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UNIVERSITY OF ZIMBABWE

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Contributions and Distribution of Workload

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Declaration

We fully declare that the following work, unless otherwise stated, is wholly the product of the students listed on the cover page. Citations and references are inserted to indicate original authors and sources of information that was used in writing out this Investigative Research Project. This project has never been submitted for assessment or examination for any degree or course in any other university.

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Abstract:

This paper serves to investigate the uptake of sustainable construction materials in Harare, Zimbabwe. Context on the need for sustainable construction materials is provided by analysis of the impact of construction from multiple perspectives including its consumption of natural resources, how energy intensive the production of materials and execution of construction is, the greenhouse gases emitted directly and indirectly from the construction sector. Sustainable construction materials are then researched in this paper. Following proposal of various sustainable construction materials, a questionnaire is designed which is sent out to various players in the construction sector in Harare. The data is then analysed using IBM SPSS software and the results are presented in both written and visual formats. The findings of the results were that there is limited awareness of sustainable construction materials in the Harare construction landscape. Only with increased efforts and collaboration from the governing bodies that determine rules and regulations will there be widespread awareness and implementation of sustainable materials in construction projects. There was a general agreement from industry professionals that to bring a new wave of sustainable construction materials into widespread use environmental regulating bodies, with the backing of government policy, would need to enact policies centred towards their implementation.

Key words:

Key words: Construction, materials, sustainable, renewable, recycled, Zimbabwe, Harare.

Abbreviations:

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1 Introduction

1.1 Background

Definitions:

Development that satisfies the requirements of the present without jeopardising future generations' ability to satiate their own needs is what the United Nations means when it talks about sustainability. This definition highlights the need for long-term sustainability and social justice through balancing economic, environmental, and social considerations (Jones Rachael, 2015).

Materials used in the construction of buildings and other structures are known as "building construction materials." Concrete, steel, wood, brick, glass, and insulating materials are just some of the many things that can fall into this category. The longevity, security, and ecological footprint of a building are all subject to the quality of the materials used in its construction. Some materials may be better able to survive severe weather or seismic activity, while others may be more cost-effective to use or have a less environmental impact. Cost, availability, local building laws and regulations, and the needs of the project are all important considerations when deciding which materials to use in construction.

Background:

The state of a society's buildings is indicative of its standard of living and quality of life. Development refers to the process of planning, designing, and constructing buildings or infrastructure projects to meet the needs of a particular community or area. It is man altering the environment to suit his wants and needs. The process of development calls upon construction to execute a proposed idea through the use of various building materials (Budher, 2011).

Building materials and technologies have evolved through the ages. Building conditions reflect the living standards of a society. Primitive building materials were stones, mud, thatch/leaves, and timber. There was no energy expenditure involved in making these, and their longevity was dubious at best. Bricks were one of the first instances of a lasting building material made utilising energy, and the process of burning them dates back to antiquity. This was followed by the use of metal products and the subsequent use of lime as a building material. The development of Portland cement in 1824 marked a significant step forward in the evolution of construction materials, allowing for the construction of more expansive buildings.

These required no energy in their manufacturing and their durability was questionable. The burning of bricks was one of the earliest examples of using energy in the manufacturing of durable construction materials. This was followed by the use of metal products and the subsequent use of lime as a building material. Portland cement's invention in 1824 was a major milestone in the advancements of building materials and enabled larger structures to be built.

Today, one of the most commonly and widely used construction materials are concrete and steel. The widespread use of these materials can be attributed to the relatively low cost of these materials and their low maintenance cost.

The environmental, economic, and resource impacts of the construction sector are far-reaching. Demand for construction materials is increasing in a world with an ever-growing population coupled with urban migration. Steel, cement, glass, aluminium, plastics, bricks, etc are materials that are commonly used in building construction although they are energy intensive have a significant environmental impact. There is a need to find alternative materials that are sustainable to be used in the construction industry, an alternative approach to offset the high energy requirements for the production of these materials would be to ensure they are implemented in long life cycle applications.

Table 1 Required energy and C02 emissions in production of building materials

Building materials	**Energy (MJ/kg)**	**Kg CO2/kg**
Aggregate	0.083	0.0048
Concrete (1:1:5:3 e.g., floor panels in situ, construction)	1.11	0.159
Cement mortar (1:3)	1.33	0.208
Steel	20.10	1.37
Bricks (all)	3.0	0.24

Up to 40% of all mined minerals, 70% of all electricity, 12% of all fresh water, and 45%-66% of all waste destined for landfills are all used by structures in industrialised countries (Pulselli et al., 2007). The output from buildings has to date accounted for 30% of ozone depleting substances (Carbon Fluoro Chlorides and the associated free radicals). Noting their contribution to the environment and climate gives context as to why the implementation of sustainable buildings and building materials is of significant importance. Sustainable building materials are described by Fisher (1992) as having:

i. Non-harmful inner environment.
ii. Significantly high energy efficiency.
iii. Ecologically benign materials.
iv. Good design. A blend of long life-span, relatively low consumption of energy and materials automated systems, efficient use of materials.
v. Financially feasible.

To maximise life span of concrete structures the impact of the external environment must be protected against. Freeze thaw, shrinkage, hardening are crack causing defects occurring in concrete brought about by the unmitigated environmental effects. These defects ultimately result in reduced performance of the concrete, reduced lifespan of structures, increased maintenance costs and a risk of failure if not attended to.

Moderating the impact of structures over their life cycles is the main aim of Green Building. This is achievable by prioritising usage of earth benevolent materials, execution of more efficient and resourceful systems among other tactics (Kumar Sharma, 2020).

The project aims to consider the materials currently in use in the Zimbabwean construction industry and attempts to come up with alternatives that:

i. Have excellent physical and mechanical properties.
ii. Have a low carbon footprint or reduce the overall carbon footprint of the construction industry.
iii. Have low energy consumption in their manufacturing process.
iv. Have high durability.
v. Readily available (may be recycled or naturally abundant).
vi. Are cost effective.

1.2 Problem Statement

Zimbabwe is a developing country with current and future plans to invest heavily in the construction industry/sector to build/better/enhance the economy. The major materials used in construction are non-renewable and cause irreparable damage to the environment in their procurement, refinement, and disposal. Striking a balance between development and maintaining the environment is a necessity given the finite nature of environmental resources despite a growing population (and its demands). This balance can be approached through the use of sustainable construction materials. This research project aims to propose sustainable solutions and evaluate their uptake in Zimbabwe, Harare.

1.3 Justification

The world population is ever growing and has surpassed 8billion (Mazbhelli, 2023) and with Zimbabwe’s population at 15 520 393 in 2023 according to Worldometers.info . This ever-growing population coupled with urban sprawl places on countries to invest in construction. Construction is a process that traditionally had limited regard for the natural world and its impact on the environment. Construction, if left unmonitored, has the potential to cause widespread damage to the environment. As such construction should have sustainability as one of its main focuses. Attaining sustainability will not only benefit the environment but also, reduce usage of materials, limit amount of waste produced and may result in cost savings for companies.

1.4 Objectives

1.4.1 Main Objective

The main objective of this research is to propose and evaluate whether construction companies operating in Zimbabwe are implementing sustainable methods and making use of sustainable materials in the projects they are engaged in.

1.4.2 Specific objectives

1. To identify the commonly used sustainable construction materials in Harare and evaluate the current usage and uptake of sustainable construction materials in Harare.
2. To assess the awareness and knowledge of local construction professionals about sustainable materials.
3. To determine the factors influencing the uptake of sustainable construction materials in Harare. In addition to investigate the potential and challenges associated with increasing the uptake of sustainable construction materials in Harare.
4. To provide recommendations and strategies for promoting and increasing the uptake of sustainable construction materials in Harare.

2 Literature Review

This literature review aims to provides an overview of the research on sustainable building construction materials and clearly define the scope of this research project as well as highlight the range of topics.

2.1 Mass Timber

Mass timber products are created by mechanically bonding various types of softwood to form large prefabricated wood components. Builders are using mass timber more frequently for components including roofs, flooring, beams, columns, and other structural elements in the United States. Mass timber offers a feasible alternative to conventional building materials with a higher carbon footprint, such as steel and concrete, in terms of sustainability. Emissions can be greatly reduced by using mass timber instead of standard building materials. The global warming potential of a hybrid CLT building is on average 26.5 percent lower than that of a concrete building, excluding biogenic carbon emissions, according to a study that examined the environmental impact of a reinforced concrete building and a commercial building made of CLT hybrids (Huang, Simonen, & Pierobon, 2019). Additionally, mass-timber buildings may be built more quickly and with less waste, which lessens the projects' impact on the environment. Cross-laminated timber comes from timber. It can also be utilized in mid-rise building; however, it is commonly employed to replace steel and concrete in high-rise construction. It is a superb example of a sustainable building material. Cross-laminated timber enables architects to build taller structures, without having to use either steel or concrete. The building is safer during earthquakes since its weight is spread more uniformly than with other materials. It is made by adhering layers of timber together (Ringhofer, 2016). CLT has a number of benefits over steel and concrete, including the capacity to construct taller buildings. and consume less energy to during production.

<u>Advantages of a Cross Laminated Timber structure:</u>

In comparison to conventional materials like steel and concrete, a CLT construction has a higher load-bearing capability and uses less material overall. They can be taller than comparable buildings because CLT buildings can support greater weight if they are denser and have smaller window, door, and roof openings (Huang, Simonen, & Pierobon, 2019). Higher strength with less flexural stiffness has been demonstrated for CLTs.

Shown below is the T3 (Timber, Technology, Transit) is a high-performance office block in Minneapolis that was constructed entirely out of mass timber and is meant to adapt to the city's unpredictable weather patterns."

Figure 1: T3 office building in Minneapolis.

Figure 2: At 85.4 metres, the Mjøstårnet building in Norway is the tallest timber-frame structure in the world.

The use of cross-laminated wood itself dates back many years, especially in Austria and Germany. Concern over the greenhouse gas emissions produced by concrete and steel are driving up interest in the material. According to a United Nations report, the manufacturing of building materials including steel, cement, and glass is responsible for 10% of the world's energy-related CO2 emissions (Ali & Hossain, 2011).

2.2 Flexible Concrete

Ductile in comparison to the brittle nature of regular concrete, flexible (or bendable) concrete is a type of engineered cementitious composite (ECC). To give conventional concrete a flexible nature, the material composition is altered. Victor Li, a professor at the University of Michigan, invented the malleable concrete. (Ogwezi, 2022).

Important constituents of flexible concrete:

Coarse aggregate is not used in the production of flexible concrete, which instead includes increased amounts of fibres.

i. Fibres

The most widely utilized fibres include silica, asbestos, glass, steel, and others. The fibres that are found in flexible concrete give it its flexibility. The fibres also serve as concrete reinforcement. The slick coating, an anti-friction coating applied to the fibres, reduces friction. The coating makes it easier for the fibres to enfold one another. As a result, the fibres won't rub against one another, which prevents the development of cracks in the concrete. Additionally, the concrete will be more flexible as a result (Sandeep, 2019).

ii. Fine Aggregates

The optimum fine aggregate for flexible concrete is typically the fine sand used in water treatment processes. In the absence of this, ordinary sand may be used. For this concrete-making process, substitutes including fly ash, blast furnace slag, and silica fume can also be employed.

iii. Superplasticizers

Superplasticizers are required because flexible concrete needs a higher degree of workability. Superplasticizers include, among others, the following:

- Lignin,
- Naphthalene,
- Melamine formaldehyde,
- Sulphonate,
- Polycarboxylate ether,
- Lignosulfonates.

Features of Flexible Concrete:

i. Flexible concrete has a tensile strength between 10 and 15 MPa.
ii. Up to 70MPa compressive strength can be attained with flexible concrete.
iii. As a result of the cement's contact with rainfall, flexible concrete has a self-healing ability that aids in filling the microcracks.
iv. Bendable concrete's maximal tensile strain can reach 3%-5%.
v. Flexible concrete has a strain capacity 300 times that of regular concrete. The concrete's adaptability comes from this (Mutalib, 2021).

Advantages of flexible concrete:

i. Ecologically, you should use bendable concrete. Carbon dioxide can be incorporated into the concrete, making it stronger with less cement and reducing emissions.
ii. Buildings will have lower financial and environmental costs thanks to ECC's ductility. Concrete that can be bent can bear greater pressures than regular concrete, which frequently breaks and needs to be repaired. Because of this, it requires less upkeep and repair, which saves contractors time, money, and carbon emissions when they use it.
iii. In comparison to traditional concrete, flexible concrete is lighter in weight by 20 to 40%.

Disadvantages of flexible concrete:

i. Skilled workers are needed.
ii. The preliminary investment in flexible concrete building is substantial.
iii. Flexible concrete requires specialised materials that can be difficult to source.
iv. The quality of flexible concrete is dependent on the quality of the materials and the atmospheric conditions it is made.
v. Flexible concrete has a lower compressive strength than regular concrete.

Applications of flexible concrete:

i. Construction of roads and bridges using flexible concrete eliminates the use of expansion and contraction joints. This is because the flexible concrete has the ability to change its shape within it.

Figure 3: ECC Link Slab, (replaced a conventional expansion joint) on a Michigan bridge deck, has lasted over a decade without repair or maintenance.

Case Study: Bendable concrete usage in the 61-story Kitahama tower in Osaka, Japan:

The 61-story Kitahama tower in Osaka, Japan is a notable example of the use of bendable concrete in high-rise construction. The tower, which was completed in 2019, is the first building of its kind to use this innovative material (Yu, 2021).

In the case of the Kitahama tower, bendable concrete was used in the core walls of the building, which support its weight and provide stability. The use of this material allowed the tower to be constructed with a smaller footprint, as the walls could be made thinner than with traditional concrete. This in turn allowed for more usable space in the building and reduced the overall weight of the structure (Li and Li, 2019).

The use of bendable concrete in the Kitahama tower has been hailed as a major innovation in high-rise construction, and it is likely that this material will be used in other tall buildings in the future. Its ability to withstand earthquakes and other natural disasters makes it an attractive option for buildings in areas prone to seismic activity, and its flexibility and strength also make it useful for a wide range of other construction applications (Mishra and Yu, 2019).

Figure 4: Kitahama Tower in Osaka

Overall, the use of bendable concrete in the Kitahama tower in Osaka, Japan represents a significant step forward in the development of more resilient and sustainable building materials. As the technology continues to evolve and become more widely adopted, it has the potential to revolutionize the way we build and design structures, making them safer, more efficient, and more adaptable to a changing world (Lee et al., 2022).

2.3 Bamboo

According to the International Plant Names Index, the name "bamboo" originates from the Arabic word "bamboo," which meaning "a reed that has been split." Bamboo has been a staple material in Asia for centuries. Bamboo's rapid growth and lack of toxicity make it a promising candidate for use in eco-friendly construction. In addition, bamboo may be harvested once a year with minimal environmental impact because it can grow as much as three feet in a single day. Because of its versatility, bamboo has been used for everything from traditional construction tools to low-cost housing. At a fraction of the cost of fibreglass, it can be moulded into virtually any shape or form, from wood to concrete to stiff foam panels to foam insulation, and beyond. India is the world's second-largest producer of bamboo. Bamboo has been regarded as a possible alternative for steel and wood due to environmental degradation and the depletion of wood resources brought on by an increased reliance on traditional building materials (Zhao, 2023).

Advantages of bamboo as a construction material:

i. Waste is minimal when working with bamboo. Even unused portions of a bamboo tree's stem can be recycled back into the earth through natural decomposition and composting processes.
ii. It can be harvested at any time and does not need to be replanted. A perennial grass rather than a tree, bamboo may be found on every continent barring Europe and Antarctica (Kim, 2019).
iii. It is also stronger than brick and concrete and has a higher strength-to-weight ratio than either. Therefore, it is the best choice for cabinetry and flooring alike. In terms of tensile strength, bamboo excels over its compressive strength. Actually, bamboo's fibres are quite stretchy and strong at the same time.
iv. The bamboo's elastic modulus is one of its most significant characteristics. The grade of the bamboo is higher with a higher elastic modulus. The bamboo tube wall's elastic modulus is impacted by the build-up of strong fibres.

Disadvantages of bamboo as a construction material:

i. When bamboo loses water, it shrinks more than wood and timber do. Because of this, it is vital that appropriate steps be taken to avoid water loss while using bamboo as a construction material.
ii. If the bamboo is not sufficiently treated it may undergo the fungus attack or attacks caused by insects.
iii. There may be a problem of swelling and shrinkage of bamboo in the concrete.
iv. Bamboo may absorb water during the casting and curing of the concrete.

Bamboo Architecture:

In bamboo architecture and design, bamboo is a highly common and commonly utilized material. Bamboo has excellent versatility, both in terms of strength and thickness, allowing for a variety of combinations and alterations to be made in accordance with architectural principles. Nowadays, bamboo is employed extensively in building construction and is quite popular. Bamboo is a great building material that may be used to create low-carbon and environmentally friendly structures.

The following image illustrates the application of Bamboo and concrete which were combined to create the textured walls of Bali's Tiing hotel, which complemented the area's natural surroundings.

Figure 5: Tiing Hotel in Bali has walls made of bamboo

<u>Case study: Green school, Bali-Indonesia</u>

An Arc gymnasium by Architecture Studio Ibuku.

The Arc is the latest building to be completed on the site of the Green school – a private educational institution that promotes sustainability through learning in a natural environment (Karsono et al., 2020).

Figure 6: The Ark is made from bamboo. Above: it is surrounded by a forest

The building was designed by Green School founders John and Cynthia Hardy's daughter Elora Hardy and her studio Ibuku in collaboration with bamboo architect Jorg Stamm and structural engineering firm Atelier One (Lianto et al., 2019). It forms a protective roof sheltering a multipurpose sports court with a floor area of 760 square metres.

Figure 7: The undulating canopy covers a sports pitch

The lightweight structure features bamboo arches that support an organically shaped canopy. The 14-metre-high arches are connected by anticlastic grid shells that curve in two directions to create a robust, tensioned structure.

Figure 8: The organically shaped roof was made from bamboo

The building's organic form and structural system were informed by natural systems, in particular the way our ribcages are held in place by the tension from an outer layer of muscle and skin. In The Arc, bamboo splits transfer forces from arch to arch.

Several months of research and development led to the creation of a precise geometrical solution that allowed the structure to enclose a large inner volume with a minimal amount of material (Widanti, 2022). The grid shells use shape stiffness to form the roof enclosure and provide buckling resistance to the parabolic arches (Karsono et al., 2020). The two systems together create a unique and highly efficient structure, able to flex under load allowing the structure to redistribute weight, easing localised forces on the arches (Alimin et al., 2021).

The arches supporting the pavilion's roof span 19 metres and allow for a large floor area that is uninterrupted by supporting columns. Spaces around the base of the canopy allow breezes to flow through, providing natural ventilation. Vents at the roof's apex also allow warm air to escape. The Green School has been constructing bamboo buildings at its campus in Bali, Indonesia, since it was founded in 2008 (Lianto et al., 2019). The school now also operates campuses in New Zealand, South Africa, and Mexico. All of the buildings at the jungle site in Bali's Badung regency are designed to be energy efficient and constructed using natural materials wherever possible. John Hardy and Jörg Stamm worked together with designer Aldo Landwehr to create the initial buildings and infrastructure including bridges and a spiralling three-storey building housing the high school and administrative areas (Taib et al., 2023).

Figure 9: Air can circulate through its openings

2.4 Recycled Materials

Majority of the large-scale industries and thermal power plants generate solid wastes in bulk quantities. Red-mud, coal ash, slag, fly ash, etc. represent such wastes unutilized for several decades. These materials are discarded in landfills and pose environmental and pollution hazards. These materials can be used to for the manufacture of bricks, substituted for the fine aggregates in concrete, and the partial replacement of cement in concrete.

Demolition debris recycling is another option to investigate in the search for optimal material utilisation. Steel, stone, and wood are all recycled to some degree, although they have not been fully optimised for recycling. Based on research by Venkatarama Reddy (2004).

2.5 Filter Slab Roofs

Figure 10: Filler Roof Slabs

Uses partially precast beams covered with panels as shown above. Varieties for beams are available (materials) and cross sections may be altered to either achieve max strength or minimise material usage or achieve both as needed by the building requirements.

<u>Advantages:</u>

i. The ability to prefabricate and construct rapidly.
ii. Prefabrication allows for higher quality control.
iii. Savings in volume of materials and hence cost effectiveness.
iv. Potential to improve thermal comfort with the use of hollow panels.

Solid reinforced concrete slabs with partial replacement of the concrete side in the tension zone by filler material. Filler material may be cheaper and lighter and may be any of the following (brick, Mangalore tile, clay tile, stabilised mud block, etc.). In a typical circumstance, 25% of the concrete can be replaced with a material that costs one third as much as concrete by employing a stabilized mud block. This means that 15–20% of the cost of concrete can be saved by this operation.

2.6 Fine Concrete Blocks

Similar to SMB production with soil being replaced by fines (20-25% of soil by weight) Examples include fly ash, polished stone waste and may be mixed with quarry dust with cement and water. The curing process is 28 days.

<u>Advantages:</u>

i. Red loamy soil (10%) may be added to enhance appearance, usage of waste materials.

2.7 Straw Bales

Straw bale construction refers to the practise of constructing buildings mostly out of bales or bundles of straw. An easily accessible agricultural by-product with potential as a building material. Straw bales are gaining popularity again due to their sustainable properties, although they have long been used as a popular building material in many parts of the world. Straw bales are commonly utilised in earthen or "natural" architecture projects (Thomson, 2014).

A load-bearing structure made of straw bales can also be utilized to handle the lateral or shear resistance of wind and seismic stresses. Due to their insulating qualities, straw bales are frequently used as in-fill in a variety of load-bearing frames as a non-load bearing component. Bales of straw are frequently bound together using two or three threads. While three-string bales are better suited for load-carrying purposes, two-string bales are best for non-load-bearing applications. Bales are joined together using polypropylene twine or baling wire (Walker, 2020).

Its main advantage is a reduction in the amount of energy required by the building for heating applications. This is mainly attributed to the insulating properties of straw.

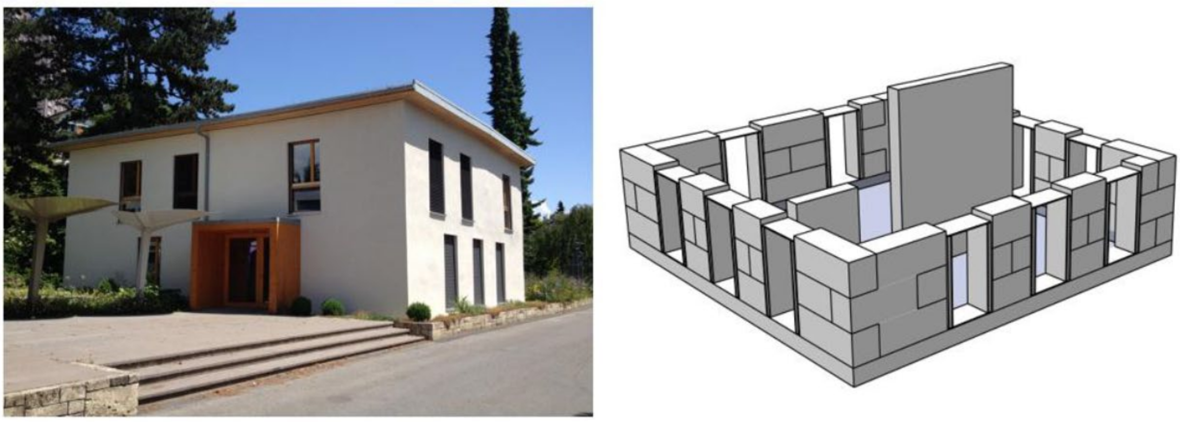

Figure 11: ECO46 completed building (left); EECO46 Render (right)

The Swiss city of Lausanne accepted the use of this material in the construction of an administrative office building called ECO46 because it was looking for sustainable building options. There were enough desks for seven people, as well as two meeting rooms, a kitchen, and a small dining area, in this two-story facility. The entire structure is a load-bearing example of the Nebraska method, in which straw bales are used. To minimise its influence on the environment, the ECO46 building was mostly built with earth (for its centre wall), wood from local woods (for its floors, decks, and structural parts), and wheat straw (for its walls, roof, and insulation).

While the straw construction process is competitively priced in comparison to conventional methods, it is not yet optimised, and as more research is conducted into the applications of this non-traditional material in construction, its prices may drop to become significantly lower than conventional methods. The ease of use that permits DIY construction is another positive aspect of this approach. Buildings made using non-traditional materials can attain the same efficiency as conventional, low-energy-use structures, as confirmed by ECO46. Straw is an agricultural by-product that is typically discarded by farmers and disposed of in one of two ways: either by burying it or burning it. The use of straw in building appears to be a reasonable reaction to the depletion of finite resources. When compared to conventional building materials like wood and brick, straw presents an intriguing option.

Figure 12: Straw Bale House

Construction of Straw Bales:

First, waste stalk and straw from wheat, rye, and other crops are collected and turned into bales. The bales are connected with three threads of polypropylene wiring string or baling wire to create a load-bearing wall. 12mm threaded rods are used to build the foundation, which is then covered with the top layer. With each next layer, more rods are added. The bales have window and door holes carved into them. The second layer of bales is positioned above the first layer so that the centre of each bale in the uppermost layer is directly above the beam that connects the bottom two layers of bales. A sturdy and long-lasting wall is produced by stacking with running bonds. The roof is supported by a wooden crate beam that serves as the top plate. The entire wall is connected by the connecting rod that protrudes from the box beam. Plumbing, wiring, and power have all been installed in the spaces between the bales (Walker, 2020).

Advantages of Straw Bale:

i. Extremely light material (250kg/m^3 compared to 2200kg/m^3 for concrete).
ii. Renewable and abundant construction material.
iii. Carbon neutral material.
iv. Construction raw materials are inexpensive.
v. Due to their dense packing, straw bales are three times more fire resistant than conventionally constructed walls.
vi. It may sound contradictory, but straw bale is a good alternative in wildfire-prone locations.
vii. The massive, sturdy walls are soundproof, providing a haven from the outside world.
viii. The straw is not harmful if it was grown without the use of standard pesticides or fertilizers. There won't be any dangerous materials or off-gassing.
ix. Because the building components are large and simple to install, construction may be completed quickly.
x. Straw bales are strong enough to withstand severe winds while remaining flexible in the event of an earthquake.

Disadvantages of Straw Bale:

i. Issues of overheating as less mass to conduct heat is available.
ii. Not as strong as conventional materials (compressive strength).
iii. A central wall is often needed in structures as a load bearing structure to compensate for the low compressive strength of straw bale.
iv. If straw bales are not stored properly, they are prone to rot and mould.
v. Due to their rarity as a building material and the fact that not all municipalities have building regulations that apply to them, straw bale construction can also be challenging in terms of obtaining building licenses or insurance coverage.
vi. Rodents and other small animals must be kept out of straw bales while they are being built.

vii. Because of the thickness of the walls, more of the building's total floor space is unused.
viii. Fire is also a problem, although due to the density of the bales, fires tend to smoulder instead of spread when an ignition stimulus is removed.

This is a readily available waste from agriculture that is useable as a construction material.

Its main advantage is a reduction in the amount of energy required by the building for heating applications. This is mainly attributed to the insulating properties of straw.

2.8 Agro-Waste

The construction sector has, in modern times is faced by a myriad of challenges primarily due to the increase in the urban population and increase natural resources that facilitate the production of construction materials, in addition to the said ideas, a greater understanding of climate change is causing companies to reconsider how they approach the development of more sustainable construction materials (Maraveas, 2020). The materials made from agro waste include brick (masonry elements, green concrete, insulation materials for buildings and bio-based plastics. Agricultural waste is either burned into ash, which is used to make concrete, or it is crushed and transformed into fine and coarse aggregates. Agricultural solid waste is a lightweight aggregate used in the production of masonry blocks (Mangesh, et al, 2013).

Buildings' decreasing capacity to maintain a comfortable internal atmosphere without the use of mechanical air conditioning has led to a rise in the usage of agro waste as thermal insulators in recent years. Cement composites reinforced with vegetable bagasse fibres were subjected to thermal conductivity and specific heat testing, with the findings showing that the addition of ratified bagasse fibres decreases thermal conductivity and produces a weaker specific heat (Passe-Coutrin Nady, et al, 2010).

Taking another direction to look at agro waste being used aggregate, Mannan and Ganapathy utilized oil palm shell (OPS) as a coarse aggregate for a structural concrete.

Figure 13: Image showing standard bricks from agro-waste

The results indicated that the bulk density of OPS concrete is about 1850kg/m3 and the compressive strength was between 20 and 24 N/mm2 for 28 days which satisfies the strength requirement of structural lightweight concrete. The results also indicated samples had the same physical properties as those of natural sand and these samples also showed better mechanical results than the already being used convectional mortar (Sales Almir et al, 2020). Fibre replacement is also another application of agro waste material in the goal of achieving sustainable construction. Vegetables fibres contain cellulose, a natural polymer as the main reinforcement material. The fibrils are assembled in various layers to build up the structure of the fibre, fibres are cemented together in the plant by lignin. These fibres can then be used as reinforcement for soil and cement composites. These fibres are very good thermal insulators as well enhancing the ventilation of a structure (Coutts RSP et al, 2020).

2.9 Recycled Steel

Environmental issues such as exhaustion of natural resources and generation of enormous amounts of waste and their dumping are currently steering the modern civilization to sustainable construction. Steel fibre reinforced concrete has been in application for many decades because of its capability in arresting crack and introducing ductility to structural concrete. Concerning about natural resources and adverse environment impact of carbon dioxide which is largely produced by steel fibre production. As a counter act to its hazardous effect on the environment, recycled steel fibre reinforced cement mixtures behave differently (Liew, 2020). Recycled steel can be used as aggregate in concrete and has shown to be sustainable and economical alternative to natural aggregates which were being used and also effective in non-structural components where strength is not critical (Sepani Senaratne, 2017).

Figure 14: Waste steel to be used for recycling

Figure 15: Recycled steel being used in construction

Recycled steel brings about making old used steel come back to being useful again reducing pacing reduction natural resources. In construction is the corner stone of most structures due to its long life-span, physical and mechanical properties hence steel is required in large quantities. Recycled steel has more or less the same properties being offered by fresh steel hence adopting the use of recycled steel is worthy consideration.

2.10 Geopolymer foam concrete

Geopolymer foam concrete, created as a result of recent developments, combines the performance advantages and operating energy savings made possible by the use of a geopolymer binder made from fly ash. An alternative to Portland cement is geopolymer, which is made of tetrahedral silicate and aluminate units connected by covalent connections to form a three-dimensional structure. In terms of lowered production energy requirements and fewer carbon dioxide emissions, geopolymers are typically reported to be substantially more environmentally friendly than Portland cement (Oliver et al, 2012). The two most popular raw materials used to create geopolymers for use in building are fly ash and calcined clay.

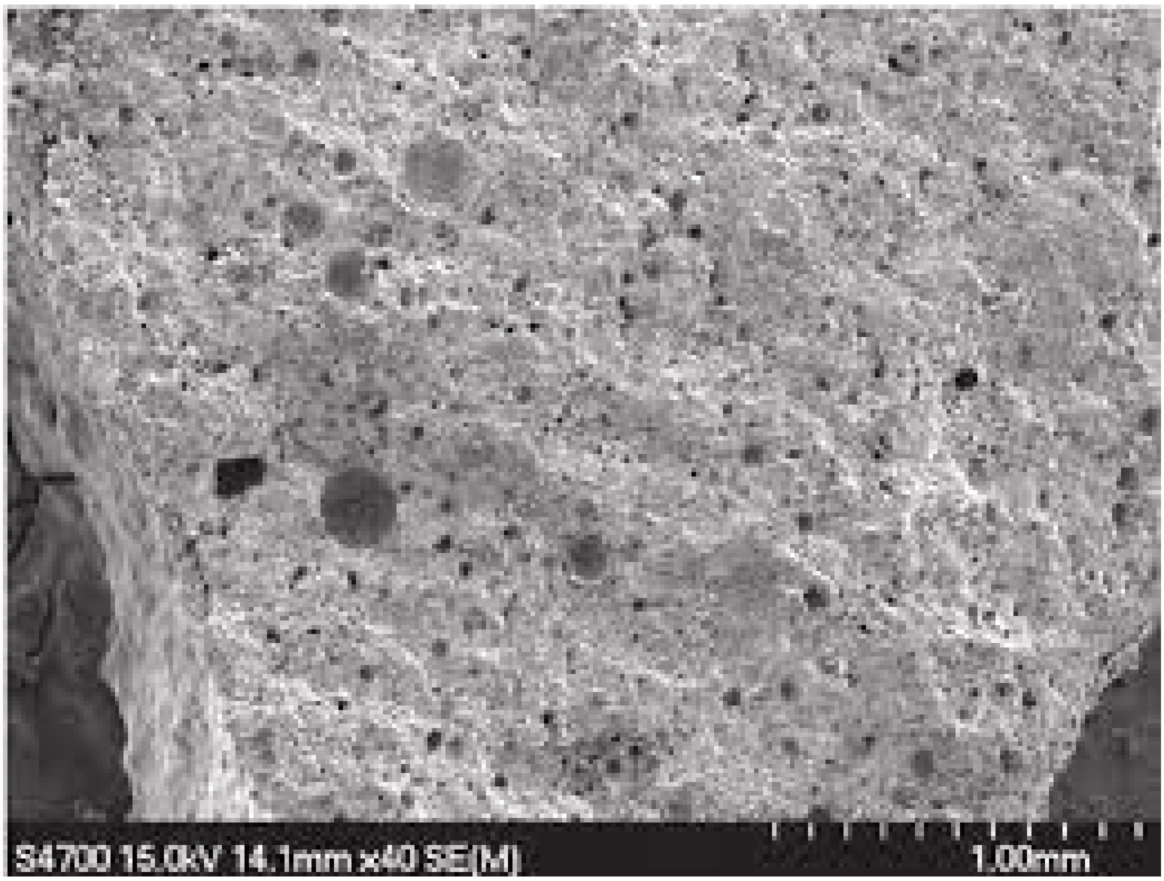

Figure 16: Geopolymer foam used as aggregates for construction

Figure 17: Geopolymer as foundation for construction

Fly ash is an industrial waste by product generated through coal fired electricity generation. A more recent innovation, geo polymer foam concrete combines the advantages of foam concrete and geopolymer technology, and provides the opportunity to reduce the environmental footprint of construction materials in terms of raw materials, embodied carbon dioxide and operational energy in service (Patel, 2018). The properties of foam concrete are far superior to those of Portland cement, defining in terms of thermal insulation, foam concretes are popularly mainly because of their good thermal properties. When tests were carried out, they showed greater thermal properties due to their density, porosity, and voids ratio in comparison to limestone concrete. The mechanical properties of geopolymer foam concrete have modulus of elasticity ranging from 1.7 to 3,5GPa.

2.11 Reclaimed Wood and Plastic

One of the most recent developments pointing to environmentally friendly building materials is the potential use of recycled plastic and salvaged timber. Recent years have seen a significant increase in the amount of solid trash generated worldwide that is related to plastic, with considerable negative effects on the environment and human health. The creation of high strength lightweight concrete using recycled high impact polyethylene and low-density polythene plastic wastes in cement-based composites (Sarath Chandra et al, 2021).

Figure 18: Waste plastic recycled and converted to bricks for construction

These polymers were recycled to create plastic granules with particle sizes of around 2 mm, which were used in concrete mixes at varying percentages to partially replace sand. As the amount of recycled waste plastic granules used rose, its workability, density, and compressive strength all decreased. These characteristics imply that high- and low-density polyethylene plastic waste, at a maximum of 10%, can be used to make lightweight-high strength concrete with properties very similar to those of lightweight concrete made with convective materials, such as Portland cement (MOSA, 2018).

2.12 Implementation of Sustainable Construction Materials

In order for frontline industry experts (government authorities, contractors, project managers) to effectively execute the use of sustainable construction materials, it is necessary to first identify possible drivers and restricting factors. Locating the positive and negative influences on sustainable building is crucial because it will facilitate the adoption of the former and the elimination or regulation of the latter. Therefore, Table 2 gives a summary of research conducted in various countries that were particularly concerned with sustainability consciousness, as well as the reasons for, prospects of, and impediments to achieving sustainable construction practises. The literature provides a good basis for the study's goals, which include identifying driver factors, impediments, and gauging the level of knowledge regarding sustainable construction among industry professionals in Harare.

Table 2 Overview of the literature on the drivers of, and barriers to, sustainable construction (SC).

Location	Reference	Findings
Korea	(Whang & Kim, 2015)	**Environmental:** energy efficiency, indoor air quality, waste management, ecological environment. **Economic:** life-cycle cost, knowledge management, value for money in delivery, retention of skilled labour, innovation. **Social:** well-being, community, education/training, health, and safety.
Canada	(Ruparathna & Hewage, 2015)	**Barriers:** lack of consideration of sustainability criteria in the evaluation of bids, unavailability of standard methods for procurement, lack of knowledge of local conditions, lack of explicit statutory requirements that cover sustainable procurement.
Malaysia	(Shaffi, Ali, & Othman, 2006)	**Barriers:** lack of awareness on sustainable building, lack of training and education, the higher cost of sustainable building options, procurement issues, regulatory barriers, lack of professional capabilities/designers, disincentive factors for local material production, lack of case studies/examples.

Chile	(Vera, Kort, & Serpell, 2013)	**Drivers:** laws and government regulations, corporate awareness, corporate image, customer demand, cost cutting, market differentiation, suppliers. **Barriers:** lack of financial incentives, designers work alone, economic priorities taking precedence, the exclusion of environmental expenses from the cost structure, bureaucracy within the governmental, ignorance on sustainable technologies, lack of environmental awareness, and affordability.
UK	(Pitt, Tucker, & Riley, 2009)	**Drivers:** client awareness, client demand, financial incentives, investment, labelling/measurement, planning policy, taxes. **Barriers:** cost, building standards, lack of client awareness, lack of business case understanding, lack of client demand, lack of proven alternative technologies, lack of a common labelling/measurement standard, planning policies.

Table 3 Overview of the literature on the drivers of, and barriers to, sustainable construction

Location	Reference	Findings
Finland	(Manodialis, Tsolas, & Nakou, 2006)	**Drivers:** development of client awareness about the benefits of sustainable construction, developing and implementing techniques for managing sustainable building requirements, mobilizing of sustainable building tools, enhancing designers' abilities and team-work and the creating novel ideas and services. **Barriers:** steering mechanisms, economics, a lack of client understanding, process (procurement and tendering, scheduling, cooperation, and networking), and underlying knowledge (knowledge and common language, the availability of methods and tools, innovation).
Greece	(Hakkinen & Belloni, 2011)	**Drivers:** energy conservation, waste reduction, air quality, environmentally-friendly energy technologies, resource conservation, performance-based incentive programmes, land-use regulations and urban-planning policies, education and training, re-engineering the design process, sustainable construction materials, new cost metrics based on economic and ecological value systems, new kinds of partnerships and project stakeholders, product innovation and/or certification, recognition of commercial buildings as productivity assets.

3 Methodology

3.1 Steps to be taken

1. Research design:

   This study will use a mixed-methods approach, combining qualitative and quantitative techniques, as its research design. Quantitative methods will be utilised to collect data on the actual uptake of sustainable construction materials in Harare, while qualitative methods will be used to gain data on the attitudes and views of potential buyers.

2. Sampling:

   Participants in the Harare construction sector (architects, engineers, contractors, suppliers, and government officials) will make up the study's sampling frame. To guarantee that the sample is statistically valid and representative of the population of interest, we will select 30 individuals at random to participate in the study.

3. Data collection:

   Multiple methods, including surveys and document analysis, will be used to gather information. All attendees will be given surveys to compile quantitative data on the actual uptake of green building products in the Zimbabwean capital of Harare. The proper documentation will be analysed along with the pertinent literature. The current investigation will be based on the results of a comprehensive literature review. The literature study will be used as a blueprint for the survey's layout. The questionnaire will be written so that it may be filled out by the respondent in the researcher's absence and that it answers the questions and achieves the aims of the study. The majority of the items in the survey will be of a limited length and type. Contractors, subcontractors, clients, consultants, developers, academics/researchers from recognised institutes, facility managers, and any specialists from the construction sector (private and government sectors) will be among those who receive the questionnaire and fill it out. These persons were chosen to fill out the survey because they have both theoretical and practical knowledge of the building industry in Harare.

4. Data analysis:

   There will be an emphasis on both descriptive and inferential statistics during this data study. Means and frequencies will be utilised alongside other descriptive statistics to sketch the actual take-up of sustainable construction materials in Harare. We will employ inferential statistics like regression analysis to identify the drivers of demand for eco-friendly building supplies in Zimbabwe's capital city.

5. Ethical considerations:

   Ethical considerations will be taken into account throughout the research process. Informed consent will be obtained from all participants before data collection. Participants will be informed of the purpose of the study, their rights as participants, and the confidentiality of their responses. Data will be stored securely and anonymously, and any identifying information will be removed before analysis.

6. Limitations:

   Some limitations of this study may include a potential bias in the sample selection due to the purposive sampling technique, the potential for response bias in surveys, and the limited generalizability of the findings due to the specific context of Harare.

3.2 Surveys to be conducted

2 survey questionnaires are to be conducted as a means of data collection. The first is an open-ended questionnaire that contains guided questions. The second is a Likert Scale survey in which responses are given on a scale from 1 to 5. Both survey questionnaires may be conducted in person or sent electronically for respondents to complete at a time convenient to them. The surveys are included in Appendix 1.

3.3 Companies to be approached

The scope of the project limited the companies which were to be approached to a geographic area of Harare, Zimbabwe. In the selection of companies to be chosen to fill out the questionnaire the authors of this research project selected companies with a wide scope of areas of specialty ranging from building contractors, road construction companies and companies whose line of work encompasses multiple structures.

The following companies were approached:

- i. Fossil Contracting (4 individuals).
- ii. Tensor Systems (3 individuals).
- iii. Integrated Construction Projects (ICP) (2 individual).
- iv. Engineering Infrastructure and Estates (University of Zimbabwe) (3 individuals).
- v. Brian Colquhoun Hugh O'Donnell & Partners (BCHOD) (3 individuals).
- vi. Masimba Holdings (3 individuals).
- vii. ProMech Construction (2 individuals).
- viii. Frontline Contracting (1 individual).
- ix. KW Construction (3 individuals).
- x. Tovaka Construction (2 individuals).

xi. Tencraft Construction (1 individuals).
xii. A.M. Machado Building Contractors (3 individuals).

4 Results and Discussion

4.1 Respondents' Profile

The questionnaire survey forms were distributed to local construction stakeholders associated with the Harare construction industry. A total of 30 questionnaires were distributed and 22 completed questionnaires were received. Table 4 summarizes the respondents' profile.

Table 4: Summary of Respondents' profile

Category	**Respondents**	
	Number	**%**
Business category		
Engineer Contractor Consultant Facility manager	10 6 4 2	45% 27% 18% 9%
Years of experience		
<5 5 to 10 10 to 15 15 to 20 >20	3 10 8 0 1	14% 45% 36% 0% 5%

The largest number of respondents came from 45% engineers, followed by 27% contractor and 18% consultant. Fewer results were received from 9% facility manager. Of the respondents surveyed, 45% had between 5-10 years of experience in construction industry, 5% had more than 20 years of experience, 36% had between 10-15 years of experience and there was no-one with 15-20 years of experience. These questions also help to suggest the idea of the sustainability of construction projects in Harare to the research participants, in order to open avenues for new research in terms of addressing public and private sector perceptions of moving towards usage of sustainable construction materials in Harare.

4.2 Level of knowledge, awareness and understanding of sustainable construction materials

In order to gain an insight into the level of awareness and knowledge among construction stakeholders with regard to the concept of sustainability, the respondents were asked to define a sustainable construction material and rate how familiar were they with these materials. A total of 68.2% of respondents considered the concept of sustainable construction materials to be somewhat and moderately familiar. Figure 14 below demonstrates that 13.6% of the respondents considered the concept of sustainable construction materials to be very familiar. The percentage of respondents who claimed to have either excellent knowledge or zero knowledge stood equally at 9.1%. Judging by how respondents defined a sustainable construction material and outlined its benefits, the level of awareness and understanding of these materials is generally moderate.

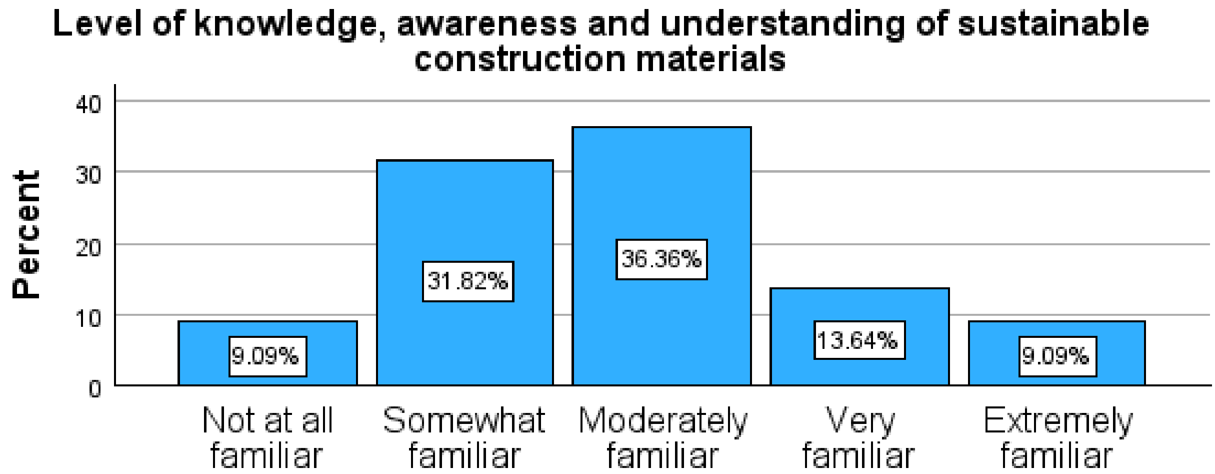

Figure 19: Level of Awareness of Sustainable Construction Materials

4.3 Current usage of sustainable building construction materials in Harare

The bar chart below shows that 50% of the respondents rarely use recycled aggregates in the construction projects they take part in. This is a bigger percentage as compared to other respondents of 4.55% who often use recycled materials and 9.09% who never use recycled materials. This shows that the current usage of sustainable construction materials is still relatively low. For materials like bamboo, strawbale and bendable concrete, they acknowledged their properties but they said have never used those kinds of materials in construction projects.

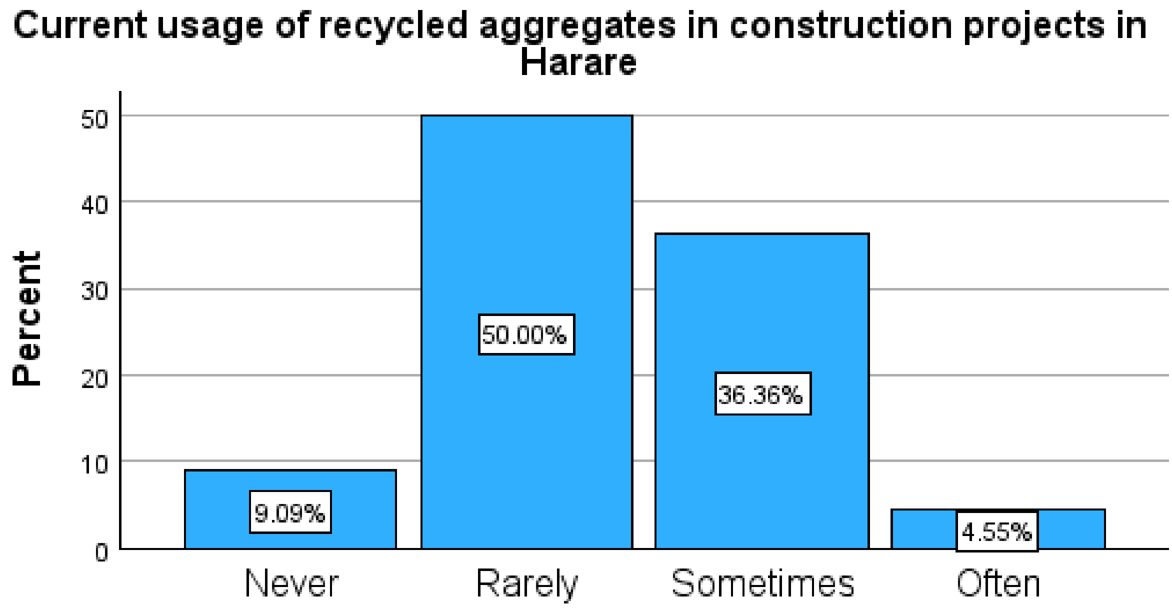

Figure 20: Current Usage of Recycled Aggregates in Construction Projects in Harare

4.4 Willingness to act by incorporating necessary changes to implement usage of sustainable construction materials

Figure below illustrates the initiative and willingness of the surveyed respondents with regard to incorporating sustainable construction materials in their future projects or future company strategy. The majority of respondents showed good willingness to incorporate sustainable practices into their future projects. Moreover, the results suggest that only 4.5% of respondents indicated a 'not at all willing level' on the scale, indicating that they have minimal or zero intentions to implement sustainable construction materials in future projects.

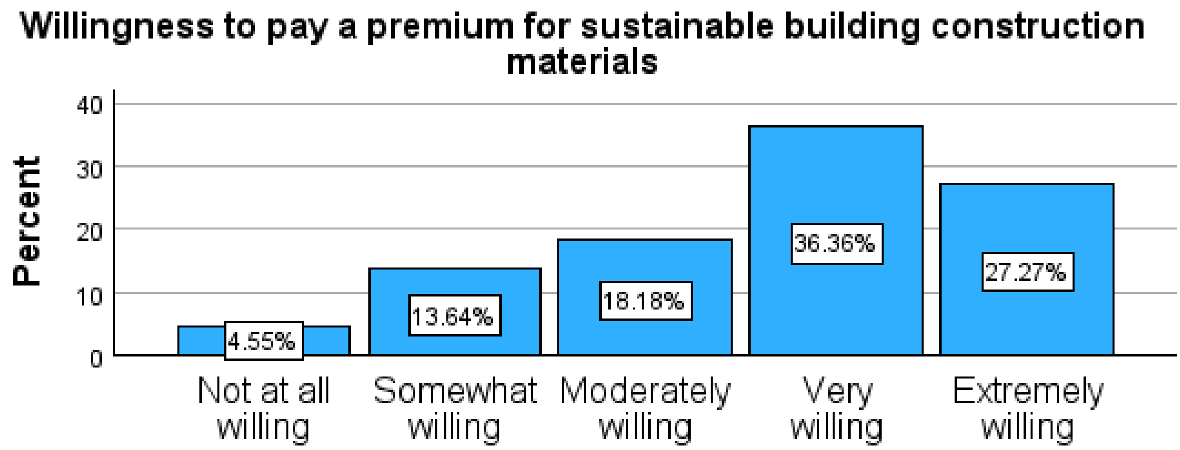

Figure 21: Willingness to Pay a Premium for Sustainable Construction Materials

The level of awareness and the level of implementation and practice are closely linked. The effort put into action and adoption towards the concept of sustainability depends on the awareness, knowledge, and an understanding of the consequences of key individual actions (Zainul Abidin Nazirah, 2010). The factors that push the sustainable movement are knowledge and awareness, furthermore these factors provide interest in and demand for sustainable construction (Häkkinen and Belloni, 2011). It is further suggested that comprehensive education and training is required to bring awareness in the stakeholders, and this is essential to the implementation of a successful sustainable building project (Cattano, Valdes-Vasquez and Klotz, 2012).

Additionally, the results illustrate that the awareness levels of construction stakeholders surveyed in Harare range from moderate to low. Harare still lacks in this issue. Public awareness can play a crucial role in achieving sustainability within a construction environment. It is necessary to increase the level of awareness in construction stakeholders for achieving sustainability and building eco-friendly buildings. For this purpose, both public and private sectors play their part but there is still a need for inclination. The advantages of sustainable construction materials should be publicized to the stakeholders of construction industry and to guide them towards changing their lifestyle towards lowering high CO2 emissions [2]. Knowledge sharing must be continued to inspire people to accept the new concept of sustainable construction. Therefore, through implementation and experience construction stakeholders will learn about this new concept. It is recommended that an increase in the level of awareness can be achieved by increasing the level of conferences seminars, training, and workshops.

4.5 The Driving Factors behind sustainable construction

For new practices to emerge in construction, some sort of drive is necessary to expedite and encourage efforts towards their adoption. The respondents were therefore asked to mention what they perceived to be the most significant driving factors in promoting the adoption of sustainable construction practices. We got a lot of factors from the respondents and we had to filter them according to the frequency in they were mentioned by respondents. We filtered them until they were four.

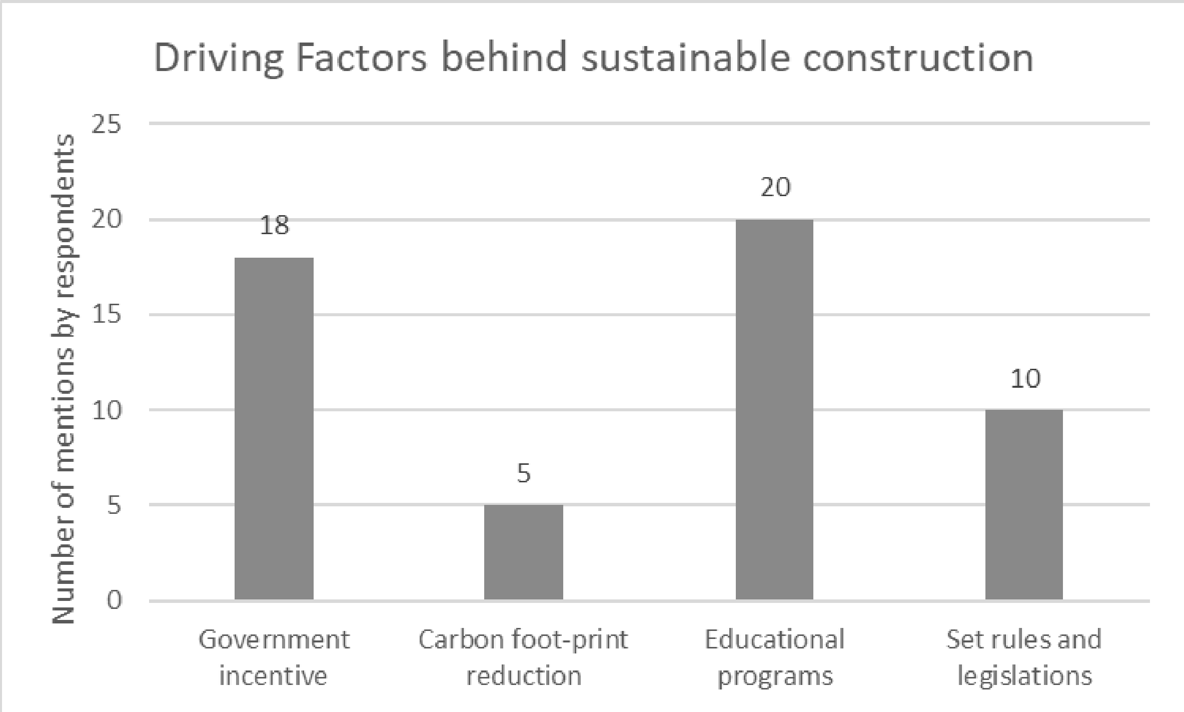

Figure 22: Driving Factors behind Sustainable Construction.

Figure above shows that educational programs (number of mentions = 20) are perceived to be the most important factor in order to promote and expedite efforts towards sustainable construction projects in Harare. The findings also highlighted other important factors, such as “set rules and legislation”, and “government incentives”. Despite being the one with the least mentions, “carbon foot-print reduction” is still an important factor. The results reveal that the majority of respondents believe that education is a key in order to expedite the movement towards incorporating sustainable construction materials in future projects. The poor demand for sustainable construction materials evident in these results could also be due to the lack of credible research on the benefits of using sustainable construction materials. Improved knowledge of the benefits offered by sustainable materials could increase construction stakeholders' interest in incorporating sustainable techniques; however, most of the respondents believed that this could be best expedited by providing government subsidies for the research on sustainable construction materials. Furthermore, the senior management teams of construction companies could then convey the evident benefits of sustainable buildings to society and individuals, as well as their long-term cost benefits, thus raising national awareness of the need for sustainable construction.

4.6 Perceived Barriers to the Implementation of Sustainable construction materials

Barriers were identified from literature and industry practitioners were asked to rate each factor according to its significance as a barrier to the implementation of sustainable construction materials in Harare. The data gathered was then assessed and analysed based on the mean values. Understanding the barriers to successful implementation of sustainable construction materials will help to identify ways to promote sustainable materials in the construction industry. It is necessary to understand the barriers that exist from a stakeholder perspective in order to provide pragmatic solutions and recommendations to mitigate such barriers to expedite the growth of a sustainable construction model. The barriers listed in the questionnaire were devised in accordance with the literature review.

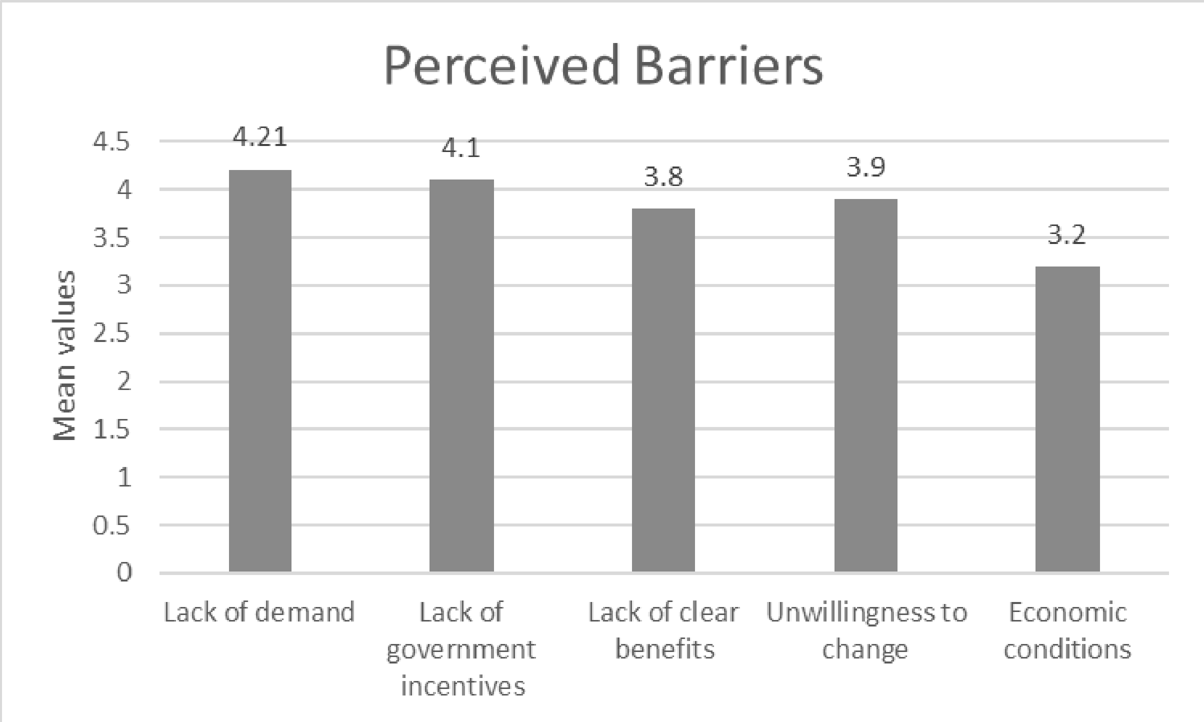

Figure 23: Perceived Barriers to Sustainable Construction.

Figure above illustrates the results of the respondent's perception towards the barriers of sustainable construction materials, ranked according to the mean value. The results demonstrate that the two most important barriers highlighted, considered by respondents to be of almost equal importance, were lack of demand (mean = 4.21) and lack of government incentives (mean = 4.10). This is in line with (Williams and Dair, 2007) whose research suggests that there is a need for regulation and policy to keep pace with best practices to allow more regulatory power as it is required. Conversely, the barrier considered the least important was economic conditions (mean = 3.20). Educating the relevant parties in order to raise awareness of the sustainability concept is vital in order to overcome several obstacles to the dissemination of sustainability in construction, such as the lack of awareness and knowledge of these methods and their benefits. Economic incentives are equally important steps that the government can provide to construction groups in order to overcome the obstacle of the cost of acquiring other sustainable construction materials. The results also suggest that unwillingness to change is also another deterrent from a stakeholder's perspective. This is not only because of the lack of awareness, knowledge, and concern for the environment, but also because of the view that traditional practices of undertaking design, construction and maintenance projects are satisfactory. In this context, improving knowledge through the introduction of an educational program in this sector would lead to more experienced consumers who demand more efficient construction projects from the companies with which they work, thus promoting sustainable practices.

5 Conclusion and Recommendations

This study has presented data collected using a questionnaire and analysis of the results. The objectives of the questionnaire were to assess the level of awareness and knowledge of local construction professionals about sustainable construction materials in Harare, in order to measure current usage of sustainable materials by respondents in their organisations; to measure how the respondents' views of the key issues related to sustainable design; and to examine drivers and any barriers that may exist towards implementing the practice of sustainable construction. To achieve these objectives, the questionnaire was administered to experienced stakeholders in Harare building and construction industry; a total of 22 completed questionnaires were used for this part of the research project.

The data from the questionnaires was then organised and analysed using SPSS software. The results highlighted that the general awareness levels towards the concept of sustainable construction materials are generally low with 40.89% of respondents being less than moderately familiar with sustainable construction materials. To remedy this low level of awareness, greater effort is required to raise awareness in order to accelerate the growth, adoption, and implementation of sustainable construction materials in Harare.

In addition, the questionnaire results revealed that implementation of sustainable materials in projects is rare with only 41% of respondents using sustainable construction materials on a regular basis. Rules and regulations are required as guidelines for meeting the needs of both society and the environment. To promote sustainable construction materials, the government should revise the current standards or introduce new regulations that stimulate increased usage of sustainable construction materials. This will then encourage all stakeholders involved to make changes in order for them to comply with the new legislation. Cooperation between the private and governmental sectors is required to ensure that the standards and rules are set in an appropriate, achievable way to ensure that the construction industry will be able to adapt and implement the new legislation accordingly.

There is a high willingness to incorporate sustainable construction materials showing that if awareness levels increase and legislation is enacted to encourage usage of construction materials the construction industry in Harare is enthusiastic to embrace these materials. This prompted an analysis of the current barriers and the need to address them. Educational programmes was the driving factor cited the most by industry professionals from our survey sample. There is therefore a need to adjust educational programmes to keep with the times and inform students (soon to be professionals) of the importance of sustainable construction materials as well as to inform them of viable materials that can be implemented in Harare. Incorporation of this knowledge into educational systems will be the first step in transforming the construction landscape in Harare.

The factor that was cited the second most frequently as being a driving factor behind sustainable construction is government incentive. Government incentive may be used to encourage the construction sector to embrace and implement sustainable construction materials in their projects. This may be achieved through tax credits, tax deductions or tax exemptions, grants or subsidies granted to players in the construction sector who are embracing sustainable construction material. One can postulate that this factor may be related to the most cited factor (educational programmes). Should educational programmes pivot and incorporate sustainable construction materials, there will be increased awareness across multiple sectors of industry including withing the upper ranks of the legislative branches of government. This may in turn foster new legislation that is pro-sustainable construction materials so as to allow the construction industry to transition and implement the new legislation with minimal disruption and risk.

There is also a need to address and tackle the perceived barriers to sustainable construction in Harare. Lack of demand may be addressed by ensuring implementations of sustainable materials are visually pleasing (e.g., the Green School in Bali, the T3 building in Minneapolis, the Mjøstårnet building in Norway). Such structures work well in breaking the misconception that structures built with sustainable construction materials are not aesthetically pleasing.

The second barrier, lack of government incentives was addressed in the above paragraph.

Lack of clear benefits is the third barrier identified by industry professionals. This barrier can be disproved by taking case studies into account including the Kitahama Tower in Osaka. This is a structure incorporating flexible concrete into its design to make it more earthquake resilient while still maintaining functionality in all other areas.

Unwillingness to change may perhaps be the most difficult barrier to tackle, however change is inevitable and if all other barriers are addressed then this too may be overcome.

Economic conditions was also a barrier frequently mentioned by industry professionals. Implementation of government incentives may offset the effects of this barrier.

Tackling all the above-mentioned factors is crucial to increasing the uptake of sustainable construction materials in Harare. Stakeholders need to initiate discussions, seminars, training, and workshops on sustainable construction materials. Only then will the uptake of sustainable construction materials significantly increase in the construction sector in Harare.

6 Appendix 1: Surveys conducted

6.1 Survey 1 (Open-ended Questionnaire)

Instructions
Kindly fill in the questions asked in the blue table provided below.

Questions

1. Please state the name of this company and how long it has been in business for.

2. We know you are involved in building construction. What projects are you currently involved in?

i.

3. Please give an outline of the materials you use (quantities per month) and if possible, where they are procured from.

Material	Quantity per month	Source of procurement

4. What are the main factors that influence your decision to use particular construction materials?

i.

5. What is the most common challenge your company faces during the construction process?

6. Challenges faced with the following materials:
   For each material, please specify challenges:
      -in the procurement.
      -In the waste disposal.
      -In the process technology.

Material	Procurement	Disposal	Process Technology
Bricks			
Cement			
Wood			
Steel			
Aluminum			
Fine Aggregate			
Coarse Aggregate			

7. What steps does your company take to minimize environmental impact during construction projects?

   i.

8. Please elaborate on how the term "sustainable" applies to your field and your company.

9. Have you ever used sustainable construction materials in your projects? If yes, which ones?

10. Have you ever encountered any technical challenges when using sustainable construction materials? If yes, what were they?

i.

11. What are the main barriers to the adoption of sustainable building construction materials in Harare, and how can these barriers be overcome?

i.

12. Are you aware of the applications of the following materials in the construction industry:

a. Mass timber?
b. Bendable concrete?
c. Bamboo?
d. Recycled materials?
e. Fine concrete blocks?
f. Straw bales?
g. Agro waste?
h. Recycled steel?
i. Geopolymer foam concrete?
j. Reclaimed wood and plastic?

13. Are you currently implementing any of the above-mentioned technologies/materials?

14. Would your company be willing to implement any of the above-mentioned materials? If not please indicate the possible reasons for their stance against adopting these materials.

15. What are your recommendations for promoting the uptake of sustainable building construction materials in Harare?

16. How do you think the government and other stakeholders can support the uptake of sustainable building construction materials by construction companies?

17. How do you think the government and other stakeholders can support the uptake of sustainable building construction materials by construction companies?

Final Remarks

Thank you for your participation in our survey. Please leave your contact details if you would want the results of this research to be made available to you.

6.2 Survey 2 (Likert Scale Questionnaire)

Response Table

Question	Response	Question	Response
1		7	
2		8	
3		9	
4		10	
5		11	
6		12	

Questions

1. How important is sustainability to you when choosing building materials?
a. Not important at all.
b. Somewhat important.
c. Moderately important.
d. Very important.
e. Extremely important.

2. How familiar are you with sustainable building construction materials?
a. Not at all familiar.
b. Somewhat familiar.
c. Moderately familiar.
d. Very familiar.
e. Extremely familiar.

3. How easy is it to find sustainable building construction materials in your area?
a. Very difficult.
b. Somewhat difficult.
c. Neutral.
d. Somewhat easy.
e. Very easy.

4. How affordable are sustainable building construction materials compared to traditional materials?
a. Much more expensive.
b. Slightly more expensive.
c. About the same.
d. Slightly less expensive.
e. Much less expensive.

5. How willing are you to pay a premium for sustainable building construction materials?
a. Not at all willing.
b. Somewhat willing.

c. Moderately willing.
d. Very willing.
e. Extremely willing.

6. How important are government incentives or regulations in promoting the use of sustainable building construction materials?
a. Not important at all.
b. Somewhat important.
c. Moderately important.
d. Very important.
e. Extremely important.

7. How motivated are you to learn more about sustainable building construction materials and their benefits?
a. Not at all motivated.
b. Somewhat motivated.
c. Moderately motivated.
d. Very motivated.
e. Extremely motivated.

8. How concerned are you about the environmental impact of building construction materials?
a. Not concerned at all.
b. Slightly concerned.
c. Moderately concerned.
d. Very concerned.
e. Extremely concerned.

9. How important is reducing carbon footprint in your decision to choose building construction materials?
a. Not important at all.
b. Slightly important.
c. Moderately important.
d. Very important.
e. Extremely important.

10. How often do you use Recycled Aggregates in your construction projects?
a. Never.
b. Rarely.
c. Sometimes.
d. Often.
e. Always.

11. How satisfied are you with the quality of sustainable building construction materials?
a. Very dissatisfied.

b. Somewhat dissatisfied.
c. Neutral.
d. Somewhat satisfied.
e. Very satisfied.

12. How likely are you to recommend sustainable building construction materials to other professionals in the industry?
a. Not at all likely.
b. Slightly likely.
c. Moderately likely.
d. Very likely.
e. Extremely likely.

7 Appendix 2: Supporting Data

7.1 IBM SPSS Supporting Data

The project data was compiled and analysed using IBM SPSS Software. Statistical Analysis as well as outputting the information in visual format was achieved using this software. The files for the project are hosted on the website with the link provided below:

https://github.com/jabes3/Investigative-Research-Project/tree/main/SPSS%20Data

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