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Low-Emission Material Selection in “EDGE”-Based Green Building Design Practices: Evaluation of Recycled Terrazzo

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ABSTRACT

The construction sector significantly contributes to global carbon emissions, both from building operationals and embodied carbon in materials. Floor covering is the important component, where conventional materials such as ceramic, marble, and exposed concrete have a relatively high carbon footprint. This study evaluates recycled terrazzo as an alternative low-emission flooring material to support green building strategies based on the EDGE (Excellence in Design for Greater Efficiencies). This study aims to analyze the embodied carbon reduction potential of recycled terrazzo compared to ceramic, marble, and exposed concrete, while also examining its technical advantages and disadvantages. The descriptive-comparative quantitative method was applied through EDGE software simulation combined with literature analysis. The simulation results indicated that recycled terrazzo has the lowest embodied carbon at 7.40 kgCO₂e/m² savings 2.02% compared to ceramic, and significantly lower than marble (33.5 kgCO₂e/m²). Exposed concrete shows 8.90 kgCO₂e/m², which is still higher than terrazzo. From a technical aspect, recycled terrazzo offers sustainability, aesthetics flexibility, and durability, although installation requires expertise. The findings indicate that selecting recycled terrazzo as a flooring not only reduces carbon emissions but also enhances durability and design quality. This finding emphasizes the importance of material selection from the early design stage as a concrete strategy in realizing green buildings.

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1. INTRODUCTION

Global warming is the process of increasing the average temperature of the Earth's atmosphere, oceans, and land, which can disrupt the balance of its ecosystem. According to Uda and Wibowo (2018), more than 2,000 million tons of carbon dioxide are emitted annually in Southeast Asia due to peatland destruction, 90% of which is from peatlands in Indonesia. One of the causes of global warming is the release of carbon gases or carbon emissions (Pihawiano et.al, 2024). The construction sector in buildings is one of the largest contributors to global carbon emissions, both from operational activities and from the production process. According to the Intergovernmental Panel on Climate Change (IPCC), buildings are one of the main contributors to resource consumption, consuming more than a third of the world's resources, including energy and water. So that developments have a significant impact on the environment. Supported by data from the World Green Building Council (2019), it states that buildings are currently responsible for 39% of global energy-related carbon emissions: 28% of operational emissions, from the energy needed to heat, cool and power buildings, and the remaining 11% from materials.

One of the main sources of carbon emissions and air pollution in construction is embodied carbon. Embodied carbon is carbon emissions arising from the production, distribution, and construction of building materials, which is now a major focus in efforts to decarbonize the global construction sector (Wicaksono & Bayu Aji, 2025). According to a report by the Global Alliance for Buildings and Construction (UN Environment Programme, 2022), the building sector contributes around 39% of global carbon emissions, of which 11% comes from non-operational stages such as material selection and use. According to Putra (2023), embodied carbon indicates the total greenhouse gas emissions released during the material production cycle. Embodied carbon is the amount of carbon released by materials during the production process until the installation process. Flooring materials are one of the materials that contribute to embodied carbon, especially materials such as ceramics, marble, and conventional concrete. According to the UN, through the pgnlmg.co.id website (2023), carbon emissions have several major impacts and a domino effect, namely: Climate Change, Environmental Degradation, Biodiversity Loss, Natural Disasters, Reduced Water and Food Availability, and Human Health.

Current construction practices still lack consideration of the use of environmentally friendly materials from the planning and design stages, resulting in negative impacts that not only affect building users but also the surrounding environment and ecosystems in the development area (Ayuningtyas et al., 2020). The climate crisis and limited natural resources are driving the construction world towards the application of the concept of green building or sustainable architecture. According to Mangunwijaya in the journal Harda and Kridarso (2022), sustainable architecture is one method of developing an environmentally friendly ecosystem. Architectural buildings that strive to limit negative impacts on the environment and restore natural balance in the use of materials, energy, space enhancement and other environmental aspects (Harda and Kridarso, 2022). There are basic principles of sustainable architecture that refer to Ardiani's (2016) book entitled *Sustainable Architecture*. According to Yanita Mila Ardiani's view in her book, sustainable architecture has nine important principles, namely urban ecology, energy strategy, water management, waste management, material selection, environmental community development, economic strategy, cultural preservation, and operational management. All human needs and demands can be met through sustainable development without sacrificing the environment and resources for future generations (Arsitur, 2020). Therefore, sustainable architecture can fundamentally

benefit us all in the long term, and this can be achieved without compromising the aesthetic value and beauty of the building.

The way to realize sustainable buildings and green buildings is by using green materials. Sedayu et. al. (2020) formulated fifty performance criteria for contractors in implementing green buildings. Of the 50 criteria, there are eight criteria related to the materials that can be used, namely: 1. Reliable performance of construction and non-construction materials. 2. Material specifications that support the aesthetics and artistic value of the building. 3. The level of durability and resistance of construction and non-construction materials. 4. Material specifications in accordance with the ideal technical requirements for the building. 5. Materials that can be used (reusable) and recycled (recycled). 6. Ergonomic materials according to the physical and psychological comfort of users. 7. Materials that are environmentally friendly and appropriate to local conditions. And 8. Materials that are friendly to people with disabilities, pregnant women, toddlers, and the elderly.

One solution to reducing the carbon footprint in construction is the reuse of construction materials, such as recycled Terrazzo flooring. According to Vania (2025), the use of Terrazzo flooring is currently trending again and has grown rapidly. Terrazzo flooring is now recognized as a valuable material due to its artistic appearance, durability, versatility, and easy maintenance. Currently, this flooring is commonly used in high-traffic areas such as airports, hospitals, and schools.

Terrazzo flooring is a type of concrete brick flooring material typically made from cement, water, and aggregate (Huynh et al., 2024). The aggregate itself can be marble, glass, stone, or plastic. Utilizing recycled materials (e.g., used marble, glass, or plastic) can reduce dependence on new materials and reduce construction waste. However, previous research has focused more on building operational emissions or discussed the content of terrazzo flooring, which has not been compared with other flooring materials. Meanwhile, studies related to the embodied carbon of floor covering materials are still rarely conducted quantitatively and comprehensively.

Recycled terrazzo innovation offers great potential in reducing embodied carbon, especially if its production is carried out locally with a low-energy approach. Evaluation of recycled terrazzo as a low-emission material has not been widely studied using a simulation-based approach using EDGE (Excellence in Design for Greater Efficiencies) software. Therefore, to conduct this research, the author used EDGE Software in Material Efficiency Simulation. In addition, most studies only review the sustainability aspect from the carbon side, while technical aspects are often neglected. Therefore, to be accepted as a material solution in supporting sustainable architecture, this material needs to be evaluated not only from the embodied carbon side, but also from technical aspects such as ease of installation, aesthetic value, and durability.

EDGE is software developed by the International Finance Corporation (IFC) to evaluate building resource efficiency in three main aspects: energy, water, and materials (International Finance Corporation, 2018). In the context of materials, EDGE can calculate embodied energy and embodied carbon savings based on material composition data and volume of use. For floor covering materials, it can assess and evaluate the embodied energy in floor coverings by calculating the impact of all main materials per unit area. Floor thickness also contributes to this embodied energy evaluation (International Finance Corporation, 2020). This software provides quantitative data that is used to compare different material conditions, including recycled materials such as terrazzo, so that evaluation results can be more objective and measurable.

Therefore, this research and writing aims to analyze and explore the comparison of recycled Terrazzo material with other conventional floor covering materials in reducing

embodied carbon, towards the implementation of green buildings, especially in supporting material efficiency indicators based on EDGE simulations and providing recommendations for design in integrating the best materials into green building design strategies. Thus, this research is expected to contribute to the literature on architectural design practices, especially related to aspects of sustainable consumption (SDG 12) and climate aspects (SDG 13), while supporting the improvement of Environmental, Social, and Governance (ESG) performance (Guo, 2025; Lee & Liang, 2024). This approach through EDGE simulation also shows how the initial strategy in architectural design practices plays an active role in technical decision-making that has a strategic impact on the sustainability of the national construction sector.

2. RESEARCH METHODS

This study uses a descriptive-comparative quantitative approach through the EDGE software simulation method and comparative analysis between materials. This method was chosen to understand terrazzo flooring materials in depth descriptively through literature analysis and simulation using software, which then compares it with other materials. Quantitative research according to Sugiyono (2024) is a research method based on the philosophy of positivism, where in this research method uses research instruments, and data analysis is statistical or quantitative. Furthermore, the purpose of descriptive research according to Sugiyono (2023) is research that describes and measures the value of one or more variables, and this descriptive research does not have a variable comparison.

Then, comparative research according to Sugiyono (2023) is research by comparing two or more variables in more than two populations, samples, and different times or a combination of all. So it can be concluded that descriptive-comparative quantitative research is a research method with statistical data analysis which is then compared with the level of research explanation between variables and then described descriptively. The conventional covering materials chosen and will be used as a comparison are materials commonly used in buildings in Indonesia today, namely ceramic floors, vinyl floors, parquet floors, and exposed concrete/cement plaster floors. The research steps using the EDGE software simulation method through the research flow diagram are as follows:

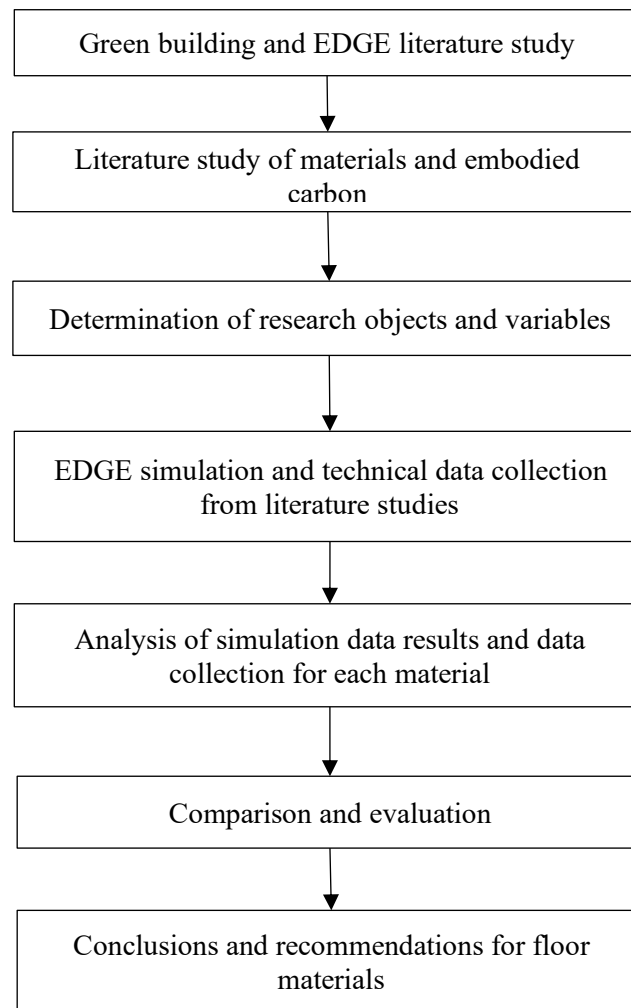


Figure 1. Research Flow Diagram
(Source: Author's Analysis, 2025)

This research process is more exploratory-applicative, because it aims to explore the potential innovation of terrazzo flooring materials in achieving green building. The instruments used in this study are software or supporting tools for analysis and green material standards from NTMA and EDGE buildings. EDGE (Excellence in Design for Greater Efficiencies) buildings are used to calculate and simulate the amount of energy contained in the materials to be analyzed. Through green material standards, comparisons are made to evaluate the green material aspect and other technical aspects such as aesthetics, ease of installation, durability, and sustainability.

The data collection technique was carried out through three main methods, namely Literature Study by reviewing various academic sources such as international and national journals, scientific articles, and standard publications from government organizations such as NTMA, ACI, and EDGE Buildings. EDGE provides standard parameters based on the global database on EDGE that can be used to compare the sustainability performance of material objects. The results of the simulation and literature study were analyzed comparatively in terms of embodied carbon value, advantages and disadvantages, as well as technical aspects (such as visual aesthetics, ease of installation, durability, and sustainability) of each material.

3. RESULTS AND DISCUSSION

The main focus of this research is to test the effectiveness of recycled terrazzo flooring material in reducing embodied carbon/embodied energy compared to other flooring materials, namely ceramic, marble, and exposed concrete/cement. The analysis was conducted through simulations using EDGE software, assuming a commercial building as the typology reference.

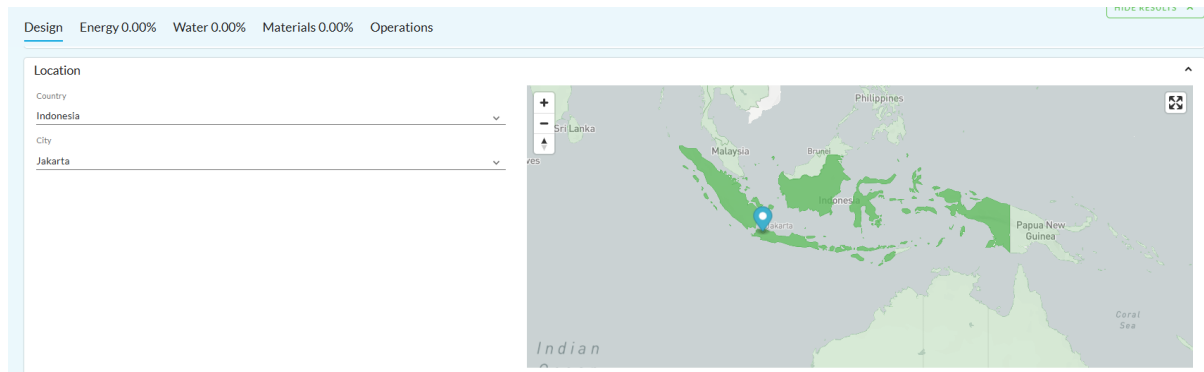


Figure 2. Assumptive Data on Building Typology and Location
(Source: Author's Analysis through EDGE Simulation, 2025)

The building project is located in Jakarta, and the building area data is based on standard EDGE assumptions, but without the basement area. The data is as follows:

- Gross internal area : 10,000 m²
- Total floors : 10 floors
- Basement floors : 0 (no basement)
- Floor-to-floor : 3.5 m

In this case, the roof surface area (aggregate roof area) is ignored because this study only covers the building's floors. The aggregate roof area focuses on the building's thermal analysis, so the figures follow the software's default values. Similarly, the building's operational details follow the EDGE software standard because that point focuses on thermal analysis, as can be seen in the following figure.

Building Data			
Default		User Entry	
Gross Internal Area (m ²)	10,000	Gross Internal Area (m ²)	
No. of Floors Above Grade	10	No. of Floors Above Grade	
No. of Floors Below Grade	2	No. of Floors Below Grade	0
Floor-to-Floor Height (m)	3.5	Floor-to-Floor Height (m)	
Aggregate Roof Area (m ²)	1,000	Aggregate Roof Area (m ²)	
Operational Details		User Entry	
Working Days (Days/Week)	5.00	Working Days (Days/Week)	
No. of Holidays (Days/Year)	24.00	No. of Holidays (Days/Year)	
Hours of Operation (Hrs/Day)	8.00	Hours of Operation (Hrs/Day)	
Occupancy Density (m ² /Person)	28	Occupancy Density (m ² /Person)	
Building Costs			

Figure 3. Building Data
(Source: Author's Analysis through EDGE Simulation, 2025)

Furthermore, the assumption is that the building shape is square with the building dimensions per side of the building, namely on the north, east, south and west sides, namely 20m, with the northeast, southeast, southwest and northwest sides being 0, which can be seen in the following image.

Dimensi Bangunan	
Bawaan Panjang Bangunan (m)	Entri Pengguna (m)
Utara 16.14	Utara 20
Timur Laut 16.14	Timur Laut 0
Timur 16.14	Timur 20
Tenggara 16.14	Tenggara 0
Selatan 16.14	Selatan 20
Barat Daya 16.14	Barat Daya 0
Barat 16.14	Barat 20
Barat Laut 16.14	Barat Laut 0

Figure 4. Building Dimensions
(Source: Author's Analysis through EDGE Simulation, 2025)

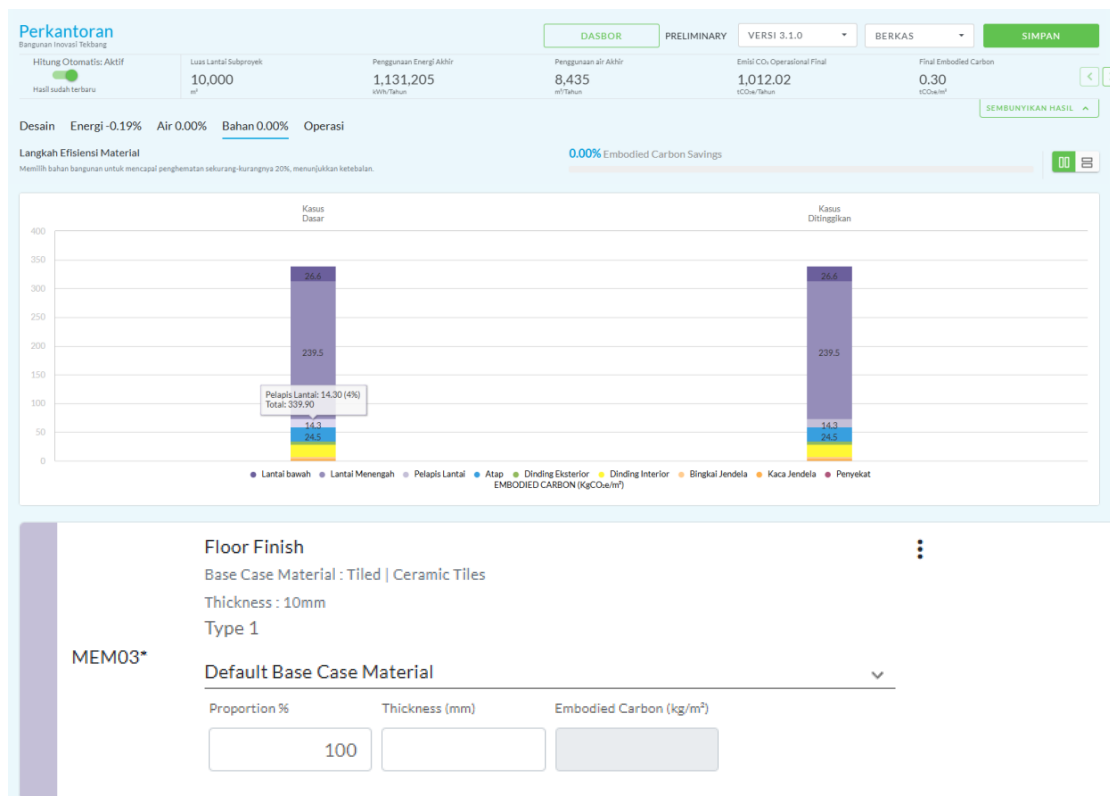


Figure 5. Interim Results of Embodied Carbon Calculations in Buildings
(Source: Author's Analysis through EDGE Simulation, 2025)

Based on the data above, before material treatment, the total embodied carbon of the building was 0.30 tCO₂e/m², which, according to the graph, equals 339.90 tCO₂e/m². More precisely, the floor covering contributed 4% equals 14.3 tCO₂e/m² of the total embodied

carbon in the building. In this condition, the floor covering material still used was a common material, namely ceramic, resulting in this value. Based on the simulation results, the analysis can be summarized in the following table.

Table 1. Comparison of Embodied Carbon in Floor Materials

No.	Material Type	Material Thickness (mm)	Embodied Carbon (kgCO ₂ e/m ²)	Saving Efforts (%)	Difference (kgCO ₂ e/m ²)
1.	Recycled Terrazzo (Epoxy)	9.5	7.40	2.02	6.90 (decrease)
2.	Ceramic	10	14.3	0	0
3.	Marble	50	33.50	-5.65	19.2 (increase)
4.	Exposed Concrete/Cement	50	8.90	1.58	5.4 (decrease)

(Source: Author's Analysis through EDGE Simulation, 2025)

Based on the analysis results in the table above of the four types of flooring materials, it can be concluded that recycled terrazzo (with Epoxy, polyacrylate, and rustic systems) shows the best performance in the context of reducing carbon footprint. The thickness of this material is the thinnest compared to other materials, namely 9.5mm thick, this material produces the lowest embodied carbon, namely 7.40 kgCO₂e/m², and is able to save carbon by 2.02% compared to other materials, with a savings difference reaching 6.90 kgCO₂e/m².

Meanwhile, based on the table, ceramics as a reference material, showed the second highest embodied carbon value of 14.3 kgCO₂e/m², marble actually showed results that were less supportive of sustainability because it produced the highest emissions of 33.5 kgCO₂e/m² which experienced an increase in the carbon footprint of 5.65%, which showed the material with the largest environmental impact in this study. Then, exposed concrete/cement showed quite good performance with an embodied carbon value of 8.90 kgCO₂e/m² and savings of 1.58%, but in this case, recycled terrazzo was still higher, both in terms of embodied carbon savings and the thickness of the material layer.

The EDGE simulation results related to embodied carbon show that recycled terrazzo has the lowest embodied carbon value compared to ceramic, marble, and exposed concrete/cement. The amount of embodied carbon produced is 7.4 kgCO₂e/m², lower than exposed concrete/cement at 8.9 kgCO₂e/m² and ceramic at 14.3 kgCO₂e/m², and much lower than marble at 33.5 kgCO₂e/m². This shows the effectiveness of terrazzo flooring in reducing embodied carbon.

In supporting the concept of sustainable architecture, which refers to Ardiani's book entitled *Sustainable Architecture* (2016), building materials should also reduce the exploitation of new resources and minimize waste so as to reduce the value of embodied carbon in building materials, in addition to this will also affect the economic efficiency throughout the life cycle of the building. Recycled terrazzo material as an alternative sustainable floor covering also makes it possible to contribute to this aspect.

The results of the literature study analyzed by the author comparatively in terms of the value of advantages and disadvantages, as well as technical aspects (such as visual aesthetics, ease of installation, durability, and sustainability) of each material are presented in the table below.

Table 2. Comparison of Technical Aspects and Advantages and Disadvantages of Floor Materials

Technical Aspects	Recycled Terrazzo	Ceramics	Marble	Exposed Concrete / Cement
Sustainability	Recycled aggregate material. Low embodied carbon. Lightweight.	Materials not derived from recycled materials High embodied carbon.	Natural materials. Non-renewable. Heavy mining production. High embodied carbon content.	The embodied carbon value is quite low compared to ceramics and marble. The manufacturing process requires a high energy requirement.
Aesthetics	Flexible design Patterns and colors vary.	Limited motifs according to the factory.	Natural and unique motifs. Gives a luxurious impression.	Monotonous No pattern, just gray
Installation	Requires special skills. Takes time.	Easy and fast.	It's quite flexible but requires expertise. It requires coating and overlaying.	Requires plastering skills. Requires repeated coatings
Durability	Scratch and high traffic resistant.	Quite strong but easy to break.	Durable. Porous and therefore prone to stains. Sensitive to acids and harsh cleaners.	Strong but susceptible to cracking and humid environments.
Maintenance	Easy but must be polished regularly.	Easy, but requires proper grout maintenance.	Need intensive care.	Easy to clean, but easy to get dirty

(Source: Author's Analysis based on Literature Study, 2025)

Based on the literature analysis above, it can be concluded that recycled terrazzo performs well in terms of sustainability, aesthetics, and durability, although its installation requires a high level of complexity. Ceramic is easy to install, but falls short in terms of environmental and durability. Furthermore, marble has advantages in terms of aesthetics and durability, but is less so in terms of environmental and installation. Exposed concrete/cement offers good durability and maintenance, but lacks in terms of aesthetics.

Conceptually, the use of recycled terrazzo aligns with the principles of Life Cycle Assessment (LCA), where emission reduction efforts are implemented from the initial stages of production and material selection. Zhao et al. (2024) emphasized that significant embodied carbon efficiency can be achieved if material selection decisions are made strategically from the design phase. This aligns with the findings of Lai et al. (2023), which show that green building trends in Southeast Asia have shifted from simply reducing operational energy consumption to initial carbon reduction through efficient material use and reuse practices.

The EDGE simulation results in this study support the concept of early-stage carbon intervention as proposed by Sun (2024), who emphasized that material selection during the planning stage has the greatest impact on controlling total building emissions. The simulation

data demonstrates that carbon efficiency is not the result of post-construction interventions, but rather stems from data-driven design decisions from the outset.

As previously explained, the contribution of embodied carbon from building materials is estimated to reach 11% of total emissions. Based on EDGE analysis, recycled terrazzo flooring material shows a 2.02% higher carbon savings efficiency compared to ceramic, which is the most commonly used conventional material. This finding confirms that data-driven material selection and sustainability principles are not only technically relevant but also have a significant impact on the environment. This comparison method reflects architectural design practices that refer to data, methodological transparency, and suitability to the global challenges of sustainable development.

4. CONCLUSION

The use of recycled terrazzo flooring can significantly reduce embodied carbon. Simulation results show that terrazzo only produces 7.4 kgCO₂e/m², this figure is lower than ceramic, marble, and exposed concrete/cement. By saving embodied carbon, a single building saves 2% compared to ceramic. The best type of terrazzo system to be applied to the interior of commercial buildings, especially for commercial buildings, is the epoxy system, because it has a light weight and high design flexibility and durability. For damp areas such as toilets and others, the polyacrylate system is more suitable because of its resistance in damp areas. From a technical aspect, recycled terrazzo scores the highest compared to other materials, recycled terrazzo excels in terms of material sustainability, aesthetics, physical strength, and ease of maintenance, but in terms of installation, terrazzo has a very low score, because the installation process requires special skills and time. The overall evaluation results of the five aspects, terrazzo flooring received the highest score, indicating the best and most effective material in terms of achieving environmentally friendly design, compared to other materials, namely ceramic, marble, and exposed concrete/cement. Recycled terrazzo has proven not only efficient in reducing embodied carbon, but also provides a design solution that is in line with green building principles. For architects and practitioners, this material can offer a combination of sustainability, aesthetics, and durability. Through EDGE simulation, the selection of flooring materials in architectural design can be used as a concrete strategy in realizing more environmentally friendly buildings. This study confirms that recycled materials are not only a technical innovation, but also an integrated part of sustainable architectural design practices and in achieving green buildings.

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