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# Influence of Recycled Aggregate on Concrete Properties and Sustainability Analysis

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***Abstract:*** ***Consumption of abundant yet limited natural resources and subsequent waste generation is increasing rapidly in construction practices around the world. In the quest of producing a sustainable solution, the uses of various waste materials are being tested lately. This paper aims to find a sustainable and economical mode to utilize the recycled concrete aggregate (RCA) as partial replacement of natural coarse aggregate by performing various tests to find physical and mechanical properties of recycled aggregate concrete (RAC). It was found that the recycled aggregate concrete has comparable properties as of conventional concrete up to a certain percentage replacement.***

***Keywords: Recycled aggregate concrete; waste management; compressive strength; flexure strength; sustainability***

## I. INTRODUCTION

All natural resources though abundant, are non-renewable and finite. The concrete industry is well known for contributing significantly to environmental damage and $CO_2$ emissions. According to Global Cement Report 2019, world cement consumption is estimated to have expanded by 2.8% to make it to 4.08 billion tonnes in 2019. And the concrete output is projected to be about 6 billion tonnes per year, or 1 tonne per person annually.

The concrete industry is identified as a major user of natural resources and subsequent waste generation. Official estimates carried out by Centre of Science and Environment (CSE) say India generated 150 million tonnes of C&D waste annually, while our country has a recycling capacity of only about 6500 tonnes per day, i.e. just 1.58 per cent of the total C&D waste generated. This much amount of waste is generally handled by dumping it in landfills, which in turn creates massive piles of waste. As a result, an efficient waste management solution is needed to control the waste generation and to recycle it effectively. In that process, using recycled concrete aggregate instead of natural aggregates in construction may be a viable alternative to address the problem.

Recycled aggregates (RCA) have been extensively researched as a complete or partial replacement for natural aggregate. The use of RCA in potential implementation is usually restricted to non-structural concrete, with a replacement ratio of NA by RCA up to 30%. Recycled aggregates are obtained from various sources such as demolition of structures, pavements or concrete specimens used for testing of concrete. The properties are greatly dependent on the mortar adhered to the surface of aggregate. It has increased porosity and higher water absorption than natural aggregates which can be accounted due to the porous cement mortar attached with it. According to A. K. Padmini, K. Ramamurthy (2008), it was found that z/compressive strength of RAC is on the lesser side than that of concrete made with NA. Also, strength of concrete made with recycled aggregates greatly depends on the strength and grade of parent concrete. Xiao et al. and Zhang et al., in their studies found that more water is required to achieve similar workability, attributed to higher water absorption of recycled coarse aggregate. Using different kinds of supplementary cementing materials (SCMs), specially, Fly Ash (FA) as a cement substitute could substantially lower the final concrete product's overall $CO_2$ footprint. Over the years, fly ash has been widely accepted by the researchers to incorporate into construction practices and is proven to improve various properties of concrete.

## II. EXPERIMENTAL PROGRAMME

Recycled aggregates collected from demolished sites contained minor impurities such as bricks, tiles etc. which are to be taken into account for the deviation in properties of RCA.

### *A. Materials*

1) *Cement and fly ash:* Ordinary Portland cement of strength 43 MPa (OPC 43) obtained locally confirming to IS 8112:2013 and ASTM Class F fly ash were used in mixes.
2) *Aggregates:* Natural aggregates were used in this study in combination with recycled coarse aggregates. The natural aggregates were obtained from local suppliers of maximum size about 20 mm while the recycled aggregates were obtained from various sources such as demolished concrete structures manually collected in order to have least amount of impurities as plastic, wood etc. from the site and from tested specimens of concrete taken from testing lab. Aggregates are confirming to IS 1383:1970

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River sand is used in making of concrete of Zone II and gradation of sand is done.

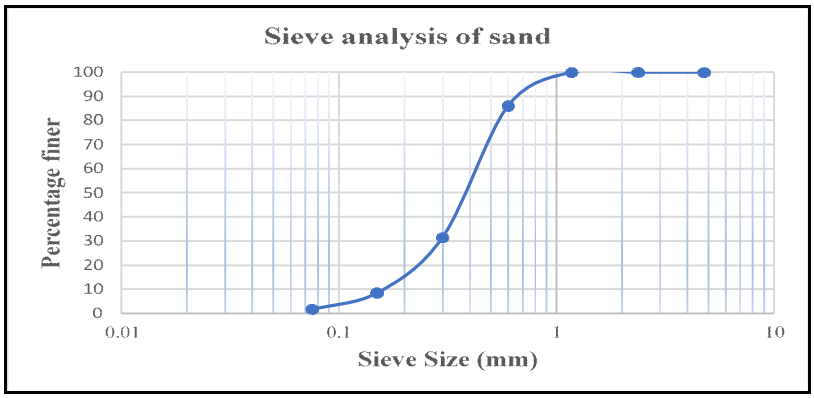


Fig. 1 Graph representing sieve analysis of fine aggregate

*B. Concrete Mix Design*

Concrete mixtures are made of grade M30 and M40. The fly ash was used as 10% partial replacement of cement. The recycled coarse aggregate was used to replace the natural coarse aggregate as 0%, 10%, 20%, and 30% replacement by volume.

Then slump of concrete was kept similar of each mix by modifying the water cement ratio or by use of superplasticizers.

Physical Properties of Materials

| Property | Cement | Fly Ash | NA | RCA |
|---|---|---|---|---|
| Specific Gravity | 3.13 | 2.21 | 2.6 | 2.48 |
| Water Absorption | - | - | 0.6 % | 6.28 % |

## III. TEST PROCEDURES

*A. Properties of Recycled Aggregate Concrete*

1) *Particle size distribution:* Natural aggregates and recycled aggregates were reduced to maximum size of 20mm by the help of crushing and hammering. Then sieve analysis was done according to IS 2386:1963 (Part 1).
2) *Water Absorption:* Water absorption test was carried out on natural aggregates and recycled coarse aggregates as per IS 2386 (Part III):1963. The recycled aggregates have natural aggregates adhered with hardened mortar to its surface resulting in more porous structure altogether. The RCA were air dried before immersion in water at 27-32˚C for a 24±1 hours. This test was done to determine the water holding capacity of RCA as compared to NA.
3) *Specific Gravity:* Specific gravity of recycled aggregates was found to be less than natural aggregate when tested. The results, however has shown that specific gravity of RA was satisfactory as per the guidelines mentioned in IS code.

*B. Compressive strength*

Compressive strength of concrete mixes was determined by testing 150mm cubes in compression testing machine at the ages of 7 days and 28 days curing. Three cubes of each mix were tested as per IS 516. The strength was calculated by dividing failure load by surface area.

*C. Flexural strength*

Flexural strength was tested on a beam of size 100×100×500mm under three point loading mechanism immediately after taking out the specimen from curing of 28 days. Average flexural strength of recycled aggregate concrete was found out to be lesser as compared to the flexural strength of concrete made with 100% natural aggregate.

*D. Workability*

Various studies have indicated that the inclusion of various waste materials in making of concrete to achieve sustainability could affect different properties including those of fresh concrete. Workability is one of the properties of the concrete mixes determined by slump test and compaction factor test. Slump test is done using Abram's cone on the fresh concrete mixed in tilt type drum mixer.

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## IV. RESULTS AND DISCUSSIONS

### *A. Water absorption*

Water absorption values ranged from 4.8% - 7.1%. It could be attributed to the fact that the mortar attached to the surface of aggregate itself is a porous in nature and is capable of holding water. The values of water absorption of natural aggregates ranged from 0.5% - 0.8% which is quite less than that of recycled aggregate.

### *B. Specific Gravity*

The specific graviSy of recycled coarse aggregate varied from 2.42 to 2.55 depending on the source of recycled aggregate. Lower value was found for aggregate obtained from demolished concrete while the aggregate from tested specimen was free from any impurities, hence, was having higher specific gravity.

### *C. Strength Characteristics*

1) *Compressive strength:* Test result showed that the compressive strength of concrete mixes having recycled aggregates partially have marginally lower compressive strength as compared to control mixes. Also, when fly ash was used as partial replacement of cement with recycled aggregates showed an increase in compressive strength than that of the mix without the fly ash. However, the compressive strength of concrete mixes was found to be greater than the target strengths indicating towards safe and effective use of recycled aggregates in construction practices of other than heavy structures requiring greater strength.
2) *Flexural Strength:* The test results of flexural strength indicated that the reduction in strength of recycled aggregate concrete (RAC) as compared to control mix was in the range of 5 – 19%. Also decrease in strength was found to be more in higher strength concrete i.e. M40 as that of M30.

### *D. Workability*

In the slump cone test, it was found that the slump value kept increasing with increase in the content of recycled coarse aggregates. The use of plasticizers also contributed towards higher workability. This could be explained by higher water absorption values of recycled aggregate.

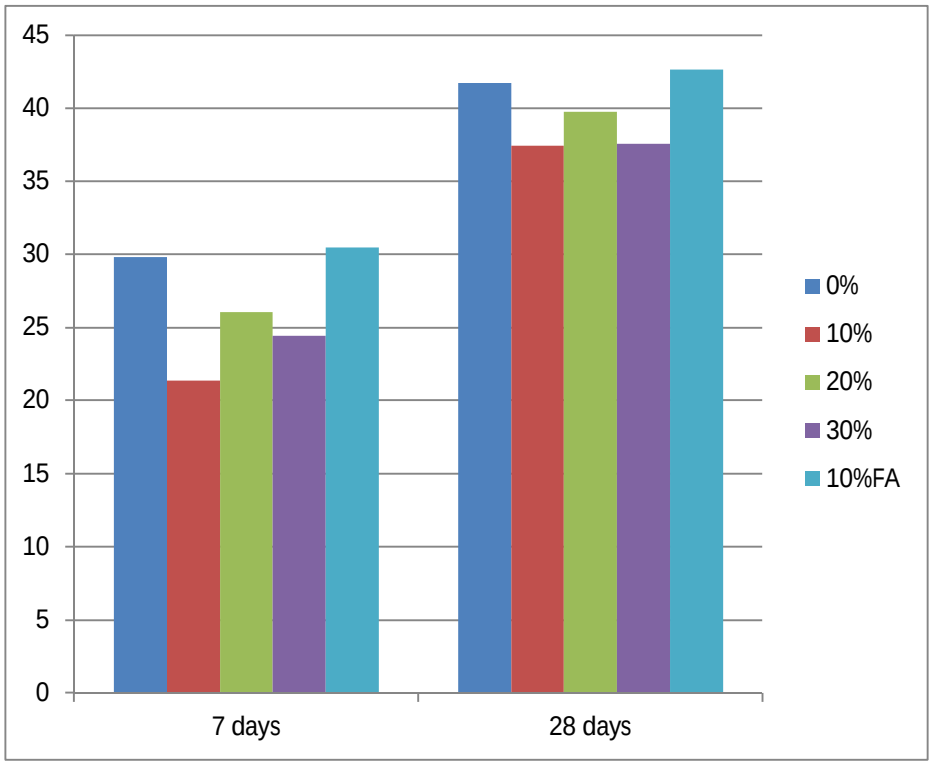


Fig. 1 Compressive strength - M30

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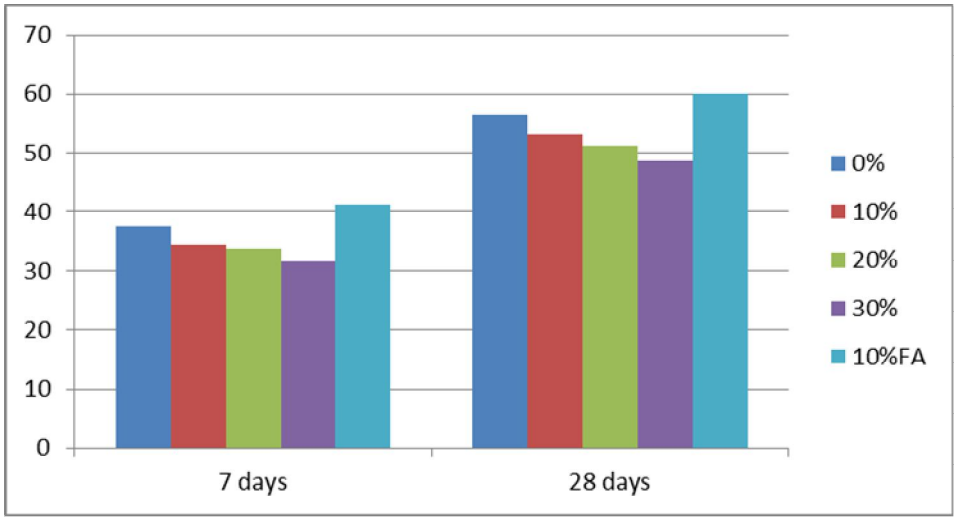


Fig. 2 Compressive strength - M40

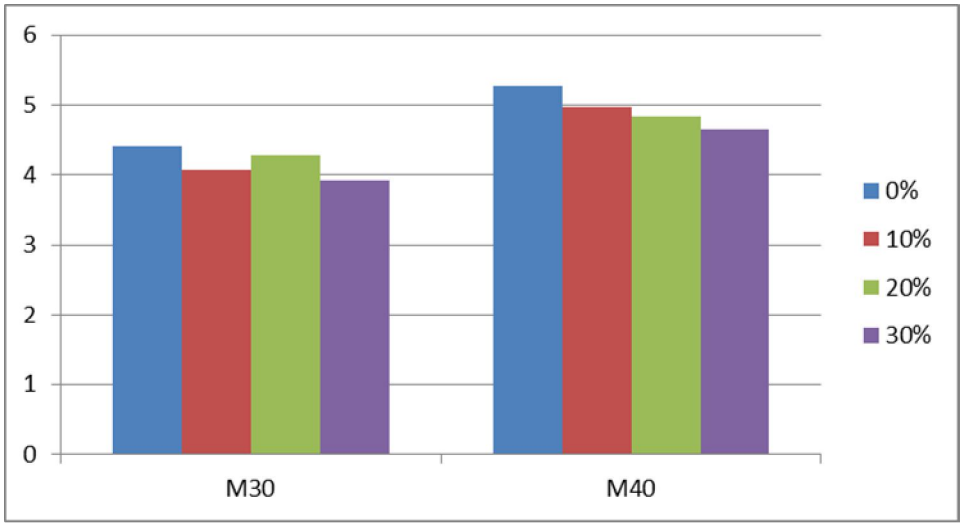


Fig. 3 Flexural strength - 28 days

## V. CONCLUSION

*A.* The study shows that the compressive strength reduces as the RCA content increases. However, usage of recycled aggregate up to 30% replacement has no major impact on the compressive strength of the concrete.

*B.* It was found that the physical properties of RCA depend on the characteristics of parent concrete. Increase in water absorption was noticed when the parent concrete of higher grade was used to obtain the aggregate.

*C.* The compressive strength was found to be increased up to 5-15% when Fly Ash was used as a partial replacement of cement in conjunction with RCA.

*D.* There was no significant decrement found in flexural strength in concrete mixes with or without recycled aggregates. Also, the results were satisfactory in the overall strength criterion as they were well above the target strength.

It can be concluded that up to 30% replacement of natural aggregate by RCA in concrete mixes with or without other waste material such as fly ash could be useful in reducing the environmental impact of the waste material and the cost included in the handling the waste could also be minimized to attain proper waste management and sustainable construction practices without any major compromise in strength characteristics.

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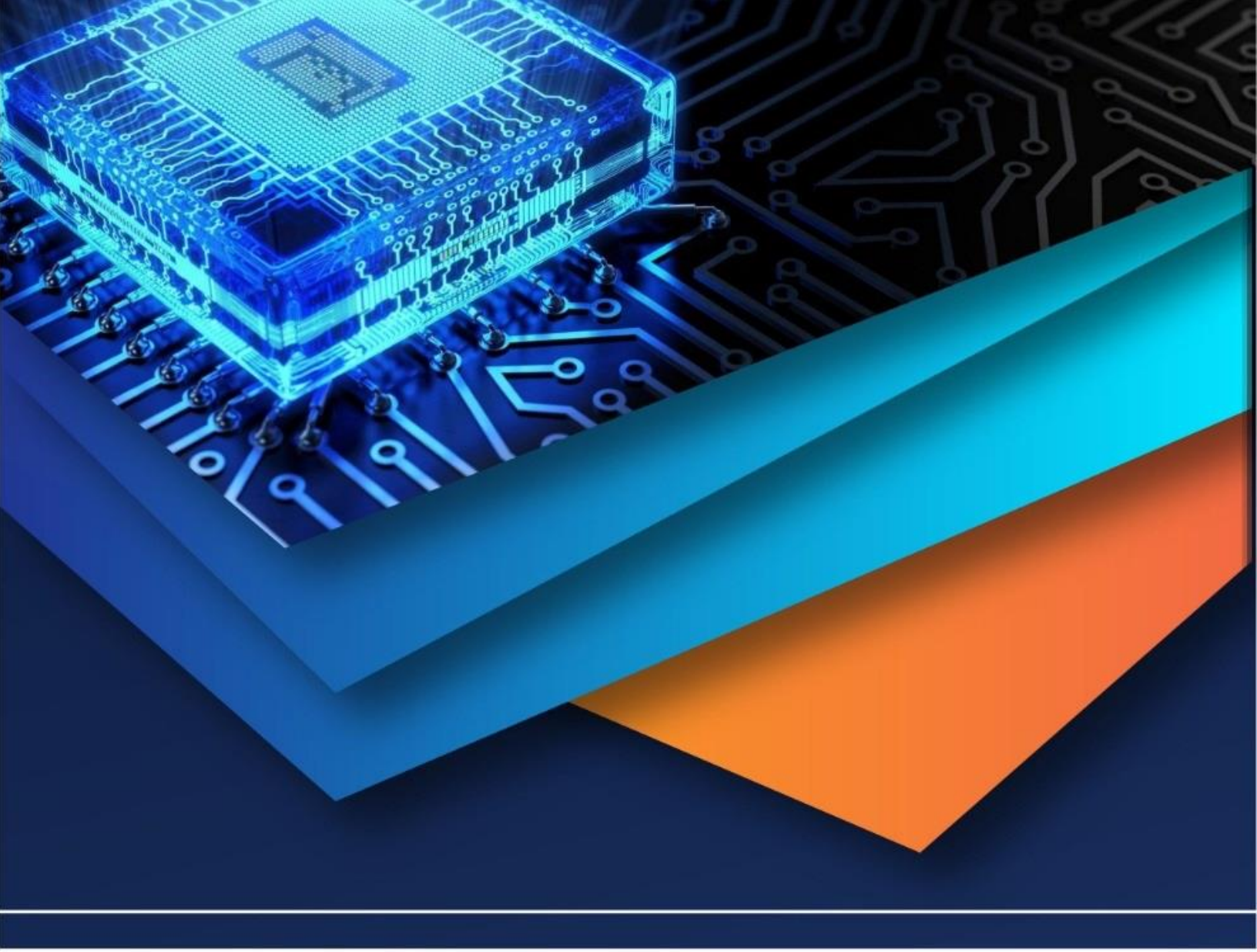

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