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Enhancing Sustainability Through the Partial Replacement of Recycled Aggregates and Rice Husk ASH

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Abstract
Concrete, as one of the most widely used construction materials globally, poses both environmental and economic challenges due to its resource-intensive production and disposal. This study explores sustainable alternatives by investigating the incorporation of recycled aggregates (RA) and rice husk ash (RHA) as partial replacements for conventional aggregates and cement, respectively. Recycled aggregates, obtained from demolished structures, help reduce the depletion of natural resources and landfill waste. This study evaluates the mechanical properties, durability and workability of concrete mixes with varying proportions of recycled aggregates, providing insights into the optimal blend for achieving structural integrity. Rice husk ash, a waste product from rice milling, has pozzolanic properties that enhance the performance of concrete. By partially replacing cement with RHA, this research aims to reduce greenhouse gas emissions during cement production while improving the overall durability of concrete. The study assesses the compressive strength, water permeability, and resistance to chemical attacks of RHA- blended concrete mixes. The results demonstrate the economic benefits of utilizing these sustainable materials are discussed, emphasizing the need for a balanced approach that considers both environmental and economic factors.

Keywords: *Rice Husk Ash, Recycled Coarse Aggregate, Compressive Strength, Split Tensile Strength, Flexural Strength.*

1. Introduction

Concrete has been used for many millennia; the Minoan culture discovered it approximately 2000 BC and is credited with using the material's first known application. Around 300 BC, in the early days of the Roman Empire, the Romans discovered that combining lime mortar with sand from volcanic ash produced a hard, water-resistant material that is now known as concrete [1]. We are currently investigating the durability of concrete by partially replacing coarse aggregates with destroyed recycled aggregate and cement with rice husk ash. The most often used cementitious material in the construction and building sector is Portland cement (PC). However, their continued manufacturing and use have had a negative influence on the environment. For example, global PC manufacturing was expected to be 4.1 billion tons in 2017, accounting for around 5-8% of global anthropogenic CO2 emissions. This figure is likely to rise due to population growth and infrastructure improvement in both developed and developing countries. Other constraints of PC, including as substantial energy consumption and excessive usage of non-renewable, naturally occurring raw materials, have prompted severe questions about its sustainability. As a result, there is a growing desire for an alternative binder with lower carbon emissions that may be used.

1.1.Introduction to Demolished Aggregates

India already generates 23.75 million tons of construction and demolition (C & D) trash each year, with these estimates expected to more than double in the next 7 years. C&D debris, particularly concrete, has been viewed as a resource in developed countries. Recycling research has underlined that if old concrete is to be used in second generation concrete, the product must meet the required compressive strength. This research reviews the existing literature on the use of recycled concrete as aggregates in concrete, focusing on compressive strength, and offers a method for using recycled concrete aggregate without compromising strength [1]. When up to 30% of the coarse aggregate was substituted by destroyed trash, the strength was closer to that of plain concrete cubes, with strength retention ranging from 86.84-94.74% when compared to ordinary concrete [6].

1.1.1. The Indian Case

This industrial sector's growth rate is continuing. The Central Pollution Control Board estimates that India generates 48 million tons of solid garbage every year, with the building industry accounting for 25% of that total. The entire amount of garbage generated by the building industry is estimated to be 12 to 14.7 million tons per year[1].

1.2.Introduction of Rice Husk ASH

The rice husk Ash is a byproduct of the burning of rice husk into ashes. RHA has been discovered to be a good material that meets the physical properties and chemical composition of mineral admixtures. Rice Husk Ash is ash produced by burning rice husk until it has been reduced by 25%. Rice Husk was procured locally for the study. These Husk were then debated on till fine ash was created. These ashes were sieved using a 300 Micron sieve to remove any remaining contaminants. Even at high burning temperatures of 500 to 700 °C, the generated RHA had a significant carbon content due to the short blazing spans (15 - 360 minutes) [2].

1.2.1. Indian Case

From five tonnes of rice paddy, roughly one ton of rice husk is produced, and around 120 million tonnes of rice husk is produced annually.

2. Objectives

2.1.Recycled Aggregates

The purpose of this study was not only to determine the utilization of waste materials on concrete in order to compare them economically, but also to evaluate the feasibility of doing so. Employing materials from dismantled structures. It is believed that the study's findings will persuade experts to use second-hand components in new buildings/constructions [3].

1. The use of destroyed and construction waste aggregate in fresh concrete decreases environmental pollution while also giving an economic value for the waste material [3].
2. To investigate the use of destroyed and construction waste as a substitute for natural coarse aggregate.

2.2.Rice Husk ASH

The addition of rice husk ash to concrete transforms it into an environmentally acceptable additional cementitious material. The addition of rice husk changes the following qualities of the concrete:

1. The hydration heat is minimized. This aids in drying shrinkage and increases the durability of the concrete mix[4].
2. The permeability of a concrete building is reduced. This will aid in the penetration of chloride ions, preventing the concrete structure from disintegrating[4].
3. Resistance to chloride and sulfate assault has increased significantly [4].
4. They discovered that after 28 days, fine particals of rice husk ash provide more strength than coarse rice husk ash in concrete, implying that the average partical size of rice husk ash is 150 - 300 Microns, which has a significant impact on the strength of rice husk ash-based concrete [7].

3. Experimental Materials

The selection and type of materials used in the production of any sort of concrete are critical because all of the attributes are dependent on them.
The materials listed below are being used.

- ✓ Cement was replaced by RHA
- ✓ Fine aggregate (sand)
- ✓ coarse aggregate was substituted for RCA
- ✓ Water.

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3.1.Cement

Ordinary Portland Cement (OPC) is the most common type of cement used (Figure 1). OPC of grade 53 (IS: 8112-1989) is utilized. It is a powerful adhesive and cohesive substance that, when mixed with fine aggregate, coarse aggregate, and water, forms a paste that, after curing for a specified amount of time, hardens into a mass of hard stone [1]. The proper selection of cement is critical because the strength of concrete is largely determined by it. Properties of Cement is shown in Table 1.

Figure 1 Cement

Table 1 Properties of Cement

S.NO	PROPERTIES	VALUES
1.	Specific Gravity	3.15
2.	Normal Consistency	30%
3.	Initial Setting Time	30min
4.	Final Setting Time	8hr
5.	Fineness Of Cement	6%

3.2.Rice Husk ASH

Rice husk ash is a pozzalanic substance derived from paddy in the Ananthapuramu District (Figure 2). It can be burned to produce ash that has the physical properties and chemical composition of mineral admixtures. Pozzolanic activity of rice husk ash (RHA) is affected by [5].

1. silica content,
2. silica crystallization phase, and
3. ash particle size and surface area[6].

Furthermore, ash must include only a trace of carbon. RHA with amorphous silica content and a wide surface area can be generated by controlled temperature burning of rice husk [5].

Figure 2 Rice Husk ASH

The pozzolanic process in hydrated cement blocks the voids while also reducing the alkali character of the material and minimizing concrete expansion. Because to the tiny porous structure, the alkali iron on the surface of the rice husk ash concrete aggregate [8]. Physical Properties & Chemical Properties are shown in Table 2 and 3.

Table 2 Physical Properties

S.No	Characteristics	Values
1.	Specific Gravity	2.3
2.	Appearance	Very Fine Powder
3.	Colour	Gray
4.	Odour	Odourless
5.	Mineralogy	Non-crystalline

Table 3 Chemical Properties

S.No	Compounds	%Composition
1.	Calcium oxide (CaO)	2.2
2.	Silicon Oxide (SiO_2)	86.94
3.	Aluminum Oxide (Al_2O_3)	0.2
4.	Iron Oxide (Fe_2O_3)	0.1
5.	Magnesium Oxide (MgO)	0.6
6.	Sodium Oxide (Na_2O)	0.8
7.	Potassium Oxide (K_2O)	2.3
8.	Loss On Ignition (LOI)	4.4

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3.3. Aggregates

Aggregates are inert granular materials that are end products in their own right, such as sand, gravel, or crushed stone. They are also the raw components that are used to make concrete. Aggregates for a good concrete mix must be clean, firm, and robust, with no absorbed chemicals or coatings of clay or other fine impurities that could cause concrete deterioration [1]. Aggregates are categorized into two groups based on their size.

- Fine Aggregate
- Coarse Aggregate
- Recycled Aggregate

3.3.1. Fine Aggregate

River sand, passing through a sieve size 4.75 mm and retained on a 600 Micron m sieve, conforming to Zone II as per IS 383-1970, was used as fine aggregate in the current project (Figure 3). The sand is devoid of clay, silt, and organic contaminants. The aggregate was evaluated for physical specifications such as gradation, fineness modulus, specific gravity, and bulk modulus in line with IS: 2386-1963[8-11]. Physical Properties are shown in Table 4.

Figure 3 Fine Aggregate

Table 4 Physical Properties

S.No	Characteristics	Values
1.	Specific Gravity	2.64
2.	Zone	II

3.3.2. Coarse Aggregate

As coarse aggregate, a local supply of machine crushed angular granite metal with a nominal size of 20mm and below is employed (Figure 4). It is free of contaminants such as dust, clay particles and organic substances (Table 5), and so on [9].

Figure 4 Coarse Aggregate

Table 5 Physical Properties

S.No	Characteristics	Values
1.	Nominal Size	20mm and Below
2.	Specific Gravity	2.73
3.	Water Content	0%
4.	Water Absorption	0.6%

3.3.3. Recycled Aggregate

Waste from the destruction of concrete constructions is collected, and aggregates are sorted as recycled aggregates (Figure 5). The proposed recycled aggregates are employed in the concrete mix for this project. Grading is used to shape the recycled aggregates. For partial replacement, 20 mm angular recycled aggregates are specified [1] (Table 6).

Figure 5 Recycled Aggregate

Table 6 Physical Properties

S.No	Characteristics	Values
1.	Nominal Size	20mm
2.	Specific Gravity	2.68
3.	Water Content	0.3%
4.	Water Absorption	0.9%

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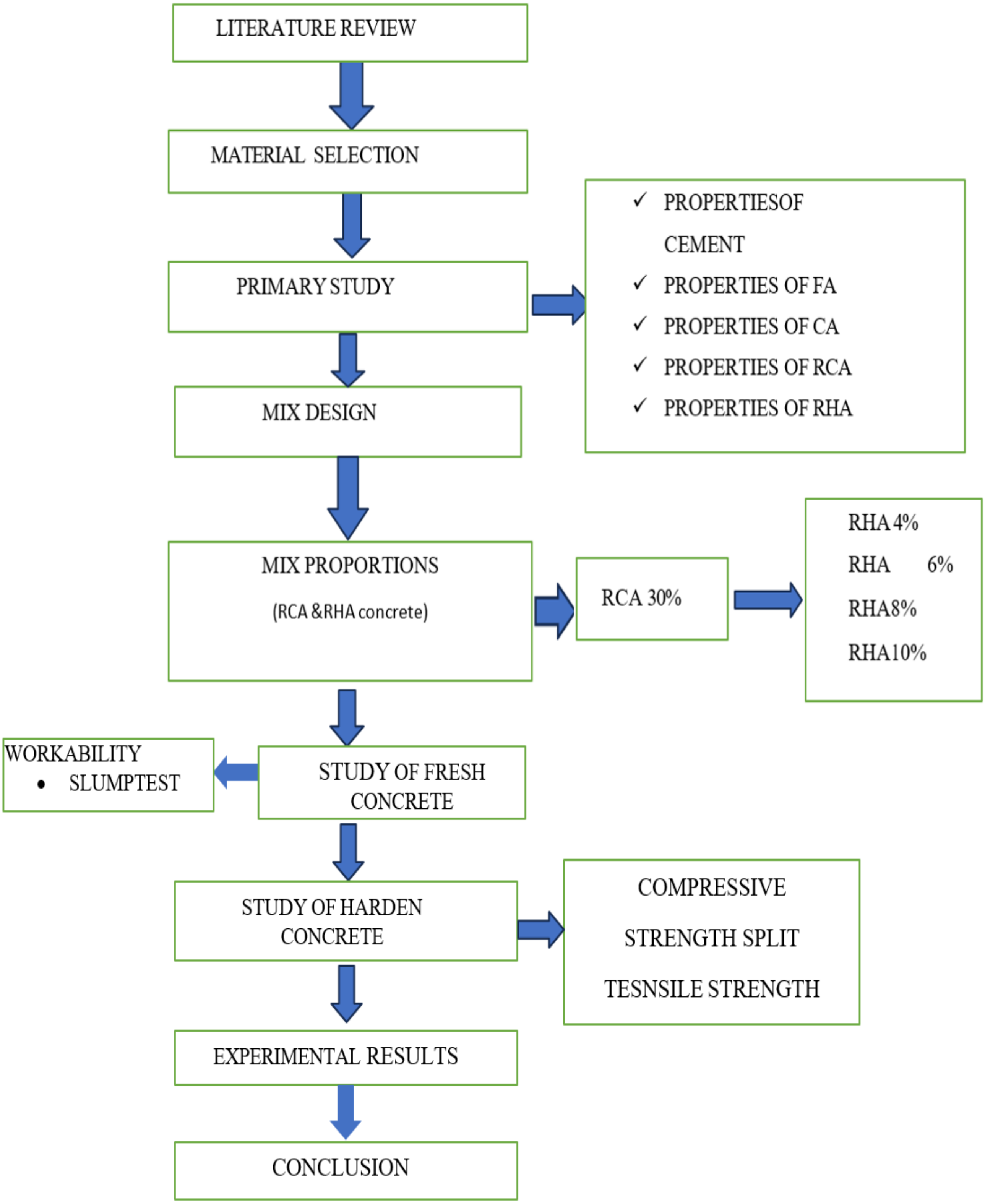
4. Methodology



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5. Mix Design

Table 7 Mix Content - Grade of Concrete-M30 Slump-75mm

Mixture	X_0	X_1	X_2	X_3	X_4
Cement (kg)	17.5	16.97	16.54	16.19	15.75
Rice Husk Ash (kg)	0	0.624	1.056	1.408	2
Coarse Aggregate (kg)	43.39	43.3	43.3	43.3	43.3
Recycled Coarse Aggregate (kg)	0	9.51	9.51	9.51	9.51
Fine Aggregate (kg)	29.6	29.6	29.6	29.6	29.6
Water (lit)	8.83	8.83	8.83	8.83	8.83

Table 8 Proportion Details

Mix	Proportions	
X_0	Convectional Concrete (100%)	
X_1	RCA (30%) + NCA (70%)	RHA (4%) + OPC (96%)
X_2	RCA (30%) + NCA (70%)	RHA (6%) + OPC (94%)
X_3	RCA (30%) + NCA (70%)	RHA (8%) + OPC (92%)
X_4	RCA (30%) + NCA (70%)	RHA (10%) + OPC (90%)

6. Experimental Research

6.1. Compressive Strength Test

Figure 6 Compressive Strength Test

Crushing strength was measured on concrete cubes 150*150*150mm. These cubes are compressed tested after 28 days of curing (Figure 6). The sample is centered on the machine's base plate, and the load must be applied. Gradually apply 140 kg/cm2 per minute until the specimen fails. The greatest load applied to the specimen is then recorded [12]. Refer Tables 7 to 11.

- The compressive strength of a cube is thus fc=P/A N/mm2.
- Where P is the ultimate load in N
- A is the cube cross sectional area in mm2.

Table 9 Proportion Details

Proportions	Result for 28 Days
X_o	35.77
X1	30.7
X2	36.06
X3	38.86
X4	32.56

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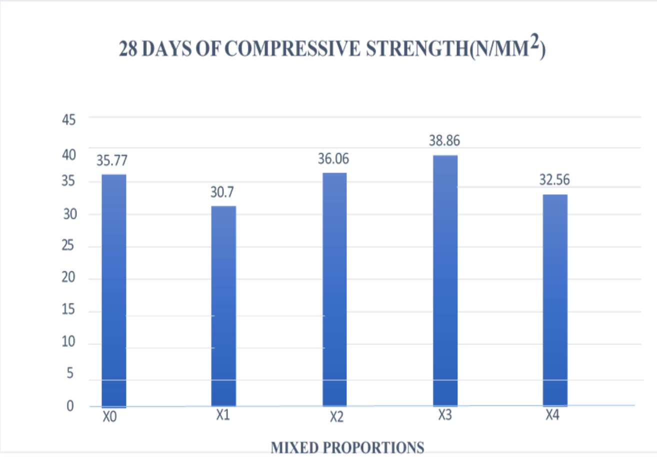

Figure 7 **Shows 28 Days Compressive Strength**

6.2.Split Tensile Strength

Figure 8 **Split Tensile Strength**

A splitting tensile strength test on a concrete cylinder is a method for determining concrete tensile strength. Because of its brittle nature, concrete is extremely fragile in stress. It is not expected to withstand direct stress. When tensile forces are applied to concrete, cracks form. As a result, determining the tensile strength of concrete is required to establish the load at which the concrete members may crack. A splitting tensile strength test on a concrete cylinder is a method for determining concrete tensile strength. For this test, 150mm*300mm cylinders were used. The specimens were tested for 28 days with the cylinder specimen put horizontally on the testing equipment. The following relationship exists used to find out the spilt tensile strength of cylinder. Refer Figures 7 to 11.

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

where Ft is split tensile strength,

P= Ultimate load in KN

L = Length of the cylinder in mm,

D=Diameter of the cylinder in mm

Table 10 **Proportion Details**

Proportions	Result For 28 Days
X_o	3.2
X1	2.02
X2	3.12
X3	3.30
X4	3.1

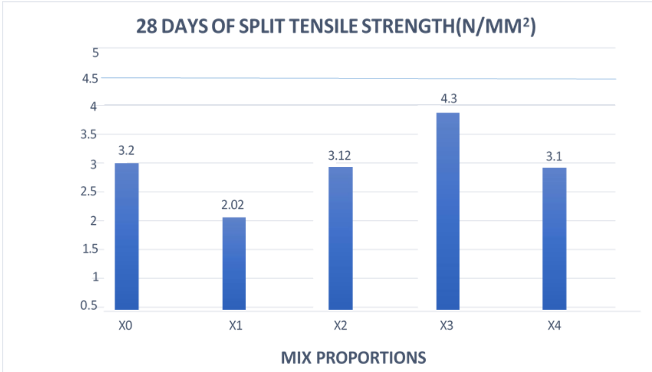

Figure 9 **Shows 28 Days of Split Tensile Strength**

6.3.Flexural Strength

Figure 10 **Flexural Strength**

For this test, 300*100*100mm beams were employed, and the test specimen was inserted in the machine at the bearing surfaces of the supporting and loading rollers. As a result, the load should be applied gradually and without shock. The load must be increased until the specimen fails, and the highest load applied during the test must be documented.

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$F = PL/BD^2$

where P is the load in KN

L, B is the length and width in mm.

D is the depth in mm.

F denotes the Flexure strength in N/mm2.

Table 11 Proportion Details

Proportions	Result For 28 Days
X_o	4.43
X1	3.9
X2	5.13
X3	7.86
X4	6.2

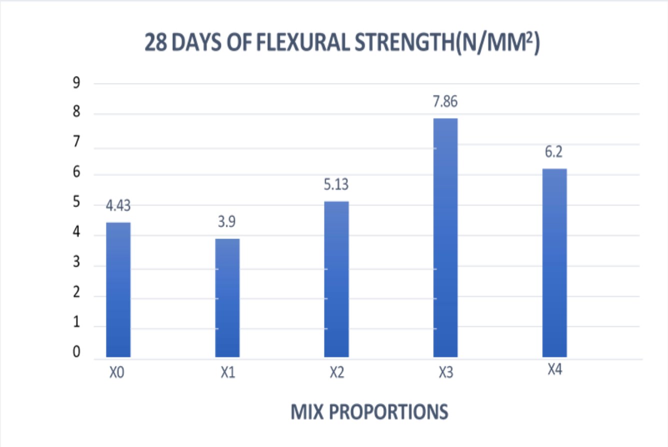

Figure 11 Shows 28 Days of Flexural Strength Test Values

Conclusion

From detail examination on RCA and RHA with 30% and 4,6,8 and 10% Concrete of 1:1.65:3 mix ratio at 0.5 water-cement ratio, the experimental results can be concluded as:

- The bulk density and specific gravity of Recycled coarse aggregate is less when compared to Natural coarse aggregates. This is because of the attached mortar exist on the recycled aggregate surface.
- The workability of concrete is good within the range of 75-120mm, In comparison to regular concrete, the slump value is 85 mm at 30%RCA and 8%RHA, representing an increased percentage of 5.8% comparing with the conventional concrete.
- The compressive strength of concrete at 28 days with the value of 38.86MPa at 30%RCA and 8%RHA, representing an increased percentage of 16.9% comparing with the conventional concrete.
- The split tensile strength of concrete at 28 days with the value of 3.30MPaat 30%RCA and 8%RHA, representing an increased percentage of 6.45% comparing with the conventional concrete.
- The flexural strength of concrete at 28 days with the value of 7.86MPa at 30%RCA and 8%RHA, representing an increased percentage of 26.77% comparing with the conventional concrete.
- The amount of water absorption of concrete at 28 days with the value of 0.78% at 30%RCA and 8%RHA, representing an increased percentage of 11.43% comparing with the conventional concrete.

And the results are found to be satisfactory. From the above investigations it can be hence concluded that the optimum replacement for this particular mix for high strength concrete is 30% Recycled Coarse Aggregate and 8% Rice Husk Ash. Thus, such type of concrete not only utilizes the waste but reduce the cost of project. Whereas RHA compensate strength to the concrete by replacement to Coarse Aggregate with Recycled Coarse Aggregate.

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