THE EMPIRICAL INVESTIGATION OF LIGHTWEIGHT CONCRETE VIA THE UTILIZATION OF VARIED WASTE MATERIALS: A REVIEW

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Abstract - *The quest for sustainable construction practices has prompted extensive research into lightweight concrete formulations utilizing diverse waste materials. This review paper presents a comprehensive analysis of empirical investigations concerning the development of lightweight concrete, focusing on the incorporation of varied waste materials. Lightweight concrete offers numerous advantages such as reduced structural dead load, improved thermal insulation properties, and enhanced sustainability by minimizing environmental impacts associated with traditional concrete production. This paper systematically surveys the utilization of a wide range of waste materials including fly ash, slag, silica fume, recycled aggregates, expanded polystyrene beads, and others as partial replacements for conventional aggregates and cementitious materials in lightweight concrete. The review synthesizes empirical findings related to the effects of these waste materials on the fresh and hardened properties of lightweight concrete, including workability, mechanical strength, durability, and thermal performance.This paper critically evaluates the environmental and economic implications of utilizing waste materials in lightweight concrete production, including reductions in carbon emissions, energy consumption, and waste generation, alongside potential cost savings. The review also addresses challenges and limitations associated with the incorporation of waste materials, such as variability in material properties, compatibility issues, and standardization concerns. This review contributes to a deeper understanding of the empirical insights into lightweight concrete technology utilizing varied waste materials, offering valuable guidance for researchers, practitioners, and policymakers striving towards sustainable construction practices.*

Key Words: Lightweight concrete, Waste materials, Sustainability, Empirical investigation ,Fly ash, Recycled aggregates.

1.INTRODUCTION

Lightweight concrete, a specialized variant of traditional concrete, distinguishes itself through its significantly lower density achieved by incorporating lightweight aggregates or air voids. Ranging from 500 to 1850 kg/m^3, its reduced density confers a multitude of benefits, including diminished dead loads, simplified construction logistics, and enhanced thermal insulation. Notably, the incorporation of lightweight aggregates fosters superior thermal resistance and fire resilience, augmenting its suitability for diverse structural applications. Moreover, its composition often integrates recycled or industrial by-product aggregates, bolstering sustainability efforts by mitigating resource depletion and waste accumulation. From load-bearing walls to insulated roofing systems, lightweight concrete finds extensive use in both residential and commercial construction, underlining its versatility and burgeoning significance in modern construction practices.

Figure-1: Light Weight Concrete.

1.1.PURPOSE OF THE LIGHT WEIGHT CONCRETE

The purpose of lightweight concrete is multifaceted and driven by diverse considerations within the realm of construction. Fundamentally, it aims to alleviate structural burdens by significantly reducing the weight of concrete elements. Achieved through the integration of lightweight aggregates or air voids, this weight reduction not only eases construction logistics but also holds potential for cost savings in foundational requirements. Moreover, lightweight concrete serves as a key player in enhancing thermal insulation within structures, thereby curbing energy consumption for heating and cooling, and fostering occupant comfort. Its ability to offer heightened fire resistance further underscores its significance in safeguarding structures against fire hazards. Beyond functional attributes, lightweight concrete aligns closely with sustainability imperatives by integrating recycled or industrial by-product aggregates, thereby curbing resource depletion and waste accumulation. Despite its lower density, the purpose-driven engineering of lightweight concrete ensures it meets stringent structural demands, maintaining strength, durability, and resilience in diverse environmental conditions. This versatility positions lightweight concrete as a versatile solution across a spectrum of construction projects, from high-rise buildings to residential dwellings, embodying a harmonious blend of efficiency, safety, and environmental responsibility.

1.2.PRINCIPLE OF LIGHT CONCRETE

The principle of lightweight concrete revolves around reducing the density of traditional concrete while maintaining or improving its mechanical properties. This is achieved through two main approaches: incorporating lightweight aggregates and introducing air voids.

Lightweight Aggregates: The primary principle involves replacing some or all of the conventional aggregates (such as sand and gravel) with lightweight materials. These lightweight aggregates can include expanded clay, shale, perlite, vermiculite, or pumice. These materials are porous and have lower densities compared to traditional aggregates, thus reducing the overall weight of the concrete mixture.

Air Void Incorporation: Another principle involves incorporating air voids into the concrete mixture. This can be achieved through the addition of air-entraining agents or by using foaming agents. The introduction of air voids reduces the density of the concrete without compromising its strength or structural integrity.

In both cases, the key principle is to reduce the mass of the concrete while ensuring that the resulting material still meets the required performance criteria. This can include considerations such as compressive strength, durability, and thermal properties. By adhering to these principles, lightweight concrete offers advantages such as reduced structural loads, improved thermal insulation, and enhanced sustainability compared to traditional concrete.

2.WASTE MATERIAL IN THE LIGHT WEIGHT CONCRETE

Waste materials play a significant role in the production of lightweight concrete, contributing to both its environmental sustainability and material efficiency. These materials are often utilized as partial replacements for conventional aggregates or cementitious binders, thereby reducing the consumption of natural resources and diverting waste from landfills. Here are some common waste materials used in lightweight concrete production:

Fly Ash: A by-product of coal combustion in power plants, fly ash is a pozzolanic material that can be used as a partial replacement for cement in lightweight concrete mixtures. Its fine particle size and spherical shape contribute to improved workability and durability, while also reducing the overall carbon footprint of concrete production.

Figure-2: Fly Ash.

Ground Granulated Blast Furnace Slag (GGBFS): Produced as a by-product in the manufacturing of iron, GGBFS is rich in silicates and alumina compounds. When used as a supplementary cementitious material in lightweight concrete, GGBFS enhances long-term strength development, reduces heat generation during hydration, and improves resistance to sulfate attack and alkali-silica reaction.

Recycled Aggregates: Crushed concrete rubble or demolished construction waste can be processed and used as lightweight aggregates in concrete production. By incorporating recycled aggregates, lightweight concrete not only reduces the demand for virgin aggregates but also minimizes the environmental impact associated with quarrying and transportation.

Expanded Polystyrene (EPS) Beads: EPS beads, derived from recycled polystyrene foam, are lightweight and possess excellent insulating properties. When added to concrete mixtures, EPS beads create air voids within the matrix, resulting in a lightweight, thermally insulating material suitable for applications requiring both structural integrity and thermal efficiency.

Silica Fume: A by-product of silicon and ferrosilicon alloy production, silica fume is a highly reactive pozzolan that enhances the strength, durability, and impermeability of lightweight concrete. Its ultrafine particles fill voids between cement grains, densifying the concrete matrix and reducing permeability, thereby improving resistance to chemical attack and freeze-thaw cycles.

Figure-3: Silica Fume

Recycled Plastic Waste: In recent years, there has been growing interest in incorporating recycled plastic waste, such as plastic bottles or shredded polymer fibers, into lightweight concrete mixtures. These materials can act as lightweight fillers or reinforcement, offering potential benefits in terms of reducing material costs, enhancing ductility, and mitigating environmental pollution.

By integrating these waste materials into lightweight concrete production, construction industry stakeholders can promote sustainable practices while simultaneously improving the performance, efficiency, and environmental footprint of concrete structures. However, it is essential to conduct thorough testing and quality control measures to ensure that the resulting lightweight concrete meets the required standards for strength, durability, and structural integrity.

3.LITERATURE SURVEY

During the literature survey section, our team delved into the research work that has been completed regarding our chosen topic. We thoroughly analyzed and summarized all relevant research studies, in order to gain a comprehensive understanding of the existing knowledge on this subject matter. Our findings and insights are presented below for your reference.

Emilia et.al. The aim of the study was to investigate the feasibility of utilizing Vermiculite as a substitute for fine aggregate in concrete composites and to delineate the guidelines for its usage. The elements of concrete composites were subjected to rigorous testing, and the results have been documented. This type of research can furnish precise data regarding the percentage increase in Compressive and Flexural strength of Concrete, along with statistics on Durability. Consequently, vermiculite can be deemed a highly effective alternative. Overall, this research contributes significantly towards enhancing the sustainability of concrete production by reducing reliance on traditional materials and promoting innovative substitutes.

Jurga et.al. In the quest for more sustainable and eco-friendly construction practices, alternative materials are being explored. Among these materials are quarry dust and Marble Sludge power (MSP). Recent investigations into the use of MSP as a filler in self-compacting concrete (SCC) manufacture have yielded promising results. The addition of up to 30% quarry dust, 14% clinkers, and 8% limestone powder with silica fume as a mineral admixture did not affect the self-compacting property of SCC. This suggests that MSP could be a viable alternative to traditional fillers used in SCC production. While further research is needed to fully understand the behavior of high-strength self-compacting concrete (HSSCC), some conclusive discoveries have been made thus far. These findings reinforce the feasibility of using alternative materials like MSP in construction projects. By incorporating sustainable practices like these, we can work towards creating a more environmentally conscious built environment while still maintaining structural integrity and durability.

Fahad, Idrees. Due to growing concerns about ecological and environmental issues, a recent experimental study on the availability of natural sand for concrete has been postponed. The purpose of this study is to investigate how chloride penetration affects self-compacting green concrete (SCGC) made from marble sludge powder (MSP) and quarry rock dust (CRD) obtained from various types of industrial waste. MSP may be used as a filler in order to reduce the number of pores in concrete, which can increase its lifespan. Multiple experiments have been conducted to determine the effects of MSP and CRD on SCGC's resistance to chloride when used together. Based on the findings, it was discovered that using CRD with 15% MSP is more preferable than river sand when producing SCGC. This information can be applied by construction professionals in order to create stronger and more durable structures while also reducing environmental impact.

Nakkeeran et.al. In order to achieve a plastic density of 1900 kg/m3, two different foam concrete mixes were developed - one with sand and the other without. To determine the strength of foamed concrete compared to conventional concrete, force and percentage results were analyzed. A total of eighteen cube specimens were created and subjected to both physical (Density) and specialized structural (Compressive Strength) testing in various combinations. By analyzing these results, we can gain a better understanding of the potential benefits and drawbacks of using foam concrete in construction projects.

Firas et.al. The use of common sand as fine aggregate in concrete is a crucial component in construction projects around the world. However, with extensive sand mining operations, there is an increasing concern over the reduction of biodiversity and the potential increase in scour depth and surge risks. To address this issue, it has become imperative to explore alternative options for concrete materials. One such option is marble, which is extensively used in the building process. During the handling of marble squares, a significant amount (around 20-25%) of raw marble is converted into powdered form. Unfortunately, this practice has detrimental effects on the environment and the marble industry bears some responsibility for it.

Recent studies have shown that recycled marble powder could be a viable replacement for sand in building materials. By replacing 10%, 15%, and 20% of cement with recycled marble powder, we analyzed the properties of the resulting cement. This finding offers a promising solution to mitigate the negative impact caused by sand mining while simultaneously providing an eco-friendly alternative for builders worldwide. As we continue to explore sustainable practices in construction, it's essential to consider innovative solutions like these that can help us build a better future for generations to come.

Aparna, Bindu. In the realm of construction, the use of charred brick has become indispensable for many countries. The current focus on eco-friendly and non-detrimental solutions to national issues has made it imperative to find materials that meet both the requirements of the building industry and the goals of the green movement. One such material is foam, which can be utilized at temperatures below freezing, making it an excellent choice for insulation and soundproofing. Foamed cement is a popular choice in underdeveloped nations due to its ability to provide a lightweight yet sturdy base for construction. By using a slurry of cement, fly ash, and water mixed with pre-frothed stable foam in a solid blender, concrete squares can be created with varying thicknesses ranging from 4-8 inches.

This study aims to explore how this phenomenon has affected the progress of concrete production. It demonstrates how the use of lightweight concrete squares can help satisfy both industry requirements and environmental goals by providing a sustainable solution that reduces carbon emissions during construction. By embracing innovative materials like foamed cement and lightweight concrete squares, we can build structures that are not only durable but also environmentally friendly. As we continue to prioritize eco-friendly solutions in all aspects of life, it is crucial that we consider these options for construction projects around the world.

Ambreen. The topic of discussion was the composition and characteristics of "foamed" concrete, which is primarily made up of cement, water, fine aggregate, and air. Notably absent from this type of concrete is a coarse aggregate phase, resulting in a distinct uniformity in texture. The properties of foamed concrete are heavily influenced by both the binder and the foaming agent used - with chemical and natural agents being common choices. To increase the strength of foam concrete, a binding component known as silica fume is often added to the mix. This study centers on understanding how silica fume affects the production process and overall characteristics of foamed concrete. By summarizing current knowledge in this field, it aims to provide valuable insights into improving the quality and durability of this unique building material.

Fahad. Aerated lightweight concrete is a material that has air pockets within it, which gives it some advantages over conventional concrete. One of these advantages is a lower thermal expansion coefficient, meaning that the material is less likely to expand or contract due to temperature changes. Additionally, aerated lightweight concrete has greater noise-deadening ability, which can be useful in structures where sound insulation is important.

The two primary constituents of aerated lightweight concrete are foamed concrete and autoclaved concrete. These two types of concrete are made using different methods and have different properties. By systematically dissecting each type of concrete, we can better understand their individual properties and how they contribute to the overall characteristics of aerated lightweight concrete. There are many possible components, additives, and applications of aerated concrete. Some examples include using it as insulation in walls or roofs, creating precast blocks or panels for construction projects, or using it as a base material for roads or other infrastructure projects. When studying aerated lightweight materials, researchers often focus on topics such as porosity (the amount of open space within the material), permeability (how easily fluids can pass through the material), compressive strength (how much weight the material can support without breaking), and splitting strength (how well the material resists cracking under pressure). By understanding these factors and how they relate to aerated lightweight concrete specifically, we can continue to develop new and innovative uses for this versatile building material.

Sercan et.al. The benefits of using fly ash concrete have been proven to be both economical and environmentally friendly. In fact, the production of concrete may even contribute to environmental sustainability. Despite this, India only utilizes around half of its fly ash output. However, there is hope for the global economy as infrastructure construction is currently at an all-time high worldwide. Cement is the most widely used building material and its manufacture contributes to 7 percent of all human-caused carbon dioxide emissions. As carbon dioxide is the most dangerous greenhouse gas that can raise global temperatures, there has been widespread interest in finding practical alternatives to CO_2 for use in cement production. Unfortunately, no such alternative has been found yet. Recently, there has been a shift towards utilizing building materials with a reduced cement content, and concrete is a prime example of this trend. This paper aims to discuss how fly ash concrete can be used as a solution to two major problems: (a) the massive disposal of fly ash produced by thermal power plants that results in environmental degradation through large landfills; and (b) the high percentage of carbon dioxide emissions into the atmosphere from the cement industry. By using fly ash in concrete production, we can not only decrease our reliance on cement but also reduce waste and lower carbon emissions, thus contributing positively towards environmental sustainability.

Steve. In this study, various materials were used in foamed concrete experiments, including AR-glass, polypropylene, steel, kenaf and oil palm fiber. The aim was to produce foamed concrete mixtures with a target density of 1000kg/m3 using a specific mix ratio of (1:1.5:0.45). The fibers were added as fillers and maintained at a volume of between 0.25 to 0.40 percent throughout the experiment. The focus was on examining the impact of fiber on the durability of foamed concrete by measuring its permeability to water, thermal expansion and shrinkage. The results showed that AR-glass fiber had the lowest drying shrinkage value compared to other fibers used in the experiment. This suggests that AR-glass can be an effective material for improving the durability of foamed concrete structures. These findings have important implications for construction engineers and architects who are looking for sustainable building materials that can withstand environmental pressures over time. Overall, this study highlights the potential benefits of incorporating various types of fibers into foamed concrete mixtures to enhance their properties and performance. It also underscores the importance of conducting research into innovative building materials that can contribute to more sustainable and resilient infrastructure in our communities.

Rong et.al. The study aimed to examine the impact of MSP and CRD on the toughness and tensile strength of SCC. To achieve this objective, a series of durability tests were conducted, including compression, split tensile strength, water absorption, permeability to chloride ions, electrical resistance, and half-cell potential. The findings revealed that incorporating MSP as a substitute for up to 15% of the CRD could enhance the compressive strength of SCC. Moreover, there was a direct correlation between compressive strength and split tensile strength. Interestingly, the electrical resistivity was highest in normal concrete with 100% CRD; however, significant improvements were observed in SCC samples. In summary, these results highlight the potential benefits of using MSP as an alternative to CRD in enhancing the mechanical properties of SCC while maintaining its durability characteristics.

Saad, Abbas. The study investigated the effects of using quarry dust as a partial replacement for sand in foam concrete. The goal was to analyze the compressive strength of this type of concrete. To achieve this, various ratios of quarry dust-to-foam concrete were developed and tested, ranging from 10% to 50%. Cube tests were conducted to determine the compressive strength of the resulting concrete, with results compared to those obtained from control foam concrete. The findings indicate that quarry dust foam concrete has a compressive strength that is approximately 43% higher than that of conventional foam concrete.

As a result of these promising results, foam concrete blocks may be considered as an alternative to traditional burnt clay bricks. A cost-effectiveness analysis was conducted to assess the viability of manufacturing and deploying foam concrete bricks. This study demonstrates that utilizing quarry dust in foam concrete can lead to superior performance when compared to traditional sand-based foams, providing an eco-friendly and cost-effective solution for construction purposes.

Silvina et.al. In this write-up, we delve into an in-depth analysis of the characteristics and manufacturing methods of foam concrete. This material poses a unique challenge when it comes to its creation and utilization. We explore the current state of knowledge regarding the impact of blending various materials, admixtures, and fibers on the functionality and effectiveness of foamed concrete. Furthermore, we argue that any future work done in this field should be founded on principles of sustainable development. By doing so, we can ensure that our efforts towards developing foam concrete are both environmentally conscious and economically viable in the long run.

Febryyandi, Sinta. The present study demonstrates the impact of blending cement with river sand, sea sand, and quarry dust on the durability of foam concrete. Varying ratios of cement-to-aggregate by weight including 0:1, 1:3, 1:2, and 1:3 were employed. The mixture was then combined with water and a foaming agent before being poured into a mold measuring 19 centimetres in length, 9 centimetres in width, and 9 centimetres in height to create brick samples. These samples were cured for twenty-eight days in water prior to testing their compressive strength at room temperature. Additionally, after curing for twenty-eight days at room temperature they were subjected to heating at one hundred degrees Celsius for twenty-four hours followed by immersion in water before assessing their compressive strength again. Both control and experimental concrete underwent heat resistance tests while cold shock resistance tests were performed using river sand as filler. The findings suggest that sea sand and quarry dust can be used interchangeably with natural river sand without compromising the performance of foam concrete.

Gavril et.al. According to research, strawboard-lined cold-formed steel high-strength lightweight foamed concrete (CSHLFC) shear walls are an effective solution for improving the seismic behavior of CFS shear walls. To determine the failure mode, load capacity, ductility, stiffness characteristic, and energy dissipation of these walls, six full-scale shear wall specimens were tested under different conditions such as a range of HLFC densities, stud section areas, wall thicknesses, and vertical loads. The results showed that the seismic performance and failure mechanism of shear walls were more influenced by HLFC than previously thought. The wall's ductility and energy absorption characteristics were proven by its various modes of failure including cracking and crushing of HLFC, cracking of straw boards, local buckling of studs, and relative sliding between HLFC and studs. The compressive bearing capacity of HLFC improved the shear strength and stiffness while also restricting impact on the steel frame. It was observed that when the vertical load was increased, the seismic performance suffered. However, increasing wall thickness, HLFC density grade or stud section size improved its overall performance. These findings indicate that CSHLFC shear walls can be a reliable option in seismic zones where safety is a top priority.

Sami, Yazan. Empirical findings indicate that quarry rock dust and marble muck powder are viable alternatives to sand in concrete. Various research studies have compared the durability of green concrete with that of natural sand concrete. As per these studies, quarry rock dust-based concrete exhibits over 14% greater strength than conventional concrete, as measured by its compressive strength, split tensile strength, and durability. Furthermore, it is observed that the harmful impact of sulfates on such kind of concrete is significantly diminished. If you aim to enhance your environmental credentials while ensuring long-lasting performance even under extreme conditions, consider employing green concrete in your next project.

Ammar et.al. The paper provided delves into the subject of lightweight self-compacting concrete (LWSCC) and its development through the utilization of waste materials such as Expanded Polystyrene Beads (EPS) and Waste Plastic Fibers (WPFs). The focus of the paper is directed towards examining the fresh, hardened, and mechanical properties of LWSCC mixtures. However, it must be noted that there is no explicit mention made regarding an empirical investigation into lightweight concrete that utilizes a diverse range of waste materials. It is important to limit the use of waste materials such as EPS and WPFs in SCC due to their low levels of hardened and durability properties. To obtain full strength and durability benefits, a longer curing time period of 56 to 90 days is recommended.

Hussein et.al. The provided paper investigates the use of waste crushed clay brick powder as a filler material to produce lightweight concrete and evaluates its effects on various physical and microstructural characteristics of the concrete. However, it does not specifically mention the utilization of other waste materials in the empirical investigation of lightweight concrete. In this article , the effect of using an air-entraining agent (AEA) for additional pore formation on concrete performance was evaluated and the results indicated that the use of CBP as filler material enhances the mechanical and durability characteristics of the concrete.

Thamer et.al. The paper discusses the use of waste materials as lightweight aggregates in concrete, but it does not specifically mention an empirical investigation of lightweight concrete using varied waste materials. In this paper , the authors discussed the materials used as lightweight aggregate in concrete and showed that utilizing trash as a lightweight aggregate not only improves the characteristics of concrete but also gives a sustainable approach to minimize global waste.

Hyejin et.al. The provided paper focuses on the empirical investigation of lightweight concrete using bottom ash aggregates as a replacement for natural aggregates. It does not specifically mention the utilization of other waste materials. Empirical equations are proposed to predict mechanical properties of lightweight concrete with bottom ash aggregate. The proposed equations show reasonably positive agreement with measured value.

4. CONCLUSION

In conclusion, the empirical investigation of lightweight concrete utilizing diverse waste materials presents a promising avenue for sustainable construction practices. Through a comprehensive review, it is evident that the incorporation of waste materials not only reduces environmental impact but also enhances the properties of lightweight concrete. The utilization of waste materials such as fly ash, slag, recycled aggregates, and others contributes to the development of high-performance lightweight concrete with improved mechanical, thermal, and durability characteristics. However, further research is warranted to optimize mix designs, understand long-term performance, and address potential challenges associated with the use of these materials. Overall, the findings underscore the significance of continued exploration and implementation of waste-based lightweight concrete in construction to foster environmental sustainability and resource efficiency.

REFERENCE

1) Potential of Waste Material as Coarse Aggregates for Lightweight Concrete Production: A Sustainable Approach. Potential of Waste Material as Coarse Aggregates for Lightweight Concrete Production: A Sustainable Approach.

2) The Effect of Expanded Glass and Crushed Expanded Polystyrene on the Performance Characteristics of Lightweight Concrete. The Effect of Expanded Glass and Crushed Expanded Polystyrene on the Performance Characteristics of Lightweight Concrete. Applied Sciences.

3) Exploring the Effect of Different Waste Fillers in Manufactured Sustainable Plastic Aggregates Matrix on the Structural Lightweight Green Concrete. Exploring the Effect of Different Waste Fillers in Manufactured Sustainable Plastic Aggregates Matrix on the Structural Lightweight Green Concrete. Sustainability.

4) Lightweight Heat Resistant Concrete Panels Using Recycled Materials. Lightweight Heat Resistant Concrete Panels Using Recycled Materials. IOP Conference Series: Earth and Environmental Science.

5) Experimental investigation and optimization of lightweight concrete bricks developed using vermiculite. Experimental investigation and optimization of lightweight concrete bricks developed using vermiculite. Frontiers in Materials.

6) A study of characteristics of man-made lightweight aggregate and lightweight concrete made from expanded polystyrene (eps) and cement mortar. A study of characteristics of man-made lightweight aggregate and lightweight concrete made from expanded polystyrene (eps) and cement mortar. Open Engineering.

7) Utilization of waste materials as a substitute for the sand drain in clayey soil. Utilization of waste materials as a substitute for the sand drain in clayey soil. International Journal of Geo-engineering.

8) Study on Properties of Concrete After Incorporating Waste Materials. Study on Properties of Concrete After Incorporating Waste Materials. IOP Conference Series.

9) A Sustainable Alternative for Green Structural Lightweight Concrete: Performance Evaluation. A Sustainable Alternative for Green Structural Lightweight Concrete: Performance Evaluation. Materials.

10) Utilization of Recyclable Concrete and Ceramic Waste as Filling Material in Hot Mix Asphalt. Utilization of Recyclable Concrete and Ceramic Waste as Filling Material in Hot Mix Asphalt. Periodica Polytechnica-civil Engineering.

11) Utilization of modified plastic waste on the porous concrete block containing fine aggregate. (n.d.). Utilization of modified plastic waste on the porous concrete block containing fine aggregate. 85(4), 143–151. https://doi.org/10.11113/jurnalteknologi.v85.19219

12) Study of the Compressive Properties of Heavy Calcium Carbonate-Reinforced Epoxy Composite Spheres (HC-R-EMS) Composite Lightweight Concrete. (n.d.). Study of the Compressive Properties of Heavy Calcium Carbonate-Reinforced Epoxy Composite Spheres (HC-R-EMS) Composite Lightweight Concrete. 15(5), 1278–1278. https://doi.org/10.3390/polym15051278

13) The Use of Lightweight Aggregate in Concrete: A Review. (2022). The Use of Lightweight Aggregate in Concrete: A Review. 28(11), 1–13.

14) Recycled Construction and Demolition Waste as Supplementary Cementing Materials in Eco-Friendly Concrete. (n.d.). Recycled Construction and Demolition Waste as Supplementary Cementing Materials in Eco-Friendly Concrete. 8(4), 54–54. https://doi.org/10.3390/recycling8040054

15) Analisis Pengaruh Penambahan Kaolin Sebagai Subtitusi Semen Terhadap Kuat Tekan Beton Ringan. (n.d.). Analisis Pengaruh Penambahan Kaolin Sebagai Subtitusi Semen Terhadap Kuat Tekan Beton Ringan. 11(1). https://doi.org/10.36982/jtg.v11i1.2804

16) Experimental Investigation on Mechanical and Thermal Properties of Concrete Using Waste Materials as an Aggregate Substitution. (n.d.). Experimental Investigation on Mechanical and Thermal Properties of Concrete Using Waste Materials as an Aggregate Substitution. 15(5), 1728–1728. https://doi.org/10.3390/ma15051728

17) Uso de materiales ligeros para la producción de hormigón de baja densidad: una revisión literaria. (2022). Uso de materiales ligeros para la producción de hormigón de baja densidad: una revisión literaria. 12(1), 90–101. https://doi.org/10.22320/07190700.2022.12.01.06

18) Experimental Investigation of Recycled Fine Aggregate from Demolition Waste in Concrete. (n.d.). Experimental Investigation of Recycled Fine Aggregate from Demolition Waste in Concrete. 14(17), 10787–10787. https://doi.org/10.3390/su141710787

19) Alkali Activated Concrete using Industrial and Agro Waste-Mix proportioning and Experimental Investigation. (n.d.). Alkali Activated Concrete using Industrial and Agro Waste-Mix proportioning and Experimental Investigation. 1, 1327–1331. https://doi.org/10.38208/acp.v1.659

20) Alkali Activated Concrete using Industrial and Agro Waste-Mix proportioning and Experimental Investigation. (n.d.). Alkali Activated Concrete using Industrial and Agro Waste-Mix proportioning and Experimental Investigation. 1, 1327–1331. https://doi.org/10.38208/acp.v1.659

21) The Effect of Finely-Grinded Crushed Brick Powder on Physical and Microstructural Characteristics of

Lightweight Concrete. (n.d.). The Effect of Finely-Grinded Crushed Brick Powder on Physical and Microstructural Characteristics of Lightweight Concrete. 12(2), 159–159. https://doi.org/10.3390/min12020159

22) Sustainable Materials Used as Lightweight Aggregate :(An Overview). (n.d.). Sustainable Materials Used as Lightweight Aggregate :(An Overview). 961(1), 012027–012027. https://doi.org/10.1088/1755-1315/961/1/012027

23) Improving nonlinear behavior and tensile and compressive strengths of sustainable lightweight concrete using waste glass powder, nanosilica, and recycled polypropylene fiber. (2022). Improving nonlinear behavior and tensile and compressive strengths of sustainable lightweight concrete using waste glass powder, nanosilica, and recycled polypropylene fiber. 11(1), 58–70. https://doi.org/10.1515/nleng-2022-0008