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Sustainable Material Choice for Residential Building Construction: A Life Cycle Assessment Based on BIM

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ABSTRACT

This study focuses on the sustainable material choice for residential building construction through the use of Building Information Modelling (BIM) and a Life Cycle Matrix tool. The objective of this research is to evaluate the environmental impact of various materials used in residential building construction and identify sustainable alternatives. The research methodology involves using BIM to create a virtual model of the building, which is then used to generate a Life Cycle Matrix tool to analyse the life cycle of the building materials. The Life Cycle Matrix tool enables the comparison of the environmental impact of different materials over the entire life cycle of the building. The results show that the use of sustainable materials such as recycled steel, bamboo, and cellulose insulation can significantly reduce the environmental impact of residential buildings. This research provides a valuable tool for architects, engineers, and building designers to make informed decisions about sustainable material choices in building construction.

INTRODUCTION

Residential building construction plays a significant role in the global economy and is responsible for a considerable amount of energy consumption and greenhouse gas emissions. In recent years, the concept of sustainable construction has gained momentum as the need for environmental preservation becomes increasingly pressing. Sustainable construction practices emphasize the use of sustainable building materials that reduce the environmental impact of building construction and promote the efficient use of natural resources.

Building Information Modelling (BIM) and Life Cycle Matrix tools are two innovative approaches that can aid in sustainable material choice for residential building construction. BIM enables the creation of virtual models of buildings, which can be used to assess the environmental impact of building materials and optimize building design. Life Cycle Matrix tools, on the other hand, provide a comprehensive analysis of the environmental impact of building materials over their entire life cycle.

This study aims to evaluate the environmental impact of various building materials used in residential construction and identify sustainable alternatives through the use of BIM and Life Cycle Matrix tools. The study will help identify sustainable material choices that reduce the environmental impact of building construction while maintaining structural integrity and durability. By employing sustainable material choices in residential building construction, we can help protect the environment and promote a more sustainable future.

LITERATURE REVIEW

4D BIM Simulation Guideline for Construction Visualization and Analysis of Renovation Projects

The powerful technique known as four-dimensional building information modelling (4D BIM) allows construction professionals to visualise and analyse construction projects by fusing 3D models with time or scheduling data. Renovation projects benefit greatly from this technology because it enables stakeholders to comprehend how the construction will develop over time and foresee potential issues. For the analysis and visualisation of construction projects, 4D BIM simulation is a crucial tool. Construction professionals can envision the construction process, foresee future issues, and settle conflicts before they arise by generating a realistic 3D model and incorporating time or scheduling data.

A systematic review of BIM usage for life cycle impact assessment

The systematic study discovered that by increasing the precision and thoroughness of data gathering, better the visualisation of environmental impacts, and assisting decision-making processes, BIM has the potential to promote LCIA in the building industry. The studies' shortcomings have drawn attention to the need for more investigation into interoperability problems, defined data exchange formats, and practitioner training for BIM for LCIA implementation. Overall, the analysis sheds light on the existing state of understanding around the application of BIM for LCIA and emphasises areas in which further study and advancement are possible.

LCA and BIM Integrated assessment and visualization of buildings elements embodied impact for design guidance in early stages

Building information modelling (BIM) and life cycle assessment (LCA) are two crucial techniques that are being used more frequently in the design and construction of buildings to evaluate and improve their environmental performance. Whereas BIM is a digital model of a building that contains data on its physical and functional properties, LCA is a methodology that assesses the environmental impacts of a product or process over its full life cycle, from raw material extraction to disposal.

BIM Based life cycle assessment of buildings an investigation of industry practice and needs.

In a BIM-based LCA, data on the building's embodied energy, carbon emissions, and other environmental effects are gathered using the BIM model during the building's entire life cycle, from construction to demolition. The outcomes of the LCA can then be used to guide design choices and find ways to enhance the building's environmental performance. Notwithstanding the potential advantages of BIM-based LCA, there are a number of obstacles in the way of its mainstream implementation in the AEC sector. Lack of defined procedures for performing BIM-based LCAs, which can make it challenging to compare results across various projects or areas, is one of the major issues. Further training and education are required since many industry personnel lack the knowledge and abilities necessary to conduct BIM-based LCAs.

The coupling of BIM and LCA challenges identification through case study implementation.

The sustainability of building design and construction could be considerably increased by combining Life Cycle Assessment (LCA) and Building Information Modelling (BIM). The integration of these two methodologies does present certain difficulties, though, and a case study implementation can help to identify these difficulties. In one study, BIM-LCA coupling was used as a case study for a project involving building renovation. The study found a number of issues with this method, such as the dearth of BIM data for existing structures, the difficulty of incorporating LCA data into the BIM model, and the requirement for specific software and training.

Method to enable LCA analysis through each level of development of a BIM model.

A building's environmental impacts are evaluated using the life cycle assessment (LCA) technique from the time of construction till demolition. Building information modelling (BIM) is a digital depiction of a building that enables data sharing and analysis during the whole construction process. Using LCA analysis in BIM models helps improve decision-making by revealing important information about a building's environmental performance. In conclusion, incorporating LCA research into BIM models helps enhance the sustainability of buildings by supplying useful data that can be utilised to make better decisions during the construction process.

BIM Based LCA Throughout the design process: A dynamic approach

A more thorough approach to sustainable building design and construction is made possible by integrating life cycle assessment (LCA) in a BIM context. With the help of BIM, it is possible to replicate every stage of a building's life cycle, from construction to operation and deconstruction. LCA is a technique for evaluating a building's or product's environmental impact over the course of its full life cycle. Incorporating LCA in a BIM environment enables for the evaluation of the environmental impact of alternative design options in real-time, enabling designers to make educated decisions that reduce the environmental impact of the project. The LCA data can be integrated with other crucial data, such as cost and performance statistics, by using BIM.

METHODOLOGY

The methodology for sustainable material choice for residential building construction using BIM and Life Cycle Matrix tool can be divided into the following steps:

Building Information Modelling (BIM) creation: The first step is to create a virtual model of the building using BIM software. The virtual model should include all the structural and non-structural components of the building, such as walls, windows, doors, roofs, and other building systems.

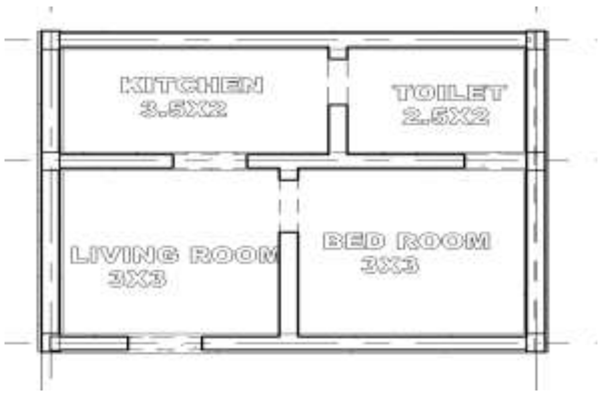

Figure:1-Plan of the Residential Building

Figure:2- 3D Model of Residential Building

Figure:3- Structure of Residential Building

Material identification: The next step is to identify all the materials used in the building construction, including the structural and non-structural materials. This information can be obtained from the building plans, specifications, and construction documents.

Life Cycle Matrix tool development: Once the materials have been identified, a Life Cycle Matrix tool can be developed to assess the environmental impact of the materials. The Life Cycle Matrix tool should consider the entire life cycle of the building materials, including their production, transportation, installation, use, and disposal.

Environmental impact analysis: The Life Cycle Matrix tool can be used to assess the environmental impact of each material in terms of energy consumption, greenhouse gas emissions, water consumption, and other environmental indicators. The results of the analysis can be used to identify materials with the lowest environmental impact and sustainable alternatives.

Sustainable material choice: Based on the results of the environmental impact analysis, sustainable material choices can be made. The choice of sustainable materials should be based on their environmental impact, cost, durability, availability, and other factors that may be relevant to the project.

Building design optimization: Finally, the building design can be optimized to incorporate the sustainable materials identified in the previous steps. The virtual model can be modified to reflect the use of sustainable materials and their impact on the overall building performance.

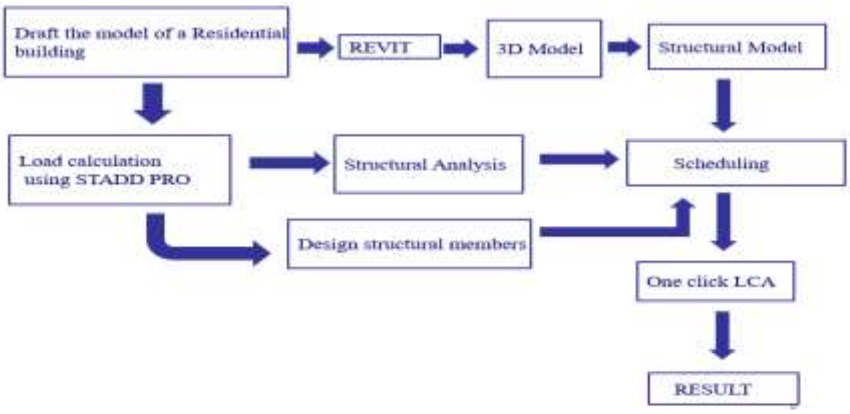

Figure:4- Methodology flowchart

RESULTS AND DISCUSSION

To perform load analysis for a residential building using STAAD.Pro and OneClick LCA is a software tool that can be used to perform life cycle assessment (LCA) of buildings. LCA is a method used to evaluate the environmental impact of a product or system throughout its entire life cycle, from raw material extraction, to manufacturing, use, and disposal.

In the case of OneClick LCA, the tool helps designers and builders to identify the carbon footprint of a building by analyzing the embodied carbon of the materials used in construction. Embodied carbon refers to the carbon emissions associated with the production and transportation of building materials.

By using sustainable materials, such as those with low embodied carbon or those made from renewable sources, the overall carbon footprint of the building can be reduced. Additionally, OneClick LCA can be used to optimize the design of the building in order to reduce energy use during the operational phase, which also contributes to the reduction of carbon emissions.

Overall, OneClick LCA helps designers and builders to make informed decisions about the materials and design strategies that can lead to reduced carbon emissions in residential buildings. By doing so, it can support the transition to a more sustainable and low-carbon built environment.

Model the structure: Use STAAD.Pro to create a 3D model of the building. This can be done by selecting the appropriate tools to create the walls, slabs, columns, beams, and any other structural components. The model should accurately represent the geometry and layout of the building.

Define the properties of the materials: Assign appropriate properties for the different materials used in the building, such as concrete, steel, and masonry. This can be done by selecting the material properties from STAAD.Pro's library or by manually entering them.

Define the loads: Define the loads that will act on the structure. These may include dead loads (weight of the building components), live loads (occupant loads, furniture, etc.), wind loads, seismic loads, and snow loads. These loads can be defined using STAAD.Pro's load definition tools.

Analyze the structure: Once the loads have been defined, use STAAD. Pro's analysis tools to calculate the internal forces and stresses within the structure. This step will provide a detailed analysis of the building's ability to withstand the defined loads.

Review the results: Review the results of the analysis to determine if the building can withstand the loads applied. If the results indicate that the building is not able to withstand the loads, modifications may need to be made to the design to ensure structural integrity.

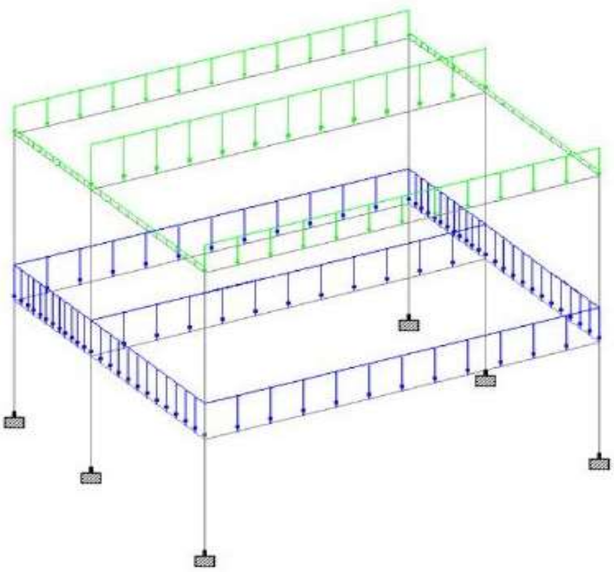

Figure:5-Load application details for structural members

Generate reports: Generate reports to summarize the results of the load analysis. These reports can be used to communicate the findings to stakeholders, such as building owners, architects, and engineers.

In conclusion, by following these steps, you can perform a load analysis for a residential building using STAAD.Pro. It is important to ensure that the model accurately represents the building's geometry and that the loads applied are appropriate for the intended use of the building. Details of the bending moment and shear force will be displayed. And the design details for the structural members are as follows: beam: 8mm and 10mm dia @250mm c/c spacing along x and z directions; column: 12mm dia @250mm c/c spacing along y direction; foundation: 10mm dia @70mm spacing along x and z direction; slab reinforcement detailing: 8mm dia @100mm c/c along x direction and 8mm dia @275mm c/c along z direction for 3x6m and 8mm dia @150mm c/c along x direction and 8mm dia @275mm c/c along z direction for 2x6m.

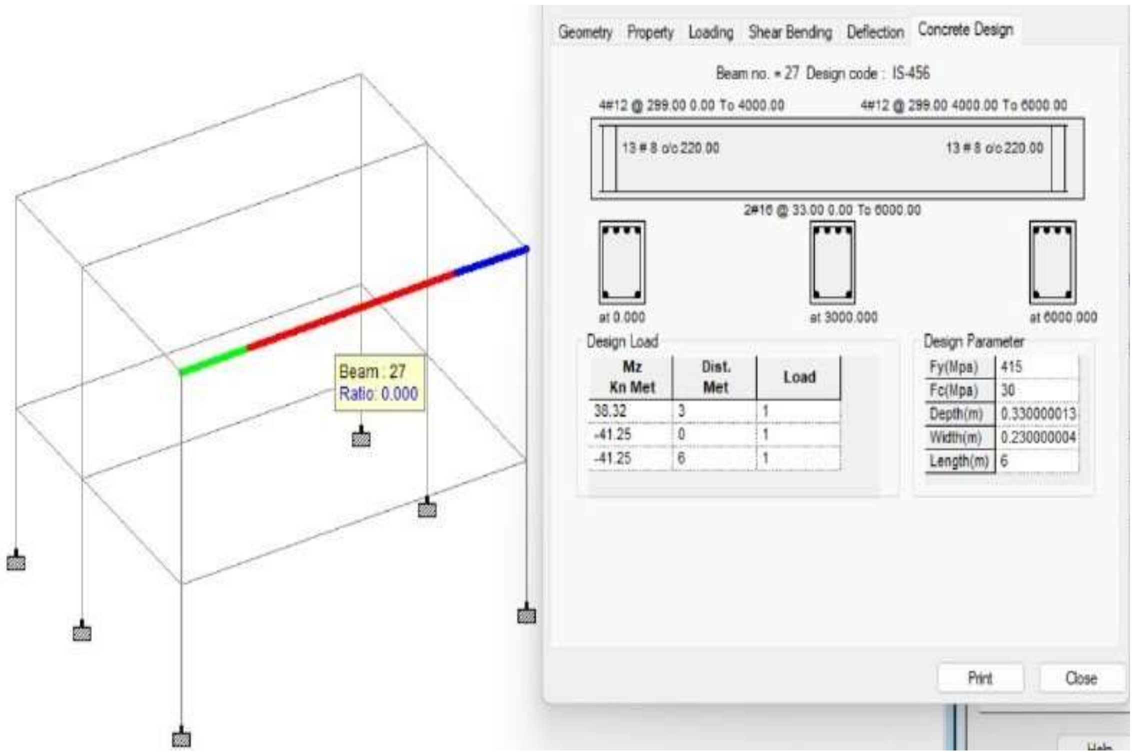

Figure:6-Beam Design

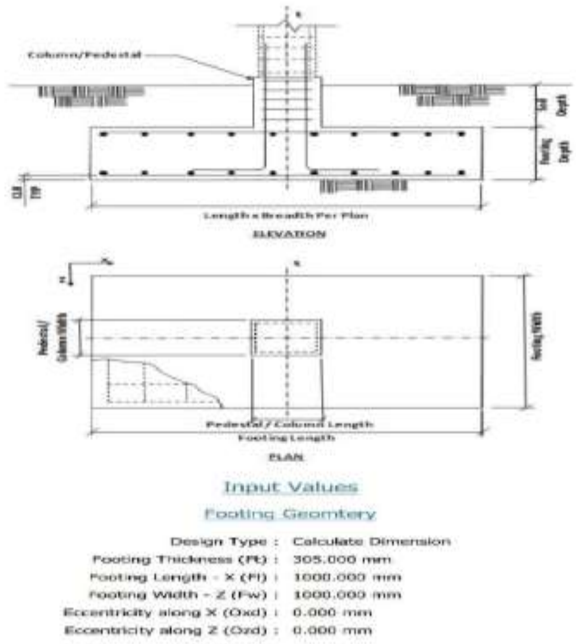

Figure:7-Foundation Design

OneClick LCA is a software tool that can be used to perform life cycle assessment (LCA) of buildings. LCA is a method used to evaluate the environmental impact of a product or system throughout its entire life cycle, from raw material extraction, to manufacturing, use, and disposal. In the case of OneClick LCA, the tool helps designers and builders to identify the carbon footprint of a building by analyzing the embodied carbon of the materials used in construction. Embodied carbon refers to the carbon emissions associated with the production and transportation of building materials. By using sustainable materials, such as those with low embodied carbon or those made from renewable sources, the overall carbon footprint of the building can be reduced. Additionally, OneClick LCA can be used to optimize the design of the building in order to reduce energy use during the operational phase, which also contributes to the reduction of carbon emissions. Overall, OneClick LCA helps designers and builders to make informed decisions about the materials and design strategies that can lead to reduced carbon emissions in residential buildings. By doing so, it can support the transition to a more sustainable and low-carbon built environment. The parameters in One Click LCA is three they are 1. Building materials, 2. Construction Site Operations and 3. Building Floor Area these parameters we need to give for the carbon emission result.

The use of BIM as a tool in this study has simplified the process of selecting sustainable materials for residential buildings, the material take-off process, and the simulation necessary to assess how different building materials behave in terms of energy consumption. The BIM 3D model must include the physical and thermal characteristics of each material that will be used in the project. The modelling was constructed based on Degree of Development since the components are graphically represented as a specific object with information on specifics, manufacture, assembly, and installation. The first of the three Life Cycle Stages is called Cradle to Gate (A1-A3 stage) A1: Supply of raw materials, A2: Transportation, and A3: Production.

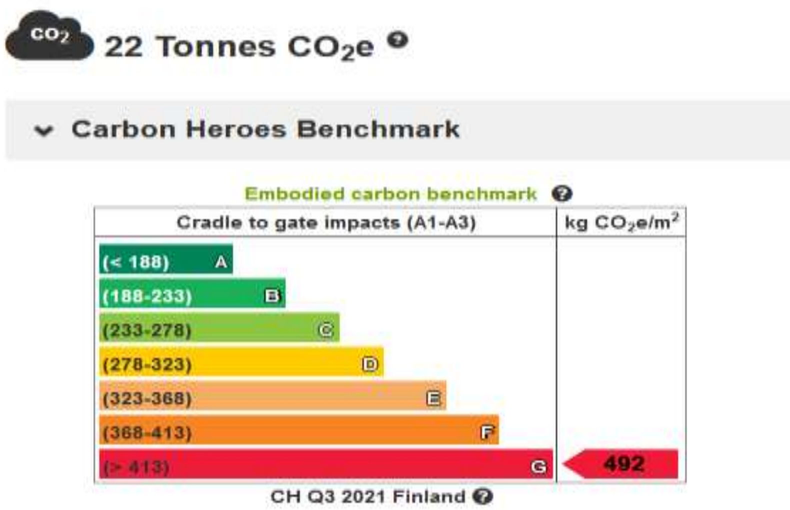

Figure:8-carbon emission result for case:1

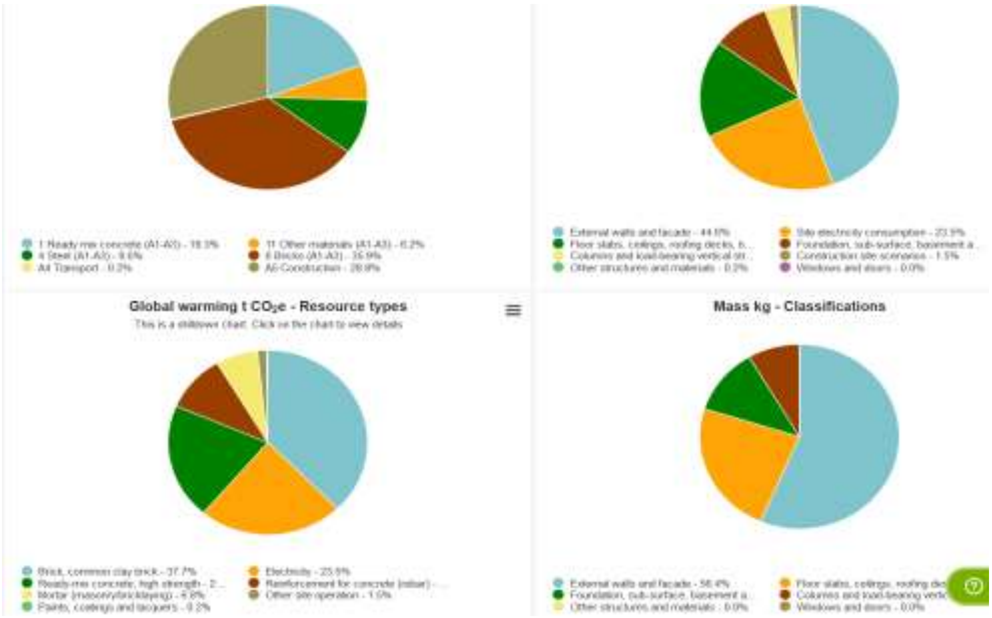

Figure:9-Pie charts result for case:1

The second case Building materials is ready mix concrete we are selected the 20% fly ash content in cement, reinforced steel we used the 60% recycled content and clay bricks for these we get the 34 tons of co2 content.

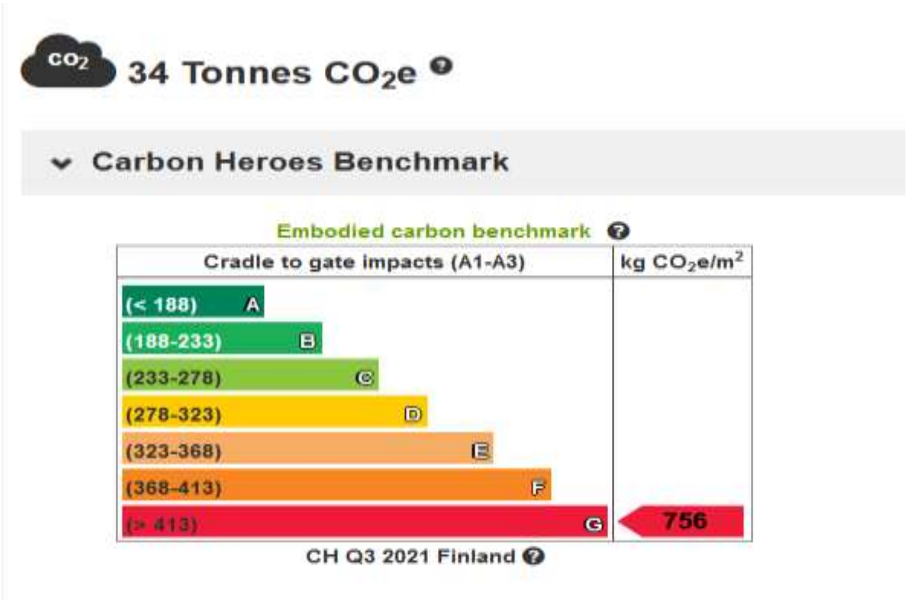

Figure:10-Carbon emission results for case:2

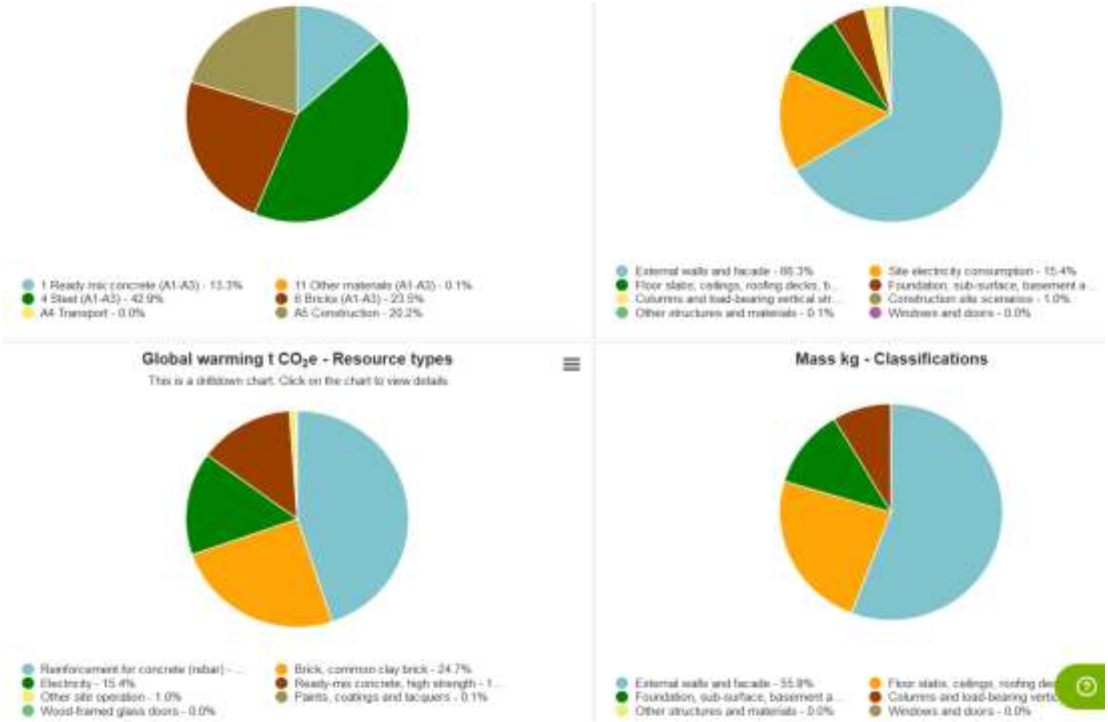

Figure:11- Pie charts result for case:2

The third case Building materials is ready mix concrete we are selected the 30% fly ash content in cement, reinforced steel we used the 70% recycled content and reclaimed bricks for these we get the 21 tons of co2 content.

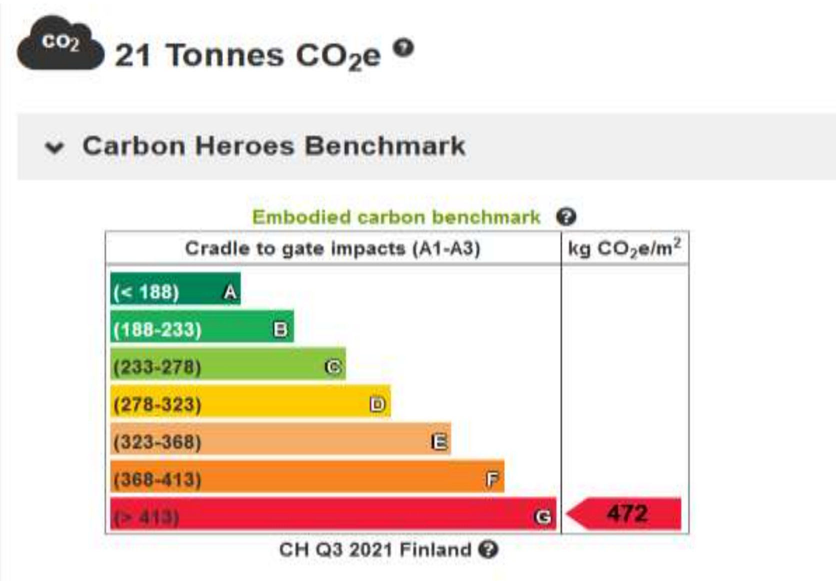

Figure:12- Carbon emission results for case:3

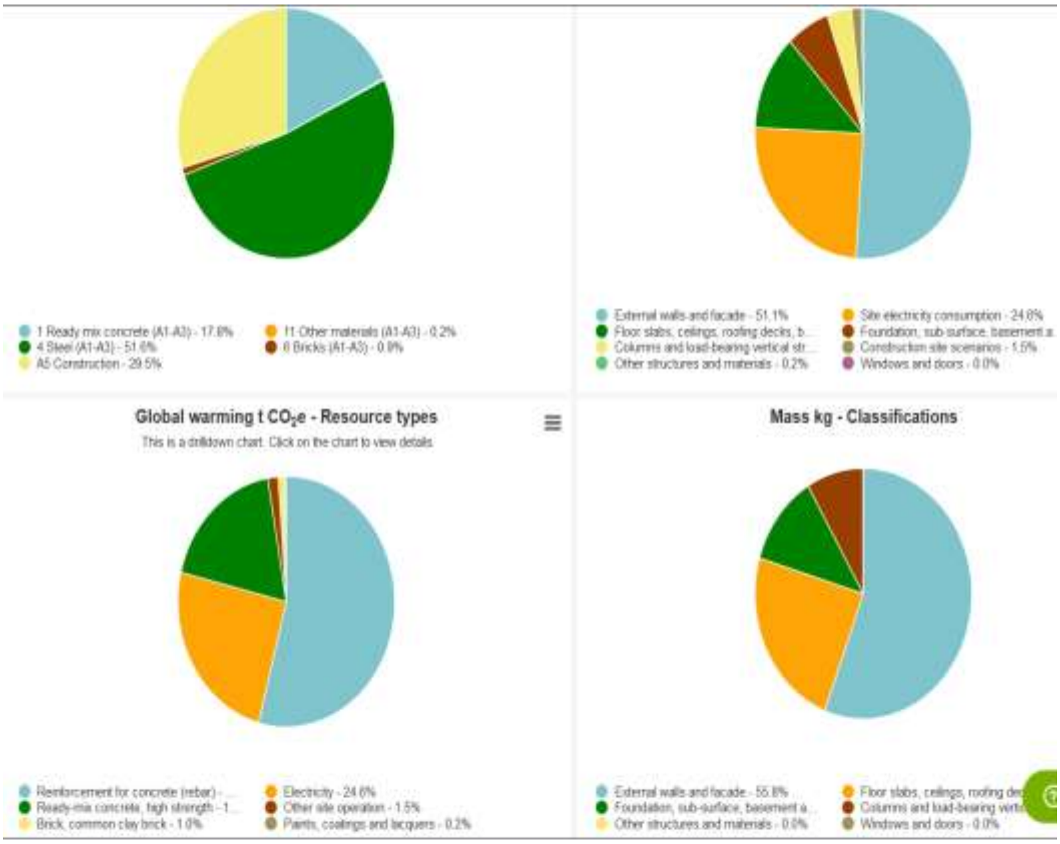

Figure:13- Pie charts result for case:3

CONCLUSION

sustainable material choice for residential building construction using BIM and Life Cycle Matrix tool is an essential approach towards reducing the environmental impact of building construction. The use of BIM enables the creation of virtual models of buildings, allowing architects, engineers, and building designers to optimize building design and assess the environmental impact of building materials. The Life Cycle Matrix tool provides a comprehensive analysis of the environmental impact of building materials over their entire life cycle, enabling the identification of sustainable material alternatives that have the lowest environmental impact.

Through the methodology outlined in this study, sustainable material choices such as recycled steel, bamboo, and cellulose insulation can be identified and incorporated into the building design. These sustainable materials offer lower environmental impacts while maintaining structural integrity and durability. The use of sustainable materials in residential building construction can contribute to a more sustainable future, where natural resources are used more efficiently, and the environment is protected.

In conclusion, the sustainable material choice for residential building construction using BIM and Life Cycle Matrix tool is a valuable approach that can help reduce the environmental impact of building construction, promote sustainable development, and create a healthier environment for present and future generations. In our research of all the different parameters, we discovered that while an increase in fly ash content reduces carbon dioxide emissions, an increase in recycled steel will have the opposite effect. In comparison to clay bricks, reclaimed bricks have lower CO2 emissions.

The final recommendation made by this study is to investigate the application of the suggested framework in actual buildings while figuring out efficient methods for balancing various influences and precisely measuring qualitative factors.

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