Prestieesci Research Review

INNOVATIONS IN SUSTAINABLE CONSTRUCTION: INVESTIGATING THE PROPERTIES AND APPLICATION OF HIGH-PERFORMANCE AND LIGHT-WEIGHT CONCRETE

Zhao Yuhuan, Aiman Al-Odaini

Department of Engineering ,Lincoln University College, 47301 Petaling Jaya, Selangor D. E., Malaysia.

Corresponding author: Zhao Yuhuan, Department of Engineering ,Lincoln University College, 47301 Petaling Jaya, Selangor D. E., Malaysia. Email ID: 330410593@qq.com

ABSTRACT

In our synthesis of Innovations around Sustainable Construction, which offers Studying the Fundamentals in addition to Application concerning High-Performance and Lightweight Concrete, we propose employing citation-context in conjunction with the paper's content model. Citations may have been used before to create scientific summaries, but since they exclude crucial context, they are unable to accurately capture the content of the cited publication. Although the dataset we use for evaluation originates from the construction industry, most of our approaches are general and can therefore be used to other areas. The innovations in sustainable construction industries is now at an important turning point, as it must both contribute to global growth while also reducing its negative effects on the ecosystem. At this crossroads, the building sector must decide how to best assist global growth while simultaneously reducing its negative effects on the environment. A possible answer to this problem is the use of high-performance, lightweight concrete, which improves the sustainability of building practices while drastically lowering the carbon impact. There is an immediate need for ecologically sound alternatives to conventional building practices, and this study investigates those implications. It emphasizes the benefits of high-performance plus lightweight concrete, such as its greater adaptability, less carbon emissions, better thermal insulation, and lighter weight. These cutting-edge materials have the ability to propel sustainable building, as shown by their use in famous projects like the 3D-printed concrete bridge in Amsterdam and the Bosco Vertical in Milan. Investment within research, regulatory backing, education, and stakeholder engagement are some of the measures outlined in the study's conclusion that the construction sector must do in order to completely adopt this technology. This research will provide a balance between development with environmental stewardship. The environmental impact of conventional building methods is substantial. One of the leading causes of global warming is the manufacture of concrete, an essential building material. Construction projects also have the potential to disturb ecosystems due to the garbage they produce. Sand, gravel, and lumber are raw materials that the sector uses extensively, which depletes these resources. To guarantee the continued availability about these resources in the future, sustainable practices are crucial. More and more people throughout the world are settling into cities, which is boosting the need for new. Currently as much as ever, the building industry must find a way to boost global expansion while simultaneously lowering its environmental impact. A game-changer in the fight for eco-friendly building practices is high-performance, lightweight concrete. There will be much less of an effect on the environment by building using this material since it increases durability, decreases carbon emissions, and has many other uses. Adopting such advances will be critical for the industry's transition to an environmentally friendly future, as it strives to balance development with environmental responsibility. Sustainable expansion in the building business is possible with the help of education, cooperation, regulatory backing, and research.

Keyword: Innovative Materials, Ecological Imprint, High-Performance Concrete, Advanced Concrete Mix ,Lightweight Concrete, Carbon Footprint.

INTRODUCTION

The building sector is confronted with the urgent problem of striking a balance between sustainability and expansion as urbanization and infrastructural needs rise. Adopting lightweight, high-performance concrete may be one way to solve this problem. It can change building methods and make a major contribution to environmental sustainability. This study designed, modeled, and experimentally characterized lightweight concrete empty bricks using recycled tire rubber particles and acoustically excellent fractal cavities (Sambucci, et. al. 2022). The brick models' structural with acoustic behavior was examined using finite element analysis, and the generated prototypes' performance was assessed using compressive testing and sound-absorption measurements. Because of its lower density compared to conventional concrete, lightweight concrete—also called low-density concrete—represents a major invention in the building business. The use of expanding agents increases the mixture's volume and imparts other desirable features, such as decreased dead weight and better nail ability, which are built into this unique substance (Wang, et. al. 2021). Lightweight concrete's key selling point is that it doesn't create laitance layers as well as cement films when used to build things like walls—it just keeps big holes. Aerated lightweight concrete is the subject of this study, which aims to shed light on its capabilities, features, and its usage in green building (Tam, et. al. 2021). When compared to conventional circular hollow patterns, fractal cavities enhanced the medium-high frequency noise dampening, mechanical strength, and structural efficiency. When used as a whole concrete aggregate, ground scrap tire rubber provides an environmentally beneficial option with improved mechanical ductility, sound attenuation, and lightweight characteristics. Rubber-concrete blocks that are almost entirely compliant with standard specifications and have additional value show promise as aggregate with non-structural uses for discarded rubber (Sambucci, et. al. 2022).

The construction sector has a growing challenge as urban populations continue to outstrip rural areas: how to increase global development while reducing environmental impact. Because of its many benefits—including increased durability and less carbon emissions—high-performance, lightweight concrete is revolutionizing the movement for environmentally responsible construction techniques. In its quest to strike a balance between growth and environmental responsibility, the sector must embrace such developments if it is to make the transition to a more sustainable future (Jamil, et. al. 2023). There has never been a more important time for the sustainable building sector to step up and help spur global development while simultaneously lowering its environmental impact. Lightweight, high-performance concrete has the potential to address this issue by being more versatile, producing less carbon emissions, improving thermal insulation, and being less heavy. Renown examples such as the Bosco Vertical from Milan and the 3D-printed ceramic bridge in Amsterdam show that this innovative material can drive sustainable construction. For the construction industry to completely embrace this technology, there must be investments in research, support from regulators, education, and involvement of stakeholders (Alqahtani, et. al. 2022). Concrete, a byproduct of conventional construction, is one of the main contributors to climate change. Garbage from construction sites also depletes natural resources like timber, sand, and gravel, which in turn disrupts ecosystems. To guarantee that resources will still be available in the future, sustainable practices are essential.

BACKGROUND OF THE STUDY

In order to better understand lightweight concrete along with its function in contemporary building, it is necessary to first familiarize oneself with its history, practical uses, and distinctive characteristics. More sustainable construction practices may be achieved with lightweight concrete, thanks to its decreased weight, enhanced insulation, and increased durability. This follows is an in-depth analysis of the material's properties along with the way they relate to sustainable building practices in the future. Because of its exceptional qualities and environmental advantages, lightweight concrete—also called low-density concrete—has become a game-changing invention in the building sector. Lightweight concrete is built to have a lower density than regular concrete. It does this by adding expanding agents to the mixture, which increases its volume and gives it properties like better nail ability and less dead mass (Sambucci, et. al. 2022) .Lightweight concrete has a long history, being used in the building of Rome's Pantheon in the second century. This historic building is proof that pumice, as a lightweight aggregate, can withstand the test of time. Built about eighteen centuries ago, the structure known as the Pantheon is still a prime illustration of the durability that lightweight concrete may provide (Alqahtani, et. al. 2022). Aerated lightweight concrete's performance is examined in this study paper, which summarizes the project's operations and development. Tests for compressive strength, water absorption, density, and comparisons to other lightweight concrete kinds are important topics of investigation.

THE PURPOSE OF THE RESEARCH

The research intends to provide recommendations for the mixing, laying, highly curing of high-performance highly lightweight concrete, according to experimental data. The recommendations will be verified and updated based on input from industry experts and policymakers. Statistical analysis is being performed to establish the significance of the distinctions amongst lightweight and conventional concrete and study correlations between mix design factors and performance attributes. Ethical issues include data accuracy, openness, and security of interviewees including proprietary information through case studies. The conclusion of the research will be constructed around these results.

LITERATURE REVIEW

This research is to confirm the feasibility of using lightweight concrete to promote environmentally friendly building methods by conducting extensive analyses and experiments. This material's historical use demonstrates its practicality; its popularity has led to its adoption in many countries, including the United States, due to its many advantages. To make lightweight concrete, lightweight materials including sand, perlite (a volcanic glasses), vermiculite (a mineral), pumice (a volcanic rock), and expanded clay are mixed in. Lightweight concrete is 87 to 23% lower than regular concrete because of the materials used, which have dry densities that vary between 300 kg/m^3 through 1840 kg/m^3 (Wang, et. al. 2021).Using expanded clay, perlite, or vermiculite as lightweight aggregates is what lightweight aggregate concrete is all about. An air-enhanced concrete is one that has air bubbles or holes mixed in, either by hand or by means of a foaming agent. The absence of coarse aggregate in no-fines concrete makes it a porous and lightweight substance that is composed of sand, water, and cement. Beyond just being lighter, lightweight concrete has several other advantages. Enhanced fire resistance, longer lifespan, and better thermal insulation are some of its benefits. These characteristics, which contribute to its overall longevity and structural integrity, are a result of its decreased heat conductivity and resistance to freeze-thaw cycles (Tam, et. al. 2021). Dead loads are decreased, building speeds are accelerated, and transportation and handling expenses are decreased due to the material's low density. There are a few problems with lightweight concrete, despite all its benefits. It calls for unique mixing and installation techniques because to its lower compressive strength than regular concrete. Furthermore, depending on the accessibility of appropriate aggregate resources in a given area, lightweight concrete may be more costly and scarce (Jamil, et. al. 2023) .This research attempts to solve the environmental problems that come with conventional construction methods, namely with lightweight concrete. Conventional concrete emits a lot of greenhouse gases and wastes resources, among other detrimental effects on the environment. The benefits of lightweight concrete include reduced weight, improved thermal insulation, and extended durability. Its disadvantages include lesser compressive strength, increased prices, and a restricted supply of appropriate aggregate materials. The popularity of low-density concrete, also referred to as "lightweight concrete," has grown as a result of its special attributes and advantages for sustainability. In order to raise the volume of the mixture and impart qualities like reduced dead weight and enhanced nail ability, expanding agents are utilized in the engineering process. Pumice is a prime example of the material's durability and strength as it was the primary lightweight aggregate used to build Rome's Pantheon cathedral. Expanded clay, slate's exterior, perlite, vermiculite are pumice stones, and light-weight sand may all be added to concrete to create lightweight concrete. But because of its lower compressive strength, it has to be mixed and placed differently, and it could cost more. Additionally, depending on local access to suitable aggregate resources, its availability can be limited. To sum up, light-weight concrete has the ability to lessen its negative effects on the environment and encourage sustainable building methods in the building industry.

PROBLEM STATEMENT

"The construction sector has trouble achieving sustainable expansion because of the problems with the environment brought about by conventional concrete methods. Conventional techniques worsen climate change, have a detrimental effect on public health, and result in waste, diminished resources, and excessive greenhouse gas emissions. While lightweight concrete has benefits like reduced weight, improved insulation, and extended durability, it also has disadvantages like lower compressive strength, increased prices, and restricted availability."

RESEARCH OBJECTIVE

1. To assess the compressive strength, water absorption, density, and thermal conductivity of high-performance and lightweight concrete to establish a comprehensive understanding of its performance characteristics.
2. To explore the practical applications of high-performance and lightweight concrete in various construction scenarios, including residential, commercial, and infrastructure projects, to demonstrate its versatility and effectiveness.
3. To Examine the economic and environmental benefits of using high-performance and lightweight concrete in construction, focusing on reduced dead loads, improved insulation, faster construction rates, lower transportation and handling costs, and decreased greenhouse gas emissions.

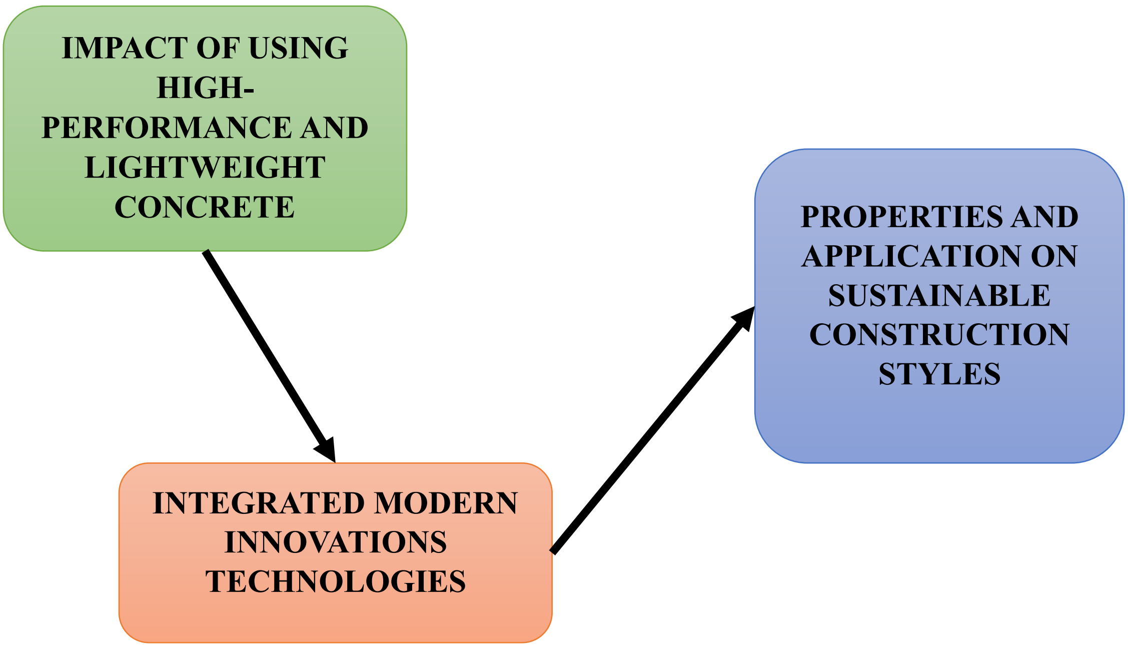
4. To create guidelines and best practices for the implementation of high-performance and lightweight concrete in sustainable construction, providing a valuable resource for industry professionals and policymakers.

RESEARCH QUESTION

1. What are the practical challenges and considerations in implementing high-performance and lightweight concrete in different construction scenarios?
2. What are the economic benefits of using high-performance and lightweight concrete in terms of reduced dead loads, faster construction rates, and lower transportation and handling costs?

3. How does high-performance and lightweight concrete compare to traditional concrete in terms of structural performance, environmental impact, and cost-effectiveness?
4. What are the compressive strength, water absorption, density, and thermal conductivity characteristics of high-performance and lightweight concrete compared to traditional concrete?

THE THEORETICAL FRAMEWORK



RESEARCH METHODOLOGY

The research also delves into Finding a sustainable growth balance is a major problem for the building business. There are a lot of negative effects on the environment caused by traditional building processes, especially when using conventional concrete. These include a lot of waste, resource loss, and high emissions of greenhouse gases. These methods have negative impacts on public health, drive up building prices, and exacerbate climate change. Although lightweight concrete has several advantages, including being lighter, better insulating, and lasting longer, it also has some drawbacks, like having less compressive strength, being more expensive, and having restricted geographical availability of aggregate materials that are acceptable. The purpose of this study is to find solutions to these problems by analyzing the properties of enriched lightweight concrete, particularly its density, water absorption capacity, and compressive strength. Research into and enhancements to these characteristics are part of a larger effort to prove that lightweight concrete may help reduce the negative effects of the construction sector on the environment and promote more sustainable building practices. Conventional building processes, such as conventional concrete, have major environmental implications, the construction sector confronts a huge issue in combining expansion with sustainability. Low-density concrete, sometimes referred to as lightweight concrete, has many advantages over lightweight concrete, including lighter weight, better thermal insulation, and increased durability. However, lightweight concrete has drawbacks as well, including higher costs, lower compressive strength, and restricted regional availability of appropriate aggregate materials. By examining the performance of oxygenated lightweight concrete and paying particular attention to its compressive strength, retention of water, and density, this study seeks to solve these problems. Low-density concrete, also referred to as lightweight concrete, has become a key invention in the building sector because of its special qualities and advantages for sustainability. Expanding agents are used in its engineering to raise the mixture's volume and impart properties like decreased dead weight. Pumice was used as the main lightweight aggregate for building the Pantheon cathedral in Rome, which is a prime illustration of the material's strength and endurance (Jamil, et. al. 2023).

Expanded clay, slate, perlite, vermiculite, pumice stones, and lightweight sand are examples of lightweight aggregates that may be added to concrete to create lightweight concrete that significantly reduces weight. However, because of its reduced compressive strength, it requires specific mixing and placing techniques. Moreover, its cost may be higher and its availability may be restricted based on area access to appropriate aggregate resources.

Hypothesis (H_0): “High-performance and lightweight concrete does not significantly differ from traditional concrete in terms of compressive strength, water absorption, density, thermal conductivity, environmental impact, and cost-effectiveness”.

Alternative Hypothesis (H_1): "High-performance and lightweight concrete significantly differs from traditional concrete, offering superior compressive strength, reduced water absorption, lower density, better thermal conductivity, lower environmental impact, and improved cost-effectiveness".

RESEARCH DESIGN

The research design is structured to provide a comprehensive understanding of the properties, applications, and benefits of high-performance and lightweight concrete in sustainable construction. Through a combination of experimental testing, comparative analysis, case studies, economic and environmental assessments, and the development of practical guidelines, this study aims to validate the potential of lightweight concrete to drive innovation and sustainability in the construction industry. This research studies the qualities, uses, and advantages of high-performance along with lightweight concrete within sustainable building. It combines experimental and comparative approaches to produce multiple mix designs utilizing these materials, integrating varying kinds and quantities of lightweight aggregates and extra elements. Compressive strength testing, absorbance of water tests, gravity measurements, and heat conductivity tests are done on concrete samples at various curing ages. Comparative examination is undertaken between conventional and lightweight concrete, including samples manufactured and analyzed using the same processes (Sambucci, et. al. 2022). Data analysis is undertaken to compare performance attributes of high-performance as well as lightweight concrete with conventional concrete. Case studies as well as practical applications are chosen, with field research and interviews done to examine the deployment of lightweight concrete in different building settings. Economic waste environmental analysis is undertaken, examining the economic advantages of adopting high-performance waste lightweight concrete, which include decreased structural costs, quicker building rates, and cheaper handling and transportation costs (Jamil, et. al. 2023). An ecological impact assessment is undertaken to quantify emission of greenhouse gases, resource utilization, and trash creation, and compare the ecological effects of lightweight concrete against regular concrete to uncover possible sustainability benefits. Guidelines along with best practices are created to continue explore the possibilities of lightweight construction in sustainable building.

RESULTS

The research intends to provide recommendations for the mixing, laying, highly curing of high-performance highly lightweight concrete, according to experimental data. Which disclose by the study as According to the research, slump, freshness density, airflow content, 72-hourly rate shrinkage of plastique, hardened density, compressible strength, as well as flexural strength are all highly impacted by CRA and RCWTB concentration. Factors A and B, CRA and RCWTB, respectively, have a major impact with regard to slump, freshness density, airflow content, toughened density, and age. The influence of age (Factor C) is just moderately significant. Age, RCWTB content, and CRA content all have a major impact on the degree of compression (Factor B), compressed strength (Factor A), and compressive strength (Factor C). Curing (Factor D) has no appreciable impact. The following factors have a major impact on flexural strength: age, curing, RCWTB content, and CRA content. The recommendations will be verified and updated based on input from industry experts and policymakers. Statistical analysis is being performed as P-values for the Factors According to ANOVA to establish the significance of the distinctions amongst lightweight and conventional concrete and study correlations between mix design factors and performance attributes. Ethical issues include data accuracy, openness, and security of interviewees including proprietary information through case studies.

TABLE 1: FACTORS P-VALUE ACCORDING TO ANOVA

Property	*Cement, River sand, and Aggregate (Factor A) Content*	*Rice husk ash, Cement, Water, Sand, and Blast furnace slag (Factor B)*	*Age (Factor C)*	*Curing (Factor D)*
Slump	***0.0000***	***0.0000***	–	–
Fresh density	***0.0001***	***0.0006***	–	–
Air content	***0.0002***	***0.0000***	–	–
72-h plastic shrinkage	***0.0060***	***0.0005***	–	–
Hardened density	***0.0010***	***0.0000***	*0.0520*	–
Compressive strength	***0.0030***	***0.0500***	*0.00140*	*0.7571*
Flexural strength	***0.00180***	***0.00450***	*0.00100*	*0.0101*

“**Slump:** Both CRA content (Factor A) and RCWTB content (Factor B) significantly affect the slump ($p < 0.05$). Fresh Density: Both CRA content (Factor A) and RCWTB content (Factor B) significantly affect the fresh density ($p < 0.05$). Air Content: Both CRA content (Factor A) and RCWTB content (Factor B) significantly affect the air content ($p < 0.05$). 72-hour Plastic Shrinkage: Both CRA content (Factor A) and RCWTB content (Factor B) significantly affect the 72-hour plastic shrinkage ($p < 0.05$). Hardened Density: CRA content (Factor A) and RCWTB content (Factor B) significantly affect the hardened density (p < 0.05). Age (Factor C) has a marginally significant effect (p = 0.0520). Compressive Strength: CRA content (Factor A), RCWTB content (Factor B), and Age (Factor C) significantly affect compressive strength (p < 0.05). Curing (Factor D) does not have a significant effect (p = 0.7571). Flexural Strength: CRA content (Factor A), RCWTB content (Factor B), Age (Factor C), and Curing (Factor D) all significantly affect flexural strength" (p < 0.05).

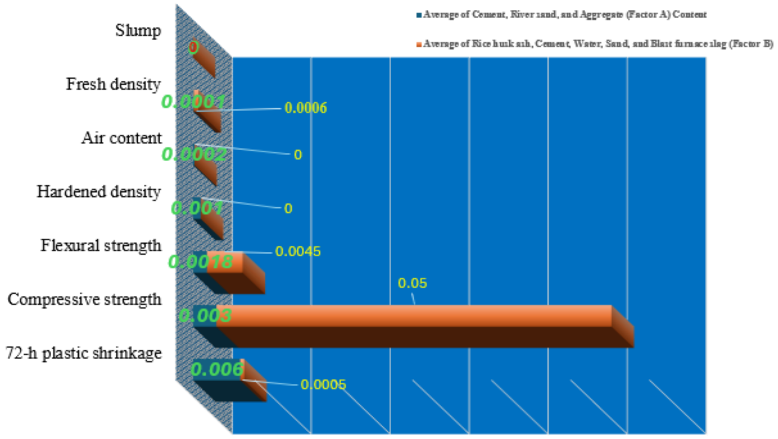


Figure 1. Graphical Representation Factors P-Value According To Anova

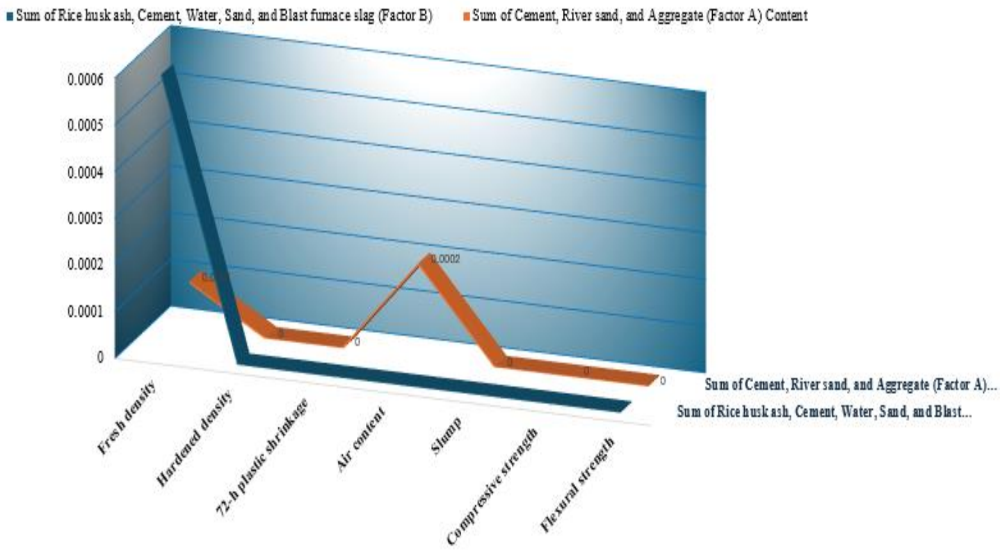


Figure 2. Graphical Representation On Factors P-Value According To Anova

The conclusion of the research will be constructed around these results.

CONCLUSION

The ANOVA findings show that the amount of CRA and RCWTB mixed high-performance lightweight concrete has a substantial impact on its slump, fresh the density, air content, 72-hour shrinkage of plastic, hardened density, compressive property, overall flexural strength. These elements may have a substantial impact on the concrete's workability, necessitating proportional changes to get the appropriate qualities. The concrete's age also affects how the characteristics of the concrete change over time, therefore mix design must take this into account. The amount of CRA and RCWTB in the concrete has a major influence on its compressive strength, although the curing procedure has little effect. These elements also have a substantial impact on the concrete's flexural strength, highlighting the intricate interactions among them. The building industry will be significantly impacted by these discoveries in terms of material efficiency, mix architecture, sustainability, and the creation of standards (Wang, et. al. 2021). Concrete's performance qualities may be precisely controlled by enhancing its different features with adjustments to its CRA and RCWTB contents. Mix design has to be customized to meet the needs of individual applications and performance objectives. By minimizing resource use and environmental effect, optimizing the utilization of portable and recycled materials may support sustainable building practices. The guidelines derived from these discoveries have great value for experts in the sector who are using sustainable building techniques.Future studies should investigate other variables, validate in the field, and carry out a thorough cost-benefit analysis to assess the feasibility of using outstanding performance lightweight cement in building projects. By resolving these issues, the building sector may use the advantages of high-performance flexible concrete and keep moving forward toward more efficient and sustainable building methods (Sambucci, et. al. 2022)

LIMITATION OF THE STUDY

This study on lightweight, high-performance concrete provides insightful information and useful suggestions. Nevertheless, it has a number of drawbacks, such as restricted material diversity, experimental setup, a short-term emphasis, practical and financial concerns, environmental effect, adherence to laws and regulations, and climatic and geographical restrictions.The research mainly focuses on certain kinds of lightweight aggregates, with the value recycled concrete waste, shale, and expanded clay. It's possible that the findings won't apply to other novel or lightweight aggregate kinds that weren't included in the research. Because raw materials varied naturally, it was difficult to standardize material qualities. The controlled laboratory circumstances used for the experiments may not have accurately captured the complexity and variability of actual building sites.Short-term testing were used to evaluate long-term performance, and long-term material property changes were not thoroughly investigated. Cost analysis, realistic implementation, environmental effect, regulatory alignment, as well as policy integration are examples of economic and practical factors. Waste management was not adequately addressed, nor was a thorough life cycle assessment (LCA) to measure the environmental advantages during high-performance lightweight concrete throughout the course of its lifetime included.In order to verify the study's suggestions against existing industry standards and construction codes—which differ across locations and might affect the viability of using new materials and techniques—regulatory and norm compliance is essential. Regional variability as well as site-specific characteristics are examples of geographic and climatic limits.Future research should look into a wider range of lightweight aggregates along with supplemental materials to address these limitations. It should also validate laboratory findings through field studies as well as long-term monitoring, conduct thorough economic alongside environmental analyses, and work with governing bodies to ensure that recommendations are in line with current standards and make it easier for the construction industry to adopt them.

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