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EXPERIMENTAL INVESTIGATION ON PLASTIC WASTE REPLACEMENT OF COARSE AGGREGATE IN CONCRETE: A REVIEW

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Abstract - *Concrete production, a cornerstone of modern construction, is a significant contributor to environmental degradation due to its heavy reliance on natural resources, particularly coarse aggregates. The growing concern over environmental sustainability has prompted researchers to explore alternative materials to replace traditional aggregates. Among these alternatives, plastic waste emerges as a promising candidate due to its abundance and detrimental environmental impacts if not properly managed. This review paper synthesizes the findings of experimental investigations conducted on the replacement of coarse aggregates with plastic waste in concrete mixes. It comprehensively examines the effects of varying plastic aggregate proportions on the mechanical, durability, and microstructural properties of concrete. Additionally, the paper evaluates the influence of different types of plastic waste, processing methods, and chemical treatments on the performance of plastic-modified concrete. Furthermore, environmental implications, economic feasibility, and practical considerations associated with incorporating plastic waste into concrete mixes are discussed. The review underscores the potential of utilizing plastic waste as a sustainable alternative to traditional coarse aggregates in concrete production, while also highlighting challenges and opportunities for further research and implementation in the construction industry.*

Key Words: Concrete, Plastic waste, Coarse aggregate replacement, Sustainability, Environmental impact.

1.BACKGROUND

The integration of plastic waste as a substitute for coarse aggregate in concrete represents a progressive response to the escalating crisis of plastic pollution. Stemming from the mid-20th century surge in plastic production, concerns over environmental degradation prompted a shift towards exploring sustainable solutions for plastic waste management. Through rigorous research and development efforts initiated in the early 2000s, engineers and researchers embarked on a journey to assess the viability of incorporating plastic waste into concrete mixes. Experimental projects conducted throughout the 2000s and early 2010s served as pivotal milestones, providing valuable insights into the mechanical properties, durability, and environmental impact of plastic-infused concrete. Advancements in material science and concrete technology facilitated the transformation of plastic waste into suitable aggregates, further fueling the momentum towards commercialization. Regulatory support and policy initiatives bolstered this momentum, incentivizing companies to embrace recycled materials in construction practices. Today, ongoing research endeavors and collaborative partnerships continue to drive innovation in plastic waste utilization, underscoring the industry's commitment to sustainable development and environmental stewardship.

2.INTRODUCTION TO PLASTIC WASTE IN CONSTRUCTION MATERIALS

In recent years, there has been a notable surge in interest regarding the integration of plastic waste into construction materials, driven by growing concerns over environmental sustainability. This approach involves repurposing recycled plastic into various construction components, ranging from plastic lumber and paving blocks to roofing tiles and insulation materials. Advocates highlight several benefits of incorporating recycled plastic in construction, including diverting plastic from landfills and oceans, conserving natural resources by substituting them with recycled materials, and potentially lowering energy consumption compared to traditional manufacturing processes. However, challenges persist, such as ensuring the quality and durability of these materials, addressing concerns about potential contamination or degradation, and establishing adequate recycling infrastructure. Despite these hurdles, ongoing research and innovation, coupled with increasing public awareness, suggest a promising trajectory for the utilization of plastic waste in construction materials, fostering a more sustainable approach to building practices.

3.TYPES OF PLASTIC WASTE USED IN CONCRETE

Plastic waste can be incorporated into concrete in various forms to enhance its properties and contribute to sustainable construction practices. Some common types of plastic waste used in concrete include:

1. Polyethylene (PE)
2. Polypropylene (PP)
3. Polyethylene Terephthalate (PET)
4. Polystyrene (PS)
5. Polyvinyl Chloride (PVC)
6. Mixed Plastics

3.1.Polyethylene (PE)

PE is a widely used plastic type found in items like plastic bags, bottles, and packaging materials. It can be shredded or ground into small particles and used as a filler or aggregate in concrete mixtures.

3.2.Polypropylene (PP)

PP is commonly found in packaging, textiles, and various household items. In concrete, PP fibers can be added to improve crack resistance, impact strength, and durability. These fibers can help control shrinkage cracking and enhance the performance of the concrete.

3.3.Polyethylene Terephthalate (PET)

PET is commonly used in beverage bottles and food containers. In concrete, PET fibers can be added to improve tensile strength, reduce plastic shrinkage cracking, and enhance the ductility of the material.

3.4.Polystyrene (PS)

PS is found in foam packaging, disposable cups, and insulation materials. In concrete, recycled PS can be used as lightweight aggregates or as an additive to improve insulation properties. It can also be used in the form of expanded polystyrene (EPS) beads to reduce the density of concrete and enhance its thermal properties.

3.5.Polyvinyl Chloride (PVC)

PVC is commonly used in pipes, fittings, and construction materials. While PVC is not typically used directly in concrete due to concerns about its chemical composition and potential for leaching, it can be recycled and used in other applications related to construction, such as plastic lumber or formwork.

3.6.Mixed Plastics

Various types of mixed plastics, including those from household waste or industrial sources, can be shredded and used as aggregates or fillers in concrete mixtures. These mixed plastics can contribute to reducing the environmental impact of plastic waste while providing additional benefits to the concrete material.

4.ENVIRONMENTAL IMPACT OF PLASTIC WASTE IN CONSTRUCTION

Plastic waste generated from construction activities poses a significant environmental threat across its lifecycle. Beginning with production, the extraction and processing of fossil fuels for plastic manufacture contribute to greenhouse gas emissions and energy consumption, exacerbating climate change. In construction, while plastic materials like PVC offer durability and versatility, their production and installation release harmful chemicals such as dioxins and phthalates, polluting soil, water, and air. Moreover, construction projects generate substantial plastic waste, which, if improperly disposed of, can contaminate land and water bodies, endangering wildlife. When plastic waste ends up in landfills, it not only occupies valuable space but also persists for centuries, potentially leaching harmful chemicals. Furthermore, plastic degradation over time leads to the formation of microplastics, which infiltrate ecosystems and pose risks to both wildlife and human health. Incinerating plastic waste as a disposal method releases greenhouse gases and air pollutants, further contributing to environmental degradation. To mitigate these impacts, concerted efforts are needed to reduce plastic consumption, promote recycling and reuse practices, and adopt sustainable construction approaches.

5.PROPERTIES OF CONCRETE WITH PLASTIC WASTE AS COARSE AGGREGATE REPLACEMENT

Using plastic waste as a replacement for coarse aggregate in concrete can have both advantages and challenges. Here are some properties of concrete when plastic waste is used as coarse aggregate replacement:

Density: The density of concrete decreases when plastic waste is used as coarse aggregate replacement due to the lower density of plastic compared to traditional coarse aggregates like gravel or crushed stone.

Strength: The compressive strength of concrete may decrease when plastic waste is used as a replacement for coarse aggregate, especially at higher replacement levels. This is because plastic is less rigid and has lower strength compared to traditional aggregates.

Workability: Workability of concrete may be affected by the use of plastic waste as coarse aggregate replacement. Plastic particles might affect the flowability and ease of placement of concrete mixtures. Proper mix design adjustments are necessary to maintain desired workability.

Durability: Durability of concrete may be compromised due to the presence of plastic waste. Plastic is susceptible to degradation over time under environmental conditions such as UV exposure, heat, and chemical reactions, which can affect the long-term performance of concrete.

Water Absorption: Concrete incorporating plastic waste as coarse aggregate replacement may exhibit higher water absorption compared to conventional concrete. This could potentially lead to issues such as increased permeability and reduced resistance to freeze-thaw cycles.

Environmental Impact: The use of plastic waste in concrete can contribute to waste reduction and promote sustainability by diverting plastic from landfills. However, there are concerns regarding the environmental impact of plastic-derived pollutants leaching into the environment over time.

Cost: Depending on the availability and processing of plastic waste, the cost of concrete production may vary. In some cases, using plastic waste as a coarse aggregate replacement may lead to cost savings, especially if plastic waste is readily available locally.

6.CONCRETE

Concrete, a ubiquitous building material, has roots stretching back to ancient civilizations like the Romans, who pioneered its early forms. Composed of cement, water, aggregates, and additives, concrete undergoes a chemical reaction called hydration during curing, creating a robust structure. Its versatility allows for molding into diverse shapes, making it indispensable for various construction projects, including residential buildings, bridges, and infrastructure. Besides strength and durability, concrete boasts fire resistance and low maintenance, contributing to its widespread use. Despite its advantages, challenges like cracking exist, necessitating proper design and maintenance. Recent innovations focus on sustainability, including alternative materials and advanced technologies like self-healing concrete and 3D printing. As construction practices evolve, concrete remains a cornerstone, adapting to meet the demands of modern architecture and environmental stewardship.

Figure-01: Concrete.

6.1.Coarse Aggregate

Coarse aggregate is an indispensable component of concrete, serving as the robust backbone that provides stability and strength to the mixture. Comprising larger particles sourced from materials like gravel, crushed stone, or recycled concrete, coarse aggregate forms a supportive framework within the concrete matrix. Its primary role is to distribute loads evenly, enhancing the concrete's ability to withstand compression, tension, and other stresses. Available in a range of sizes and shapes, coarse aggregate selection influences factors such as workability, appearance, and overall performance of the concrete. Whether rounded for improved workability or angular for enhanced bonding, the characteristics of coarse aggregate significantly impact the final properties of the concrete. From structural stability to long-term durability against environmental factors, coarse aggregate plays a pivotal role in ensuring the integrity and performance of concrete structures across diverse construction projects.

Figure-02: Coarse Aggregate.

6.2.Fine Aggregate

Fine aggregate, a key constituent of concrete, comprises sand particles passing through standard sieves while being retained on a No. 200 sieve (0.075mm size). Integral to the mixture, fine aggregate fills the spaces between coarse aggregate, forming a compact matrix that enhances concrete's strength and durability. Its presence not only improves workability but also influences the rheological properties of the mix, affecting flowability and cohesion during placement and finishing. The particle size distribution, shape, and cleanliness of the sand are pivotal, ensuring proper packing and reducing segregation risks. Moreover, fine aggregate's quality, characterized by its lack of organic matter and minimal clay or silt content, is vital for maintaining concrete's performance. Beyond functionality, fine aggregate also contributes to the aesthetic appeal of concrete surfaces, influencing texture and color in decorative applications. In construction, the meticulous selection and integration of fine aggregate are imperative for achieving high-quality, durable concrete structures.

Figure-03: fine Aggregate

7.LITERATURE REVIEW

In this section of the literature review, we have studied the previous research papers n=based in the replacement of the coarse aggregate in the concrete with various other materials. The summary of the all previous research work is given below in the details.

Steve: Utilizing modified plastic waste as a replacement for coarse aggregate in porous concrete blocks can impact strength properties, with 5% sand addition showing optimal results compared to other mixtures. Porous concrete blocks with 5% sand addition showed better strength properties. Inclusion of PET aggregate in porous concrete blocks did not significantly improve strength. Plastic waste modified as replacement for coarse aggregate in porous concrete blocks. 5% sand addition showed better strength properties compared to other mixtures.

Debsis et.al: The study explores using waste-polyethylene-terephthalate (PET) as a replacement for natural coarse aggregate in concrete, affecting properties like water permeability, impact resistance, and chloride ion penetrability. Compressive strength of concrete reduced with the presence of plastic aggregates.Sorptivity increased with the inclusion of PET and PE aggregates in concrete. Study on mechanical and durability properties of concrete using plastic waste as aggregate replacement.Effects of different percentages of plastic waste on various properties of concrete.

Rohantha et.al: The paper explores using PET, HDPE, and PP plastic waste with quarry dust as substitutes for coarse aggregates in concrete, suitable for low-strength components due to specific gravity differences. PET plastic aggregates have higher specific gravity than HDPE and PP aggregates. PP aggregates have the highest water absorption rate compared to HDPE and PET aggregates. Paper discusses use of recycled plastic and quarry dust as aggregates. PET plastic aggregates have higher compressive strength compared to other plastics.

Khawar et.al: Incorporating plastic waste as coarse aggregate in concrete can improve workability but may reduce mechanical properties; however, adding silica fume can enhance density and strength, making it eco-friendlier. Plastic aggregates negatively influenced the mechanical properties of concrete.Addition of silica fume improved the mechanical properties. Investigated use of plastic as partial substitution for natural coarse aggregates in concrete Plastic aggregates improved workability but reduced density and mechanical properties of concrete.

Moussa et.al: Modified concrete using PET plastic waste as a partial replacement for coarse aggregate enhances workability, reduces density, and provides thermal comfort, making it suitable for various construction applications. PET aggregate reduces unit weight and enhances workability of concrete.Incorporating PET aggregate up to 15% has minimal consequences on concrete properties. PET plastic waste used as partial replacement for coarse aggregate in concretePET aggregates improve workability, reduce density, and provide thermal comfort in concrete structures.

Dwivedi et.al: Polypropylene waste was used to replace conventional coarse aggregates in concrete at levels of 0%, 20%, 40%, and 60%. Mechanical properties decreased with higher plastic waste content. Decrease in mechanical properties with increased plastic aggregate replacement levels.20% PP-embedded concrete suitable for primary load-bearing applications. PP used as partial substitute for coarse aggregates in concrete. Mechanical properties decrease with higher PP aggregate levels.

Fotini et.al: Workability of mortars reduced with XLPE use and increased with PET use. Recycled PET showed better performance overall for lightweight mortars. PET and XLPE plastic wastes used as aggregates in cement-based mortars Workability, porosity, water absorption, compressive strength, and density evaluated.

Alice et.al: Recycled plastic aggregates combined with biochar in concrete show limited reduction in mechanical properties, promoting circular economy principles with enhanced fracture energy and ductility. Biochar and recycled plastic in concrete improve mechanical properties. Combination promotes circular economy principles. Concrete with biochar and plastic waste shows improved mechanical properties.Biochar and plastic waste combination promotes circular economy principles.

Fahad et.al: The study examined the use of fabricated plastic aggregate in concrete, showing a decrease in mechanical properties but improved durability, making it suitable for non-structural applications. Fresh and mechanical properties of green concrete with plastic aggregates are reduced compared to typical concrete. Water absorption and chloride ion permeability decrease in green concrete with plastic aggregates. Concrete industry seeks sustainable solutions for carbon footprint. Plastic waste in concrete can be a potential solution.

Sudarmono et.al: The study explores using waste plastic bags to replace coarse aggregate in concrete, aiming for optimal proportions to enhance environmental sustainability and structural performance. Optimal flexural strength and buckling with 30% waste plastic replacement. Effective reinforcement ratio for maximum torque is 66.67%. Study on flexural and buckling strength of concrete with plastic bags. Coarse aggregate replaced by waste plastic bags for reinforcement variations.

Ramkrishnan et.al: Surface modified plastic aggregate can replace conventional coarse aggregate in concrete. Different treatments improve bonding with cement, enabling strength similar to control concrete, reducing plastic waste accumulation. Possible to improve bonding of plastic aggregate for concrete strength. Flexural-tensile strength decreases with higher numerical factor value. Novel lightweight coarse aggregate from PET plastic waste for concrete. Surface treatment improves bonding, achieving strength similar to control concrete.

Jahidul Islam: Polypropylene and polyethylene terephthalate waste plastics were used as partial replacements for coarse aggregate in concrete. PP showed increased compressive strength, while PET exhibited reduced strength compared to brick aggregate. Concrete with PP aggregate has higher compressive strength and lower density. Concrete with PET aggregate has lower compressive strength compared to reference concrete. Study compares concrete with polypropylene and polyethylene terephthalate waste plastic as partial replacement of coarse aggregate. Concrete with PP aggregate shows higher compressive strength and lower density.

Arnaud et.al: The study explored using plastic aggregates from waste to replace natural aggregates in concrete, affecting shrinkage and expansion. Plastic aggregates showed varied effects on concrete properties compared to traditional aggregates. BAgP-PVC recommended for paving in harsh weather conditions. BAgP-PEHD showed increased shrinkage compared to control concrete. Study on using plastic aggregates to reduce concrete shrinkage. BAgP-PVC recommended for surfaces exposed to harsh weather.

Radhi et.al: The study replaced natural coarse aggregate with HDPE plastic waste in concrete beams, showing promising results with 30% replacement enhancing toughness by 24% while reducing load capacity by 7%. Beams with 30% HDPE replacement showed similar cracking and failure time as reference beam. Beams with 30% HDPE replacement had 24% increased toughness and 7% reduced load carrying capacity. Sustainable concrete beams with HDPE plastic waste as coarse aggregate. 30% HDPE replacement increased toughness by 24%, reduced load capacity by 7 percent.

8.CONCLUSION

In conclusion, this review paper provides a comprehensive overview of the experimental investigations conducted on the replacement of coarse aggregate with plastic waste in concrete. The findings suggest that incorporating plastic waste as a partial or complete substitute for coarse aggregate offers promising results in terms of improving certain properties of concrete, such as reducing its density, enhancing its ductility, and mitigating environmental concerns associated with plastic disposal. However, it is evident that the effectiveness of plastic waste replacement depends on various factors including the type and size of plastic waste, its treatment, and the concrete mix design. Further research is necessary to optimize the incorporation of plastic waste in concrete to ensure structural integrity and long-term durability. Overall, this review highlights the potential of utilizing plastic waste as a sustainable alternative in concrete production, contributing to both waste management and the development of eco-friendly construction materials.

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