C&D Waste: A viable source of Coarse Aggregate for Sustainability

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Abstract

The most prevalent sort of C&D waste generated by the construction sector is concrete trash, which is generally disposed of in landfills. Recycling this waste into recycled coarse aggregates (RCA) and replacing it for natural aggregates in the concrete making process could result in environmental conservation. The qualities of Recycled Aggregate Concrete (RAC) are assessed in the current research effort. The creation of two distinct concrete sample types, one using RCA and the other using NCA, or Natural Coarse Aggregate. Through lab experiments, the focus of the research is on finding out how concrete works at its most basic level. The main goal of these tests is to look at the main qualities of recycled aggregate materials and see if they can replace virgin aggregate materials. To determine the most effective version of the materials, the substitution rate fluctuates. Up to 20% of natural aggregate materials have been replaced with recycled aggregate materials, and the results have been evaluated. It is well knowledge that adding recycled aggregates to concrete can reduce the material's durability and compressive strength. Different ways have been tried to deal with the poorer grade of recycled aggregates used to make concrete. In this study, the effects of adding fly ash to the design of the concrete mix are looked at as a way to lessen the effects of using recycled particles that aren't as good.

Keywords: Construction and demolition waste (C&D Waste), Recycled Coarse Aggregates (RCA), Recycled Aggregate Concrete (RAC), Natural Coarse Aggregate (NCA)

Introduction

The need for new structures and infrastructure develops as the world population rises and urbanization continues. Due to this tendency, the building sector is using a significant quantity of natural resources and producing a lot of garbage, especially during demolition and renovation projects. To reduce the building industry's effects on the environment, there is a growing interest in building materials derived from construction and demolition (C&D) waste, with increasing attention being directed towards them. This study focuses on the possibility of using C&D waste as a supply of coarse aggregate for making concrete, which can aid in sustainable development by lowering waste output and preserving natural resources. In this paper, the qualities, efficacy, and environmental effects of employing recycled coarse aggregate in concrete are reviewed in the literature. According to the research, using recycled coarse aggregate can provide products with mechanical qualities that are equal to those manufactured with natural coarse aggregate while also having less of an impact on the environment.

The most recent information on the generation and use of C&D waste (construction and demolition trash) differs by location and nation. United States: 569 million tonnes of C&D garbage were produced in the US in 2018, with 90% of that debris coming from demolition, according to the US Environmental Protection Agency. 25% of C&D waste, or around 145 million tonnes, was recycled or used again [1].

European Union: The European Commission estimates that C&D waste accounts for about 25% of the EU's total trash, with an annual generation of 1.5 billion tonnes. With a goal of 70% recycling by 2020, the EU recycled about 50% of C&D trash in 2014 [2].

China: According to a World Bank report, the country created 1.5 billion tonnes of C&D garbage in 2015, or approximately 40% of all waste produced there. The paper also mentions China's low recycling rate for C&D trash, which is thought to be less than 5% [3].

India: According to the Ministry of Environment, Forests, and Climate Change, the nation generates about 530 million tonnes of C&D trash per year. However, it is only believed that 10% of C&D trash is recycled in India.[4]

Paper Review on properties

Workability

How well C&D waste-recycled aggregate materials can be used determines the recycling utilization area. It is also helpful for figuring out how effective recycled aggregate-containing concrete ingredients.

The recycling utilization area must be determined based on how well the C&D waste-derived recycled aggregate can be put to use. It is also helpful for figuring out how effective recycled aggregate-containing concrete ingredients are [5].

For ease of reuse, "Phani et al." argue that C&D waste RCA is often round. When utilized in place of natural aggregate materials, Rounded aggregates improve concrete workability. According to the literature, SFC (Silica Fume Cement) paste improved the workability of the RCA. The decline was caused by the RCA's lowered WA following SFC paste treatment [6].

Ismail et al. say that the sharp edges and rough surfaces of recycled concrete aggregate (RCA) particles may make fresh concrete mix harder to work with, which is different from standard concrete aggregates. This effect is more pronounced at higher doses, causing a reduction in workability [7].

Datta et al. have also shown that as the percentage of recycled concrete aggregate (RCA) replacement goes up, the slump value of the concrete can go down. This can be explained by the fact that RCA can absorb more water than other materials. Also, when different types of concrete are compared, it is seen that the 12-20 mm aggregate concrete has a higher slump than the 5-12 mm aggregate concrete. This is because of how the smaller aggregates fit together and how close together they are.

On the other hand, Arun et al. have suggested that reducing the water-to-cement (W/C) ratio can enhance the compressive, split tensile, and flexural strengths of RCA concrete. However, lowering the W/C ratio can also decrease workability, which can be addressed by incorporating superplasticizers to attain the desired level of workability [8].

Compressive Strength

Arun et al. (2021) investigated M20 grade concrete with a 0.55 w/c ratio, OPC 53 cement, and in place of natural coarse aggregate (RCA), 100% recycled coarse aggregate (RCA) is used. Their study revealed that RCA The compressive strength of concrete was lower than that of natural aggregate concrete but reducing the w/c ratio could improve the strength even if it would compromise workability.

In another study by Ismail et al. (2019), RCA was used in place of up to 60% of the natural coarse aggregate in M50 grade concrete. The findings indicated that as the content of recycled concrete aggregate (RCA) increased, the compressive strength of the concrete declined. This decrease can be attributed to the presence of loose residual mortar on the surface of the RCA.

However, treated RCA increased strength, and the best strength was attained when up to 45% of RCA was replaced in the concrete mix.

B. Chaudhary et al. (2021) investigated the use of demolition waste from demolished concrete in M30 grade concrete with 10% to 100% replacement. The study found that using waste concrete from demolished buildings boosted the compressive strength of the concrete up to a point where it started to decline (60%).

In a study conducted by SD Datta et al. (2022), different concrete mixtures were investigated, utilizing coarse aggregate sizes of 5-12 mm and 12-20 mm, with varying rates of recycled concrete aggregate (RCA) replacement at 15%, 30%, and 45%. The research findings indicated that the most effective approach for producing concrete with moderate strength, enhanced durability, and improved resistivity was achieved by utilizing recycled aggregate concrete (RAC) with a 30% replacement of 5-12 mm size aggregate.

In a study done by Yonatan et al. in 2022, it was found that compressive strength barely changed when recycled aggregate material replaced as much as thirty-five percent of standard aggregate material. The study looked at M20 grade concrete and how recycled aggregate material could be used instead of regular aggregate material at different levels, from 0% to 100%.

SC Kou et al. did a study on using recycled aggregate in concrete. They looked at how much natural aggregate could be replaced by recycled aggregate at 0, 20, 50, and fully by volume. The research showed that adding recycled aggregates, which have lesser mechanical and physical properties, together with the greater the original free water content in the concrete mixture, led to a decrease in the 28-day compressive strength of the concrete mixtures as the amount of recycled aggregate increased. But adding fly ash to the cement, no matter how much recycled aggregate was used instead, increased the compressive strength of the concrete by a lot [12].

Methodology

Slump Test

The IS 1199-1959 standard in India says that the Slump cone test is used to find out how workable a concrete mix made in the lab is. Even though the concrete slump value is often used to measure workability and show the water-cement ratio, it can also be affected by other things, such as the qualities of the materials, mixing methods, dosage, and admixtures.

After the Slump test is done, a concrete mix, such as M15, with the right weight ratio of water to cement must be pre-mixed in the lab and used to make six cubes for more testing.

To make concrete cubes, you have to prepare the mould, add four layers of the concrete mixture to the mould, tamp each layer with a tamping rod,

To determine the slump value of a concrete sample, begin by using a trowel to remove any excess concrete from the surface. Next, swiftly lift the mould in a vertical direction away from the concrete. Once the mould is successfully removed, the discrepancy between the height of the mould and the height of the tested sample is measured to calculate the slump value.

It's important to remember that the slump test can give an idea of how easy the concrete mix is to work with, but it's not the only thing that affects the overall quality of the concrete. Other things that can have an effect are the properties of the materials, how they are mixed, how much they are used, and what else is added [13].

Compaction Factor Test

In laboratory environments, the compaction factor test is carried out to evaluate the workability of concrete, gauging its ease of handling. By comparing the weight of partially compacted concrete to that of fully compacted concrete, the compaction factor is determined. This test is specifically conducted on concrete that presents challenges in workability and does not meet the criteria set by the slump test.

Follow these steps to figure out how well concrete is packed:

Fill the upper hopper with a sample of concrete until it can hold no more.

Open the trapdoor at the bottom of the upper hopper to let the concrete out so it can flow into the lower hopper.

Open the lower hopper's trap door to let the concrete fall into the cylinder below.

Use trowels to get rid of any extra concrete on the cylinder's top surface.

Afterward, ensure the levelled surface around the cylinder. Clean the exterior of the cylinder thoroughly and proceed to weigh it together with the contained concrete (referred to as W1). Fill the cylinder with layers of the same concrete mixture that are about 5 cm thick and ram each layer hard to make sure it is fully compacted. Put the compacted concrete in the cylinder and weigh it (W2). Lastly, find the weight of the empty cylinder (W) so that you can divide (W1-W) by (W2-W) to get the compaction factor [14].

Compaction Factor Value= (W1-W) / (W2-W)

Fig 1: Slump Cone Apparatus   Fig 2: Compacting Factor Apparatus

Compressive Strength

IS 516 (1959) describes the compressive strength test, which is often used to figure out how strong concrete is as a whole. The test is done on a sample that is either a cube or a cylinder. A new mix of M30 concrete is poured into a 15 cm x 15 cm x 15 cm mould and carefully pressed down to make sure there are no holes. After 24 hours, the test samples are taken out of the moulds and put in water to cure. The tops of these samples should be smooth and level.

After curing for 7 or 28 days, these samples are checked with a compression testing machine. The load is gradually applied at a rate of 140 kg/cm^2 per minute until the specimen fractures. To determine the compressive strength of concrete, divide the load at the point of failure by the cross-sectional area of the specimen. It is advisable to conduct tests on a minimum of six cubes with dimensions of 15 cm x 15 cm x 15 cm each to obtain a reliable estimation of the concrete's compressive strength [14].

Fig 3: Casted cubes and beams

Fig 4: Curing

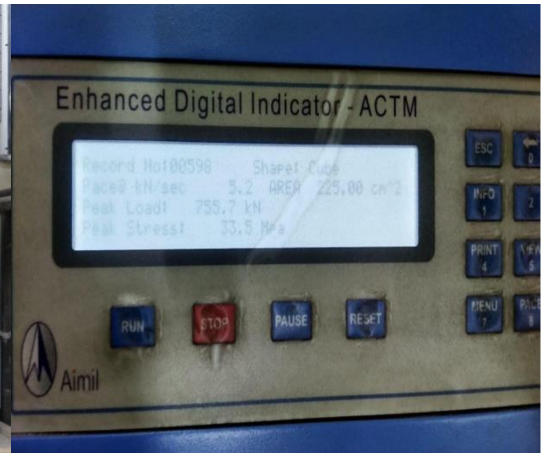

Fig 5: Testing of concrete

Fig 6: Compression testing machine

Result and discussion

Workability

There are two ways to measure workability: the compaction factor test and the slump test. The test findings from both methodologies indicate a deteriorating trend in workability with increasing RCA substitution in concrete mixtures of 0%, 5%, 10%, 15%, and 20%.

The increased water absorption of RCA, which is 2.45% compared to natural aggregate's 0.5%, it might be the result of mortar that has been stuck to the aggregate's surface. Superplasticizers can be used to attain the necessary amount of workability.

The results are shown below:

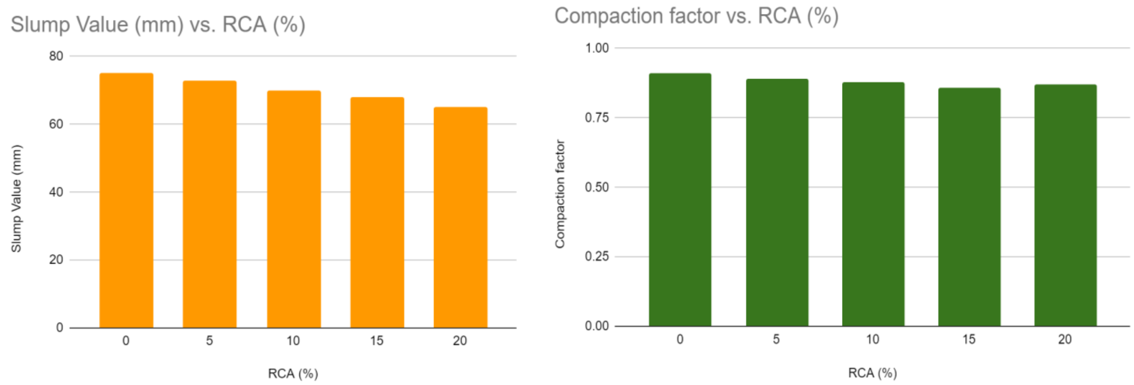

Fig 7:- Workability of concrete mixes

Compressive Strength

To assess the compressive strength of the concrete, we created test cubes with dimensions of 150 x 150 x 150 mm. These cubes were subjected to testing using a compressive testing machine (CTM), as determining the compressive strength is a vital aspect of evaluating concrete strength. The compressive strength tests were conducted on two sets of cubes: one composed of recycled coarse aggregate (RCA) and the other using new coarse aggregate. Both cube sets were made with a grade of concrete known as M30.

Following the cube preparation, they were subjected to a curing process lasting 28 days. After the curing period, the cubes were removed from the curing environment and any excess surface moisture was carefully wiped off. Subsequently, the cubes were positioned in the compression testing machine, where pressure was steadily applied until failure occurred, enabling the evaluation of their strength.

To enhance the precision of our results, we performed compressive strength tests on three individual cubes. The average value of these three test results will be regarded as the concrete's compressive strength.

The results are provided as follows:

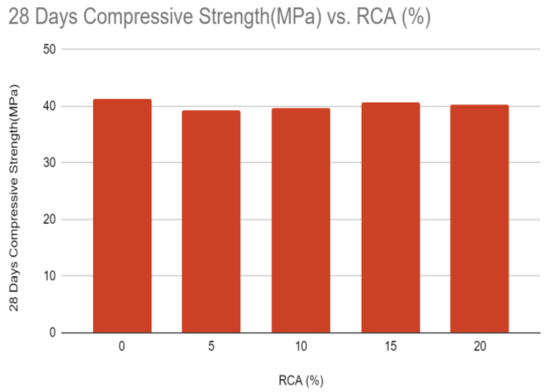

Fig 8:- Compressive strength of concrete mixes

Incorporating fly ash as a partial substitute for cement in RCA concrete resulted in a significant improvement in compressive strength compared to when fly ash was not utilized. This increase in strength can be attributed to the pozzolanic characteristics of fly ash, which enhance the compactness and durability of the concrete. Additionally, the utilization of fly ash helps mitigate the environmental impact associated with concrete production by reducing the amount of cement required. Therefore, substituting cement with fly ash presents a favourable approach to augmenting the compressive strength of RCA concrete.

Conclusion

- Although the values of slump and compaction factor in various concrete mixes are within range, there is a discernible decline. This might be because mortar that has been applied to the surface raises the water absorption value, which reduces workability.
- Results for compressive strength show a downward trend, and one of the main causes is that RCA absorbs more water than natural aggregates, which results in a significant drop in the ratio of water to cement around the aggregates and causes incomplete hydration around them. Another major factor is the poor quality of the adhered mortar, which went through the crushing process and caused weak spots in the concrete.

  The RCA's produced cracks and voids are another factor contributing to the concrete's decreased compressive strength.

- Overall, we may draw the conclusion that, with adequate RCA treatment and the use of admixtures (Fly Ash), RCA can be utilized to substitute natural aggregates. Laboratory tests demonstrate that using RCA up to a specific replacement percentage is safe.

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