International Organization of Research & Development (IORD)
ISSN: 2348-0831
Vol 13 Special Issue 02 | 2026

Towards Sustainable Infrastructure: Strength Characteristics of Recycled Aggregate Concrete

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DOI: 10.5281/zenodo.19538054

ABSTRACT

Rapid growth in infrastructure development has resulted in increased consumption of natural aggregates, leading to serious environmental concerns. Simultaneously, the construction and demolition industry generates large quantities of waste materials every year, creating environmental, economic, and social challenges. The use of recycled aggregates as a replacement for natural aggregates offers a sustainable solution to these issues. This paper presents a systematic review of previous research on recycled aggregate concrete (RAC) as an alternative construction material. The effect of recycled aggregates on the mechanical properties of concrete, including compressive strength, split tensile strength, and flexural strength, is critically analyzed. In addition, the study reviews the provisions related to the use of recycled aggregates in concrete as specified in standards and codes of practice of different countries, highlighting their role in sustainable development. A comparative evaluation of key parameters such as density, water absorption, contaminant limits, and permissible strength levels of RAC is also presented. The findings indicate that recycled aggregates can be effectively used in concrete with proper quality control.

Keywords: - Recycled aggregates, compressive strength, flexural strength, split tensile strength, workability.

1. INTRODUCTION

Recycling is the process of converting used materials into new products in order to reduce the consumption of fresh raw materials and minimize environmental impact. With rapid advancement in infrastructure development, the demand for natural aggregates has increased significantly, leading to depletion of natural resources. To overcome this issue, recycled aggregates can be effectively used as replacement materials for natural aggregates in concrete production.

Recycled aggregates consist of crushed and graded inorganic particles obtained from processed construction and demolition waste. These materials are primarily derived from demolished buildings, roads, bridges, and other civil engineering structures. In some cases, recycled aggregates are also sourced from debris generated due to natural or man-made disasters such as earthquakes and wars. The utilization of recycled aggregates not only conserves natural resources but also reduces landfill requirements and promotes sustainable construction practices.

1.1 Problem Statement

Rapid infrastructure development has increased the demand for natural aggregates, leading to depletion of natural resources and environmental degradation. Simultaneously, the construction and demolition industry generates large quantities of waste materials, creating serious disposal and sustainability challenges. Recycled aggregates offer a potential solution; however, their use in structural concrete remains limited due to concerns regarding strength, workability, and lack of standardized guidelines. There is a need to evaluate the effect of recycled aggregates on the mechanical properties of concrete, including compressive strength, split tensile strength, and flexural strength, to determine their suitability for sustainable and structural construction applications

1.2 Objectives

- To study the feasibility of using recycled aggregates obtained from construction and demolition waste in structural concrete.
- To investigate the effect of partial and full replacement of natural coarse aggregate with recycled aggregate (0% to 100%) on concrete strength.
- To determine the compressive strength of recycled aggregate concrete at different ages.

- To evaluate the split tensile strength and flexural strength of recycled aggregate concrete.
- To study the workability characteristics of concrete mixes containing recycled aggregates.
- To compare the performance of recycled aggregate concrete with conventional concrete.
- To identify suitable replacement levels and mix conditions for achieving acceptable strength in structural applications.

2. LITERATURE REVIEW

The use of recycled aggregates in construction has become increasingly popular due to the growing need for sustainable building materials. Many studies have been carried out globally to assess how well recycled aggregates perform in concrete. The key focus of these studies is to determine the strength properties of recycled aggregate concrete and whether it can be used effectively in construction projects.

Hanson and Torben (1986) noted that research on recycled aggregates has been ongoing since 1945 in various countries.

Some of the literature reviews on recycled aggregates are as follows. The main goal of testing recycled aggregates is to identify their strength characteristics and to determine if they are suitable for construction applications.

According to Rammamurthy and Gumaster (1998), the compressive strength of recycled aggregate concrete is generally lower, and the variation in strength depends on the strength of the original concrete from which the aggregate was obtained. Limbachiya and Leelawat (2000) found that recycled concrete aggregate has 7 to 9% less relative density and absorbs twice as much water as natural aggregate. Based on their test results, it was shown that replacing 30% of coarse recycled concrete aggregate did not affect the strength of the concrete. They also mentioned that recycled concrete aggregate can be used in high-strength concrete mixes where the recycled content is included in the concrete. Sagoe, Brown, and Taylor (2002) stated that the differences between fresh and hardened recycled aggregate concrete and natural aggregate concrete are smaller compared to laboratory crushed recycled aggregate concrete mixes. There was no significant difference at the 5% level in the compressive and tensile strength of recycled concrete and normal concrete made from natural aggregate. In the same year, Poon (2002) reported that replacing 25% and 50% of recycled aggregate in brick specimens had little effect on compressive strength. However, as the percentage of recycled aggregate increased, the compressive strength of the specimens decreased. Mandal, Chakraborty, and Gupta (2002) also found that replacing 30% of recycled aggregate had no significant effect on concrete strength. But as the amount of recycled aggregate increased, the compressive strength gradually decreased. They concluded that the properties and strength characteristics of recycled aggregate concrete were not as good as those made from natural aggregate. Limbachiya (2003) found that using up to 30% of coarse recycled concrete aggregate had no effect on the compressive strength of standard 100mm concrete cubes. However, when the percentage of recycled aggregate increased, the compressive strength decreased. Bodin and Zaharieva (2002) stated that the reduced strength of recycled concrete specimens was due to an increased water-to-cement ratio needed to maintain workability. There are several methods to improve the strength of recycled aggregate concrete. Kantawong and Laksana (1998) mentioned that the fineness modulus and water absorption of recycled aggregate are higher than those of natural aggregate. The results showed that adding water-reducing admixture increased the compressive strength of concrete. Concrete made with recycled aggregate had higher compressive strength than that made with natural coarse aggregate.Sawamoto and Takehino (2000) found that the strength of recycled aggregate concrete can be improved by using pozzolanic materials that can absorb water. Mandal (2002) stated that adjusting the water-to-cement ratio during the mixing process when using recycled concrete aggregate can improve the strength of recycled aggregate concrete specimens. The results showed that recycled aggregate concrete specimens had similar engineering and durability performance to those made with natural aggregate within 28 days of curing. Chen and Kuan (2003) found that the strength of concrete specimens was affected by the use of unwashed recycled aggregate.

This effect was more pronounced at a low water-to-cement ratio. These effects could be improved by using washed recycled aggregate. Another way to improve performance is by using silica fume during mixing. Mandal (2002) also stated that the use of fly ash in recycled concrete aggregate improved the durability of the concrete. Poon (2002) also mentioned that using fly ash could enhance the strength characteristics of recycled aggregate. He stated that the compressive strength of concrete paving blocks reached 49 MPa at 28 days when fly ash was used. Berry and Malhotra (1980) stated that for high-strength concrete, fly ash contributes to increased strength at later curing stages (56 to 91 days), which cannot be achieved by adding more Portland cement. Some precautions are necessary when using recycled aggregate in concrete mixing. According to Bodin and Zaharieva, these precautions are necessary because recycled aggregates may contain harmful reactions such as alkali-aggregate reaction and sulfate reaction.

They also mentioned that the mix proportions of recycled aggregate concrete must be appropriately adjusted when both fine and coarse recycled aggregates are used instead of natural aggregates.

2.1 Conclusion Based on Reviewed Literature

Based on the reviewed literature, it is evident that recycled aggregates obtained from construction and demolition waste can be effectively used in concrete as a partial replacement for natural aggregates. Most studies report a reduction in compressive, split tensile, and flexural strength with an increase in recycled aggregate content, primarily due to higher water absorption, lower density, and the presence of adhered mortar. However, research also indicates that up to 30–35% replacement of natural aggregates does not significantly affect concrete strength when proper mix design and quality control are adopted. The use of mineral admixtures such as fly ash and silica fume, along with a reduced water–cement ratio and chemical admixtures, has been shown to improve strength and workability. Overall, the literature confirms that recycled aggregate concrete is a viable and sustainable construction material when used under controlled conditions.

2.2 Identified Research Gaps

Although extensive research has been conducted on recycled aggregate concrete, several gaps still exist. Most studies primarily focus on compressive strength, while limited attention has been given to split tensile strength, flexural strength, and workability under varying replacement levels of recycled aggregates. There is a lack of consistent data on the performance of concrete with high percentages of recycled aggregate replacement, particularly for structural applications. Variations in the quality of recycled aggregates due to different sources of parent concrete are not adequately addressed in existing studies. Additionally, limited research is available on optimizing mix design parameters such as water–cement ratio and aggregate pre-treatment methods to improve performance. Furthermore, standardized guidelines and design recommendations for the large-scale use of recycled aggregate concrete in structural applications remain insufficient, highlighting the need for further experimental investigation.

3. METHODOLOGY

The methodology adopted in this study aims to evaluate the feasibility and performance of recycled aggregate concrete by examining its fresh and hardened properties. The experimental program was designed to compare conventional concrete with recycled aggregate concrete at different replacement levels.

3.1 Materials Used

Ordinary Portland Cement (OPC) of 43 grade conforming to relevant IS specifications was used in the study. Natural river sand was used as fine aggregate, while crushed stone aggregate was used as natural coarse aggregate. Recycled coarse aggregates were obtained from demolished concrete waste and processed by crushing, cleaning, and grading to the required size. Potable water free from impurities was used for mixing and curing.

3.2 Preparation of Recycled Aggregates

The demolished concrete was crushed using a mechanical crusher. The crushed material was sieved to obtain the desired aggregate size and manually cleaned to remove impurities such as wood, plastic, and dust. The recycled aggregates were then washed and air-dried to minimize the effect of adhered mortar and dust on concrete properties.

3.3 Mix Proportioning

Concrete mixes were designed for a specified target strength using the IS mix design method. Natural coarse aggregates were replaced with recycled coarse aggregates at varying percentages, namely 0%, 20%, 40%, 60%, 80%, and 100%. To achieve comparable strength, adjustments were made to the water-cement ratio based on the replacement level.

3.4 Casting of Specimens

Concrete was mixed thoroughly using a mechanical mixer to ensure uniform distribution of materials. The fresh concrete was tested for workability using the slump test. Standard specimens were cast, including cubes for compressive strength testing, cylinders for split tensile strength testing, and beams for flexural strength testing. All specimens were compacted properly and finished smoothly.

3.5 Curing of Specimens

After 24 hours of casting, the specimens were demoulded and cured in clean water at room temperature. Curing was carried out for 7 and 28 days to study the development of strength at different ages.

3.6 Testing of Hardened Concrete

Compressive strength tests were conducted on concrete cubes using a compression testing machine as per IS standards. Split tensile strength was determined using cylindrical specimens, and flexural strength was evaluated using beam specimens under two-point loading. The test results were recorded and analyzed to compare the performance of recycled aggregate concrete with conventional concrete.

3.7 Analysis of Results

The test results were systematically analyzed to evaluate the effect of recycled aggregate replacement on strength and workability. Comparative graphs and tables were prepared to assess trends and identify suitable replacement levels for structural applications.

4. RESULTS & DISCUSSION

4.1 Slump Cone Test

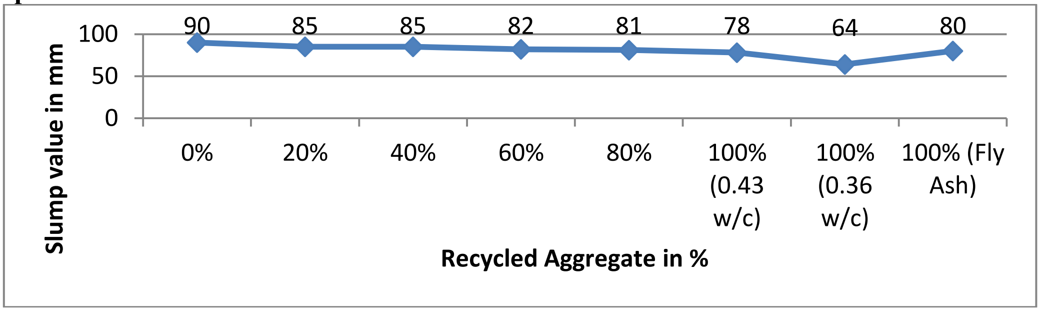


Chart -1 Slump Cone Test

The experimental results indicate that the highest slump value recorded was 90 mm for the control mix containing 0% recycled aggregate, while the lowest slump was 64 mm for the mix with 100% recycled aggregate at a 0.36 water–cement ratio. The average slump for all batches was approximately 82 mm, which falls within the target range of 50 mm to 120 mm, confirming that the required workability was achieved for most mixes. Concrete containing 0% to 80% recycled aggregate showed moderate workability, with a gradual reduction in slump ranging from 5 mm to 9 mm as the replacement level increased. The mixes with 100% recycled aggregate at 0.43 water–cement ratio and with fly ash cement achieved an average slump of about 79 mm, indicating satisfactory placement and compaction. However, the mix with 100% recycled aggregate at 0.36 water–cement ratio exhibited reduced workability due to the higher water absorption capacity of recycled aggregates. Overall, workability decreased as the percentage of recycled aggregate increased.

4.2 Compressive strength Test

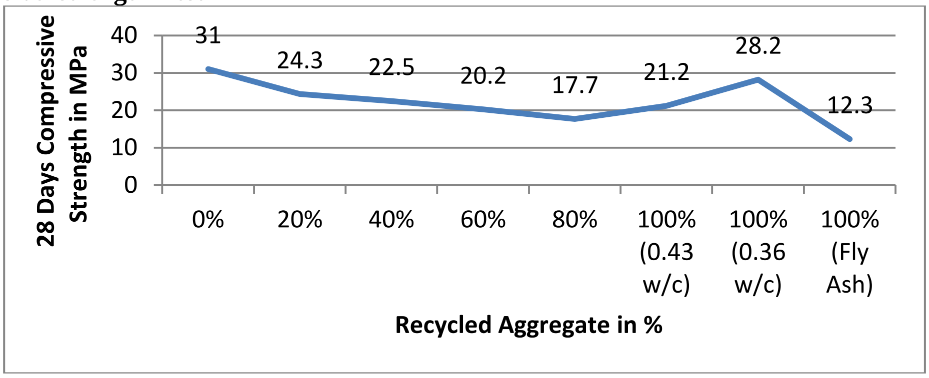
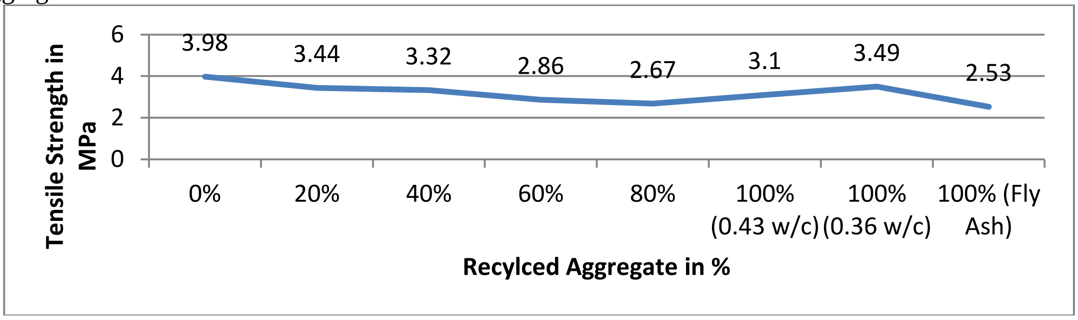


Chart -2 Compressive Strength Test

The compression test results indicate that the compressive strength of all concrete specimens increased with age, particularly showing significant strength gain at the early curing stage. However, it was observed that concrete containing recycled aggregates exhibited lower compressive strength compared to conventional concrete made with natural aggregates. The reduction in strength became more noticeable as the percentage of recycled aggregate increased. Chart 2 presents the recorded compressive strength values at different curing ages, while Chart-2 illustrates the variation and decreasing trend in compressive strength for each batch with increasing recycled aggregate content. Overall, although strength development followed the normal hydration pattern, higher replacement levels of recycled aggregate resulted in comparatively lower compressive strength. The results also shows that the concrete specimens with more replacement of recycled aggregate will get the lowest strength when compared to the concrete specimens with less recycled aggregate

4.3 Split Tensile strength Test

The experimental results show that the split tensile strength gradually decreased as the percentage of recycled aggregate increased from 0% to 80%, with an average reduction of approximately 0.26 MPa within this replacement range. The concrete mixes containing 100% recycled aggregate with water–cement ratios of 0.42 and 0.36 exhibited an average tensile strength of about 3.30 MPa. However, the mix prepared with 100% recycled aggregate using fly ash cement showed the lowest tensile strength value of 2.53 MPa, indicating a significant reduction compared to the control mix. This decrease in tensile strength can be attributed to the weaker bond between the cement paste and recycled aggregates, as well as the presence of adhered mortar on the aggregate surface.



It was also observed that reducing the water–cement ratio improved the tensile strength of recycled aggregate concrete, suggesting that appropriate mix design adjustments can enhance its overall performance.

The experimental results show the recycled aggregate will influence much in fresh and hardened properties of a concrete. As the percentage of the recycled aggregate increased, the workability and strength of the concrete will decreased. By comparing the different type of 100% recycled aggregate specimens, it was found that fly ash cement recycled aggregate concrete mix batch were not sufficient to achieve the high strength target. The reduced water (0.36 water/cement ratio) recycled aggregate concrete mix indicates a higher strength but the workability is not very satisfied.

5. CONCLUSION

The study concludes that recycled aggregate can be effectively used in structural concrete with proper mix design. Although workability and strength decrease as the percentage of recycled aggregate increases, reducing the water–cement ratio significantly improves compressive and tensile strength. Concrete with 100% recycled aggregate achieved satisfactory strength for structural applications when optimized. However, careful control of water content is essential to maintain adequate workability.

6. REFERENCES

[1] Ajdukiewiez and A. Kliszczewicz, “Influence of recycled aggregates on mechanical properties of HS/HPC,”*Cement and Concrete Composites*, vol. 24, pp. 269–279, 2002.
[2] A. Katz, “Properties of concrete made with recycled aggregate from partially hydrated old concrete,” *Cement and Concrete Research*, vol. 33, pp. 703–711, 2003.
[3] J. Biojen, “Waste materials and alternative products: Pro’s and con’s,” in *Concrete for Environmental Enhancement and Protection*, E & FN Spon, pp. 587–598, 1996.
[4] T. Esin and N. Cosgun, “A study conducted to reduce construction waste generation in Turkey,” *Building and Environment*, vol. 42, pp. 1667–1674, 2007.
[5] J. Ferguson, O. N. Kermode, C. L. Nash, W. A. J. Sketch, and R. P. Huxford, *Managing and Minimising Construction Waste*, Institution of Civil Engineers, Thomas Telford Publications, U.K., pp. 1–60, 1995.
[6] T. C. Hansen, *Recycling of Demolished Concrete Masonry*, RILEM Report No. 6, E & FN Spon, London, Great Britain, 1992.
[7] J. M. Khatib, “Properties of concrete incorporating fine recycled aggregate,” *Cement and Concrete Research*, vol. 35, no. 4, pp. 763–769, 2005.
[8] P. K. Mehta, “Reducing the environmental impact of concrete,” *Concrete International*, vol. 23, no. 10, pp. 61–66, Oct. 2001.
[9] M. Chakradhara Rao, S. K. Bhattacharyya, and S. V. Barai, “Influence of field recycled coarse aggregate on properties of concrete,” *Materials and Structures*, Apr. 2010, doi: 10.1617/s11527-010-9620-x.
[10] N. Deshpande, “Effectiveness of using coarse recycled concrete aggregate in concrete,” 2011.
[11] N. D. Oikonomou, “Recycled concrete aggregates,” *Cement & Concrete Composites*, vol. 27, pp. 315–318, 2005.
[12] G. Thielen, “Concrete Technology Reports 2001–2003,” German Cement Works Association, 2004.