Engineering the Concrete to Achieve the Mechanical Properties by Replacing Demolished Concrete Wastes as Aggregates and adding Steel Fibers as Micro-Reinforcements

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Abstract. Even for the construction of conventional buildings, materials for construction expense is unnecessarily rising, and this is becoming a major factor impacting the global housing market. This has made research into the economy of building materials necessary. In this regard, concretes have been created that partially substitute conventional aggregates with Demolished Concrete Waste (DCW) as coarse and fine aggregates. By bridging concrete cracks, the steel fibers' characteristic helps to increase the inherent tensile strength of the material. For the purposes of this study, three distinct combinations of DCW content replacement were created using M25 grade concrete: 50% of Aggregate obtained through recycling process (RCA) + 20% Recycled Fine Aggregate (RFA), 50% RCA + 10% RFA, and 50% RCA. Additionally, 1% steel fiber reinforcements were added to each combination. To ascertain the required mechanical properties, concrete specimens in the shape of a “cube, cylinder, & prism” were cast and tested after seven, fourteen, and twenty eight days of curing. The mechanical properties of the newly developed concrete included splitting tensile strength, flexural strength, and compressive strength. These properties were evaluated and compared to those of traditional concrete. According to test results, the newly developed concrete produced strengths that were on par with those of conventional concrete.

KEYWORDS: compressive strength, demolished concrete waste, flexural strength, recycled coarse aggregate, recycled fine aggregate, split tensile strength

1. INTRODUCTION

The best building material for civil engineering is concrete. The main reasons it is regarded as brittle material are its low tensile strength and low fracture toughness. Cement, water, aggregates and ad-mixtures are among the additive used in the manufacturing of concrete. This study focuses on using steel fibers to create fiber-reinforced concrete, using recycled aggregates instead of natural one as fine and coarse aggregates. There are a lot of waste materials that don't break down naturally, and they could stay in the environment. The environment would be impacted by the waste disposal crisis brought on by the non-decaying waste materials. The rapid utilization of these resources helps preserve natural aggregate sources. Given this, alternative materials are used in modern civil engineering construction instead of natural aggregate during the concrete's production process, making concrete a feasible and ecological friendly building material. In place of natural aggregate, various alternative waste materials and industrial by-products, including fly ash, bottom ash, recycled accumulate, foundry sand, china clay sand, crumb ,glass & rubber were used. The properties of the concretes were then examined. A small number of studies have revealed that C and D Waste, the recycled byproduct, can also be utilized as aggregate in concrete in addition to the waste materials and industrial byproducts already mentioned. Approximately 20% of the C and D waste produced worldwide is produced in Barat. Because demolished waste is difficult to decompose, disposing of it presents environmental challenges. Aggregate that is produced economically by crushing razed waste and extracting the coarse aggregate for use in place of freshly purchased aggregate. Because C&D waste has already been used and cannot be replaced in all situations, its disposal raises environmental concerns.

2. MATERIAL TRAITS

2.1 Materials

The performance of conventional concrete is largely dependent on the proper ingredient selection, which is determined by assessing each ingredient's properties and comprehending how various materials interact with one another. Cement, sand, super plasticizer, coarse aggregate and crushed concrete waste in the form of fine & coarse aggregate are the ingredients.

2.2 Demolished Concrete Waste

The minimum requirements of newly purchased aggregates are satisfied by the concrete produced using waste aggregate that has been demolished. C&D waste aggregates are used to make concrete that has the appropriate strength needed for structural concrete. Demolished waste could be useful as a coarse aggregate and as a possible building substance in the construction industry, which would simultaneously solve the ecological issue of lowering the amount of hard waste produced. It is discovered that the waste cement used for the destroyed building is very compatible and doesn't need to be pre-treated. Because the coarse aggregates have a smoother surface, demolished waste concrete is more workable. When compared to regular concrete, C&D waste concrete has a higher impact resistance.

The razed waste is obtained from a construction site and it has to dried for several days before undergoing manual crushing. The debris that has been demolished and removed from the site is first cleaned, dried, and then manually crushed. Depending on the crushing process, coarse aggregate exhibits a wide range of variations in size, weight, shape, and colour.

2.3 Recycled Coarse Granules

Table 1. Properties of Recycled Coarse granules

S.No	Physical Properties	Result
1	Specific gravity	2.4
2	Physical form	Coarse
3	Size	20mm

Fig 1. Recycled Coarse Granules

2.4 Recycled Fine Granules

Table 2. Properties of Recycled Fine Granules

S.No	Physical properties	Result
1.	Specific gravity	2.7
2.	Physical form	Gravel
3.	Size	0.75mic-4.75mm

2.5 Super Plasticizers

Con-plast SP430, a super plasticizer, is employed. They can increase the axial compression of concrete by upto 30% when it comes to mixing water requirements. Conplast Super Plasticizer (SP 430), a super plasticizer based on sulphonated naphthalene formaldehyde, u. Table 2.3 displays the super plasticizer's properties.

Table 3. Properties of Super-Plasticizer

S.NO	Physical Property	Value
I.	Solid content	42%
II.	Specific gravity	1.22

3. MIX DESIGN

3.1 General

Concrete mix design is the act of choosing suitable components for concrete and figuring out their ratio in order to produce a concrete that is both workable and strong enough. This is done as economically as possible. The way that ingredients are proportioned in concrete is largely determined by how well the material performs in its plastic and hardened states. Chemical admixtures should be added to the concrete if its workability is determined to be unsatisfactory in order to create a workable concrete.

3.2 Mix Proportions

The below data shows the mix ratio of concrete.

Mixture 1**:**

Cement = 383.2 kg
Fine granules = 700 kg/m^3
Water = 191.6 kg/m
Coarse granules = 1130.04 kg/m^3

Mixture 2**:**

Cement = 383.2 kg/m^3
Fine granules = 700 kg/m^3
Water = 191.6 kg/m^3

Coarse granules = 565.02 kg/m^3
RCA kg/ m^3 = 565.02 kg/m^3

Mixture 3**:**

Cement = 383.2 kg/m^3
Water = 191.6 kg/m^3
Fine granules = 630.63 kg/m
Coarse granules = 565.02 kg/m3
RCA = 565.02 kg/m^3
RFA = 62.2 kg/m^3

Mixture 4**:**

Cement = 383.2 kg/m^3
Water = 191.6 kg/m^3
Fine granules = 560 kg/m^3
Coarse granules = 565.02 kg/m^3
RCA = 565.02 kg/m^3
RFA = 138.52 kg/m^3

Mixture 5**:**

Cement	= 307 kg/m^3
Water	= 153.2 kg/m^3
Fine granules	= 602.56 kg/m^3
Coarse granules	= 614.5 kg/m^3
RCA	= 558.64 kg/m^3
RFA kg/m^3	= 152.366
Chemical admixture	= 6.14

4. EXPERIMENTAL PROGRAM

4.1 Compression Test (Ref: IS: 516-1959)

The reason it is the most widely used test for hardened concrete is that most of its desirable characteristics are directly correlated with its compressive strength, making it a simple test to conduct. Compressive strengths were obtained from the compressive tests executed on 150 x 150 x 150 mm cube sample. The cube was set up on the compression testing machine's platform (Fig. 2). The weight was gradually increased until the concrete cubes failed. In accordance with IS: 516-1969, the samples are exposed to compressive loads in a compression testing machine. The crushing load is recorded, providing the cube's compressive strength. The fraction of the specimens' surface area to crushing load, expressed in N/mm2, is their compressive strength. Consequently, all of the cubes' compression strength values are determined.

Fig 2. Test Set up for Compressive Strength Test

4.2 Flexure Test (Ref: IS: 516-1959)

At the point of rupture, the flexural strength causes the greatest amount of stress in the material. Stress is used to measure it, and the symbol f_{cr} is used here. Flexural tests on prism prototype measuring 100 mm by 100 mm by 500 mm were used to determine the flexural strengths of the corresponding specimens. As per standard, a two-point loading frame machine is used to test the flexural strength, as illustrated in Figure 3.

Fig 3. Test Set-up for Flexural Strength Test

The modulus of rupture can be resolved by using the formula given below

$$f_{cr} = \frac{P_{max} \times L}{bh^2}$$

where,

f_{cr} = Flexural strength
P_{max} = max. load in (N) kg.
b = width of the prism in mm
h = depth of the prism in mm
L = span of the prism in mm

The specimen should not be subjected to any tensional stresses or restraints when the loading is applied centrally. It is possible to line up the specimen's axis with the loading tool's axis. The load must be applied smoothly and steadily increase at the predetermined rate.

4.3 Split Tensile Strength Test (Ref: IS: 5816-1999)

Usually, testing simple concrete cylinders yields this information. Concrete of M25 grade was used to cast the 150 x 300 mm cylinders. Specimens were cast using two different percentages of SCC and conventional concrete. Tamping rods were used to manually compact the traditional concrete cubes during the casting process. The specimens are taken out of the mould after a day and allowed to cure in water for a period of “7, 14, or 28 days”. Following curing, a calibrated compression testing machine with a 2000KN potential was used to test the specimens for compressive strength in accordance with IS: 5816-1999. Between the specimens, there were two 3 mm thick plywood packing strips—one at the top and one at the bottom. After positioning the specimen on the plywood strip, make sure that the load-applying axis and its central horizontal axis are exactly perpendicular to each other. The top platen was lowered until it touched the second plywood strip, which was positioned

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lengthwise on the cylinder. Without using any shock, the load was applied and increased steadily until the prototype's resistance to the growing load failed and no higher load could be maintained.

Tensile strength of concrete,

$$f_t = \frac{2P}{\pi DL}$$

Where,
P = Max load applied to prototype
L = Measured length of the prototype
D = Measured diameter of the prototype

5. RESULTS AND DISCUSSION

The findings from the numerous tests carried out to access physical characteristics are covered in this section. Determining the compressive strength, flexural strength, and splited tensile strength is the goal of this study. Thus the test specimen results are displayed. This section also includes a discussion of the results. Standard experiments are used to determine the physical characteristics of concrete, such as split tensile strength, flexural strength, and compressive strength". They are listed below,

5.1 Compression durability

Table 4. Compression durability of Cubes with Partial Substitution of demolished concrete

COMPRESSION DURABILITY N/mm^2				
Days taken for Curing	**Mixture 1 (0%)**	**Mixture 2(50% RCA)**	**Mixture 3 (10%RFA & 50% RCA)**	**Mixture 4(20%RFA & 50%RCA)**
7	21.3	21.6	16.8	15.3
28	29.5	27.3	25.7	24.5

5.2 FLEXURAL STRENGTH

Table 5. Flexural Strength of beams with Partial Substitution of demolished concrete waste aggregate

Curing Days	**FLEXURAL STRENGTH N/mm^2**			
	Mixture 1	**Mixture 2**	**Mixture 3**	**Mixture 4**
28 days	5.26	4.87	5.01	4.55

5.3 SPLIT TENSILE STRENGTH

The variation in split tensile strength after 28 days with different percentages of crushed concrete leftovers as coarse and fine granules. The test outcomes showed that a mix with 50% RCA replacement of the coarse granules produced the highest split tensile strength.

Table 6. Split tensile strength of Cylinder with Partial Substitution of DCW granules

Days taken for Curing	SPLIT TENSILE STRENGTH N/mm^2			
	Mixture 1	Mixture 2	Mixture 3	Mixture 4
28 days	3.2	3.3	2.4	2.1

6. CONCLUSIONS

1. It was discovered that 50% replacement of the RCA's demolished concrete waste was the ideal level, with results that were more in line with conventional concrete.
2. In addition, 10% RCA replacement of fine aggregate brings results closer to 50% RCA in conventional concrete.
3. However, in addition to the 20% RFA replacement, the compression durability gradually declines. Mineral admixtures can be added to solve this issue.
4. The three sets of substitute concrete also have flexural strengths that are closer to the conventional concrete's value.
5. The 50% RCA substituted concrete's splitting tensile test value is closer to the conventional concrete's value.
6. However, the splitting tensile test values for two additional sets—50 percentage RCA & 10 percentage RFA and 50 percentage RCA & 20 percentage RFA—are progressively reduced.
7. Reusing the waste from old, razed concrete in new concrete will lower the expense of producing concrete and lessen the amount of waste that is produced from it.

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