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UTILIZATION OF RECYCLED COARSE AGGREGATES (RCA) FOR DEVELOPMENT OF CONCRETE: REVIEW

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Abstract: The global construction industry faces profound challenges related to resource depletion, environmental degradation, and waste generation. Concrete, being the cornerstone of construction, contributes significantly to these challenges due to its heavy reliance on natural aggregates. Disposal of construction and demolition waste further exacerbates environmental burdens. In response, researchers are exploring sustainable alternatives, with recycled coarse aggregates (RCA) emerging as a promising solution for concrete production. RCA, obtained from crushed concrete waste, divert significant waste from landfills while reducing the demand for natural aggregates. Integrating RCA into concrete offers environmental, technical, and economic benefits. By substituting natural aggregates with RCA, the environmental impact associated with aggregate extraction and transportation can be significantly reduced, conserving natural resources and minimizing energy consumption and greenhouse gas emissions throughout the construction lifecycle.

Keywords: Recycled Coarse Aggregates (RCA), Concrete, Mix Design M_{20}

1. INTRODUCTION

In recent years, the global construction industry has been facing unprecedented challenges associated with the depletion of natural resources, environmental degradation, and increasing waste generation. Concrete, being the most widely used construction material, significantly contributes to these issues due to its heavy reliance on natural aggregates such as gravel and sand. The extraction of these aggregates poses environmental concerns, leading to habitat destruction, landscape alteration, and energy consumption. Moreover, the disposal of construction and demolition waste exacerbates the landfill crisis, further intensifying the environmental burden.

To address these challenges, researchers and practitioners have been exploring sustainable alternatives to traditional construction materials and methods. One promising approach is the utilization of recycled aggregates, particularly recycled coarse aggregates (RCA), in concrete production. RCA are obtained from crushed concrete waste obtained from demolition sites, thus diverting significant amounts of waste from landfills while reducing the demand for natural aggregates.

The integration of RCA in concrete offers several potential benefits, including environmental conservation, resource efficiency, and economic viability. By substituting natural aggregates with RCA, the environmental impact associated with aggregate extraction and transportation can be significantly reduced. This not only conserves natural resources but also minimizes energy consumption and greenhouse gas emissions throughout the construction lifecycle. Additionally, incorporating RCA in concrete promotes circular economy principles by converting waste materials into valuable resources, thereby mitigating the environmental footprint of the construction industry.

Furthermore, research indicates that concrete incorporating RCA can exhibit comparable mechanical properties and durability characteristics to conventional concrete. However, challenges such as increased porosity, variability in quality, and potential alkali-silica reaction need to be addressed to ensure the performance and long-term durability of RCA concrete structures. Therefore, ongoing research endeavors aim to optimize mix designs, enhance quality control measures, and develop innovative techniques to overcome these challenges and maximize the potential of RCA in concrete applications.

This research paper aims to critically evaluate the utilization of recycled coarse aggregate in concrete, focusing on its environmental, technical, and economic implications. By synthesizing existing literature, analyzing case studies, and discussing current advancements, this study seeks to provide insights into the opportunities and challenges associated with incorporating RCA in concrete production. Ultimately, the findings of this research endeavor can contribute to the advancement of sustainable construction practices and foster the adoption of recycled materials in the construction industry.

2. LITERATURE REVIEW

Ravi Patil et al (2013), reasoned that the early compressive strength of concrete made of regular substitution of 40% of Recycled Aggregate the compaction factor esteem is greatest, the most elevated compacting factor proportion is 0.90, reused aggregate concrete is more functional. Pattern of compressive strength in the early age of the concrete examples with 60% reused In any case, it shows that the strength of reused aggregate examples were continuously increment up to 40% substitution of reused aggregate and then it diminishes at the 100% substitution of reused aggregate following 28 days outcomes likewise show that the concrete examples with 40% substitution of reused aggregate get the most elevated strength when contrasted with the concrete examples with various level of reused aggregate. From the obtained result, it is possible to use 40% recycled aggregate for higher strength of concretes. Hence the recycled aggregate can be used in concrete with 40% replacement of natural coarse aggregate Ashraf M waigh et al (2013), presumed that concrete rubble could be changed into helpful reused aggregate utilized in concrete creation with properties reasonable for most primary concrete Hardly any properties of RCA, for example, retention and scraped area obstruction were lower than those needed by Egyptian concrete code of training in spite of the RAC with substitution proportion up to 100% of NA which is reasonable for most primary concrete applications in Egypt. Aggregates by RCA prompted less usefulness and a lessening in concrete strength and to conquer utilized to have a more minimized network which prompted upgrading primary concrete Rigidity and elasticity modulus of RAC with 100% RCA content are lower than those Replacing proportions AQ from 25% to 50% of NCA with RCA achieved a good performance of concrete mixes. 25% of NCA with RCA has no significant adverse effect on structural concrete performance. When the replacement ratio increased to 50%, the compressive strength reduction ranged from Jitender Sharma et al (2014), reasoned that when the water concrete proportion utilized in reused aggregate blend is decreased, rigidity and modulus of elasticity are improved. RCAs are of lower quality than NCAs as they contain mortar, cleared that 10% additional water and 5% additional concrete ought to be liked to create a rich blend by utilizing RCAs. Reused aggregate materials produce brutal blends in with lower usefulness than NAs. New guidelines ought to be presented for reused aggregates with the goal Goudappa Biradar (2015), reasoned that the compressive of the reused aggregate concrete is discovered to be lower than the regular aggregate. The strength of reused aggregate concrete can Reused aggregate treated with nitric corrosive and according to practical perspective; water and corrosive treated reused aggregates can be utilized instead of normal aggregates for brief designs. A trial investigation conducted by Shahid Kabir et al (2016) studied the engineering properties of aggregate from different sources including lab-tested concrete waste, recovered construction and demolition waste, and standard aggregate. The study found that the density of the C&D waste was higher and the number of voids was lower compared to market products. The specific gravity of crushed recycled aggregate was lower than virgin aggregate. The compressive strength of the C&D waste was lower than the control test, but it was closest to the intended strength. It was observed that an increase in compressive strength led to an increase in flexural and split tensile strength. Shahiron Shahidan et al (2016) found that aggregates measuring 10mm had the optimum results for the split tensile test, compressive strength test, and water absorption test. Kirtikanta Sahoo et al (2016) concluded that the compressive strength of concrete made from older RC-2 aggregate was lower than RC-1 concrete, but could be improved by increasing the water-to-cement ratio. Additionally, the drying shrinkage strain and air content increased with successive recycling. The splitting tensile strength and flexural strength decreased with successive recycling.

Ravi Patil et al. (2013) conducted a study indicating that concrete made with 40% replacement of natural coarse aggregate with recycled aggregate exhibited the highest early compressive strength, with a maximum compaction factor value of 0.90. The compressive strength trend showed continuous improvement up to 40% substitution of recycled aggregate, after which it decreased at 100% substitution. The study concluded that using 40% recycled aggregate could result in higher strength concrete.

Ashraf M. Waigh et al. (2013) suggested that concrete rubble could be effectively transformed into recycled aggregate suitable for most structural concrete applications, despite some properties of recycled concrete aggregate (RCA) being lower than those required by the Egyptian concrete code. They found that while concrete with 100% RCA content had lower functionality and reduced strength, replacing 25% to 50% of natural coarse aggregate with RCA achieved good concrete performance.

Jitender Sharma et al. (2014) observed that reducing the water-to-concrete ratio in recycled aggregate mixes improved the rigidity and modulus of elasticity. They recommended using additional water and concrete to produce a richer mix with recycled aggregates, which tend to yield harsh mixes with lower functionality than natural aggregates.

Goudappa Biradar (2015) concluded that the compressive strength of recycled aggregate concrete was lower than that of concrete with natural aggregate. However, they suggested that recycled aggregate treated with nitric acid could be utilized for temporary structures as an economical alternative to natural aggregates.

Shahid Kabir et al. (2016) investigated the engineering properties of aggregates from various sources, including lab-tested concrete waste and recovered construction and demolition waste. They found differences in density, voids, specific gravity, and compressive strength between recycled and virgin aggregates, with recycled aggregates demonstrating lower compressive strength but being closer to the intended strength compared to control tests.

Shahiron Shahidan et al. (2016) determined that aggregates measuring 10mm yielded optimal results for split tensile strength, compressive strength, and water absorption tests.

Kirtikanta Sahoo et al. (2016) concluded that concrete made from older recycled aggregate had lower compressive strength compared to concrete made from fresher recycled aggregate, but this could be mitigated by increasing the water-to-cement ratio. However, successive recycling led to increased drying shrinkage strain and air content, with reductions in splitting tensile strength and flexural strength.

3. MATERIAL AND EQUIPMENT

A. Cement

Cement is a binder, a substance used for construction that sets, hardens and adheres to other materials, binding them together. Cement is seldom used on its own, but rather to bind sand and gravel (aggregate) together. Cement is used with fine aggregate to produce mortar for masonry, or with sand and gravel aggregates to produce concrete. Ordinary Portland cement of 43 grade was used for the investigation. Figure 1 shows the cement OPC 43 grade used.

B. Aggregate

The bulk of concrete is made of aggregates. Aggregates are inert material or chemically inactive material like crushed rock, sand, broken bricks, gravel etc.

1. Fine aggregate

It is the aggregate most of which passes through a 4.75 mm IS Sieve and contains only that much coarser material as permitted by the specifications.

IS Sieve designation	Grading zone I	Grading zone II	Grading zone III	Grading zone IV
10mm	100	100	100	100
4.75mm	90-100	90-100	90-100	95-100
2.36 mm	60-95	75-100	85-100	95-100
1.18 mm	30-70	55-90	75-100	90-100
600 micron	15-34	35-59	60-79	80-100
300 micron	5-20	8-30	12-40	15-50
150 micron	0-10	0-10	0-10	0-15

Table: 1.1 IS 383: 2016 clause 4.3

2. Recycled coarse aggregate

Normal properties of recycled coarse aggregates are lower density, lower elastic modulus and a higher absorption than natural coarse aggregate. These properties are because of the way that the reused coarse aggregate have mostly followed mortar which has generally high volume of porosity. It is difficult to reject that properties of reused aggregates are exceptionally subject to the measure of followed mortar. The other legitimate conceivable outcomes to foster the properties of reused aggregates are the technique for pounding guardian concrete and the unpredictable state of reused aggregate. The recycled aggregate for this study were obtained by collecting concrete waste from different sites of grater Noida and was then crushed to size of 10-12 mm Figure 4 shows the recycled aggregate used.

4. OBJECTIVE OF STUDY

With increasing urbanization, construction and demolition waste containing hazardous materials like lead, asbestos, and rubble is generated.

India produces 530 million tons of construction and demolition waste annually, contributing to environmental pollution and resource depletion when disposed in landfills or dumped along roadsides and rivers.

To mitigate this environmental risk, recycling this waste can be an effective solution.

- This study focuses on replacing natural coarse aggregate (NCA) with recycled coarse aggregate (RCA) in concrete.
- Concrete samples were collected from various sites and crushed to obtain coarse aggregate of 10mm size.
- Concrete of M20 grade was prepared and cast into 42 molds of size 150mm×150mm×150 mm.
- Different percentages of RCA were used as replacements for NCA, ranging from 0% to 100%.
- Seven cubes were cast for each percentage to optimize results, and compressive strength and density were tested after 7, 14, and 28 days.

5. SCOPE AND IDENTIFYING RESEARCH GAP

Research in the utilization of recycled coarse aggregates in concrete faces several gaps that hinder a comprehensive understanding and application. Firstly, many studies tend to focus on a narrow range of mix proportions, potentially overlooking optimal combinations that balance strength, durability, and other properties. Secondly, existing research predominantly concentrates on short-term properties of concrete, neglecting crucial long-term performance aspects, including durability under various environmental conditions. Thirdly, the influence of different processing techniques for recycled aggregates remains understudied, with a lack of systematic evaluation of their impact on concrete properties. Furthermore, while some attention has been given to the environmental benefits of using recycled aggregates, there is a gap in comprehensive environmental impact assessments, including life cycle analyses. Additionally, the interaction of admixtures with recycled coarse aggregates requires more exploration to understand their effects on concrete properties. Moreover, the absence of standardized guidelines for incorporating recycled aggregates into concrete poses a challenge for consistent and reliable performance. Lastly, limited research on the economic viability of using recycled aggregates in concrete construction indicates a need for comprehensive cost-benefit analyses. Addressing these research gaps is crucial for advancing sustainable practices and guidelines in the construction industry.

6. PROBLEM FORMULATION

Research on concrete with recycled coarse aggregates has primarily focused on a specific range of mix proportions, potentially hindering the identification of optimal combinations balancing strength, durability, and other properties. Additionally, there's a significant emphasis on short-term properties, with inadequate data on long-term performance and durability under various environmental conditions. The effects of different processing techniques on recycled aggregate concrete properties remain underexplored, as do comprehensive environmental impact assessments and the influence of admixtures. The absence of standardized guidelines and limited research on economic viability further complicates the widespread implementation of recycled aggregates in concrete. Addressing these gaps is crucial for promoting sustainable construction practices and developing guidelines for economically viable use in the industry.

7. CONCLUSION

In conclusion, concrete stands as a fundamental material in global construction endeavors, evolving across centuries to meet diverse architectural and engineering needs. Recent trends highlight a shift towards sustainable practices within the concrete industry, driven by growing environmental awareness and the imperative for resource efficiency. In the context of India, concrete plays a pivotal role in infrastructure development, spurred by rapid urbanization and ambitious governmental initiatives. Despite challenges such as raw material availability and quality control, ongoing research and development efforts aim to address these issues, ensuring the continued growth and improvement of India's concrete sector. Reviewing existing literature provides valuable insights into optimizing concrete production processes and enhancing material properties. Studies by Tiwary, Sambangi, Raju, and others explore the incorporation of supplementary materials such as fly ash and copper slag to improve concrete characteristics. These investigations emphasize the potential benefits of utilizing industrial by-products, contributing to sustainable construction practices. However, gaps in research exist, particularly regarding the long-term performance of concrete structures, the relationship between laboratory experiments and real-world applications, and the combined effects of waste materials like copper slag and fly ash. Addressing these gaps is imperative for advancing concrete technology and promoting sustainable construction practices.

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