by the clients [27].

2.2.4 Compressed earth or blocks technology

Compressed earth or blocks technology are similar to adobes, with the main difference being that, they are not fully saturated with water, they are denser than adobes and are significantly more uniform [24]. This technique involves a mixture of raw materials like soil, gravel and sand [25]. According to [28] rammed earth or blocks are highly non-combustible, thermally massive, very durable and very strong as well. These blocks are created using a variety of machines. Some like the Cinva-Ram invented in South America, uses relatively inexpensive labour, that is locally based with high experience. Because of their uniformity, compressed earth or block needs little mortar, and can even be dry-stacked. This speed up the laying process and results in straighter walls [25]. In Ghana, the rammed earth technique is usually known as Atakpame, which was first built among the Ewe ethnic groups and near the border country like Togo and Benin. The detailed construction with this technology has been widely discussed by [27].

2.2.5 Timber home technology

Timber has been available as a construction material for most societies since the human race first started to build shelters [29]. It was further argued that a diversity of tree species exists and most climate zones have at least one that has adapted to the prevailing conditions within the area. Agyekum [1] stated that in Ghana, timber used to be part of natural resources until recently, but the few structures which were built with timber have stood the test of time as compared to those constructed with conventional materials. They continued to claim that timber products used for construction in Ghana are classified either as structural or nonstructural. Structural timber is used in the construction for load-bearing walls, frames, etc. The non-structural timbers on the other hand, are normally used for non-structural works like wall sidings, ceilings, and floors. Among timber desirable properties are, its versatility, durability, resistance to fire attacks when well treated, it has good thermal conductivity and expansion, and it is attractive [30].

2.3 Research Methodology

The research method adopted for the study is a quantitative research method where a questionnaire survey was used for the collection of data for the research. The primary data was gathered from building and construction professionals from the following professional bodies: Ghana Institute of Architects, Ghana Institution of Surveyors, and Ghana Institution of Engineers. Also, self-built clients of appropriate technologies and designed buildings were contacted for additional information. Kumar et al. [31] indicated that the selection of key respondents is generally based on those who have knowledge about the problem and subject area being researched into. Indications are that their responses will minimize response error. Hence, the respondents selected for the study were those who have in-depth knowledge on appropriate technologies and design. The cities (Accra, Takoradi and Cape Coast) selected for the research can be found in the southern part of Ghana. These locations were chosen among the cities in Ghana because they are highly industrial cities (specially Accra and Takoradi) and most building and construction professionals are based in these cities. The study area was also chosen because, it had quite a number of self-built clients who own houses that were constructed with appropriate designs and technological concepts. Although these geographical locations have the target respondents, thus, building and construction professionals, however, getting those professionals who have in-depth knowledge concerning the issues under investigation was difficult. Agyekum [1] indicated that when faced with such a problem, it is good to use non-probability sampling approach to obtain the required sample. Hence, non-probability sampling technique was used for the study.

The respondents for the study were contacted using purposive and snowball sampling method. The questionnaires were distributed and retrieved in person to ensure that the questionnaire got to the intended recipients. The approach helps to collect as much as possible information for the research. The secondary data was also obtained through statistical department of Ghana's reports on housing and population census 2021 and government publications on housing policies [10].

Out of the 110 questionnaires distributed, 68 were retrieved. However, 12 were found to be invalid and were discarded from the analysis as a result of improper filling. Hence, remaining 56, representing an effective response rate of 36%. This response rate is considered adequate because, according to [32,33], a response rate of

30% is good enough in construction studies or the construction industry.

The researchers employed descriptive statistics as a tool for analyzing the data collected from the field. The Statistical Package for Social Sciences (SPSS) Version 22 was used for the data analysis. Principal Component Analysis (PCA) was adopted to reduce the number of items into smaller components and also to enhance suitable presentation for easy interpretation and understanding of the results [34]. The results were presented in the form of mean score ranking, percentages, and standard deviations. The mean score ranking was used to determine the appropriate technologies that were most dominant or important for the delivery of sustainable and affordable housing.

3. RESULTS AND DISCUSION

3.1 Building Construction Professionals

Table 1 indicates that twelve (12) representing (21.4%) of the respondents were Architects, twenty-two (22) representing (39.3%) of the respondents were Structural Engineers, and Twenty-Two (22) representing (39.3%) of the respondents were also quantity surveyors.

The results revealed that, Structural Engineers and Quantity surveyors constituted about 79% of the professionals who responded to the questionnaire. These categories of professionals were deemed to have in-depth knowledge and experience required to contribute to the subject matter.

3.2 Types of Technology Applicable for Construction of Housing in Ghana

Table 2 revealed that, fifty (50) representing (88.3%) of the respondents or firms, uses high technological means for construction of houses in Ghana, while six (6) representing (10.7%) of the respondents use appropriate technologies or local and community-based practice for housing construction.

The results shown above implies that, almost all the firms construct houses with high technology, that is about (90%) with just (10%) using appropriate technology. The implication is the huge housing deficit in the country. The overdependence on high technology has led to the under development of local materials [15]. According to [35] a lot of savings can be made every step of the way when houses are built by incorporating appropriate technologies and design, initial building costs are lower, and home owners save money on operations and long-term maintenance. Appropriate technology is immensely cheaper than the sophisticated, capital-intensive technologies currently in use [16].

Table 1. Respondents (Building construction professionals)

Professional	Frequency	Percentages (%)
Architects	12	21.4
Structural Engineers	22	39.3
Quantity surveyors	22	39.3
Total	56	100

Table 2. Applicable technology for housing delivery

Type of technology	Frequency	Percentages (%)
High-Technologies	50	89.3
Appropriate Technologies	6	10.7
Total	56	100

Table 3. Appropriate technology techniques which can be used for sustainable and affordable housing

Appropriate technology techniques	Mean	Ranking
Hydrafoam/interlocking blocks technology	3.93	1
Adobe bricks/blocks technology	3.68	2
Timber Homes technology	3.32	3
Compressed earth/ blocks technology	3.27	4
Wattle and Duab technology	2.71	5
Straw bale construction technology	2.59	6

Table 4. indicating major and sub related factors of design qualities for sustainable and affordable housing

Principal Component Analysis (PCA)	
Major factors	**Sub- related factors**
Must encourage cyclic construction processes instead of linear construction process design	It always must encourage the conservation of scarce resources-materials Improving or making good the dry environment Encourages restoration of damage environment and resources Must recycle resources Must re-use resources Avoid ozone layer depleting chemicals and materials for construction and Must encourage the renovation of older buildings
Must encourage maximization of resource reuse	It must encourage minimization of resource consumption Must uses renewable resources Protect the natural environment Ensure good sound and thermal comfort and It must use Salvage materials
Must always consider low energy designs,	It must protect water quality Encourage waste minimization Must depend on green building construction principles Must be flexible in nature and Must reduce energy in use in all aspect of construction,
Avoid potential health hazards design	It is designs for future reuse adaptability Designs must be cherished but affordable and sustainable in nature and Must always ensure safety measures when designing and constructing
It must be economical and social sustainable designs	It must base on appropriate technologies practices and strategies and Must encourage the re-use of old building materials
It must harvest rain water and conserve them for re-use	The use of low -embodied energy materials must be encouraged and It must also encourage the uses of solar energy and resources, finally
Must always be in safer and favor of future generations	It must be in safer and favor of future generations and Discourage the use of foreign imported building materials, technologies and designs for housing delivery

3.3 Appropriate Technology Techniques for Sustainable and Affordable Housing

In Table 3, the respondents disagreed with the use of straw bale construction technology (6), as appropriate technology technique for sustainable affordable housing. Furthermore, respondents expressed their agreement for wattle and duab technology (**5**), compressed earth block (**4**), timber homes technology (**3**), to be used for sustainable affordable housing. Meanwhile respondents strongly agreed to the use of Adobe bricks/blocks technology (**2)'** and Hydrafoam (interlocking) block technology (**1**), as the appropriate technologies which should be used for sustainable and affordable housing. Respondents however, did not express any strong disagreement on any of the technology identified.

The results in the Table 3 implies that, hydrafoam/interlocking blocks technology, Adobe bricks/blocks technology. timber homes technology and compressed earth/blocks technology were considered the most dominant and acceptable appropriate technologies for the construction of sustainable and affordable housing. While wattle and daub technology and straw bale technology were considered to be less important or adopted for sustainable and affordable housing. Vergragt [4] stated that, in

order to improve upon these technologies, is to learn from our past mistakes for ignoring its usage, creating public awareness about its usage, addressing its durability and appealing issues, ability to resist moisture penetrations, addressing it maintenance and insurance issues, or to combine elements of appropriate technology with some aspects of high-technology into a new paradigm to ensure sustainable and affordable housing.

3.4 Designs qualities for Sustainable and Affordable Housing Delivery

The results from the analytical tool, Principal Component Analysis (PCA) Table 4 shows that the design qualities for sustainable and affordable housing can be categorized into Seven most important related qualities/factors, among them were**,** it must encourage cyclic construction processes instead of linear construction process design: It always must encourage the conservation of scarce resources-materials, improving or making good the dry environment, encourages restoration of damage environment and resources, uses recyclable resources, avoid ozone layer depleting chemicals and materials for construction and must encourage the renovation of older buildings, it must encourage maximization of resource reuse. The sub- related factors also include the following: It must encourages minimization of resource consumption, must uses renewable resources, protect the natural environment, ensure good sound and thermal comfort and it must uses salvage materials, it must always consider low energy designs, the sub-factors include the following: It must protect water quality, encourage waste minimization, must depend on green building construction principles, must be flexible in nature and must reduce energy in use in all aspect of construction, avoid potential health hazards design, the sub related factors were as follows: It is designs for future reuse adaptability, designs building must be cherished but affordable and sustainable in nature, and must always ensure safety measures when designing and constructing, it must be economical and social sustainable designs, the sub factors includes: It must base on appropriate technologies practices and strategies, and must encourage the re-use of old building materials, it must harvest rain water and conserve them for re-use, the sub factors includes: The use of low embodied energy materials must be encourage and it must also encourage the uses of solar energy and resources, finally, must always be safer and favor future generations, the sub factors include the following: It must be safer and favor future generations and discourage the use of foreign imported building materials, technologies and designs for housing delivery.

These factors in all, are design principles that can be safer and favor both the present and future generations. It's also to discourage the use of foreign imported building materials, techniques and designs for housing delivery in Ghana.

The Table 5 indicates the mean scores and ranking of housing designs qualities or factors for sustainable and affordable housing, in order of importance. This statistical tool (PCA) was employed in order to compress the number of housing designs qualities or factors affecting the delivery of sustainable and affordable housing in the simplest way for better understanding and interpretation.

The results indicated above implies that, the three most important good design qualities for sustainable and affordable housing delivery comprises the usage of cyclic construction processes instead of linear construction processes, maximization of resources for reuse and the application of low energy designs. According to [19] the designs of building structures, impact the delivery of housing in variety of ways. For instance, the choice of design type, materials and their applications have significant environmental impact, depending on the sources of materials, durability, and potential reuse. This can first ensure environmental comfort but reduce the cost of housing to the extent that the low- income class can afford to build houses with ease. On the other hand, all possible measures must be employed to ensure cost efficiency, durability, good circulation of natural air, and a good thermal and sound insulation, and appearance.

The results shown in Table 6 indicate that, appropriate technology and designs have been lowly and moderately used, and this implies that less emphasis has been placed on the use of appropriate technology and design in addressing housing sustainability and affordability. The issue is awareness creation, shifting, and developing taste to accept the use of home-made products for housing. The role of government and stakeholders is to mainstream the use of alternative designs, appropriate technologies and local materials for housing.

Table 5. Design qualities for sustainable and affordable housing

Housing design qualities	Mean	Ranking
Must encourage cyclic construction instead of linear construction process designs	0.908	1
Must encourage maximization of resource for reuse	0.900	2
Must always consider low energy designs	0.801	3
Must avoid potential health hazards	0.790	4
Must be economical and socially sustainable	0.770	5
Must always be safer and favour future generations	0.750	6
Must discourage the uses of foreign imported building materials	0.600	7

Table 6. The extent to which appropriate technology and designs have been employed for housing sustainability and affordability in Ghana

The extent	Mean	Rankings
Low Extent	3.98	1
Moderate Extent	2.31	2
Some what Extent	2.11	3
Large Extent	1.98	4

3.5 Appropriate Local Building Materials for Sustainable and Affordable Housing

According to Table 7, it was revealed that, grass and poles / sticks (**15**), paper & board / timber (**14**), and Earth bags **(13),** were considered as not very certain local available building materials for sustainable affordable housing delivery in Ghana, plaster and / fibrous cement (**12**), thatch (**11),** laterite (**10**), natural plaster and finishes (**9**), mud bricks (**8**) landcrete blocks (**7**), Timber / wood (**6**), stones (**5**) Bamboo **(4**), and unburnt clay brocks (**3**) were considered the important local available building material for sustainable affording housing delivery in Ghana, Whiles, clay bricks (**2**) and clay Pozzolana cement (**1**) were considered Very important local available building materials for sustainable affordable housing delivery in Ghana. However, none of the available local building materials in the table were considered not very important.

The results in Table 7 indicates that, clay pozzolana cement, clay bricks, unburnt clay bricks, bamboo, stones, timber/wood, and landcrete blocks were considered the most important and acceptable available local building materials that can be employed for sustainable and affordable housing. However, grass and poles/sticks and paper and board timber were considered less important. Abdul [35] suggested that instead of transporting materials from hundreds or thousands of miles away into the country for housing, it is far better to research into indigenous materials and technologies to improve them and utilize them fully. Abdul [35, 36] further indicated that much priority should be placed on the use of local materials and technologies to support sustainable development.

Table 7. Appropriate local available materials for sustainable and affordable housing

Local Important Building Materials	Mean	Ranking
Clay pozzolana cement	3.91	1
Clay bricks	3.89	2
Unburnt clay bricks	3.39	3
Bamboo	3.25	4
Stones	3.23	5
Timber /wood	3.23	6
Land crete blocks	3.14	7
Mudbricks	2.84	8
Natural plaster and finishes	2.80	9
Laterite	2.77	10
Thatch	2.73	11
Plaster and / fibrous cement	2.70	12
Eathbags	1.98	13
Paper and board / timber	1.82	14
Grass and poles /sticks	1.82	15

4. CONCLUSION

The important concerns such as unprecedented catastrophe which has already caused irreversible damage to the biosphere due to the application of technology for resource extraction, environmental issues, and water pollution by industries from activities like construction, energy generation and others have been immensely argued in literature. However, less priority has been placed on the use of appropriate technology and design for resolving the issues indicated. Appropriate technology and design for the provision of adequate sustainable and affordable housing, offers, environmental, social and economic benefits. This paper aimed at determining the extent to which this appropriate technologies and designs are currently adopted in addressing housing sustainability and affordability in Ghana. The findings of the study revealed that, although appropriate technology and design solution for sustainable and affordable housing delivery, the extent to which it has been adopted in major cities of the country is low. This implies that less emphasis is placed on the use of appropriate technology and design in resolving housing issues in major cities. It was further revealed that, hydrafoam/interlocking blocks technology, adobe bricks technology, timber homes technology and compressed earth/block technology (Atakpeme) were considered the most used and important appropriate technologies for the construction of sustainable and affordable housing in Ghana. Whiles wattle and daub technology and straw bale technology were considered less important. Clay pozzolana cement, clay bricks, unburnt clay bricks, bamboo, stones, timber/wood, and landcrete blocks were seen as the most important and acceptable available local building materials that could be employed to address housing sustainability and affordability. The outcome of the paper demonstrates that, both current and future housing policies can only be successful if the perception of the Ghanaian changes on the use of local natural building materials and appropriate technologies and designs. Government and stakeholders, especially civil society organizations (CSOs), research institutions must intensify education on the use of appropriate technologies and the use of locally produced products as a panacea to solving the housing deficit in the country especially in the major cities. Government must support research in this area, and put in the right laws to support all this important area within the built environment or the construction sector landscape.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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