Sustainable Construction in the Era of the Fourth Industrial Revolution, Vol. 107, 2023, 95–105
https://doi.org/10.54941/ahfe1003096

Limitations of Futuristic Building Materials for Achieving Sustainability in the Construction Industry

Olusegun Aanuoluwapo Oguntona[1], Opeoluwa Akinradewo[2], Onalerona Mokono[2], Babatunde Ogunbayo[2], and Clinton Aigbavboa[2]

[1]Department of Built Environment, Faculty of Engineering and Technology, Walter Sisulu University, South Africa
[2]cidb Centre of Excellence & Sustainable Human Settlement and Construction Research Centre, Faculty of Engineering and the Built Environment, University of Johannesburg, South Africa

ABSTRACT

Globally, the construction industry (CI) is regarded as one of the largest consumers of raw materials and natural resources. The industry is also known to be a major source of pollution, waste, and other adverse environmental issues within the built environment. It is therefore imperative to introduce strategies, processes, materials, and technologies that have the potential to revolutionize the CI to a sustainable state, especially in this fourth industrial revolution (4IR) era. Futuristic building materials (FBMs) are the generation of novel and cutting-edge materials with significant potential to solve ongoing challenges and address environmental issues attributed to the CI. Hence, the objective of this paper is to evaluate the hindrances to the utilization of FBMs in realizing a sustainable CI in South Africa. The quantitative research approach was employed in this study. A structured questionnaire survey was administered to construction professionals in the South African construction industry (SACI). Data collected were analyzed using a descriptive statistical method and exploratory factor analysis. Findings from the study revealed the impact of the 15 barriers identified in the reviewed literature. The study also revealed a lack of awareness, lack of knowledge, shortage of skills, poor economic conditions, and escalating costs of building materials as the major barriers hindering the adoption of FBMs. In conclusion, the availability, and accessibility of FBMs are discovered to be limited in the SACI. Research and development (R&D), awareness creation, and multi-disciplinary collaboration is recommended to maximize the effectiveness of FBMs for a sustainable and innovative SACI.

Keywords: Architecture, Engineering, Construction industry, Futuristic building materials, Innovation, Sustainable construction, South Africa

INTRODUCTION

The construction industry (CI) is known to have several negative impacts on the human and natural environment (Asare et al., 2021). For example, the construction process itself significantly pollutes the air, soil, and water. Also, the use of heavy machinery and equipment in the CI releases emissions and dust into the air, which are found to be harmful to both humans and wildlife. Additionally, the excavation and clearing of land for construction sites cause soil erosion, loss of valuable ecosystems, loss of wildlife habitats, and harm to the natural ecosystem (Shurrab et al., 2019). Another significant negative impact of the CI is the strain it puts on resources such as water, energy, and materials. The production of building materials such as concrete, steel, and glass requires a large amount of energy and resources, leading to increased greenhouse gas (GHG) emissions and depletion of natural resources. The construction activities and processes also require large amounts of water, putting a strain on local water resources and potentially leading to water scarcity in certain geographic locations. The CI also contributes to waste production and deforestation, as many construction materials are not recyclable and reusable. Generally, it can be deduced that construction materials and products determine the type of impact (negative or positive) a building or infrastructural project will have on the environment (Oguntona and Aigbavboa, 2019).

The traditional construction materials massively in use result in pollution (air, water, soil contamination, and toxic waste), waste generation (concrete, asphalt, wood, etc), GHG emissions, and natural resource depletion among others. Specifically, construction materials, such as concrete and asphalt, are a significant source of pollution and degradation to the environment due to their toxic heavy metals and chemical constituents. The production and transportation of these materials contribute to air pollution and the release of toxins into the atmosphere and soil. In addition, cement manufacturing factories globally are regarded as major contributors of carbon dioxide which is a dangerous environmental pollutant (Hanifa et al., 2023). Therefore, the CI can minimize its negative environmental impacts by adopting sustainable construction practices, such as using reducing waste and GHG emissions, specification and use of sustainable technologies, and utilization of futuristic building materials (FBMs) among others.

Sustainable construction materials are those materials with eco-friendly properties. FBMs as a sustainable construction material have the potential to revolutionize the CI and the way we build our structures. These materials can provide increased strength, durability, sustainability, and adaptability to changing environmental conditions, making our buildings safer, more efficient, more resilient, and more sustainable (Oguntona and Aigabvboa, 2016). One of the major benefits of FBMs is their potential for sustainability. Many advanced materials have a lower carbon footprint compared to traditional building materials such as steel and concrete, making them an attractive option for sustainable construction. For example, cross-laminated timber is a renewable resource that is both strong and lightweight, making it a great alternative to steel or concrete in construction. Additionally, materials like bamboo are fast-growing and can be harvested in just a few years, reducing the impact on the environment. Another major benefit of FBMs is their durability. These materials are designed to be more resistant to wear and tear, providing a longer lifespan for buildings. Self-healing concrete, for example, contains microcapsules filled with healing agents that can automatically repair cracks that form over time. Similarly, graphene-reinforced composites are incredibly strong and lightweight, making them ideal for use in high-stress applications.

Many FBMs are also incredibly lightweight, making them ideal for use in high-rise buildings. Aerogel, for example, is one of the lightest solid materials, with incredibly low thermal conductivity. Vacuum-insulated panels are also incredibly lightweight, with exceptional insulation properties, making them ideal for use in energy-efficient buildings. These materials help reduce the weight of buildings, allowing for taller, more dynamic designs while also reducing the amount of energy required to heat and cool the building. Another major benefit of FBMs is their improved thermal efficiency. They can absorb and store heat during the day, releasing it back into the building at night, reducing the need for artificial heating and cooling. Similarly, materials like smart glass can be electronically controlled to regulate the amount of light and heat that enters a building, helping to reduce energy costs and improve comfort levels. Finally, FBMs can provide enhanced safety in the event of a fire, natural disaster, or extreme weather conditions. Fire-resistant cladding, for example, can prevent the spread of fire in high-rise buildings, protecting both the building and its occupants. Smart glass, which can be electronically controlled, can also be used to provide additional protection in the event of natural disasters or extreme weather conditions. These materials can provide peace of mind to building owners and occupants, helping to ensure their safety and well-being. Owing to the numerous benefits of FBMs, it is imperative to assess the factors limiting their adoption and use in the race toward achieving sustainability in the CI. Hence, this study is aimed at evaluating the hindrances to the utilization of FBMs towards realizing a sustainable CI in South Africa.

LIMITING INDICATORS OF FUTURISTIC BUILDING MATERIALS

FBMs such as recycled plastics, bamboo, timbercrete, self-healing concrete, ashcrete, wood, graphene, mycelium, aerogel, ferrock, biochar, and straw bale possess amazing attributes that are beneficial (Ahmed et al., 2021; Dalal and Dalal, 2021; Sharma and Sumbria, 2022). Despite the numerous benefits accrued to the use of FBMs, the CI is still yet to maximize and reinvent itself in the face of the global call for sustainability and sustainable practices adoption. Addressing the barriers hindering the use of FBMs is, therefore, necessary to ensure the incorporation of their benefits in realizing the sustainability agenda of the CI.

Factors limiting the use of FBMs are lack of awareness, high cost, low demand, lack of creativity, difficult access to capital, poor economic conditions, policy implementation failure, lack of incentives for adoption, skills shortage, and lack of life cycle evaluation of construction materials (Levitt, 2002; Berge, 2009; Utting, 2009; Sieczka, 2011; Mulder, 2013; AlSanad, 2015; Howes et al., 2017). One of the biggest limitations of FBMs is their cost. Many of these materials are still in the early stages of development and can be much more expensive than traditional building materials. Another limitation is the limited availability of many FBMs. Some of these materials are still in the research and development phase and are not widely available for commercial use. There is a lack of standardization in the use of FBMs, with many different approaches and techniques being used. This makes it difficult for builders and architects to compare materials and specify the best option for their needs. Many FBMs have not been thoroughly tested, and their long-term performance and durability are still unknown. This makes it difficult to assess their suitability for use in construction. Also, some FBMs may require regular maintenance or replacement, adding to the cost and complexity of a construction project. The use of FBMs often requires a high level of skill and expertise, making it difficult to find qualified workers. Likewise, FBMs may not be compatible with traditional building methods and materials, making it difficult to integrate them into existing construction projects. Some FBMs may also have environmental concerns associated with their production and disposal, making it important to carefully consider their impact on the environment. These materials may also be subjected to local, state, or federal regulations, which can limit their use and increase the cost and complexity of construction projects. Conclusively, FBMs are not recyclable, making it difficult to reduce waste and promote sustainability in construction. in South Africa.

METHODOLOGY

The purpose of the study was to gather information about the limitations of futuristic building materials in South Africa by surveying professionals in the construction industry. The study used a quantitative research method and collected data using a structured questionnaire. The respondents for the study includes engineers, quantity surveyors, construction managers, project managers, and architects and were reached through a random sampling approach. The questionnaire was divided into two sections, one to gather demographic information and the other to measure the limitations. A total of 155 questionnaires were distributed and 111 were returned, resulting in a 72% response rate. The data were analyzed using various statistical methods such as Mean Item Score (MIS), Standard Deviation (SD), and Exploratory Factor Analysis (EFA). The retrieved data was found to be reliable with a Cronbach coefficient of 0.88.

FINDINGS AND DISCUSSION

From the analysis of the demographic information of the respondents, the highest number of respondents (30.6%) have a Bachelor's degree. The least number of respondents (0.9%) have a Doctorate. The other categories of academic qualifications of the respondents are Honors' Degree (17.1%), Master's Degree (17.1%), Matric Certificate (2.7%), and Post-Matric Certificate or Diploma (31.5%). The professional qualification of the respondents indicated that the most common professional qualification is Construction Manager (21.6%) followed by Construction Project Manager (23.4%) and Quantity Surveyor (19.8%). The least common professional qualification is Mechanical Engineer (1.8%). The other categories of professional qualifications are Architect (3.6%), Project Manager (12.6%), and Town Planner

(2.7%). Finally, the largest number of respondents (38.7%) have 0 to 5 years of experience, followed by 5 to 10 years of experience (20.7%) and 10 to 15 years of experience (12.6%). The least number of respondents have more than 20 years of experience (17.1%) and 15 to 20 years of experience (10.8%). Overall, based on the academic and professional qualifications and years of experience of the respondents, it can be concluded that they have the prerequisite knowledge and experience to provide professional opinions on the subject matter of this research.

Descriptive Analysis: Limitations of Futuristic Building Materials

Table 1 provides the results of a descriptive analysis of the limitations of futuristic building materials in which the mean score, standard deviation, and rank of each variable are presented. According to the data, the highest-ranking limitation of futuristic building materials is "Lack of Awareness," with a mean score of 4.40 and a standard deviation of 0.907. This means that the majority of respondents rated this limitation as having a high impact on the implementation of futuristic building materials. The second-highest ranking limitation is "Lack of Knowledge" with a mean score of 4.33 and a standard deviation of 0.918. This means that the majority of respondents rated this limitation as having a moderate impact on the implementation of futuristic building materials. The third-highest ranking limitation is "Shortage of Skills," with a mean score of 4.15 and a standard deviation of 1.072. This means that the majority of respondents rated this limitation as having a low impact on the implementation of futuristic building materials. The mean

Table 1. Limitations of futuristic building materials.

Benefits	Mean	Std. Deviation	Ranks
Lack of awareness	4.40	0.907	1
Lack of knowledge	4.33	0.918	2
Shortage of skills	4.15	1.072	3
Escalating costs of building materials	4.13	1.045	4
Poor economic conditions	4.13	0.992	4
Lack of life cycle evaluation of building materials	4.06	0.937	6
Lack of creative thinking	4.05	0.971	7
Difficulties in accessing capital	4.05	0.994	7
Large amount of investment required	4.02	1.079	9
Insufficient incentives	4.01	1.057	10
Stakeholder's resistance to change	3.99	1.014	11
Policy implementation failure	3.95	0.989	12
Shortage of material supply	3.93	1.101	13
Lack of communication	3.93	1.085	13
Fluctuations in the manufacturing sector	3.93	1.024	13
Low demand	3.93	1.134	13
Outdated national building regulations	3.88	1.007	17
Lack of regulation and frameworks	3.85	1.002	18
Insufficient supply chain of raw materials	3.85	1.046	18
Inability to meet SABS requirement	3.67	1.106	20

score for the remaining limitations is below 4.15, with insufficient incentives, stakeholder resistance to change, and policy implementation failure being among the lowest-ranked limitations. Overall, the results of the study indicate that the major limitations of futuristic building materials are related to the lack of awareness and knowledge, followed by the shortage of skills and the escalating costs of building materials. It also highlights the importance of addressing the limitations to ensure the successful development and implementation of futuristic building materials.

Exploratory Factor Analysis: Limitations of Futuristic Building Materials

For EFA purposes, the data was checked with the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's Test of sphericity. To evaluate sampling quality, the KMO index was used, which gave a value of 0.884. As long as the value is greater than 0.6, it can be used in factor analysis. When subjected to Bartlett's sphericity test, the result was a statistically significant 0.000. Bartlett's test of sphericity, denoted by "Sig." provides a statistical measure of the multivariate normality of the distributions. The total variance of limitations of futuristic building materials in South Africa variables according to the respondents broken down into four clusters with eigenvalue over 1 component: (9.513, 1.540, 1.132, and 1.013). The components' eigenvalue defined the 47.563%, 7.698%, 5.658%, and 5.066% respectively of the variance which indicates 65.985% of the total variance of the data set. This satisfies the cumulative proportion of variance criterion which states that the extracted components should together be 50% of the variation. Therefore, the four-factor groupings can be used to adequately represent the opinion of professionals in South Africa. The study adopted factor grouping based on PCA and direct oblimin rotation. Table 2 presents the pattern matrix which highlights how the factors have been clustered together.

The exploratory factor analysis pattern matrix in Table 2 provides the factor loadings of the individual limitations of futuristic building materials. The factor loading refers to the strength of the association between each limitation and a specific factor, where higher loadings indicate a stronger association. In this matrix, factor loadings above 0.5 are considered to be moderate or strong. The analysis shows that the limitations of futuristic building materials can be grouped into four components or factors.

The first factor consists of limitations related to outdated national building regulations, lack of regulations and policy frameworks, and policy implementation failure, with factor loadings of 0.835, 0.809, and 0.683 respectively. These limitations suggest that current policies and regulations are inadequate for promoting the use of futuristic building materials. These barriers can significantly impact the usage of futuristic building materials. One of the major barriers is outdated national building regulations, which may not take into account the latest advances in building materials and construction techniques. This can limit the use of futuristic building materials that may not meet the current regulations (Ndlovu, 2021). Another barrier is the lack of

Table 2. Exploratory factor analysis pattern matrix for limitations of futuristic building materials.

	Component			
	1	2	3	4
Outdated National building regulations	0.835			
Lack of regulations and policy frameworks	0.809			
Policy implementation failure	0.683			
Lack of life cycle evaluation of building materials	0.576			
Lack of awareness	0.470			
Stakeholders' resistance to change	0.443			
Escalating costs of building materials		0.793		
Large amount of investment required		0.741		
Shortage of material supply		0.732		
Insufficient supply chain of raw materials		0.642		
Difficulties in accessing capital		0.593		
Fluctuations in the manufacturing sector		0.554		
Shortage of skills			0.769	
Inability to meet SABS requirements			0.739	
Poor economic conditions			0.676	
Lack of knowledge			0.492	
Insufficient incentives			0.438	
Lack of communication			0.436	
Low demand				0.767
Lack of creative thinking				0.608
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.				0.884
Bartlett's Test of Sphericity		Approx. Chi-Square		1372.179
		df		190
		Sig.		0.000

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.
a. Rotation converged in 18 iterations.

regulations and policy frameworks, which can result in a lack of clear guidelines and standards for the usage of these materials. Policy implementation failure is another barrier, as policies may exist but not be effectively implemented, hindering the adoption of futuristic building materials (Omollo, 2019). Additionally, the lack of life cycle evaluation of building materials can make it difficult to determine their long-term impact and sustainability, reducing their usage (Rahla et al., 2021). Finally, stakeholder resistance to change and a lack of awareness about the benefits of futuristic building materials can also limit their usage, as individuals and organizations may be hesitant to adopt new materials and techniques (Gounder et al., 2021).

The second factor includes limitations related to the cost of building materials, such as escalating costs and a large amount of investment required, with factor loadings of 0.793 and 0.741 respectively. Cost-related barriers can significantly impact the usage of futuristic building materials. One of the major barriers is the escalating costs of building materials, which can make it more difficult for individuals and organizations to afford these materials, limiting their usage (Nasereddin and Price, 2021). Another barrier is a large amount of investment required to adopt futuristic building materials, which may not be feasible for many individuals and organizations (Agenda, 2016). Difficulties in accessing capital can also limit the usage of futuristic building materials, as individuals and organizations may not have the financial resources to invest in these materials (Ackah and Vuvor, 2011). Shortage of material supply is another cost-related barrier, as demand may exceed the available supply, limiting the usage of these materials (Mancini et al., 2013). Finally, fluctuations in the manufacturing sector, such as a decrease in demand, can impact the production and availability of futuristic building materials, further limiting their usage (Allwood et al., 2013).

The third factor consists of limitations related to the shortage of skills and the inability to meet SABS requirements, with factor loadings of 0.769 and 0.739 respectively. This factor highlights the need for more trained professionals who can effectively utilize futuristic building materials. The implementation of standards barriers can have a significant impact on the usage of futuristic building materials. One of the major barriers is the shortage of skills, as a lack of skilled professionals who can work with these materials can limit their usage (Ndlovu, 2021; Mewomo et al., 2022). Another barrier is the inability to meet South African Bureau of Standards (SABS) requirements, as these materials may not meet the current standards set by SABS, limiting their usage in South Africa (Takawira, 2019). Poor economic conditions can also limit the usage of futuristic building materials, as individuals and organizations may not have the financial resources to invest in these materials during economic downturns (Pheng et al., 2019). Additionally, a lack of knowledge about the benefits and potential of futuristic building materials can limit their usage, as individuals and organizations may not be aware of their potential (Agenda, 2016). Finally, insufficient incentives for individuals and organizations to adopt these materials and a lack of communication and collaboration between relevant stakeholders can also limit their usage, as there may be a lack of coordination and cooperation (Ndlovu, 2021).

The fourth factor includes limitations related to the lack of demand, poor economic conditions, lack of knowledge, insufficient incentives, lack of communication, low demand, and lack of creative thinking, with factor loadings ranging from 0.608 to 0.676. These limitations suggest that there is a lack of interest or understanding of the benefits and potential of futuristic building materials. Low market demand and limited innovation barriers can have a significant impact on the usage of futuristic building materials. One of the major barriers is low demand, as individuals and organizations may not see a need for these materials, limiting their usage (Louis and Macamo, 2011). Another barrier is a lack of creative thinking and innovation, as individuals and organizations may not be aware of the potential of futuristic building materials or may not see them as viable solutions (Pheng et al., 2019). This can limit the usage of these materials as there may be a lack of investment and resources devoted to their development and implementation (Agenda, 2016). Additionally, without market demand, manufacturers may not be motivated to produce these materials, further limiting their availability (Takawira, 2019). Finally, without innovation, the potential benefits and uses of futuristic building materials may not be fully realized, further limiting their usage.

In conclusion, the exploratory factor analysis pattern matrix provides insights into the interrelatedness of the limitations of futuristic building materials and how they can be grouped into distinct components. The analysis highlights the need for policy and regulatory reform, investment in skills and training, and greater awareness and understanding of the benefits of futuristic building materials.

CONCLUSION AND RECOMMENDATION

The construction industry is known to have negative impacts on the environment and human health due to pollution, resource depletion, and waste generation. Sustainable construction practices, such as using futuristic building materials (FBMs), can revolutionize the industry and minimize negative impacts. FBMs have numerous benefits including sustainability, durability, improved thermal efficiency, and safety. Despite their benefits, the adoption of FBMs is limited, and there is a need to assess the hindrances to their utilization towards realizing a sustainable construction industry in South Africa. This study adopted a quantitative research methodology and data was retrieved from respondents in South Africa. The data were analyzed using descriptive and inferential analysis. In conclusion, the results of the study on the limitations of futuristic building materials in South Africa indicate that various barriers can impact the usage of these materials. The results were broken down into four clusters, named Sustainable Building Development Barriers, Cost-related Barriers, Implementation of Standards Barriers, and Low Market Demand and Limited Innovation Barriers. These barriers can impact the use of futuristic building materials in various ways, such as outdated regulations, lack of clear guidelines, high costs, lack of skills, low demand, and limited innovation. It is recommended that policies and regulations should be updated to take into account the latest advances in building materials and that stakeholders should be made aware of the benefits of these materials. Additionally, more resources should be devoted to the development and implementation of these materials, and incentives should be provided to encourage their adoption.

ACKNOWLEDGMENT

The authors would like to acknowledge the cidb Centre of Excellence, University of Johannesburg, South Africa, the Department of Built Environment, Faculty of Engineering and Technology, and the Directorate of Research Development and Innovation, Walter Sisulu University, South Africa.

REFERENCES

Ackah, J., and Vuvor, S. (2011). The Challenges faced by Small & Medium Enterprises (SMEs) in Obtaining Credit in Ghana.

Agenda, I. (2016). Shaping the future of construction a breakthrough in mindset and technology. In World Economic Forum.

Ahmed, A. S., Almanea, A., Alsuliman, A., Alsuliman, A., and Ismail, M. (2021). A Case Study on Green Buildings and its Applicability in Bahrain. In Proceedings of the 2021 Third International Sustainability and Resilience Conference: Climate Change (469–473). IEEE.

Allwood, J. M., Ashby, M. F., Gutowski, T. G., and Worrell, E. (2013). Material efficiency: providing material services with less material production. Philosophical transactions of the royal society a: mathematical, physical and engineering sciences, 371(1986), 20120496.

AlSanad, S. (2015). Awareness, Drivers, Actions, and Barriers of Sustainable Construction in Kuwait. Procedia Engineering, 118, 969–983.

Asare, B. Y. A., Kwasnicka, D., Powell, D., and Robinson, S. (2021). Health and Well-being of Rotation Workers in the Mining, Offshore Oil And Gas, And Construction Industry: A Systematic Review. BMJ Global Health, 6(7), e005112.

Berge, B. (2009). The Ecology of Building Materials (2nd ed.). Routledge. https://doi.org/10.4324/9780080949741

Dalal, S. P., and Dalal, P. (2021). Experimental Investigation on Strength and Durability of Graphene Nanoengineered Concrete. Construction and Building Materials, 276, 122236.

Gounder, S., Hasan, A., Shrestha, A., and Elmualim, A. (2021). Barriers to the use of sustainable materials in Australian building projects. Engineering, Construction and Architectural Management, (ahead-of-print).

Hanifa, M., Agarwal, R., Sharma, U., Thapliyal, P. C., and Singh, L. P. (2023). A Review On CO2 Capture and Sequestration in the Construction Industry: Emerging Approaches and Commercialised Technologies. Journal of CO2 Utilization, 67, 102292.

Howes, M., Wortley, L., Potts, R., Dedekorkut-Howes, A., Serrao-Neumann, S., Davidson, J., Smith, T., and Nunn, P. (2017). Environmental Sustainability: A Case of Policy Implementation Failure? Sustainability, 9(2), 165.

Levitt, K. (2002). Silent Surrender: The multinational corporation in Canada. McGill-Queen's Press-MQUP.

Louis, D., and Macamo, P. (2011). Barriers to business growth: A study on small enterprises in Maputo.

Mancini, L., De Camillis, C., and Pennington, D. (2013). Security of supply and scarcity of raw materials. Towards a methodological framework for sustainability assessment.

Mewomo, M. C., Ndlovu, P. M., and Iyiola, C. O. (2022). Factors affecting effective facilities management practices in South Africa: a case study of Kwazulu Natal Province. Facilities, 40(15/16), 107–124. DOI: https://doi.org/10.1108/F-09-2021-0087.

Mulder, R. H. (2013). Exploring Feedback Incidents, their Characteristics, and the Informal Learning Activities that Emanate from them. European Journal of Training and Development, 37(1), 49–71.

Nasereddin, M., & Price, A. (2021). Addressing the capital cost barrier to sustainable construction. Developments in the Built Environment, 7, 100049. Ndlovu, S. (2021). Barriers to consumer acceptance of innovative building technologies for low-cost housing (Doctoral dissertation, Durban University of Technology).

Ndlovu, P. M. (2021). Examining issues influencing effective facilities management practice on selected public sector buildings in South Africa (Masters dissertation, University of Pretoria).

Oguntona, O. A., and Aigbavboa, C. O. (2016). Promoting Biomimetic Materials for a Sustainable Construction Industry. Bioinspired, Biomimetic and Nanobiomaterials, 6(3), 122–130.

Oguntona, O. A., and Aigbavboa, C. O. (2019). The Role of Product Eco-labels in Realising the Greening Agenda of the Construction Industry. In Proceedings of the Creative Construction Conference 2019, (139–144). Budapest University of Technology and Economics, Budapest, Hungary.

Omollo, W. O. (2019). Barriers to the Effective Regulation of the Building Construction Industry: An Empirical Analysis. Journal of Construction Business and Management, 3(2), 49–58.

Pheng, L. S., and Hou, L. S. (2019). The economy and the construction industry. In: Construction Quality and the Economy: A study at the firm level. Management in the Built Environment, 21–54, Springer, Singapore. DOI: https://doi.org/10.1007/978-981-13-5847-0_2.

Rahla, K. M., Mateus, R., and Bragança, L. (2021). Selection criteria for building materials and components in line with the circular economy principles in the built environment—A review of current trends. Infrastructures, 6(4), 49.

Sharma, R., and Sumbria, R. (2022). Mycelium Bricks and Composites for Sustainable Construction Industry: A State-Of-The-Art Review. Innovative Infrastructure Solutions, 7(5), 298.

Shurrab, J., Hussain, M., and Khan, M. (2019). Green and Sustainable Practices in the Construction Industry: A Confirmatory Factor Analysis Approach. Engineering, Construction, and Architectural Management, 26(6), 1063–1086.

Sieczka, Karen. (January 25, 2023). Cause and Effect: Barriers to Creativity and Innovation. Strategy, Alignment and Planning, Training Industry: https://trainingindustry.com/articles/strategy-alignment-and-planning/cause-and-effect-barriers-to-creativity-and-innovation/

Takawira, M. (2019). Addressing skills shortages in the South African residential construction industry through automation–a case of Gauteng region. Unpublished MSc thesis, University of the Witwatersrand, Johannesburg.

Utting, K. (2009). Assessing the Impact of Fair Trade Coffee: Towards an Integrative Framework. Journal of Business Ethics, 86 (Suppl 1), 127–149.