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Comparative Study of Strength Parameters on Concrete Made Using Expanded Polystyrene Beads, Lightweight Expanded Clay Aggregate and Waste Iron Chips- A Review

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Abstract: The demand for sustainable and cost-effective construction materials has accelerated the exploration of alternative aggregates to replace conventional coarse aggregates in concrete production. This review focuses on the comparative analysis of strength parameters in concrete produced using Expanded Polystyrene (EPS) beads, Lightweight Expanded Clay Aggregate (LECA), and waste iron chips. These materials offer promising advantages in terms of environmental sustainability, structural efficiency, and resource optimization. While EPS beads and LECA provide significant weight reduction and improved thermal insulation, waste iron chips enhance the density and potentially increase the compressive strength due to their metallic composition. This paper presents a detailed examination of existing studies to highlight the mechanical performance, workability, durability, and potential structural applications of concrete modified with these lightweight and waste-derived materials.
Keywords: Sustainable construction, Lightweight concrete, Expanded Polystyrene (EPS) beads, Lightweight Expanded Clay Aggregate (LECA), Waste iron chips.

I. INTRODUCTION

Concrete is the most widely used construction material globally, but its production contributes significantly to environmental degradation due to the high demand for natural aggregates and cement. With growing concerns about sustainability, the construction industry has been moving toward alternative materials that reduce environmental impact without compromising performance. Lightweight concrete (LWC) has emerged as a viable solution, offering reduced structural dead load, enhanced thermal properties, and improved cost-efficiency. Incorporating non-traditional materials such as Expanded Polystyrene (EPS) beads, Lightweight Expanded Clay Aggregate (LECA), and waste iron chips as partial or full replacements for conventional aggregates provides a means to achieve sustainability goals. EPS beads are thermoplastic polymers that significantly reduce concrete density and improve insulation, although their low strength can be a concern. LECA is a sintered clay-based aggregate with high strength-to-weight ratio and good fire resistance, making it suitable for structural and non-structural applications. Waste iron chips, a by-product of metal industries, offer a dual benefit of waste utilization and enhanced mechanical properties when used judiciously in concrete. The need to understand how these alternatives compare in terms of compressive, tensile, and flexural strength is vital for determining their suitability in real-world applications. This paper reviews various studies focusing on the individual and comparative performance of these materials in concrete mixes to assess their effectiveness and limitations.

II. LITERATURE REVIEW

Numerous studies have investigated the performance of lightweight and waste materials in concrete. Researchers evaluating EPS concrete have noted that its unit weight reduces significantly, typically ranging from 1000 to 1800 kg/m³, making it ideal for non-load-bearing structures. However, the compressive strength tends to decline with increased EPS content, often falling below 20 MPa, which limits its structural applicability. To mitigate this, researchers have explored combining EPS with supplementary cementitious materials like fly ash and silica fume to improve strength and bond. LECA-based concrete, on the other hand, has demonstrated more balanced performance. Its strength ranges from 15 to 40 MPa, depending on the mix design and curing methods. LECA enhances durability, provides good thermal insulation, and reduces dead weight without drastically compromising strength.

Studies comparing LECA to EPS show that LECA provides better mechanical strength, though at a slightly higher cost and weight. In contrast, waste iron chips, often derived from lathe or milling operations, have shown to enhance compressive and flexural strength due to their metallic stiffness and improved bonding with cement paste. Concrete mixes incorporating iron chips, even at partial replacement levels (5–15%), have reported compressive strengths exceeding 30 MPa, which surpasses that of conventional concrete in certain cases. However, concerns about corrosion, workability, and uniform distribution need to be addressed. Several comparative studies suggest that a hybrid approach, combining lightweight aggregates with metallic waste, can lead to concrete that is both structurally competent and sustainable. One such study reported an optimal mix design that utilized 50% LECA and 10% iron chips, achieving a balance between reduced weight and improved strength. Durability studies also indicate that LECA and iron chip concretes perform well in freeze-thaw and chemical attack environments, whereas EPS concretes are better suited for insulation and non-structural elements. Overall, the literature indicates that each material offers distinct advantages, and their use should be tailored to the intended structural function and performance requirements.

A. Previous Studies Research Article

Concrete is the most widely used construction material due to its excellent compressive strength, durability, and workability. However, traditional concrete is heavy, which increases structural loads and construction costs. To address this, researchers have explored lightweight aggregate concrete (LWAC) using alternative materials such as Expanded Polystyrene (EPS) beads, Lightweight Expanded Clay Aggregate (LECA), and Waste Iron Chips (WIC). Expanded polystyrene (EPS) beads, a by-product of plastic industries, are extensively studied for their potential as lightweight aggregates due to their low density, thermal insulation properties, and resistance to chemical degradation. Several studies indicate that replacing a portion of conventional coarse aggregate with EPS beads reduces density and enhances workability but leads to a decrease in compressive strength due to the weaker bond between EPS and the cement matrix. However, modifications like surface treatment of EPS or adding mineral admixtures such as silica fume and fly ash have shown improvements in interfacial bonding, thereby enhancing mechanical performance. On the other hand, Lightweight Expanded Clay Aggregate (LECA), a ceramic material produced by expanding clay at high temperatures, is another promising lightweight aggregate used to enhance the mechanical properties of concrete. Research indicates that LECA-based concrete exhibits better compressive strength compared to EPS concrete due to its porous nature, improved bond strength, and adequate load-bearing capacity. Additionally, LECA offers enhanced durability, thermal resistance, and improved ductility, making it a viable alternative in structural applications where weight reduction is critical. In contrast, the use of Waste Iron Chips (WIC) as a partial replacement for coarse aggregates is an innovative approach to sustainable construction and industrial waste utilization. Waste iron chips, generated from machining and metal fabrication processes, contribute to enhancing the mechanical properties of concrete by improving compressive strength, flexural strength, and toughness due to their higher density and rigidity. Several experimental studies have demonstrated that incorporating iron chips in concrete significantly increases its load-bearing capacity while slightly increasing the self-weight. Moreover, the synergistic combination of EPS, LECA, and WIC in different proportions has been explored to develop a balanced mix that optimizes both strength and weight reduction. Research findings suggest that hybrid combinations of these materials, when proportioned correctly, can mitigate the strength loss typically associated with lightweight aggregates while leveraging their benefits for structural and non-structural applications. Furthermore, durability aspects such as water absorption, shrinkage, and chloride permeability vary based on the type and percentage of replacement. EPS-based concrete generally exhibits higher water absorption due to its porous nature, whereas WIC addition can lead to increased density, reducing permeability. Additionally, LECA-based concrete demonstrates better impact resistance and thermal insulation compared to conventional concrete. Overall, the comparative study of EPS beads, LECA, and WIC in concrete presents a promising direction for sustainable, lightweight, and high-strength construction materials. However, further research is required to establish optimal mix designs, long-term durability, and cost-effectiveness for large-scale implementation in the construction industry.

1) Effect of Expanded polystyrene (EPS) on Strength Parameters of Concrete as a Partial Replacement of Coarse Aggregates by Hitesh Patidar, Mayur Singi, Abhijeet Bhawsar (2019)- Patidar et al. (2019) conducted an extensive study on the effect of Expanded Polystyrene (EPS) as a partial replacement for coarse aggregates in concrete to address sustainability concerns and the increasing demand for construction materials. EPS, a lightweight and non-biodegradable material derived from packaging industries, presents an opportunity for sustainable concrete production. The research aimed to analyze the influence of varying percentages of EPS replacement (5%, 10%, 15%, 20%, 25%, and 30%) in M30 and M40 grade concrete on key mechanical properties, including compressive strength, split tensile strength, and flexural strength. The study found that the incorporation of EPS significantly affects the density and mechanical properties of hardened concrete. As the percentage of EPS replacement increased, a reduction in compressive strength was observed, primarily due to the lower density and weaker bond between the polystyrene beads and cement matrix. However, the concrete mix demonstrated high workability even at low water-cement ratios, which can be beneficial for specific construction applications requiring lightweight concrete. The experimental results indicated that while EPS-modified concrete does not match the strength characteristics of conventional concrete, it offers advantages such as reduced self-weight and improved workability. This makes it suitable for non-load-bearing structures and insulation applications in the construction industry. The study emphasizes the potential of EPS in sustainable construction and highlights the necessity of optimizing mix proportions to achieve an ideal balance between strength and workability.

2) Physical and Mechanical Properties of a Bulk Lightweight Concrete with Expanded Polystyrene (EPS) Beads and Soft Marine Clay by Jianguo Wang, Bowen Hu and Jia Hwei Soon (2019)- Wang et al. (2019) conducted a comprehensive study on the physical and mechanical properties of a bulk lightweight concrete incorporating Expanded Polystyrene (EPS) beads and soft marine clay. The research aimed to investigate the influence of EPS and cement content on mass density, stress–strain behavior, and compressive strength under varying confining pressures. The lightweight bulk filling material was fabricated using a combination of Singapore marine clay, ordinary Portland cement, and EPS beads, and was subjected to unconsolidated and undrained (UU) triaxial tests. Different mix ratios were examined, where the mass ratio of EPS beads to dry clay (E/S) was varied from 0% to 4%, and the cement-to-dry-clay ratio (C/S) was set at 10% and 15%. Additionally, the curing duration of the samples was considered, with tests conducted after three, seven, and 28 days. The study revealed that the mass density of the material was primarily influenced by the EPS content. An increase in EPS content from 0% to 4% resulted in a significant reduction in mass density—by 55.6% for the C/S ratio of 10% and by 54.9% for the C/S ratio of 15% after three curing days. Furthermore, shear failure was found to occur more easily in specimens with higher cement content and lower confining pressure. The research also established empirical relationships between compressive strength and mass density or failure strain using power functions. It was observed that increasing the cement content while reducing the EPS content led to an increase in both mass density and compressive strength. Additionally, the compressive strength demonstrated a logarithmic increase with curing time, with correlation coefficients ranging from 0.83 to 0.97 across different confining pressures. These findings provide valuable empirical formulae for estimating the physical and mechanical behavior of lightweight concrete in various engineering applications, particularly in geotechnical and construction fields.

3) Light Weight Concrete by Using Eps Beads by Prof. Ashish S. Moon, Lokesh S. Selokar, Anuradha I. Patle (2020)- Moon et al. (2020) conducted a study on lightweight concrete using Expanded Polystyrene (EPS) beads to analyze its compressive strength and compare it with conventional concrete. The research aimed to evaluate the effect of incorporating EPS beads as a partial replacement of coarse aggregates in M25 grade concrete, following IS 10262:2009 guidelines. The study also included the addition of 30% fly ash to enhance the properties of lightweight concrete. The experimental investigation involved preparing concrete cubes with varying EPS replacement levels—5%, 10%, 15%, 20%, 25%, and 30%—and testing their compressive strength after 7 and 28 days of curing. The results indicated that the compressive strength of the concrete decreased as the percentage of EPS beads increased. Among all tested samples, the mix with 5% EPS beads exhibited the highest compressive strength, with recorded values of 8 MPa and 11 MPa after 7 and 28 days of curing, respectively. This suggests that while EPS contributes to reducing the self-weight of concrete, excessive replacement negatively impacts strength due to the lightweight nature and low bonding capacity of EPS beads within the cement matrix. The study concluded that lightweight concrete with EPS beads can be an effective solution for non-structural applications, where reduced weight is a priority over high compressive strength. The findings also emphasize the need for an optimized mix proportion to balance weight reduction and mechanical performance in lightweight concrete applications.

4) The Effect of Expanded Glass and Crushed Expanded Polystyrene on the Performance Characteristics of Lightweight Concrete by Jurga Šeputytė-Jucikė, Sigitas Vėjelis,Viktor Kizinievič (2023)- Šeputytė-Jucikė et al. (2023) investigated the performance characteristics of lightweight concrete (LWC) incorporating porous aggregates such as expanded glass (EG) from glass waste and crushed expanded polystyrene waste (CEPW) derived from packaging waste. The study aimed to evaluate the impact of these lightweight aggregates on the density, thermal conductivity, mechanical properties, water absorption, deformation behavior, and freeze–thaw resistance of LWC. The research focused on modifying the mix composition by varying the proportions of EG and CEPW while maintaining ordinary Portland cement (OPC) as the binder. The results demonstrated that incorporating CEPW led to a significant reduction in the thermal conductivity of LWC, decreasing from 0.0977 W/(mK) to 0.0720 W/(mK), making it more suitable for thermal insulation applications. Additionally, the presence of CEPW did not adversely affect the compressive and bending strengths, nor did it increase the water absorption of LWC. The freeze–thaw resistance of the LWC was evaluated using two methods: one-side freezing and compressive strength reduction after 25, 100, and 200 freeze–thaw cycles. The findings showed that modifying the LWC structure with CEPW aggregates enhanced durability and reduced deformations, making it a promising material for sustainable and resilient construction.

5) Lightweight self-compacting concrete: A review by Suman Kumar Adhikary, Deepankar Kumar Ashish (2022)- Adhikary et al. (2022) reviewed the advancements in lightweight self-compacting concrete (LWSCC), highlighting its potential for structural and non-structural applications in civil engineering. The study focused on the effects of different types of lightweight aggregates (LWA) on the density, strength, and workability of LWSCC. The review found that larger cell sizes in lightweight aggregates tend to decrease density and mechanical strength. However, LWA contributes to internal curing, positively influencing cement hydration and improving long-term performance. Additionally, the study noted that incorporating nano-materials can enhance the strength properties of LWSCC, while the use of ultrafine particles reduces water absorption, leading to improved durability. It was demonstrated that LWSCC can be developed even with a density below 1000 kg/m³ while maintaining its self-compacting characteristics. Moreover, LWSCC exhibits excellent frost resistance, making it suitable for applications in extreme weather conditions. The review serves as a comprehensive resource for understanding the development and future prospects of LWSCC, promoting its broader acceptance in the construction industry.

6) Review on Parametric Study on Effect of Expanded Polystyrene Beads on Physical Properties of Concrete by Vedanti Puram, Milind Nikhar (2023)- Puram and Nikhar (2023) conducted a review on the impact of expanded polystyrene (EPS) beads on the physical properties of concrete, with a focus on structural lightweight concrete. The study emphasized that lightweight concrete, when combined with steel reinforcement, can provide an economical and sustainable alternative to traditional concrete. The researchers highlighted the increasing use of lightweight aggregates in the construction industry due to their functional and cost advantages, particularly in house-building projects. The paper noted that conventional concrete has a density of 24-25 kN/m³, which contributes significantly to the self-weight of structures. To address this issue, the study explored the use of EPS beads as a partial replacement for coarse aggregate, aiming to produce lightweight concrete while maintaining adequate strength. The research aimed to determine the optimum dosage of EPS beads to balance weight reduction and mechanical performance. The findings suggest that EPS-based lightweight concrete can effectively lower the density of concrete, reduce construction costs, and improve material sustainability, making it a viable solution for modern construction needs.

7) Comparative Study on Light Weight Concrete by using Light Expanded Clay Aggregate and Pumice Stone by K. VarshaSri, G. Vishnu Vardhan, K. Swathi, D. Prasanna (2024)- VarshaSri et al. (2024) conducted a comparative study on lightweight concrete using light expanded clay aggregate (LECA) and pumice stone to improve compressive strength while reducing thickness and weight. The study aimed to analyze the properties of M20-grade lightweight concrete in both fresh and hardened states. The research involved the preparation of unique concrete mixes, with each mix containing three cubes and three cylinders to measure compressive and flexural strength. Additionally, the study investigated the effects of incorporating different mineral admixtures into the concrete mixture. The experimental results demonstrated that strength and weight loss improved simultaneously across multiple trials. Among the materials tested, lightweight expanded clay aggregate (LECA) exhibited superior properties compared to pumice stone and conventional concrete, making it a more effective lightweight aggregate. The findings highlight the potential of LECA as a sustainable and efficient alternative in lightweight concrete applications.

8) Parametric Study on Strength of Light Weight Concrete by using EPS Beads and Bagasse Ash by Abhishek M, Shashi Preetham N, Shreehari P P, Mohammed Akthar S A, Arvind Gowda A (2022)- Abhishek M et al. (2022) conducted a parametric study to evaluate the strength characteristics of lightweight concrete (LWC) incorporating sugarcane bagasse ash (SCBA) and expanded polystyrene (EPS) beads as partial replacements for cement and coarse aggregates, respectively. The study aimed to develop a sustainable lightweight concrete mix by reducing the use of conventional materials while maintaining structural integrity. The research followed the IS 10262:2009 mix design guidelines for M30-grade concrete. EPS beads were replaced at varying percentages (0%, 10%, 20%, 30%, and 40% by volume), while bagasse ash replacement was kept constant at 10% by weight of cement. A chemical admixture was added to achieve the desired slump. Experimental results indicated that compressive strength decreased with increasing EPS bead content. However, the optimum mix was found to be 10% bagasse ash and 10% EPS beads, which provided satisfactory strength while enhancing the lightweight properties of concrete. The study highlights the potential of EPS beads and SCBA in producing eco-friendly and lightweight concrete for various construction applications, such as repairing wooden floors, low thermal conductivity walls, bridge decks, and floating structures.

9) Light Weight Concrete Using EPS (Expanded Polystyrene) Beads by CH. Vinay Kumar, E. Arun, B. Bhaskar (2021)- With the increasing demand for sustainable construction materials, lightweight concrete (LWC) incorporating Expanded Polystyrene (EPS) beads is being explored as a viable alternative. This study by Vinay Kumar et al. (2021) investigates the properties of EPS bead-infused concrete, focusing on its compressive and tensile strengths. The research compares EPS-based lightweight concrete with conventional concrete to assess its viability in construction applications. The experiment involved replacing 50%

of the coarse aggregate with EPS beads in M15-grade concrete, using two different water-cement (W/C) ratios of 0.50 and 0.40. The results indicated that the presence of EPS beads significantly influenced the hardened properties of concrete. While lightweight concrete exhibits reduced density (ranging from 300 to 1850 kg/m³) compared to conventional concrete (2200–2600 kg/m³), it also provides functional and environmental benefits such as enhanced thermal insulation and lower heat conductivity. The study highlights that lightweight concrete's strength varies from 1 MPa to 20 MPa, making it a suitable option for non-structural and some structural applications. Moreover, EPS-based lightweight concrete can be 50-75% lighter than conventional concrete, leading to potential cost savings in construction by reducing self-weight.

10) Proportioning of Lightweight Concrete by the Inclusion of Expanded Polystyrene (EPS) by M. Gunavel1, S. Aishwarya, K. Indhumathi, N. Jalapriya (2020)- This paper explores the characteristics of a novel lightweight concrete incorporating polystyrene, sand, cement, coarse aggregate, and water. The study introduces a simplified and cost-effective mixing method that eliminates the need for complex machinery systems, making it a promising approach for lightweight concrete applications. A key focus of this research is to determine the optimum dosage of Expanded Polystyrene (EPS) beads, which were incorporated into the concrete mix at varying proportions of 10%, 20%, and 30% by volume of fine aggregate. The mechanical properties, including compressive strength, split tensile strength, and flexural strength, were evaluated to assess the performance of the modified concrete. Based on the results obtained, it was observed that an optimal replacement of 10% EPS beads provides a balance between weight reduction and strength retention, making it a viable option for plain concrete structures where M25 grade concrete is typically used. The findings suggest that this lightweight concrete can be effectively utilized in construction applications requiring reduced density while maintaining adequate strength.
11) Physical and Mechanical Properties of Lightweight Expanded Clay Aggregate Concrete by Orkun Uysal, İlbüke Uslu, Can B. Aktaş (2024)- The porous nature of lightweight expanded clay aggregate (LECA) plays a crucial role in determining the physical and mechanical properties of concrete. This study presents a comprehensive experimental investigation involving 13 different mixtures and a total of 234 specimens, evaluating key parameters such as density, absorption capacity, porosity, compressive strength, splitting tensile strength, modulus of elasticity, and the impact of moisture state on LECA concrete. The results indicate that dry compressive strengths of the mixtures ranged between 18 MPa and 38 MPa, with an average increase of 9% compared to moist compressive strength. Furthermore, the modulus of elasticity exhibited a significant reduction when the specimens were oven-dried, showing an average decrease of 26%. The study also critically examines existing modulus of elasticity prediction models, revealing that all models consistently overestimated the dry modulus of elasticity, which poses challenges for structural applications of LECA concrete. To address this issue, a novel predictive model for the modulus of elasticity was developed and validated using independent data from the literature, demonstrating its accuracy and potential for practical application.
12) A study on strength parameters of concrete with expanded fly ash clay aggregate by J. Bright BrabinWinsley, M. Muthukannan (2022)- For decades, significant advancements have been made in developing new processes to enhance the strength of concrete. In countries like India, materials such as fly ash and bottom ash have been widely used to reinforce construction work and serve as key components in Reinforced Cement Concrete (RCC). In recent years, civil engineers and industry professionals have increasingly turned to fly ash as a sustainable alternative for building construction. One of the notable developments in this field is the incorporation of Expanded Fly Ash Clay Aggregate (EFCA) alongside fly ash and bottom ash. This study investigates the use of EFCA in an M20 concrete mix, incorporating cement, fine aggregate, bottom ash, expanded fly ash clay aggregate, and coarse aggregate at respective proportions of 6%, 12%, 13%, 22%, and 25%. The research evaluates key strength parameters, including compressive strength and split tensile strength, with assessments conducted at curing intervals of 7 days, 28 days, and 56 days. Additionally, the flexural strength of the concrete mix was examined over these durations. The findings are analyzed based on the optimum dosage required for achieving the best balance between compressive strength and split tensile strength, providing valuable insights into the suitability of EFCA as a sustainable material for concrete applications.
13) Experimental Study on Light Weight Concrete by Using Light Expanded Clay Aggregate (LECA) by Arivalagan S, Dinesh Kumar K S A (2022)- This study investigates the structural behavior of lightweight concrete (LWAC) incorporating light expanded clay aggregates (LECA) and normal-weight aggregates, focusing on the effect of partial and full replacement of coarse aggregate with LECA in an M25 concrete mix. The replacement levels considered in this research include 20%, 40%, 60%, 80%, and 100%. The analysis was conducted in both the fresh and hardened states to evaluate the mechanical properties of the concrete, with a primary emphasis on performance parameters such as compressive strength and splitting tensile strength. The results indicate that the density of lightweight concrete varies between 1996 kg/m³ and 1597 kg/m³ as the LECA replacement increases from 40% to 100%. The study highlights that incorporating LECA significantly reduces the overall

weight and cost of concrete by minimizing the dependency on conventional aggregates, making it a more economical and sustainable construction material.

14) Experimental study on strength and durability properties of iron scrap with fly ash-based concrete by R. Dharmara (2021)- Concrete is one of the most widely used materials in modern construction, primarily due to its versatility, durability, and cost-effectiveness. However, concerns about sustainability and resource efficiency have led researchers to explore alternative materials that enhance the mechanical properties of concrete while incorporating industrial waste products. Dharmaraj (2021) conducted an experimental study to analyze the impact of iron scrap and fly ash on the strength and durability properties of concrete. The research investigated the effects of varying percentages of iron scrap (ranging from 2.5% to 15% by volume) in an M20 concrete mix. The study demonstrated that incorporating iron scrap enhanced compressive and flexural strength, with an optimal aspect ratio of 100. Additionally, the inclusion of fly ash as a supplementary material further improved performance, contributing to increased sustainability in concrete production. The study further evaluated durability aspects such as Dorry's abrasion resistance, demonstrating the potential of iron scrap to enhance wear resistance in concrete applications. The findings suggest that utilizing industrial waste steel strips as reinforcement in concrete is both a cost-effective and structurally viable solution for various civil engineering applications. Several studies have explored the integration of alternative materials in concrete to improve mechanical properties and reduce environmental impact. Researchers have previously investigated the influence of steel fibers and fly ash on concrete strength and durability, supporting the assertion that these materials can improve performance characteristics. The findings by Dharmaraj (2021) align with prior research indicating that industrial waste incorporation in concrete not only enhances strength but also promotes sustainability in construction practices.

15) Effect of Recycled Iron Powder as Fine Aggregate on the Mechanical, Durability, and High Temperature Behavior of Mortars by Md Jihad Miah,Md Kawsar Ali,Suvash Chandra Paul (2020)- Sustainable construction practices have increasingly focused on integrating industrial waste materials into cementitious composites to enhance mechanical performance and durability while reducing environmental impact. One such approach involves using recycled iron powder (RIP) as a replacement for natural sand (NS) in mortar, an area explored in recent research. Miah et al. (2020) investigated the effects of incorporating RIP as a fine aggregate in mortar, analyzing its mechanical strength, shrinkage behavior, durability, and residual compressive strength at elevated temperatures (20°C to 600°C). The study incorporated various replacement levels of NS with RIP (ranging from 0% to 50%) and found that an optimal replacement level of 30% resulted in significant improvements in mechanical properties. The 28-day compressive strength increased by 30%, tensile strength by 18%, and flexural strength by 47% compared to conventional mortar. Additionally, the inclusion of RIP led to reduced porosity (by 36%) and capillary water absorption (by 48%), indicating enhanced durability performance. The study also highlighted the thermal resistance of RIP-incorporated mortar, showing that strength degradation was more pronounced at temperatures above 250°C, especially for mixtures containing 50% RIP. Shrinkage behavior varied, with higher RIP content inducing both shrinkage and expansion effects. The research concludes that RIP, when used up to 30% replacement of NS, offers structural benefits while improving durability and sustainability in mortar applications.

16) The implementation of scale and steel chips waste as a replacement for raw sand in concrete manufacturing by Mohamed Alwaeli (2016)- With the increasing scarcity of natural sand and the growing ecological concerns over industrial waste disposal, researchers have explored sustainable alternatives for concrete production. The incorporation of steel industry by-products, such as scale and steel chips waste, into cementitious materials has emerged as a viable solution to enhance mechanical properties while reducing environmental impact. Alwaeli (2016) investigated the feasibility of replacing natural sand with scale and steel chips waste from the iron and steel industries in concrete. The study examined the compressive strength and thickness variations in concrete mixtures containing different percentages (25% to 100%) of scale and steel chips as a replacement for sand. The findings revealed that concrete mixed with steel chips exhibited superior compressive strength compared to conventional concrete, whereas mixtures with over 25% scale waste resulted in strength reduction. Additionally, the research assessed the thickness of mixed concrete shields in comparison to ordinary concrete shields (OC-0) using lead equivalent (LE) for X-ray radiation protection. It was observed that increasing the proportion of scale and steel chips waste led to a decrease in concrete thickness. These results indicate that while steel chips improve strength, scale waste should be used in controlled proportions to avoid compromising compressive strength.

B. Gap Identified

Despite extensive research on lightweight aggregate concrete (LWAC) incorporating Expanded Polystyrene (EPS) beads, Lightweight Expanded Clay Aggregate (LECA), and Waste Iron Chips (WIC), several research gaps remain unaddressed.

Most studies primarily focus on the individual effects of these materials on the mechanical properties of concrete, but limited research has been conducted on the combined use of EPS, LECA, and WIC to achieve an optimal balance between strength, density reduction, and durability. The variation in mix proportions and the absence of standardized guidelines for hybrid aggregate replacement create inconsistencies in reported results, making it difficult to establish universally applicable design recommendations. Moreover, while EPS-based concrete has been widely investigated for its lightweight properties, its strength limitations due to weak bonding with the cement matrix remain a challenge. Although surface treatment methods such as coating or pre-soaking of EPS beads have shown promise in improving adhesion, comprehensive studies on the long-term durability and degradation resistance of such treatments are lacking. Similarly, LECA has demonstrated enhanced strength compared to EPS, but research is limited regarding its performance in aggressive environmental conditions, such as exposure to freeze-thaw cycles, sulfate attack, and carbonation. In the case of WIC, while studies indicate improved mechanical properties due to the higher density and rigidity of iron chips, research on its impact on workability, corrosion potential, and long-term durability is still insufficient. Additionally, the thermal insulation and energy efficiency aspects of LWAC made from these alternative aggregates are understudied, especially in the context of sustainable construction and green building certifications. Another significant research gap lies in the environmental and economic feasibility of integrating EPS, LECA, and WIC in large-scale applications. Most studies focus on laboratory-scale experiments, with minimal research on real-world applications, lifecycle assessment, and cost-benefit analysis.

Furthermore, there is limited investigation into the combined effect of supplementary cementitious materials (SCMs) such as fly ash, silica fume, and ground granulated blast furnace slag (GGBS) in enhancing the performance of these lightweight concrete mixes. The role of fiber reinforcement in mitigating the brittleness of lightweight concrete containing EPS and LECA also remains an underexplored area. Additionally, numerical modeling and predictive analysis techniques, such as artificial intelligence and machine learning, could be employed to optimize mix designs, but research in this domain is scarce. Overall, while existing studies provide valuable insights into the use of EPS, LECA, and WIC in concrete, further investigations are needed to develop standardized mix proportions, assess long-term performance, and establish guidelines for practical applications in structural and non-structural elements. Addressing these research gaps would contribute significantly to advancing lightweight, high-strength, and sustainable concrete solutions for modern construction.

C. Aim Of The Study

The aim of this study is to conduct a comparative analysis of the strength parameters of concrete made using Expanded Polystyrene (EPS) beads, Lightweight Expanded Clay Aggregate (LECA), and Waste Iron Chips (WIC) as partial replacements for conventional aggregates. This research seeks to evaluate the impact of these alternative materials on the mechanical properties of concrete, including compressive strength, flexural strength, and durability. Additionally, the study aims to identify an optimal mix proportion that balances weight reduction and structural performance, making concrete more sustainable and efficient for construction applications. Furthermore, the study will assess the workability, density, water absorption, and thermal insulation properties of the modified concrete mixes to determine their suitability for various structural and non-structural applications. Through experimental investigations and comparative analysis, the research aims to provide insights into the feasibility of using EPS, LECA, and WIC in combination or individually to develop lightweight, high-strength, and eco-friendly concrete solutions.

D. Objectives Of The Study

The objectives of this study are:

1) To investigate the compressive strength of concrete incorporating Expanded Polystyrene (EPS) beads, Lightweight Expanded Clay Aggregate (LECA), and Waste Iron Chips.
2) To evaluate the flexural strength of different concrete mixes containing these alternative aggregates.
3) To assess the split tensile strength characteristics of concrete made with these materials.
4) To compare the performance of each material in enhancing the mechanical properties of concrete.
5) To determine the feasibility of using these materials in practical construction applications based on their strength characteristics and sustainability benefits.

III. CONCLUSION

From the review of current literature, it is evident that the integration of alternative materials such as EPS beads, LECA, and waste iron chips into concrete can significantly influence its mechanical and durability characteristics. EPS beads are most beneficial for lightweight applications where thermal insulation is a priority, though their lower strength limits structural use.

LECA offers a superior balance between weight reduction and mechanical strength, making it a promising substitute for conventional aggregates in both structural and architectural applications. Waste iron chips not only contribute to waste minimization but also enhance strength, particularly in compressive and flexural aspects, though careful mix design is necessary to prevent segregation and corrosion. Comparative studies highlight that hybrid mixes or the combination of these materials may offer optimal performance in terms of both sustainability and structural integrity. Future research should focus on long-term durability studies, corrosion behavior, life cycle assessment, and practical implementation strategies to further explore the feasibility of large-scale adoption. As construction practices shift toward greener technologies, such comparative evaluations serve as a critical foundation for engineering sustainable and high-performance concrete materials.

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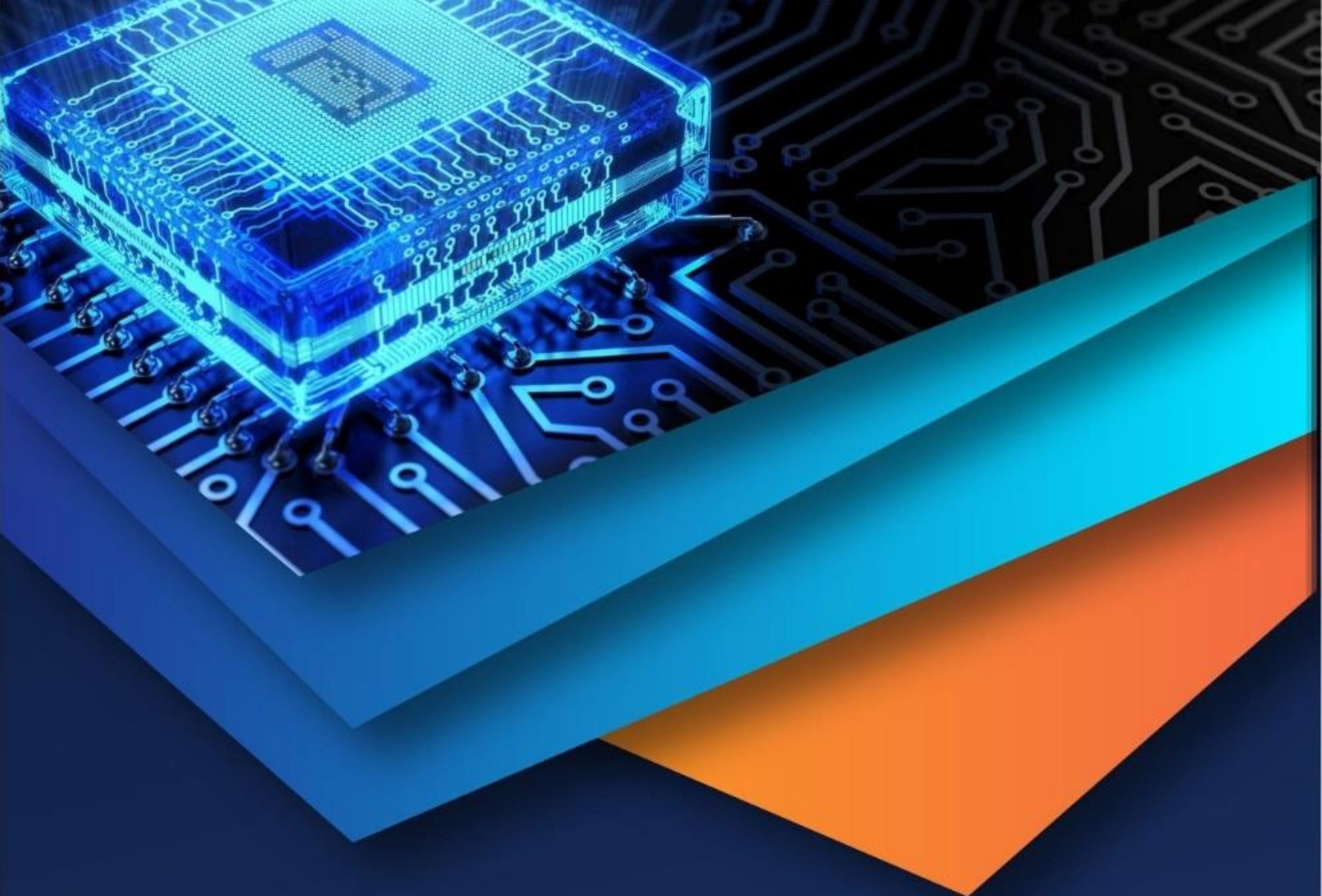

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