Study of Properties of Concrete Using Waste Refractory Brick as Coarse Aggregate

[1]Chittaranjan Garai, [2]Nagarampalli Manoj Kumar (Guide)

[1]PG Scholar, [2]Assistant Professor
Department of Civil Engineering
GIET University, Gunupur, Odisha, India

***Abstract*: The constant and unsustainable exploitation of naturally available aggregates have accelerated the depletion of their natural deposits at an alarming rate, due to which the present demands of the concrete industry are not fulfilled properly. By recycling waste products from various industries as aggregates or binder in concrete, the impact caused due to these products on the environment can be reduced to a great extent and a sustainable supply of aggregates for the concrete industry can also be preserved. In the present research work, the physical and mechanical characteristics of Refractory Brick waste aggregates (RBWA) obtained by crushing discarded refractory bricks into aggregates are studied to check the suitability of these materials as a possible alternative to natural coarse aggregates (NCA). Six concrete mixes were prepared with 0%, 20%, 40%, 60%, 80% and 100% RBWA by replacing the natural coarse aggregate to study the mechanical properties such as workability, density, compressive strength, split tensile strength, flexural strength of the concrete made with RBWA. A comparison was made with the conventionally made concrete. The test results indicate that though the RBWA are inferior to NCA, the workability of the RBWA concrete is good and the strength parameters are comparable to those of the conventional concrete. The attained strength did not show much difference for percentages about 20%, at which it reached the compressive strength of 32.36 N/mm2 in 28 days which was higher than the estimated target strength for the design mix. Hence, it is recommended for partial replacement of natural aggregates up to 20%.**

***Keywords*: Compressive strength, lightweight aggregate, flexural strength, refractory brick waste aggregates (RBWA), split tensile strength.**

I. INTRODUCTION

Traditional concrete consists of sand as fine aggregate and limestone or granite in various sizes and shapes as coarse aggregate. The aggregates generally account for 60–75 % of the concrete volume and play a significant role in various concrete properties such as workability, strength, dimensional stability and durability. The inconsiderate and selfish use of the natural resources has depleted most of the available resources due to which the availability of naturally available fine and coarse aggregates is becoming scarce leading to a rising interest in using alternatives to these aggregates in making concrete.

Use of waste materials as alternative aggregate materials are has two benefits: one the waste material can be reused and recycled and second it will take the pressure away from the conventional aggregates. It is a prodigious step towards solving one part of the depletion of natural aggregates as the alternative aggregates processed from waste materials would appear to be a more sustainable solution. According to Metha PK.(2001) and Meyer C.(2009) the finest way for the construction industry to become more sustainable is by using wastes from other industries as building materials.

II. LITERATURE REVIEW

Akhtaruzzaman and Hasnat (1988) used manually crushed, well burnt clay bricks as coarse aggregates and tested four grades of concrete made with crushed brick as aggregate to determine their physical and mechanical properties. Normal compressive strength ranged from

13.8 to 34.5 MPa. In general, for the same grade of concrete, the modulus of elasticity of the concrete produced with crushed brick aggregates was about 30% lower, the tensile strength was about 11% higher and the unit weight was about 17% less than that of natural aggregate normal concrete. Empirical equations predicting the modulus of elasticity and the tensile strength of brick aggregate concrete have been derived.

Mansur et al (1999) studied the suitability of crushed clay bricks as coarse aggregate for concrete, comparing its basic properties with those of conventional concrete, produced with granite aggregates. Four basic mixes were used corresponding to grades ranging from 30 to 60 MPa. For identical mix proportions, the use of crushed brick aggregates resulted in higher compressive and tensile strengths, lower drying shrinkage, and an almost identical specific creep. However, and in parallel with the previously described study, the use of crushed brick led to a significant reduction in the modulus of elasticity and a substantial loss in the workability of the fresh concrete. A stress-strain curve equation for brick-aggregate concrete was proposed.

Devenny and Khalaf (1999) also studied the possibility of using crushed brick as coarse aggregate in concrete, comparing the compressive strength of normal concrete manufactured with granite aggregates with that of concrete made with crushed brick aggregates, obtained from four types of bricks, with compressive strengths varying from 39 to 81 MPa. They concluded that the use of crushed brick aggregates may exceed the compressive strengths reached using granite aggregate, even allowing for the production of high strength concrete, with a simultaneous lower density, which is suitable for low dead-weight applications. The authors observed that concrete compressive strength consistently increases with the brick compressive strength and with the concrete density.

Khatib (2005) used fine recycled aggregates obtained from crushed bricks to replace increasing fractions of the sand of a conventional concrete. For a 50% replacement fraction, no compressive strength reduction was observed and for an integral replacement, the reduction in strength was only 10%.

Cachim (2009) used crushed brick obtained from construction waste as coarse aggregates. Comparing the results, it was concluded that crushed brick aggregates can be replaced with NCA up to 15% without strength reduction. Crushed bricks when moderately used as substitute may act as self-curing agents for concrete when they are pre-saturated. As the quantity of crushed bricks increase, poor results are obtained due to the porosity of bricks.

III. MATERIALS USED

Cement:

Ordinary Portland Cement (OPC) 43 grade conforming to the requirements of BIS (IS: 8112- 1989) is used in the entire experimental study. To avoid the long storage times and to avoid the loss of strength, cement was procured according to the phase wise requirements. The cement is stored in bags in air tight room to have minimum exposure to the humidity. The cement used in the test is OPC 43 Grade manufactured by Ultratech Cement Co. India. Listed below are the various physical and mechanical properties of cement.

Fine Aggregate:

Sand with 4.75 mm maximum size which is locally available was used as fine aggregate (FA). The sieve analysis of fine aggregate and particle size distribution fine aggregate is shown in results and discussion part. From the sieve analysis, it was found that the sand belonged to Grading Zone III (Table 4, IS 383) and has a Fineness Modulus of 2.34.

Coarse Aggregate:

Natural granite stone aggregates of nominal sizes of 20mm and 10mm which are locally available are used in the study.

Refractory Brick Waste Aggregates (RBWA):

The refractory brick waste was brought from TRL Krosaki Refractories Limited, Belpahar, Jharsuguda, Odisha. These are made by crushing the bricks which discarded for any kind of deformities. A sample of RBWA is shown in Figure below.

Fig. 1: Crushed RBWA of size 10mm and 20mm

Water:

Potable drinking water is used for the present work in the preparation of concrete.

IV. RESULTS & DISCUSSIONS

Table 1. Details of mix proportions

Symbol	w/c	Cement (OPC) Kg/m^3	FA Kg/m^3	RWCA Kg/m^3	NCA 20mm Kg/m^3	NCA 10mm Kg/m^3
RW0	0.5	394	685	0	728	480
RW2	0.5	394	685	160	582	384
RW4	0.5	394	685	319	437	288
RW6	0.5	394	685	478	291	192
RW8	0.5	394	685	638	146	96
RW10	0.5	394	685	797	0	0

Particle Size Gradation:

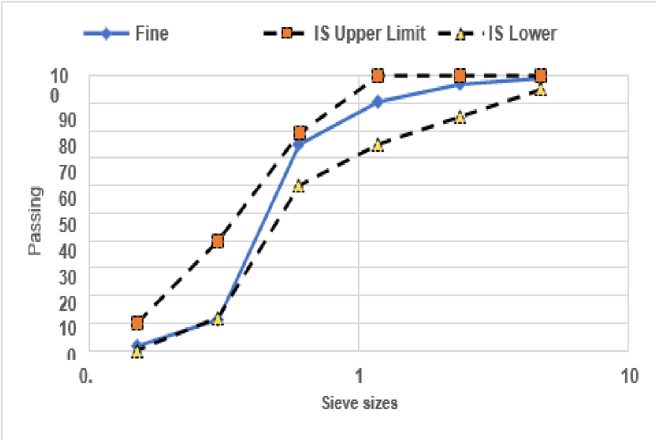

Fig. 2: Particle size distribution of fine aggregate

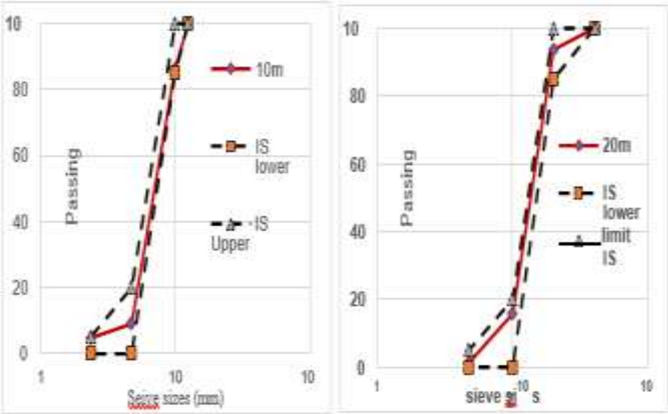

Fig. 3: Particle size distribution of 10mm & 20mm NCA

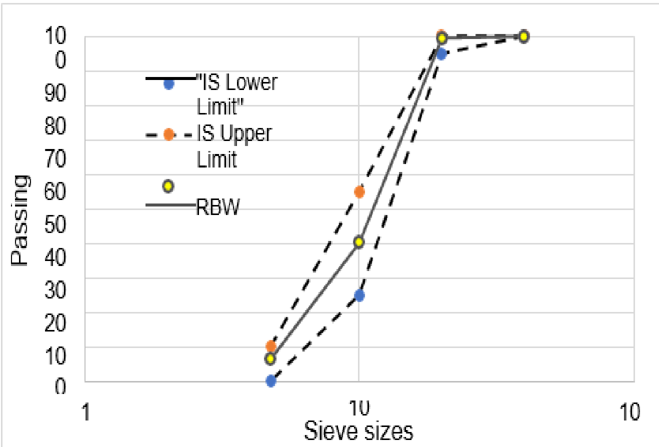

Fig. 4: Particle size distribution of RBWA

Slump Test Results:

The slump value tested for each mix was presented in the chart below. It represents the slump values of different concrete mixes at different percentage of RBWA. It is observed that the slump of control concrete mix (RW0) was 77 mm which decreases to 56 mm for RW100 mix. It is observed that with the increase in RWBA content the slump value decreases. Though water absorbed by the aggregates was added initially during the mixing process a steady decrease in slump value is observed as the replacement percentage of RBWA with NCA is increased. Low Specific gravity of RBWA may be one of the reasons for this behavior.

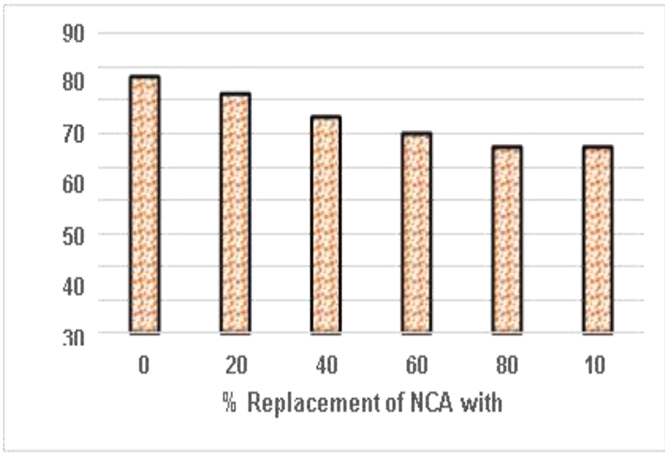

Fig. 5: Slump in mm at varying replacement levels of RBWA

Compressive strength test results:

A linear decrease in the compressive strength is observed as the percentage of replacement of NCA is increased. It is also observed that RW4, RW6 and RW2 mix specimen reach the target strength of mix design whereas the RW10 mix specimen do not reach the target strength. Compressive Strength decreased on replacement of NCA by RBWA. This may be due to lower mechanical properties of RBWA in comparison to NCA.

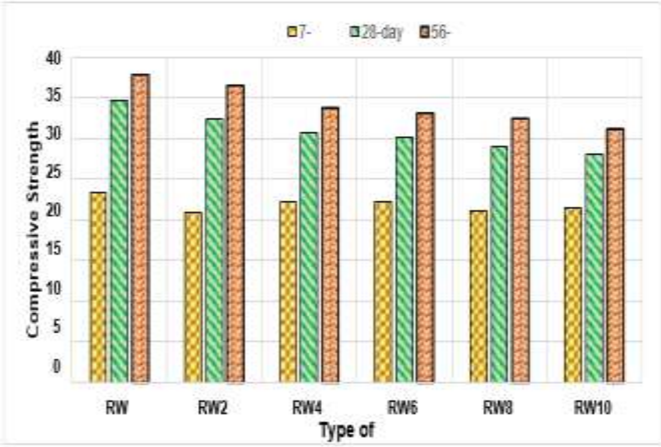

Fig 4: Compressive strength versus the type of mix

Split tensile strength test results:

A linear decrease in the compressive strength is observed as the percentage of replacement of NCA is increased. Split tensile strength tests showed that the failure occurred through the coarse aggregate particle, thus conforming good bond of the RBWA aggregates. Whereas, some bond failure along with coarse aggregate failure was observed in case of NCA indicating bonding of NCA with mortar is weak.

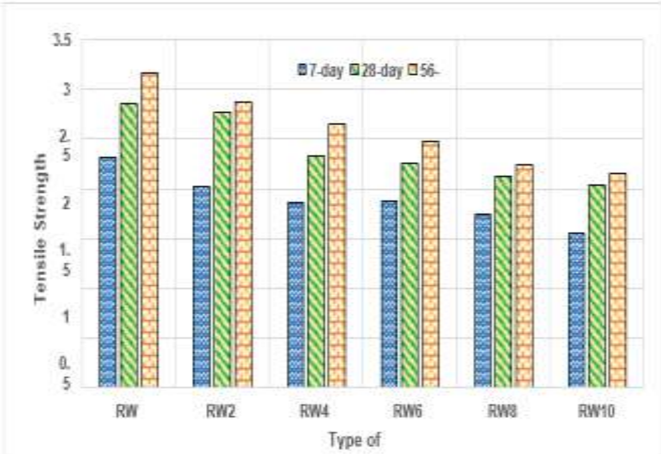

Fig 5: Tensile strength for the mixes at 7, 28 and 56 day

Flexural Strength Test Results:

Here also a linear decrease in the strength is observed as the percentage of replacement of NCA is increased. We can conclude that a depression from the trend in flexural strength of RW4 is seen. RW10 is gaining some strength as compared to its 7day strength but if compared with RW0 mix the gain in strength is much less.

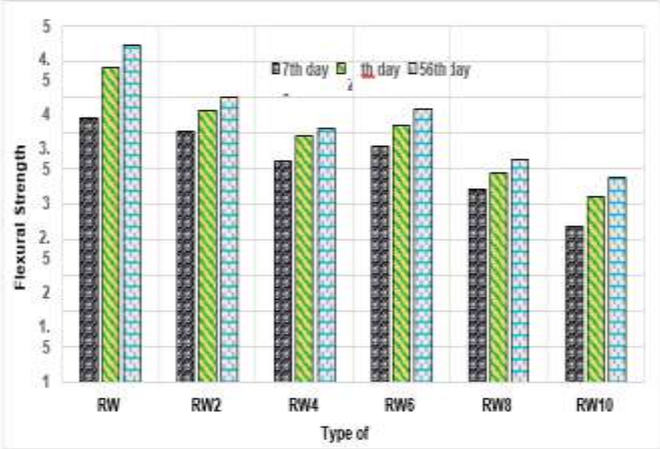

Fig 6: Flexural strength for the mixes at 7, 28 and 56 day

Table 2: The change in percentage strength of properties as compared to RW0 mix

Properties	Replacement level	7day % change	28day %change	56day %change
Compressive Strength	20%	-10.4	-6.8	-3.5
	40%	-4.9	-11.8	-10.7
	60%	-5.2	-12.9	-12.5
	80%	-10.1	-16.4	-14.2
	100%	-8.3	-18.8	-17.6
Split Tensile strength	20%	-12.9	-3.2	-9.5
	40%	-19.4	-18.5	-16.4
	60%	-18.9	-21.3	-21.8
	80%	-25	-25.8	-29.34
	100%	-32.7	-28.6	-32.18
Flexural Strength	20%	-5.4	-13.4	-15.2
	40%	-16.6	-21.7	-24.6
	60%	-10.7	-18.4	-18.8
	80%	-26.8	-33.4	-34.1
	100%	-40.8	-41	-39.1

CONCLUSIONS

Based on the present experimental investigation conducted and the analysis of test results, the following conclusions are found out:

1. The slump value of RBWA concrete is less than the normal concrete and it is reduced with the increase in RBWA percentage. Due to the higher water absorption and low specific gravity of the RBWA, the slump value of concrete mixes decreases with the increase in RBWA content. However, it was observed that with low slump value also the concrete mixes made with RBWA had good workability
2. Density of RBWA incorporated concrete is much less than the normal concrete and it is further reduced with the increase in RBWA percentage. The decrease in density of RW0 and RW10 mix is noted as 19% which is a considerable reduction in density. This is due to the light weight of the replacement aggregates. Therefore, we can conclude that RBWA reduces concrete density which leads to lower transportation cost and lower load.
3. Results of concrete specimens confirm that the increase in the recycled aggregates content decreases the concrete compressive strength. AT 20% replacement the concrete mix reaches the target strength after 28 day curing period whereas it was also observed that the mixes with higher levels of RBWA also reached the target strength but after 56 day of curing. Therefore, we can conclude that the compressive strength concrete made with RBWA increases with ageing.
4. The rate of gain in compressive strength of concrete mixes with RBWA is comparatively more at the early curing of 7 day while comparing with concrete with natural aggregates. All mixes show strength variation of ±10% after 7 days of curing.
5. The splitting tensile strength also follows the same trend as that of the compressive strength. i.e. larger the addition percentage of RBWA. A high variation of almost 40% was observed between RW0 and RW10 showing that the concrete made with RBWA is very weak as compared to control mix concrete. This can be attributed to the inferior strength properties of the refractory brick waste aggregates.

6. The flexural strength of the concrete mixes also decreases with the increase in the replacement percentage of RBWA. A high variation of almost 40% was observed between RW0 and RW10 showing that the concrete made with RBWA is very weak in flexure as compared to control mix concrete.
7. In General, the experimental results clearly show that all the strength properties decrease as the quantity of refractory aggregates in concrete increases, since they are lighter and lesser resistant than the natural coarse aggregates. However, the attained strength showed that crushed refractory bricks can be used to substitute natural aggregates in concrete (32.36 N/mm2) for percentages about 20%. Hence, the use of refractory brick waste aggregates in percentages up to 20% in concrete can be recommended.

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