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Awareness Level of Construction Professionals Towards Futuristic Building Materials in South Africa

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Abstract

The global quest and concerted efforts towards achieving sustainability in the construction industry (CI) are hampered by many factors. An example of such a factor is the continued patronage specification and use of conventional construction materials with severe environmental impacts. To overcome this challenge, the availability, awareness, adoption, and utilisation of building materials and technologies with sustainable attributes are imperative. A class of materials in this category are the futuristic building materials (FBMs) known to possess eco-friendly attributes and are highly effective in realising the sustainability agenda of the CI. Hence, this study examines the awareness level of FBMs among construction professionals in South Africa. This study employed the quantitative research method. A well-structured questionnaire survey was administered to duly registered and practicing construction professionals in the South African construction industry (SACI). The duo of descriptive and exploratory factor analysis was used to analyse the collected data. Findings from the study showed fifteen (15) FBMs in their order of awareness. Wood, recycled plastic, bamboo, rammed earth, and timbercrete are identified as the top FBMs known to construction professionals in the SACI. Conclusively, the result further reiterated the general knowledge that construction professionals are reluctant to change thereby limiting their awareness level and use of the FBMs. It is therefore recommended that a multi-stakeholder approach is directed toward FBMs to ensure their proliferation, adoption, and use in the CI.

Keywords

Built Environment, Construction Materials, Futuristic Building Materials, South Africa, Sustainable Construction.

1. Introduction

There are numerous socioeconomic benefits traceable to the construction industry (CI). To mention a few, these benefits are employment/job creation, and provision of basic and critical infrastructures such as roads, power plants, hospitals, schools, rails, and many more. In the process of providing these amenities, the global CI now contributes significant negative environmental impacts, primarily due to the excessive use of natural resources and massive generation of waste. By nature, construction activities are not environmentally friendly (Lu & Tam, 2013). The extraction and transportation of construction raw materials such as timber, gravel, and sand contribute to deforestation, soil erosion, and pollution (air and water) among others (Ayarkwa et al., 2014). Furthermore, the production of construction materials such as cement and steel is known to be energy intensive (Hammond & Jones, 2008), and results in the emission of greenhouse gases (GHGs), which largely contribute to climate change. The conventional construction processes still majorly undertaken by most construction professionals also consume large amounts of energy, leading to further emissions of carbon dioxide and other pollutants into the atmosphere.

Other significant adverse environmental impacts of the CI are waste generation, loss of biodiversity, and natural ecosystems. Construction sites generate vast amounts of construction and demolition (C&D) waste, including building materials, packaging, and demolition debris (Mah et al., 2018). These wastes take up valuable landfill space, contribute to air, land, and water pollution, and cause the deterioration of the environment. Additionally, the indiscriminate disposal of hazardous materials such as lead paint and asbestos has the potential to pose a threat to human health and the environment. The CI needs to implement better waste management practices to reduce its environmental impact. The CI also impacts the environment through the loss of natural habitats and biodiversity. Buildings and infrastructural developments often require the clearing of forests and other natural areas, leading to the displacement of wildlife and loss of biodiversity. The destruction of natural ecosystems can have long-term consequences for the environment and society, including the loss of natural resources, reduced soil quality, and decreased water availability. To minimize the negative impact on the human and natural environment, the CI must consider the environmental impact of construction activities, minimise the use of traditional building materials with unsustainable attributes and implement measures to mitigate these impacts (Oguntona & Aigbavboa, 2019). Hence, the concept of sustainability creates a consciousness around the social, economic, and environmental footprints of human activities.

According to the WCED, SD is a global concept that aims to meet the needs of the present without compromising the ability of future generations to meet their own needs (Imran et al., 2014). It is a holistic approach to development that encompasses and considers the social, economic, and environmental dimensions. The goal of SD is to strike a balance between economic growth, social equity, and environmental protection. To achieve this goal, a long-term perspective, and a commitment to finding solutions that benefit both people and the planet is imperative. A key principle of SD is the idea of intergenerational equity. This means that the onus is on the people to ensure that the resources and opportunities available today are not depleted or destroyed in a way that will prevent future generations from being able to partake of the same benefits. This requires a focus on long-term planning and decision-making, and a willingness to make sacrifices today to ensure a better future for posterity. The concept of SD also requires a commitment to social equity which is highly pronounced in the 2030 Sustainable Development Goals (SDGs) of the United Nations. This means that work must be done to ensure that everyone has access to the resources and opportunities required to live a fulfilling life, regardless of factors such as income, gender, and race among others. This includes access to education, healthcare, clean water and sanitation, and basic human rights. By promoting social equity, a more stable and prosperous society will be created to benefit everyone, not just a privileged few. The significance of SD, therefore, was what culminated in the notion of sustainable practices in the CI.

Sustainable construction (SC) is an approach or concept in the CI to reduce the environmental impacts of construction activities while creating buildings and infrastructure that are durable, safe, and functional. This concept involves the utilisation of eco-friendly materials, the design and development of energy-efficient buildings, and minimising waste throughout the construction process. The concept of SC also considers the long-term environmental impact of buildings and infrastructure, ensuring that they are built to last and can be easily maintained. Energy efficiency is another critical component of SC. This involves designing, constructing, operating, and maintaining buildings that are energy-efficient and use renewable energy sources such as solar and wind. Energy-efficient buildings reduce GHG emissions and energy costs, ensuring their sustainability in the long run. Other strategies for energy efficiency include using natural ventilation, insulation, and efficient lighting systems. By adopting SC practices, we can create buildings and infrastructure that are environmentally friendly, cost-effective, and long-lasting.

One of the key principles of SC is the use of environmentally friendly building materials. This includes using materials that have a low carbon footprint, renewable, recyclable, reusable, energy-efficient, and are sourced from sustainable sources (Akadiri et al., 2012). Examples of sustainable materials include recycled steel, bamboo, and reclaimed wood. The concept of SC also involves using materials that have a long lifespan, reducing the need for frequent replacements and reducing waste. A major class of material in this category is futuristic building materials (FBMs). Therefore, maximising the potential and benefits of FBMs and other sustainable materials relies solely on their awareness, acceptance, adoption, specification, patronage, and implementation by relevant stakeholders in the CI. Hence, this study seeks to assess the awareness level of FBMs among construction professionals in the South African construction industry (SACI).

2. An Overview of Futuristic Building Materials

As technology continues to advance and the global clamour for sustainability, novel, and sustainable materials will continue to emerge, providing more breakthroughs for the construction industry (CI). Futuristic building materials (FBMs) offer the prospect of designing and building structures that are durable, strong, energy-efficient, and environmentally friendly due to their characteristics (Khitab et al., 2015). These materials are a crucial component of the sustainable construction concept. Examples of FBMs include graphene, aerogel, spider silk, mycelium, biochar, ferrock, straw bale, papercrete bricks, ashcrete, self-healing concrete, timbercrete, rammed earth, bamboo, recycled plastic, bio-plastics, wood, transparent wood, carbon fiber reinforced polymers, and 3D-printed concrete among others. These materials are durable, sustainable, cost-efficient, energy-efficient, superior insulation, strong and resistant to damage, lightweight, flexible, resistant to natural disasters, aesthetically superior, improve health and safety, improve acoustics, reduce waste, reduce carbon footprint, improve air quality, improve weather resistance, and increase building lifespan (Khamidi et al., 2014; Kariyawasam & Jayasinghe, 2016; Ribeiro et al., 2016; De Luca et al., 2023; Panda et al., 2017; De Belie et al., 2018; Ghosh, 2018; Layla et al., 2019; Olofinnade et al., 2021).

Despite the numerous benefits associated with FBMs, there are a few hindrances associated with their adoption and use within the CI. These issues are related to limited availability, cost, lack of awareness, resistance to change among professionals, complexity, regulatory issues, compatibility issues, technical challenges, cultural barriers, limited versatility, security concerns, low patronage, low client demand, and supply chain disruptions among others. Therefore, robust and widespread awareness and education on the benefits of FBMs are imperative to drive their adoption in the CI. Also, a multistakeholder partnership with research entities, industry experts, government, professional bodies, international agencies, and higher education institutions is another path to the proliferation and utilization of FBMs in the CI. Hence, the significance of this study is to assess the awareness level of construction professionals on FBMs in the SACI.

3. Research Methodology

The quantitative method of research was utilised in this study to assess the awareness level of FBMs among construction professionals in the SACI. To achieve this objective, a well-structured close-ended questionnaire survey was prepared and administered to the respondents. The respondents are practicing and duly registered construction professionals within the Gauteng province of South Africa which is the research study area. The respondents sampled are construction project managers, mechanical engineers, construction managers, quantity surveyors, civil engineers, architects, town planners, and project managers who are actively affiliated with their respective professional bodies. The questionnaire provided the respondents with fifteen (15) FBMs that are identified through a review of extant literature. The questionnaire was prepared using a five-point Likert awareness scale. To ensure their completeness and usefulness for the analysis, the completed questionnaires were reviewed and cleaned. The study employed both descriptive and exploratory factor analysis (EFA) methods to analyse the retrieved and collated data. The study achieved a Cronbach alpha value of 0.924 thereby giving credence to the reliability of the data collection instrument and the correctness of the collated results.

4. Findings and Discussions

The analysis of the background information of the respondents showed that 64% of the population sample are males while females represent 36%. Also, 23.4% of the respondents are construction project managers, 21.6% are construction managers, 19.8% are quantity surveyors, 14.4% are civil engineers, 12.6% are project managers, 3.6% are architects, 2.7% are town planners, and mechanical engineers account for 1.8%. A total of 40.5% of the respondents work for consulting firms, 31.5% work for the government, and 28% work for contracting entities. Respondents with five and below years of experience in the CI account for 38.7%, 5-10 years of experience account for 20.7%, 10-15 years of experience account for 12.6%, 15-20 years of experience account for 10.8%, and respondents with more than 20 years of experience account for 17.2%.

4.1 Descriptive Analysis: Awareness Level of Futuristic Building Materials

A total of fifteen (15) FBMs were identified and extracted for use in this study after a concise review of relevant scholarly research publications. Based on the data retrieved and collated, a mean item score (MIS) analysis was performed on the identified variables. Table 1 below presents the results of the analysis. The table presents data on the awareness level of futuristic building materials in South Africa. The materials are ranked based on their mean score, with wood being the most familiar and aerogel being the least familiar among the respondents. Wood had the highest mean score of 4.59, indicating that it was the most well-known futuristic building material. Recycled plastic was ranked second with a mean score of 4.05, followed by bamboo with a mean score of 3.41. Rammed earth and timbercrete were ranked fourth and fifth, respectively, with mean scores of 3.13 and 3.11. The least familiar materials among the respondents were aerogel, spider silk, graphene, and mycelium, with mean scores of 1.97, 2.06, 2.10, and 2.12, respectively. The overall standard deviation ranged from 0.813 for wood to 1.517 for self-healing concrete, indicating varying levels of familiarity among the respondents for each material.

Table 1. Awareness level of futuristic building materials in South Africa.

Materials	Mean Score	Standard Deviation	Ranks
Wood	4.59	0.813	1
Recycled Plastic	4.05	1.099	2
Bamboo	3.41	1.372	3
Rammed Earth	3.13	1.490	4
Timbercrete	3.11	1.377	5
Self-healing concrete	3.01	1.517	6
Ashcrete	2.97	1.436	7
Papercrete bricks	2.95	1.285	8
Straw bale	2.84	1.468	9
Ferrock	2.22	1.384	10
Biochar	2.20	1.197	11
Mycelium	2.12	1.270	12
Graphene	2.10	1.243	13
Spider Silk	2.06	1.267	14
Aerogel	1.97	1.171	15

4.2 Exploratory Factor Analysis: Awareness Level of Futuristic Building Materials

Further to the descriptive analysis carried out on the retrieved data, exploratory factor analysis was done. Table 2 shows the results of the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity. The KMO value of 0.877 indicates that the sample size is adequate for factor analysis. Bartlett's Test of Sphericity has a chi-square value of 1002.213 with 105 degrees of freedom and a p-value of 0.000, indicating that the correlation matrix is significantly different from an identity matrix, and factor analysis can be used to extract meaningful factors from the data.

Table 2. KMO and Bartlett's Test.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.877
Bartlett's Test of Sphericity	Approx. Chi-Square	1002.213
	df	105
	Sig.	0.000

Table 3 shows the communalities of futuristic building materials (FBMs) in South Africa using the principal component analysis (PCA) extraction method. Communalities represent the proportion of variance in each variable that can be explained by the factors extracted. The initial communalities of all variables are 1.000 because they are extracted from the same set of data. The extraction communalities range from 0.572 (Rammed Earth) to 0.793 (Graphene), indicating that the factors extracted account for a considerable amount of variance in the variables. The results suggest that the variables are suitable for further analysis using PCA.

Table 3. Communalities of FBMs in South Africa.

	Initial	Extraction
Aerogel	1.000	0.602
Graphene	1.000	0.793
Mycelium	1.000	0.776
Bamboo	1.000	0.601

Timbercrete	1.000	0.676
Papercrete bricks	1.000	0.586
Biochar	1.000	0.650
Recycled Plastic	1.000	0.681
Wood	1.000	0.678
Spider Silk	1.000	0.635
Ferrock	1.000	0.748
Straw bale	1.000	0.593
Self-healing concrete	1.000	0.605
Rammed Earth	1.000	0.572
Ashcrete	1.000	0.651

Extraction Method: Principal Component Analysis.

The variance of the components was extracted, and it was discovered that the first component has the highest initial and extraction sums of squared loadings, explaining 48.697% of the variance with eigen value of 7.305 in the data. The second and third components also have relatively high extraction sums of squared loadings, explaining 10.033% and 6.915% of the variance together with 1.505 and 1.037 eigen values, respectively. The remaining components explained less than 6% of the variance each. Hence, the three components were extracted as evident from the Scree plot shown in Figure 1.

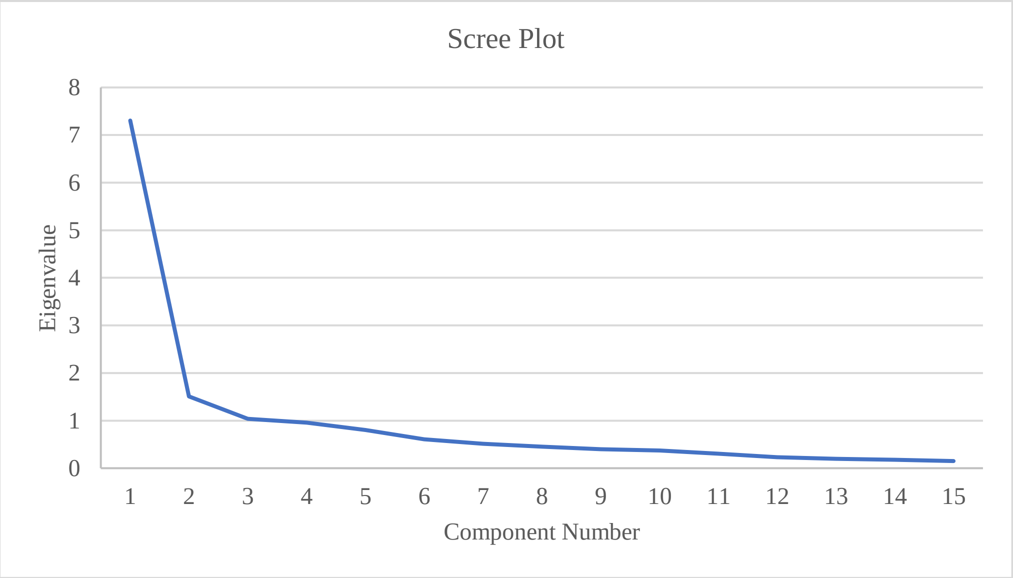

Fig. 1. Scree plot for FBMs in South Africa.

Table 4 presents the pattern matrix for FBM in South Africa after performing principal component analysis with oblique rotation. The matrix shows the correlations between each of the FBM and the extracted components. The table shows three components with corresponding loadings for each of the FBM. Only the loadings with an absolute value greater than 0.5 are considered significant. The FBM with significant loadings on a particular component is said to be associated with that component.

From the table, the first component is associated with mycelium, graphene, biochar, aerogel, self-healing concrete, recycled plastic, and wood. These materials are positively correlated with each other, suggesting that they share common characteristics and may be used interchangeably in building construction. The second component is associated with bamboo, papercrete bricks, timbercrete, and ferrock, and is negatively correlated with the first component. These materials may have unique properties that distinguish them from the materials associated with the first component. The third component is associated with ashcrete, straw bale, spider silk, and rammed earth and is negatively correlated with the first and second components. These materials may also have unique properties that distinguish them from other materials. Overall, the pattern matrix provides information on the relationships between FBMs in South Africa and the extracted components, allowing for a better understanding and classification of these materials based on their characteristics and potential applications.

Table 4. Pattern Matrix for FBMs in South Africa.

	Component		
	1	2	3
Mycelium	0.933		
Graphene	0.910		
Biochar	0.705		
Aerogel	0.642		
Self-healing concrete	0.548		
Wood		0.801	
Recycled Plastic		0.731	
Bamboo		0.544	
Ashcrete			-0.865
Papercrete bricks			-0.761
Timbercrete			-0.718
Ferrock			-0.689
Straw bale			-0.618
Spider Silk			-0.558
Rammed Earth			-0.502

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.
a. Rotation converged in 13 iterations.

There are numerous benefits to using different types of FBM in South Africa. Mycelium, for instance, is a versatile and sustainable material with potential applications in many fields such as construction, packaging, and furniture (Yang et al., 2021). Graphene, on the other hand, has high strength and conductivity and can be used to make lightweight, durable, and efficient energy storage devices (Ali et al., 2022). Biochar is a soil enhancer that helps to increase crop yield and reduce greenhouse gas emissions (Vijay et al., 2021).

Also, aerogel is a lightweight and highly insulating material that can be used in building insulation, aerospace applications, and many other fields. Self-healing concrete has the potential to reduce maintenance costs and increase the durability of concrete structures (Berardi, 2019; De Belie et al., 2018). Wood is a renewable and sustainable building material with numerous environmental and aesthetic benefits. Bamboo is a fast-growing and renewable resource that has high strength and versatility, making it an ideal material for a variety of applications. Recycled plastic can be used to create durable and lightweight building materials that help reduce plastic waste in the environment (Robert, 2010; Lamba et al., 2022).

Furthermore, ashcrete, papercrete bricks, and timbercrete are all sustainable and eco-friendly alternatives to traditional concrete that can be used in construction (Pranav et al., 2020). Ferrock is an innovative and sustainable material made from waste steel dust and silica that has the potential to replace traditional concrete. Straw bale construction is an eco-friendly and energy-efficient building technique that uses straw bales as a structural element (Akadiri et al., 2012). Spider silk has high strength and elasticity, and its potential applications range from textiles to medical devices. Finally, Rammed Earth is a sustainable and low-cost building material that is ideal for hot and dry climates (Khitab et al., 2015).

5. Conclusions and Recommendations

In conclusion, the study analysed the awareness level of futuristic building materials (FBM) in South Africa. The sample size included respondents with varied levels of experience and represented different professions within the construction industry. Descriptive and exploratory factor analysis were performed on the data retrieved from the questionnaire, and the results showed that wood, recycled plastic, and bamboo were the most familiar materials among respondents, while aerogel, spider silk, graphene, and mycelium were the least familiar. PCA extraction method on EFA was used to further analyze the data, and the results showed that the FBM were grouped into three components based on their characteristics. Based on the findings, it is recommended that stakeholders in the construction industry in South Africa should consider educating professionals on the potential benefits of using futuristic building materials in construction projects. Additionally, the government could provide incentives to encourage the use of these materials, which could lead to a more sustainable construction industry. It is also recommended that future studies investigate the barriers and drivers to the adoption of futuristic building materials in South Africa to develop appropriate strategies to address them. The study could also be replicated in other countries to compare the results and gain a better understanding of the level of awareness of futuristic building materials globally.

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