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Effect of Casting Technique on the Compressive Behaviour of Fully Recycled Aggregate Concrete

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ABSTRACT. *The research work presented in this contribution investigated the impact of Compression Casting Technique (CCT) on the compressive behavior of fully Recycled Aggregates Concrete (RAC). RAC mix containing 30% fine aggregates, 70% coarse aggregates and 15% cement by weight of total aggregates was prepared under two different casting pressures (i.e., 25 & 35 MPa). For the purpose of comparison, Natural Aggregate Concrete (NAC) mix was also prepared under same casting pressures. Samples of RAC mix were also made by compaction through vibration. Recycled concrete aggregates required for this study were prepared by crushing of damaged concrete samples having compressive strength in the range of 21 to 28 MPa. Compressive response was evaluated in terms of compressive strength and modulus of elasticity (MOE). Ultrasonic pulse velocity test was employed to check the quality of internal matrix of concrete samples prepared by CCT and vibration. The results demonstrated positive effect of CCT on the properties of concrete resulting in higher compressive strength and MOE compared to properties of concrete prepared by compaction through vibration. With the increase in casting pressure from 25 to 35 MPa, compressive strength and MOE of RAC was increased by 21% and 29%, respectively. It was found that RAC mix exhibited inferior properties (i.e., compressive strength and MOE) compared with NAC mix.*

Keywords: Recycled aggregates concrete, Casting method, Compressive behavior, UPV

1. INTRODUCTION

Construction and Demolition (C&D) waste has been increasing rapidly in the recent years because of rapid urbanization process. In China, on average 200 million tonnes of C&D wastes are produced annually [1]. To avoid problem of environmental pollution due to C&D waste, exploring different methods for its effective management is presently a hot topic of research in different parts of the world. One of the best possible solutions is to recycle C&D waste and use it as recycled concrete aggregates in new concrete known as Recycled Aggregate Concrete (RAC).

To fulfil the needs of ever-growing construction industry, it is observed that the annual consumption of natural concrete aggregates has increased significantly, and it has resulted in scarcity of their natural resources and a negative impact on our ecosystem. The use of RAC could also help to reduce burden on the natural resources required to produce concrete aggregates. Due to its high water absorption, low density, and complicated origin, which have been shown to impair the mechanical characteristics of the resulting concrete [2], RAC was first applied to non-structural application (such as landfills) due to its inferior mechanical and durability properties in comparison of NAC. However, many research works have been performed in the recent years to support the structural application of RAC, for instance [3].

Some studies such as [4,5] have demonstrated positive effect of CCT on the properties of RAC. To further strengthen the idea of employing compression casting to get improved properties of RAC, this study aimed to investigate the compressive strength and modulus of elasticity and to check the quality of RAC prepared by CCT through UPV test. The study parameter included casting technique (compression casting versus compaction through vibration) and casting pressure value (i.e., 25 and 35 MPa).

2. MATERIALS AND METHODS

2.1 Materials

To prepare concrete mixes, ordinary Portland cement was used. Table 1 and Table 2 provide the chemical composition and properties of cement, respectively. Laboratory-tested concrete specimens (cylinders and cubes) with compressive strengths of 21MPa (3000 psi) to 28MPa (4000 psi) were acquired and crushed with the help of jaw and roller crushers to get Recycled Coarse Aggregates (RCA) of maximum 12 mm particle size and Recycled Fine Aggregates (RFA). RCA were used in SSD conditions. For this purpose, the RCA were soaked in water for one day and before use, their surfaces were wiped off with a cloth to bring them in SSD condition. Locally available natural concrete aggregates were used to prepare NAC mix. Portable water was used for all concrete mixtures.

Table -1: Chemical composition of cement

CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	SO_3
62.6 %	20.8 %	5.06 %	3.27 %	2.56 %	1.57 %

Table -2: Physical Properties of Cement

Fineness	Soundness	Initial & final setting	Standard consistency
8%	9mm	105 - 215	30%

2.2 Mix Proportions

In this research investigation, total 5 concrete mixes were made and tested. These concrete mixes varied in terms of type of aggregates (NA & RA), methods of casting (CCT or vibration), and casting pressure (25 and 35 MPa). All RAC mixtures contained 100% recycled aggregates. Table 3 provides detail of all five concrete mixtures.

2.3 Test Specimen Preparations

Cylindrical concrete specimens of 150 mm height and 75 mm diameter were prepared in this study using CCT and commonly employed casting method (i.e., through vibration). A customized metallic mold (shown in Figure 1) was designed and fabricated specifically to sustain the load for CCT. After preparation, the concrete mix was poured into the metallic mold in two layers by giving each layer 25 blows with a steel rod. The desired pressure was then applied on concrete through plunger with the help of machine and was maintained for 15 seconds. The sample was subsequently extruded. Additionally, samples were also cast using the conventional casting technique (i.e., through vibration). After air drying for 24 hours, all samples were water cured.

Table -3: Concrete Mix Proportions.

<table>
<tr><th>Sr. #</th><th>Designation</th><th>Cement Content</th><th>W/C Ratio</th><th>Casting Pressure in MPa</th></tr>
<tr><td>1</td><td rowspan="2">RAC-30F70C</td><td rowspan="5">15% by Total weight of Aggregates</td><td rowspan="5">w/c ratio = 0.5 (Coarse recycled aggregates used in SSD condition)</td><td>25</td></tr>
<tr><td>2</td><td>35</td></tr>
<tr><td>3</td><td rowspan="2">NAC-30F70C</td><td>25</td></tr>
<tr><td>4</td><td>35</td></tr>
<tr><td>5</td><td>RAC-30F70C-V</td><td>Compaction by Vibration (Conventional method)</td></tr>
</table>

2.4 Testing Methods

After 28 days of casting, displacement controlled compressive strength tests were performed on all samples. The tests were performed using Universal Testing Machine (UTM) with maximum loading capacity of 1000 kN and at loading rate of 0.5mm/min. Strain gauges were used to measure longitudinal deformation in compression of the test sample which was used to determine the static elastic modulus (E) of concrete in compression following the procedure described in ASTM standard C469. The ultrasonic pulse velocity test was carried out as per ASTM

C597. To determine the Ultrasonic Pulse Velocity (UPV) value of each test specimen, standard UPV apparatus as shown in Figure 2, was used. As per standard procedure, time to travel the wave between transmitter and receiver placed at the ends of specimen is measured using standard device and then based on length of each specimen, UPV is calculated. This value is then used to rate the quality of core concrete of test sample.

Fig -1: Metallic Mold

Fig -1: UPV Testing Device/ Apparatus

3. RESULTS AND DISCUSSIONS

3.1 Compressive Strength

Chart 1 shows the compressive strength attained by test samples of RAC and NAC mixes prepared by CCT and of RAC mix prepared by conventional casting method. It was observed from these results that with the increase of casting pressure from 25 MPa to 35 MPa, the compressive strength of RAC as well as NAC was increased; an increase of 21% and 7% in compressive strength was observed for RAC and NAC, respectively. The compressive strength of NAC was found to be higher than RAC at both casting pressures. The results presented in Figure 3 also showed that the vibrated RAC samples were not able to achieve compressive strength equal to or greater than RAC samples prepared by CCT. This finding clearly demonstrated the beneficial effects of compression casting technique on the compressive strength.

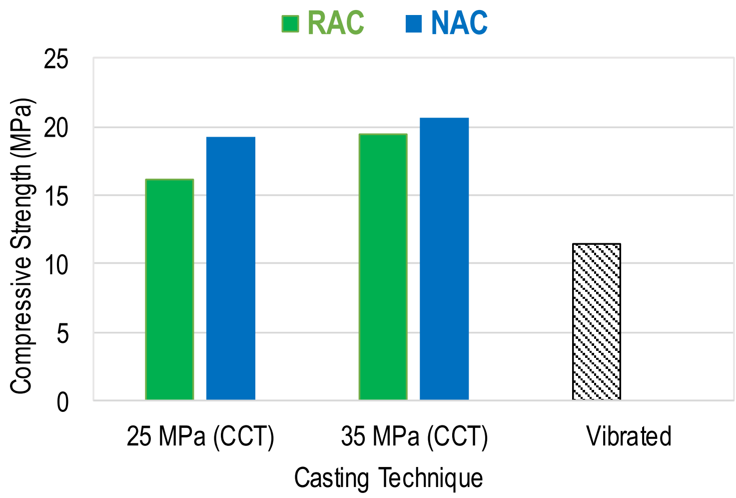

Chart -1: Compressive Strength

3.2 Modulus of Elasticity (E Value)

Modulus of elasticity values exhibited by RAC and NAC are presented in Chart 2, where the results showed that the modulus of elasticity of concrete is improved with the increase of casting pressure from 25 MPa to 35 MPa; an increase of 29% and 5.5% in the E value was observed for RAC and NAC, respectively. As evident from the Figure 4 that the E value of NAC was significantly higher than RAC at both casting pressures. At 25 MPa casting pressure, E value of RAC prepared by CCT was similar to that of vibrated RAC, however, at 35 MPa casting pressure the E value exhibited by RAC prepared by CCT was 30% higher than the value attained by vibrated RAC. The E value results made it obvious that CCT has a favorable impact on the compressive response of RAC.

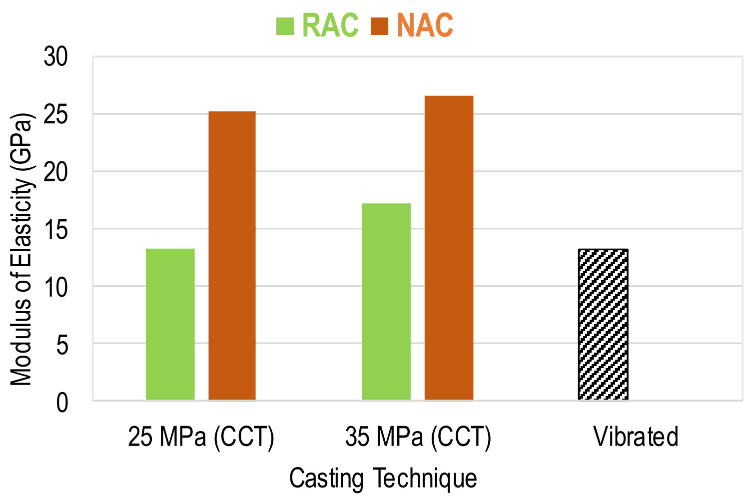

Chart -2: Modulus of Elasticity Values

3.3 Ultrasonic Pulse Velocity (UPV)

Values of Ultrasonic Pulse Velocity (UPV) of RAC and NAC samples prepared by CCT, and vibrated RAC are presented in Table 4 and their qualitative assessment is done following the criteria suggested by [6,7] based on UPV value. As per this criterion, the quality of RAC mixes prepared by CCT and vibration in this study has been rated as good while the quality of NAC is rated as excellent. Future research may be carried out to develop relationship between UPV value and compressive strength of RAC prepared by CCT for field use. It is important to mention here that criteria for concrete quality based on UPV suggested by [6,7] is for vibrated concrete. The same has been employed here for the quality assessment of compressed concrete. It is suggested that in future comprehensive experimental study may be carried out to design criteria to access the quality of compressed recycled aggregate concrete based on UPV value.

Table-4: Ultrasonic Pulse Velocity test results

<table>
<tr><th>Sr. No</th><th>Mix Designation</th><th>Cement dosage</th><th>Casting pressure, MPa</th><th>UPV ((km/s)</th><th>Quality</th></tr>
<tr><td>1</td><td rowspan="2">RAC-30F70C</td><td rowspan="5">15% by Total weight of Aggregates</td><td>25</td><td>4.053</td><td>Good</td></tr>
<tr><td>2</td><td>35</td><td>4.215</td><td>Good</td></tr>
<tr><td>3</td><td rowspan="2">NAC-30F70C</td><td>25</td><td>4.504</td><td>Excellent</td></tr>
<tr><td>4</td><td>35</td><td>4.626</td><td>Excellent</td></tr>
<tr><td>5</td><td>RAC-30F70C-V</td><td>Vibrated Concrete</td><td>3.995</td><td>Good</td></tr>
</table>

4. CONCLUSIONS

The study reported in this paper was carried out to investigate the effect of casting technique on the compressive strength and modulus of elasticity concrete made by 100% replacement natural aggregates with recycled aggregates. Ultrasonic pulse velocity test was employed to check the quality of RAC prepared by CCT and commonly employed casting method (i.e., through vibration). For comparison purpose, samples were also prepared using NAC and tested for the same properties. The experimental results obtained in this study made it possible to draw the following conclusions:

- The compressive strength of RAC is improved by compression casting. Increase in casting pressure from 25 to 35 MPa results in 21% enhancement in the compressive strength of RAC.
- Positive impact of casting technique on the modulus of elasticity of RAC is linked with higher casting pressure. Compared to vibrated RAC, an improvement of 30% in the E value of RAC prepared by 35 MPa casting pressure, was attained.
- NAC mix exhibits higher compressive strength and modulus of elasticity than RAC mix.
- Qualitative assessment of RAC and NAC prepared by CCT through UPV test was consistent with their compressive strength results.

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