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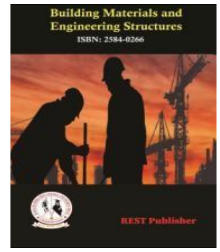

The Impact of Green Building Materials on Energy Efficiency and Environmental Sustainability

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Abstract: *As sustainable construction gains popularity worldwide, the demand for environmentally friendly construction supplies (GBM) is rapidly increasing. These materials contribute significantly to lowering the impact on the environment, increasing energy efficiency, and improving the health of occupants. By integrating environmentally friendly materials, the construction industry can significantly reduce carbon footprints while promoting long-term sustainability in infrastructure development. This paper explores the benefits and challenges of GBM adoption. Green building materials contribute to a more sustainable and resilient construction sector by reducing resource depletion, reducing emissions and improving energy efficiency. This research is significant in guiding architects, developers and policymakers towards informed decision-making. Understanding the impact of GBM adoption ensures the creation of healthy, cost-effective and environmentally friendly buildings, supporting global sustainability goals. Alternative taken as Remanufacturing (REM), Incineration (INC), landfill (LND), Polyurethane, Aluminum. Evaluation Preference taken as Tensile strength, Elongation at break, Maintenance cost , Raw material extraction. The results show that incineration (INC) has the highest ranking and landfill (LND) has the lowest ranking. Incineration (INC) has the highest value for Green Building Materials according to the WPM approach.*

Key words: *Green Building Materials (GBM), Sustainable Construction, Energy Efficiency, Environmental Impact, Green Building Rating (GBR).*

1. Introduction

In India, the market for green building materials and associated services is expanding due to the growing trend in green building construction. Sustainable building incorporates a number of tactics into a project's planning, execution, and maintenance. One important component of these initiatives is the use of green building materials, which affects both design and operating procedures. [1] They emphasized that the suggested strategy for promoting the use of reasonably priced green building materials in conventional housing should guarantee that designers have simple access to thorough information about the possibilities available. This would contribute to a more uniform and equitable selection process throughout the design stage. [2] Instead of breaking the entire structure at random, split the bamboo strands into individual pieces, much like you would with wood. Because the ensuing splinters follow the fibers' path, they have less of an effect on important places. Diffusion of energy is delayed by this process. [3] In the last ten years, many Publications about sustainable building materials are now accessible. To ensure that housing is both appropriate and affordable, scientists and organizations in developing countries are focusing more on locally available green building materials, particularly bamboo. [4] Robustness and flexibility are valued qualities in architecture, which highlights the need of using local building materials and implementing related strategies and techniques in green buildings. The ideals of vernacular architecture are user-friendly and environmentally friendly, honor the natural world, take the climate into account, and respect the community's culture and tradition. [5] By providing independent evaluation tools, Green Building Rating (GBR) solutions simplify conventional design procedures. These systems make it possible to assess methods for improving sustainability, ranging from water resource management to energy efficiency. [6] Compared to structures built in accordance with current rules, "green" or "sustainable" buildings make better use of resources including energy, water, materials, and land. Green buildings usually improve tenants' comfort, productivity, and health by utilizing more natural light and better ventilation. [7] In order to handle the growing global population, these considerations provide compelling incentives for both domestic and international businesses to invest in sustainable housing. Understanding the potential benefits of adopting green building materials (GBM) will increase consumer interest, support the growth of demand, and improve the dynamics of the green building supply. There must be a matching supply in the market as demand increases. [8] In addition to reducing a building's structural lifespan, cracks jeopardize its structural soundness. By stopping moisture absorption, a barrier layer applied to the surface can greatly increase the efficiency of low-energy, environmentally friendly green construction materials. [9] By providing rules for green buildings, the Green Building Council of Australia's Green Star system and the Environmental Assessment Methodology for Building Research Establishments (BREEAM) have emerged to help the construction industry adopt green building principles. The Green Building Standard is regarded as the most successful green building grading system among various green standards. [10] New developments must be more economical from the start. This method prolongs the life of structures while reducing the adverse effects of projects and construction. Shorter-lived components must to be made for recovery of raw materials or reuse. This can only be accomplished by carefully breaking down the building's complexity into its constituent parts and making sure that these parts can be integrated in a clear and useful way. A purely supporting and durable arrangement should be the goal of effective exchange between integrated entities. [11] Although thermal energy can be retained by a variety of materials, ceramic is unique in that it can store energy for long periods of time and only release it when needed. With enough pressure to discharge energy, each ceramic module functions similarly to a battery. Thermal energy can be stored by electrical currents or light radiation in addition to direct heat application. Thermal energy can be repeatedly absorbed and released from this material using a variety of techniques [12]. There are signs that the way that people think about sustainable development is changing. The architectural community and design practices are being shaped by the principles of "Green Building Design" more and more. Originally designed for the federal government, the American Green Building Council developed a rating system as a reference for sustainable and green design. At the moment, this "Leadership in Energy and Environmental Design" (LEED) system is regarded as standard. Numerous government organizations have adopted it in one form or another, and it contributes to the advancement of energy efficiency. [13] The Green Building Council has acknowledged that dioxin emissions from polyvinyl chloride (PVC) make PVC one of the worst building materials for human health and that PVC contains dangerous amounts of chlorine. This issue can be mitigated by reducing the negative health and environmental implications of replacing conventional building materials (CBMs) with bio composites. According to earlier research, bio composites convert non-renewable materials—such as petroleum-based composites—into renewable resources, especially lowering indoor air pollutants like volatile organic compounds (VOCs). GBM, a bio composite composed of natural fibers and biopolymer, effectively reduces indoor air pollution and its overall negative effects on the environment and human health. [14] Fungal growth is more prevalent in cellulose-rich, organic-based materials, but it can damage both inorganic and green construction materials. After being naturally exposed to native fungi, significant fungal growth was seen, especially on cellulose-rich materials like drywall and paper-free mineral ceiling tiles. On the other hand, these substances provided minimal or no assistance for the growth of fungi. Furthermore, despite the materials merely being exposed to high humidity rather than direct moisture immersion, the amount of time before fungal growth started was negligible. [15] Green Building and Green Building Materials: In this work, BMI is presented as a valuable data source for research on the green shift. Although many of the cited studies focus solely on green buildings, there aren't many studies that address green building materials. These studies frequently concentrate on the reuse, recycling, and disposal of construction materials. However, using evolutionary game theory to BMI to GBMI for cities' sustainable growth is still a very new and uncommon practice. [16] With the aid of green construction material directories and other tools, consumers and builders may select environmentally friendly products. The criteria used to select ecologically friendly products are frequently arbitrary, thus a product may perform very well in one region but poorly in another. Low emissions are an often used requirement for green products. [17] Green building techniques help to mitigate global warming and reduce their negative effects on the environment. The notion of green buildings and smart living offers a substantial chance to change the typical Indian's way of life. Developers will get more creative in their branding, marketing, and sales strategies as more people become aware of the benefits of green buildings. This change will create a climate that is conducive to the sector's explosive expansion. [18] China has a large amount of naturally occurring bamboo, but its usage as a green building material is quite limited. Despite having an estimated 5.38 million hectares of bamboo woods, China uses bamboo in construction significantly less often than other countries. It has been noted that bamboo is primarily used in China to create simple handcrafted items like baskets, mats, and curtains. Only a handful of companies concentrate on growing and utilizing bamboo for building. [19] Participants must meet two prerequisites in order to be requested to participate in the survey: They should have extensive experience in Malaysia's construction sector and be well-versed in green building materials. [20]

2. MATERIALS AND METHOD

Alternative:

Remanufacturing (REM): The process of restoring used materials or components to their original condition or better, ensuring that they meet the same specifications as new. It involves disassembly, cleaning, repair, and reassembly to extend the product's life and reduce waste.

Incineration (INC): A waste treatment process that involves burning the organic material in waste to generate energy or reduce landfill space. It converts the waste into ash, flue gas, and heat, which can sometimes be used for electricity or district heating.

Landfill (LND): A designated site where waste materials are disposed of by burial. Landfills are designed to manage waste safely, but if not properly managed, they can contribute to environmental problems such as soil contamination and greenhouse gas emissions.

Polyurethane: A versatile polymer utilized in numerous applications, such as foams, coatings, adhesives, and insulation. It is known for its flexibility, durability, and wears resistance, making it useful in industries such as automotive, construction, and furniture.

Aluminum: A common metal used in packaging, shipping, and construction that is lightweight and resistant to corrosion. Because of its great degree of recyclable nature, it is an eco-friendly material for a variety of applications.

Evaluation Preference:

Tensile strength: the highest amount of tensile (pulling) stress that a substance can sustain before failing. It is an important mechanical property used to determine the strength and durability of a material in structural and industrial applications.

Elongation at break: A measure of the proportion of a material's initial length that it can stretch before breaking. It indicates the flexibility and ductility of a material, which is important for applications that require resistance to deformation.

Maintenance cost: The total cost of keeping equipment, infrastructure, or machinery in optimal working condition. This includes repairs, replacements, inspections, and labor costs required to prevent breakdowns and extend service life.

Raw material extraction: The process of obtaining natural resources (such as minerals, metals, oil, or timber) from the earth for use in manufacturing and production. This process can have significant environmental impacts, including habitat destruction and pollution.

Method: WPM provides a more robust approach to penalizing low-priority alternatives and is computationally more efficient than the TOPSIS method. It is dimensionless, and unlike TOPSIS, it avoids ranking conflicts. The priority index for each alternative is independent of the others, helping to establish a threshold to minimize unnecessary trade-offs. Therefore, we suggest that WPM is a better choice Compared to TOPSIS in dynamic decision-making situations. The proposed method is built on the WPM approach, where the weight assignment process is guided by a sensitivity analysis of the most important criteria. [22] However, the transcription-based method of measuring WPM has several drawbacks. The length of words can vary, and their pronunciation can vary significantly due to various speech-related factors such as phonetic stress, frequency, contextual predictability, and repetition. [23] A more reliable method for penalizing less significant options is the Weighted Product Method and is computationally more efficient than the TOPSIS method. Being dimensionless, it avoids problems related to ranking conflicts. In addition, the priority index for each alternative operates independently, helping to establish thresholds to minimize unnecessary acquisitions. Therefore, we recommend WPM as a more effective choice for dynamic decision-making situations. [24] An enhanced average DBI of 1.052 is obtained by using WPM+K-Averages. Furthermore, while employing WPM+K means, K-Average iterations decrease from nine to four on average. Higher DBI values are shown in the study's conclusions, whereas lower DBI scores indicate better K-means algorithm performance. These results also show that K-means clustering improves WPM cluster evaluation measures. Additionally, it is anticipated that fewer K-means iterations will result in a shorter calculation time. [25] WPM offers Data multiplexing in both the time and frequency domains is made possible by the WPM method's provision of time and frequency resolution within the transmission packets. Data in TDM and OFDM packets will be damaged when tone and imuse interfaces are merged into a transmission packet. Even in cases of extreme interference, transmission performance can be preserved by splitting these interferences into WPM packets. This study suggests a multimode transmission technique that combines OFDM with WPM, allowing for effective data transfer in settings like WLAN systems that are impacted by multipath effects, tone, and imuse interfaces. With this approach, WPM packets are used in high interference environments, while OFDM packets are used under multipath fading conditions. [26] To our knowledge, 13 WPM is considered a fast rate for text input using a joystick. Although it was possible to use two sticks simultaneously, participants typically used only one. Therefore, it is appropriate to compare our data with other studies that used a single stick. [27] We present a chord-based text in this work input method designed for a 3x4 button keyboard that enables expert people to reach a 60 words per minute (WPM) average typing pace during character-by-character input. Our findings demonstrate that beginners using the chord method can achieve speeds of 400 WPM after 26 minutes of training and can match their multi-tap typing speed in just 80 training minutes. In addition, we explore the potential for integrating this chord method into mobile phone designs. [28] In contrast, Research on head-based methods is relatively limited input. Some users were asked to indicate keys on an electronic keyboard using either vision Using either vision or head movements, users selected keys and confirmed their selection using the spacebar. Typing speeds were found to reach 4.42 WPM and 10.98 WPM using vision-based input with head movements. We believe that head typing input is a preferred approach due to this unique feature. [29] In the WPM method, weighted normalized criterion values are used. However, instead of multiplying the normalized criterion values, each normalized criterion value the priority assigned to the relevant criterion is elevated to the weight's power. [30] We introduce a chord-based text input method this helps expert users achieve average typing speed of 60 words per minute (wpm) during character-by-character input on a 3x4 button keyboard. Our results show that beginners can reach over 400 words per minute after 26 minutes of training and can match their many plates typing speed Within 80 minutes training. In addition, we explore the feasibility of incorporating this chord typing technique into mobile phone designs. [31] A considerable amount of research has been devoted to vision typing, with many techniques relying on location-based input, where a user chooses a character by spending a specific amount of time concentrating on it of time. Most methods use a fixed location time of 450ms to 1000ms, which results in text input speeds of 5 to 10 WPM. An experiment was conducted to determine the minimum acceptable location time by gradually reducing it The mean location time dropped from 876 to 282 minutes throughout ten 15-minute sessions, and the text input speed was raised from 6.9 WPM to 19.9 WPM in order to enhance performance.

3. ANALYSIS AND DISCUSSION

TABLE 1. Green building materials

	Green building materials			
	Tensile strength	Elongation at break	Maintenance cost	Raw material extraction
Remanufacturing (REM)	99.00	867.00	96.00	32.05
Incineration (INC)	83.00	963.00	43.69	37.30
landfill (LND)	78.00	852.00	39.18	86.00
Polyurethane	59.00	741.00	26.60	37.59
Aluminum	37.00	951.00	37.96	28.90

Table 1 provides data comparing the tensile strength, elongation at break, maintenance cost, and raw material extraction of various green building materials. Remanufactured (REM) materials have the highest tensile strength at 99.00, indicating better durability, followed by incinerated (INC) at 83.00 and landfilled (LND) at 78.00. Polyurethane and aluminum show the lowest tensile strength at 59.00 and 37.00, respectively. Elongation at break, a measure of flexibility, is highest for INC at 963.00, indicating stronger ductility. Aluminum follows closely at 951.00, while REM, LND, and polyurethane show the lowest values at 867.00, 852.00, and 741.00, respectively.

Maintenance costs vary significantly, with REM having the highest cost at 96.00 and polyurethane having the lowest cost at 26.60. INC and LND have moderate maintenance costs of 43.69 and 39.18 respectively, while aluminum is at 37.96. LND has the highest raw material extraction at 86.00, indicating a higher environmental impact. REM has a relatively low extraction value of 32.05, making it the most sustainable option. INC and polyurethane have similar values at 37.30 and 37.59, while aluminum requires the least extraction at 28.90, making it a resource-efficient option.

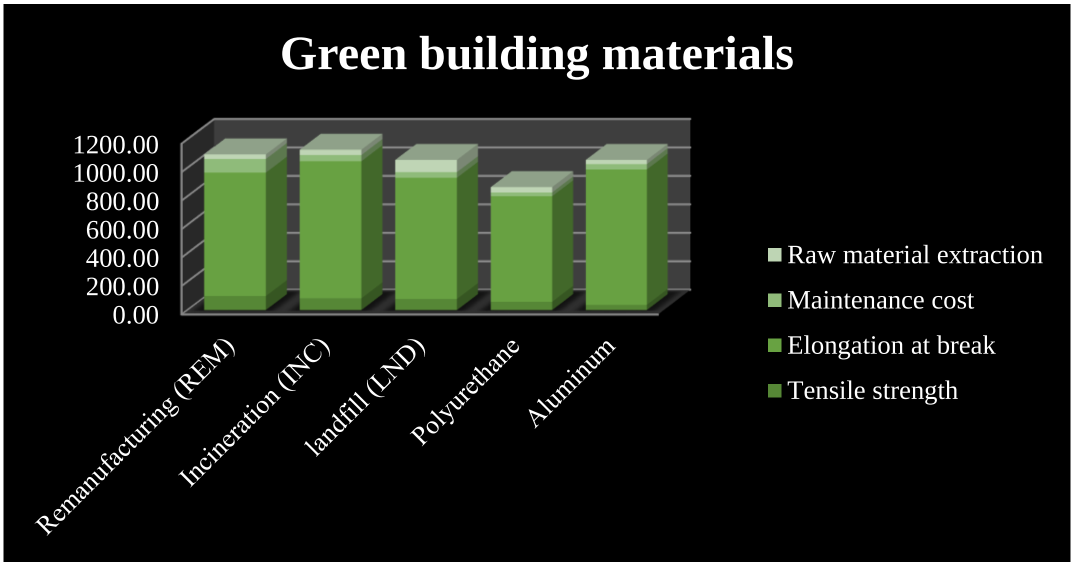

FIGURE 1. Green building materials

Figure 1 provides a comparative analysis of green building materials based on key mechanical and economic properties, including tensile strength, elongation at break, maintenance cost, and raw material extraction. Among the materials evaluated, remanufactured (REM) exhibits the highest tensile strength (99.00) and relatively high elongation at break (867.00), indicating excellent durability and flexibility. However, its maintenance cost (96.00) is significantly higher than other alternatives. Incineration (INC) follows with a tensile strength of 83.00 and high elongation at break (963.00), indicating strong mechanical performance. Its maintenance cost (43.69) is significantly lower than REM. In contrast, landfill (LND) has slightly lower tensile strength (78.00) and elongation at break (852.00), with the lowest maintenance cost (39.18). However, LND has the highest material extraction value (86.00), making it less sustainable. Polyurethane and aluminum have the lowest tensile strengths of 59.00 and 37.00, respectively. Polyurethane exhibits moderate elongation (741.00) and low maintenance cost (26.60), while aluminum has a high elongation at break (951.00) but relatively moderate maintenance cost (37.96). These findings indicate that remanufacturing provides superior mechanical properties, while landfill disposal provides cost effectiveness but higher material extraction requirements.

TABLE 2. Performance value

	Performance value			
	Tensile strength	Elongation at break	Maintenance cost	Raw material extraction
Remanufacturing (REM)	1	0.90031	0.27708	0.90172
Incineration (INC)	0.8383838	1	0.60883	0.7748
landfill (LND)	0.7878788	0.88474	0.67892	0.33605
Polyurethane	0.5959596	0.76947	1	0.76882
Aluminum	0.3737374	0.98754	0.70074	1

Table 2 presents the normalized performance values of various green building material processes, including remanufactured (REM), incinerated (INC), and landfilled (LND), polyurethane, and aluminum. The values are measured to reflect the relative performance across four key parameters: tensile strength, elongation at break, maintenance cost, and material extraction. Remanufactured (REM) demonstrates the highest tensile strength (1) and the strongest material extraction capability (0.90172), making it the most robust and sustainable option. However, its elongation at break (0.90031) is slightly lower than incinerated and aluminum and its maintenance cost (0.27708) is one of the highest. Incinerated (INC) achieves the highest elongation at break (1), meaning it offers the best flexibility, while its tensile strength (0.83838) is the strongest. Its maintenance cost (0.60883) is moderate, and its material extraction (0.7748) is relatively efficient. Landfill (LND) ranks moderately in tensile strength (0.78788) and elongation (0.88474), but it has a relatively low material extraction value (0.33605). Polyurethane achieves the lowest tensile strength (0.59596) but has the highest maintenance cost efficiency (1). Aluminum has the lowest tensile strength (0.37374) but excels in elongation at break (0.98754) and material extraction (1), making it a potentially flexible and resource-efficient material.

TABLE 3. Weight

	Weight			
Remanufacturing (REM)	0.25	0.25	0.25	0.25
Incineration (INC)	0.25	0.25	0.25	0.25
landfill (LND)	0.25	0.25	0.25	0.25
Polyurethane	0.25	0.25	0.25	0.25
Aluminum	0.25	0.25	0.25	0.25

Table 3 presents the assigned weight distribution for evaluating the performance of different green building material processes, including remanufacturing (REM), incineration (INC), landfill (LND), polyurethane, and aluminum. The table indicates an equal weight allocation (0.25) across all four parameters: tensile strength, elongation at break, maintenance cost, and raw material extraction. This uniform weighting suggests that each criterion is considered equally important in assessing the overall performance of these materials. By assigning equal significance to mechanical strength, flexibility, cost efficiency, and sustainability, the evaluation framework ensures a balanced approach that does not favor one aspect over another. This method enables a fair comparison of materials and their respective impacts, highlighting both their strengths and weaknesses without bias. The equal weight distribution may also reflect the need for a comprehensive decision-making approach in green building applications, where mechanical durability, economic feasibility, and environmental sustainability all play crucial roles. However, in practical applications, decision-makers may adjust these weights based on project-specific priorities. For instance, in cost-sensitive projects, maintenance cost might be assigned a higher weight, while sustainability-focused initiatives might prioritize raw material extraction. Nonetheless, Table 3 provides a standardized basis for comparing materials in a balanced and objective manner.

TABLE 4. Weighted normalized decision matrix

	Weighted normalized decision matrix			
Remanufacturing (REM)	1	0.974088	0.7255254	0.97447
Incineration (INC)	0.9568872	1	0.8833339	0.9382
landfill (LND)	0.9421387	0.969847	0.907725	0.76138
Polyurethane	0.8786263	0.936587	1	0.93639
Aluminum	0.7818828	0.99687	0.9149321	1

Table 4 presents the weighted normalized decision matrix for evaluating green building material processes, including remanufacturing (REM), incineration (INC), landfill (LND), polyurethane, and aluminum. These values represent the relative performance of each material across four key criteria—tensile strength, elongation at break, maintenance cost, and raw material extraction after normalization and weight application. Remanufacturing (REM) remains the strongest performer in tensile strength (1), indicating its superior structural durability. It also scores highly in elongation at break (0.974088) and raw material extraction efficiency (0.97447), though its maintenance cost performance (0.7255254) is moderate. Incineration (INC) exhibits the highest elongation at break (1), meaning it provides excellent flexibility. It also performs well in maintenance cost (0.8833339) and raw material extraction (0.9382), making it a balanced choice. Landfill (LND) shows a strong performance in maintenance cost (0.907725), but its raw material extraction efficiency (0.76138) is relatively lower, which could impact sustainability. Polyurethane leads in cost efficiency (1), making it the most economical choice, while aluminum scores highest in raw material extraction (1) and elongation (0.99687), suggesting strong sustainability and flexibility. These findings help in selecting materials based on performance priorities.

TABLE 5. Preference Score

	Preference Score
Remanufacturing (REM)	0.6886812
Incineration (INC)	0.7930177
landfill (LND)	0.6314985
Polyurethane	0.7705637
Aluminum	0.7131306

Table 5 presents the preference scores for different green building material processes, which reflect their overall performance based on weighted criteria. A higher preference score indicates a better balance between tensile strength, elongation at break, maintenance cost, and raw material extraction. Incineration (INC) achieves the highest preference score (0.7930177), suggesting it offers the best overall performance among the evaluated materials. This result is likely due to its strong elongation at break, moderate maintenance cost, and relatively high raw material efficiency. Polyurethane follows closely with a preference score of 0.7705637, primarily driven by its excellent maintenance cost efficiency and solid performance across other parameters. Aluminum ranks third with a preference score of 0.7131306, benefiting from its high raw material extraction efficiency and elongation at break. Remanufacturing (REM) scores 0.6886812, indicating strong mechanical performance but slightly lower efficiency in maintenance cost. Landfill (LND) has the lowest preference score (0.6314985), likely due to its lower sustainability and economic performance despite moderate mechanical properties.

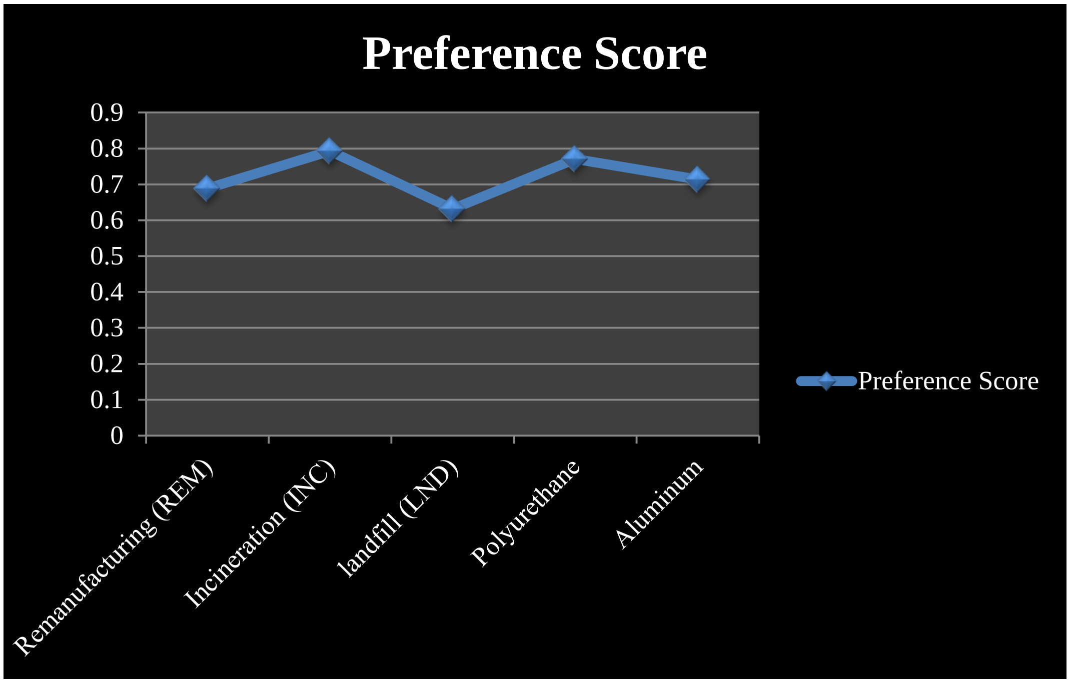

FIGURE 2. Preference Score

Figure 2 illustrates the preference scores for various green building material processes, highlighting their overall suitability based on key performance factors. The preference score is a composite measure incorporating tensile strength, elongation at break, maintenance cost, and raw material extraction, with higher values indicating better overall performance. Incineration (INC) achieves the highest preference score (0.7930177), making it the most favorable option. Its superior elongation at break and balanced performance in cost and sustainability contribute to this ranking. Polyurethane follows closely with a score of 0.7705637, driven by its excellent maintenance cost efficiency and solid material properties. Aluminum ranks third with a score of 0.7131306, benefiting from its high raw material extraction efficiency and elongation capabilities, making it a viable option where flexibility and sustainability are key concerns. Remanufacturing (REM) scores 0.6886812, reflecting its strong mechanical properties but slightly lower economic efficiency. Landfill (LND) has the lowest preference score (0.6314985), suggesting it is the least desirable option due to its lower sustainability and cost-effectiveness.

TABLE 6. Rank

	Rank
Remanufacturing (REM)	4
Incineration (INC)	1
landfill (LND)	5
Polyurethane	2
Aluminum	3

Table 6 presents the ranking of different green building material processes based on their overall performance, considering factors such as tensile strength, elongation at break, maintenance cost, and raw material extraction. A lower rank number indicates better overall suitability for green building applications. Incineration (INC) secures the top position (Rank 1), signifying its superior balance across mechanical strength, flexibility, cost-effectiveness, and sustainability. Its high elongation at break and strong overall performance contribute to this leading rank. Polyurethane follows closely at Rank 2, largely due to its excellent maintenance cost efficiency, making it a favorable option for projects prioritizing economic considerations. Aluminum is ranked third, benefiting from its high elongation and sustainability factors. Although it does not outperform INC or polyurethane, its moderate balance of properties makes it a competitive option. Remanufacturing (REM) ranks fourth, highlighting its strong tensile strength but slightly weaker performance in maintenance cost efficiency. Finally, landfill (LND) holds the lowest rank (Rank 5), indicating it is the least desirable option due to lower sustainability and cost-effectiveness.

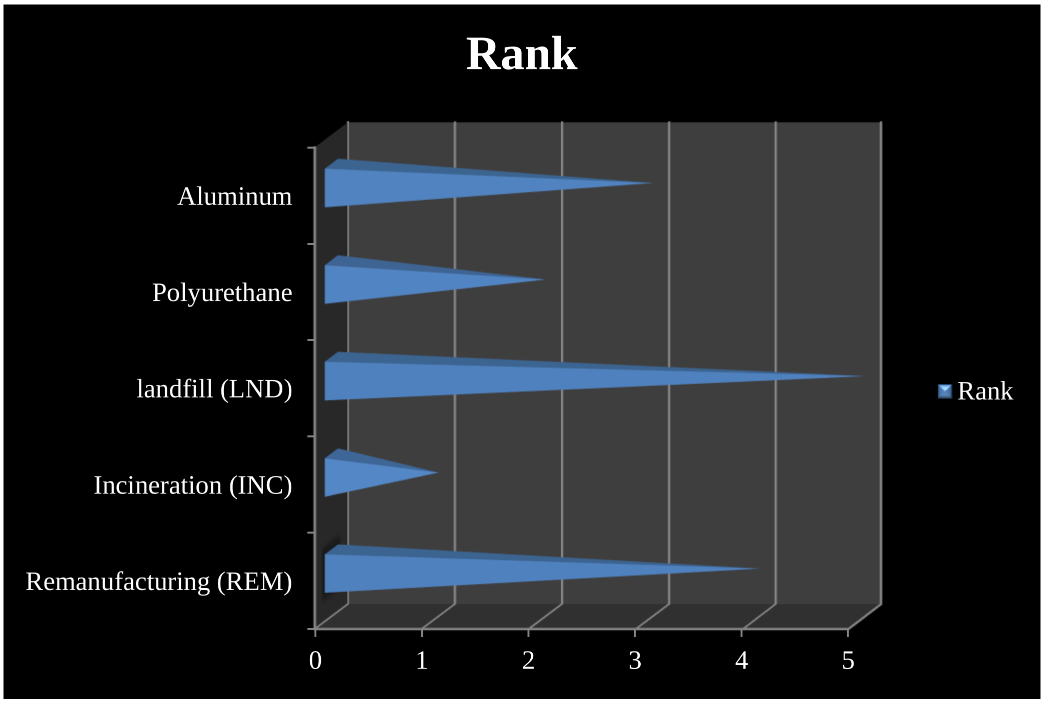

FIGURE 3. Rank

Figure 3 presents the ranking of different green building material processes based on their overall performance in key areas such as tensile strength, elongation at break, maintenance cost, and raw material extraction. The ranking system assigns lower numbers to better-performing materials, helping to identify the most efficient and sustainable options for green building applications. Incineration (INC) ranks first, indicating it is the most favorable choice. Its high elongation at break, balanced cost efficiency, and sustainability make it the best overall performer. Polyurethane follows at Rank 2, primarily due to its exceptional maintenance cost efficiency, making it an economical option while still maintaining solid structural properties. Aluminum is ranked third, benefiting from its high raw material extraction efficiency and strong elongation performance. Although it does not surpass INC or polyurethane, its combination of sustainability and flexibility makes it a competitive choice. Remanufacturing (REM) holds the fourth position, reflecting its superior tensile strength but slightly lower cost efficiency. Finally, landfill (LND) ranks last (Rank 5), indicating it is the least desirable option due to its lower sustainability and cost-effectiveness.

4. CONCLUSION

The shift to green building materials (GBM) is a key step towards sustainable growth within the building sector. With the world's population growing and urbanization spreading, the need for environmentally friendly infrastructure solutions is more urgent than ever. GBM not only reduces carbon footprints but also improves energy efficiency, enhances the quality of indoor air, and reduces long-term operational costs. One of the primary benefits of using GBM is its ability to reduce environmental degradation. Traditional construction materials, such as when steel and concrete are produced, they greatly increase greenhouse gas emissions and use. By replacing these with sustainable alternatives, such as bamboo, recycled metal and bio-composites, the industry can reduce its environmental impact. Furthermore, advanced materials such as ceramic thermal storage blocks improve energy efficiency by controlling interior temperatures and lowering the need for air conditioning and heating systems. The role of green building rating (GBR) systems, such as LEED and BREEAM, is crucial in promoting sustainable construction. These systems establish criteria for energy efficiency, water conservation, and material sustainability, ensuring that buildings meet environmentally friendly standards. Countries that incorporate GBR systems into their construction policies encourage investment in green technologies, which in turn fosters a market for sustainable materials. Despite these benefits, there are challenges to widespread adoption of GBM. High initial costs, lack of awareness, and limited availability of sustainable materials are hindering this transition. However, as public awareness grows and technology advances, the prices of green materials are expected to fall, making them more accessible for major construction projects. Governments and private companies need to collaborate to implement policies that promote sustainable building practices.

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