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Effect on Strength of Natural Aggregate Concrete and Recycled Aggregate Concrete subjected to Elevated Temperature and Gradual Cooling

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Abstract— *Concrete as a construction material has been used from many decades for obtaining better strength and long durability of the structures. Engineers and scientists have been trying hard for better acceptability of this material with various admixtures and technologies being adopted at various dimensions of the construction technology. The use of Recycled Aggregate Concrete (RAC) not only benefits the environment but its use in the making of new structures reduces the overall cost of the structure without compromising on the strength of the new structure. Recently numerous attempts have been made to develop a concrete using Recycled Coarse Aggregate (RCA) as a proportion in the casting of concrete, replacing some part of Natural Coarse Aggregate (NCA) from it. In this study, concrete cubes and cylinders are made by replacing 100% NCA with RCA to form RAC and then the compressive strength of RAC was compared with the concrete made with 100% NCA termed as Natural Aggregate Concrete (NAC) with both being subjected to elevated temperature at different durations and gradual cooling. It was observed that the strength of RAC was more affected by the rise of temperature as compared to NAC because of the presence of mortar and other impurities of RAC.*

Keywords- *Natural Aggregate Concrete (NAC), Natural Coarse Aggregate (NCA), Recycled Aggregate Concrete (RAC), Recycled Coarse Aggregate (RCA).*

INTRODUCTION

The aggregates which are obtained from processing of inorganic materials already demolished in construction, e.g. crushed concrete, masonary brick etc., are known as Recycled Aggregates and when these recycled aggregates are made mainly from crushed concrete are called as recycled concrete aggregates (RCA). The uses of recycled aggregates in construction are very broad and have been used for a very long time. In road construction the use of recycled aggregates have been done from last 100 years in Australia. The use of recycled aggregates in construction and recuperation of roads have shown significant upgradation in last 5 years. Therefore the use of recycled aggregates in construction is in favour of economic value and solving environmental problems. Now days the recycled aggregates are used in road construction, in retaining walls as a backfill, concrete production of low grade, low cost housing in block work, brickwork, etc. the volume of construction and demolition waste is increasing day by day. Therefore for solving this problem, the best way which is considered by the construction industries is sustainable concrete production. By this the target of introducing the recycled aggregates from these construction and demolition wastes can be achieved. The introduction of recycled aggregates in concrete production is to replace the some portion of natural aggregates, is very popular among the scientists. They compare the characteristics of these two aggregates. Concrete should capable of resisting the effects of elevated temperatures that might be encountered near furnaces, in fire exposed area etc. The mechanical properties of the concrete i.e., strength, elasticity modulus and durability reduces when it is subjected to high temperatures, then leads to structural failure. When the temperature rises above the 100˚C, the Calcium Silicate Hydrate bond (CSH Bond) becomes weak and start breaking, beyond 300˚C temperature. The thermal expansion of the aggregates increases the internal stresses and micro cracks are developed. When the concrete is subjected to fire, it is extinguished by water due to which the CaO gets convert into Ca $(OH)_2$ that results in cracking and crumbling of concrete. Therefore we can see the effects of elevated temperatures in concrete in the form of surface cracking and spalling. When the temperature is beyond 60˚C, the CSH gel got decomposed and the concrete got crumbled at 800˚C. Recycled Aggregate Concrete needs a better understanding for its behavior when subjected to fire due to its diverse characteristics. The objective of this study is to compare the compressive strength of the RAC and NAC when subjected to elevated temperature for different durations with gradual cooling.

PREVIOUS STUDIES

M. Tavakoli and Soroushian (1996), stated that the strength characteristics of the RAC were affected by the strength of original concrete, ratio of coarse aggregate to the fine aggregate in original concrete and the ratio of top size of the aggregate in the original concrete used in RAC. They also mentioned that the water absorption and Loss Angeles abrasion loss will affect the water content and top size ratio for the strength of RAC.

T. Morita et al (2000) described that the degree of spalling is high at the lower W/C ratio. Spalling is completely depends upon the W/C ratio of concrete.

When the W/C ratio exceeds 50% for two months old concrete and 45 % for one year old concrete, the spalling will occur. Spalling is also affected by the age of the concrete at the time of fire exposure. Since the strength and moisture condition of the concrete is affected by the age of concrete, it is observed by taking low moister content the probability of spalling will be very less due to vapour pressure in concrete.

S.C. Poon et al (2004) stated that the brick specimen made of 25% and 50% RCA has not many effects on its compressive strength. But on increasing the percentage of RCA, the compressive strength got reduced.

Jaeyoung Lee et al (2013) have done their research on partial and full heating of high strength concrete columns. When the concrete was partially heated, the crack, spalling and rupture were severe than the entire heating of the specimens. Spalling can be increased due to uneven heating of concrete.

Basil et al (2014) stated that the compressive strength of the 100% RAC is very less as compared to the 100% NAC for same water cement ratio.

According to the **Limbachiya et al (2000),** the compressive strength of concrete was not affected by replacing 30% NCA with RCA, but the compressive strength gradually decreases on increasing the percentage replacement of RCAs.

Dhir et al (1999) described that in all the cases, the RCA results in the lower compressive strength when compared with strength of NAC.

MATERIALS AND METHODS

Coarse Aggregates: The RCA are obtained from the demolished and wasted concrete lying outside of the structural and concrete laboratory of college campus with the help of hammer. The fineness modulus of RCA is 6.80, specific gravity is 2.76 and water absorption is 1.2%. The NCA was gotten from the commercial source within the city; it is made up of crushed granites from igneous rocks. The fineness modulus is 6.60; specific gravity is 2.71 and water absorption 0.58%. Both the aggregates were sieved from 20mm to 4.75 mm sieve and washed out with the help of water in order to remove the impurities from them. The size of both RCA and NCA is lying between 4.75mm to 20mm.

Fine Aggregates: Fine aggregates used were natural river sand (Gola River), having size less than 4.75mm, and washed to remove the dust particles from it.

Cement: The cement used in this research is the Ordinary Portland Cement of grade 43 conforming the specifications of IS: 8112-1989.

Experimental Procedure: In this present investigation mix design are done according to IS 10262:2009. M25 grade of concrete was casted by taking 100% RCA and 100% NCA using water cement ratio of 0.45 and 1:1.878:3.440 mix ratio. Total 96 concrete cubes of size 150mm*150mm*150mm* were casted. All the concrete cubes were properly cured by taking them immersed into the water for 28 days under room temperature. After the curing of 28 days, the specimens were heated in the furnace to different level of temperatures (75˚C, 150˚C, 250˚C, 350˚C) for different durations (1hr, 2hr, 3hr, 4hr) with gradual cooling. And then compressive strength of all the specimens was determined with the help of Compression Testing Machine (CTM).

RESULTS AND DISCUSSION

The water absorption value for RCA and NCA was measured and it was found that the RCA has more water absorption value as compared to NCA.

Table-1 Properties of Coarse Aggregates

Properties	NCA	RCA
Water absorption (%)	0.65	1.15
Specific Gravity	2.65	2.54
Bulk Density (Kg/m³)	1465	1340

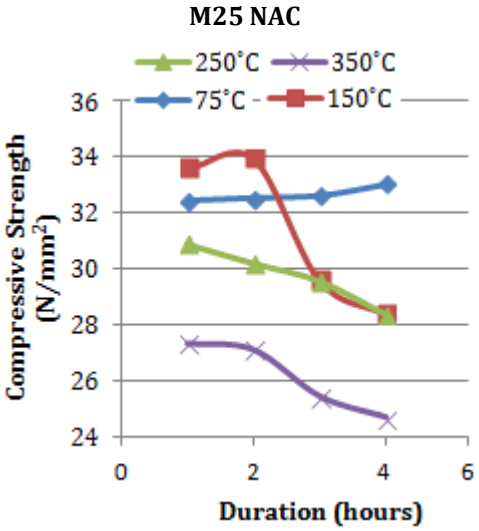

Figure-1 Graph of compressive strength against temperature

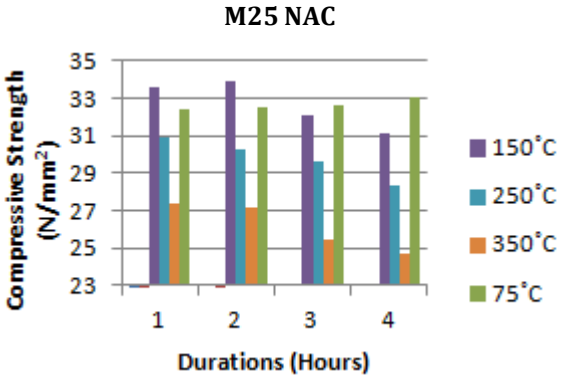

Figure-2 bar Chart for Compressive Strength

From Figure-1 and 2, we can say that the compressive strength of RAC increases at low temperatures at very less rate and reduces faster when the temperature rises above 150˚C. While in case of NAC the strength reduces at fewer rates at high temperatures. Both the graphs shows that the highest compressive strength is 33.95 N/mm² at 150˚C on 2hr duration in case of NAC while in case of RAC the highest strength is 32.22N/mm² at 150˚C on 2hr duration. The lowest compressive strength is 25.43N/mm² in case of NAC and 23.97N/mm² in case of RAC.

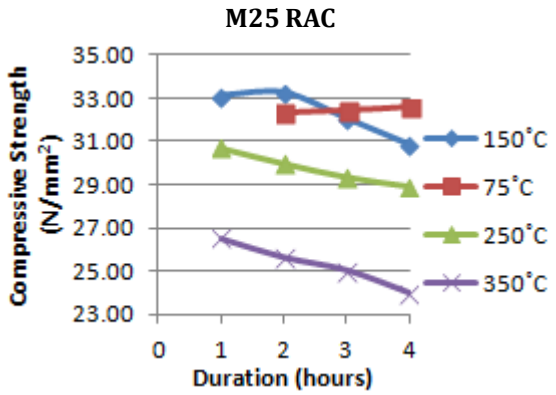

Figure-3 Graph of compressive strength against temperature

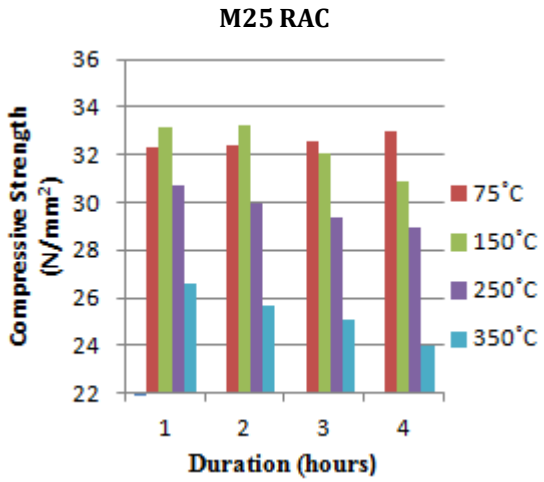

Figure-4 bar Graph for Compressive Strength

CONCLUSION

Since the strength of RAC and NAC both increases at the temperatures 75˚C and 150˚C. This sudden increase in strength is generally attributed to greater Vander Waals forces as a result of cement gel layers moving closer to each other during heating. Furthermore, during cooling, concrete gets further damaged. If the temperature exposure is increased from 150°C to 350°C it causes drastic reduction in the compressive strength when compared the same at room temperature. The specific gravity and bulk density of RCA is lower than the NCA, because of the attached mortar present in RCA. Concrete made with 100% RCA exhibits the adequate performance but not better than NAC. By this statement we are not saying that the use of RCA is unsuitable for construction. To improve its strength characteristics, we can some admixtures like silica fume, fly ash which are also available at free of cost. Then strength of RAC will be enhanced. The resistance to strength reduction is higher in RAC at high temperature as compared to NAC. By analyzing all the results we can say that the proportion of RCA should not be more than 50% in concrete, if the concrete is to be used in the areas of temperatures between 600˚C to 800˚C.

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