

**A FRAMEWORK FOR GUIDING WALLING MATERIALS  
SELECTION FOR URBAN RESIDENTIAL HOUSING DELIVERY  
IN GHANA**

By

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## ABSTRACT

This research discussed the factors that affect the selection of walling materials and developed a framework to guide the selection of such materials for urban residential housing delivery in Ghana. The study adopted a multiple research approach involving Delphi survey and questionnaire survey. Relevant factors that affect the choice of walling materials in general were discovered through literature search. This was followed up by the use of Delphi survey to determine the factors which are relevant in the Ghanaian construction industry. The Delphi study led to the confirmation of 46 factors as relevant to selection of walling materials for housing projects in Ghana. Further investigations with regard to the factors were conducted in the questionnaire survey. A sample size of 152 building construction professionals including Architects, Quantity Surveyors, and Structural Engineers were used for the questionnaire survey. These professionals were selected randomly. The data gathered were analysed using Statistical Package for Social Sciences. Out of the 46 factors identified by the study, the top ten most influential factors includes strength, initial cost, appearance, durability, owner's/user's choice, resistance to decay, maintainability, labour availability, water resistance and maintenance cost. Finally, the results help to develop a framework to guide the selection of appropriate walling materials for urban residential housing delivery in Ghana. This framework will enable building professionals and stakeholders in general to effectively and accurately evaluate the trade-offs between cost, technical, environmental, socio-cultural, sensorial, performance and some general factors during the material evaluation and selection processes. In order to ensure faster construction solutions, foster new economic development and promote better quality of building structures, decision makers should consider all the essential factors established in this study when deciding on walling materials for urban residential housing delivery in Ghana.

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## **DEDICATION**

This Thesis is dedicated to all my family members, especially the memory of my late father and mother Mr. and Mrs. Owusu Ansah.

## CHAPTER ONE

### INTRODUCTION

#### 1.1 BACKGROUND OF THE STUDY

Housing is a key factor in the sustainable development of a nation (Alabi, 2017) and a basic human need (Ganiyu, 2016). It is an essential necessity of life (Opoku-Boateng, 2012; Kwofie *et al.*, 2011; Adedeji, 2007) and provides the greatest signs of better livelihood (Nubi, 2008). Undoubtedly from creation, housing remains one of the important desires of mankind (Kwofie *et al.*, 2011). It is both societal and an economic good, thus offering core security and stimulating growth and development (Opoku-Boateng, 2012). According to Opoku-Boateng (2012) and Nubi (2008), housing is a fundamental individual right. Adedeji (2007) also stated that housing gives an important signal of general economic, past cultural and industrial development of every nation.

A house is described as a structurally detached or separate position of residence such that individual or group of individuals can protect themselves from the threats of atmosphere such as stormy weather and the sun (Bank of Ghana Report, 2007) and other environmental elements or effects. Onibokun (1998) defined housing literally as buildings or shelters in which people live, a place to live, a dwelling, and to nations a critical component in social and economic fabric.

In spite of the generally recognized significance of housing for the social welfare and protection of persons, its suitability and quality is a major challenge for the countries in Sub-Saharan Africa (Werna, 1998). Konadu-Agyemang (2001) argued that access to decent and quality housing in several parts of the nation is at crises level. On the other hand, Boamah (2010) stated that majority of the existing houses in Ghana are

badly designed or developed and without the fundamental requirements to make them habitable. However, it should be recognized that housing design includes structural functionality, function and artistic matters that can be accomplished by conventional or modern technological approaches (Stulz and Mukerji, 1981). As stated by Stulz and Mukerji (1981), whatsoever method or technique is adopted, a house cannot be constructed without basic knowledge of building materials. Ofori *et al.* (2002) also asserted that appreciating the environmental issues surrounding the use of materials for construction is imperative to ensure sustainability of a construction project.

Preferably, the house should be in accordance with the environment, both physically and aesthetically (Ansah *et al.*, 2015). According to Kwofie *et al.* (2011), Adedeji (2010) and Gardi (1973), housing delivery have been greatly influenced by nature requirement, ethnicity, geographical location, colonial impact, national policy direction, the materials of construction available, and technical possibilities open to them. Cultural factors such as culture of a community in accordance with the lifestyle of its people, a group's preferences and values or an individual owner's social status, personal taste and financial resources, also influence housing delivery (Stulz and Mukerji, 1981). Ademiluyi and Raji (2008) on the other hand, asserted that physical features of a house often rely on the environment, the surrounding topography, building materials available and the technological knowledge of the builders.

According to Nassar *et al.* (2003), building materials selection is one of numerous factors that can affect the sustainability of housing delivery. Therefore, a suitable choice of materials for a design plays a significant role during the life cycle of a building (Treloar *et al.*, 2001). The authors further stated that when suitable building materials are selected for the housing construction, they can provide a set of particular

benefits to the owner of a building such as lesser maintenance and replacement costs, enhanced occupant's health and productivity, lower costs related to changing space configurations, improved energy conservation and greater flexibility in design (Treloar *et al.*, 2001).

Flórez *et al.* (2009) posits that every construction project requires the choice of materials or means used for the selection process. As with the design procedure, careful consideration of contextual preconditions is essential to choosing suitable materials (Rahman *et al.*, 2008). Additionally, choosing appropriate alternative building material can be a very complicated procedure being affected by several preconditions, choices, and concerns (Wastiels and Wouters, 2008). Furthermore, in selecting the precise material, there is not constantly a particular requirement of choice (Rahman *et al.*, 2008; Trusty, 2003), which implies that developers/designers have to consider many of material selection factors. Hence, the accessible information on building material choices should be regularly analyzed to make proper and suitable material selections, during the design-decision making and choice processes (Chan and Tong 2007; Trusty, 2003).

According to Bank of Ghana (BoG) Report (2007), the two primary materials for the building of the external walls of a house in Ghana are mud/earth brick and concrete, which together account for 89.1 per cent of wall materials of residing units. The earth/mud brick comprises 50.0 per cent while concrete comprises 39.1 percent of the cases. Contrary, Ghana Population and Housing Census reported that cement blocks or concrete constituting 57.5percent are the primary materials used for the external walls of residing units, followed by mud bricks or earth (34.2 percent). Only 3.4 percent of materials are made of timber (Ghana Statistical Service, 2010). The report

also indicated that the conventional materials which are used for putting up of the dwelling units in Ghana were of low quality (Ghana Statistical Service, 2010). It should however be noted that in most African countries, high quality materials are inadequate in supply and high in cost (United Nation-HABITAT, 2008) and this underline the difficulties of housing delivery in Ghana. This suggests the need for a proper selection of quality low cost and sustainable building materials for housing delivery.

Abeyundara and Babel (2009), stated that, factors that significantly affect the choice of materials and products for the construction of houses are their costs and social specifications such as heat comfort, good technical qualities (strength and durability), visual features and an ability to build quickly. The authors added that preferably, the mixture of all ecological, economic and social factors can give clear description of a material and thus helps in making decisions regarding the choice of building materials appropriate for housing delivery. Hence to attain quality, standard and sustainable housing delivery in Ghana, there is the need for better selection and the use of sustainable, durable and culturally relevant materials at reasonable costs.

## **1.2 PROBLEM STATEMENT**

Even though housing is a key factor in the sustainable development of a nation (Alabi, 2017) and a basic human need (Ganiyu, 2016; Opoku-Boateng, 2012; Kwofie *et al.*, 2011; Adedeji, 2007) and also provides the greatest signs of quality of life (Nubi, 2008), more than half of the population in Ghana live in poor houses where the materials used for the construction are of poor quality and inappropriate (United Nation-HABITAT, 2008). As much as fifty percent of all dwelling houses in Ghana were designed with poor quality earth/mud bricks (Ghana Statistical Service, 2002). According to Bank of Ghana (BoG) Report (2007), earth/mud brick comprises 50.0

percent of the primary components for putting up the external walls of houses in Ghana. The use of these materials as walling materials have seen many problems over the years including dampness, which results from moisture finding its way into the walls of the buildings (Agyekum *et al.*, 2013).

United Nation-HABITAT (2008) had observed that the high cost of building materials among other factors, underline the difficulties of housing delivery in Ghana today. According to Ebsen and Rambol (2000), poor selection of building materials for the construction of houses can lead to unreliable and sub-standard housing delivery. This suggests that there is a need to develop a systematic material selection framework that will enable building professionals identify and prioritize the relevant criteria to effectively and accurately evaluate the trade-offs between technological, ecological, economic as well as issues during the material assessment and selection procedures.

Although, numerous researches on urban housing delivery and its associated issues have been undertaken across the world (Alabi, 2017; Ganiyu, 2016; Opoku-Boateng, 2012; Kwofie *et al.*, 2011; Yates *et al.*, 2008; Yates *et al.*, 2007; Burke *et al.*, 2007; Berry, 2006; Yates and Gabriel, 2006; Whitehead, 2006; Wendell, 2005; Lloyd-Sherlock, 2000), it was apparent that majority of existing research frameworks incorporated a few constructs or factors which were not enough to help decision makers in their decision taking when selecting building materials for housing projects. Several attempts to bridge the recognized existing gap have been initiated (Opoku-Boateng, 2012; Kwofie *et al.*, 2011; Hulme & Radford, 2010; Fernandez, 2006; Cooper, 1999); but, many appear not to have been accomplished. As follow-ups to the previous studies, this research was therefore undertaken to identify as much as possible, decisive factors that will help or guide decision makers to select appropriate and suitable building materials for urban residential housing delivery in Ghana.

### **1.3 AIM OF THE STUDY**

The aim of this research is to develop a framework to guide the selection of walling materials for urban residential housing delivery in Ghana.

### **1.4 RESEARCH QUESTIONS**

At the end of this research, the study hopes to seek solution to the under listed questions:

1. What are the commonly used materials for walling systems in Ghana?
2. Are the materials identified appropriate for urban residential housing delivery?
3. What is the level of involvement of relevant stakeholders and their influence in the selection of walling materials for urban residential housing delivery in Ghana?
4. What are the factors to be considered in the selection of walling materials for urban residential housing delivery in Ghana?
5. What framework can be developed to guide the selection of walling materials for urban residential housing delivery in Ghana?

### **1.5 OBJECTIVES OF THE STUDY**

The specific objectives for this study are:

1. To identify commonly used materials for walling systems and establish their appropriateness for urban residential housing delivery in Ghana;
2. To determine the level of involvement of relevant stakeholders in the construction industry in the selection of walling materials for urban residential housing delivery in Ghana

3. To identify and determine potential factors affecting the selection of walling materials for urban residential housing delivery in Ghana; and
4. To develop a framework to guide the selection of walling materials for urban residential housing delivery in Ghana.

## **1.6 SIGNIFICANCE OF THE STUDY**

Several researches have attempted to find answers to sustainable and quality housing delivery across the world but there is not much research on an integrated approach to address and discuss issues of walling materials and their selection for urban residential housing delivery in Ghana. Hence, the rationale for this research is to provide an evidence base that will help to recommend walling materials that are suitable for urban residential housing delivery in Ghana. The evidence and recommendation from this research will assist government and private agencies and individuals in Ghana in their efforts to tackle the housing delivery problems in urban centres. The research outcome will also serve as reference for the academia and researchers in their future research in the areas of housing delivery.

## **1.7 SCOPE OF THE STUDY**

This research discussed the selection of walling materials and developed a framework to guide the selection of such materials for urban residential housing delivery in Ghana. The study strived to demonstrate walling materials that are commonly used and factors that affect their selection for urban residential housing delivery in Ghana. Determination of the factors influencing walling materials selection was not only relying on technical factors but also on social, economical, financial, institutional issues. This selection dealt with "appropriateness" and "adequacy" within energy efficiency and environmental approaches for local conditions (social, economical,

financial, institutional, and environmental, amongst others). Both concepts were clarified through literature review regarding walling materials properties and building systems. In answering the research questions, the study sought the perception of building construction professionals (Architects, Quantity Surveyors and Structure Engineers) in the Ghanaian construction industry.

## **1.8 RESEARCH METHODOLOGY**

Generally, researchers adopted either quantitative or qualitative approaches to tackle a specific research problem but the research strategy adopted for this study was the mixed method (quantitative and qualitative). Combining both qualitative and quantitative research techniques has been confirmed to be better (Moffatt *et al.*, 2006) and very effective (Lee, 1991) than a single technique. Because of the extent of the study and the kind of information required for the research, Delphi survey and questionnaire survey research techniques were adopted to help in collecting research data for the study. These two methods were used due to the fact that using different or more than one approach for collecting research data lead to greater validity and reliability than using a single methodological approach (Denzin, 1970). Also, the idea of combining these methods is to make the study more realistic.

The literature review was extensively and critically undertaken throughout the study to build up a solid theoretical base for the research area and a foundation for addressing the problems and achieving the research objectives. The review also assisted to recognize the research gaps and established the basis for designing the study questionnaires to aid the collection of data for the study regarding building material selection for urban residential housing delivery in Ghana. Data was gathered from a variety of sources such as educational and industrial journals, organizations

and school databases, the internet, workshops and conferences. On the other hand, Delphi survey was conducted amongst nine selected Architects in Ghana to determine the factors which are relevant in the Ghanaian context. A cross-sectional questionnaire survey of architects, structural engineers and quantity surveyors was also designed for the study to examine issues concerning walling materials and their selection for urban residential housing projects.

A random sample selection of Architects, Quantity Surveyors, and Structural Engineers was made from the Architects Registration Council of Ghana register, Ghana Institution of Surveyors (GhIS) register, and Ghana Institution of Engineers (GhIE) register respectively. This list, representing Architects; Quantity Surveyors; and Structural Engineers was generated randomly by using Microsoft Excel 2003. The generated list (Architects; Quantity Surveyors; and Structural Engineers) was used as the total sample size for the main survey. The data obtained for the research was analysed by applying Statistical Package for Social Sciences. Other relevant research analysis techniques such as Relative index, Kendall Coefficient of Concordance and Descriptive analysis in the form of frequencies and percentages were employed.

## **1.9 ORGANISATION OF THE STUDY**

The research consisted of five chapters. These were introduction, literature review, research method, analysis or data presentation, and conclusion and recommendation. The introduction (chapter 1) began with a description of the research background. The study subject was then presented by providing and explaining the questions, research aim and objectives, scope and significance of the study. Finally, the research method and study's structure were explained. The chapter 2 presented general details and an overview of Building Materials Selection for Housing Delivery. It reviewed previous

and related work and discussed into details: time and regularity concepts in the use of building materials, commonly used building materials for housing projects, overview of Ghana standard code of practice/national building regulation on suitability of materials for building, walling systems, building materials selection consideration factors, the selection of appropriate building materials for housing projects. The chapter also explained the need and basic design for proposed conceptual for the study. The chapter 3 entailed an explanation of the techniques used for the study. The section focused on the techniques that were used in carried out the empirical research. The chapter 4 dealt with the empirical data collected from the field and answers various questions raised by the study. The chapter 5 concluded the study. Possible research area for future study was presented.

## **CHAPTER TWO**

### **LITERATURE REVIEW**

#### **2.1 INTRODUCTION**

This chapter gives general details and an overview of Building Materials Selection for Housing Delivery. The chapter also reviews previous and related work and discusses into details: time and regularity concepts in the use of building materials, commonly used building materials for housing projects, overview of Ghana standard code of practice/national building regulation on suitability of materials for building, walling systems. The influence of stakeholders in building material selection, building materials selection consideration factors and the selection of appropriate building materials for housing projects were also reviewed. This review helped to achieve the research objectives.

#### **2.2 OVERVIEW OF BUILDING MATERIALS SELECTION FOR HOUSING DELIVERY**

All housing delivery includes a selection of building materials or ways used for the selection process (Flórez *et al.*, 2009). Hence, careful consideration of contextual preconditions is critical to choosing suitable building components or materials at the design process (Rahman *et al.*, 2008). In addition, choosing appropriate or alternative building material can be a very complicated procedure, being affected by many preconditions, choices, and concerns (Wastiels and Wouters, 2008). Furthermore, in making a right choice of material, there is not constantly a particular requirement of selection, which implies that architects/designers have to take into consideration a number of material selection factors (Rahman *et al.*, 2008; Trusty, 2003). Hence, the accessible information on building materials choices should be regularly analyzed to

make proper and sensible material choices, during the design-decision making and choices procedures (Chan and Tong, 2007; Reliable, 2003).

Nassar *et al.* (2003) posits that the selection of building materials is one of numerous aspects that can affect the durability of a building structure. A suitable selection of materials for a design process performs a significant role during the life-cycle of a structure (Treloar *et al.*, 2001). Appreciating the ecological issues surrounding the extraction of raw materials, the manufacture of construction materials, and their impacts in use, is significant to ensure sustainability (Ofori *et al.*, 2002).

Before understanding the process of material selection, it is important to know the entire process of a construction project. Any project of this kind mainly contains several phases. In the first programming phase, the project has just started to be planned and the owner has only a general concept about the project. Also all potential participants have to decide whether to join in this project and get ready for bidding. In the second phase, schematic design, the project is handed to the architects and, with the assistance of the owner the architects finish the schematic design of the project. Then, in the third phase, the architects detail the design drawings and provide enough information needed for the construction phase. After preparation of the detail design drawings, contractors are invited for bidding of the project. Once a contractor is selected and is being awarded for the construction work the construction of the project begins. After the successful construction, the project can be occupied by the users.

The most important decisions on material selection are always made in the schematic design phase. This process continues to a lesser extent in the following phases. Usually, there are three steps of material selection: research, evaluation and selection (Froeschle, 1999). All of the technical information on materials such as geometric properties, Leadership in Energy and Environmental Design (LEED) features and test

results is collected in the first step. Learning technical information of different materials becomes crucial in this step. The second step involves confirmation of the technical information and more importantly compare different materials with the same functions. The final step of the selection of building materials for construction project often involves the use of individual criteria to make the final decision.

### **2.3 TIME AND REGULARITY CONCEPTS IN THE USE OF BUILDING MATERIALS**

Table 2.1 demonstrates the ideas of "time" and "regularity" in the adoption of construction components for housing delivery. The examination of specific local circumstances determines where components are best suited for their use. In addition, the era/time when techniques and components were/are frequently used determines whether they could be categorized as conventional or modern. The frequency of use determines whether components and processes could be categorized as conventional or alternative. This category will assist to evaluate the choice of a specific building material bearing in mind technological development.

**Table 2.1: Classification of Building Materials**

Classification  Of  Materials	ERA/TIME WHEN USED		REGULARITY OF USE	
	Pre- Industrial	Industrial	Frequent	Infrequent
	Traditional	Contemporary	Conventional	Alternative
<b>Raw</b>	X		X(rural)	
<b>Processed</b>		X	X(rural/urban)	X (urban)

Source: Ballerino-Chile (2002)

### 2.3.1 Raw (Natural) Building Materials

Unprocessed building materials have been utilized before the contemporary prepared building materials were utilized and before industrialization occurred. Several cultures have discovered their own way to enhance their life by using structures, which were typically built with unprocessed components (Bryan, 1985). Building development techniques have been passed on from generation to generation amongst dissimilar societies, thus conventional construction techniques differ from nation to nation and even within some nations (Yorkshire Vernacular Building Study Group, 2001). Conventional techniques include local labour and utilization of accessible organic raw components such as earth, soil, organic fibers, organic rubberized, stones and wood.

The benefit of organic unprocessed components depended on ecological concepts (renewable, energy efficient, recyclable) and social participation (self construction,

family and community working together). Drawbacks of organic unprocessed components are their requirement of local accessibility, water consumption, and potential to deal with natural risks, such as tornados, earthquakes etc., potential to deal with ultimate effects, pollution vulnerability (soluble salt, biological agents, etc.) and public acceptability (Lindberg, 1998; Stulz, & Mukerji, 1981).

### **2.3.2 Processed Building Materials**

Processed building materials relate to materials (which could be organic or man-made) such as concrete, ferro-cement and other fiber cement blend, glass, steel, polymers and reprocessed materials.

"Processed materials" are alternatives for unprocessed or recyclables and are usually considered more technically developed/advanced, with changed chemical, mechanical or physical qualities. The selection between processed - and organic unprocessed must constantly be based on local specifications.

The benefits of processed building materials are: expert applications, enhanced qualities, improved efficiency and time saving during development. The drawbacks of processed building materials are: failing to fulfill the realities of local situations and a high base cost for manufacturing/processing and transportation (Spence & Prepare, 1983). Evaluation of advantages/disadvantages of processed materials can have cost-effective, technological and ecological techniques, e.g. ecological impact in production can be validated if the final product is durable (Royal Institution of Technological Innovation & Norwegian Technique School, 1998).

It should be recognized that, over the years, traditional processed materials including cement, steel and plastic have been mixed with organic unprocessed material for housing delivery, but it has become essential to permit technology to guide the use of

non conventional/alternative and reprocessed materials. Table 2.2 shows the main variations between organic unprocessed and processed building materials.

**Table 2.2: Variation between unprocessed and processed materials**

UNPROCESSED MATERIALS	PROCESSED MATERIALS	
	CONVENTIONAL	ALTERNATIVE
<ul style="list-style-type: none"> <li>• Unprocessed               <ul style="list-style-type: none"> <li>- Animal products</li> <li>- (features, skin, hair)</li> <li>- Leaves and fibers</li> <li>- Rubber</li> <li>- Wood</li> </ul> </li> <li>• Non – Organic               <ul style="list-style-type: none"> <li>-Stones</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Natural Raw               <ul style="list-style-type: none"> <li>-Leaves and Fibres</li> <li>-Soil</li> <li>-Wood</li> </ul> </li> <li>• Animal/synthetic               <ul style="list-style-type: none"> <li>-Cement</li> <li>-Concrete</li> <li>-Steel</li> <li>-Plastic</li> <li>-paper</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>•Alternative/Synthetic               <ul style="list-style-type: none"> <li>-Polymers</li> <li>-Composites</li> </ul> </li> <li>•Recycled materials               <ul style="list-style-type: none"> <li>-Waste materials</li> <li>-By products</li> </ul> </li> </ul>
Natural resources	Natural synthetic and processed by humans	
Processed through natural processes	Produced by means of technological processes and chemical reactions	
Simple equipment used	Simple and or/sophisticated equipment used in production and during construction	
Labour intensive during construction	Less labour intensive during construction	

Source:Ballerino-Chile (2002)

Table 2.2 reveals the variations between unprocessed and prepared materials concerning origin, manufacturing techniques and labourspecifications. These variations effect (positively and/or negatively) the chosen of building materials for housing delivery.

## **2.4 COMMONLY USED BUILDING MATERIALS FOR HOUSING DELIVERY**

Kwofie *et al.* (2011) opined that before Ghana had exposure to the Western and impact of capitalism, buildings in Ghana were primarily designed with home-based components such as thatch, mud, timber, earth and bricks. Today, there are more common building materials and products such as steel, cement, glass, aluminium, plastics, blocks, paints, polished stone, ceramic products among others, for the construction of urban housing. Ballerino-Chile (2002) stated that the commonly used building materials for housing delivery are: Bamboo, Composite, Concrete, Earth/soil, Ferrocement, Clay-based product, Glass, Metal, Natural and animal fiber, Plastic, Stone, timber, Asbestos-cement products and Lime-based materials. The advantages and disadvantages of building materials depend on: technical, environmental, construction and financial/economical. The advantages and disadvantages of raw and processed building materials are presented in Table 2.3.

**Table 2.3: Advantages and Disadvantages of Raw and Processed Building Materials**

<b>Building Materials</b>	<b>Advantages</b>	<b>Disadvantages</b>
<b>TECHNICAL</b>		
<b>RAW MATERIALS</b>	<ul style="list-style-type: none"> <li>• Traditional designs</li> <li>• High thermal resistance in semi-dry and dry places</li> <li>• High fire, noise, impact resistances for soil and stones</li> <li>• High importance aesthetic service life</li> <li>• High physical service life</li> <li>• High reparability</li> <li>• High recyclability</li> </ul>	<ul style="list-style-type: none"> <li>• Low water penetration resistances</li> <li>• Low condensation capacity</li> <li>• low fire, noise, impact resistance for fibres</li> <li>• Low natural hazards resistance</li> <li>• Low durability for fibres</li> <li>• Low biological attack resistance for fibres</li> </ul>
<b>PROCESSED MATERIAL Conventional</b>	<ul style="list-style-type: none"> <li>• High thermal resistances</li> <li>• Medium water penetration resistance</li> <li>• Medium high fire, noise resistances</li> <li>• Medium to high natural hazards resistance</li> <li>• High noise, impact properties</li> <li>• Long durability if maintained</li> <li>• Medium to long physical service life</li> <li>• Medium to long technical service life</li> <li>• Medium to high reparability(need knowledge)</li> <li>• Medium recyclability</li> </ul>	<ul style="list-style-type: none"> <li>• Professional design</li> <li>• Low condensation capacity</li> <li>• low biological attack resistance</li> <li>• Short technical service life</li> </ul>
<b>PROCESSED MATERIAL Alternative</b>	<ul style="list-style-type: none"> <li>• Very high thermal and condensation resistance</li> <li>• Medium to high impact resistance</li> <li>• Long durability if maintained</li> <li>• Medium to high biological attack resistance</li> <li>• Medium to long aesthetic service life</li> <li>• Long technical service life</li> </ul>	<ul style="list-style-type: none"> <li>• Professional/ specialized designed</li> <li>• Medium to low fire resistance</li> <li>• Medium to low fire resistance</li> <li>• Long physical service life</li> <li>• Medium to low reparability</li> <li>• Low recyclability</li> </ul>

## Advantages and Disadvantages of Raw and Processed Building Materials Cont'd

<b>Building Materials Disadvantages</b>	<b>Advantages</b>	
<b>ENVIRONMENTAL</b>		
<b>RAW MATERIAL</b>	<ul style="list-style-type: none"> <li>• Renewable</li> <li>• Low, medium energy consumption during manufacturing</li> </ul>	<ul style="list-style-type: none"> <li>• Local availability</li> <li>• Depletion of natural resources, abuse</li> </ul>
<b>PROCESSED MATERIAL Conventional</b>		<ul style="list-style-type: none"> <li>• Non renewable</li> <li>• Negative impact in nature from waste disposal</li> <li>• Medium, high energy consumption during manufacturing</li> </ul>
<b>PROCESSED MATERIAL Alternative</b>		<ul style="list-style-type: none"> <li>• Non renewable</li> <li>• Imported partially or totally</li> <li>• High negative waste disposal</li> <li>• High negative waste during manufacturing</li> </ul>
<b>CONSTRUCTION</b>		
<b>RAW MATERIAL</b>	<ul style="list-style-type: none"> <li>• Knowledge is transmitted from generation to generation</li> <li>• High accessibility if natural resources available in the area</li> <li>• No special care in handling</li> <li>• Unskilled, semiskilled workers</li> <li>• High labour intensive</li> <li>• Traditional equipment</li> <li>• Normal/none storage conditions</li> </ul>	<ul style="list-style-type: none"> <li>• High time consuming</li> </ul>
<b>PROCESSED MATERIAL Conventional</b>	<ul style="list-style-type: none"> <li>• No special care in handling</li> <li>• Medium, high labour creation</li> <li>• Normal time consuming</li> <li>• Medium, high, efficiency is semi skilled or trained workers</li> <li>• Conventional equipment</li> <li>• Normal storage conditions</li> </ul>	<ul style="list-style-type: none"> <li>• Medium time consuming</li> <li>• Easy information exchange</li> <li>• Semiskilled, training is needed</li> </ul>

## Advantages and Disadvantages of Raw and Processed Building Materials Cont'd

Building Materials	Advantages	Disadvantages
<b>CONSTRUCTION</b>		
<b>PROCESSED MATERIAL Alternative</b>	<ul style="list-style-type: none"> <li>• Fast erection of structures</li> <li>• High efficiency</li> <li>• Light weight elements</li> <li>• High level of technology</li> </ul>	<ul style="list-style-type: none"> <li>• Special care in handling</li> <li>• Information is not accessible for all</li> <li>• Training is needed</li> <li>• Low labour creation</li> <li>• Sophisticated and conventional equipment</li> <li>• High control in manufacturing</li> <li>• Usually special storage conditions</li> </ul>
<b>FINANCIAL/ECONOMICAL</b>		
<b>RAW MATERIAL</b>	<ul style="list-style-type: none"> <li>• No related to transport</li> <li>• Low basic cost compared with formal sector</li> <li>• Small scale, individuals, families production</li> </ul>	<ul style="list-style-type: none"> <li>• Medium cost for professional fees</li> <li>• Low, medium training cost</li> </ul>
<b>PROCESSED MATERIAL Conventional</b>	<ul style="list-style-type: none"> <li>• Medium, high, scale production</li> </ul>	<ul style="list-style-type: none"> <li>• Medium cost related to transport</li> <li>• Medium, host cost for basic manufacture</li> <li>• Medium, high cost for professional fees</li> </ul>
<b>PROCESSED MATERIAL Alternative</b>	<ul style="list-style-type: none"> <li>• Low cost during construction phase</li> </ul>	<ul style="list-style-type: none"> <li>• High cost related to transport</li> <li>• High additional cost for basic manufacture</li> <li>• High cost for professional fees</li> <li>• High training cost</li> <li>• Need medium, high scale production to be sustainable</li> </ul>

**Source:**Ballerino-Chile (2002)

## **2.5 OVERVIEW OF GHANA STANDARD CODE OF PRACTICE/NATIONAL BUILDING REGULATION ON SUITABILITY OF MATERIALS FOR BUILDING**

Standard Code of Practice and Building Regulation are laid down guidelines and requirements that should be adhered to make sure building work meets lowest constructional requirements and also to fulfil the lowest appropriate levels of safety for building and non-structural elements. The laid down rules and standards are also provided to control the development of construction projects, amendment of building elements and carry out works or fit accessories in relationship with any building.

With regards to suitability of materials for building works, Ghana National Building Regulation (GNBR) (1996) states that whichever substance used in putting up a structure or in the structural adjustment or extension of a structure must be of a right character and quality for the reasons and circumstances in which they are to be adopted or fixed so as to effectively perform the purposes for which they are intended. Section 30(1) of GNBR (1996) states that a District Planning Authority may decline plans for the building development with elements which are: in the lack of special care, responsible to quick destruction or inappropriate for use in the construction of permanent structures. Subject to regulation 30(1), no wall of a structure shall be erected of any sheet material whether versatile or rigid supported directly or indirectly by air or other gaseous ingredients. Section 31(1) of GNBR (1996) also stipulate that the materials for the election of any structure or any fitting for which consent has been given may be subjected to appropriate assessments, if the District Planning Authority so request.

Presently, there is a New Building Code which includes all the requirements of the existing building regulations and the BRRI Draft Building Code and be in tune with

requirements of building codes to answer current land use patterns, materials for construction, construction methods, construction management practices, safety, and the energy efficient use of resources. This document, the New Ghana Building Code has been compiled under the auspices of the Ministry of Water Resources, Works and Housing (MWRWH) with funding from the UNDP, through the National Disaster Management Organization (NADMO). A technical committee made up of representatives of relevant stake holding institutions in Ghana compiled the document, using the BRRRI Draft Building Code and the national Building Codes of India (2005) and Canada as templates (MWRWH, 2012).

This New Ghana Building Code contains regulations which can be adopted immediately or enacted for use by various departments, metropolitan, municipal and district assemblies, private and public bodies. It lays down a set of minimum regulations designed to protect the safety of the public with regard to structural efficiency, fire hazards and health aspects of buildings. So long as these basic requirements are met, the choice of materials and methods of design and construction is left to the ingenuity of the building professionals (MWRWH, 2012).

Part 8 of the Code covers the minimum requirements of building materials, and the criteria for accepting new or alternative building materials. This part of the code provision state that every material used in fulfillment of the requirements of the Ghana Building Code, unless otherwise specified in this Ghana Building Code or approved, shall conform to the specifications issued by the Ghana Standards Authority. In the case of materials where Ghana Standards are not available, the materials shall conform to the specifications issued by the recognized authority. The provision further state that any new or alternative materials which are not specifically

prescribed in the New Ghana Building Code must be referenced to the Ghana Standards Authority for approval provided it is shown to be satisfactory for the purpose intended in terms of quality, strength, effectiveness, fire resistance, durability, safety, maintenance and compatibility. In any case, approval in writing shall be obtained by the owner or his agent before any new material is used. The Authority having jurisdiction shall base such approval on the principle set forth in Section 8.3.1 and shall require that tests be carried out (Section 8.6) or sufficient evidence or proof be submitted, at the expense of the owner or his agent, to substantiate any claim for the proposed material.

With regard to testing of material, the provision state that every test of material required in this part of the Code or by the Authority having jurisdiction shall be carried out in accordance with standard methods of test issued by the Ghana Standards Authority. In the absence of methods of Tests where Ghana standards are not available, the tests shall conform to the methods of tests issued by the recognized authority. Laboratory tests shall be conducted by recognized laboratories acceptable to the Ghana Standards Authority.

## **2.6 WALLING SYSTEMS**

Basically, there are three general wall systems usually used in housing projects, (i) massive (ii) frame and (iii) core. A contrast of advantages and disadvantages amongst the three systems is shown in Table 2.4. Improvements of wall system design seek to: decrease waste, decrease quantity of requisite materials, simplify assembly and increase accuracy and rapidity of construction.

**Table 2.4: Wall Systems: Advantages and Disadvantages**

<b>Wall Systems</b>	<b>Advantages</b>	<b>Disadvantages</b>
<b>MASSIVE SYSTEM</b>	<p>Reduced number of materials components</p> <p>Materials could be manufactured in - situ</p> <p>High thermal capacities (common in hot arid climate)</p> <p>Medium to high resistance dampness</p> <p>Medium construction speed</p> <p>Accessible information for design and construct and maintenance</p>	<p>High quantities of the same material needed</p> <p>It needs wall finishing to perform well</p> <p>Needs support and centering during construction (vertically problems may cause the failure of structure)</p> <p>Possibilities of insects and attack</p>

### Wall Systems: Advantages and Disadvantages Cont'd

Wall Systems	Advantages	Disadvantages
<b>FRAME SYSTEM</b>	Medium resistance to natural hazards	Increase variety of components, equipment and skills
	High construction speed	Intermediate level of accessibility of information for design, construct and maintain
	Medium innovation design and construction techniques	Compulsory use of wall finishing
<b>CORE SYSTEM</b>	Very high thermal performance	Partially or totally imported material
	High resistance to dampness	Need industrialized production rises basic cost
	Very high construction speed	Need Environmental control during manufacturing
	Lighter elements to erect	Special design and connections
	Reduce site work	Less access information for design, construct and maintenance
	High innovation design and construction techniques	High skill workers
		Sophiscated and convention equipment during construction
	Higher possibilities of insects and vermin attack	

Source: Ballerino-Chile (2002)

### **2.6.1 Massive wall system**

A massive wall system is a development relied on one kind of material. The kind of material is generally soil, artificial or natural fibers, masonry, etc. It can be used with or without additives, moulding, binder, and unique surface protection. An imperative attribute of the system is the self-supported walls. Use of construction methods and equipment differs based on selected material (HABITAT, 1988). Materials used for the construction of such systems are: Adobe which is a combination of earth and water, Burnt clay bricks which required no extra materials except mortar, Rammed earth which are constructed by consolidating earth in temporary or permanent forms, Concrete blocks which is differ from mass, hollow, interlocking and dry-stack techniques (HABITAT, 1988). Construction can attain efficiency if well monitored and conducted. The mortar can be conventional Portland cement or cement mix with lime and/or rice husk ash (HABITAT, 1988).

#### **2.6.1.1 Atakpame Buildings**

Houses in most Ghanaian villages are built using mud - a mixture of clay and water (or rammed earth), and thatch is used for the roof. This type of house is called “atakpame”. The whole community contributes to the building process and the houses are quite strong in that they normally remain in place for about twenty years if regularly maintained. Rammed earth is more often considered for use in walls, and floors. Rammed earth offer great potential as low-cost material alternatives with low embodied energy. Such buildings are neither fireproof (due to the thatched roof) nor completely waterproof (Yalley, 2008).

### **2.6.1.2 Soil blocks Buildings**

Many different materials are used around the world for walling. Where quarried stone and timber are not readily available, earth is the most common material used (Yalley, 2008). Earthen architecture has been used for centuries in many different parts of the world according to Jones (1985) cited in (Yalley, 2008). Archaeological evidence in very dry areas had also shown that earth building was a highly popular material for dwelling construction. Earth is still used today in many parts of the world where access to other forms of building material is restricted by location or cost (Yalley, 2008).

### **2.6.1.3 Sunburnt Bricks Buildings**

Sunburnt brick buildings are found both in urban and rural areas throughout Ghana (Yalley, 2008). This construction type is an improvement over the traditional “atakpame,” or adobe, and is gaining popularity at the moment. They constitute an estimated 25% of the Ghana’s rural housing stock. The walls are built on a stone platform raised above ground for the purpose of protection from floods. These buildings are built without any horizontal or vertical bar reinforcement. However, the strength of the building is relatively low compared with conventional sandcrete block houses. This type of construction is considered to be very vulnerable to earthquake effects, which, though infrequent and mild by world standards, is still a realistic threat in the region (especially in the South). Typical lifespan for buildings of this construction type is about 50 years (Yalley, 2008).



**Plate 2.1: Massive Wall System with Compressed Earth Blocks**

**Source:** <https://selfbuild.ie/wp-content/uploads/2019/03/13-wall-detail.jpg>



**Plate 2.2: Massive Wall System with Mud Bricks**

**Source:** <https://selfbuild.ie/wp-content/uploads/2019/03/13-wall-detail.jpg>



**Plate 2.3: Massive Wall System with Burnt Bricks**

**Source:** <https://selfbuild.ie/wp-content/uploads/2019/03/13-wall-detail.jpg>



**Plate 2.4: Massive Wall System with Stones**

**Source:** <https://selfbuild.ie/wp-content/uploads/2019/03/13-wall-detail.jpg>



**Plate 2.5: Innovative Massive Wall System with Precast Units**

**Source:**

<https://upload.wikimedia.org/wikipedia/commons/thumb/4/4a/Cebhomes.jpg/1200px-Cebhomes.jpg>

***Timber***

This is most likely one of normally adopted materials for housing delivery. Versatility in design relies upon the kind of timber and requirements of the end user. Modular systems are integrated to achieve efficiency and time during development (HABITAT, 1988). Timber is generally used to construct houses. Kinds of timber and components have been designed very quickly in the last several years.



**Plate 2.6: Massive Wall System with Timber**

**Source:**

<https://upload.wikimedia.org/wikipedia/commons/thumb/4/4a/Cebhomes.jpg/1200px-Cebhomes.jpg>

***Reinforced cement***

This is a combination of water and cement which has been strengthened with polypropylene fiber, glass fiber or steel/steel mesh capable to improve pressure and flexural resistance. The fiber mix in situ is not common. The walls are often consist of prefabricated panels, reduces the lead-time for construction and assembly of components (HABITAT, 1988).



**Plate 2.7: Massive Wall System with prefabricated concrete panels or Using Cement Foam Panel**

**Source:** <https://selfbuild.ie/wp-content/uploads/2019/03/13-wall-detail.jpg>

### **2.6.2 Frame Wall System**

A frame or skeleton wall system includes vertical, horizontal and angular members (timber, steel, reinforced concrete, etc.), fixed together to form a load-bearing structure. There are numerous materials for load bearing framework and in-fill systems. The construction sequence begins with the frame with the panels and accessories in a second stage. The space between the members can remain open or be filled with different components. These components will either provide the characteristics of solid walls (e.g. masonry) or lightweight walls (e.g. composite boards). The use of filling material, in addition to the roof structure, assists to strengthen the whole construction and check deformation (HABITAT, 1988).

### *Natural fibre frame*

This is a traditional technology with diversity of forms and construction methods, governed by varying weather conditions and precise social environment. Single fibers are less proof to pressure but in larger amounts, and if turned and interlocked, they can be used as structural elements. In-fill material generally comprises of leaves and other kinds of fibers (HABITAT, 1988).

### *Aluminium frame*

This system can be combined using cement board panels. The panels are created with a range of diverse densities, along with additional identifying components. They can be spray painted and also combined with polystyrene to increase thermal and sound insulation properties (HABITAT, 1988). Walls need special components in order to provide inter-panel locking. The system has been known to be structurally resistant, sound protected and simply installed if managed correctly (HABITAT, 1988).



**Plate 2.8: Frame Wall System Using Aluminium Frame with Cement Board**

**Source:** HABITAT (1988)

### *Steel frame*

This kind of frame is able to enclose many diverse materials: concrete or mud, precast panels, polyurethane foam, timber particle board, bricks, etc, thus permitting quite a number of solutions. The design of prefabricated steel frames, particularly the interlocking links and clamps, differs from company to company (HABITAT, 1988).



**Plate 2.9: Metal Pole Frame or Steel columns with Concrete Panels as an example of load bearing framework**

**Source:** HABITAT (1988)

### *Timber frame*

This kind of frame can be made in-situ or be prefabricated. The cladding has a lot of possibilities, such as wood particleboard, fiberglass mesh with cement and plaster or fiber cement sheeting. The layout is flexible to users need and the components simple and quick to put together under guidance (HABITAT, 1988).



**Plate 2.10: Timber Frame with Fibreglass Mesh and Cement Plaster**

**Source:** HABITAT (1988)

### **2.6.3 Core wall system**

The core wall system comprises of a combination of materials:

- i. an inner, or core, material that generally uses a polymer matrix resin to attain preferred specifications such as temperature efficiency, chemical resistance, fire resistance etc.;
- ii. an exterior part as protection or cladding such as mortar and;
- iii. an exterior reinforcement of metal sheets, fiber etc (HABITAT, 1988).

#### ***Polystyrene***

This kind of material is adopted to enhance heat insulating material qualities. New alternatives have been designed solutions since almost a several years ago and are still being enhanced. An example of this is "CasaBona", an incorporated structural system made of sheet metal profiles supported by blocks of expanded polystyrene, developed by Professor Gudni Jóhannesson in Sweden. A special machine is needed to produce the metal profiles. The design has differed based on location (HABITAT, 1988).

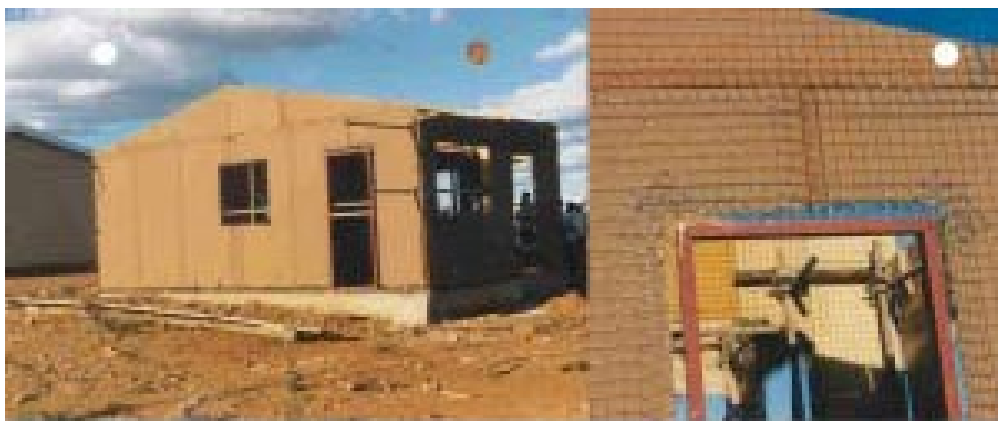


**Plate 2.11: Metal Profiles and Expanded Polystyrene Core Wall system**

**Source:** HABITAT (1988)

### *Polyurethane*

This material is used as core in a lightweight three-dimensional welded frame with sprayed concrete to obtain the desired thickness. It is a monolithic wall system with many qualities similar to conventional building components. The most suitable use is for one-storey structures and for certain industrial purposes. Common features are: structural stability, crack resistance, excellent thermal properties, good moisture barrier, good fire resistance and rapid assembly (HABITAT, 1988).



**Plate 2.12: Polyurethane Foam Core Reinforced With Mild Steel Wire**

**Source:** HABITAT (1988)

### ***Metal web or Wirewall***

This comprises of an expanded metal web filled with traditional cement mix, developed in South Africa. The walls are mounted in galvanised channels with a rod pile foundation system. The floor is a strengthened mesh and the roof of alternating tile type. It is fast to mount and no special equipment or skills are needed for construction and assembly (HABITAT, 1988).

## **2.7 THE SELECTION OF APPROPRIATE BUILDING MATERIALS FOR HOUSING DELIVERY**

People involved in the building industry are confronted with a great array of materials made from natural resources such as timber, and manufactured materials such bricks and metals. Many of these have been used effectively for centuries, but increasingly newly developed materials and systems for construction come on the market and need to be evaluated before they can effectively incorporated and stand the long term uses required of buildings (Ward-Harvey 2009). Some proven materials can become unpopular due to labour costs, or banned due to public health risks, as with lead based paints and asbestos fibres in the latter half of the 20<sup>th</sup> century (Ward-Harvey 2009).

House design and delivery entails structural performance, function and aesthetic matters that can be accomplished through conventional or modern techniques. Stulz and Mukerji, (1981) stated that, whatsoever strategy is used, a house cannot be constructed without basic knowledge of building materials. According to Marshall and Kearney (2000), the development of conventional materials (mostly raw) and techniques helps to understand social principles and desires, while technical innovation styles improve search for alternatives in the appropriate manufacturing and use of materials and development techniques. Stulz and Mukerji (1981) asserted that the first stage for any house design is the choice of “*appropriate materials*”, where

accessibility plays an essential function. "Appropriateness" of a building material or construction method can never be generalized. Factors such as industrialization of the nation, material origin, material price, transport facilities, and volume of elements made of selected material, environment interface, understanding of properties and handling, workers skills, social acceptance will determine appropriateness (Stulz, & Mukerji, 1981). "Appropriate" building materials should also consider resource level, durability, reparability and recyclability during the service lifetime.

## **2.8 INFLUENCE OF STAKEHOLDERS IN BUILDING MATERIAL SELECTION**

The material selection process is an important aspect of the building process, which includes stakeholders (client, architect, structural engineer, quantity surveyor, site manager, contractor, project manager, product manufacturers and suppliers) that are not typically considered an important aspect of the procedure. Amazingly little is accounted on the realistic impact of project stakeholders on collection of materials for housing delivery.

It should however, be recognized that, stakeholders are lawfully accountable for the work and their importance can be shown by the various ways they impact the adopting of advancement strategy (Ling *et al.*, 2007; Shen & Tam, 2002; Chinyio, 1998). Clients for example, are crucial for whether or not ecological objectives are included in the work and exert pressure on project members to enhance buildings' lifecycle performance (Gann & Salter, 2000). Furthermore, clients are accountable for setting main concerns and analyzing those concerns throughout the production process. Some clients have an apparent idea of a program, budget, and other project goals, such as the final appearance of the building. Others look to their technical professionals (Architect, Quantity Surveyor, Structural Engineer etc.) to assist them

determine the work goals and to design a building that satisfies those goals. In both instances the effectiveness of the correlation between client and technical consultants is a main factor in making and implementing design decisions throughout the project.

## **2.9 FACTORS INFLUENCING THE CHOICE OF MATERIALS FOR HOUSING DELIVERY**

In endeavors to attain better proficiency in the material selection process, and assist a positive material selection process, most researches have generated schematics of basic material selection factors for evaluating the performance metrics of a diversity of building materials or items. A survey by Florez *et al.* (2009) discovered that a number of researches on the qualities of building materials have been conducted, showing the use of objective and subjective measures in interpreting the performance metrics of building materials or items. Research studies examining the reasons why building material fail, for example Florez *et al.* (2009); Rahman *et al.* (2008); Wastiels & Wouters (2008); Ljungbeng (2007), provide lists of factors or variables believed to contribute to the performance quality of building materials or products. Rahman *et al.* (2008) study developed a multi-criteria decision making model (MCDM) that considers the performance criteria of new technologies or materials, with which decision makers are able to resolve combinational problems associated with the material selection process. The system objective, however, examined more particularly into the design of a knowledge-based model that views the life-cycle of materials and technological innovation at the least cost.

Van Kesteren *et al.* (2005) provided a material choice consideration model where product-personality, use, function, material characteristics, shape, and manufacturing processes are showed as the elements that are considered by the designer during the material selection process. On the other hand, Wastiels *et al.* (2007) questions the

credibility of their design to architecture. They maintained that architecture is not only involved with the features or procedure of formation of the material, but also the interaction with the consumer. Furthermore, Ashby and Johnson (2002) presented the intangible features of materials such as ‘aesthetic attributes’ in the material qualities list for material or product designers when explaining material factors such as visibility, comfort, or smooth. Wastiels and Wouters (2008) claim that their interest is restricted to infrequent explanation of the phenomena without offering an apparent and extensive summary that might be useful to designers or developers. Wastiels and Wouters (2008) suggestion was strengthened by producing a schematic of fundamental material selection considerations that looks into precise factors that concern the user experience or sensory stimulation, such as the material’s colour or texture for architectural design projects. However, in the presented framework, no pronouncement is made upon what categories of materials are considered and how considerations from these different categories influence each other.

Fernandez (2006) described more directly the links between the decision-making process and material service life. In it, he confirmed how modern designers make selection based on the performance features of current designs, indicating that they do not opt for materials but rather for ‘material tools or systems’. He explains that restricting the material performance to the requirements of systems restricts the necessary features inherent in the materials. The results of his research recommended that databases should mainly consider additional measurements and aspects with which other types of material could be successfully verified. On the other hand, Florez *et al.* (2009) created very subjective aspects or factors such as product’s attraction, effectiveness and performance as measurements that play significant positions in the assessment of material strength and sustainability. Their research,

however, did not state how potential customers may distinguish between sustainable and non-sustainable materials or components.

Cagan and Vogel (2002) recommended six groups of factors that promote material value or efficiency such as emotion (sensuality, power, and feeling of adventure), aesthetic (visual, responsive, and auditory), product identification (personality, sense of effect, and social), ergonomics (ease of use, safety, and comfort), primary technology (enabling and reliable), and quality (durability). Ljungberg (2007) suggested that even though it is ideal that every material meets these circumstances, they do not present enough granularities to look at the efficiency reliability of a material.

Chueh and Kao (2004) research revealed that the significant size of product quality include aspects such as performance, features, reliability, conformance, strength, serviceability, appearance, tangibles, guarantee, concern, value, participation and responsiveness. Their analysis however, facilitates consumer understanding as a significant adding factor in identifying material option.

Ljungberg (2007) designed and incorporated system in which aspects such as trend braking, low reparability, safety and users' fulfillment, were used to measure material efficiency. On the contrary Glavic and Lukman (2007) used the mixed integer optimization approach for developing material option, considering very subjective requirements. Conversely Glavic and Lukman (2007) used the mixed integer optimization approach for building material selection, considering subjective requirements in construction projects.

Abeysundara *et al.* (2009) designed a model for the quantitative analysis of a range of sustainable building materials, based on ecological aspects (embodied energy), financial problems (market prices and cost) and social factors (thermal comfort, appearance, ability to construct rapidly, strength and durability). The result of their analysis however revealed preference to ecological factors in the decision-making procedure over social and financial aspects. Ogunkah and Yang (2012) on the other hand presented six groups of variables that influence the selection of building components for housing projects such as General/Site, Cost/Economic, Technological, Socio-cultural, Sensorial, Environmental/Health.

Adding to the information provided, several researchers (Seyfang, 2009; Bevan & Woolley, 2008; Kennedy, 2004) have suggested the use of multi-criteria decision-making technique for the evaluation of the decision-making procedure in selecting local building materials under problems which associate to technical factors and low construction cost. Their activities however, maintained to highlight renewable material and energy sources, low-polluting materials, and a concern with the overall lifetime effects of structures.

**Table 2.5: Summary of Building Materials Selection Consideration models/frameworks Developed by Researchers**

<b>Author (s)</b>	<b>Building material selection Consideration models/frameworks</b>
<b>Ashley and Johnson, 2000</b>	Introduced the intangible quantities of materials such as aesthetic attributes in the material properties list for material designers when describing material aspects such as transparency, warmth or softness.
<b>Cagan and Vogel, 2002</b>	Presented six categories of factors or variables that contribute to material value or performance such as emotion (sensuality, power and sense of adventure), aesthetic (visual, tactile, and auditory), product identity (personality, sense of impact and social), ergonomics (ease of use, safety and comfort), core technology (enabling and reliable) and quality (durability).
<b>Chueh and Kao, 2004</b>	Demonstrated that the major dimensions of product quality include factors such as performance, features, reliability, conformance, durability, serviceability, aesthetics, tangibles, assurance, empathy, value, involvement and responsiveness.
<b>Van-Kesterenet al., 2005</b>	Presented a material selection consideration model where product-personality, use, functions, material characteristics, shape and manufacturing processes are represented as the element that are considered by the designer during the material selection process.
<b>Ljungbeng, 2007</b>	Integrated system in which factors such as trend breaking, low responsibility, safety and users' satisfaction, were used to measure material performance.

	<b>Building material selection models/frameworks Developed by Researchers Cont'd</b>
<b>Author (s)</b>	<b>Building material selection Consideration models/frameworks</b>
<b>Wastiels and Wouters, 2008</b>	Presented schematic of basic material selection considerations that looks into specific aspects that concern the user experience or sensory stimulation such as the material's colour or texture for architectural design projects.
<b>Rahman et al., 2008</b>	A model that consider the life-cycle of materials at the least cost.
<b>Seyfang, 2009; Bevan and Woolhey, 2008; Kennedy, 2004</b>	Suggested the use of multi-criteria decision-making methodology for assessment of the decision-making process in selecting building materials under issues which relate to technical factors and low construction cost.
<b>Florezet al., 2009</b>	Framed subjective factors or variables such as product's appeal, resourcefulness and functionality as dimensions that play influential roles in the evaluation of material or product sustainability.
<b>Abeyesuntara et al., 2009</b>	Developed a model for the quantitative analysis of a range of sustainable building materials based on environmental aspects (embodied energy), economic issues (market prices and cost) and social variables (thermal comfort, aesthetics, ability to construct quickly, strength and durability).
<b>Ogunkah and Yang (2012)</b>	Presented six main and fifty six sub categories of factors that affect the choice of building materials for housing projects such as General/Site Factors – location, distance, availability of materials, user's choice, experience, creativity, material type, site layout, regional setting/geographic information, space usage, site access, building structure, and scale; Cost/Economic Factors – life-cycle cost, material embodied energy, economic status, affordability, labour cost, and energy efficiency; Environmental/Health Factors – environmental compatibility, waste prevention, safety/health

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of user, habitat disruption, degree of pesticide treatment, climate, and total environmental impact; Sensorial Factors – appearance, texture, colour, temperature, acoustics, odour, thinness, roughness, and fineness; Socio-Cultural Factors – compatibility with cultural & aesthetics traditions, communal identity & setting, cultural implications of materials, family structure, owners view, and designers knowledge of the region; Technical Factors – reusability, demountability, maintenance level, strength, durability, fire resistance, heat resistance, water resistance, ability to accommodate movement, technical skills, material fixing, scratch resistance, weather resistance, chemical resistance, and weight & mass of material.

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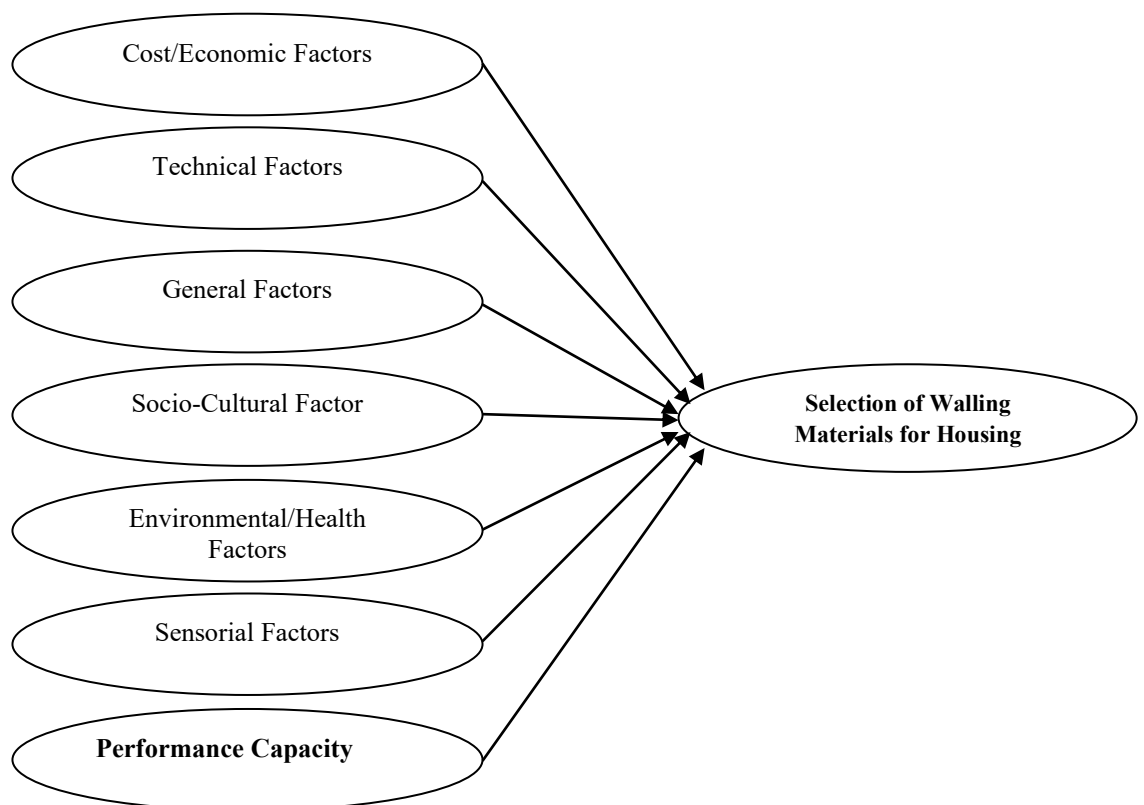
Source: Author's Compilation from Existing Literature

## **2.10 CONCEPTUAL FRAMEWORK**

Given key insights from the information provided in Table 2.5, it was apparent that majority of existing frameworks incorporated a few constructs or factors which were not enough to help decision makers in their decision-making when selecting building materials for housing projects. Several attempts to bridge the recognized existing gap have been initiated (Hulme & Radford, 2010; Fernandez, 2006; Cooper, 1999); but, almost as many appear not to have been accomplished. As follow-ups to the previous studies, this research was therefore undertaken to identify as much as possible, decisive factors that will help or guide decision makers (stakeholders/construction professionals) to select appropriate and suitable building materials for urban residential housing delivery in Ghana.

Usually, frameworks demonstrate the scientific connections between attributes. Aalbrecht *et al.* (1991) posits that frameworks support implementation and enhance the chance of success because it will provide not only overview but also more

information explaining the content of each framework element and its connection to additional elements. According to Dale (2003), framework is usually a well-liked outcome which provides as a means of introducing idea, concept, pointers and plans in a non prescriptive way. It allows users to select their own starting to the finishing point and specific course of action, and to improve or implement existing ideas, theories and concept to enhance situations and benefit people with little supervision. The main purpose of this framework is to enable building professionals and stakeholders in general recognize and focus on the appropriate requirements to successfully and perfectly evaluate the trade-offs between technological, ecological, socio-cultural, cost, sensorial, performance and some general factors during the material assessment and selection procedures. The seven constructs that formed the conceptual framework of this study were selected from the information provided in Table 2.5. Also most of the sub-constructs/factors selected for this study were based on the factors presented by Ogunkah and Yang (2012) in Table 2.5.



**Figure 2.1: Conceptual Framework for**

## **2.11 SUMMARY**

The chapter gave general details and an overview of Building Materials Selection for Housing Delivery. It reviewed previous and related work and discussed into details time and regularity concepts in the use of building materials, commonly used building materials for housing projects, overview of Ghana standard code of practice/national building regulation on suitability of materials for building, walling systems, influence of stakeholders in building material selection, building materials selection consideration factors, the selection of appropriate building materials for housing projects. The chapter also explained the need and basic design for proposed conceptual framework for the study. The next chapter discusses the research design and methodology and the general approach to the research. Sample techniques and methods for collecting and analyzing the data are also explained in the next section of the research.

## **CHAPTER THREE**

### **RESEARCH METHODOLOGY**

#### **3.1 INTRODUCTION**

The effect of research method on the possible outcome of any research endeavour cannot be overemphasized. Cooper and Schindler (2003) indicated that the next essential step in any research method after review of literature and identifying the research question is choosing best suited technique. When undertaking research, it is essential to select the right technique, to make sure that the research aim and objectives can be met and that the results can be verified (Steele 2000; Fellows & Liu, 2003). This chapter therefore discusses the research design and methodology including their strengths and weaknesses and highlights the general approach to the research. The selection of research technique/methodology and the basis for its choice are also presented. Sample techniques and methods for collecting and analyzing the data are also explained in this section of the research.

#### **3.2 Research Strategy Adopted for Study**

Generally researchers adopt either quantitative or qualitative approaches to tackle a specific research problem but research strategy adopted for this study was the mixed method which combines quantitative (positivism) and qualitative (interpretivist) research approaches to data collection. A mixture of qualitative and quantitative research approaches to data collection, the analysis of data and other stages in the study process have been recommended in modern methodology literature (Bryman, 2007; Creswell & Clark, 2007; Morgan, 2006; Tashakkori & Teddlie, 1998). Qualitative and quantitative methods represent bipolar extremes. Combining both qualitative and quantitative research techniques has confirmed to be better than a

single approach (Moffatt *et al.*, 2006) and very effective (Lee, 1991). The following section gives an overview of the research techniques employed for the study.

### **3.3 RESEARCH METHOD ADOPTED**

The research adopted two main research techniques for the study to help fully achieve the study aim and Objectives. These two methods were Delphi technique and Questionnaire survey. These two methods were used due to the fact that using different approaches for collecting research data lead to better validity and reliability than using a single methodological approach (Dixon *et al.*, 1987; Denzin, 1970). Also, the idea of combining these methods was to make the study more realistic. The overall research techniques that were used for the study and reasons for using them were discussed in the following subsection.

#### **3.3.1 Delphi Technique**

The study adopted Delphi technique to refine questionnaire survey instrument (structured questionnaire) for the study. The Delphi Technique was also used to explore the extent of the attributes (factors) impact or influence on building material selection for urban residential housing delivery in Ghana through consensus. The Delphi Technique was originally developed in the 1950s, as a tool for forecasting and problem solving of complex topics at the Rand Corporation by Helmer and Dalkey (Buckley, 1995). It was named after the ancient Greek temple where the oracle could be found. The Delphi method adopted by the Rand Corporation research team was that subject-matter experts could be solicited for their opinion about the likelihood of future events or scenarios. The Delphi Technique is a qualitative methodology seeking to produce a consensus of a group of experts on an issue of concern (Miller, 1993) through a survey consisting of rounds. It is based on structural surveys and

makes use of intuitively available information of the participants (experts) in their various fields. The method provides both qualitative and quantitative results, and has beneath its explorative, predictive even normative elements (Cuhls, 2003). There is agreement that Delphi is an expert survey in two or more 'rounds' in which the second and later rounds of the survey (the results) of the previous round are given as feedback. Thus, the experts answer from the second round based on the influence of the other experts opinions. The technique requires knowledgeable and expert contributors individually responding to questions and submitting the results to a central coordinator (researcher). The coordinator (researcher) processes the responses, looking for central and extreme tendencies, and their validations (Grisham, 2008). The results are then fed back to the input provided by the coordinator (researcher). The experts are then asked to resubmit their opinions, aided by the input provided by the coordinator (researcher). This process continues until the coordinator sees that a consensus has been formed on the questions asked. The method was intended to remove the bias that is possible when diverse groups of experts meet, which is common with other methods of decision making. With the Delphi Method, the experts do not know who the other experts are.

In the Delphi process, nobody 'loses face' because the study is done anonymously using a questionnaire. Rowe *et al.* (1991) and Häder and Häder (1995) stated that it is commonly assumed that the method makes better use of group interaction whereby the questionnaire is the medium of interaction. The Delphi Method is especially useful for long range forecasting, as expert opinions are the only source of information available. The Delphi Technique is part of a group of decision-making (policymaking) techniques that includes the Nominal Group Technique (NGT) and Interacting Group Method (IGM). The Delphi Technique differs in various ways from

NGT and IGM respectively, but primarily due to the fact that Delphi is individual based, anonymous and independent. The element of group interaction is eliminated from the process and feedback to questionnaires is in written format (Loo, 2002).

Brill, Bishop and Walker (2006) describes the Delphi as a particularly good research method for developing consensus amongst a group of entities having expertise on a particular topic where information required is subjective and where participants are separated by physical distance (Linstone & Turoff, 1975). Brill *et al.* (2006) further states that the Delphi Method has been validated in the literature as a reliable empirical method for reaching consensus in a number of areas. Amongst these areas are: distance education (Thach & Murphy, 1995), journalism (Smith, 1997), visual literacy (Brill *et al.*, 2006), electronic commerce (Addison, 2003), health care (Whitman, 1990) and others. Beside these areas, the method has also been used in many other disciplines, such as in information technology (IT) research to identify and rank key issues for management attention (Delbecq *et al.*, 1975); scientific study of GIS (Hatzichristos & Giaoutzi, 2005), quality management (Saizarbitoria, 2006), terrorism (Parente, Hiob, Silver, Jenkins, Poe & Mullins, 2005), banking (Beales, 2005), social sciences (Landeta, 2006), privatization of utilities (Critcher & Gladstone, 1998), education (Yousuf, 2007), etc. Based on the extensive usage of the method over time, the Delphi Method in a research is an accepted practice.

The Delphi's strength lies in the rounds used unlike ordinary survey research, which provide an opportunity for initial feedback, collation of feedback, and distribution of collated feedback to participants for further review (Stitt-Gohdes & Crews, 2004:62). Therefore, the Delphi Method was also considered to be a robust method of rigorous query of experts. This unique process requiring group communication is central to the strength of the Delphi (Stitt-Gohde & Crews, 2004:62). Also, Loo (2002) opined that

the Delphi process should be used when investigating policy-making or policy-evaluation strategies that will set the future direction for the public or private sector, respectively. The Delphi method was therefore considered as a useful tool for the current study.

### ***3.3.1.1 Selection of Panel Members for the Delphi Technique***

Panel members were identified from professional Architects in the Ghanaian construction industry. Some of the experts were identified from conference proceedings of West African Built Environment Research (WABER) and Association of Researchers in Construction Management (ARCOM) held in Ghana. Panellists were recruited via e-mail, with a brief overview of the study objective included therein. Thereafter, those that consented to the preliminary invitation were sent with a letter to participate with detailed description of the Delphi Study. Invitations were extended to thirteen (13) experts. Twelve (12) responded to participate but only Nine (9) completed the first round and remained throughout the study as panellists. This number of panellists was considered adequate based on literature recommendations from scholars which have employed the technique previously. Hallowell and Gambatese (2010) suggested that since most studies incorporate between eight (8) and sixteen (16) panellists, a minimum of eight (8) is suggested. Hallowell and Gambatese (2010) further argued that the size of a panel should be dictated by the study characteristics, number of available experts, the desired geographical representation and capacity of the facilitator. Therefore the panel of nine (9) experts for this study was considered adequate based on the fact that the Delphi Method does not depend on statistical power. Rather on group dynamics for arriving at consensus amongst experts. Most of the potential experts who agreed to participate during the initial stage withdrew from the study probably, due to the rigorous nature and time required in the

Delphi Method. The eventual withdrawal of three (3) experts during the first round of the study led to the completion of the study with nine (9) experts. All the panel members were Ghanaians. One of the experts is currently in Cape Coast, three are in Kumasi and the remaining five of the experts are in Accra (Table 3.1).

**Table 3.1: Residential location of experts**

<b>Regional Capitals /Cities</b>	<b>Number of Experts</b>
<b>Cape Coast</b>	<b>1</b>
<b>Kumasi</b>	<b>3</b>
<b>Accra</b>	<b>5</b>
<b>Total</b>	<b>9</b>

The highest qualifications held by the experts are tabulated in the Table 3.2 below. Two of the experts had Doctor of Philosophy (PhD) degrees and the remaining seven of the experts had Master of Science (MSc) Degrees.

**Table 3.2: Qualification of panel of experts**

<b>Highest qualification</b>	<b>Number of experts</b>
<b>Doctor of Philosophy (PhD)</b>	<b>2</b>
<b>Master of Science degree (MSc)</b>	<b>7</b>
<b>Total</b>	<b>9</b>

Table 3.3 shows that one expert had 1-5 years of experience in construction industry, one had 6-10 years of experience in construction industry, four had 11-15 years of experience in construction industry, and three had 16-20 years of experience. All the experts are professionally registered with Ghana Institute of Architect.

**Table 3.3: Panel of experts' years of experience in construction industry**

<b>Years of experience</b>	<b>Number of experts</b>
<b>1-5</b>	1
<b>6-10</b>	1
<b>11-15</b>	4
<b>16-20</b>	3
<b>Total</b>	<b>9</b>

### ***3.3.1.2 Conducting the Delphi iterations***

Sequences of questionnaire rounds are used to obtain iterative responses to issues in a Delphi Study (Masser and Foley, 1987). According to Woudenberg (1991) “two to ten rounds is appropriate because accuracy is expected to increase over rounds and the need for repetition of judgment and group pressure for conformity”, while Critcher and Gladstone (1998) suggested between two to five rounds. Two rounds of iterative process were used in the current study for the Delphi method. The attached Delphi questionnaire was sent out electronically to all panels of experts to respond to the questions, according to their ability and expertise. A questionnaire was designed for second round based on the responses to the previous one. However, the Round One Questionnaire was designed, based on a summary of the comprehensive review of literature highlighting sets of attributes and sub-attributes that are potentially relevant to building material selection for urban residential housing delivery in Ghana. Closed-ended questions were used in this round. The responses were analysed and formed the basis of Round Two of the study. The purpose of the second round of the study was to allow experts to review and comment on the attributes that determine building material selection for urban residential housing delivery in Ghana, which

were proposed by the panel of experts in Round One. Closed-ended questions were used in this round to investigate participant comments expressing agreement, disagreement or clarifications concerning proposed attributes that determine building material selection for urban residential housing delivery in Ghana.

The final Round Two was specifically aimed at:

1. Informing the experts of the findings of the analysis of responses to the questionnaire of Round One; and
2. Requesting their final affirmation or comments on attributes and issues that did not receive any consensus in Round One.

The Round Two Questionnaire was designed based on the measures of frequency responses to the questionnaire of Round One. Closed-ended questions were used and frequencies were obtained to indicate consensus reached amongst experts regarding attributes that determine building material selection for urban residential housing delivery as presented in the study. Based on the findings of the analyses of responses to the Delphi rounds, a list of attributes that determine building material selection for urban residential housing delivery was prepared, which informs the conceptual framework for the study. The Delphi Survey was conducted via electronic mail, and follow-up emails were used to encourage prompt responses to the questionnaires. Using email provides a free and faster means of communication.

With regards to the Delphi Questionnaire, panel of experts were requested to rate the likelihood of an attribute influencing building material selection for urban residential housing delivery. The probability scale ranged from one to ten representing zero to 100%. Interval ranges were set at ten (Table 3.4). Panel of experts were asked to rate the impact of the factors on building material selection for urban residential housing

delivery in Ghana. This was based on a 10 point ordinal scale ranging from negligible to very high impact.

**Table 3.4: Influence or likelihood scale**

0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100
%	%	%	%	%	%	%	%	%	%
1	2	3	4	5	6	7	8	9	10
			x				x		

**Table 3.5: Impact scale**

No impact		Low impact		Medium impact		High impact		Very high impact	
1	2	3	4	5	6	7	8	9	10
								x	

Group medians were calculated as a measure of the central tendency for each response on each element. Thus, an indicator of whether consensus had been reached on the questions for each element was determined. The median was deemed to be more suitable for the type of information that was being collected. This is because the median eliminates bias and takes into consideration outlier responses and makes consensus notion more reasonable. The mean on the other hand, may not reflect a reasonable central tendency as it considers only the outlier responses.

Group medians and the absolute deviations from the Delphi First Round were computed for each element. These were then sent back to the expert panel members

so that responses in the second round could be made taking into account the group median. Panel of experts in the second round were asked to either maintain their original response made in Round One, or they could change their initial response to be more in line with the group median. Panel members, who had responses to units above or below the group median in the second round, were requested to state their reasons for sticking to a response that does not agree with the group median. Group medians and the absolute deviations were again computed for the second round. From these calculations and after two rounds of the Delphi Process, it was determined that consensus had been reached.

Calculations for the second round of the Delphi Process indicated that there was no need to proceed to the third round as there was no further value that could be added to the degree of consensus attained at that level. Throughout the entire Delphi Process, anonymity of panel members was maintained to avoid undue influence on other members. The aspect of anonymity is crucial to the credibility of the Delphi Technique.

### ***3.3.1.3 Computation of data from Delphi Study***

Computation of data from the Delphi Study was conducted using Microsoft Office Excel, a spreadsheet software programme. The first stage involved analysis to determine consensus on responses to the predetermined criteria. This involved determining the group median responses for each question. After the second round of the Delphi, absolute deviations ( $D_i$ ) of the group medians ( $m(X)$ ) of each rating for the relevant questions as pre-determined were calculated using Equation 1.0 below.

$$D_i = [x_i - m(X)]$$

Equation

1.0

Where  $D_i$  = *Absolute deviation*

$x_i$  = *Panel rating*

$m(X)$  = *Measure of central tendency*

A computation of each and every question element was completed for the likelihood and impact of the attributes in predicting building material selection for urban residential housing delivery in Ghana. To compute the variation of the median from the responses for each question in each round, the absolute deviation given in Equation 1.0, was done. This is the absolute difference between a response within a data set and a given point. The point from which the deviation is measured is a measure of central tendency, which is the median. The results from the Delphi analysis were presented as numbers and percentages in tables in the results section: Chapter 4, Section 4.2.

#### ***3.3.1.4 Determination of Consensus from the Delphi Process***

It is required that consensus should be reached on all questions. Consensus was determined by measuring the central tendency of the various responses on all questions. The group median was computed for all responses. In order to achieve consensus, the deviation of all responses about the group median was determined not to be more than one (1) unit. This is considered to be suitable as the scale that was

used for both probability (influence) and impact was 1 to 10. The deviation of all responses was calculated using the absolute median (Equation 1.0).

Consensus is difficult to measure in Delphi Studies. The foregoing has been established from literature, that there is no consensus on how to determine consensus regarding a set of opinions. Holey *et al.* (2007:2) suggested that consensus is the same as agreement and that agreement can be determined by the following:

1. The aggregate of judgments;
2. A move to a subjective level of central tendency; or
3. Alternatively by confirming stability in responses with the consistency of answers between successive rounds of the study.

Other researchers have used frequency distribution to assess agreement and the criterion of at least 51% responding to any given response category being used to determine consensus (McKenna, 1994). Other studies, such as one conducted by Rayens and Hahn (2000), have used means and standard deviations with a decrease in standard deviations between rounds indicating an increase in agreement. Inter-quartile deviation (IQD) has also been used to determine consensus (Rayens & Hahn, 2000). Studies conducted by Rayens and Hahn (2000) have included another criterion to determine consensus in addition to the IQD to achieve stability. The criterion to achieve consensus was that, the IQD should equal one (1) unit for which more than 60% of respondents should have answered either generally positive or generally negative. Items which had an IQD  $\neq 1$  for which the percentage of generally positive or generally negative responses was between 40% and 60% were determined to indicate a lack of consensus or agreement.

The following criteria for determining consensus has used by Holey *et al.*, (2007).

1. Percentage response;
2. Percentages for each level of agreement for each question to compensate for varying response rates;
3. Computation of median, standard deviation and their associated group rankings;
4. Computation of the means, standard deviation and their associated group rankings using the importance ratings; and
5. Computation of the Weighted Kappa (k) values to compare the chance eliminated agreement between rounds.

Holey, Feeley, Di & Whittaker (2007) opined that consensus is reached when the following is present:

1. An increase in percentage agreements;
2. Convergence of importance rankings;
3. Increase in Kappa values;
4. A decrease in comments as rounds progressed;
5. A smaller range of responses; and
6. Smaller values of standard deviations.

These studies suggest that there is little agreement on how to measure consensus in a Delphi Study. It is however agreeable that for consensus to have been achieved, there has to be a convergence of ideas and reasoning towards a subjective central tendency measure. Hence, in the current study, consensus was determined to have been reached if the following was achieved:

1. More than 60% of responses are generally positive or negative with certain questions; and

2. The average of the absolute deviation was not more than one unit. The absolute deviation is calculated from Equation 1.0.

Therefore the scales of consensus adapted for this research are as following:

1. Strong consensus - median 9-10, mean 8-10, and  $\geq 80\%$  (8-10);
2. Good consensus - median 7-8.99, mean 6-7.99, and  $\geq 60\% \leq 79\%$  (6-7.99); and
3. Weak consensus - median  $\leq 6.99$ , mean  $\leq 5.99$  and  $\leq 59\%$  (5.99).

### **3.3.2 Survey**

Survey research includes obtaining information from participants through questionnaires or structured interviews, with the aim of generalizing from a sample to a population (Creswell, 2003; Babbie, 1990). It develops on past work which has already developed concepts, rules and theories that assist to decide the data specifications of the particular study (Fellows & Liu, 1997). Even though it has restrictions such as low response rates and the risk of prejudice, this approach gives the opportunity to understand more about a wide range of issues such as those envisaged in this study.

The survey research design was adopted to give, as indicated by Creswell (2003), a quantitative description of trends, attitudes, or views of the population by studying a sample of that population. Specifically, a cross-sectional questionnaire survey was adopted for the study.

#### ***3.3.2.1 Questionnaire survey***

Questionnaire is a self administrated measuring instrument including closed-ended and/or open-ended questions. Survey questionnaire was developed to cover the

research objectives. A questionnaire was used for these tasks because it is efficient and effective in sampling a large audience scattered over a wide geographical area. Also, it is a relatively cheap data collection and processing method. Once developed, the questionnaire will be ready for testing.

The precision and success of questionnaire surveys mostly rely on the cautious design of its content, framework and the response format. Therefore, certain precautions should be taken in developing questionnaires (Hoinville & Jowell, 1978): the questions should be clear and quickly understood by the respondents; should be simple to be administered by the interviewer; the recorded answers can simply be modified, coded and transferred onto a computer file for statistical analysis; and its flow, length and structure must motivate respondents to complete the questionnaire. Substantial attempt was therefore dedicated towards this endeavour.

The literature review in chapter two and Delphi questionnaire guided the formulation of the questionnaire. The questionnaire was divided into four main sections for easy analysis and reporting.

- A.** Characteristics of the respondents.
- B.** Commonly used walling materials and their suitability for urban residential housing delivery in Ghana.
- C.** Involvement of relevant stakeholders and their influence in the selection of walling materials for urban housing delivery in Ghana.
- D.** Potential factors influencing walling Material Selection for urban residential housing delivery in Ghana.

### ***3.3.2.2 Population for main survey***

To attain a thorough understanding of the specification/design process one needs a better knowledge of the individuals who influence the selection of building materials.

This study aimed at investigating three groups of building professionals involved in the building process: the Architects, Quantity Surveyors and Structural Engineers.

During the time of conducting this study (2018), the total registered members of good standing with the selected professional bodies (Ghana Institution of Architects, Ghana Institution of Surveyors, and Ghana Institution of Engineers - Structural Engineers) was 1013. The breakdown is as follows: 586 Architects, 371 Quantity Surveyors and 56 Structural Engineers. This information was obtained in 2018 from the database and directory of Ghana Institution of Architects, Ghana Institution of Surveyors, and Ghana Institution of Engineers (Structural Engineers) respectively.

### ***3.3.2.3 Sampling for main survey***

For the quantitative study, stratified sampling technique was employed in the selection of the three groups of practitioners i.e. Architects, Quantity Surveyors, and Structural Engineers within the sample frame. These three groups of practitioners were employed as the strata in stratification to allow for a proportional representation of practitioners across board. That means each unit in the sample had a known chance of being selected for the survey.

The minimum statistically acceptable sample size was determined by employing the Kish formula (Barbbie, 1995; Kish, 1965) to justify the responsive sample size of the survey. This formula states that:

$$n = \frac{n'}{1 + \left(\frac{n'}{N}\right)}$$

Where;

n = the sample size from finite population

N = the total population

n' = given by  $\frac{s^2}{v^2}$

S = the standard error of the sampling population

V = the variance of the population elements

Using a total error of 0.1 at 94% confidence level, Sis 0.5 and Vis 0.06;

For 586 good standing Architects registered with the Ghana institution of architects:

$$n = \frac{n'}{1 + \left(\frac{n'}{N}\right)}$$

$$n' = \frac{s^2}{v^2} = (0.5)^2 / (0.006)^2 = 69.44$$

N = 586

$$n = 69.44 / [1 + (69.44/586)] = 62$$

This means that the questionnaires should be distributed to 62 Architects in order to achieve 94% confidence level.

For 371 good standing Quantity Surveyors registered with the Ghana institution of surveyors:

$$n = \frac{n'}{1 + \left(\frac{n'}{N}\right)}$$

$$n' = \frac{s^2}{v^2} = (0.5)^2 / (0.006)^2 = 69.44$$

N = 371

$$n = 69.44 / [1 + (69.44/371)] = 59$$

This means that the questionnaires should be distributed to 59 Quantity surveyors in order to achieve 94% confidence level.

For 56 good standing Structural Engineers registered with the Ghana institution of Engineers:

$$n = \frac{n'}{1 + \left(\frac{n'}{N}\right)}$$

$$n' = \frac{s^2}{v^2} = (0.5)^2 / (0.006)^2 = 69.44$$

$$N = 56$$

$$n = 69.44 / [1 + (69.44/56)] = 31$$

This means that the questionnaires should be distributed to 31 Structural engineers in order to achieve 94% confidence level

So in all, the sample size added up to 152 practitioners, i.e. 62 Architects; 59 Quantity surveyors; and 31 Structural Engineers. These practitioners were selected randomly by generating random numbers in Microsoft Excel 2003. This means that the random selection method was employed in selecting the practitioners (Architects; Quantity Surveyors; and Structural Engineers) within the various strata in order to avoid researcher biases in the selection. Random sampling is where each member of a population has a known and nonzero probability of being included in the sample. It was utilized because of the low cost involved, faster data collection and since data set is smaller, it is possible to ensure homogeneity and to improve accuracy and quality of data.

### ***3.3.2.4 Data collection procedure of the main survey***

A total of 152 questionnaires were mailed (postal) out to participants for completion in this survey. The questionnaire was accompanied by a self-addressed envelope and a statement of the objective of the study to guide the respondents on the potential contribution they could make to good practice. As a follow up, some of the questionnaires were personally sent out to those participants who could be easily reached for completion. For most of the questions, respondents were required to indicate the extent to which they will agree with a given statement, on a five point scale. For other questions, respondents were asked to rank some provided factors.

## **3.4 METHOD OF DATA ANALYSIS**

The quantitative data was analysed using the Statistical Package for Social Sciences (SPSS) and Microsoft excel software. Two forms of statistical analysis were undertaken: Descriptive statistics such as percentages, charts, tables and frequencies were used to summarize information from respondents. Also inferential statistics such as relative importance index method (RII) was used herein to determine architects, quantity surveyors, and structural engineers' perceptions of the relative importance of the identified factors that affect building materials selection for urban residential housing delivery in Ghana. The RII was computed as:

$$RII = \frac{\sum W}{AXN} \dots\dots\dots (1)$$

Where:

RII = Relative importance index;

W = the weight given to each factor by the respondents and ranges from 1 to 5;

A = the highest weight = 5;

N = the total number of respondents (Enshassi, Mohamed, & Abushaban, 2009).

Kendall's coefficient of concordance was used to determine whether there is a significant degree of agreement among the 3 groups of respondents (Architects, Quantity Surveyors and Structural Engineers). In other words, Kendall's coefficient of concordance was used as a measure of agreement among raters. It indicates the degree of agreement on a zero to one scale, and is computed by the following equation (2):

$$W = \frac{12U - 3m^2n(n-1)^2}{m^2n(n-1)}, \dots\dots\dots (2)$$

Where:  $U = \sum_{i=1}^n (\sum R)^2$ ,

n = number of factors;

m = number of groups;

i = the factors 1, 2... N (Enshassi, Mohamed, & Abushaban, 2009; Frimpong, Oluwoye, & Crawford, 2003).

Kruskal-wallis test was also used to validate the results of Kendall's coefficient of concordance.

Kruskal-Wallis (KW) test is a statistical test that is used to compare the ranks means between two or more samples. This test is used in order to check out if there are any significant differences in the point of view of the respondents regarding the levels of each of the group of factors that influences the selection of building materials.

### **3.5 SUMMARY**

The chapter discussed the research design and methodology and highlighted the general approach to the research. The choice of research methodology and the reasons for its selection were also provided. The population and sample size for the study were determined. Sample techniques and methods for collecting and analyzing the data were also explained in this section of the research. The next chapter covers results from the field survey and discussion of the results.

## **CHAPTER FOUR**

### **RESULTS AND DISCUSSIONS**

#### **4.1 INTRODUCTION**

Previous chapters addressed the introduction, the review of relevant literature, and the research methodology adopted. This chapter covers results from the Delphi study and field survey and discussion of the results. The analysis and discussion of the main results have been presented in five sections: response rate; background information of respondents; commonly used building materials for housing delivery and their appropriateness; the level of involvement of relevant stakeholders in the selection of building materials for urban residential housing delivery in Ghana; and factors influencing the selection of building materials for urban housing delivery in Ghana.

#### **4.2 RESULTS**

##### **4.2.1 Results from Delphi Study**

A set of main attributes and sub-attributes that are relevant to building material selection for urban residential housing delivery were emphasised through a comprehensive review of literature (see table 2.5). This was followed up by the use of Delphi survey to determine the factors which are relevant in the Ghanaian construction industry. Hence, the Delphi survey was used to help achieving the research objective three (3) of the study. The research objective three (3) was purposely designed to identify and determine potential factors affecting the selection of walling materials for urban residential housing delivery in Ghana.

The impact of the main and sub-attributes of the Delphi survey were established by assessing the extent to which the listed attributes will determine the building material selection for urban residential housing delivery in Ghana. The rating was based on an

ordinal scale of one to ten with one being low influence or no impact and ten being high influence or very high impact. The levels of influence and impact were obtained as a product of the consensus achieved.

The objective of the Delphi study for round one was achieved through the responses received from the experts' to determine the attributes of building material selection for urban residential housing delivery in Ghana. Closed - ended questions were used throughout the two rounds of the study to investigate participant comments, expressing agreement, disagreement or clarification concerning proposed attributes that determine building material selection for urban residential housing delivery in Ghana. Frequencies were obtained to measure the degree of consensus reached amongst participants regarding the attributes that determine building material selection for urban residential housing delivery in Ghana. The purpose of the second round of the study was to allow experts to review and comment on the attributes that determine building material selection for urban residential housing delivery. In the second round, statistical information calculated from the first round was reported to each panel member. The results of each Delphi round were reviewed and compiled by the researcher. After analysing the responses from the second round, the characteristics, and features that determine building material selection as agreed upon by the panel of experts, were organized to create a complete picture of those attributes that determine building material selection for urban residential housing delivery in Ghana.

The median, mean and standard deviation of each question were calculated. During each round of questionnaires, the experts were given the results of the median of the previous round. A consensus is achieved with 100% of the participants in agreement

but, two-thirds in the agreement is considered a common consent (Stitt-Gohdes & Crews, 2004). The goal for this study was that each question or statement should have a consensus but, common consent would be acceptable. Common consent was obtained if 60.0% of the experts agreed on each statement that was achieved in the study (reference to Section 3.3.1.4).

All statements were examined individually for a consensus. The quantitative results were statistically analysed after each round of questionnaires to determine if a consensus had been reached for each question or statement using the provided scale for each question or statement. If a consensus was reached prior to the final round that question or statement was no longer required (asked/required) in the next rounds. After the second round Delphi Survey, consensus was reached regarding most of the attributes that determine building material selection for urban residential housing delivery in Ghana. Based on the findings of the analyses of responses from the Delphi rounds, a list of attributes that determine building material selection for urban residential housing delivery was prepared which informs the conceptual framework for the broader study.

By applying the Median Absolute Deviation to determine whether an attribute reached consensus or not, all the seven (7) main attributes were considered by the experts to have reached consensus. One (1) of the attribute (Cost/Economic Factors) from the seven (7) main attributes had very high impact (VHI -9-10) on building material selection for urban residential housing delivery in Ghana, while the remaining six (6) attributes had high impact (HI-7-8) under the median score (Table 4.1).

**Table 4.1: Building Materials Selection (BMS) for Urban Housing Delivery attributes**

<b>Building Materials Selection (BMS) for Urban Housing Delivery attributes</b>	$\bar{x}$	M	SD	MAD
<b>Environmental/Health Factors (EHF)</b>	7.89	8.00	1.00	0.78
<b>Cost/Economic Factors (CEF)</b>	8.78	9.00	0.97	1.00
<b>Sensorial Factors (SF)</b>	7.67	8.00	1.00	0.78
<b>Socio-cultural Factors (SCF)</b>	7.67	8.00	1.00	0.78
<b>Technical Factors (TF)</b>	8.11	8.00	0.93	0.56
<b>Performance Capacity (PCF)</b>	8.33	8.00	0.71	0.56
<b>General Factors (GF)</b>	8.11	8.00	0.60	0.33

M=Median;  $\bar{x}$ =Mean;  $\sigma_x$ =Standard Deviation (SD); |Di|=Median Absolute Deviation (MAD)

Source: Delphi Survey, 2018

Seven (7) attributes were identified from the first sub-attribute (Environmental/Health Factors). By applying the Median Absolute Deviation to determine whether an attribute reached consensus or not, all the seven (7) attributes were considered by the experts to have reached consensus. The experts also considered all the seven (7) attributes to have high impact (HI-7-8) on the attributes that determine building material selection for urban residential housing delivery in Ghana. The median score was used to determine the impact (Table 4.2).

**Table 4.2: Environmental/Health Factors**

<b>Environmental/Health Factors</b>	$\bar{x}$	<b>M</b>	<b>SD</b>	<b>MAD</b>
Environmental compatibility	7.44	8.00	0.73	0.56
Waste prevention	7.56	8.00	0.73	0.44
Health & Safety of user	8.11	8.00	0.93	0.78
Habitat disruption	7.00	7.00	1.22	1.00
Toxicity	8.33	8.00	1.03	0.92
Ozone depletion potential	7.11	8.00	1.12	0.83
Pollution	7.78	8.00	0.83	0.67

M=Median;  $\bar{x}$ =Mean;  $\sigma_x$ =Standard Deviation (SD); |Di|=Median Absolute Deviation (MAD)

Source: Delphi Survey, 2018

From the four (4) identified attributes under the second sub-attribute (Cost/Economic Factors), all the four (4) attributes were considered to have reached consensus when the median absolute deviation was used to achieve consensus. Three (3) out of the four (4) attributes had high impact (HI: 7-8) under the median score, while the remaining one (1) (Disposal cost) had medium impact (MI: 5-6) in determining building material selection for urban residential housing delivery in Ghana. The representation of all the attributes is shown in table 4.3.

**Table 4.3: Cost/Economic Factors**

<b>Cost/Economic Factors</b>	$\bar{x}$	<b>M</b>	<b>SD</b>	<b>MAD</b>
Initial cost	8.11	8.00	1.17	0.78
Maintenance cost	8.33	8.00	0.71	0.86
Disposal cost	6.78	6.00	0.97	0.97
Labour cost	7.89	8.00	0.93	0.83

M=Median;  $\bar{x}$ =Mean;  $\sigma_x$ =Standard Deviation (SD); |Di|=Median Absolute Deviation (MAD)

Source: Delphi Survey, 2018

From the seven (7) identified attributes under the third sub-attribute (Sensorial Factors), all the seven (7) attributes were considered to have reached consensus when the median absolute deviation was used to achieve consensus (Table 4.4). One (1) of the attributes (Appearance) had very high impact (VHI: 9-10) under the median score. The remaining six (6) other attributes had high impact (HI: 7-8) on building material selection for urban residential housing delivery in Ghana (Table 4.4).

**Table 4.4: Sensorial Factors (SF)**

<b>Sensorial Factors (SF)</b>	$\bar{x}$	<b>M</b>	<b>SD</b>	<b>MAD</b>
Appearance (Aesthetic value)	9.22	9.00	0.97	1.00
Texture	7.00	7.00	1.00	1.00
Temperature	7.89	8.00	0.78	0.56
Acoustics	7.33	8.00	0.87	0.78
Odour	7.67	7.00	1.12	0.91

### Sensorial Factors (SF) Continued

Sensorial Factors (SF)	$\bar{x}$	M	SD	MAD
Roughness	6.56	7.00	0.53	0.44
Fineness	6.56	7.00	0.53	0.44

M=Median;  $\bar{x}$ =Mean;  $\sigma_x$ =Standard Deviation (SD); |Di|=Median Absolute Deviation (MAD)

Source: Delphi Survey, 2018

All the four (4) attributes identified under the fourth sub-attribute (Socio-cultural Factors), were considered by the experts to have reached consensus when the median absolute deviation was used to determine consensus (Table 4.5). One (1) of the attributes (Owner/User's choice) had very high impact (VHI: 9-10) under the median score. The remaining six (6) other attributes had high impact (HI: 7-8) on building material selection for urban residential housing delivery in Ghana (Table 4.5).

**Table 4.5: Socio-cultural Factors**

Socio-cultural Factors	$\bar{x}$	M	SD	MAD
Compatibility with cultural/traditions	7.89	7.00	1.05	1.00
Owner/User's choice	8.89	9.00	1.17	0.98
Communal identity & setting	7.78	8.00	0.67	1.00
Cultural implications of material	6.56	7.00	0.53	0.44

M=Median;  $\bar{x}$ =Mean;  $\sigma_x$ =Standard Deviation (SD); |Di|=Median Absolute Deviation (MAD)

Source: Delphi Survey, 2018

All the eight (8) sub-attributes under the fifth sub-attribute (Technical Factors) identified were considered by the experts to have reached consensus when the median absolute deviation was used to determine consensus (Table 4.6). Seven out of the

eight (8) attributes had high impact (HI: 7-8) under the median score, except one (1) attribute (Weight & mass of material) which had medium impact (MI: 5-6). These representations are given in table 4.6.

**Table 4.6: Technical Factors**

Technical Factors	$\bar{x}$	M	SD	MAD
Reusability	7.33	7.00	1.22	1.00
Demountability	6.56	7.00	0.53	0.44
Ability to accommodate movement	7.00	7.00	0.71	1.00
Maintainability	8.11	8.00	0.60	0.33
Ease of construction (buildability)	8.44	8.00	1.13	0.89
Speed of Construction	7.78	8.00	0.67	0.44
Labour availability	8.44	8.00	1.13	0.87
Weight & mass of material	6.78	6.00	0.97	0.78

M=Median;  $\bar{x}$ =Mean;  $\sigma_x$ =Standard Deviation (SD); |Di|=Median Absolute Deviation (MAD)

Source: Delphi Survey, 2018

From the eight (8) attributes under the sixth sub-attribute (Performance Capacity) identified, all the eight (8) attributes were considered by the experts to have reached consensus when the Median Absolute Deviation was applied to determine consensus. Seven (7) of the attributes were considered by the experts to have high impact (HI: 7-8) under the median score. The remaining one (1) attribute (Scratch resistance) was considered by the experts to have medium impact (MI: 5-6) on building material selection for urban residential housing delivery in Ghana (Table 4.7).

**Table 4.7: Performance Capacity**

<b>Performance Capacity</b>	<b><math>\bar{x}</math></b>	<b>M</b>	<b>SD</b>	<b>MAD</b>
Fire resistance	8.44	8.00	0.88	0.67
Heat resistance	8.22	8.00	1.09	0.89
Water resistance	8.00	8.00	1.10	0.73
Chemical resistance	7.22	7.00	1.09	0.94
Scratch resistance	6.33	6.00	0.50	0.97
Strength	8.56	8.00	1.33	1.00
Durability	8.56	8.00	0.88	0.56
Resistance to decay	8.44	8.00	0.53	0.56

M=Median;  $\bar{x}$ =Mean;  $\sigma_{\bar{x}}$ =Standard Deviation (SD); |Di|=Median Absolute Deviation (MAD)

Source: Delphi Survey, 2018

From the eight (8) attributes under the seventh sub-attribute (General Factors) identified, all the eight (8) attributes were considered by the experts to have reached consensus when the Median Absolute Deviation was applied to determine consensus (Table 4.8). Two (2) of the attributes were considered by the experts to have very high impact (VHI: 9-10) under the median score. The remaining six (6) of the attributes were considered by the experts to have high impact (HI: 7-8) on building material selection for urban residential housing delivery in Ghana (Table 4.8).

**Table 4.8: General Factors**

<b>General Factors</b>	<b><math>\bar{x}</math></b>	<b>M</b>	<b>SD</b>	<b>MAD</b>
Availability of materials	9.00	9.00	0.87	0.67
Purpose of the building	8.56	9.00	1.13	1.00
Conformance with national policy	8.33	8.00	1.03	0.84
Type of Structure	8.00	8.00	1.12	0.89
Location of Site/Area climate	8.22	8.00	1.19	0.81
Energy efficiency	8.00	8.00	1.17	1.00
Shape of the structure	7.11	7.00	0.60	0.33
Material embodied energy	7.22	7.00	0.83	0.96

M=Median;  $\bar{x}$ =Mean;  $\sigma_x$ =Standard Deviation (SD); |Di|=Median Absolute Deviation (MAD)

Source: Delphi Survey, 2018

#### **4.2.2 Response Rate for the Main/Questionnaire Survey**

A total of 152 questionnaires were distributed by postal mail to respondents who were selected for the main survey. Six-two (62) questionnaires were dispensed to Architects, fifty-nine (59) to Quantity Surveyors and thirty-one (31) to Structural Engineers. Out of the 152 questionnaires distributed to the participants, 105 questionnaires (69.1%) were received for analysis as presented in Table 4.9.

**Table 4.9: Questionnaires distributed and responses received**

<b>Respondents</b>	<b>Questionnaires Distributed</b>	<b>Responses Returned</b>	<b>Percentage of Responses</b>
Architects	62	38	61.3%
Quantity	59	44	74.6%
Surveyors			
Structural Engineers	31	23	74.2%
Total	152	105	69.1%

Source: Field Data, 2018

### **4.2.3 Background Information of Respondents**

The initial part of the questionnaire included some background information regarding the respondents such as their profession, work experience, category of organization working with, position in organization, level of education etc. The size of the response across available response categories is indicated in both percentage (%) and frequency.

#### ***4.2.3.1 Profession of the respondents***

Table 4.10 shows the distribution of profession of the respondents.

**Table 4.10: Profession of Respondents**

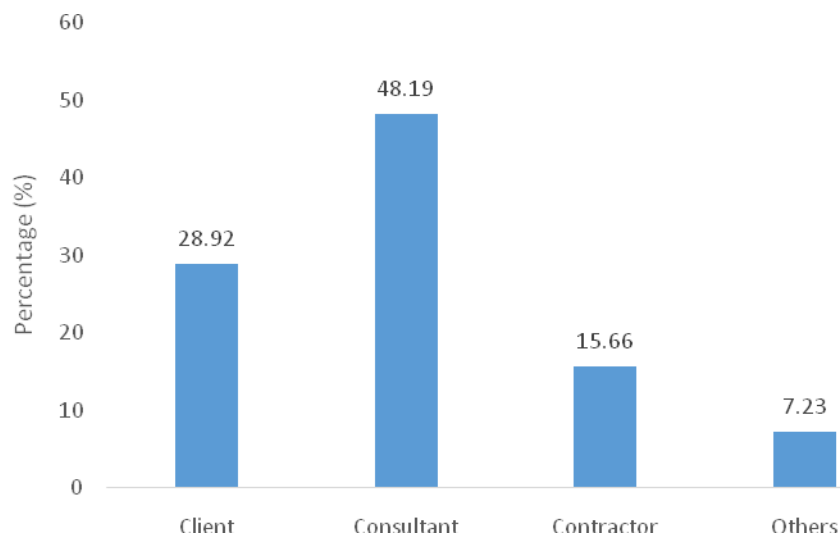
<b>Profession</b>	<b>Frequency</b>	<b>Percentage (%)</b>
Architects	38	36.2
Quantity Surveyors	44	41.9
Structural Engineers	23	21.9
<b>Total</b>	<b>105</b>	<b>100</b>

Source: Field Survey, 2018

The results from Table 4.10 shows that out of the 105 respondents in the survey, 38 (36.2%) of the respondents were Architects, 44 (41.9%) of them were Quantity Surveyors while 23 (21.9%) of the respondents were Structural Engineers.

#### **4.2.3.2 Category of organization of respondents**

Figure (4.1) shows the distribution of respondents, based on the category of organization they belong to.



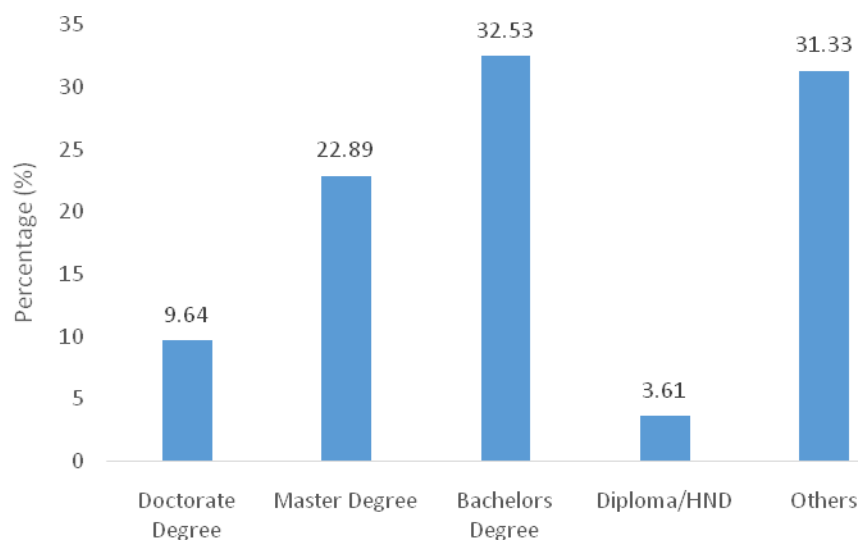
**Figure 4.1: Category of Organization of Respondents**

According to Figure 4.1, 48.2% of the respondents were in the category of Consultants, followed by client organizations which recorded 28.9%. Respondents

working with contractors were 15.7% whereas 7.2% of them work in other category of organizations.

#### 4.2.3.3 Educational qualification of respondents

The distribution of the respondents, based on their educational qualification is presented in Figure 4.2.



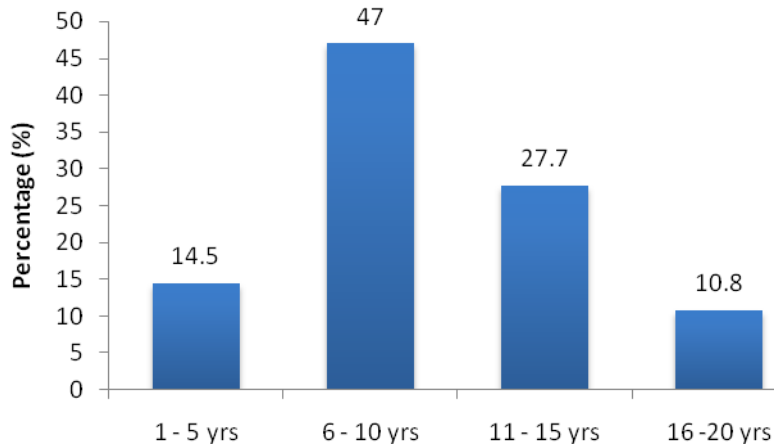
**Figure 4.2: Educational qualification of Respondents**

The study found that 9.6% of the respondents were doctorate degree holders, 22.9% of the respondents had masters degree. Respondents with Bachelors degree were highest with 32.5%. Respondents with Diploma/HND were 3.6% while 31.3% of the respondents were having other educational qualifications. The percentage of respondents with other qualifications was high because most of the architects specified their qualification to be postgraduate diploma.

This indicates that the results obtained from the survey represent the opinion of a group of well savvy professionals with good educational background and sufficient knowledge of construction projects to provide significant contribution to the study.

#### 4.2.3.4 Professional experience of respondents

Results presented in Figure 4.3 show the professional working experience of the respondents.



**Figure 4.3: Years of professional experience of respondents**

As indicated in Figure 4.3, only 10.8% of the respondents indicated their years of experience to be between 16 and above years, whilst majority (47%) of them had professional experience between 6 to 10 years. Twenty seven point seven percent (27.7%) had their professional experience between 11 to 15 years and respondents with 1 to 5 years of experience were 14.5%. As the experience of the respondents is quite respectable, opinions and views obtained through the survey can be regarded as important and reliable. Majority of respondents had reasonable experiences in the construction industry which further shows that respondents are sufficiently experienced enough to provide data which are credible.

#### 4.2.4 Commonly used Building Materials for Urban Residential Housing Delivery and Their Appropriateness

**Table 4.11: Respondents involvement in the selection of walling materials**

Response	Architects		Quantity Surveyors		Structural Engineers		Overall	
	Freq	Percent	Freq	Percent	Freq	Percent	Freq	Percent
Yes	38	100%	13	30%	23	100%	74	70%
No	0	0%	31	70%	0	0%	31	30%

Source: Field Survey, 2018

Seventy percent (70%) of the respondents indicated that they were involved in the selection of walling materials for residential housing delivery, while (30%) said they were not involved.

**Table 4.12: Types of walling materials Respondents used for residential housing construction**

Walling Materials	Architects		Quantity Surveyors		Structural Engineers		Overall	
	Freq	Percent	Freq	Percent	Freq	Percent	Freq	Percent
	Sandcrete Blocks	38	100%	13	100%	23	100%	74
Concrete Blocks	12	32%	4	31%	14	61%	30	41%
Adobe	4	11%	0	0%	5	22%	9	12%
Burnt Clay Bricks	25	66%	9	69%	18	78%	52	70%
Rammed Earth/Mud	0	0%	0	0%	0	0%	0	0%

**Types of walling materials Respondents used for residential housing construction  
Continued**

Walling Materials	Architects		Quantity Surveyors		Structural Engineers		Overall	
	Freq	Percent	Freq	Percent	Freq	Percent	Freq	Percent
	Timber	18	47%	7	54%	14	61%	39
Glass	16	42%	6	46%	18	78%	40	54%
Aluminium Panel	20	53%	7	54%	14	61%	41	55%
Plastic Panel	14	37%	6	46%	14	61%	34	46%
In-situ Concrete	7	18%	2	15%	9	39%	18	24%
Bamboo	6	16%	2	15%	5	22%	13	18%
Pre-cast Concrete Panels	6	16%	2	15%	9	39%	17	23%
Composite Boards	8	21%	2	15%	14	61%	24	32%
Steel	11	29%	4	31%	14	61%	29	39%

Source: Field Survey, 2018

With regard to types of walling materials respondents used for residential housing construction, all the 74 (100%) respondents to this question, said they used Sandcrete Blocks, 52 (70%) used Burnt lay Bricks, 41 (55%) used Aluminium, 40 (54%) used Glass, 39 (53%) used Timber, 34 (46%) used plastic Panel, 30 (41%) used Concrete Blocks, 29 (39%) used Steel, 24 (32%) used Composite Boards, 18 (24%) used In-situ Concrete, 17 (23%) used Precast concrete panels, 13 (18%) used Bamboo, 9 (12%) used Adobe, the use of Rammed Earth/Mud recorded 0 (0%).

**Table 4.13: Most Commonly used Walling Materials for Residential Housing Delivery in Ghana**

Walling Materials	Architects		Quantity Surveyors		Structural Engineers		Overall	
	Freq	Percent	Freq	Percent	Freq	Percent	Freq	Percent
	Sandcrete Blocks	38	100%	13	100%	23	100%	74
Concrete Blocks	0	0%	0	0%	0	0%	0	0%
Adobe	0	0%	0	0%	0	0%	0	0%
Burnt Clay Bricks	0	0%	0	0%	0	0%	0	0%
Rammed Earth/Mud	0	0%	0	0%	0	0%	0	0%
Timber	0	0%	0	0%	0	0%	0	0%
Glass	0	0%	0	0%	0	0%	0	0%
Aluminium Panel	0	0%	0	0%	0	0%	0	0%
Plastic Panel	0	0%	0	0%	0	0%	0	0%
In-situ Concrete	0	0%	0	0%	0	0%	0	0%
Bamboo	0	0%	0	0%	0	0%	0	0%
Pre-cast Concrete Panels	0	0%	0	0%	0	0%	0	0%
Composite Boards	0	0%	0	0%	0	0%	0	0%
Steel	0	0%	0	0%	0	0%	0	0%

Source: Field Survey, 2018

As shown in Table 4.13, all the 74 (100%) respondents indicated that the most commonly used Walling Material for residential housing delivery is Sandcrete Blocks.

**Table 4.14: Appropriateness of Walling Materials for Residential Urban Housing Delivery in Ghana**

<b>Walling Materials</b>	<b>Mean</b>	<b>SD</b>	<b>Rank</b>
Sandcrete Blocks	4.72	0.054	1 <sup>st</sup>
Concrete Blocks	3.02	0.632	5 <sup>th</sup>
Adobe	2.14	0.782	8 <sup>th</sup>
Burnt Clay Bricks	3.98	0.335	2 <sup>nd</sup>
Rammed Earth/Mud	1.11	0.081	14 <sup>th</sup>
Timber	2.78	0.839	7 <sup>th</sup>
Glass	1.29	0.783	12 <sup>th</sup>
Aluminium Panel	2.13	1.023	9 <sup>th</sup>
Plastic Panel	1.93	0.606	11 <sup>th</sup>
In-situ Concrete	2.07	0.765	10 <sup>th</sup>
Bamboo	1.22	0.226	13 <sup>th</sup>
Pre-cast Concrete Panels	3.74	0.948	3 <sup>rd</sup>
Composite Boards	2.80	0.432	6 <sup>th</sup>
Steel	3.65	0.643	4 <sup>th</sup>

Source: Field Survey, 2018

Table 4.14 indicates appropriateness of walling materials for residential urban housing delivery in Ghana. According to the respondents, Sandcrete Blocks are the most appropriate walling materials for residential urban housing delivery in Ghana which was ranked 1<sup>st</sup> with mean score of 4.72. This was followed by Burnt Clay Bricks with mean score of 3.98. Bamboo was ranked last but one (13<sup>th</sup>) and Rammed earth/Mud last (14<sup>th</sup>) with mean score of 1.22 and 1.11 respectfully.

#### 4.2.5 Level of Involvement of Relevant Stakeholders in the Selection of Building Materials for Urban Residential Housing Delivery in Ghana

**Table 4.15: Level of Involvement of stakeholders in the selection of walling materials**

Stakeholders	Architects		Quantity Surveyors		Structural Engineers		Overall	
	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank
Clients	4.94	1 <sup>st</sup>	4.67	1 <sup>st</sup>	4.72	1 <sup>st</sup>	4.76	1 <sup>st</sup>
Architects	4.82	2 <sup>nd</sup>	4.63	2 <sup>nd</sup>	4.71	2 <sup>nd</sup>	4.72	2 <sup>nd</sup>
Quantity Surveyors	3.84	3 <sup>rd</sup>	4.22	3 <sup>rd</sup>	3.68	4 <sup>th</sup>	3.91	4 <sup>th</sup>
Project Managers	1.95	8 <sup>th</sup>	1.83	7 <sup>th</sup>	2.04	7 <sup>th</sup>	1.94	7 <sup>th</sup>
Site Managers	2.28	5 <sup>th</sup>	1.98	6 <sup>th</sup>	2.14	6 <sup>th</sup>	2.13	5 <sup>th</sup>
Contractors	2.02	7 <sup>th</sup>	1.98	6 <sup>th</sup>	2.26	5 <sup>th</sup>	2.09	6 <sup>th</sup>
Structural Engineers	3.65	4 <sup>th</sup>	3.78	4 <sup>th</sup>	4.69	3 <sup>rd</sup>	4.04	3 <sup>rd</sup>
Suppliers of products	2.12	6 <sup>th</sup>	1.46	8 <sup>th</sup>	1.88	8 <sup>th</sup>	1.82	9 <sup>th</sup>
Product manufacturers	1.74	9 <sup>th</sup>	2.12	5 <sup>th</sup>	1.88	8 <sup>th</sup>	1.91	8 <sup>th</sup>

Source: Field Survey, 2018

Table 4.15 indicate level of involvement of relevant stakeholders in the selection of building materials for urban residential housing delivery in Ghana. Clients were ranked 1<sup>st</sup> with overall mean of 4.76. Architects were ranked 2<sup>nd</sup> with overall mean of 4.72. Structural Engineers were ranked 3<sup>rd</sup> with overall mean of 4.04. Quantity Surveyors were ranked 4<sup>th</sup> with overall mean of 3.91. Site Managers were ranked 5<sup>th</sup> with overall mean of 2.13. Contractors were ranked 6<sup>th</sup> with overall mean of 2.09. Project Managers were ranked 7<sup>th</sup> with overall mean of 1.94. Product Manufacturers were ranked 8<sup>th</sup> with overall mean of 1.91. Suppliers of Products were ranked 9<sup>th</sup> with overall mean of 1.82.

#### 4.2.6 Factors Influencing the Selection of Building Materials for Urban Residential Housing Delivery in Ghana

**Table 4.16: The relative importance index (RII) and rank of factors influencing the selection of building materials for urban housing delivery in Ghana**

Material Selection Factors	Architects		Quantity Surveyors		Structural Engineers		Overall	
	RII	Rank	RII	Rank	RII	Rank	RII	Rank
	<b>1. Environmental/ Health Factors</b>							
Environmental compatibility	0.750	37	0.758	32	0.775	26	0.761	33
Waste prevention	0.780	35	0.788	28	0.886	17	0.818	28
Health & Safety of user	0.890	20	0.940	8	0.889	15	0.906	13
Habitat disruption	0.820	31	0.688	37	0.689	28	0.732	36
Toxicity	0.782	34	0.698	36	0.806	22	0.762	32
Ozone depletion potential	0.820	31	0.787	29	0.655	30	0.754	34
Pollution	0.850	27	0.858	20	0.788	24	0.832	26
<b>2. Cost/ Economic Factors</b>								
Initial cost	0.976	2	0.983	1	0.956	3	0.972	2
Maintenance cost	0.920	14	0.908	12	0.933	9	0.920	10
Disposal cost	0.885	21	0.895	16	0.850	20	0.877	19
Labour cost	0.901	18	0.900	15	0.900	12	0.900	16

**The relative importance index (RII) and rank of factors influencing the selection of building materials for urban housing delivery in Ghana Continued**

Material Selection Factors	Architects		Quantity		Structural		Overall	
			Surveyors		Engineers			
	RII	Rank	RII	Rank	RII	Rank	RII	Rank
<b>3. Sensorial Factors</b>								
Appearance (Aesthetic value)	0.965	4	0.946	6	0.970	2	0.960	3
Texture	0.750	37	0.792	26	0.500	32	0.681	37
Temperature	0.835	29	0.849	21	0.788	24	0.824	27
Acoustics	0.860	25	0.753	33	0.788	24	0.800	29
Odour	0.883	22	0.685	38	0.670	29	0.746	35
Roughness	0.746	38	0.784	30	0.788	24	0.773	31
Fineness	0.677	39	0.783	31	0.550	31	0.670	38
<b>4. Socio-cultural Factors</b>								
Compatibility with cultural/traditions	0.885	21	0.842	22	0.775	26	0.834	24
Owner's/ User's choice	0.941	8	0.954	5	0.948	4	0.948	4
communal identity & setting	0.853	26	0.745	34	0.722	27	0.773	32
Cultural implications of material	0.765	36	0.820	25	0.808	21	0.798	30
<b>5. Technical Factors</b>								
Reusability	0.917	15	0.908	12	0.892	14	0.906	13
Demountability	0.806	32	0.892	17	0.800	23	0.833	25
Ability to accommodate movement	0.848	28	0.823	24	0.858	19	0.843	23
Maintainability	0.945	7	0.920	9	0.933	8	0.933	6
Ease of construction (buildability)	0.902	17	0.903	14	0.911	10	0.905	14
Speed of Construction	0.927	11	0.918	10	0.899	13	0.915	11
Labour availability	0.947	6	0.920	9	0.922	9	0.930	7
Weight & mass of material	0.922	13	0.900	15	0.850	21	0.891	17

**The relative importance index (RII) and rank of factors influencing the selection of building materials for urban housing delivery in Ghana Continued**

Material Selection Factors	Architects		Quantity Surveyors		Structural Engineers		Overall	
	RII	Rank	RII	Rank	RII	Rank	RII	Rank
	<b>6. Performance Capacity</b>							
Fire resistance	0.903	16	0.908	12	0.933	8	0.915	11
Heat resistance	0.922	13	0.908	12	0.882	17	0.904	15
Water resistance	0.953	5	0.942	7	0.902	11	0.932	8
Chemical resistance	0.922	13	0.917	11	0.900	12	0.913	12
Scratch resistance	0.832	30	0.908	12	0.850	20	0.863	20
Strength	0.983	1	0.978	2	1.000	1	0.987	1
Durability	0.975	3	0.968	3	0.938	6	0.960	3
Resistance to decay	0.927	11	0.955	4	0.935	7	0.939	5
<b>7. General Factors</b>								
Availability of materials	0.924	12	0.905	13	0.944	5	0.924	9
Material embodied energy	0.805	33	0.738	35	0.776	25	0.773	31
Energy efficiency	0.880	23	0.875	19	0.800	23	0.852	21
Type of Structure	0.891	19	0.885	18	0.850	20	0.875	20
Location of Site/Area climate	0.932	10	0.900	15	0.880	18	0.904	15
Conformance with national policy	0.935	9	0.825	23	0.900	24	0.887	18
Shape of structure	0.862	24	0.789	27	0.887	16	0.846	22
Purpose of the building	0.890	20	0.940	8	0.889	15	0.906	13

Source: Field Survey, 2018

The perspectives of Architects, Quantity Surveyors and Structural Engineers of the 46 factors influencing the selection of building materials were analyzed based on the

relative importance index. The relative importance index and ranks of building materials selection factors by all the respondents are presented in Table 4.16. The overall relative importance index is also presented in Table 4.16.

The Kruskal-Wallis (KW) test was then used to test the differences between the responses of the Architects, Quantity Surveyors and Structural Engineers. The KW results are shown in Table 4.17.

**Table 4.17: Kruskal-Wallis test for factors influencing the selection of building materials**

<b>Group/ Category</b>	<b>KW Value</b>	<b>DF</b>	<b>P-Value (Sig.)</b>
Environmental/ Health Factors	0.779	2	0.677
Cost/ Economic Factors	0.994	2	0.608
Sensorial Factors	0.298	2	0.862
Socio-Cultural Factors	0.885	2	0.642
Technical Factors	0.571	2	0.752
Performance Capacity Factors	0.073	2	0.964
General Factors	1.812	2	0.245

DF = Degree of Freedom

Source: Field Survey, 2018

As shown in Table 4.17, for all the group of factors influencing the selection of building materials, the p-value (sig.) for each group is greater than  $\alpha = 0.05$  ( $\alpha$  is the level of significance). So it can be concluded that there is no significant difference between the three groups of practitioners' (Architects, Qs and SEs) responses regarding the factors influencing the selection of building materials.

### 4.3 DISCUSSIONS OF MAIN RESULTS

#### 4.3.1 Commonly used Walling Materials for Urban Residential Housing Delivery and Their Appropriateness

It was revealed in the literature that before Ghana had contact with the European and influence of capitalism, buildings in Ghana were predominantly built with locally-based materials in the form of thatch, mud, wood, earth and bricks (Kwofie *et al.*, 2011). Today, there are more common building materials and products such as steel, cement, glass, aluminium, plastics, blocks, polished stone, ceramic products amongst others for the construction of urban residential housing. According to Bank of Ghana (BoG) Report ( 2007), the two main materials for the construction of the outer walls of a house in Ghana are mud/earth brick and cement/concrete, which together account for 89.1 per cent of wall materials of dwelling units. The earth/mud brick constitutes 50.0 per cent while concrete/cement constitutes 39.1 percent of the cases. Contrary, 2010 Ghana Population and Housing Census reported that cement blocks or concrete (57.5%) are the main construction material used for the outer walls of dwelling units in Ghana, followed by mud bricks or earth (34.2%). The results of this research indicated that nowadays, the most commonly used Walling Material for urban residential housing delivery in Ghana is Sandcrete Blocks. This was confirmed by all the respondents 74 (100%) as shown in Table 4.13.

It should be acknowledged that house design and delivery involves structural functionality, purpose and aesthetic issues that can be achieved through the choice of appropriate building materials. Stulz and Mukerji (1981) asserted that the starting point for any house design is the selection of “*appropriate materials*”, where availability plays an important role. With this regard, the respondents were asked to indicate materials that are most appropriate for urban residential housing delivery in

Ghana. As shown in Table 4.14, the respondents ranked Sandcrete Blocks first with mean score of 4.72. This indicates that, in the opinion of the respondents, Sandcrete Block is the most appropriate walling material for urban residential housing delivery in Ghana. This was followed by Burnt Clay Bricks with mean score of 3.98. Rammed earth/Mud was ranked fourteenth (last) with mean score of 1.11. Stulz and Mukerji (1981) were of the view that "Appropriateness" of a building material can never be generalized. Factors such as industrialization of the country, material origin, material price, transport facilities, and volume of elements made of selected material, climate compatibility, understanding of properties and handling, workers skills, social acceptance will determine appropriateness (Stulz&Mukerji, 1981). According to Royal Institute of Technology & Norway Technique University (1998) "Appropriate" building materials should also consider resource level, durability, reparability and recyclability during the service lifetime (aesthetic, economic, functional, physical i.e. use and maintenance and technical performance).

With regards to suitability of materials for building works, both Ghana Standard Code of Practice (GSCP) and Ghana National Building Regulation (GNBR) states that any material used in the erection of a building or in the structural alteration or extension of a building shall be of a suitable nature and quality for the purposes and conditions in which they are to be used or fixed so as to adequately perform the functions for which they are intended. Although building regulations pre-specify the materials to be used in the construction of houses, the analysis of a particular local condition will determine which materials are most suitable or appropriate for their usage. Section 32 (1) of GNBR (1996) specified that the following materials may be used in the construction of buildings so long as they conform to the provisions of these

regulations. They are: Mud used in plastic state to erect an earthen wall or for atakpame walling, Wattle and daub, Earth rammed between wooden or other formwork to make a wall in-situ, Unburnt earth bricks or blocks (adobe), Stabilized earth products, bricks or block (or landcrete), Burnt clay product, Sandcrete, concrete or reinforced concrete, Timber or bamboo products, Asbestos-cement products, Metal products, Glass and synthetic materials, Stone products, Lime-based materials.

#### **4.3.2 Involvement of Relevant Stakeholders in the Selection of Building Materials for Urban Residential Housing Delivery in Ghana**

In parallel with the growing trend in society towards greater participation in decision making, there has been a trend towards a wider view of people with an interest or ‘stake’ in organizations – the stakeholders i.e. client, architect, structural engineer, quantity surveyor, site manager, contractor, project manager, product manufacturers and suppliers (Harrison & Caron, 1998; Freeman, 1984; Mitroff, 1983). Surprisingly little is reported on the pragmatic influence of project stakeholders on selection of materials for building project. Respondents to this research were thus asked to rank the level of involvement of relevant stakeholders on a five-point scale from “lowest” (1) to “highest” (5), as it affects their material selection. Table 4.15 gives a summary of the result of respondents.

As shown in table 4.15, client has the highest degree of involvement, followed by Architects, Structural Engineers, Quantity Surveyors, Site Managers, Contractors, Project Manager, Product Manufacturers and Suppliers of product in that order. The client involvement is understandable as the client is legally responsible for the project, and carries the initial risk for the costs of the project. The importance of the client can further be reflected by the various ways they influence the adoption of innovation

strategy (Ling *et al.*, 2007; Shen & Tam, 2002; Chinyio, 1998). The client is vital for whether or not environmental goals are included in the project and exerts pressure on project participants to improve buildings' lifecycle performance (Gann & Salter, 2000). Further, the client is responsible for setting priorities and evaluating the actions throughout the production process. Some clients have a clear idea of a programme, budget, and other project objectives, including the final appearance of the building. Others look to their Architect to help them define the project objectives and to design a building that meets those objectives. In both cases the effectiveness of the relationship between client and architect is a major factor in making and implementing design decisions throughout the project.

The Architect should be the one who makes the final decision about every product and the one who takes the most responsibility for material/product selection. In reality, the leading architect teams up with the other architects like interior architects. The leading architect mainly concerns the visual design of the entire building. The Interior architect makes interior design and selects materials/products for interior use. Whenever possible and based on the contractual project arrangement, the contractor can give suggestions/recommendations to help architect when he or she didn't have enough information or experience about the materials and products. Moreover, because of the contractors' professional experiences about construction, it is possible for them to check whether the products are used for the right purpose. Also, during the process of material/product selection, the expert of materials characteristics must be the product manufacturers. To assist the architect or contractor with all their knowledge about materials/products, the product manufacturers should follow the

technical standards like standards of American Society for Testing and Materials (ASTM) to test each product.

#### **4.3.3 Factors Influencing the Selection of Walling Materials for Urban Residential Housing Delivery in Ghana**

The choice of building material has been described as an important design variable that can significantly affect the performance of the building (Nassar *et al.*, 2003). Building professionals (Architects, Structural Engineers and Quantity Surveyors) therefore have a decisive role to play in helping to implement sustainability in building project focusing on material selection. In order to maximize their influence, they need to understand the issues and factors related to building materials selection for housing projects.

The results of the study as shown in table 4.16 provide an indication of the relative importance index and rank of factors influencing the selection of building materials for housing delivery in Ghana. The following discussion is focused on the seven groups of building materials selection factors in descending order of their ranking.

##### **Cost/Economic Factors**

*The Cost/Economic factors* of building materials selection factors were ranked highest by all the respondents put together. *Initial cost* which is under *cost/economic factors* was ranked within the top ten most important factors influencing the selection of building materials for housing delivery in Ghana. *Initial cost* was determined by all respondents as the second most influential factor in the selection of building materials for housing delivery in Ghana. UN-HABITAT (2008) observed that the high cost of building materials among other factors underline the difficulties of housing delivery in Ghana. This then suggests the cost of materials as an influential factor in the

selection of building materials. However, there is the need for a suitable selection of quality low cost and sustainable building materials for housing delivery in Ghana.

### **Performance Capacity Factors**

The *performance capacity factors* were ranked the second most influential group of factors in building materials selection by the three groups of respondents. *Strength* was determined by all respondents under the performance capacity factors as the most influential factor in the selection of building materials for housing delivery in Ghana. *Strength, durability, resistance to decay, and water resistance* which are all under the *performance capacity factors* were all ranked within the top ten most important factors influencing the selection of building materials for housing delivery in Ghana. These results confirm that of Abeyundara and Babel (2009), who established that factors that greatly affect the selection of building materials for the construction of houses are good mechanical properties such as strength and durability.

### **Technical Factors**

Architects, Quantity Surveyors, and Structural Engineers together ranked *technical factors* as the third most influential group of factors in the selection of building materials for housing delivery. Within this group, Structural Engineers and Quantity Surveyors ranked *Maintainability* as the first most important factor in the selection of building materials. Architects on the contrary ranked *maintainability* as the second most important factor in building materials selection. For *labour availability*, the Architects rated 'labour availability' as the first most influential factor in the group where as Quantity Surveyors and Structural Engineers rated it as the second most influential factor in the selection of building materials. Architects and Quantity

Surveyors ranked *speed of construction* as the third most important factor in the selection of building materials. Structural Engineers on the other hand ranked *ease of construction (buildability)* as the third most important factor in building materials selection. Ademiluyi and Raji (2008) were of the view that physical characteristics of a house often depend on the technological know-how of the builders.

### **General Factors**

General factors as building materials selection factors group was ranked the fourth most important group of factors in the selection of building materials by the three groups of respondents. Within this group, Structural engineers ranked *availability of materials* as the most important factor in the selection of building materials. Quantity surveyors on the contrary ranked *purpose of the building* as the most influential factor in the selection of building materials, whereas Architects ranked *Conformance with national policy* as the most influential factor in the group. Quantity surveyors ranked *Availability of materials* as the second most influential factor while Architects rated *location of site/area climate* as the second most important factor in the selection of building materials. Structural engineers conversely rated *availability of materials* as the second most important factor in building material selection. These findings confirm that of Ademiluyi and Raji (2008) who asserted that physical characteristics of a house depend on the area's climate, the surrounding terrain, and the available building materials.

### **Socio-Cultural Factors**

Architects, Quantity Surveyors, and Structural Engineers together ranked *socio-cultural factors* as the fifth most essential building materials selection factor group

with relative importance index of 0.861, 0.840, and 0.828 respectively. Within this group, Architects, Quantity Surveyors and Structural Engineers all ranked *owner's/user's choice* as the most influential factor in the selection of building materials. Kwofie, *et al.* (2011), Adedeji (2010), and Gardi (1973), were of the view that housing delivery has been greatly influenced by ethnicity and geographical location. It should be acknowledged that cultural factors such as culture of a community in accordance with the lifestyle of its people, a group's preferences and values or an individual owner's social status, personal taste and financial resources, influence housing delivery. It is imperative to note that housing is an essential indicator of historical culture of any society (Adedeji, 2010).

### **Environmental/Health Factors**

The Environmental/Health factors group was ranked sixth by all the respondents. Architects, Quantity Surveyors and Structural Engineers all agreed that within the environmental/health factors group, health and safety of user was the major factor that influences the selection of building materials under this group. Building materials should pose no or very minimal environmental and human health risks (González & Navarro, 2006). Nonetheless, the results indicated that respondents do not consider environmental and health factors in selecting building materials for housing delivery. González and Navarro (2006) estimated that the selection of building materials with low environmental impacts can reduce carbon dioxide emissions by up to 30%. They further stated that building materials should satisfy the following criteria: rational use of natural resources; energy efficiency; elimination or reduction of generated waste; low toxicity; water conservation.

### **Sensorial Factors**

The sensorial factors group was ranked the lowest by the three groups of respondents. Regarding all the factors in the group, all the three parties ranked *appearance (aesthetic value)* as the most important building materials selection factor. The three groups further rated *temperature* as the second most important building material selection factor under this group. As indicated by the respondents, the *sensorial factors* is generally not considered so much in the selection of building materials for housing delivery in Ghana. Nevertheless, Abeysundara and Babel (2009) in their study established that building selection factors that greatly influence the selection of building materials for the construction of houses are thermal comfort and aesthetic characteristics.

Generally, all respondents agreed that the top ten most important factors influencing the selection of building materials for housing delivery in Ghana are: strength, initial cost, appearance (aesthetic value), durability, owner's/user's choice, resistance to decay, maintainability, labour availability, water resistance, and maintenance cost.

Based on the groups of building materials selection factors, the respondents generally agreed that the top three most important groups of factors are: Cost/Economic factors, Performance capacity factors, and Technical factors.

#### **4.3.4 Development of a Framework to Guide the Selection of Appropriate Walling Materials for Urban Residential Housing Delivery in Ghana**

Selecting suitable building material options for urban residential housing delivery can be a very complex process, being influenced and determined by numerous preconditions, decisions, and considerations (Wastiels & Wouters, 2008). In other

words, in choosing the right material for housing delivery, there is not always a single definite criterion of selection, which means designers have to take into account a large number of material selection factors (Rahman et al., 2008; Trusty, 2003). Nassar *et al.* (2003) asserted that, the selection of building materials is one of several factors that can impact the sustainability of a project. Treloar *et al.* (2001) were also of the view that, an appropriate choice of materials for a design process plays an important role during the life cycle of a building. Rahman et al. (2008) added that as with the design process, cautious consideration of contextual preconditions is crucial to selecting appropriate building materials. Therefore, the available information or data on building material options must be constantly evaluated to make well-considered and justifiable material choices, during the design-decision making and selection processes (Chan & Tong 2007; Trusty, 2003).

In attempts to achieve greater degree of proficiency in the material selection process and facilitate a constructive material selection process, most studies have generated material selection factors for assessing the performance of a variety of building materials for housing delivery. In order to identify and prioritize the factors, a thorough review of literature was conducted. Forty-six factors were identified through the literature review (Ogunkah & Yang, 2012; Florez *et al.*, 2009; Abeysuntara *et al.*, 2009; Seyfang, 2009; Bevan & Woolhey, 2008; Wastiels & Wouters, 2008; Rahman *et al.*, 2008; Ljungbeng, 2007; Van Kesteren *et al.*, 2005; Chueh & Kao, 2004; Kennedy, 2004; Cagan & Vogel, 2002; Ashley & Johnson, 2000). Since the factors gathered from the literature had been sufficiently tested and used in similar studies in other countries, they were used as basis for this study.

A multiple research approach involving Delphi survey and a questionnaire survey was adopted for the study. Delphi survey was carried out prior to the questionnaire survey to examine the relevance of the identified factors in the Ghanaian context. Three categories of practitioners within the construction industry were chosen for the questionnaire survey which included Architects, Quantity Surveyors and Structural Engineers. The study design led to a choice of only practitioners who are members of the following respective professional bodies: Architects Registration Council of Ghana, Ghana Institution of Surveyors and Ghana Institution of Engineers.

The Delphi survey was conducted amongst nine purposively selected architects in the Ghanaian construction industry. The Delphi survey led to the confirmation of 46 factors identified from the literature as relevant to selection of building materials for urban housing delivery in Ghana. These factors were further investigated in the questionnaire survey. The survey targeted Architects, Quantity surveyors and Structural engineers fully registered with the Architects Registration Council of Ghana (ARCG), the Ghana Institution of Surveyors (GhIS) and the Ghana Institution of Engineers (GhIE) respectively. Table 4.18 below shows the decisive factors generated by the researcher.

**Table 4.18: Decisive Factors Affecting Walling Materials Selection in order of importance**

<b>Group of Factors in order of importance</b>	<b>Sub-factors or variables in order of importance</b>
<b>1. Cost/Economic Factors</b>	<ol style="list-style-type: none"> <li>1. Initial cost (2)</li> <li>2. Maintenance cost (10)</li> <li>3. Labour cost (16)</li> <li>4. Disposal cost (19)</li> </ol>
<b>Group of Factors in order of importance</b>	<b>Sub-factors or variables in order of importance</b>
<b>2. Performance Capacity</b>	<ol style="list-style-type: none"> <li>1. Strength (1)</li> <li>2. Durability (3)</li> <li>3. Resistance to decay (5)</li> <li>4. Water resistance (8)</li> <li>5. Fire resistance (11)</li> <li>6. Chemical resistance (12)</li> <li>7. Heat resistance (15)</li> <li>8. Scratch resistance (20)</li> </ol>
<b>3. Technical Factors</b>	<ol style="list-style-type: none"> <li>1. Maintainability (6)</li> <li>2. Labour availability (7)</li> <li>3. Speed of construction (11)</li> <li>4. Reusability (13)</li> <li>5. Ease of construction (Buildability) (14)</li> <li>6. Weight &amp; Mass of the material (17)</li> <li>7. Ability to accommodate movement (23)</li> <li>8. Demountability (25)</li> </ol>

**Decisive Factors Affecting Walling Materials Selection in order of importance  
Cont'd**

<b>Group of Factors in order of importance</b>	<b>Sub-factors or variables in order of importance</b>
<p><b>4. General Factors</b></p>	<ol style="list-style-type: none"> <li>1. Availability of materials (9)</li> <li>2. Purpose of the building (13)</li> <li>3. Location of site/Area climate (15)</li> <li>4. Conformance with national policy (18)</li> <li>5. Type of structure (20)</li> <li>6. Energy efficiency (21)</li> <li>7. Shape of the structure (22)</li> <li>8. Material embodied energy (31)</li> </ol>
<p><b>5. Socio-cultural Factors</b></p>	<ol style="list-style-type: none"> <li>1. Owner's/User's choice (4)</li> <li>2. Compatibility with cultural/tradition (24)</li> <li>3. Cultural implication of material (30)</li> <li>4. Communal identity/Setting (31)</li> </ol>
<p><b>6. Environmental/ Health Factors</b></p>	<ol style="list-style-type: none"> <li>1. Health &amp; Safety of user (13)</li> <li>2. Pollution (26)</li> <li>3. Waste prevention (28)</li> <li>4. Toxicity (32)</li> <li>5. Environmental compatibility (33)</li> <li>6. Ozone depletion potential (34)</li> <li>7. Habitat disruption (36)</li> </ol>

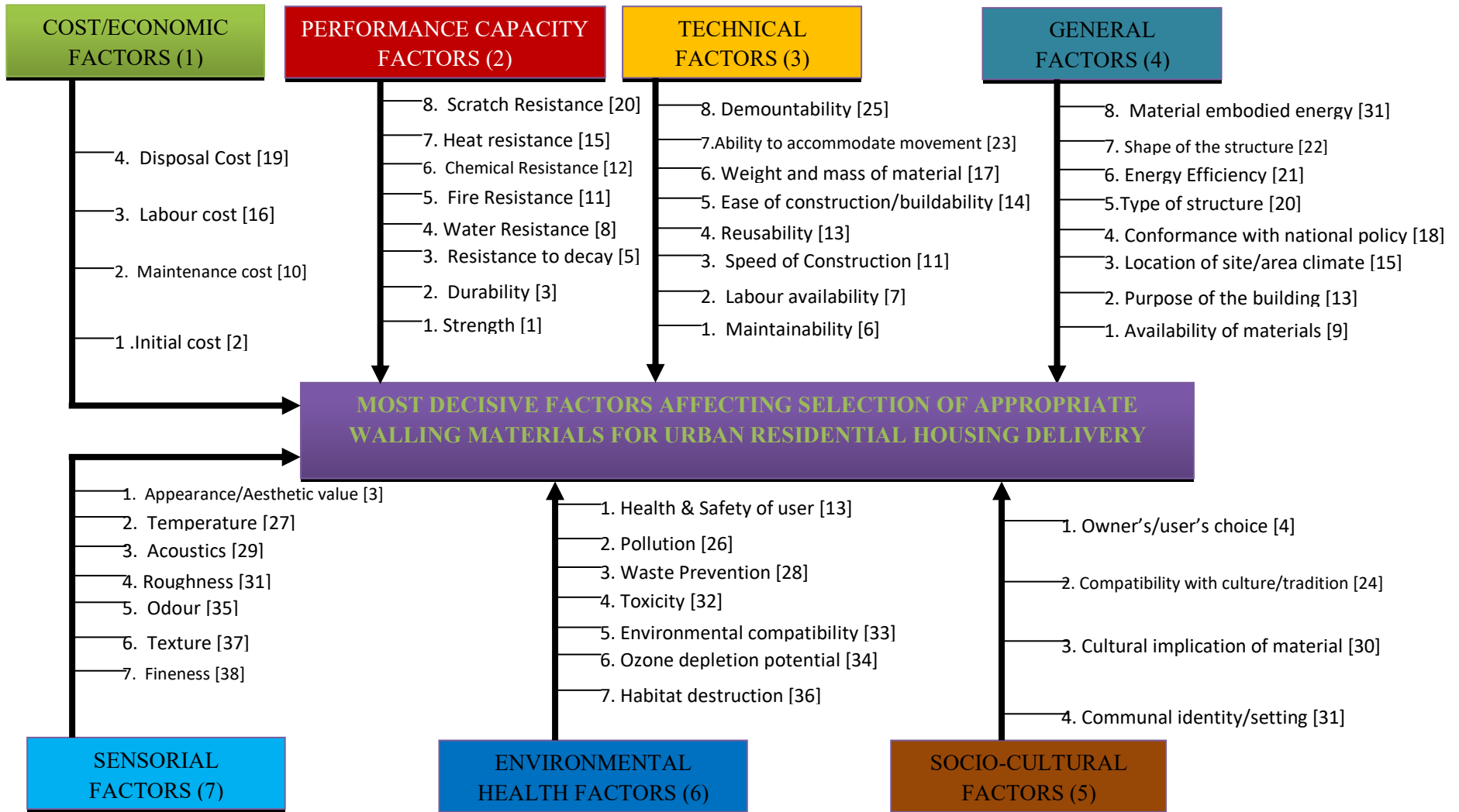
**Decisive Factors Affecting Walling Materials Selection in order of importance  
Cont'd**

<b>Group of Factors in order of importance</b>	<b>Sub-factors or variables in order of importance</b>
<b>7. Sensorial Factors</b>	<ol style="list-style-type: none"> <li>1. Appearance (Aesthetic value) (3)</li> <li>2. Temperature (27)</li> <li>3. Acoustics (29)</li> <li>4. Roughness (31)</li> <li>5. Oduor (35)</li> <li>6. Texture (37)</li> <li>7. Fineness (38)</li> </ol>

**Note:** the numbers in brackets ( ) show the position of the factors on the overall ranking

**Source:** Decisive Factors Generated by the Author

As explained early in section 4.3.4, a thorough review of literature was conducted to identify significant factors that influence the selection of building materials for urban residential housing delivery. Since the factors gathered from the literature had been sufficiently tested and used in similar studies in other countries, they were used as basis for this study. A multiple research approach involving Delphi survey and a questionnaire survey was used as a followed up to examine, prioritize and confirm the relevance of the identified factors in the Ghanaian context. Seven (7) main factors (Constructs) and forty-six sub-factors (variables) were confirmed at end of the processes (See Table 4.18). The numbers in brackets ( ) show the position of the factors on the overall ranking.



**Figure 4.4: Proposed Framework for Guiding the Selection of Appropriate Walling Materials for Urban Residential Housing Delivery in Ghana**

Figure 4.4 shows proposed framework for selecting appropriate walling materials for urban residential housing delivery in Ghana. The proposed framework is developed based on the significant factors established in the research objective three. These factors which the proposed framework was built upon were set of core factors that are the foundation for integrating and assessing the performance of a variety of building materials for housing delivery. The framework is presented in order of importance. The set of Group of Factors (main factors) in order of importance forming the building blocks of the proposed framework in harmony with this research were Cost/Economic Factors, Technical Factors, General Factors, Socio-cultural Factors, Environmental/Health Factors, Sensorial Factors, and Performance Capacity. Sub-factors or sub-variables were also generated from this set of main/group of factor to underpin the framework (See Table 4.18).

#### **4.4 SUMMARY**

The chapter covered results from the field survey and discussion of the results. The analysis and discussion were presented in six sections: response rate; background information of respondents; commonly used building materials for housing delivery and their appropriateness; the level of involvement of relevant stakeholders in the selection of building materials for urban residential housing delivery in Ghana; and factors influencing the selection of building materials for urban housing delivery in Ghana. Finally, the chapter presented a decisive factor framework to guide the selection of appropriate walling materials for urban residential housing delivery in Ghana. The next chapter presents the conclusions and recommendations that have been drawn from the

study. It also presents the contribution that this study has added to knowledge and recommendation for further studies.

## **CHAPTER FIVE**

### **SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS**

#### **5.1 INTRODUCTION**

This chapter presents the review of the research objectives, conclusion and recommendations that have been drawn from the study. It also includes the contribution that this study has added to knowledge and recommendation for further studies.

#### **5.2 REVIEW OF RESEARCH OBJECTIVES**

The aim of the research was to determine the factors affecting the selection of walling materials and develop a framework to guide the selection of such materials for urban residential housing delivery in Ghana. In pursuing this aim, four objectives were established. These objectives have been achieved by undertaking an extensive literature review, Delphi survey and a field survey on building materials selection for housing delivery. The fulfilment of each of the four research objectives is explained in the following subsections.

##### **5.2.1 Review of First Objective**

The first objective of the research focused on the commonly used walling materials for urban residential housing delivery in Ghana and their appropriateness. It was revealed that there are more common walling materials and products such as steel, cement, glass, aluminium, plastics, blocks, polished stone, and ceramic products amongst others for the

construction of urban residential housing in Ghana. Among all the materials stated in the survey, Sandcrete Block is the most commonly used Walling Material for urban residential housing delivery in Ghana. Also, it was found that Sandcrete Block is the most appropriate walling material for urban residential housing delivery in Ghana.

### **5.2.2 Review of second Objective**

The research objective two focused on the involvement of relevant stakeholders in the selection of walling materials for urban residential housing delivery in Ghana. The finding of this objective indicated that client has the highest degree of involvement in the selection of walling Materials for urban residential housing delivery in Ghana, followed by Architects, Structural Engineers, Quantity Surveyors, Site Managers, Contractors, Project Manager, Product Manufacturers and Suppliers of product in that order.

### **5.2.3 Review of Third Objective**

The third objective of the research focused on the factors influencing the selection of walling materials for urban residential housing delivery in Ghana. The study showed that, out of a total of 46 walling materials selection factors identified, the top ten most influential factors in the selection of walling materials for housing delivery in Ghana are as: strength, initial cost, appearance (aesthetic value), durability, owner's/user's choice, resistance to decay, maintainability, labour availability, water resistance and maintenance cost. The 46 walling materials selection factors identified in the study were grouped into seven categories and ranked accordingly.

#### **5.2.4 Review of Fourth Objective**

The research objective four focused on developing a framework to guide the selection of appropriate walling materials for urban residential housing delivery in Ghana. This framework development was important because it was apparent that majority of the existing building materials selection models/frameworks incorporated a few factors or variables which were not enough to help decision makers in their decision taken when selecting building materials for housing projects. This research objective sought to generate a schematic of material selection consideration factors that looks into specific aspects that concern practitioners in the construction industry in Ghana. This objective was realised based on most decisive materials selection factors identified in the research objective three.

### **5.3 CONCLUSION**

The study focused on walling materials selection for urban residential housing delivery in Ghana. Commonly used walling materials for urban residential housing delivery in Ghana and their appropriateness was identified. Among all the materials stated in the survey, Sandcrete Block is the most commonly used and the most appropriate Walling Material for urban residential housing delivery in Ghana. Involvement of relevant stakeholders in the selection of walling materials for urban residential housing delivery in Ghana was also considered in the study. The finding indicated that client has the highest degree of involvement in the selection of Walling Materials for urban residential housing delivery in Ghana, followed by Architects, Structural Engineers, Quantity Surveyors, Site

Managers, Contractors, Project Manager, Product Manufacturers and Suppliers of product in that order.

Out of a total of 46 walling materials selection factors identified, the top ten most influential factors in the selection of walling materials for housing delivery in Ghana are as follows: strength, initial cost, appearance (aesthetic value), durability, owner's/user's choice, resistance to decay, maintainability, labour availability, water resistance and maintenance cost. The 46 walling materials selection factors identified in the study were grouped into seven categories and ranked accordingly. All the respondents agreed that the cost/economic factors group of walling materials selection factors was the most influential group. Performance capacity factors group was considered the second most influential walling materials selection group of factors followed by technical factors. It is therefore, worthy to note that the appropriate selection of materials can influence the original cost, maintenance, durability and, of course, appearance of a building.

Finally, a framework to guide the selection of appropriate walling materials for urban residential housing delivery in Ghana was developed. This framework development was important because it was apparent that majority of the existing building materials selection models/frameworks incorporated a few factors or variables which were not enough to help decision makers in their decision taken when selecting building materials for housing projects and that has resulted in structures that are vulnerable, fragile, and difficult to maintain. This research objective sought to generate a schematic of material selection consideration factors that looks into specific aspects that concern practitioners in the construction industry in Ghana. This proposed material selection framework will

enable building professionals and stakeholders in general identify and prioritize the relevant criteria to effectively and accurately evaluate the trade-offs between technical, environmental, socio-cultural, cost, sensorial, performance and some general factors during the material evaluation and selection processes.

#### **5.4 RECOMMENDATIONS**

1. Stakeholders (Clients, Architects, Quantity Surveyors, and Structural Engineers) should consider all the important factors identified in this study when selecting walling materials for housing project in Ghana.
2. Building professionals and stakeholders in general in the construction industry should be encouraged to adopt the framework proposed by this study when selecting walling materials for urban residential housing delivery.
3. This framework when adopted by building professionals, will enable them identify and prioritize the relevant criteria to effectively and accurately evaluate the trade-offs between technical, environmental, socio-cultural, cost, sensorial, performance and some general factors during the material evaluation and selection processes.

#### **5.5 CONTRIBUTION TO KNOWLEDGE**

It was found in the literature that no framework/model have been developed to guide decision makers to select walling materials for urban residential housing delivery in Ghana. This research has identified decisive factors to guide decision makers to select

appropriate and suitable walling materials for urban residential housing delivery in Ghana. These decisive factors formed a framework which looks into specific aspects that concern practitioners in the Ghanaian construction industry. The adoption of this framework by stakeholders (decision makers) will help or guide them to select appropriate and suitable walling materials for urban residential housing delivery in Ghana.

#### **5.6 RECOMMENDATION FOR FURTHER STUDIES**

This study recommends that further studies should be carried out on materials selection for housing delivery. Hence, the specific topic recommended for further studies is ‘An integrated materials selection model for selecting sustainable materials for low-cost and sustainable housing delivery’. In considering this topic, the views of clients must be incorporated.

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## **APPENDICES**

### **APPENDIX A: DELPHI SURVEY**

#### **DELPHI INSTRUCTIONS FOR ROUND ONE QUESTIONNAIRE**

##### **DELPHI SURVEY – ROUND 1**

Thank you for accepting to serve on the Delphi panel for this research. Your acceptance is highly appreciated. This first Round survey is intended to complete in approximately 10-15 minutes. Subsequent surveys will require significantly less time to complete. You will be given the opportunity to change your response later on after all Delphi participants have completed the first Round survey and results have been analysed. The result will be communicated to you. The results will be in simple statistics e.g. median, average, range and percentage.

When you have finished answering all of the questions, please email your response to [skansah@hotmail.co.uk](mailto:skansah@hotmail.co.uk)

##### **INSTRUCTIONS**

1. Please answer all of the questions to the best of your ability.
2. Please indicate your response by placing an 'X' in the appropriate boxes. The survey requests that you rate the prospect of the elements influencing building materials selection for urban housing delivery in Ghana. You are also requested to rate the impact of other factors in predicting building materials selection for urban housing delivery in Ghana.

3. The influence (probability) scale is presented, and only a number should be used for a probability range. For instance, if you consider the influence (probability) range to be between 71 & 80% of the feature's influence then you should mark 'X' under the box '8'. If the impact is considered to be high, then 'X' should be marked under the '7' or '8' box depending on whether your opinion is inclined more towards high or very high impact.(See the attached questions).

Please use your experience, expertise and judgement to rate what you perceive to be the average negative or positive influence of the various features on building materials selection for urban housing delivery in Ghana.

**PROBABILITY SCALE (likelihood in percentage)**

1-10%	11-20%	21-30%	31-40	41-50	51-60	61-70	71-80	81-90	91-100
							<b>X</b>		

**IMPACT SCALE**

No impact		Low impact		Medium impact		High impact		Very high impact	
1	2	3	4	5	6	7	8	9	10

Q. 1. BUILDING MATERIALS SELECTION FOR URBAN HOUSING DELIVERY

MAIN ATTRIBUTES: To identify the main attributes that contribute to building materials selection for urban housing delivery in Ghana.

Building Materials Selection (BMS) for Urban Housing Delivery main attributes	What is the <b>influence</b> of the listed attributes on building materials selection for urban housing delivery in Ghana? (1=low probability, 10=high probability)											
		1	2	3	4	5	6	7	8	9	10	Median
<b>Environmental/Health Factors (EHF)</b>									x			
<b>Cost/Economic Factors (CEF)</b>									x			
<b>Sensorial Factors (SF)</b>									x			
<b>Socio-cultural Factors (SCF)</b>									x			
<b>Technical Factors (TF)</b>									x			
<b>Performance Capacity (PCF)</b>									x			
<b>General Factors (GF)</b>									x			

Q. 2. BUILDING MATERIALS SELECTION FOR URBAN HOUSING DELIVERY

SUB-ATTRIBUTES: To identify the sub-attributes that contributes to building materials selection for urban housing delivery in Ghana.

Q. 2.1 ENVIRONMENTAL/HEALTH FEATURES:

<b>Environmental/Health Factors</b>	What is the <b>impact</b> of the listed Environmental/Health features on building materials selection for urban housing delivery? (1=low probability, 10=high probability)											
	No impact		Low impact		Medium impact		High impact		Very high impact			
	1	2	3	4	5	6	7	8	9	10	Median	
Environmental compatibility								x				
Waste prevention								x				

Health & Safety of user								x			
Habitat disruption								x			
Toxicity								x			
Ozone depletion potential								x			
Pollution							x				

Q. 2.2 COST/ECONOMIC FEATURES:

<b>Cost/Economic Factors</b>	What is the <b>impact</b> of the listed Cost/Economic features on building materials selection for urban housing delivery? (1=low probability, 10=high probability)										
	No impact		Low impact		Medium impact		High impact		Very high impact		
	1	2	3	4	5	6	7	8	9	10	Median
Initial cost								x			
Maintenance cost								x			
Disposal cost								x			
Labour cost								x			

Q. 2.3 SENSORIAL FEATURES:

<b>Sensorial Factors (SF)</b>	What is the <b>impact</b> of the listed Sensorial features on building materials selection for urban housing delivery? (1=low probability, 10=high probability)										
	No impact		Low impact		Medium impact		High impact		Very high impact		
	1	2	3	4	5	6	7	8	9	10	Median
Appearance (Aesthetic value)									x		
Texture								x			
Temperature								x			

Acoustics								x			
Odour							x				
Roughness							x				
Fineness							x				

Q. 2.4 SOCIO-CULTURAL FEATURES:

<b>Socio-cultural Factors</b>	What is the <b>impact</b> of the listed Socio-cultural features on building materials selection for urban housing delivery? (1=low probability, 10=high probability)										
	No impact		Low impact		Medium impact		High impact		Very high impact		
	1	2	3	4	5	6	7	8	9	10	Median
Compatibility with cultural/traditions									x		
Owner/User's choice									x		
Communal identity & setting								x			
Cultural implications of material						x					

Q. 2.5 TECHNICAL FEATURES:

<b>Technical Factors</b>	What is the <b>impact</b> of the listed Technical features on building materials selection for urban housing delivery? (1=low probability, 10=high probability)										
	No impact		Low impact		Medium impact		High impact		Very high impact		
	1	2	3	4	5	6	7	8	9	10	Median
Reusability								x			
Demountability							x				
Ability to accommodate movement								x			
Maintainability								x			
Ease of construction								x			

(buildability)											
Speed of Construction							x				
Labour availability							x				
Weight & mass of material						x					

Q. 2.6 PERFORMANCE CAPACITY FEATURES:

<b>Performance Capacity</b>	What is the <b>impact</b> of the listed Performance features on building materials selection for urban housing delivery? (1=low probability, 10=high probability)										
	No impact		Low impact		Medium impact		High impact		Very high impact		
	1	2	3	4	5	6	7	8	9	10	Median
Fire resistance								x			
Heat resistance								x			
Water resistance								x			
Chemical resistance								x			
Scratch resistance							x				
Strength								x			
Durability								x			
Resistance to decay								x			

Q. 2.7 GENERAL FEATURES:

<b>General Factors</b>	What is the <b>impact</b> of the listed General features on building materials selection for urban housing delivery? (1=low probability, 10=high probability)										
	No impact		Low impact		Medium impact		High impact		Very high impact		
	1	2	3	4	5	6	7	8	9	10	Median
Availability of materials								x			
Purpose of the building								x			
Conformance with								x			

national policy											
Type of Structure								x			
Location of Site/Area climate								x			
Energy efficiency								x			
Shape of the structure							X				
Material embodied energy							X				

## Q. 2. PERSONAL INFORMATION OF EXPERT PANEL MEMBERS

Title (Mr, Mrs, Ms, Rev, Dr, Prof)	
Email:	
Highest qualification	
Field of specialisation	
Professional registration (ICIOB, MCIOB, FCIQB, MGIOC, FGIOC, MGhIS, FGhIS, etc.)	
Years of experience (Total Quality Management)	
Current employer	
Position	
Region	

Thank you for taking your time to fill out this first round survey. The second round of the Delphi process will be a follow-up email.

Please do not hesitate to contact me if you have any questions about this survey or the research project in general. Kindly see contact details below.

### Contact details:

**Samuel Kwame Ansah, Phil. Candidate**  
**Department of Construction Technology and Management**  
**College of Art and Built Environment**  
**Kwame Nkrumah University Science and Technology**  
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**APPENDIX B: QUESTIONNAIRE**

**KWAME NKURUMAH UNIVERSITY OF SCIENCE AND  
TECHNOLOGY**

**COLLEGE OF ARTS AND BUILT ENVIRONMENT**

**DEPARTMENT OF BUILDING TECHNOLOGY**

**SAMUEL KWAME ANSAH**

**MASTER OF PHILOSOPHY IN BUILDING TECHNOLOGY**

**(QUESTIONNAIRE)**

**Research Topic: A Framework for Guiding Walling Materials Selection for Urban Residential Housing Delivery in Ghana**

This research is part of a Master of Philosophy (MPhil.) thesis being conducted in the Department of Building Technology, Kwame Nkrumah University of Science and technology, KNUST, Kumasi.

Your participation in this study is voluntary but key to the success of the study. In order to protect your welfare and potential well-being, your identity will be protected by applying the principles of anonymity and confidentiality. These will be achieved by first making sure that readers of the final report cannot link a given response to any specific respondents, and secondly ensuring that the identity of respondent are not disclosed in any part of this research report.

This questionnaire is required to be filled with exact relevant facts as much as possible. Your co-operation would be greatly appreciated. Thank you for your time.

**SECTION A: Background of Respondent / General Information**

1. Profession (If more than one please ticks (√) them accordingly)

<b>Profession</b>	<b>Please Tick (√)</b>
1. Architect	
2. Quantity surveyor	
3. Project manager	
4. Construction manager	
5. Structural engineer	
6. Other (Specify.....)	

2. How long have you been in professional practice? Please indicate by ticking:  
 a. (1-5 years), b. (6-10 years), c. (11 – 15 years), d. (16 and above)

3. Category of Organization working with:

<b>Organization</b>	<b>Please Tick (√)</b>
1. Client	
2. Consultant	
3. Contractor	
4. Supplier	
5. Other (Specify.....)	

4. Please state your position in your organisation.....

5. Highest level of Educational?

<b>Qualification</b>	<b>Please Tick (√)</b>
1. Doctorate Degree	
2. Masters Degree	
3. Bachelors Degree	
4. HND	
5. CTC II/III	
6. Other (Specify.....)	

**SECTION B: Commonly used Building Materials for Housing Delivery and their Appropriateness**

6. Do you normally take part in the selection of walling materials for building construction?

Yes [ ]                      No [ ]                      (If No Go to Q8)

7. Indicate the various type of walling materials you used in your building construction works(*You can tick more than one*)

Walling Materials	Please Tick (√)
1. Sandcrete Blocks	
2. Concrete Blocks	
3. Adobe	
4. Burnt Clay Bricks	
5. Rammed Earth/Mud	
6. Timber	
7. Glass	
8. Aluminium Panel	
9. Plastic panel	
10. In-situ Concrete	
11. Bamboo	
12. Pre-cast Concrete Panels	
13. Composite Boards	
14. Steel	
15. Other (Specify.....)	

8. Indicate the most commonly used building material for walling systems in Ghana(*Please tick √ the appropriate box*)

Walling Materials	Please Tick (√)
1. Sandcrete Blocks	
2. Concrete Blocks	
3. Adobe	
4. Burnt Clay Bricks	
5. Rammed Earth/Mud	
6. Timber	
7. Glass	
8. Aluminium Panel	
9. Plastic panel	
10. In-situ Concrete	

11. Bamboo	
12. Pre-cast Concrete Panels	
13. Composite Boards	
14. Steel	
15. Other (Specify.....)	

9. Please in your view indicate the appropriateness of the following materials for urban residential housing delivery in Ghana *(Please tick ✓ the appropriate box)*

Materials	Not appropriate	Somewhat appropriate	appropriate	More appropriate	Most appropriate
	1	2	3	4	5
Sandcrete blocks					
Concrete blocks					
Adobe					
Burnt clay bricks					
Rammed earth / mud					
Timber					
Glass					
Aluminium panel					
Plastic panel					
In-situ concrete					
Bamboo					
Precast concrete panels					
Composite board					
Steel					
Others					

**SECTION C: Level of involvement of relevant Construction Industry stakeholders in the selection of building materials for Urban Housing delivery in Ghana**

10. Please rate on a scale of 1 – 5, the Level of Involvement of the following Stakeholders in the selection of materials for urban housing delivery in Ghana (**Not involved = 1 and Most involved = 5**) *(Please tick ✓ the appropriate box)*

Stakeholders	Not involved	Somewhat involved	Involved	More involved	Most involved
	1	2	3	4	5
Client/client Representative					
Architect					
Quantity Surveyors					
Project Managers					
Site Managers					
Contractors					
Structural Engineers					
Suppliers of products					
Product manufacturers					
Others (please specify)					

**SECTION D: Factors influencing the Selection of building materials for Urban Housing delivery in Ghana**

11. The following are factors influencing the selection of building materials. Please express your opinion on its importance in Ghana or which you think influences the selection of building materials in Ghana. Your perceived factors could be added. (Please tick the appropriate box).

1 - Not Important 2 – Slightly important 3 - Important 4 - Very Important 5 - Highly Important

Material Selection Factors	1	2	3	4	5
<b>1. Environmental/Health Factors</b>					
Environmental compatibility					
Waste prevention					
Health & Safety of user					
Habitat disruption					
Toxicity					
Ozone depletion potential					
Pollution					
<b>2. Cost/Economic Factors</b>					
Initial cost					
Maintenance cost					
Disposal cost					
Labour cost					

<b>3. Sensorial Factors</b>					
Appearance (Aesthetic value)					
Texture					
Colour					
Temperature					
Acoustics					
Odour					
Roughness					
Fineness					
<b>4. Socio-cultural Factors</b>					
Compatibility with cultural/traditions					
Owner/User's choice					
Communal identity & setting					
Cultural implications of material					
<b>5. Technical Factors</b>					
Reusability					
Demountability					
Ability to accommodate movement					
Maintainability					
Ease of construction (buildability)					
Speed of Construction					
Labour availability					
Weight & mass of material					
<b>6. Performance Capacity</b>					
Fire resistance					
Heat resistance					
Water resistance					
Chemical resistance					
Scratch resistance					
Strength					
Durability					
Resistance to decay					
<b>7. General Factors</b>					
Availability of materials					
Material embodied energy					
Energy efficiency					
Type of Structure					
Location of Site/Area climate					

Conformance with national policy					
Shape of structure					
Purpose of the building					