STUDIES ON USE OF CONSTRUCTION DEMOLISHED WASTE AS AGGREGATES FOR CONCRETE

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Abstract: This paper presents a report of an experimental investigation on the effect of replacement of natural aggregate by recycled concrete aggregate in the production of concrete and the strength of concrete. This research work deals with the study of strength of concrete incorporating Recycled Aggregate concrete. The project involves a comparative study of compressive strength, flexural strength and split tensile strength of normal and recycled aggregate concrete. Recycled aggregate materials were crushed and sieved to give the same grading for each mix. Natural sand was used as fine aggregate. The mixes were adjusted to account for the different water absorption characteristics of the aggregates but were otherwise identical. Prism specimens with a centrally placed reinforcing bar, cylindrical specimens and non reinforced slabs were cast from each of the concretes. A series of tests were carried out to determine the compressive strength, split tensile strength, flexural strength with and without recycled aggregates. Natural coarse aggregates in concrete were replaced with 0%, 20%, 40%, 60%, 80% and 100% of crushed concrete coarse aggregates. For the strength characteristics, the result showed a gradual decrease in compressive strength, split tensile strength, flexural strength and modulus of elasticity as the percentage of recycled aggregate is increased. However up to 20% replacement of recycled aggregate concrete does nor loose significant strength and hence can be used as upper limit.
Keywords: Concrete, Natural aggregate, Recycle Aggregate, Demolition waste, compressive strength

I. INTRODUCTION

The global concrete industry uses approximately 10 billion tonnes of sand and rock annually, which makes it the largest consumer of natural resources in the world Mining, processing, and transportation of cement-making raw materials and concrete aggregates consume a great deal of energy. Also, cement production alone contributes approximately 5% of global emissions through the combustion of fossil fuels and the decomposition of limestone. The driving force for recycling concrete is three-fold: preserving natural resources, utilizing the growing waste and saving energy and money. Hence people are looking for alternative sources for the concrete ingredients in order to full fill their requirements.

The search for alternative resources instead of existing natural resources, the continuing shortage of landfill sites due to rapid urbanization, the sharp increase in transportation and disposal costs and severe environmental pollution and regulation control have raised a new challenge to planners and engineers to recycle construction and demolition waste material. While some waste concrete is currently being crushed and used for grading and base material for highways, it has not been used as the aggregate in new concrete in Canada, largely because of the plentiful supply of good quality virgin material. However, crushed concrete is being used in new concrete in other parts of the world where the local aggregate is inferior, and there is now a push within the Canadian cement and concrete sector to improve the industry sustainability, one aspect of which is recycling of materials. The research done to date has emphasized the influence of recycled concrete aggregate (RCA) on the workability and strength of the new concrete with little attention being paid to the behaviour in service. In this project work it is concentrated mainly on the behaviour of concrete with R.C.A. A series of tests were carried out to determine the compressive strength, split tensile strength, flexural strength with and without recycled aggregates. The objective of the work is to study the compressive strength, split tensile strength and flexural strength of reinforced concrete made with old, contaminated and new, clean recycled aggregate. For this purpose, a comparative study has been made of the physical and mechanical properties of RCA and of hardened concrete incorporating RCA. The tests include porosity, water absorption, chloride permeability, abrasion resistance, salt scaling resistance, reinforcement corrosion and compressive strength.

II. RECYCLED AGGREGATE

Before using R.A. for producing concrete, it is necessary to know the various properties of it. Number of research workers has made an attempt to study the various properties of recycled aggregates.

Figure 1. Demolished concrete

Figure 2. Recycled Aggregate(un sieved)

Old concrete debris is crushed to obtain R.C.A of suitable sizes with the help of crushers. By the slight adjustment of the openings of the crushers, we can obtain a well graded R.C.A. It was showed that the grading of the crusher product was not significantly affected by the grades of the original concrete. The amounts of the fine material (passing 5mm B.S. Sieve) generated by high, medium and low grades of original concrete are 23.1, 25.7 and 26.5% by weights respectively. In general lower the grade of original concretes, the higher was the percentage of fine materials. This is partly due to the presence of a higher proportion of F.A in lower grades of concrete.

When old concrete is crushed, a certain amount of mortar from the original concrete remains attached to stone particles in R.A. Hansen and Narud reported the percentage volume of mortar which remains attached to gravel in R.C.A. They found the volume percent of mortar attached to natural gravel particles to be between 25% and 35% for 16-32 mm coarse recycled aggregates, around 40% for 8-16 mm coarse recycled aggregates and around 60% for 4-8 mm coarse recycled aggregates, in general the Recycled Aggregates contain an average of about 50% by volume of mortar from the original concrete. Densities of coarse recycled aggregates in saturated surface dry condition ranging from 2,340 kg/m^3 (for 4-8 mm material) to 2,490 kg/m^3 (for 16-32 mm material), independent of the quality of original concrete. Corresponding densities of original coarse aggregates ranged from 2,500 to 2,610 kg/m^3. Narud found saturated surface dry density of 2,279 kg/m^3 for fine recycled aggregates produced from one original concrete which was made with a water cement ratio of 0.70.Water absorptions of coarse recycled aggregates ranging from 8.7% for 4-8 mm material to 3.7% for 16-32 mm material, regardless of the quality of original concrete. Corresponding water absorptions of original aggregates ranged from 3.7 to 0.8%.Narud found water absorption of 9.8% for a fine recycled aggregate produced from an original concrete with a water-cement ratio of 0.70. Recycled concretes have an approximately 5 percent higher free water requirement, compared to otherwise identical fresh concretes made with natural gravel.

III. EXPERIMENTAL INVESTIGATION

The total experimental investigations involved in this paper work have been done in details. The details of the work are given below.

MATERIALS

The materials used in the entire investigations is as follows.

Cement: Cement used is 53 grade Ordinary Portland Cement (OPC) and the results of various preliminary tests conducted on this cement. Natural Coarse Aggregates: The N.C.A used here are of 20 mm down size. Preliminary test such as water absorption, moisture content, sieve analysis, specific gravity and crushing strength tests have carried out. Natural Fine Aggregate: The source for fine aggregate used is from natural river bed, the details regarding test conducted. Recycled Aggregate Concrete: The waste concrete was brought from the demolished structure situated at nearby city bus stand. The coarse aggregate (C.A) is separated from the concrete by hammering. Mortar adhered to the aggregate is also removed from the aggregate as much as possible. Obtained C.A is sieved under 20mm sieve (passing) and 4.75mmsieve (retained), later these aggregates can be used as R.C.A for further work.

Preliminary tests conducted on Recycled Coarse Aggregates: After obtaining the R.C.A from original concrete, preliminary tests such as sieve analysis, water absorption, moisture content, specific gravity and crushing strengths have been carried out. The results of above tests are as given in Table 1. below

Table 1: Preliminary tests results of R.C.A

S.NO	PARTICULARS	RESULTS
1.	Moisture content	1.2%
2.	Water absorption	2.5%
3.	Specific gravity	2.55
4.	Crushing strength	19.64%

MIX PRAPORTIONS: M-25 mix was used for this experimental work. Normal aggregate was replaced by Recycled aggregate at 0, 20, 40, 60, 80 and 100%.

CASTING, CURING AND TESTING WORK:

For each mix six cubes of 150mm x 150mm x 150mm in size, six cylinders of 150mm diameter and 300mm height and six flexural beams of size 100mmx100mmx500mm were cast using steel moulds. The cast specimens were kept in ambient temperature for 24 hours. After 24 hours they were de-moulded and placed in water for curing. Cubes were used to determine the compressive strength of concrete at 7 days and 28 days. Six cylinders were used to determine the split tensile strength of concrete at 7 days and 28 days. Flexural beam were used to find out the flexural strength of concrete at 7days and 28 days by two point bending test with a supporting span of 133.33mm, using a universal testing machine of capacity 1000 kN. Quantities of the concrete ingredients which are obtained based on N.C.A and R.C.A have been co-related with each other. Using the material quantities obtained after co-relation, cubes cylinders and flexural beams are cast. Here, six different mixes are made and in each mix the N.C.A are replaced by R.C.A by 20% i.e., in the 1st mix 100% N.C.A are used in concrete mix where as in 2nd, 3rd, 4th and 5th mix, 20%, 40%, 60% and 80% replacement of N.C.A by R.CA is made. In the final 6th mix N.C.A are completely replaced 100% by R.C.A. Prepared specimens were kept immersed in water and tested for their strength after 7-days and 28-days of curing.

IV. RESULTS AND DISCUSSION

The results of various experiments which were carried out in the dissertation work are given in this chapter. Based on the obtained results, some of the salient points are discussed below.

COMPRESSIVE STRENGTH:

The cube compressive strength for all the mixes at 7 and 28 days of curing is presented in Table 2. The results show that the concrete specimens with more replacement of recycled aggregate have the lowest compressive strength when compared to the concrete specimens with less recycled aggregate for both 7 days and 28 days of curing. 7 days compressive strength is generally 60-80% of the 28 days compressive strength. Figure 9 shows that the compressive strength at 28 days for 20% replacement of R.C.A has dropped around 5.14%. Even up to 60% replacement of recycled aggregate, the compressive strength gets reduced only to a maximum of 10.79% with respect to that of control concrete. There is a drop of 29.11% compressive strength for the 100% recycled aggregate. The compressive strength of the concrete specimens for 60% recycled aggregate is 27.61N/mm^2, which meets the target strength of 27.6N/mm^2. From the obtained results, it is clear that there is a possibility to use 60% recycled coarse aggregate in applications like concrete blocks and pavements.

SPLIT TENSILE STRENGTH:

The split tensile test indicates a decreasing trend of split tensile strength at 7days and 28 days of curing, when the percentage of recycled aggregate is increased. Table 3 represents the tensile strength values for mixes at7 days and 28 days of curing. The Figure 10 shows that the 28 days split tensile strength is significantly greater than 7 days split tensile strength. The concrete specimen with 100% recycled coarse aggregate at 28 days of curing has the lowest tensile strength, which was only 1.952 N/mm^2. It is around 38.81% drop when compared to control concrete specimen. There is a drop in tensile strength of 10.66%, 18.18%, 24.76% and 34.79% for the concrete specimens with 20%, 40%, 60% and 80% recycled coarse aggregate respectively. Even up to 60% replacement, the split tensile strength gets reduced to a maximum of 24.76% with respect to that of control concrete.

FLEXURAL STRENGTH:

The flexural strength for all the mixes at 7 days and 28 days of curing is presented in Table 4. The results show that the concrete specimens with more replacement of recycled aggregate have the lowest flexural strength when compared to the concrete specimens with less recycled aggregate. Figure shows that there is a drop in flexural strength of 7.9%, 13.58%, 24.20%, 35.31% and 43.45% for the concrete specimens with 20%, 40%, 60%, 80% and 100% coarse aggregates respectively.

Table 2: Compressive strength using correlated properties in concrete mix design with %age replacement of N.C.A. by R.C.A

MIX NO	% replacement of N.C.A by R.C.A	Days of curing	Compressive Strength (N/mm^2)
1.	0	7-days	24.26
		28-days	30.94
2.	20	7-days	22.95
		28-days	29.35
3.	40	7-days	22.23
		28-days	28.18
4.	60	7-days	22.08
		28-days	27.60
5.	80	7-days	20.34
		28-days	24.19
6.	100	7-days	18.45
		28-days	21.93

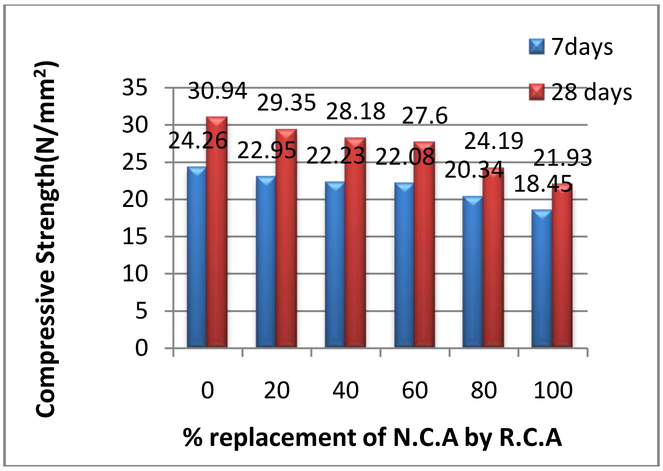

Figure 3 Compressive strength using correlated properties in concrete mix design with %age replacement of N.C.A. by R.C.A

Table 3: Split tensile strength using correlated properties in concrete mix design with %age replacement of N.C.A. by R.C.A

MIX NO	% replacement of N.C.A by R.C.A	Days of curing	Split Tensile Strength(N/mm^2)
1.	0	7-days	1.121
		28-days	3.18
2.	20	7-days	1.003
		28-days	2.84
3.	40	7-days	0.890
		28-days	2.60
4.	60	7-days	0.836
		28-days	2.39
5.	80	7-days	0.727
		28-days	2.07
6.	100	7-days	0.681
		28-days	1.951

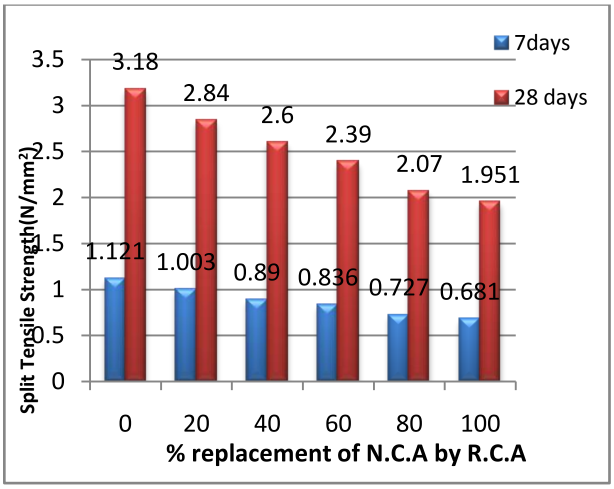

Figure 4. Split tensile strength using correlated properties in concrete mix design with %age replacement of N.C.A. by R.C.A

Table 4: Flexural strength using correlated properties in concrete mix design with %age replacement of N.C.A. by R.C.A

MIX NO	% replacement of N.C.A by R.C.A	Days of curing	Flexural Strength(N/mm^2)
1.	0	7-days	3.01
		28-days	4.04
2.	20	7-days	2.64
		28-days	3.72
3.	40	7-days	1.95
		28-days	3.49
4.	60	7-days	1.732
		28-days	3.06
5.	80	7-days	1.634
		28-days	2.61
6.	100	7-days	1.439
		28-days	2.28

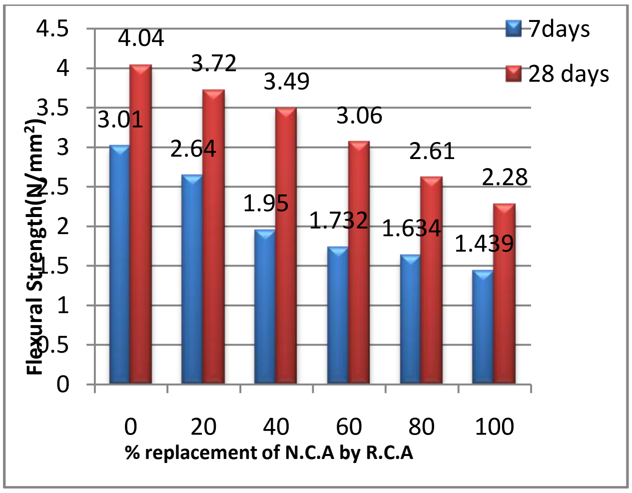

Figure 5. Flexural strength using correlated properties in concrete mix design with %age replacement of N.C.A. by R.C.A

V. CONCLUSIONS

Based on the results and discussions given, some of the conclusions drawn are as listed below.

1. Little variation in %age passing (Sieve Analysis) is observed between N.C.A and R.C.A. this is mainly because of carrying out proper sieve analysis of R.C.A and by removing the surface dirt present on R.C.A by rubbing with dry cloth
2. Water absorption of RCA is more than the water absorption of NCA due to the older mortar adhered to the surface of aggregate which contribute towards decrease of strengths
3. From the obtained results, it is clear that there is a possibility to use 60% recycled coarse aggregate in applications like concrete blocks and pavements.
4. The split tensile test indicates a decreasing trend of split tensile strength at 7days and 28 days of curing, when the percentage of recycled aggregate is increased.
5. The results show that the concrete specimens with more replacement of recycled aggregate have the lowest flexural strength when compared to the concrete specimens with less recycled aggregate.

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