Sustainable building materials utilization in the construction sector and the implications on labour productivity

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Abstract

Purpose – The United Nations has demonstrated a commitment to preserving the ecosystem through its 2030 sustainable development goals agenda. One crucial objective of these goals is to promote a healthy ecosystem and discourage practices that harm it. Building materials production significantly contributes to the emissions of greenhouse gases. This poses a threat to the ecosystem and prompts a growing demand for sustainable building materials (SBMs). The purpose of this study is to investigate SBMs to determine their utilization in construction operations and the potential impact their application could have on construction productivity.

Design/methodology/approach – A systematic review of the existing literature in the field of SBMs was conducted for the study. The search strings used were “sustainable” AND (“building” OR “construction”) AND “materials” AND “productivity”. A total of 146 articles were obtained from the Scopus database and reviewed.

Findings – Bio-based, cementitious and phase change materials were the main categories of SBMs. Materials in these categories have the potential to substantially contribute to sustainability in the construction sector. However, challenges such as availability, cost, expertise, awareness, social acceptance and resistance to innovation must be addressed to promote the increased utilization of SBMs and enhance construction productivity.

Originality/value – Many studies have explored SBMs, but there is a dearth of studies that address productivity in the context of SBMs, which leaves a gap in understanding. This study addresses this gap by drawing on existing studies to determine the potential implications that using SBMs could have on construction productivity.

Keywords Construction productivity, Environmental sustainability, Social sustainability, Economic sustainability, Sustainable building materials, Sustainable development goals

Paper type Literature review

1. Introduction

The strategic role of the construction sector in achieving global sustainability objectives has garnered significant attention, leading to a continued focus on sustainability among construction stakeholders (Sharma and Sharma, 2022). Buildings are notable contributors to CO2 emissions...
(Mehrzad et al., 2022), generating a substantial portion of ozone-depleting chlorofluorocarbons during their production and operation (Sahlol et al., 2021). The resulting emission of heat-trapping greenhouse gases (GHG), such as carbon dioxide, has fuelled concerns about climate change (Novais et al., 2020). Recognizing the importance of environmental preservation, the United Nations has demonstrated a strong commitment to sustainable development goals, particularly in promoting sustainable cities and communities (Chaurasia, 2019). The International Energy Agency (IEA) highlights buildings as the largest energy-consuming sector globally, accounting for over 40% of global energy consumption and a significant portion of electricity usage in countries like India (IEA, 2013; Azad and Rakshit, 2018). Reducing energy consumption and emissions in the buildings sector is a challenging yet vital endeavour. The IEA advocates for substantial reductions in CO2 emissions in the building sector to limit global warming to below 2°C (IEA, 2020). With the building sector responsible for a considerable share of global GHG emissions, including those associated with building materials production, there is a growing call for sustainable practices within the industry (IEA, 2020; Singh et al., 2023). Building materials play a significant role in embodied energy and GHG emissions, underscoring the importance of choosing recyclable and sustainable options (Mehrzad et al., 2022; Al-Mudhaffer et al., 2022). Therefore, it is imperative for the construction sector to embrace sustainable building materials (SBMs) that minimize environmental impact, conserve resources and promote energy efficiency. SBMs are sourced, produced, used and disposed of in a manner that prioritizes ecological balance, social well-being and long-term sustainability.

SBMs have received significant research attention in the field of construction to promote sustainability (Unni and Anjali, 2022; Mansour and Ali, 2015; Suksiripattanapong et al., 2015). Various subfields within sustainability, such as sustainable construction management (Kibert, 2007), life cycle assessment (Zabalza et al., 2013), waste reduction (Ajayi et al., 2017) and corporate social responsibility (Xia et al., 2018), have been explored to enhance sustainable practices in construction. Scholars have investigated innovative building materials, including phase change materials (PCMs) (Li et al., 2013; Saxena et al., 2020; Lamrani et al., 2021; Agarwal and Prabhakar, 2023), alternative cementitious materials (Pahlevani and Sahajwalla, 2018; He et al., 2020; Sadok et al., 2022), bamboo (Chaurasia, 2019; Chaowana et al., 2021; Boity et al., 2022), sugarcane bagasse waste (Mehrzad et al., 2022) and alternative aggregates (Halicka et al., 2013; Awoyera et al., 2018; Vijayakumar et al., 2019; Alayish and Celik, 2021). Although the preponderance of existing studies in the field of sustainability has resulted in significant contributions to the research field, studies have not yet examined the implication of using SBMs on construction productivity. Construction productivity must continue to improve and the construction sector must increasingly embrace sustainable practices. Attaining success in these areas is crucial for fostering an economically, environmentally and socially responsible construction industry. This study categorizes SBMs and examines the potential impact of their utilization on construction productivity. Despite a plethora of studies on SBMs, there is a dearth of studies that address productivity in the context of SBMs, which leaves a gap in understanding. The study draws on existing research to determine the potential implications that utilizing SBMs could have on construction productivity. To achieve these objectives, a systematic review was undertaken to explore the existing body of literature in the field of SBMs. The purpose was to gather and analyse research articles published in the past decade that can provide contemporary development and understanding of SBMs.

2. Literature review

2.1 An overview of construction productivity

Construction productivity is commonly measured through two forms: single-factor productivity (SFP) and total-factor productivity (TFP). SFP focuses on one specific resource,
such as labour, plant, or capital, as the input (Adebowale and Agumba, 2021). However, SFP has a major limitation in that it cannot separate productivity changes from the influence of technology utilized by workers (Adebowale and Smallwood, 2020). On the contrary, TFP considers multiple factors, including labour, equipment, materials and capital, as input resources (Adebowale and Agumba, 2022a). TFP is widely recognized as a sustainable source of long-term economic growth due to its consideration of multiple input resources across organizations (Adebowale and Agumba, 2022b).

In the construction industry, labour productivity is typically evaluated as multi-factor productivity or TFP, unless otherwise specified (McKinsey Global Institute, 2017). In this study, labour productivity refers to TFP, which encompasses the productivity of various construction resources driven by the construction workforce. This research does not aim to measure productivity directly but seeks to gather evidence from the literature to assess the potential impact of using SBMs on labour productivity.

The issue of slow construction productivity growth has been a subject of ongoing debates among practitioners and academics in the industry (Cai et al., 2018; Poh et al., 2018). A study examining European countries and the USA highlighted the top-performing industries in terms of TFP growth, with telecommunications, agriculture and manufacturing showing positive growth, while construction experienced negative growth (Sidorova et al., 2021). Over the past two decades, construction TFP has only grown at an annual rate of 1%, which is lower than the growth observed in most sectors dependent on the economy (McKinsey Global Institute, 2017). It is concerning that five out of ten construction projects are typically behind schedule, and six often exceed budget limits, indicating poor productivity (Bevan and Steve, 2016). These common occurrences of time and cost overruns in construction projects raise concerns, given the industry’s significant role in micro and macroeconomic performance (Raynold and Philip, 2022). Global construction productivity growth has the potential to generate a substantial economic impact, with an estimated upside of $1.6tn, equivalent to a 2% increase in global gross domestic product (Barbosa et al., 2017). Therefore, achieving steady construction productivity growth has become increasingly crucial in project delivery (Buitrago et al., 2016).

The construction industry faces various challenges that impact labour productivity. One significant obstacle is the industry’s longstanding resistance to embracing innovative technologies, which has been identified as a key contributor to poor productivity performance (Young et al., 2021; Busta, 2016). In addition, concerns arise in the context of high-rise buildings due to the associated risks involved in vertical transport of construction workers and materials (Cai et al., 2018). Furthermore, the United Nations projects a global population increase from 8 billion people in 2023 to approximately 8.5 billion in 2030 and 9.7 billion in 2050 (United Nations, 2019). This population growth is expected to drive a surge in demand for private residences and commercial building facilities (Boity et al., 2022).

The construction sector significantly contributes to energy consumption and depletion of natural resources (Yadav and Agarwal, 2021), and these concerns are expected to worsen with population growth (Kumar et al., 2021). Building construction alone consumes 40% of the global annual sand, stone and gravel production and uses 25% of timber from forests (Sharma and Sharma, 2022). Given the increasing scale of construction operations, there is a pressing need for sustainable practices to ensure the safety of the ecosystem for current and future generations (IEA, 2020; Sahlol et al., 2021). The high embodied energy associated with modern construction materials has led to a growing advocacy for the adoption of SBMs (Boity et al., 2022; Singh et al., 2023). However, it is crucial to consider the implications of such materials on construction productivity. While the increased adoption of SBMs has the potential to promote sustainability, it may also worsen the existing productivity challenges in the
construction sector. Therefore, it is essential to examine the potential implications of adopting SBMs on productivity in the construction sector.

2.2 The triple bottom line and sustainable building materials
SBMs play a crucial role in advancing economic, environmental and social sustainability within the construction sector. From an economic perspective, SBMs offer long-term advantages and financial viability for construction projects. Through a consideration of life cycle costs and benefits, SBMs contribute to cost-effective solutions and resource optimization (He et al., 2020). They promote robust construction practices, leading to reduced maintenance and replacement costs over time. The adoption of energy-efficient SBMs results in energy cost savings and improved operational efficiency (Sadok et al., 2022).

Concerning environmental sustainability, SBMs are specifically designed to minimize the negative environmental impact of the construction sector (Agarwal and Prabhakar, 2023). They prioritize resource efficiency by incorporating renewable or recycled materials, reducing waste generation and optimizing material consumption. SBMs also focus on energy efficiency to decrease energy consumption and mitigate GHG emissions (Novais et al., 2020). Water conservation strategies, such as the utilization of water-saving fixtures and rainwater harvesting systems, are integrated into SBMs to reduce water consumption and preserve this valuable resource (Johra et al., 2021). In addition, SBMs emphasize the protection of biodiversity and ecosystems, striving to minimize habitat destruction and incorporate green spaces that support biodiversity preservation (Mehrzad et al., 2022).

In terms of social sustainability, SBMs prioritize the well-being and safety of individuals and communities (Sharma and Sharma, 2022). They consider factors such as occupant health, comfort and accessibility. For instance, SBMs promote healthy indoor environments by minimizing the use of hazardous materials and improving indoor air quality (Alam et al., 2022). They also incorporate universal design principles to ensure that buildings are inclusive and accessible to people of all ages, abilities and mobility levels (Mofidi et al., 2020). Through the integration of social, environmental and economic benefits, SBMs offer a comprehensive approach to sustainable construction practices.

2.3 Sustainable building materials and productivity
The integration of SBMs into construction and the improvement of productivity performance necessitate the examination of various factors, including construction techniques, stakeholders’ acceptability, availability, quality and cost implications. Construction techniques play a pivotal role in effectively incorporating SBMs into building projects. Scholarly research emphasizes the importance of material selection, preparation, installation and finishing methods to optimize the utilization of SBMs (Sandanayake et al., 2020; Sahlol et al., 2021). These techniques ensure that SBMs contribute to enhanced sustainability and improved productivity throughout the construction process. Proper handling and preservation practices are crucial to maintaining the quality and performance of SBMs (Prajapati and Dua, 2021). Mofidi et al. (2020) emphasized the significance of careful transportation, storage and protection of SBMs to prevent damage or deterioration. Adhering to recommended handling procedures, as highlighted by Fahim et al. (2022), ensures that SBMs retain their desired properties, thereby contributing to the success of construction projects and optimizing productivity.

The availability of SBMs in the construction market is a critical factor influencing their adoption and usage. Scholars such as Kaur (2018) have examined the current state of SBMs’ availability, considering factors such as production capacity, market demand and distribution networks. Understanding the availability of SBMs aids in assessing their feasibility and
accessibility, informing decision-making processes for construction professionals. Stakeholders’ acceptability of SBMs is a significant aspect of their successful implementation. Tenorio et al. (2020) and Opoku et al. (2016) have conducted studies exploring stakeholders’ perceptions, attitudes, and barriers towards SBMs. Architects, engineers, contractors, suppliers and building occupants all play important roles in shaping the adoption and usage of SBMs. Assessing stakeholders’ acceptability helps identify challenges and develop strategies to promote the widespread adoption of SBMs in construction practices.

The quality assessment of SBMs is crucial for their performance and long-term sustainability. Awoyera et al. (2018) and Suksiripattanapong et al. (2015) have focused on evaluating the durability, strength, fire resistance and other performance characteristics of SBMs. These studies provide valuable insights into the methodologies, standards and certifications relevant to assessing the quality of SBMs. Such evaluations aid in selecting appropriate materials that meet construction requirements, thereby enhancing productivity while maintaining sustainability objectives. The cost implications of utilizing SBMs have been extensively studied by Alam et al. (2022) and Unni and Anjali (2022). These studies analysed the upfront and life-cycle costs associated with SBMs and examine case studies to determine their cost-effectiveness. Understanding the cost dynamics of SBMs is crucial for making informed decisions that balance affordability, productivity and sustainability objectives in construction projects. These factors are critical for consideration to improve the adoption of SBMs without undermining construction productivity.

2.4 Classification of sustainable building materials

Traditional building materials are materials that have been historically used in construction. The materials are associated with low carbon emissions and are also reusable and recyclable for other functions and are usually produced on-site or in nearby areas to reduce transportation costs and embodied energy. In recent years, traditional building materials are being transformed to produce innovative materials that are economically, socially and environmentally responsible. These materials serve as alternatives to modern building materials. The goal is to make construction projects more sustainable (Sahlol et al., 2021; Boity et al., 2022). Table 1 presents existing studies that have contributed to the field of SBMs. The table presents 18 materials, their application areas and benefits, and how the materials are sourced.

2.4.1 Bio-based materials. Treated rice straw, fly ash and construction wastes have been used to produce alkali-activated fly ash bricks for non-load-bearing partition walls (Singh et al., 2023). Locally available rice straw, bamboo dry leaves, Syzygium cumini and Mangifera indica were collected and dried before using fly ash, a thermal power plant and granulated blast furnace slag for brick and panel casting. A huge quantity of bio-based resources is burnt due to their perceived negligible value. Due to the adverse effect of their incineration, there is an increase in the use of bio-based materials. Lightweight bio-bricks produced from dry sugarcane bagasse, lime, stone dust and water can be used in the framed structure as non-load-bearing walls with excellent heat and sound insulation can be produced (Rautray et al., 2019). Sugarcane bagasse waste is eco-friendly in terms of its high thermal and acoustic performance (Mehrzad et al., 2022). Residues of pineapple and rice are suitable for reducing summer cooling consumption (Asdrubali et al., 2015). The production of insulators made of natural materials such as sugarcane, pineapple and rice should not be in conflict with the plantation and harvesting of food crops, but it should be focused on using residues and by-products of the agricultural sector (Asdrubali et al., 2015).

The use of clay as a SBM has also been identified due to its environmental friendliness in terms of its reusability, health benefit, thermal comfort and economic benefit (Lekshmi et al., 2020).
### Table 1. Sustainable building materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Benefit</th>
<th>Application area</th>
<th>Sourcing</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase change materials</td>
<td>Improve thermal comfort</td>
<td>Building envelope</td>
<td>Eicosane, OM35, paraffin wax</td>
<td>Li et al. (2013); Beemkumar et al. (2020); Frigione et al. (2020); Saxena et al. (2020); Henig et al. (2021); Lamrani et al. (2021); Li et al. (2022); Sarcinella et al. (2022); Agarwal et al. (2023)</td>
</tr>
<tr>
<td>Bricks</td>
<td>Reduce depletion of fertile soil used for agricultural purposes and minimize the risk of air pollution; environmental sustainability</td>
<td>Non-load-bearing partitions walls, building envelope</td>
<td>Demolition and bio-wastes; incineration of solid waste; red soil, lime, and fly ash; palm oil fuel ash</td>
<td>Rautray et al. (2019); Djamaluddin et al. (2021); Alam et al. (2022); Narendhran et al. (2023); Singh et al. (2023)</td>
</tr>
<tr>
<td>Cementitious materials</td>
<td>Reduce GHG emissions and energy and costs savings; Reduce cost and CO₂ emission; reduced energy consumption and emission of CO₂ emission during cement production</td>
<td>Building envelope</td>
<td>Calcined dredged sediments from dams; autoclaved aerated concrete waste; ceramic waste; river sediments</td>
<td>Junakova and Junak (2017); Pahlevani and Sahajwalla (2018); He et al. (2020); Li et al. (2020); Sadok et al. (2022)</td>
</tr>
<tr>
<td>Bamboo</td>
<td>Reduce carbon emissions and promote environmental protection</td>
<td>Wall, floor, roof construction</td>
<td>Natural forests</td>
<td>Chaurasia (2019); Chaowana et al. (2021); Boity et al. (2022)</td>
</tr>
<tr>
<td>Sugarcane bagasse waste</td>
<td>Improve thermal and acoustic performance</td>
<td>Building envelope</td>
<td>Agro-industrial by-product</td>
<td>Mehrzad et al. (2022)</td>
</tr>
<tr>
<td>Multifunctional alkali-activated composites</td>
<td>Improve thermal and acoustic performance</td>
<td>Building envelope</td>
<td>Cork as a lightweight aggregate</td>
<td>Novais et al. (2020)</td>
</tr>
<tr>
<td>Calcium silicate board material</td>
<td>Energy-saving and enhanced flexural strength of the material</td>
<td>Ceiling and insulation panels</td>
<td>Paper sludge powder (paper sludge ash and alkali recovery paper sludge)</td>
<td>Chen et al. (2019)</td>
</tr>
<tr>
<td>Seacrete</td>
<td>Reduction in CO₂ emissions and natural resources extraction</td>
<td>Substitute concrete in certain building elements such as low-rise indoor elements</td>
<td>Coastlines</td>
<td>Johra et al. (2021)</td>
</tr>
</tbody>
</table>

(continued)
<table>
<thead>
<tr>
<th>Material</th>
<th>Benefit</th>
<th>Application area</th>
<th>Sourcing</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass</td>
<td>Reduce environmental pollution</td>
<td>Kitchen’s benchtops, bathroom vanities, wall and floor tiles</td>
<td>Waste glass</td>
<td>Pahlevani et al. (2018)</td>
</tr>
<tr>
<td>Aggregates</td>
<td>Reduce CO₂ emissions and natural resources extraction</td>
<td>Building envelope</td>
<td>Ceramic wastes; foundry sand and foundry slag wastes; sewage sludge; solid waste and ground granulated blast furnace slag; ferrochrome slag</td>
<td>Halicka et al. (2013); Awoyera et al. (2018); Vijayakumar et al. (2019); Alayish and Celik (2021); Colangelo et al. (2021); Sohel et al. (2022)</td>
</tr>
<tr>
<td>Green concrete</td>
<td>Reduce CO₂ emissions and natural resources extraction</td>
<td>Building structures</td>
<td>Fly ash from burnt pulverized coal, glass powder, and demolished construction wastes converted to fine powdered form</td>
<td>Khan et al. (2020)</td>
</tr>
<tr>
<td>Hyacinth cement panels</td>
<td>Improve embodied and operational energy</td>
<td>Building envelope</td>
<td>Water bodies</td>
<td>Philip and Rakendu (2020)</td>
</tr>
<tr>
<td>Aerogel</td>
<td>Energy efficiency in buildings</td>
<td>Attic and floor slabs</td>
<td>Created by removing moisture from a gel while maintaining the gel structure</td>
<td>Bashir and Leite (2022)</td>
</tr>
<tr>
<td>Recycled materials</td>
<td>Improve indoor air temperature during winter and summer</td>
<td>Roof</td>
<td>Straw bale, recycled waste glass, and sheep wool</td>
<td>Ahmad et al. (2022)</td>
</tr>
<tr>
<td>Paving bricks and roofing tiles</td>
<td>Environmental sustainability</td>
<td>Walkway and roof, roof board</td>
<td>Fly ash; empty fruit bunch and mesocarp fibre</td>
<td>Kalombe et al. (2020); Deraman et al. (2022); Vitola et al. (2022), Agyekum et al. (2021), Bukhari et al. (2021)</td>
</tr>
<tr>
<td>Hempcrete blocks or panels</td>
<td>Good insulator</td>
<td>Wall or slab insulation</td>
<td>Hemp, hursds and lime</td>
<td>Lekshma et al. (2017); Zaryoun and Hosseini (2019)</td>
</tr>
<tr>
<td>Clay</td>
<td>Thermal comfort, economic benefit, reusability</td>
<td>Partitions, tiles of false ceiling, external walls, building’s façade, load bearing walls in small rural dwellings</td>
<td>Earth</td>
<td></td>
</tr>
</tbody>
</table>

**Source:** Authors' own work
Considering the weakness of mass clay during natural disasters, lightweight fibre-reinforced clay has been proposed for resilience against natural disastrous events (Zaryoun and Hosseini, 2019). However, recent studies are beginning to advocate the replacement of clay in building construction. Sewage sludge and fly ash have been used as a replacement for clay in brick production (Taki et al., 2020). Fly ash promises to be a novel renewable material for energy performance in building construction (Sagbansua and Balo, 2017). Palm oil fuel ash, a waste generated from the palm oil industry, was similarly used as a replacement for clay in brick production (Djamaluddin et al., 2021). Municipal solid waste incinerated bottom ash has been used in brick production (Alam et al., 2022), and fly ash from incinerated municipal solid waste and ground granulated blast furnace slag used to produce innovative low-cost and energy-saving lightweight aggregates (Colangelo et al., 2021). Although the incineration of solid wastes contributes to air pollution, utilizing bottom and fly ash obtained from incineration contributes to reducing pressure on natural resources and reducing environmental pollution occasioned by solid wastes. Cost analysis of bottom ash bricks was done with the conventional ones, which confirms the efficiency and cost-effectiveness of the bricks for the construction industry (Alam et al., 2022).

Unburnt bricks from native red soil have been manufactured using an optimized proportion of low-cost binders (Narendhran et al., 2023). The native red soil is taken as the aggregate, and lime, cement and fly ash are taken as the binding materials. The results indicate that an equal combination of lime and cement can give the highest compressive strength, whereas a tertiary combination of lime, cement and fly ash can give comparable results. Insulation materials are commonly fabricated from petrochemicals with high energy consumption, causing significant detrimental effects on the environment during the production and discarding stage (García Sánchez et al., 2021). A huge amount of energy is still generated from producing recycled materials; therefore, bio-based materials present a good alternative solution for environmental sustainability (García Sánchez et al., 2021; Yadav and Agarwal, 2021). Water hyacinth invasive weeds have been used to produce hyacinth cement panels (Philip and Rakendu, 2020), which provide a sustainable insulation material for buildings. Hyacinth cement panels not only have the potential to improve building energy savings but can eliminate the problems caused by water hyacinth in the water bodies.

More bio-based building materials include residues of pineapple and rice, timber, mycelium, hempcrete, fique flax boards, straw, mussel shells and reed (Asdrubali et al., 2015; Yadav and Agarwal, 2021). Hempcrete as a bio-composite material contains a mixture of hemp, hurds and lime. Lime reduces the internal room temperatures by 4°C–5°C compared to cement (Kumar et al., 2021). Hemp structures date back to Roman times and have a lower carbon footprint than many materials. Hemp’s good insulation property promotes its acceptance in the building industry (Vitola et al., 2022; Bukhari et al., 2021). Fique as an important crop in Colombia also has a good thermal insulation property in buildings (García Sánchez et al., 2021), while empty fruit bunch and mesocarp fibre are potential materials for the production of roof board thermal insulation (Deraman et al., 2022).

Bamboo has been established as a building material that can reduce the carbon footprint of the construction process due to its low embodied energy (Chaurasia, 2019). Bamboo can be grown at multiple locations with little investment and can easily be replenished (Boity et al., 2022). Bamboo culm is a renewable and lightweight material with high strength, particularly tensile strength (Chaowana et al., 2021). Chaurasia (2019) reported the suitability of bamboo for wall, roof and floor construction. Calcium silicate board material is a new environmentally friendly and energy-saving building material for the construction of ceilings and partitions, roofs of warehouses and thermal insulation panels for walls.
Sustainable calcium silicate board material has been developed with paper sludge ash and alkali recovery paper sludge, which is a by-product of wastewater treatment (Chen et al., 2019). Using recycled paper sludge powder presents a great potential to develop sustainable and energy-saving calcium silicate board material with enhanced flexural strength and reduced water absorption tendency.

2.4.2 Cementitious materials. One of the widely used construction materials is cement. Cement production is responsible for producing more than 6% of all CO$_2$ emissions (Khan et al., 2020). Cement replacement has been considered a plausible measure to reduce GHG emissions (Sandanayake et al., 2020). Different elements, including calcined dredged sediments (Sadok et al., 2022), reservoir sediment (Junakova and Junak, 2017), micro-ceramic powder (Li et al., 2020) and autoclaved aerated concrete waste (He et al., 2020) have been used to partially or completely replace cement in construction. The potential of GHG emissions and energy consumption are found to be significantly less when calcined dredged sediments are added to mortars (Sadok et al., 2022). Calcined dredged sediments could be used as a partial cement replacement in the cement industry to provide a positive environmental impact. Reservoir sediments can be used as a replacement for portland cement in concrete with a substitution ratio of 40% without any chemical modifications (Junakova and Junak, 2017), while a similar 40% replacement of cement with micro-ceramic powder in building construction projects is advocated (Li et al., 2020). The building sector produces between 45% and 65% of the waste disposed of in landfills (Kumar et al., 2021). The application of micro-ceramic powder as a partial replacement for cement presents the benefit of converting landfilled waste material to valuable construction material (Ajayi et al., 2017). Wastes must be reused and recycled in order to reduce waste generated in the building industry (Sharma and Sharma, 2022). It would also contribute to overall energy consumption and emission of CO$_2$ emission during cement production (Sadok et al., 2022). Autoclaved aerated concrete waste could be efficiently used as an alternative cementitious material in cement and concrete after wet-milling treatment (He et al., 2020). Wider utilization of autoclaved aerated concrete waste will not just provide the benefit of an alternative cementitious material, but also presents an efficient way to dispose and utilize the aerated concrete waste from building demolition. Geopolymerization offers a route for the replacement of cement with coal fly ash in the construction industry. Kalombe et al. (2020) reported on the production of fly ash-based geopolymers without adding aggregates, sand, and/or cement. Due to the release of a high amount of CO$_2$ from the production of conventional concrete, green concrete, which offers a sustainable and eco-friendly solution as a building material is the latest development in the field of construction technology (Sandanayake et al., 2020). Green concrete has been produced by partially replacing cement with fly ash and completely replacing fine aggregate with a 50%–50% combination of glass powder and demolished construction wastes converted to fine powdered form (Khan et al., 2020).

2.4.3 Phase change materials. PCMs are chemical compounds with a large amount of heat energy stored in the form of latent heat which is absorbed or released when the materials change state from solid to liquid or liquid to solid (Agarwal and Prabhakar, 2023). PCMs retain their latent heat without any change in physical or chemical properties over thousands of cycles (Li et al., 2022). The suitability of polymer-based PCMs for energy efficiency in buildings has been advocated (Frigione et al., 2020). PCMs incorporated bricks using Eicosane and OM35 have been found suitable as a SBM. Compared to the traditional bricks, a temperature reduction of 5°C–6°C across PCMs bricks was observed (Saxena et al., 2020) and a reduction in heat flow by 8% and 12% for Eicosane and OM35, respectively. Paraffin wax is also used as PCMs with pumice fine aggregates to produce concrete hollow blocks (Heniegal et al., 2021). Paraffin wax and pumice
fine aggregates have the potential to keep the indoor temperature at a comfortable temperature and reduce the electrical consumption energy of buildings. PCMs have also been integrated into cement mortars (Li et al., 2013), lime mortars (Frigione et al., 2020), walls (Lamrani et al., 2021), roofs (Beemkumar et al., 2020) and glazing (Li et al., 2022) to enhance thermal comfort in buildings. PCMs obtained as a by-product of stone processing, impregnated by polyethylene glycol can be used to replace the fine aggregates in mortars. The mortars containing the mixed PCM show a wider interval of melting/crystallization temperatures, suggesting that the mortar is suitable for both warm and cold climates (Sarcinella et al., 2022).

2.4.4 Others. The high global demand for concrete increases the amount of CO\textsubscript{2} emissions induced by cement production, while aggregate extraction during concrete fabrication endangers the ecosystems. Due to the established similarities in the mechanical properties and strength of seacrete and concrete (Hilbertz, 1979), seacrete is considered a good alternative to concrete (Johra et al., 2021). Seacrete can be produced nearby all coastlines without any need for mining, extraction or transportation of additional material, while its fabrication can easily be powered by low-intensity or local intermittent renewable energy sources. Ceramic wastes have been adopted to partially replace the natural aggregates in mortars/concretes (Halicka et al., 2013) focusing on their mechanical strength (Awoyera et al., 2018) and durability (Medina et al., 2013). For concrete production, the complete substitution of fine and coarse aggregate with foundry sand and foundry slag wastes could produce a great result (Vijayakumar et al., 2019). This can reduce environmental problems connected with aggregate mining and suggest the best option for waste disposal. Substituting fine and coarse aggregate with foundry sand and foundry slag wastes provides optimum compressive strength for concrete in 28 days. Sewage sludge from wastewater treatment plants has also been proven to have the potential to be used for lightweight aggregate production (Alayish and Celik, 2021). Steel companies generate large quantities of ferrochrome slag annually during the production process of ferrochrome alloy. Most of the quantities of the ferrochrome slag generated are disposed of without being reused, posing a threat to the environment. Waste ferrochrome slag can be used as green coarse and fine aggregate concrete production (Sohel et al., 2022).

Sewage sludge ash is effective for cement replacement due to its pozzolanic properties (Taki et al., 2020). Sewage sludge from wastewater treatment plants used as a SBM can reduce waste disposal to the environment. The need to reuse waste plastic bottles as an alternative SBM has been reported (Mansour and Ali, 2015). Thermal-wise, air-filled bottles showed better thermal insulation than the traditional block construction, therefore, could act as thermal insulation material in buildings. Among its several qualities, aerogel is a good thermal insulation material for buildings (Bashir and Leite, 2022). Aerogel had the highest influence when inserted in the attic and floor slabs with the potential to produce a 15% reduction in energy consumption. Straw bales, recycled waste glass and sheep wool can be recycled and used on rooftops to improve indoor air temperature in construction projects (Ahmad et al., 2022). Recycled glass reportedly gives the best thermal comfort in winter and summer compared to straw bale and sheep wool. By adjusting the humidity levels inside buildings, alkali-activated composites, prepared using cork as a lightweight aggregate similarly enhance thermal comfort (Novais et al., 2020). Cork is an exceptional material with excellent thermal insulation making it ideal for lightweight aggregate production. As an innovative sustainable solution, Pahlevani and Sahajwalla (2018) developed a cost-effective new process that transforms large quantities of mixed waste glass into valuable polymeric glass composite panels. Conventional glass recycling technologies are limited by the sensitivity of the remelting process. Pahlevani and Sahajwalla (2018) offered a new recycling process that embodies an important unique alternative to the remelting of waste glass.
3. Research methodology

3.1 Research approach
A systematic literature search was carried out in this study. The review included a scientific research approach that assesses, summarizes and presents the research results. Researchers had used systematic reviews to study different areas of construction, including lean construction (Babalola et al., 2019); robotic technologies (Gharbia et al., 2020); augmented reality (Raynold and Philip, 2022); and sustainable construction management (Araujo et al., 2020; Goh et al., 2020). These studies have made contributions in different research areas.

3.2 Database selection
This study considered the Scopus database to search and select SBM articles relevant to the study objective. The Scopus database was considered because it covers a wider range of scientific publications compared to the other databases (Babalola et al., 2019). Most construction-related publications in other databases are also usually hosted in the Scopus database. Besides, Scopus reportedly has the largest research literature citation database, containing publications from a variety of construction journals (Abioye et al., 2021).

3.3 Article selection
The search was conducted on 15 February 2023. The search was conducted using important keywords obtained from the research topic. The search terms were limited to “sustainable” AND (“building” OR “construction”) AND “materials” AND “productivity” because they are relevant to the study focus. To retrieve the most relevant articles for the study, the search query parameters were designed to align with the research goals. The inclusion of the keyword “sustainable” in the search terms ensures that articles related to sustainability are captured. With this keyword, the Scopus database can yield articles that specifically address the concept of sustainability in various contexts, including the building and construction industry. The keywords “building” and “construction” were necessary to further narrow down the search to articles that specifically focus on sustainability within the building and construction industry. This specificity ensures that the retrieved articles are directly relevant to the research topic. The inclusion of the keyword “materials” is justified by the research’s primary focus on sustainable materials in the building and construction sector. Regarding “building” and “construction”, it was found that some authors prefer one term over the other when referring to materials used in the construction sector. For example, some authors prefer to use building materials, while others have a preference for construction materials. By including both terms, the search query accommodates the preferences of different authors, ensuring that articles using either “building” or “construction” terminology are included in the search results. This strategy increases the likelihood of capturing a wide range of relevant literature. While it was observed during the background study that not many studies explicitly highlight productivity in the context of SBMs, “productivity” was included in the search query due to its significance to the research. It allows for getting any available literature that may touch upon productivity in SBM studies.

The search was performed within the article title, abstract and keyword fields of the Scopus database. Most systematic reviews have preferred these fields for search queries, as it provides extensive publications (Babalola et al., 2019). The research focuses on examining recent development in SBM applications in the construction sector, therefore, relevance to the contemporary context was considered to limit the search to the past decade (2013–2023). Restricting the search to the past decade ensures that the review reflects the current state of knowledge and practices in the fields. As sustainability and construction practices evolve over time, recent publications are more likely to address the latest developments, trends and
challenges faced by the industry. The search yielded journal articles, conference papers, reviews, book chapters and editorials. The database yielded 296 documents. Table 2 presents the summary of article selection and screening.

3.4 Articles screening
More substantive information and robust empirical evidence needed to be considered; therefore, reviews, book chapters and editorials were excluded from the list of articles. Only journal articles and conference papers were retained for this study. Journal articles and conference papers usually contain comprehensive scholarly literature (Hosseini et al., 2018). Although book chapters also present reliable scholarly information, book chapters were not considered in this research. After the initial screening, 231 articles were found satisfactory. Five articles written in German and Italian languages were eliminated. Another three articles in the press were subsequently excluded from the list of articles. Article abstracts were read to determine which articles were relevant to the research objective. The inclusion and exclusion criteria used by Babalola et al. (2019) were adapted to choose articles in accordance with their relevance to the research objective. The rating scale consisted of the numbers 0 for no relevance, 1 for little relevance, 2 for medium relevance and 3 for high relevance. The relevance of the articles was determined by analysing their abstracts. Seventy-seven articles were eliminated, as they were irrelevant to the research objective. The 146 articles that met the screening criteria were reviewed.

3.5 Publication channels
Publications in the field of SBMs spread across 138 publication channels. Journal of Cleaner Production, IOP Conference Series Earth and Environmental Science, Sustainability Switzerland and IOP Conference Series Materials Science and Engineering were the leading publication channels with a minimum of ten publications. Table 3 presents the 12 leading publication channels with a minimum of three publications. Considering the 138 publication channels, the total articles in the 12 leading publication channels presented in Table 3 account for 63.01% of the total publications. Publications in the research field spread across

<table>
<thead>
<tr>
<th>Stage</th>
<th>Articles extraction and screening</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1</td>
<td>Search string: “sustainable” AND (“building” OR “construction”) AND “materials” AND “productivity”. Search within: Articles title, abstract, keywords</td>
<td>296</td>
</tr>
<tr>
<td>Stage 2</td>
<td>Screening by articles type</td>
<td>231</td>
</tr>
<tr>
<td></td>
<td>Excluded: Review, book chapters, editorials (N = 65)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Included: Journal articles, conference papers (N = 231)</td>
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<tr>
<td>Stage 3</td>
<td>Screening by articles language</td>
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<tr>
<td></td>
<td>Excluded: German, Italian (N = 5)</td>
<td></td>
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<td></td>
<td>Included: English (N = 226)</td>
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<td>Stage 4</td>
<td>Excluded: Article in press (N = 3)</td>
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<tr>
<td></td>
<td>Included: Final (N = 223)</td>
<td></td>
</tr>
<tr>
<td>Stage 5</td>
<td>Relevance to the research goal</td>
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</tr>
<tr>
<td></td>
<td>Excluded: No relevance, low relevance (N = 77)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Included: Medium relevance, high relevance (N = 146)</td>
<td></td>
</tr>
</tbody>
</table>

Table 2.
Research process
Source: Authors’ own work
57 countries, where India (41), China (17), Italy (17) and Egypt (15) were the leading countries in terms of the number of articles published.

4. Results
This section provides a synthesis of the research trends in SBMs, drawing upon existing studies. Figure 1 serves as a visual representation of the major themes identified in SBMs, based on a review of relevant literature. The contents are organized and categorized according to the three pillars of sustainability, commonly known as the triple bottom line: economic, environmental and social factors. By adopting and integrating these factors into the construction sector, it becomes possible to foster a more sustainable and resilient industry.

5. Discussions of the findings
Innovative materials have emerged as viable alternatives to conventional building materials, offering potential economic, environmental and social benefits. This study categorizes these materials into four main types: bio-based, cementitious, phase change and others. Bio-based materials have gained significant attention in building construction, particularly due to their sustainability advantages. Examples of bio-based materials include rice straw, bamboo leaves, sugarcane bagasse waste, water hyacinth invasive weeds, hemp and pineapple, which have been widely used in the production of building bricks. Bamboo, with approximately 1,662 species found across Africa, Asia, Europe and America, is especially noteworthy (Boity et al., 2022). The bamboo trunk, in addition to its leaves, is increasingly recognized as a SBM due to its potential to reduce carbon emissions and its superior compressive and tensile strength compared to materials like concrete. The abundant availability of these materials can enhance construction productivity by providing readily accessible and renewable resources for construction projects (Johra et al., 2021). The utilization of bamboo as a mainstream building material can significantly reduce construction costs, benefiting clients and bamboo producers alike. Moreover, the increasing importance of bamboo in construction arises from the need to curb deforestation caused by tree cutting in many countries.

<table>
<thead>
<tr>
<th>S/N</th>
<th>Publication channels</th>
<th>No. of publications</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><em>Journal of Cleaner Production</em></td>
<td>14</td>
<td>9.59</td>
</tr>
<tr>
<td>2</td>
<td><em>IOP Conference Series Earth and Environmental Science</em></td>
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<td>8.22</td>
</tr>
<tr>
<td>3</td>
<td><em>Sustainability Switzerland</em></td>
<td>11</td>
<td>7.53</td>
</tr>
<tr>
<td>4</td>
<td><em>IOP Conference Series Materials Science and Engineering</em></td>
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</tr>
<tr>
<td>5</td>
<td><em>Materials Today Proceedings</em></td>
<td>9</td>
<td>6.16</td>
</tr>
<tr>
<td>6</td>
<td><em>Construction and Building Materials</em></td>
<td>8</td>
<td>5.48</td>
</tr>
<tr>
<td>7</td>
<td><em>Journal of Building Engineering</em></td>
<td>8</td>
<td>5.48</td>
</tr>
<tr>
<td>8</td>
<td><em>AIP Conference Proceedings</em></td>
<td>5</td>
<td>3.42</td>
</tr>
<tr>
<td>9</td>
<td><em>Buildings</em></td>
<td>4</td>
<td>2.74</td>
</tr>
<tr>
<td>10</td>
<td><em>Materials</em></td>
<td>4</td>
<td>2.74</td>
</tr>
<tr>
<td>11</td>
<td><em>Sustainable Materials and Technologies</em></td>
<td>4</td>
<td>2.74</td>
</tr>
<tr>
<td>12</td>
<td><em>Building and Environment</em></td>
<td>3</td>
<td>2.05</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>92</td>
<td>63.01</td>
</tr>
</tbody>
</table>

*Source:* Authors’ own work

<table>
<thead>
<tr>
<th>Publication source with a minimum of three articles</th>
<th>Sustainable building materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 3.</td>
<td></td>
</tr>
</tbody>
</table>


Other bio-based materials, such as pineapple, rice and sugarcane bagasse wastes, have demonstrated significant potential for improving thermal and acoustic performance in buildings, offering energy-saving benefits to the construction sector (Asdrubali et al., 2015). Invasive weeds found in water bodies and calcium silicate boards are also recognized as excellent insulation materials, promoting energy efficiency in buildings. Calcium silicate board, as an SBM, has been successfully applied in various construction applications, including ceilings, partitions, warehouse roofs and thermal insulation panels for walls. Fique, hemp, hurds and lime are additional materials known for their favourable thermal insulation properties. While clay has been promoted as an SBM due to its reusability, health benefits, thermal comfort and economic advantages (Lekshmi et al., 2017), concerns regarding the depletion of natural resources have led to calls for the partial replacement of clay in brick production. Eco-friendly materials such as sewage sludge, fly ash and palm oil fuel ash have been used as partial substitutes for clay in brick production. These bio-based bricks, suitable for constructing non-load-bearing walls, offer excellent heat and sound...
insulation properties. In addition, empty fruit bunch and mesocarp fibre can be used to produce roof boards. The broader application of these materials not only helps reduce the depletion of fertile soil used in agriculture but also minimizes the risks of air pollution resulting from traditional brick kilns and the burning of residual biowastes.

The production of cement has posed a significant threat to the ecosystem due to the substantial amount of CO₂ emissions associated with its production process. As a result, there is a growing promotion of options for partially replacing cement in building construction (Sandanayake et al., 2020). Several elements, such as calcined dredged sediments, reservoir sediment, micro-ceramic powder and autoclaved aerated concrete waste, have shown potential as partial replacements for cement (Junakova and Junak, 2017; Li et al., 2020; He et al., 2020; Sadok et al., 2022). These materials can be used as supplementary components in cement production within the cement industry. The partial replacement of cement with these materials would effectively reduce the overall quantity of cement required for construction, thus minimizing the CO₂ emissions associated with cement production.

It is important to note that the wastes used in the production of cementitious materials contribute significantly to landfill volumes. Therefore, their utilization for producing SBMs would not only reduce construction landfill but also mitigate the negative environmental effects associated with landfill. Fly ash and sewage sludge, due to their pozzolanic properties, are gaining increasing relevance as alternatives for cement replacement. When used in combination with other eco-friendly aggregates, they contribute to the production of sustainable concrete in construction projects (Khan et al., 2020; Taki et al., 2020).

Given the projected global population increase from 8 billion in 2023 to an estimated 9.7 billion in 2050, corresponding to a growth of 21.25%, it is crucial for construction stakeholders and global leaders to be increasingly concerned (United Nations, 2019). This population growth will lead to increased demands for housing and industrial facilities, subsequently driving the demand for cement in construction projects. Therefore, alternative cementitious materials present a viable option in the construction sector, providing an opportunity to address the challenges associated with cement production and its environmental impact.

The substitution of fine and coarse aggregate with foundry sand and foundry slag wastes provides significant environmental benefits (Vijayakumar et al., 2019). Sewage sludge also proves to be an effective material for producing lightweight aggregate. In steel production, ceramic wastes and ferrochrome slag-generated wastes are valuable materials for replacing coarse and fine aggregate in concrete production. Considering the widespread use of concrete in the construction industry, the production of green concrete using fly ash and other suitable materials offers a viable option. In addition to reducing the demand for cement, this approach alleviates pressure on rapidly depleting natural resources (Khan et al., 2020). Seacrete, a sustainable alternative to concrete, can be produced locally along coastlines without the need for mining, extraction, or transportation of additional materials. Its fabrication can be powered by low-intensity or local intermittent renewable energy sources (Khan et al., 2020).

Another method of improving the energy efficiency of buildings is by incorporating PCMs within the building envelope to increase thermal mass. The utilization of PCMs has been recognized for enhancing energy efficiency in buildings (Agarwal and Prabhakar, 2023). Specific compounds such as eicosane and OM35, which possess heat-retaining properties, can be used in the production of burnt bricks and cement. PCM-incorporated bricks made from eicosane and OM35 have demonstrated the ability to reduce temperature fluctuations and heat loss in buildings. While these PCM-based bricks are more environmentally friendly than traditional bricks, the production of burnt bricks and cement still contributes to GHG emissions. Therefore, the continuous production of these materials
alongside the use of PCMs can perpetuate GHG emissions, although PCMs address energy-related concerns (Saxena et al., 2020). This underscores the growing advocacy for the use of alternative materials such as fly ash and sewage sludge in cement production.

Palm oil fuel ash and bottom ash from waste materials have been identified as potential alternative materials for cement in burnt clay bricks. Bio-bricks, with lower average density, offer a suitable replacement for burnt clay bricks and concrete blocks in partition walls of column beam structures. This is particularly advantageous for high-rise structures, as it reduces the overall load on the frame structure compared to traditional walls. The wider utilization of bio-bricks can lead to the design of lighter frame structures, thereby reducing the use of concrete and steel and lowering construction costs (Rautray et al., 2019). Heat-retaining compounds, such as paraffin wax, when used with sustainable pumice aggregate, can produce building blocks. PCMs are also effective materials in mortars used for plastering (Sarcinella et al., 2022). The application of PCMs to walls, roof members, and glazing enables the control of indoor temperature. Recycled materials like straw bale, waste glass and sheep wool can be used on rooftops to improve indoor air temperature in construction projects. In addition, aerogel, a synthetic porous ultralight material, exhibits extremely low thermal conductivity, making it an excellent thermal insulation material for buildings. These innovative building materials contribute to energy savings and enhance occupant comfort. Their application in construction can significantly reduce CO₂ emissions from the building sector and contribute to the achievement of global sustainable development goals.

6. Implications on labour productivity
This section provides insights into the potential implications of using SBMs on construction productivity, considering economic, environmental and social factors. While SBMs offer benefits for current and future generations, their increased adoption can present challenges to construction productivity if not effectively managed. The scarcity of certain SBMs is a significant concern that can impact construction productivity. Many bio-based materials suitable for SBMs are locally available natural resources, but their availability is not universal across countries due to limited awareness and utilization of SBMs in the construction industry (Agyekum et al., 2021). For example, cork, an excellent thermal insulation material and lightweight aggregate, is derived from the cork oak tree found in Spain and Portugal. Similarly, aerogel, a suitable material for building thermal insulation, is still expensive and less accessible compared to conventional insulation materials. Seacrete, an alternative to concrete, has a slow growth rate of only a few centimetres per year, limiting its production speed for construction elements (Johra et al., 2021). The scarcity of these green materials results in higher procurement costs, which can be criticized and discourage their adoption by project clients (Sandanayake et al., 2020). The limited availability and higher costs of SBMs restrict their widespread application in construction (Bashir et al., 2022).

Considering the scale of the construction industry and the materials required to meet its demand, SBMs, including bio-based, cementitious, PCMs and others, are not yet available in quantities that can meet the construction sector’s material needs. Material shortages in construction have been widely reported as hindrances to productivity (Adebowale and Agumba, 2021) and relying heavily on scarce SBMs can exacerbate these shortages, potentially leading to delays in construction. These factors may make construction stakeholders more inclined to continue using traditional construction materials, underscoring the need for strategies to enhance the accessibility of SBMs in construction.

The expertise of contractors and designers in using SBMs in design and construction is of utmost importance. Although some architects and contractors may be passionate about using SBMs, many of these materials are relatively new and require further scientific
investigation to determine their suitability in the building and construction sectors. One of the major issues affecting productivity in the construction sector is delay resulting from the buildability problem (Osuizugbo et al., 2022). The use of SBMs without the requisite expertise can worsen the buildability problem, which is a major issue affecting productivity in the construction sector (Osuizugbo et al., 2022). Construction practitioners must develop expertise in sourcing, handling, and construction methods and techniques for SBMs. Scientific investigations are also needed to demonstrate their safe application. Effective communication channels and collaborative decision-making among stakeholders, including architects, quantity surveyors, engineers and contractors, are critical. Such communication fosters the exchange of information, ideas and concerns related to the selection, sourcing and integration of SBMs. This helps address challenges, align goals and expectations, increase awareness and minimize conflicts that may affect construction progress. Effective collaboration can attract clients and investors, creating new market opportunities. Stakeholders’ synergy would enable the evaluation of SBMs’ feasibility and suitability for specific projects, facilitating comprehensive understanding and informed choices that enhance construction productivity. However, challenges such as limited availability, higher costs and compatibility issues with existing practices require careful consideration.

The construction industry is characterized by resistance to adopting new innovations and practices (Dithebe et al., 2019). The social acceptance of SBMs by industry practitioners, including clients, consultants and contractors, can pose challenges to their widespread utilization. Poor social acceptance may hinder the development of skills necessary for working with SBMs, ultimately impacting productivity when these materials are needed for specific projects. Poor acceptance can be influenced by misconceptions and misunderstandings. For example, the association of hemp with marijuana and the lack of expertise in producing hemp-related building materials have been identified as limitations to the adoption of hemp as a sustainable alternative (Agyekum et al., 2021).

The use of SBMs in construction can be linked to building performance and durability, which in turn can affect productivity during maintenance activities. Incorporating SBMs with enhanced performance characteristics can potentially reduce the frequency and intensity of maintenance and repair tasks, leading to improved long-term productivity. By selecting SBMs that exhibit greater durability and longevity, future maintenance and repair costs can be minimized. Therefore, the consideration of durability is essential when selecting SBMs. Durable SBMs not only contribute to environmental sustainability but also result in long-term cost savings, promoting economic sustainability. Furthermore, the hot weather conditions significantly impact the productivity of workers on construction sites (Yi and Chan, 2017). Workers’ heat stress is associated with the depletion of the ozone layer, which, in turn, is linked to climate change resulting from unsustainable practices across various industries. Given that approximately 25% of ozone-depleting chlorofluorocarbons are released during the production of building materials (Sahlol et al., 2021), embracing the use of SBMs in construction can have a significant impact on climate change, thereby creating a better climate for construction workers to operate in.

7. Conclusions
The construction industry plays a crucial role in advancing global sustainability objectives. However, the sector’s practices have led to negative environmental impacts, particularly concerning global warming and ecosystem degradation. In response, researchers have focused on studying sustainable construction management, waste reduction and recycling and the utilization of eco-friendly materials. SBMs offer a potential solution for reducing energy consumption in buildings. This study examines various construction materials that
have demonstrated the potential to enhance environmental sustainability. The study provides insights into the materials, their applications in buildings, sourcing and production procedures and the benefits associated with their utilization.

The study recognizes that widespread acceptance and utilization of SBMs in building construction would greatly enhance sustainability in the construction industry. However, it is crucial to assess the potential implications of using SBMs on construction productivity. The study identifies availability, high costs, lack of expertise, low awareness, poor social acceptance and resistance to innovation as potential challenges affecting the productivity of construction organizations when adopting SBMs. To address these challenges, the study recommends practical demonstrations of SBM applications in building construction to instil confidence among construction stakeholders. Stakeholders should prioritize locally available materials that can sufficiently meet the building industry’s needs in different countries. Training programs for construction practitioners and awareness campaigns for clients are essential to improve social acceptance and confidence in SBM utilization. Effective collaboration and communication among construction stakeholders are crucial for sharing information, ideas and concerns related to the selection, sourcing and integration of SBMs, thereby enhancing understanding and enabling informed decision-making. This study has implications for public policy and society. It raises awareness among stakeholders about the importance of considering the sustainability of construction operations, particularly in terms of productivity performance when transitioning from conventional materials to SBMs. Policymakers can use the study’s findings to develop strategies that promote wider accessibility and utilization of SBMs and foster the development of expertise in sourcing, handling and application to improve productivity. Both increased application of SBMs and improved construction productivity are related to economic, environmental and social sustainability, which aligns with the objectives of SDGs. Among the seventeen global goals established by the United Nations in 2015, this study promotes sustainable cities and communities. While the study provides valuable insights, it is not without limitations. The analysis focused on articles available in the Scopus database, but a broader search across additional databases may have yielded a more comprehensive selection of articles for analysis. Furthermore, the study did not address regulatory challenges or potential health and safety concerns associated with SBMs. Finally, regional or contextual factors that may influence the availability and feasibility of SBMs in different construction markets were not considered. Future research should address these limitations and further explore SBMs to develop strategies that effectively address challenges and maximize the benefits of their implementation.

References


Sustainable building materials


**Further reading**


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