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Influence of Using Recycled Concrete Aggregates on Compressive Strength of Concrete

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Abstract
The increase of world population has led to the expansion of construction industry and depletion of natural resources. Accordingly, the need for recycling the demolished waste and producing recycled concrete aggregate (RCA), so that it can be used to replace natural aggregate (NA), became one of effective solutions to attain sustainability. This study aims to investigate the compressive strength of concrete containing different ratios of recycled coarse aggregates. Five mixes with target compressive strength ranging from 20 to 30 MPa were cast with five replacement ratios (i.e., 0%,25%,50%,75% and 100%). The results revealed that use of RCA with replacement ratios up to 50% showed good compressive strength compared to conventional concrete specimens (CC) made with Natural Aggregates (NA). When using higher replacement ratios , the samples showed about 16% compressive strength less than CC specimens. It is revealed that modulus of elasticity decreased by 7% for RCA replacement ratio (i.e., 75% and 100%), While it was similar to CC samples when replacement ratio of RCA was up to 50%.

Keywords: Recycled Concrete Aggregates, Recycled Aggregates, Compressive Strength, Mechanical properties.

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I. Introduction

Every year, the world consumes billions of tons of concrete raw materials. The rapid urbanization has led to increased construction of new structures and demolition of old ones. The demolished waste would be used in pavement construction or dumped in the landfill. Recycled concrete aggregate (RCA) and natural aggregate properties are slightly different. This is due to the presence of adhered old mortar in recycled concrete aggregate , accordingly, this affects the behaviour of new recycled aggregate concrete that can be enhanced with the use of optimum ratios of admixtures along with recycled concrete aggregate. The use of recycled aggregate concrete in construction industry results in saving natural resources, minimizing the cost of transportation and helping in reducing disposal [1-9].

Tapsh and Abdelfatah [1]. Studied the strength of concrete incorporating RCA. They found that soundness and toughness of RCA specimens showed lower percentage than NA specimens. They revealed that mix proportions affect the compressive strength and splitting tensile strength or RCA concrete.

Gayarre et al.[3] studied the influence of recycled aggregates quality on recycled concrete properties. They found that compressive strength is affected by the quality of recycled aggregates. While it is not affected when using additives enhancing workability of concrete mix when water cement ratio is kept constant, regardless with RCA replacement ratios.

Kou and Poon [2] studied the effect of the parent concrete quality on the properties of high performance recycled aggregate concrete (HPRAC). They used the parent concrete (PC) with strength grades ranging from 30 – 100 MPa to produce normal strength recycled aggregate concrete (NSRAC) and (HPRAC). They observed that compressive strength of NSRAC and HPRAC prepared with recycled aggregate derived from 80 – 100 MPa parent concretes was similar or slightly higher than that of natural aggregate concrete. Accordingly, it can be used to replace 100% natural aggregate for the production of high performance concrete.

Kou et al [4]studied low grade recycled aggregates concrete properties. They prepared three mixes with the use of low grade or trade recycled aggregates, with four replacement ratios (i.e., 0%, 25%, 50% and 100%), cement content and water cement ratio were 410 kg/m^3 and 0.55 respectively. For each mix, they casted 100 mm cubes to determine the compressive strength of concrete. They also casted 100 mm diameter and 200 mm high cylinders for evaluation of splitting tensile strength, chloride ion penetration resistance and the static modulus of elasticity. They found that use of low-grade recycled aggregates decreased the modulus of elasticity and compressive strength of concrete.

Rahal [5] reported the results of an experimental study on mechanical properties of RAC compared to those of NAC. They found that indirect shear strength and compressive strength of cubes and cylinders at 28 days were 10% lower than NAC with the same mix proportions.

II. Materials And Methods

A. Materials:

Cement: The Ordinary Portland Cement (OPC) was used in the concrete mixtures in this study.

Coarse and Fine Aggregates: Two types of coarse aggregates were used (i.e., NA and RCA) Fig. 1 with maximum aggregate nominal size of 19 mm. NA was crushed limestone, while RCA was sourced from the demolition of cubes of parent concrete of 28-35 MP compressive strength. The gradation of aggregates was between 5 to 20 mm. The fine aggregate was natural sand Fig. 1. Properties of Coarse aggregates (i.e., NA and RCA) are shown in Table 1.

Superplasticizer: Conplast SP430 superplasticizer was used. Concrete properties can be enhanced with the use of superplasticizer by reducing the w/c ratio, providing a large increase in concrete strength at all ages and a speed strength gain at early ages.

(a) Recycled Concrete Aggregates

(b) Natural Aggregates

(c) Sand

Fig 1: Coarse and Fine Aggregates

Table 1: Properties of Coarse Aggregates

Property	RCA	NA
Bulk Specific Gravity(SSD)	2.33	2.26
Apparent Specific Gravity	2.61	2.40
Absorption (%)	7.0	6.0
LA Abrasion (% Loss)	30	38

B. Mix Proportions:

Five concrete mixes were designed. Each mix comprises six cubes. Water-to-cement w/c ratio of 0.574 was adopted for all mixes. In order to achieve compressive strength greater than 25 MPa after 28 days. The amount of superplasticizer used in each mix was ranged from 1-2 litres. The mixture proportions for the five mixes are shown in Table 2.

Table 2 : Concrete Mix Proportions

Cement (kg/m^3)	Fine aggregates (kg/m^3)	Water (kg/m^3)	Coarse aggregates (kg/m^3)	Superplasticizer ($Liters/m^3$)
388	930	223	1200	9.8

C. Testing Procedure:

The mixing process was done in the concrete laboratory, six cubes of 150mm side length were used for each mix, in order to test compressive strength. Three cubes were tested at 7 days and the others at 28 days after immersing them in water tank Fig.2.

Compressive strength of specimens was obtained using compressive strength machine Fig. 3.

Fig 2: Curing Tank for the cube specimens

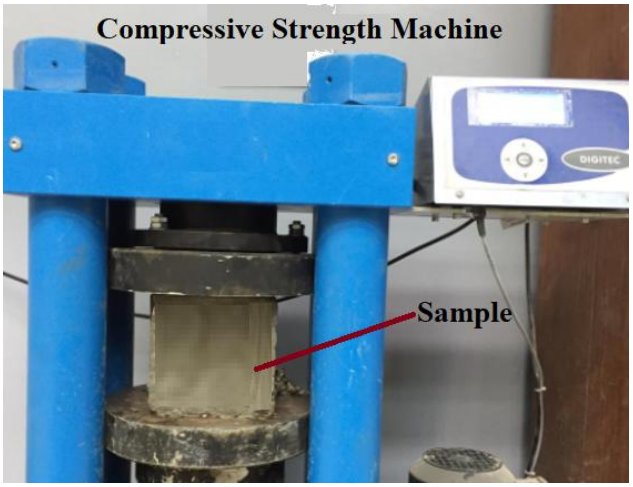

Fig 3: Compressive Force Testing Machine

III. Results And Discussion

According to test results of coarse aggregates (Table 1), it was observed that RCA had more absorption and more specific gravity than NA. The low density of adhered mortar in RCA leads to higher absorption. NA abrasion value is high compared to RCA, which indicates more toughness in RCA. It is attributed to the cement coating aggregates, resulting in crushing resistance.

The average compressive strength of control mix CC after 28 days was 26 MPa. The average compressive strength values after 7 days and 28 days for all tested mixes are shown in Table 3, where the relative F'c is related to compressive strength of control mix after 28 days. Modulus of elasticity and Density of specimens are shown in Table 3.

It is revealed that modulus of elasticity decreased by 7% for RCA replacement ratio (i.e., 75% and 100%), While it was similar to CC samples when replacement ratio of RCA was up to 50%. The results revealed that use of RCA with replacement ratios up to 50% showed good compressive strength compared to conventional concrete specimens (CC) made with Natural Aggregates (NA). When using higher replacement ratios , the samples showed about 16% compressive strength less than CC specimens.

Table 3: Density, Modulus of Elasticity and Compressive Strength of Concrete Cubes After 7 and 28 Days

Sample	Density kg/m^3	Modulus of Elasticity E_c (GPa)	F'_c (Mpa) after 7 days	F'_c(Mpa) after 28 days	Relative Compressive Strength after 28 days
NA 100%	2423.70	23.7	18.21	26	1
RCA 25%	2417.77	23.3	18.74	24.6	0.94
RCA 50%	2412.84	23.4	18.62	25.9	0.99
RCA 75%	2380.24	21.9	14.16	21.8	0.83
RCA 100%	2361.48	22.1	16.43	22.1	0.85

IV. Conclusion

According to the findings of the study, adhered mortar governs the properties of RCA. RCA exhibits higher specific gravity and absorption values (i.e., 3% and 8% respectively) compared to NA

The parent concrete of RCA affects slightly the concrete test results , such as modulus of elasticity ,compressive strength and density.

The results revealed that use of RCA with replacement ratios up to 50% showed good compressive strength compared to conventional concrete specimens (CC) made with Natural Aggregates (NA). When using higher replacement ratios , the samples showed about 16% compressive strength less than CC specimens. It is revealed that modulus of elasticity decreased by 7% for RCA replacement ratio (i.e., 75% and 100%), While it was similar to CC samples when replacement ratio of RCA was up to 50%.

The workability of concrete is affected by the method of preparing RCA mixtures. Compared to NA mixtures, RCA mixtures required additional water demand.

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