THE UNIVERSITY OF NAIROBI

AN EVALUATION OF ADOPTION CRITERIA OF ALTERNATIVE BUILDING MATERIALS BY BUILDING PROFESSIONALS

(Case study of Nairobi City)

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MA IN CONSTRUCTION MANAGEMENT PROJECT

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DECLARATION

This project report is my original work and has not been presented to any university for academic award

Sign: --- ---

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B53/75505/2014

This project report has been submitted for examination with my approval as the University Supervisor

Sign: --- ---

Dr.-Ing.Christopher M.Mbatha Date

DEDICATION

I dedicate this project report to my wife Eng. Caroline Nzioka and my family for their support and bearing with me during this process. I will remain forever grateful.

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ABBREVIATIONS AND ACRONYMS

ABM	**-**	Alternative Building Materials
ASTM	-	American Society for Testing and Materials
CO2	-	Carbon Dioxide
CSSB	-	Cement Stabilized Soil Blocks
DCS	-	Dry Compressive Strength
EPS	-	Expanded Polystyrene
FRC	-	Fibre Reinforced Concrete
HFC	-	Housing Finance Corporation
HPRFC	-	High Performance Fiber Reinforced Cementitious Composites
HSC	-	composite Honeycomb
ISSB	-	Interlocking Stabilized Soil Blocks (ISSB
KEBS	-	Kenya Bureau of Standards
MCR	-	Micro Concrete Roofing
MgO	-	Magnesium Oxide
MPa	-	Megapascal
OSB	-	Oriented Strand Board
PCF	-	Photonic Crystal Fiber
PS	-	Polystyrene
PSi	-	Per Square Inch
SIP	-	Structural Insulated Panels

SPSS	**-**	Statistical Package of Social Sciences
WCS	-	Wet Compressive Strength

ABSTRACT

All buildings will in one way or another involve the selection of building materials to be used or means used for the adoption process (Florez et al., 2009). Selecting the appropriate building material is a complicated task which involves making choices among very many competing factors. In selection of a building material, there are various considerations to be made and there is no specific criterion of adoption. This study mainly aimed at evaluating the adoption criteria of alternative building materials by building professionals with a focus on Nairobi city. Specifically the study sought to; identify the locally available alternative building materials; establish the published quality standards of the alternative building materials; establish specification criteria by building professionals, regulator's (KEBS) published quality standards, opinions and experiences of building professionals (Architects, Civil/structural engineers and Quantity surveyors). The study adopted a descriptive research design. The study targeted 63 building professionals in Kenya plus one respondent from Kenya Bureau of Standards. The study relied on data collected through structured questionnaires. Responses were tabulated, coded and processed by use of a computer software (Statistical Package for Social Science (SPSS) version 20.0) to analyze the data. The study found out that majority of building professionals are aware but have not used the ABM. The study further found that commercial status (the building selling price) is considered the least important and cost as the most important criteria in adoption of ABM by building professionals.

CHAPTER ONE

INTRODUCTION

1.0 Background to the Study

Before commencement of any building project, the consultants will have to make a decision on what type of building material they will use (Florez et al., 2009). Selection of suitable building material is a complex process which is influenced and determined by many preconditions and considerations. There are various criterion considered before one makes a decision on what building material to choose and this is influenced by various factors. During the design-decision making and adoption process, the information available on the materials and products under consideration has to be well analysed so that the most appropriate decision is made in choosing the building material. With increased advocacy for green building or the low-carbon building movement, researchers are working very hard to promote the use of locally available building materials or recycled materials in building construction industry as alternative building materials (Chan, 2007). Studies by experts have proved that the use of locally available building materials or recycled materials do reduce the amount of carbon dioxide emissions and therefore resulting into healthier buildings, and also improving the local economy (Kibert, 2008). Those opposed to the use of alternative building materials argue that information available on alternative building materials is sourced from biased studies, and only considering very limited factors or variables (Hulme and Radford, 2010). These two researchers also argue that the full potential of these alternative building materials has not been empirically considered, despite the fact that there is a lot of activism for low- impact development both locally and internationally. These approaches have limited the adoption levels of these alternative building materials and thwarted their full adoption (Fernandez, 2006).

While it is a fact that there is need to actively embrace the use of new technologies to optimize the use of greener building materials, it is also a fact that there exists various modern technologies in use in Kenya. Many of these technologies have evolved from earlier campaigns promoting construction of sustainable buildings, originating from the 1970s environmental movement and there after supported by the push for the construction of green buildings (Hulme and Radford, 2010). The green proponents have termed their approach as successful in spreading ideas about best practices. However, builders looking for a different way of assessing the material-adoption process have been faced with a limited availability of such systems that support the effective use of locally available building materials or recycled building materials in the design-decision making stage of a building (Fernandez, 2006). There are several factors to be considered in determining whether an alternative building material is better for the environment, these factors include; the cost of the material, its manufacturing process, its design suitability, source of its components, how it is transported and many more (Trusty, 2003). The fact that various factors have to be considered in selecting a building material means that there is need to develop a systematic material adoption system that enables consultants involved in material selection during the design-decision making process choose the best criteria to evaluate the trade –offs between performance, environment, technical and economic issues during the material assessment and selection process. For the process of material selection to be objective and efficient, it is important that the person (s) involved in the material selection consider various material-adoption factors or variables (Rahman et al., 2008).

There are various factors that contribute to the value of a given construction material or its performance which include ergonomics, aesthetics, quality and technology used in its' production (Cagan and Vogel, 2002). It is important to note that, their research was in agreement that consumer perception is a main determining factor in material choice. Even though it is important for every building material to satisfy these factors, they are not enough to measure the performance of a given building material (Ljungberg, 2007).The major determinants of the quality of a building material include serviceability, aesthetics, reliability, durability, conformance and value (Chueh and Kao , 2004). They also found consumer perception as a major determinant of material choice and performance. In his study, Ljungberg was able to develop a mixed system where factors such as low reparability, trend breaking, users' satisfaction and safety were used to measure material performance.

Glaric,P.; Lukman, R (2007) made use of the mixed integer optimization approach as a tool to be used for building material adoption while at the same time considering subjective needs in building projects. In this system, sustainability index expressed by a set of binary scores was used to assist decision makers in optimizing the adoption of various materials. In Kenya, architects have out of their training been inclined to implement their design solutions for building by using conventional approaches. For that reason many of the building projects have mainly depended on supplies of factory-made building materials, such as steel, glass and cement (Magutu, 2015). The demand for factory-made materials in most cases surpass the supply, this causes wastage, high material costs, delays and in some instances the emergence of black markets (Spence and Cook, 1983). Until recently, many colleges in Kenya which train architects and engineers did not include appropriate technology in the curricula and many of these professionals are reluctant to deviate from conventional approaches when designing buildings. This results to an end product which is unaffordable and inappropriate to the end user (Goodman, et al., 1976). Since most projects are restricted by time, architects or designers don't get adequate time to research on other available alternative building materials which promote low cost building. Various studies done elsewhere have shown that the main obstacle to the use of alternative building materials in the building industry is mainly to do with attitudes of the low income end users who see these materials as being cheap, temporary and backward (Goodman et al., 1976). Kenya Bureau of Standards (KEBS) has taken various steps aimed at promoting the adoption of alternative building materials such as application of these materials and technologies in major urban centers and also enactment of some guide standards (Magutu, 2015).

1.1 Problem Statement

It has been observed that, despite the emergence of various alternative building materials as outlined in the literature review, most building professionals (Architects, Civil engineers and Quantity Surveyors) prefer to specify the use of conventional building materials. Even with the concerted effort by the proponents of these alternative building materials (including the Kenyan government through Housing Finance Corporation (HFC)) to increase their adoption into the market, the adoption rate is very low (Magutu, 2015). It is for this reason that a research is necessary to identify the alternative building materials which are available in the market and can be used in place of the conventional building materials. Establish the criteria used by building professionals in selecting the type of building material to be used in different areas in a building. It is also necessary to establish whether the alternative building materials meet the specified quality standards by relevant organizations and also establish whether KEBS has undertaken quality tests on these ABM to ensure that they are of the expected standards. Most important is to establish whether these ABM have passed the critical tests so that they can be allowed to be used in the building industry.

1.2 Research Questions

The research questions are;

i. Are there locally available alternative building materials which can be used instead of the conventional building materials?
ii. Have the ABM met the quality standards as specified by KEBS?
iii. What are the adoption criteria of these ABM by building professionals?

iv. What are the opinions and experiences of building professionals on the use of ABM?

1.3 Objectives of the Study

The objectives of the study are;

i. To identify the locally available alternative building materials
ii. To establish the published quality standards of the alternative building materials
iii. To establish the adoption criteria of these ABM by building professionals
iv. To establish the opinions and experiences of building professionals on the use of ABM

1.4 Significance of the Study

Building materials form a very significant percentage of the total resources involved in all building works. Over the years, building materials have continued to be scarce as their sources get depleted every day. This has led to increased cost of construction and environmental degradation. In view of the above, we have had the emergence of other alternative building materials (ABM) which can be used instead of the conventional building materials. Researchers have found these materials to be of good quality, less costly and also environmentally friendly. Despite these findings, building professionals in Nairobi city continue to use the conventional building materials! It is for this reason that this research has been undertaken to find out why the adoption rate of the ABM is very low even with all the advantages they are associated with.

1.5 Limitations of the Study

This study was carried out in Nairobi City and its findings may not be applicable in other areas. The study depends purely on information obtained from third parties and no attempt was made to verify the information obtained especially information on the quality of various ABM.

1.6 Assumptions of the Study

The study assumes that data collected from secondary sources is accurate and reliable and also respondents of questionnaires given are genuine and data collected from these questionnaires is accurate and also reliable.

1.7 Structure and Organization of the Study

The study is presented in five chapters;

i. Introduction

ii. Literature review

iii. Research methodology

iv. Data analysis, presentation and interpretation

v. Summary, discussion, conclusions and recommendations

1.8 Conclusion

At the end of the study, the objectives of the study were met and recommendations were made for further research. Some challenges were encountered in the process of data collection although not significant enough to affect the study objectives.

CHAPTER TWO

LITERATURE REVIEW

2.0 Building Materials in General

Clay, sand, wood, rocks, leaves and twigs have been used as building materials for a very long time. Other than naturally occurring materials, many artificial building materials have emerged over time. The manufacturing of building materials is well established in many countries all over the world and is typically segmented into specific specialty trades, such as plumbing, roofing work, masonry, insulation and carpentry. Alternative building materials (ABM) are those materials which have been newly created or noticed and are growing in strength or popularity. On the other hand, conventional building materials are those materials which have been in use for centuries and have become common practice in the construction industry. The ABM in this case study are; expanded polystyrene panels, structural insulated panels, fibre reinforced concrete, precast concrete panels, interlocking stabilized soil blocks, artificial pozzolans (biomass fly ash) and concrete with quarry dust as fine aggregate. There are conventional building materials which have been in use in Kenya for very many years. Some of these materials are; wood/timber, natural fibres, natural stone products, earth/soil, concrete, glass and metals (Paterson, 1971).

2.1 Alternative Building Materials

There are various alternative building materials in the Kenyan market. The manufacturers or suppliers of these materials have put forth a spirited campaign for their adoption in the Kenyan market. For any building material to be allowed to enter the Kenyan market, it has to meet the standard specifications laid down by statutory bodies e.g. KEBS. The proponents have in their various campaigns outlined various reasons as to why builders/home owners should adopt ABM instead of using the conventional building materials. These materials are said to be widely used in other countries yet their adoption in Kenya has been very slow (Magutu, 2015). Research done by Magutu in the year 2015 found the following alternative building materials as the most available in Nairobi and that is why they were chosen for this study. They are;

1. Expanded polystyrene panels
2. Structural insulated panels
3. Fibre reinforced concrete
4. Precast concrete panels
5. Interlocking Stabilized Soil Blocks (ISSB)
6. Artificial pozzolans e.g. biomass fly ash
7. Concrete with quarry dust as fine aggregate

2.1.1 Expanded Polystyrene Panels/Sheets

Polystyrene (PS) is a synthetic aromatic polymer made from the monomer styrene. It can be solid or foamed. Expanded polystyrene (EPS) is tough and rigid. EPS is usually white in colour and it is made using pre-expanded polystyrene beads. EPS is used in making molded sheets for building insulation and packing materials. Styroboard EPS has been proven to be a good construction material (Mwafongo, 2012). Styroboard EPS is strong, easy to handle, light in weight and easy to clean. Styroboard EPS has insulating properties against unwanted temperatures and noise and therefore it can be used as a base for rendered panels. Panels made of EPS are weather resistant and have low moisture absorbency rates. Styroboard EPS is an appropriate material for insulating ceilings, flat and inverted roofs, coldrooms and underslabs. Styroboard EPS sheets are manufactured in varying thicknesses depending on where they are to be used. Although EPS is a good insulator, and generally resistant to moisture gain, moisture content affects its thermal performance just like any other insulating material. When Styroboard EPS is incorporated in concrete and masonry walls, the thermal mass advantage of concrete and masonry walls are enhanced (Mwafongo, 2012). There is a linear relationship between moisture content increase by volume and thermal resistance (R-Value). Approximately, 1% of moisture content increase by volume will result in a 2.5% loss of R-value (Mwafongo, 2012). The production of Styroboard EPS doesn't produce ozone depleting gases and it can therefore be termed as environmentally friendly. The production of Styroboard EPS ensures minimal emissions of carbondioxide and consequently reduces the effects of global warming. Styroboard EPS doesn't degrade into harmful substances or contaminate ground water. Unlike other building materials like asbestos, there has not been any report by any world organization to the effect that there exist any harmful effects on health that could be associated with casual relationship with Styroboard EPS (Mwafongo, 2012).

2.1.1.1 Structural Properties of EPS

EPS is a closed cell, thermalpastic material that can be manufactured to meet particular requirements of residential, commercial and civil engineering projects. EPS has comprehensive strengths ranging from 10 PSi to 60 Psi depending on the end use of the panels (Mwafongo, 2012).Table 2.1 below shows different strength properties of EPS of different densities taken at 70^{o} F Test Temperature.

Density (pcf)	**Compressive strength (Psi)**	**Tensile Strength (Psi)**	**Flexural Strength (Psi)**	**Shear Strength (Psi)**
1.0	10-14	16-20	25-30	18-22
1.5	15-21	18-22	40-50	26-32
2.0	25-33	23-27	50-75	33-37
2.5	42	74	75	92
3.0	64	88	88	118
3.3	67	98	105	140
4.0	80	108	125	175

Table 2.1: Structural Properties of EPS (70^{o} F Test Temperature)

Source: ASTM, 2012

2.1.1.2 Water Absorption and Vapor Transmission of EPS

EPS has been tested and proved to be non-hygroscopic. Its closed-cell structure reduces absorption of moisture. Tests carried out on EPS have confirmed that its low moisture absorption rate ensures that its thermal performance is least affected even when exposed to high levels of moisture content. EPS is resistant to liquid water but it is moderately permeable to water vapor under pressure differentials (Mwafongo, 2012).Vapor permeability is determined by both thickness and density. Mechanical properties of EPS are not affected by either liquid water or water vapor. Table 2.2 below gives a summary of data on water absorption and vapor transmission properties of EPS.

	Type I (0.90 pcf)	**Type VIII (1.15 pcf)**	**Type II (1.35pcf)**	**Type IX (1.80 pcf)**
Max absorption percentage by volume	<4.0%	<3.0%	<3.0%	<2.0%
Max water vapor transmission	2.0-5.0 perms	1.5-3.5 perms	1.0-3.5 perms	0.6-2.0 perms
Capillary action	None	None	None	None

Table 2.2: Water Absorption and Vapor Transmission properties of EPS

Source: Mwafongo, 2012

2.1.2 Interlocking Stabilized Soil Blocks (ISSB)

Research carried out on ISSB has proved them to be appropriate construction material and they have been found to be more economical as compared to building materials such as natural stones or bricks. Various organizations have successfully promoted their adoption in various countries. In production of ISSB, a small amount of cement is mixed with local soil and water in a given ratio depending on the quality of soil. The mix is placed in a simple hand operated machine and compacted into blocks. The blocks are then arranged in lines and covered with polythene paper to avoid direct sun light. They are left covered for a period of one week to cure. After one week, they are ready for use in construction (Geoffrey, 2001).

Unlike clay bricks, ISSB are formed by a mixture of cement, soil and water and they are cured rather than fired. This ensures that trees are not cut down to fuel brick kilns and therefore ISSB are more environmentally friendly than bricks. By not cutting trees, forests are preserved and emission of carbon dioxide into the atmosphere is reduced. Since ISSB have an interlocking mechanism, less mortar is needed between courses. This makes construction easier and faster hence reducing costs. ISSB technology has various advantages compared to other technologies; it is versatile in use, affordable, user friendly, environmentally friendly among others (Geoffrey, 2001). However, care must always be taken to ensure the blocks are of high quality. The quality of ISSB will depend on the type of soil used, the stabilizer used to compliment the soil and the method of production used. The production process of ISSB can be customized to produce curved ISSB. The curved blocks can be used in construction of water tanks, lining for pit latrines and septic tanks. The machine used to make ISSB is easy to use and maintain. Table 2.3 below shows how the compressive strength of ISSB after 28 days varies with different percentages of cement content used in the mixture.

CEMENT CONTENT	**MEAN COMPRESSIVE STRENGTH (Mpa)**		
	Cement Stabilized Soil Block (CSSB)		
%	Wet compressive Strength (WCS)	Dry compressive Strength (DCS)	Ratio
3	1.43	2.70	1.9
5	2.48	4.61	1.9
7	4.57	7.33	1.6
9	6.54	9.66	1.5
11	8.99	12.30	1.3

Table 2.3: Values of the 28 day mean WCS and DCS of CSSB

Source: Geoffrey, 2001

2.1.3 Structural Insulated Panels (SIP)

SIP are appropriate building systems for both light commercial construction and residential construction. The panels are made of an insulating foam core inserted between two structural facings commonly oriented strand board (OSB). The board can be made of different materials depending on the intended use of the SIP. The board can be made of plywood, magnesium oxide board (MgO), sheet metal or OSB. The core can be made of polyurethane foam, extruded polystyrene foam (EPS), expanded polystyrene foam (EPS), composite honeycomb or polyisocyanurate. SIP are prefabricated in a factory and can be fabricated to fit any architectural design needed. SIP have nearly the same structural properties as I-column or I-beam. The sheathing acts as the flanges in an I-beam or I-column while the rigid insulation core acts as the web (Mwafongo, 2012). SIP can be used for many applications such as foundation systems, floor systems and exterior walls or even in roofing. Table 2.4 below shows different basic properties of SIP with extruded polystyrene foam as the core.

Properties	**Units**	**Strong-Axis Bending**	**Weak-Axis Bending**
Allowable Tensile Stress	Ft (psi)	495	245
Allowable Compressive Stress	Fc (psi)	580	340
Elastic Modulus (Bending	Eb (psi)	658800	738900
Shear Modulus	G (psi)	405	207
Allowable Core Shear Stress	Fv (psi)	5.0	4.5
Core Compressive Modulus	Ec (psi)	360	360
Reference Depth	Ho (in)	4.625	4.625
Shear Depth Factor Exponent	m	0.086	0.084

Table 2.4: Basic properties of SIP with EPS as the core

Source: NTA Code Listing, 2012

2.1.4 Precast Concrete Panels

Precast concrete panels are a product of a process in which concrete is poured or casted in reusable molds, cured in a controlled environment or a factory setup. After adequate curing, the panels are transported to the construction site and placed appropriately by use of lifting equipment. Precast concrete is different from standard concrete because standard concrete is poured into site –specific forms and cured on site. Precast concrete makes use of fine aggregate in the mixture and therefore the end product appears like a naturally occurring rock. Precast concrete panels are produced in a precast plant/factory or a controlled environment. The process is properly monitored and therefore the panels are properly cured and of good quality. Precast concrete system has various advantages over site casting of concrete. The quality of materials used can be better controlled and workmanship improved through close supervision. Safety is enhanced since the production process is performed on ground level. The forms used in a precast setup can be reused several times before replacement; this reduces the cost of formwork per unit produced as compared to site-cast production.

2.1.5 Fiber Reinforced Concrete (FRC)

FRC contains fibrous material which boosts the tensile strength of the concrete. The discrete fibers are randomly oriented and uniformly distributed. These fibers can either be synthetic fibers, steel fibers, glass fibers or natural fibers which introduce different structural properties to the concrete. The properties of fiber-reinforced concrete vary depending on the fiber material, densities, geometrics, orientation and fiber distribution. When fibers are introduced into concrete, you are able to control cracking due to drying and plastic shrinkage. The fibers also reduce the concrete permeability hence reducing bleeding of water. Some fibers will increase shatter resistance of the concrete and also produce greater impact abrasion. However, fibers cannot replace structural steel reinforcement as they don't increase the flexural strength of concrete. FRC can be used to produce roofing tiles as an affordable alternative to conventional roofing materials such as asbestos cement, galvanized iron sheeting or even a more traditional material like thatch (Gallen, 1992).

FRC tiles are durable (with a life span of more than 25 years in some regions), relatively affordable, able to offer adequate safety from direct sunlight and rain, and they are also aesthetically acceptable (Roland and Kiran, 1993). In order to enjoy the advantages of the various types of fibers, different types of fibers can be added in concrete. For example, one can use both steel fibers and polymeric fibers in order to utilize benefits derived from each type of fiber; the resistance to explosive spalling and plastic shrinkage improvement provided by polymeric fibers and the structural improvement provided by steel fibers. In industrial flooring, steel fibers or macro synthetic fibers can entirely replace rebar.

The different types of fiber reinforcements are tested in a laboratory to ensure that they conform to their performance requirements. As fiber reinforced concrete technology is adopted, one must ensure that the local design code requirements are met which stipulates the minimum amount of steel/rebar reinforcement required for each class of concrete. Researchers have tested and approved micro-Rebar as a replacement for conventional reinforcement in vertical walls designed in accordance with ACI 318 Chapter 14 (Gallen, 1992).

An alternative to conventional steel reinforcement has been found in micro concrete roofing (MCR) and earlier on in fiber reinforced concrete roofing (FRC). They are roofing elements typically made of cement, sand and water. However, in the case of FRC, synthetic or natural fibers are added to act as reinforcement. There is another group of fiber-reinforced cement-based composites known as High-performance fiber-reinforced cementitious composites (HPFRC) which are able to flex and self-strengthen before fracturing. This type of concrete was designed to try and solve the structural problem inherent in typical concrete like the tendency to fail in a brittle manner under excessive loading and its inadequate durability. HPFRC is able to strain harden when overloaded (Gallen, 1992). Most HPFRC are made of at least the following ingredients: Cement, fine aggregates, polymeric or metallic fibers, superplasticizer and water.

The main advantages of MCR and FRC are:

1. Unlike thatch roofs, MCR and FRC are fire resistant and more durable
2. Their thermal and acoustic performance is better than that of gci
3. Their production and installation technology is easy to learn

4. They require less timber as supporting structure as compared with burnt clay tiles and therefore they cost less and they are as durable as burnt clay tiles
5. They can be produced locally where cement is available at relatively low cost
6. The technology involved is adaptable to any scale of production; including one-man production units (Gallen, 1992).

However, there are some problems associated with MCR and FRC:

1. Cement still remains expensive in most developing countries.
2. A lot of clean water is required for production and curing of the roofing elements and this can be a problem in dry areas.
3. Production of MCR and FRC requires strict quality control otherwise failures are almost certain.
4. The roofing elements have to be handled carefully during transportation and installation to avoid cracks and breakage.
5. The lack of sufficient information by potential users who may not know the advantages associated with MCR and FRC (Gallen, 1992).

The figure 2.1 below shows the strain/stress relationship of regular FRC and HPFRC

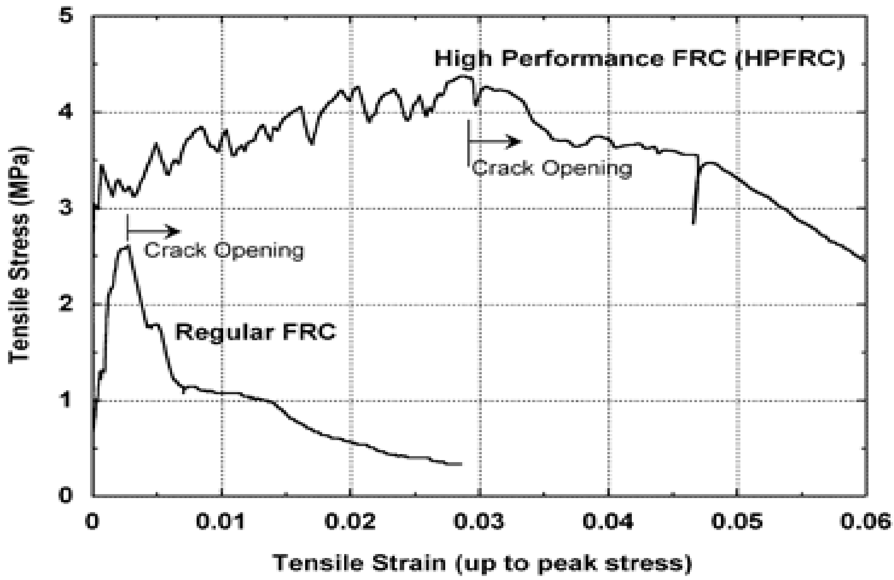

Figure 2.1: Strain/stress relationship of regular FRC and HPFRC

Source: Gallen, 1992

2.1.6 Artificial Pozzolans

A pozzolan by itself possesses little or no cementitious value. A pozzolan is an aluminous and siliceous material which when powdered and mixed with calcium hydroxide in the presence of water reacts chemically at ordinary temperature to form compounds possessing cementitious properties (Mehta, 1987). Any material that reacts with calcium hydroxide and water to form a compound possessing cementitious properties can broadly be referred to as a pozzolan or can be referred to as Pozzolanic. Pozzolans of volcanic origin are known as Pozzolana. Different pozzolans have different origins, composition and properties. There are natural and artificial pozzolans, artificial pozzolans are man-made and can be produced by thermal activation of kaolin-clays to obtain metakaolin. Artificial pozzolans can be produced as by-products of high-temperature process. Fly ashes are pozzolans obtained as by-products of coal-fired electricity production (Schneider et al., 2011). Currently, industrial by-products make the majority of the most used pozzolans such as rice husk ash, highly reactive metakaolin, fly ash and silica fume from silicon smelting.

The benefits of pozzolan use in cement can be broken into three (Schneider et al, 2011);

1. Environmental friendliness achieved by reducing the Portland cement environmental cost associated with emission of green gases during production.
2. Cost advantage gained by use of pollution free and cheaper pozzolans.
3. Increased durability of the final product.

The use of pozzolans has minimal interference in the conventional production process of Portland cement and also it creates value by converting industrial and societal waste into useful construction materials. Pozzolans can be used to reduce cost, reduce pollution, control setting and increase concrete durability without affecting performance properties of concrete like its compressive strength (Mehta, 1987). Table 2.6 below shows different chemical composition of biomass fly ash before and after firing.

	As-Received Biomass Fly Ash	**Biomass Fly Ash at 950°C for 1 hour**
COMPOUND	WEIGHT %	WEIGHT %
SiO2	47.14	58.17
AL2O3	5.85	7.07
Fe2O3	3.95	4.75
CaO	13.98	16.77
Others	29.08	13.24

Table 2.5: Chemical composition of biomass fly ash before and after firing

Source: Lowe, 2012

As shown in table 2.6, the largest components of biomass fly ash is Silicon dioxide (SiO2) and calcium oxide (CaO).The results are very promising as silica and calcium are key components in the Pozzolanic and cementitious reactions (Lowe, 2012). The ASTM C168 specifications requires that the iron oxide, aluminium oxide and silicon dioxide content be greater than 70 percent for class F fly ash and greater than 50 percent for class C. Table 2.6 above shows that the iron, aluminium and silicon contents are 56.94 and 69.99 percent for the as-received ash and the fired ash respectively.

2.1.7 Concrete with quarry dust as fine aggregate

River sand has conventionally been used as fine aggregate in concrete production. There has been a deliberate attempt to replace river sand with other alternatives (Adepegba, 1977). In bituminous concrete, quarry dust is used as a filler material. Quarry dust/sand has been accumulating in alarming rates in the recent past and this has caused environmental problems. It has been argued that one way of dealing with this problem is to incorporate quarry dust into structural concrete system (Maurice and Ukpata, 2012). It is important for one to know the structural properties and performance of concrete made with quarry dust for accurate design of structural elements in bridges and buildings construction. The critical strength parameter of concrete is its compressive strength (Maurice and Ukpata, 2012).This is so because concrete is strong under compression but weak in tension.

A study was done in Thailand to determine the compressive strength of concrete with quarry sand/dust as fine aggregate, the study found out that when 70% of the fine aggregate was made of quarry sand, the concrete produced had better compressive strength as compared to concrete made with river sand as the main fine aggregate (Khamput, 2006). This is shown in figure 2.2 below. Khamput (2006) recommended that quarry dust replaces river sand in general concrete structures. Ilangwana R., Mahendrana N and Nagamani K (2008) did a number of studies about the durability and strength properties of concrete with quarry sand as fine aggregate and found out that the durability, compressive and flexural strengths were about 10% more than the conventional concrete which is made purely with river sand as the fine aggregate. The workability of concrete made with quarry dust as fine aggregate showed compacting factor ranging from 0.87-0.90 for grade 20 concrete and slump values ranging between

60-90mm. After 28 days of curing, flexural and compressive strengths of grade 20 concrete were found to be 3.45-6.40N/mm2 and 23.7-34.5N/mm2 respectively.

In conclusion, it can be seen that the combination of laterite/river sand and quarry sand to replace the use of laterite as the sole fine aggregate in production of concrete in Nigeria and other tropical countries in Africa results in buildings with acceptable structural characteristics as shown in figure.2.2 below. Therefore, the use of quarry dust as an alternative to conventional river sand in concrete production should be encouraged especially if the concrete produced is cheaper (Maurice and Ukpata, 2012).Figure 2.2 below shows the relationship between compressive strength and water/cement ratio for a 1:1:2 concrete mix by varying the composition of laterite and quarry dust/sand forming the fine aggregate.

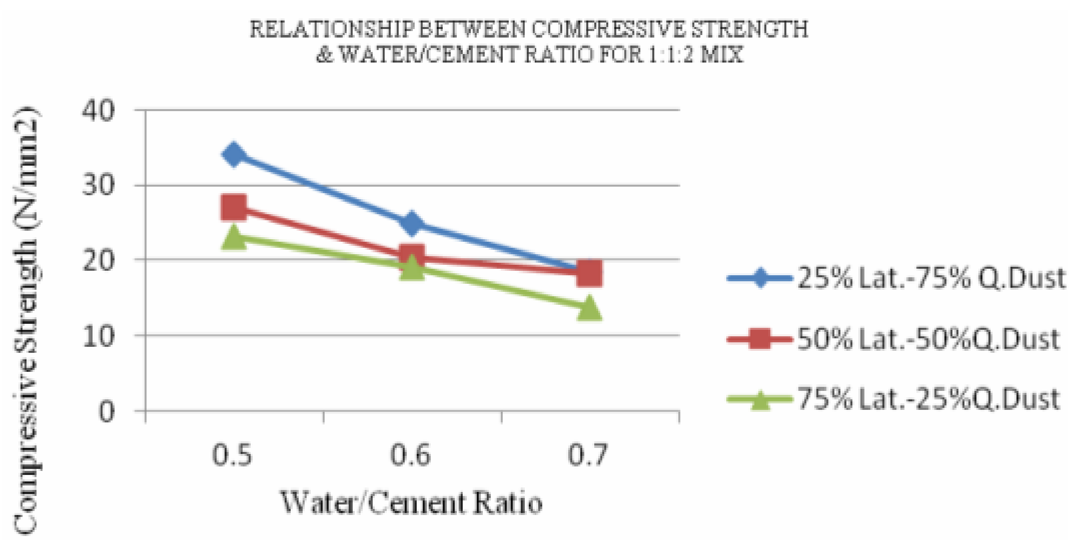

Figure 2.2: Relationship between compressive strength and water/cement ratio for a 1:1:2 concrete mix by varying the composition of laterite and quarry dust/sand forming the fine aggregate

Source: Maurice and Ukpata, 2012

2.2 The difficulties encountered in adopting ABM

The rising cost of raw materials used in production of alternative building materials has been found to be a significant hindrance to the adoption of ABM in the building industry. Cement for example is one of the commonly used ingredients in production of many alternative building materials. The cost of cement in most African countries is high and keeps on rising day in day out. However, the cost of cement is different in different countries or even within the same country. In a country like Malawi, raising costs of cement are heavily associated with the high importation costs of raw materials (U.S Geological Survey, 2011).

Transportation costs of both raw materials and finished products in Malawi also contribute to the rising cost of cement (Acosta, 2000). The main cement producing countries in Malawi have tried to encourage the use of locally available raw materials in production of cement in order to reduce the production costs hence promote affordability, however, since there are few competing cement producing companies in Malawi, cost of cement still remains high. Fuel costs is also high in Malawi just like in many other

African countries, this leads to high transportation costs of raw and finished products and also increases production costs. Inflation is another cause of high costs of raw materials required in production of ABM. In Tunisia, cement producing companies are able to produce sufficient raw materials to meet the countries demand, inflation is still the main factor causing high cost of cement (UNHABITAT, 2011c). Equipments used in the production of cement also contribute to other hidden production costs which include maintenance and training costs. As the technologies used in production of ABM become widely used, some costs are reduced due to economies of scale; most of those targeted by promoters of ABM are low class citizens who still find these alternative building materials unaffordable. The use of alternative building materials especially those which make use of manufactured raw materials is highly recommended as a better option to the use of conventional building materials many of which are scarce, very expensive and environmentally unfriendly. However, affordability still remains a major challenge to those promoting the use of ABM.

Many building professional and developers still lack the technical knowhow on various alternative building materials. This limits the chances of their adoption by many building professionals. This is mainly due to inadequate information on these ABM as it regards their structural properties and also how to use them. In most South Saharan Africa countries, where the main target groups in housing development are the small scale developers and people in the informal sectors, most building professionals and small scale developers are not aware of the specifications of the ABM leading to their low adoption rate and also poor performance of the final product (UN-HABITAT, 2010, 2011a). The information provided is based on foreign technology which is not supported locally or even in foreign language. Where there is incompatibility in terms of local construction climatic and physical conditions, not even considering the building code, the performance of the ABM will be poor (Liso et al., 2007).

It is therefore important to have locally based studies done on ABM to determine the best suitable ABM in a given locality since a building material suitable in one region may be unsuitable in another. This will help building professionals and developers embrace the use of ABM in place of conventional building materials (Acosta, 2000).

Another major challenge hindering the adoption of ABM by designers and other stakeholders is failure to formulate and implement various policies (Liso et al., 2007). Policies, economic measures and regulations are mostly used to determine environmental friendliness of a given building material in South Saharan Africa countries (Mpakati et al, 2011). These measures have serious limitations and therefore they are inappropriate in promoting sustainable construction. The main limitations of this framework is its inability to meet local building requirements, use of inaccurate data on which the strategies are based and the lack of measurable targets (Halliday, 2008).

Poor policy strategies lead to poor interpretation of the policies and thereby promoting use of inappropriate measures (Liso et al., 2007). Poorly structured strategies can be due to superimposed proposals which are in one way or the other influenced by third parties (Acosta, 2000). This state of affairs results in disharmony between the local agenda and the proposed policies. Frequent restructuring can be used as a means to improve the effectiveness of such policies, such improvements may not be effective and this is witnessed even in developed countries (Halliday, 2008).

There are many other factors which affect the adoption rates of alternative building materials other than policy strategies. These factors vary from one country to another. As observed in countries like Malawi and Ghana, the policy challenges affecting designers and developers ability to adopt ABM include institutional capacity to implement the policy strategies (Matope, 2000; UN-HABITAT, 2011a). Lack of institutional capacity may lead to inadequate enforcement of the law even when the policies and regulations are in place. Where enforcement of the law leads to use of significant government resources, the decision makers use their discretion in deciding which policies priorities and which not to enforce (Tisdell, 2005 and Shen et al., 2006). A study conducted in Tanzania found out that those in charge of policy implementation may deliberately ignore some proposals made when their financial implication or political interference are deemed to be more important than their environmental effect (Myers, 1999).

Inadequate information on the environmental effects of many ABM discourages building designers and developers from adopting the ABM. Flawed policy frameworks and regulatory mechanisms worsen the situation. Enough research has not been done in many

Soth Saharan Africa countries to determine the extent to which the construction industry contributes to deforestation in terms of wood quality, the type of wood utilized and where the wood is sourced (Zingano, 2005). Malawi has done well in putting in place policy strategies and regulatory mechanism in the building sector to curb deforestation and in the process reduce the effects of global warming. The production of cement which is a main ingredient in most ABM leads to environmental pollution which needs to be evaluated in its effects analyzed. By focusing only on certain environmental aspects and ignoring others leads to shifting from one environmental problem to another (Mpakati et al., 2011). The local council in Kenya has laws which in certain aspects are inconsistent to each other and in such cases building designers and developers are at cross roads as to what standards to follow (UN-HABITAT, 2011a).

Sustainability is an important factor to consider when carrying out building projects. In adopting a given alternative building material, a designer or a developer must ensure that its sustainability is considered thoroughly. There are no measurable targets of sustainability at both local and global setting and this contributes to the slow adoption rates of alternative building materials in different countries (Liso et al., 2007).

Based on the above issues, it can be seen that the adoption of ABM is faced by various challenges and a lot has to be done to try and mitigate them so that the adoption rate can increase and help the building industry enjoy the numerous benefits associated with ABM.

The literature review has shown that indeed there are alternative building materials which can be used instead of the conventional building materials. Studies undertaken by various researchers have shown that the alternative building materials are of good quality and in most cases are more appropriate than the conventional building materials. The selection of a building material is a complex exercise and it involves tradeoffs among various competing factors. The adoption of ABM has faced various obstacles; these hindrances include limited information on the quality of ABM; lack of standardization of the adoption criteria and also fear of the unknown by many building professionals.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

Research methodology is a plan, structure or an overall scheme tailored in such a manner that it helps the researcher answer the research questions and objectives (Cohen et al., 2007). This chapter analyzes the design and methods which were employed in carrying out this study. It is a blue print for the collection, measurement and analysis of data. The sub-topics under research methodology are: research design, target population, research instruments, data collection methods, research procedures, data analysis and assumption to the study.

3.2 Research Design

Research design is a master plan that explains the procedures and techniques employed in collecting and analyzing desired information (Kothari, 2008). This study employed a descriptive research design. Descriptive research design is able to minimize bias and maximize reliability of information gathered. This design is necessary where the population under study is large. Descriptive research design enables the researcher to determine and report the way things are and it also helps in establishing the current status of the population under study (Mugenda and Mugenda, 2003). Descriptive research design collects data from members of a population whereby the researcher is able to get the descriptive existing phenomena by asking individuals about their attitudes, perceptions, values or behavior (Nachmias and Nachmias, 2007). This design is appropriate for this study as it ascertains and describes the characteristics of the variable of interest in a situation.

3.3 Target Population

A population is the entire group of events, people or things of interest that the researcher wishes to investigate and its abbreviation is N (Wambugu et al., 2015). A target population is a specific proportion of the entire population which the researcher can narrow down to in order to achieve the research objectives (Cohen et al., 2007). The target population for this study was building professionals namely: Quantity surveyors, civil/Structural Engineers and Architects.

The area of study was Nairobi city. This was a suitable area of study given the inadequate housing which has been worsened by the huge population explosion in the region. Nairobi is the capital and largest city of Kenya and is the most populous city in East Africa. This study used registered professional firms in the three field of professionalism to collect data. From data obtained from Board of Registration of Architects and Quantity Surveyors as at 12th January 2017, the number of registered Architectural firms was 192 while that of registered Quantity surveying firms was 151. The data obtained from Engineers Registration Board showed that as at 12th January 2017, there were 92 registered Civil & Structural engineering consulting firms. Therefore, the population size (N) for this study was 435.

3.3.1 Sample Size

Statistically, the study can't be carried out on the total population. Therefore, a sample size (n) was calculated using a formula derived by Chara f., David N., and Nachmias D (1996) where;

$$n= Z^2.P.Q.N / e^2 (N-1)+ (Z^2 .P.Q)$$

Where; N is the size of the population

n is the sample size

P is the sample proportion estimated to have a characteristic being measured (that is 95% confidence level of target population)

Q is the significance level (1-P)

e is the acceptable error at 5% (0.05)

Z is the standard normal deviation required at 95% confidence level (1.96)

Therefore, the sample size (n) for a target population of 435 is;

$$n= 1.96x1.96x0.05x0.95x435 / (0.05x0.05x434) + (1.96x1.96x0.05x0.95)$$

$$n=63$$

The sample size was then apportioned to the three professions in accordance with their numbers in the target population. The respective sample sizes were as follows;

Architectural firms considered were; (192/435)* 63=28

Quantity surveying firms considered were; (151/435)*63=22

Civil/Structural engineering consulting firms considered were; (92/435)*63=13

Random sampling technique was used to select the 63 firms using the Lottery technique. Out of the 192 registered Architectural firms, 28 firms were randomly chosen, Out of the 151 registered quantity surveying firms, 22 were randomly chosen and out of the 92 registered Civil/Structural engineering consulting firms, 13 were chosen.

3.4 Research Instruments

This section of the study discusses the research instrument or tool to be used for this study. This study collected both primary and secondary data using a number of methods so as to generate quantitative and qualitative data. Secondary data was obtained from Kenya bureau of standards (KEBS) and existing literature from competent authors. Primary data was obtained through structured questionnaires. Secondary data was used to establish the availability of alternative building materials in the city of Nairobi and also establish if they meet the set standards. Quantitative data was collected from the respondents using a questionnaire. Through a questionnaire, one is able to collect a lot of information within a reasonable span of time (Kothari, 2008; Wambugu et al., 2015). The questionnaire was comprised of questions which were seeking to answer questions related to the objectives of this study. The questionnaire was divided into two sections; the first section delved into demographics data of the respondents while the rest of the sections looked into the evaluation of adoption criteria of alternative building materials by building professionals with a focus on Nairobi city presented as per the objectives of the study. Secondary data for the study was collected from literature from library materials, journals, articles and publications.

By analyzing the secondary data provided by KEBS, the study established whether the alternative building materials pass the quality standards set out. Primary data sought to establish the level of awareness by building professionals in the building sector of the existence of alternative building materials, their opinions and experiences about these alternative building materials and the adoption criteria used by various users of these alternative building materials; it also gave an oversight on the levels of acceptability of these alternative building materials by professionals within Nairobi.

3.4.1 Validity of the Research Instrument

Validity of a research instrument refers to the meaningfulness; appropriateness and usefulness of the inferences that a researcher makes from the use of a given research instrument (Wambugu et al., 2015). Validity is one of the key criterion of sound measurement and shows the accuracy to which an instrument measures what it is meant to measure (Kothari, 2008; Wambugu et al., 2015). This study made use of content validity which is the level to which an instrument provides adequate coverage of the area under study. Content validity was used to determine whether the instruments answered well the research questions. In order to establish content validity and make alterations, additions or adjustments to the research instruments, discussions and consultations were critically undertaken. Any abstruseness in the questionnaire to be administered to respondents was removed before the questionnaire was used for data collection.

3.4.2 Reliability of the Research Instrument

Reliability refers to the level of consistency that the research instrument or tool demonstrates when repeatedly used (Kothari, 2008; Wambugu et al., 2015). To ensure reliability, the study employed self-administration approach of data collection and monitored the progress to make sure that only those within the sample filled the questionnaire. More often than not, the questionnaire was filled in the presence of the researcher. This enabled the researcher to provide clarification if needed. Where the questionnaire was to be filled in the absence of the researcher, any clarifications arising were raised through telephone calls thus raising reliability.

3.5 Data Collection Procedures

The researcher obtained a transmittal letter from the University Department of Real Estate and Construction Management in order to collect data from the respondents and also assure the respondents that the data required was for academic use only. Only one questionnaire was administered per firm or company. The questionnaire was administered to one of the firm's senior staff who had to be a registered member by either the Board of Registration of Architects and Quantity Surveyors or the Engineers Registration Board of Kenya depending on the professionalism of the firm. The views of that respondent were assumed to represent the views of the firm as a whole. The researcher used trained and qualified research assistants to assist with the questionnaire distribution. To ensure that the purpose of the study was achieved, the researcher communicated orally with the respondents, one person at a time in a period less than ten minutes each. The researcher explained the purpose of the study and offered guidance to the respondents on the way to fill in the questionnaire before administering the questionnaire. The respondents were assured verbally that the information obtained from them would be treated with ultimate confidentiality. They were therefore requested to provide the information truthfully and honestly. The questionnaires were administered through drop and pick method whereby the respondents were left with the questionnaire to fill in their convenient time. The researcher made subsequent visits and courtesy calls when necessary to remind the respondents to fill the questionnaires and by so doing increased the response rate. The study relied on data collected through a questionnaire structured to meet the objectives of the study.

3.6 Data Analysis

Both descriptive and statistical data analysis were used to analyze primary data collected through the structured questionnaires in order to evaluate the adoption criteria of the alternative building materials by building professionals. Data collected from the completed questionnaires was summarized, coded, tabulated and checked for any errors and omissions. Frequency tables, percentages and sample means were used to present the findings. Responses in the questionnaires were processed by use of a computer Statistical Package for Social Science (SPSS) version 20.0 programme to analyze the data. The responses from the open-ended questions were listed to obtain proportions appropriately;

the responses were then reported by descriptive narrative as qualitative analysis. Quantitative data was analyzed using descriptive statistics including percentages and sample means. Descriptive analytical approach was used to analyze Secondary data. The data was presented by use of bar charts and frequency tables.

3.7 Assumptions of the study with regard to methodology

The study was based on a number of assumptions i.e.

i. Data collected from secondary sources is accurate and reliable
ii. The particular areas chosen for study are typical and findings can be applied to any other place within Nairobi city regardless of such differences as geographical location
iii. Respondents of questionnaires given are genuine and data collected from these questionnaires is accurate and reliable
iv. The professional firms considered had equal influence in determining the adoption criteria of ABM irrespective of whether they were Architects, Quantity surveyors or Structural engineers
v. The views of the respondent in each firm or company represented the views of the firm as a whole.

3.8 Conclusion

The research method used was found to be adequate and the study was able to achieve its objectives. However, various challenges were encountered during data collection; one such challenge was instances where target respondents didn’t return the questionnaires left with them or even instances where some target respondents were unwilling to fill the questionnaires. The response rate was sufficient as it was more than 60% which is deemed as a good response rate (Mugenda and Mugenda, 2003).

CHAPTER FOUR

DATA ANALYSIS, PRESENTATION AND INTERPRETATION

4.1 Introduction

In this chapter the key issues related to data presentation, analysis and interpretation are discussed. This chapter is presented in three different sections looking into two different respondents. The first and second sections look at responses from building professionals and the Kenya Bureau of Standards respectively, the third section deals with data presentation and interpretation. All two sections present study responses regarding an evaluation of adoption criteria of alternative building materials by building professionals with a focus on Nairobi city. First, the research response rate has been computed and presented. Secondly, the demographic characteristics of the participants have been described. Thirdly, the findings on the key objective areas of the study have been presented and interpreted. The responses were analyzed using descriptive and inferential statistics. The data has been presented in tables.

4.2 Responses from the Questionnaires

This section is presented in five sections: Section A, B, C, D and E.

4.3 The Study Response Rate

Out of 63 questionnaires which had been administered, 55 of them were returned for analysis. 24 questionnaires were returned from Architectural firms, 19 from Quantity surveying firms and 12 from civil/structural engineering firms. This translates to 87 percent return rate of the respondents. As compared to the threshold response rate in

Mugenda and Mugenda (2003), where a response rate of 60% is considered good and a response rate of more than 70% is considered very good, 87% response rate for this study is very good. Table 4.1 below shows the response rates of the respondents;

Table 4.1: Distribution of the Respondents by Responses Rate

Response Rate	**Frequency (F)**	**Percentage (%)**
Returned	55	87
Not Returned	8	13
Issued	**63**	**100.0**

4.3.1 Demographic Characteristics of the Respondents

The summary of the respondents' distribution by their profession is given in Figure 4.1

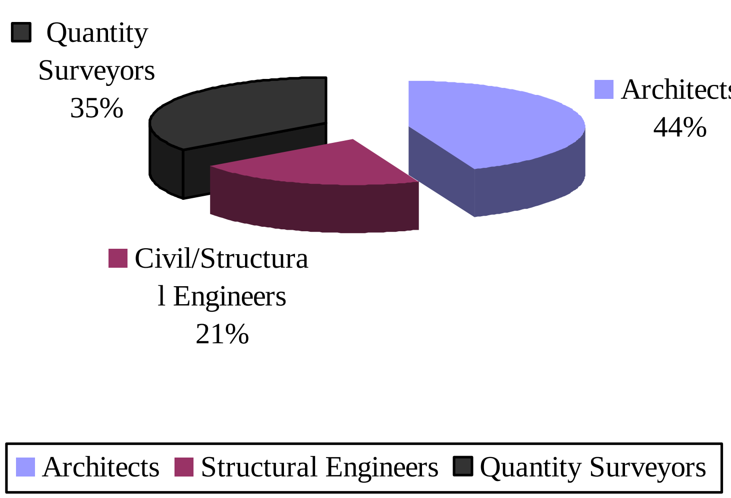

Figure 4.1: Distribution of respondents by Profession

Source: authors field investigations (2017)

According to the data shown in Figure 4.1, out of 63 respondents who participated in the study, 13 (21%) were Civil/structural engineers, 28 (44%) were architects, 22 (35%) were quantity surveyors. The distribution of the building professionals by years of experience in the profession is given in Figure 4.2

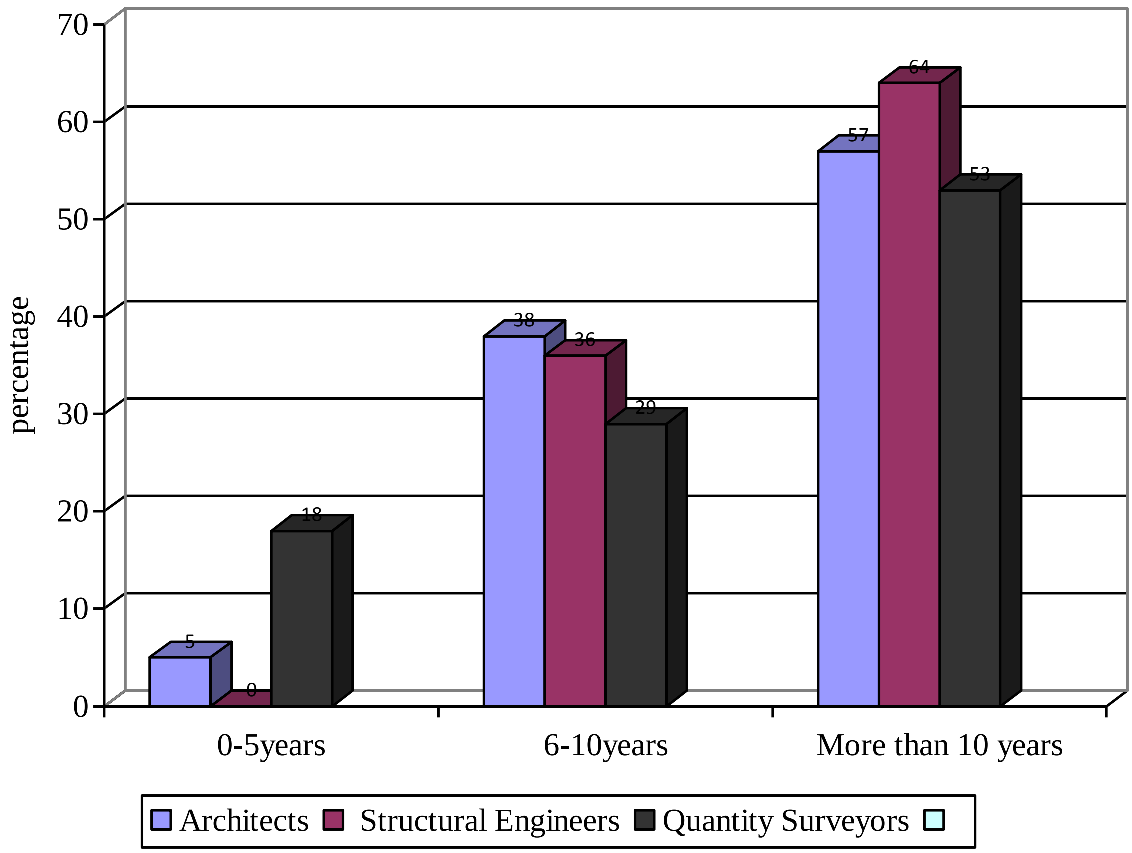

Figure 4.2: Distribution of the building professionals by years of experience in the profession

Source: authors field investigations (2017)

It is evident from the data shown in Table 4.2 that, majority of the respondents have been in their profession for more than 10 years meaning that they had good experience in their areas of specialization. There percentage was: Civil/structural engineers (64.0%), Quantity Surveyors (53.0%) and Architects (57.0%).

4.4 Level of awareness and Usage of ABM

The distribution of the respondents by awareness of the existence of the ABM is given in Figure 4.3.

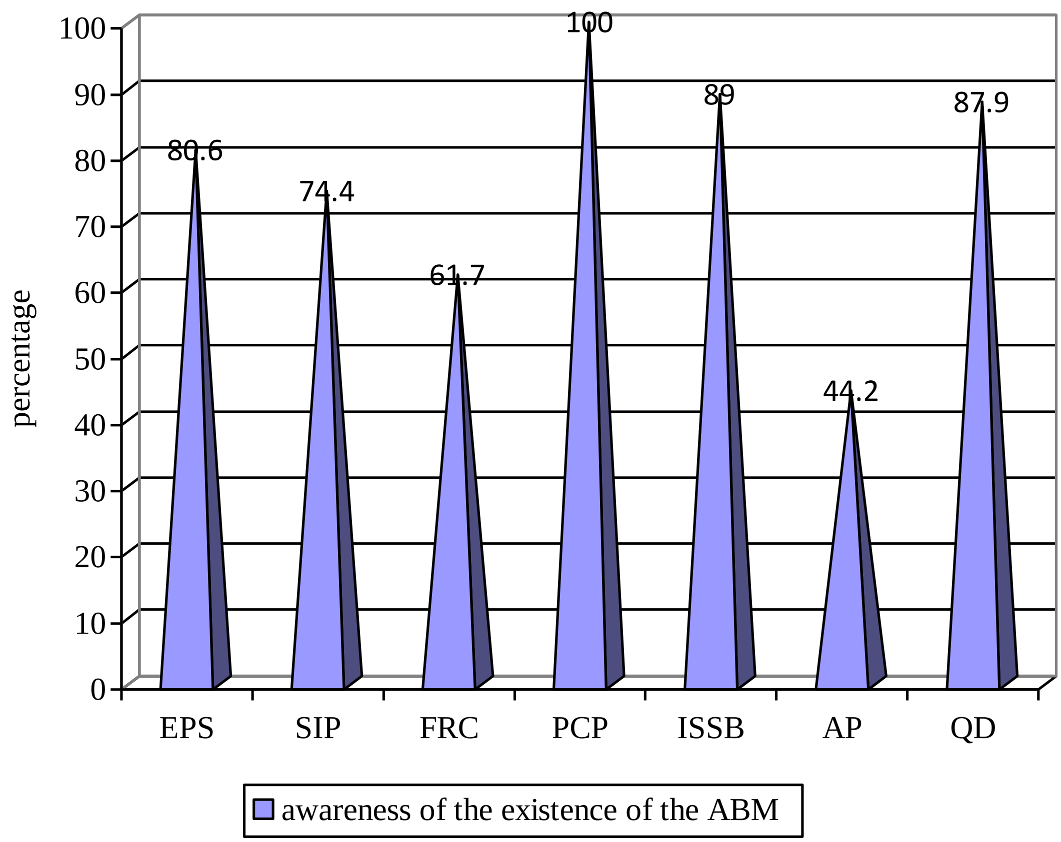

Figure 4.3: Distribution of the respondent by awareness of the existence of the ABM

Source: authors field investigations (2017)

The findings on Figure 4.3 reveal that majority of the respondents are aware of the existence of the ABM: PCP (100.0%), ISSB (89.0%), QD (87.9%), EPS (80.6%), SIP (74.4%), FRC (61.7%), and AP (44.2%). The findings further reveal that the mean on awareness of the existence of ABM is very high at 76.8%, indicating that more than two thirds of the respondents are aware of the existence of the ABM.

The distribution of the respondents' by those who are aware of the ABM and have used them is given in Table 4.2 below.

ABM	**No of respondents aware**	**Aware and have used**	**Percentage (%) of respondents aware and have used ABM**
EPS	45	11	24.3
SIP	38	10	26.1
FRC	30	13	42.8
PCP	55	46	84.5
ISSB	50	26	51.7
AP	16	2	14.3
QD	48	30	61.5
	Mean		**43.6**

Table 4.2: Awareness and usage of ABM

Source: authors field investigations (2017)

The findings reveal that the majority of the respondents' 46 (84.5%) are aware and have used PCP, 30 (61.5%) are aware and have used QD, 26 (51.7%) are aware and have used ISSB, and 13 (42.8%) are aware and have used FRC. The table further reveals that even though 76.8 % of the respondents are aware of ABM, on average only 43.6% of the total number of respondents have used the ABM.

The distribution of the respondents by reasons given for using ABM over conventional building materials is given in Table 4.3:

Item	Reason	EPS	SIP	FRC	PCP	ISSB	AP	QD	
		NO OF RESPONDENTS							**Mean**
1	Durability	8	10	13	37	27	0	23	**17**
2	Cost advantage	9	9	12	44	24	0	26	**18**
3	Availability of ABM	0	0	5	15	23	0	29	**10**
4	Environmental friendliness	5	6	5	23	16	0	8	**9**
5	Better quality	0	0	0	19	14	0	7	**6**
6	Good constructability	8	0	5	13	25	0	2	**8**
7	Government incentives	0	0	0	8	5	1	0	**2**
8	Recyclable	0	9	10	10	0	0	0	**4**
9	Client interest	11	9	12	31	23	2	0	**13**

Table 4.3: Reasons given by respondents for using ABM over conventional building materials

Source: authors field investigations (2017)

The findings in the table reveal that the majority of the respondents ranked cost advantage (18) as the major reason for using ABM over conventional building materials, followed by durability (17), client interest (13), availability (10), environmental friendliness (9), good constructability (8), better quality (6), recyclable (4) and government incentives(2) in that order .

The distribution of the respondents by the reasons given for not using ABM over conventional building materials even though they are aware of their existence is given in Table 4.4:

Item	Reason	EPS	SIP	FRC	PCP	ISSB	AP	QD	
		NO OF RESPONDENTS							Mean
1	Lack of standards	20	24	0	0	17	10	16	**12**
2	Unavailability in local market	6	22	3	0	7	10	0	**7**
3	Inadequate knowledge of materials	32	28	6	0	18	13	15	**16**
4	Attitude of building professionals towards these ABM	28	25	0	0	20	13	15	**14**
5	Low profit margins	3	5	0	0	0	0	0	**1**
6	More tests required on these ABM	30	24	2	0	6	11	4	**11**
7	Low levels of competent labour	25	5	0	0	5	2	0	**5**
8	Lack of government support/incentives	3	1	1	0	6	7	10	**4**
9	Public perception	30	20	9	0	15	13	12	**14**
10	Environmental issues	2	4	0	0	0	0	5	**2**
11	Low aesthetic value	8	0	0	0	3	0	0	**2**
12	Doubtful durability and life span	30	20	9	0	17	9	9	**13**

Table 4.4: Reasons given by respondents for not using ABM over conventional building materials

Source: authors field investigations (2017)

The findings in the table shows that the main reason for not using ABM even though aware of their existence was Inadequate knowledge of materials (16.0) followed by Attitude of building professionals towards these ABM (14.0), Public perception (14.0), Doubtful durability and life span (13.0), Lack of standards (12.0), More tests required on these ABM (11.0), Unavailability in local market (7.0), Low levels of competent labour (5.0), Lack of government support/incentives (4.0), Low aesthetic value (2.0), Environmental issues (2.0), and Low profit margins (1.0).

The distribution of the respondents by awareness on any published quality specifications of the seven ABM is given in table 4.5.

Item	ABM	Respondents aware of the existence of the ABM	No of respondents aware of published quality specifications	% of respondents aware of published quality specifications
1	EPS	44	20	45
2	SIP	30	2	8
3	FRC	34	10	28
4	PCP	55	47	86
5	ISSB	49	25	52
6	AP	24	3	13
7	QD	48	15	31
			Mean	**38**

Table 4.5: Awareness on any published quality specifications of the seven ABM

Source: authors field investigations (2017)

The findings reveal that PCP (86.0%) had the highest number of respondents who were aware of published quality specifications, followed by ISSB (52.0%), EPS (45.0%), QD (31.0%), FRC (28.0%), AP (13.0%), and SIP (8.0%). The table further shows that on average, the majority of those aware of the existence of ABM were not aware of any published quality specifications of the seven ABM (62%).

The respondents' personal opinion on whether these ABM meet laid down standards by relevant authorities e.g. KEBS or BS (British standards) is shown in Table 4.6

Item	**ABM**	**No of respondents aware of published quality specifications**	**No of respondents who think that the ABM do meet laid down standards**	**% of respondents who think that the ABM do meet laid down standards**
1	EPS	20	16	80
2	SIP	2	2	100
3	FRC	10	8	77
4	PCP	47	46	98
5	ISSB	25	22	88
6	AP	3	2	67
7	QD	15	14	90
			Mean	**86**

Table 4.6: Respondents personal opinion on whether these ABM meet laid down standards by relevant authorities e.g. KEBS or BS (British standards)

Source: authors field investigations (2017)

The findings on Table 4.6 indicate that the majority of the respondents (86%) in their personal opinion agreed that these ABM meet laid down standards by relevant authorities e.g. KEBS or BS (British standards).

The ranking of different material adoption criteria by the respondents is tabulated in Table 4.7.

CRITERIA	IMPORTANCE ON A SCALE OF 1-10
Cost	1
Aesthetic value	9
Availability in the local market	7
Durability	2
Clients interest	4
Compatibility with other materials	8
Environmental friendliness	5
Public perception	6
Availability of standards	3
Commercial status	10

Table 4.7: Ranking of different material adoption criteria

Source: authors field investigations (2017)

The table reveals that the respondents ranked cost as the most important adoption criteria and commercial status being the least important. The least important being 10 and the most important being 1: commercial status (10), Aesthetic value (9), Compatibility with other materials (8), Availability in the local market (7), Public perception (6), Environmental friendliness (5), Clients interest (4), Availability of standards (3), durability (2) and cost of material (1) as the most important criteria.

4.5 Building professionals' general opinion on the level of adoption of ABM in Nairobi city

The study sought to find out the building professionals' general opinion on the level of adoption of ABM in Nairobi city. The responses given were that; adoption has been very low and more must be done to increase their usage; the adoption of ABM should certainly be encouraged as this will facilitate innovation in the construction industry and this may lead to better building practices as well as cost saving benefiting all stakeholders; it requires broad public awareness; government and real estate developers must take initiative to use the ABM as an option; the design team must encourage the use of ABM as an alternative to conventional building materials; and that most projects where ABM have been used are those projects funded by the national government through National Housing Cooperation (NHC).

Other responses given for the low adoption levels of ABM include: limited literature available; lack of public awareness/promotion by professionals and statutory bodies; manufacturers of ABM do not promote/advertise their products adequately; and fear of the unknown by the public, developers and building professionals.

4.6 Building professionals' experience on the use of ABM

The study sought to find out the building professionals' experience with ABM. The responses given include: some methods such as ISSB are very good with small scale community projects; they are an efficient option in construction because they save time and labour as they deliver a suitable product, however, acceptance of the technology has been low owing to the uncertainty attached to these products; need for high capacity industries for mass production to satisfy the market demand; ABM are most useful as an alternative when conventional building materials prove to be too expensive or unavailable; by use of ABM, one is able to achieve timely delivery of a project and at the same time achieve cost savings.

4.7 Kenya Bureau of Standards

The study sought to find out if KEBS has undertaken any critical quality tests on the alternative building materials (ABM), and if they passed the tests. The respondent for KEBS was the chief technician in charge of the building materials section. The findings are tabulated in table 4.8 below:

NO	ABM	Critical Test	Test Done		Test Passed		
			Yes	No	Yes	No	N/A
1	Expanded polystyrene panels (EPS)	Flexural strength		x			x
		Compressive strength		x			x
		Flame propagation characteristics		x			x
		Other: Specify Dimensions/ finish					x
2	Structural insulated panels (SIP)	Thermal resistance		x			x
		Flexural strength		x			x
		Compressive strength		x			x
		Other: Specify					x

3	Fibre reinforced concrete (FRC)	Compressive strength		x			x
		Shrinkage		x			x
		Flexural strength		x			x
		Other: Specify					x
4	Precast concrete panels (PCP)	Compressive strength	x		x		
		Flexural strength		x			x
		Other: Specify					x
5	Interlocking Stabilized Soil Blocks (ISSB)	Compressive strength	x		x		
		Dry density		x			x
		Water absorption	x		x		
		Other: Specify					x
6	Biomass fly ash as an artificial pozzolans (AP)	Particle size		x			x
		Carbon content		x			x
		Compressive strength of concrete		x			x
		Other: Specify					x
7	Concrete with quarry dust as fine aggregate (QD)	Compressive strength		x			x
		Slump test		x			x
		Flexural strength		x			x
		Other: Specify					x

Table 4.8: Undertaking of any critical quality tests on the following alternative building materials

Source: authors field investigations (2017)

The table reveals that KEBS has not done any of the critical tests for EPS, SIP, FRC, AP or QD. However, they have done some critical tests for PCP and ISSB, and they passed. The respondent further indicated that for FRC, PCP and QD, KEBS do not usually establish the component or constituents of the concrete cube being tested. The respondent for KEBS also indicated that the main reason they don't undertake most of the critical tests listed in table 4.8 above is lack of equipment to carry out the tests. Even though KEBS adopts existing international standards for alternative building materials, they are not well equipped to carry out tests to ascertain whether the locally available ABM meet these standards.

4.8 Conclusion

From the analysis of the data collected, it has come out very clearly that the majority of the professionals in the building industry are aware of the existence of ABM. However, the adoption level of ABM in the industry is still low due to various hindrances which need to be addressed by relevant stakeholders to ensure that the adoption level is increased. It has also come out clearly that the relevant statutory body (KEBS) which is entrusted to verify the adherence of these ABM to the set standards lacks capacity to fully undertake its mandate. This has left many building professionals uncertain whether the locally available ABM are good enough for the building industry.

CHAPTER FIVE

SUMMARY, DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of Research Findings

This study aimed at evaluating the adoption criteria of alternative building materials by building professionals with a focus on Nairobi city. The task included; identifying the locally available alternative building materials; establishing the published quality standards of the alternative building materials; establishing the adoption criteria by building professionals; establishing whether KEBS has undertaken any critical tests on the ABM researched in this project and establishing the opinions and experiences of building professionals (Architects, Civil/structural engineers and Quantity surveyors) who have used the ABM.

This study adopted a descriptive survey design and employed quantitative research as the main approach to guide the study. The study used 63 building professionals in Kenya and one respondent from Kenya Bureau of Standards working in the civil engineering materials testing department. The research instrument used in data collection was a questionnaire to draw information from the respondents. To ensure validity of the instrument, expert opinion was sought. Data analysis was started immediately after the field investigation stage. Data was summarized into frequencies and percentages and presented in tables. This section comprises of discussions based on the specific research objectives of the study.

The respondents' who participated in the study were civil/structural engineers, architects, quantity surveyors and Kenya Bureau of Standards. The findings also reveal that majority of the respondents have been in their profession for more than 10 years, and therefore their responses are deemed to be reliable by this study.

The study findings reveal that majority of the respondents are aware of the existence of ABM: PCP, ISSB, QD, EPS, SIP, FRC and AP. The mean awareness of the existence of ABM is very high at 76.8% indicating that more than two thirds of the respondents are aware of the existence of the ABM.

The study established that most of the respondents have used PCP but the majority have not used the rest of the ABM included in the questionnaire. The study also established that even though the majority of the respondents are aware of the ABM (mean of 76.8%), on average, only 43.6% of those aware of the ABM have used them. This means that the adoption level is very low.

The use of ABM is considered as a way of reducing the negative environmental impacts associated with the building industry, however, more studies need to be done to show the extent of environmental attributes associated with the building industry (Mpakati et al., 2011).

Most of the respondents (62%) who are aware of the existence of the ABM are not aware of any published quality specifications of PCP, ISSB, EPS, QD, FRC, AP, and SIP. On average, 38% of the respondents who are aware of the existence of ABM are aware of some published quality specifications of the seven examples of ABM.

PCP (86.0%) had the highest number of respondents who were aware of published quality specifications, followed by ISSB (52.0%), EPS (45.0%), QD (31.0%), FRC (28.0%), AP (13.0%), and SIP (8.0%). The majority of the respondents (86%) who are aware of some published quality specifications in their personal opinion agreed that these ABM meet laid down standards by relevant authorities e.g. KEBS or BS (British standards).

It was established that, on average, the respondents ranked cost as the most important adoption criteria and commercial status as the least important consideration in adopting a construction material. The least important being 10 and the most important being 1.The entire rank was as follows; commercial status (10), Aesthetic value (9), Compatibility with other materials (8), Availability in the local market (7), Public perception (6), Environmental friendliness (5), Clients interest (4), Availability of standards (3), durability (2) and cost of material (1).

The study established that KEBS has not done any of the critical tests for EPS, SIP, FRC, AP or QD. However, they have done some critical tests for PCP and ISSB, and the materials passed the tests. The respondent further indicated that for FRC, PCP and QD, KEBS do not usually establish the constituents of the concrete cube being tested. The respondent for KEBS also indicated that the main reason they don't undertake most of the critical tests listed is the lack of equipment to carry out the tests, meaning they don't have the capacity to provide quality assurance. KEBS has to rely on other private organizations like SGS to carry out these tests. This reliance on third parties to undertake its statutory mandate may result in compromised test results which may lead to substandard materials entering the Kenyan market.

The study has shown that researchers have published quality standards of the alternative building materials which have been found to be within the specified standards by relevant organizations. ASTM has published test results of various alternative building materials and their quality has been found to be good.

Majority of the building professionals who have used the ABM affirm that they are of good quality, they reduce construction time and their use should be encouraged so that developers can enjoy the various benefits associated with them.

5.2 Discussions of the Findings

The study findings show that majority of the respondents are aware of the existence of the ABM: PCP, ISSB, QD, EPS, SIP, FRC, and AP. Most of the respondents' are aware of and have used PCP but have not used the other six ABM. The awareness of the origin of ABM by building professionals is important to the understanding of their collective environmental impact when they form a building (Mwafogo, 2012).

Some ABM are avoided by building professionals due to their poor aesthetics and low durability (Duguma and Hager, 2010). Soil/earth which is highly promoted as an alternative building material in many developing countries partly due to its low embodied energy is regarded as a building material for the less fortunate in the society who can hardly afford any other alternative material in the market (Duguma and Hager, 2010). This challenge among others has forced developers to continue using the conventional building materials even though there are well established policies and regulations in some countries. For such reasons, some projects are left uncompleted and those completed don't deliver the intended outcome. Due to the many challenges facing ABM, many professionals don't adopt them either at the design stage or the construction stage. Due to limited literature on ABM, further inquiry based on an individual country practices need to be undertaken (Halliday, 2008).

The study therefore concludes that the adoption criteria of alternative building materials is dependent on various factors and may vary from one region to another. Public perception has also been found to be a key factor in determining how well an ABM will be embraced in a given area.

5.3 Implications and Recommendations of the Study

The study recommends that the adoption of ABM should certainly be encouraged. The Kenyan government must lead by example and increase its use of ABM in public projects, by so doing; it will encourage the general public to adopt the usage of ABM. The design team must in its designs endeavor to specify the use of the ABM when appropriate. In addition, sufficient literature on ABM should be availed to enable stakeholders make informed decisions. Creation of public awareness/promotion by professionals and statutory bodies on the advantages of ABM should be intensified. Manufacturers of ABM should also promote/advertise their products adequately by use of both electronic and print media. Reduction of the fear of the unknown by the public, developers and building professionals through seminars and workshops held by relevant authorities like National Construction Authority and NHC will help in increasing the level of adoption of ABM.

There is need for investment in high capacity industries for mass production to satisfy the market demand. The government should accelerate the process of operationalizing the regional ABT (Alternative Building Technology) Centre at Mavoko to act as the advisory centre on ABMT development in the Country. Stakeholders should develop linkages for collaboration and partnerships with technical institutions and industry entrepreneurs for training of technicians, with regard to providing the Kenyan construction market with requisite expertise in ABM. KEBS should enhance an effective collaboration mechanism with well established and recognized quality assurance companies e.g. SGS in order to ensure that the quality of ABM in the market is assured and no counterfeits are allowed in the market.

There is need to harmonize policies and regulations on use of ABM in Kenya. The government should offer incentives towards research and development of local alternative building materials. Introduction of peer vetted research papers in the research field of ABM as a strategy for adoption by Universities for promotion of lecturers and academic staff.

5.4 Recommendations for further Research

Although the research attained its objectives, further research needs to be undertaken to find out how the ABM which have been used in various building projects have performed compared to conventional building materials say after a period of twenty years. Since this research only dealt with building professionals, further research can also be undertaken to find out what is the general public view on the use of ABM.

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APPENDICES

APPENDIX I: INTRODUCTION LETTER

Nicholas Mweu,

P.O Box 30197,

Nairobi, Kenya

13th August 2016.

Dear Respondent,

RE: **DATA COLLECTION**

I am a student at University of Nairobi currently undertaking a research study to fulfill the requirements of the Award of Master of Arts in Construction Management on **an evaluation of adoption criteria of alternative building materials by building professionals with a focus on Nairobi city**. You have been selected to participate in this study and I would highly appreciate if you assisted me by responding to all questions in the attached questionnaire as completely, correctly and honestly as possible. Your response will be treated with utmost confidentiality and will be used for research purposes of this study only.

Your participation in the exercise is voluntary. Kindly spare a few minutes from your busy schedule to complete the attached questionnaire.

Thank you in advance for your co-operation.

Yours Faithfully,
Nicholas Mweu (Researcher)

APPENDIX II: QUESTIONNAIRE

This questionnaire is designed to collect data on an evaluation of adoption criteria of alternative building materials by building professionals. Kindly complete the following questionnaire using the instructions provided for each set of question. Tick appropriately.

SECTION A

1. Respondents name ………………………………………
2. Profession (Engineer, Architect, QS)……………………
3. Years of experience: …………
4. Area of specialization (Design or construction).....................................

SACTION B

1. Are you aware of the existence of alternative building materials (ABM) in Nairobi other than the conventional building materials ………………? (Yes or No)?
2. If yes, are you aware of any of the following ABM, if aware, have you used it?

NO	**ABM**	**AWARE**		**USED**	
		Yes	**No**	**Yes**	**No**
1	Expanded polystyrene panels (EPS)				
2	Structural insulated panels (SIP)				
3	Fibre reinforced concrete (FRC)				

4	Precast concrete panels (PCP)				
5	Interlocking Stabilized Soil Blocks (ISSB)				
6	Artificial pozzolans in manufacturing of cement (AP) e.g. biomass fly ash				
7	Concrete with quarry dust as fine aggregate (QD)				

3. If aware and have used the ABM, What were your reasons for using the ABM and not the conventional building materials?

REASON	**EPS**	**SIP**	**FRC**	**PCP**	**ISSB**	**AP**	**QD**
Durability							
Cost advantage							
Availability							
Environmental friendliness							
Better quality							
Good constructability							
Government incentives							

Recyclable							
Client interest							
Other (Specify)							

4. If aware but have not used, what were your reasons for not using the ABM?

	EPS	SIP	FRC	PCP	ISSB	AP	QD
Lack of standards							
Unavailability in local market							
Inadequate knowledge of material							
Attitude of building professionals towards these materials							
Low profit margins							

More tests required on these materials							
Low levels of competent labour							
Lack of government support/incentives							
Public perception							
Environmental issues							
Low aesthetic value							
Doubtful durability & life span							
Other (Specify)							

SECTION C

1. Are you aware of any published quality specifications of these alternative building materials?

NO	ABM	AWARE	
		Yes	**No**
1	Expanded polystyrene panels (EPS)		
2	Structural insulated panels (SIP)		
3	Fibre reinforced concrete (FRC)		
4	Precast concrete panels (PCP)		
5	Interlocking Stabilized Soil Blocks (ISSB)		
6	Artificial pozzolans in manufacturing of cement (AP) e.g. biomass fly ash		
7	Concrete with quarry dust as fine aggregate (QD)		

2. If aware, do they in your opinion meet the laid down standards by the relevant authorities? e.g. KEBS or BS (British Standards)

NO	ABM	Yes	No
1	Expanded polystyrene panels (EPS)		
2	Structural insulated panels (SIP)		
3	Fibre reinforced concrete (FRC)		
4	Precast concrete panels (PCP)		
5	Interlocking Stabilized Soil Blocks (ISSB)		
6	Artificial pozzolans in manufacturing of cement (AP) e.g. biomass fly ash		
7	Concrete with quarry dust as fine aggregate (QD)		

SECTION D

1. In a scale of 1-10, how would you rank the following material adoption criteria in terms of importance? (Where 1 represents Most important and 10 Least important). Each rank in the scale should only be used once.

CRITERIA	**IMPORTANCE (1-10)**
Cost	
Aesthetic value	
Availability in the local market	
Durability	
Clients interest	
Compatibility with other materials	
Environmental friendliness	
Public perception	
Availability of standards	
Commercial status	

2. Briefly, what is your general opinion on the level of adoption of ABM in Nairobi city?

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

3. If you have used any ABM, what has been your experience?

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

Kenya Bureau of Standards

1. Are you aware of the existence of ABM in Nairobi city, if yes have you undertaken any critical quality tests on the following alternative building materials (ABM), if yes, did they pass the tests?

NO	ABM	Critical Test	Test Done		Test Passed		
			Yes	No	Yes	No	N/A
1	Expanded polystyrene panels (EPS)	Flexural strength					
		Compressive strength					
		Flame propagation characteristics					
		Other: Specify					
2	Structural insulated panels (SIP)	Thermal resistance					
		Flexural strength					
		Compressive strength					
		Other: Specify					
3	Fibre reinforced concrete (FRC)	Compressive strength					
		Shrinkage					

		Flexural strength					
		Other: Specify					
4	Precast concrete panels (PCP)	Compressive strength					
		Flexural strength					
		Other: Specify					
5	Interlocking Stabilized Soil Blocks (ISSB)	Compressive strength					
		Dry density					
		Water absorption					
		Other: Specify					
6	Biomass fly ash as an artificial pozzolans (AP)	Particle size					
		Carbon content					
		Compressive strength of concrete					
		Other: Specify					
7	Concrete with quarry dust as fine	Compressive strength					

	aggregate (QD)	Slump test					
		Flexural strength					
		Other: Specify					

General

Remarks………………………………………………………………………………………

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