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Use of Recycled Coarse Aggregates in Pavement Quality Concrete for Sustainable Development

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Abstract - *In developing countries like India, the deposition of construction and demolition waste material is in the rate of millions of tons in a year, these deposited waste material contains a reusable materials like coarse aggregates and fine aggregates with a content of cement mortar adhered to it, sustainable development becomes when they are effectively used for production of concrete by preserving the natural resources, on the other hand If they are not properly employed that will become source of pollution and occupy landfill space. The present study investigating that the possibility of replacing the natural coarse aggregates (NCA) with recycled coarse aggregates (RCA) in a conventional concrete used in pavement quality concrete surface, in this study mix design is prepared for M40 grade is being used with a different proportions as NCA with RCA i.e 0:100, 30:70, 70:30, and 100:0. Total are considered in a percentage to the weight of natural coarse aggregates and the physical properties of natural and recycled aggregates has found by conducting the basic tests on aggregates and before to cast a specimens, we have tested a three cubes for M40 grade to fix a final mix proportion. And the optimum percentage of replacement of NCA with RCA was determined by conducting the tests for various proportion mixes of RCA and NCA and the required 28 days characteristic strength for pavement quality concrete is being evaluated in this project, The ultimate aim is to attain a suitable strength on usage of recycled coarse aggregates for pavement quality concrete thus to implement cost effective nature and durability.*

Key Words: Recycled coarse aggregates, pavement quality concrete, sustainable development, Optimum percentage of RCA, Compressive strength test.

1. INTRODUCTION

In India infrastructure development is one of the important concerns in construction field and the need of raw materials is increasing with a demand, In our country yearly 165 – 170 million tons of construction and demolition waste is producing as reported by the Indian government and the destruction of old structures with construction of new ones are on the rise due to rapid urbanization. The unwanted materials produced from the demolition of concrete structures are not only cause of environmental pollution but also problem for disposal [1]. In certain countries the construction and demolition waste is reutilizing as a new construction material as being one of the main objectives with respect to sustainable construction activities and the production of concrete by effective utilization that addresses the dual problems of sustainability of natural material and its disposal. Generally the recycled concrete aggregates are having an in-homogeneous shape as compared with natural aggregates as per earlier investigations the physical & mechanical properties of the recycled aggregates must be determined to evaluate in construction works and the recycled concrete aggregates properties need to be similar with natural aggregate properties for better concrete production and the quality of concrete depends on quality of the recycled concrete aggregates. In some developing nations the recycled concrete aggregates are suggested as a replacement to the natural aggregates in road and building construction activities some of these countries having specific codes dealing with the handling & use of RCA in such activities [2]. High quality concrete layer lay over top of rigid pavement or cement concrete road is known as pavement quality concrete (PQC). PQC is a special type of plain cement concrete (PCC) and should be hard and strong enough to distribute the wheel load of vehicles to bottom layers without any deformation. The coarse aggregates should not exceed 25 mm in size and should be clean, hard, strong & non-porous pieces of crushed stone and there's also continuous steps are taken by the state & central governments to improve the performance existing pavements to meet the future necessities and also construction of proposed new concrete road projects hence demand for CA portion is always exist. And the expected quality of RCA was obtained by removing adhered old mortar portions stick in the debris before use as aggregate in new concrete, the water absorption and surface porosity of the RCA is higher than the conventional granite aggregates, the reductions in strength characteristics and durability of RCA concrete are observed in various research findings , the review from various studies reported that reduction of mechanical properties and durability of RCA concrete is attributed to adhered old mortar stick in the RCA, also various methods are used to eliminate stick mortar portion in RCA for performance improvement, those are thermal treatment, acid treatment are the examples to resolve old mortar portion in RCA so by that here intended to evaluate

appropriateness of RCA in PQC based on the compressive and flexural strength test[4].

2. LITERATURE REVIEW

S.Jagadeesh.et.al. (2018), some tests were conducted using the recycled aggregates to study and compare the results with the naturally available aggregates. The tests were conducted on the aggregates which weren't subjected to any prior treatment. The impact value for recycled aggregate was obtained as 22.75% and that for natural aggregate as 16.83%. The abrasion value for recycled aggregate was obtained as 33.46% and that for natural aggregate as 27.86%. Water absorption of recycled aggregate (5.57%) was found to be higher when compared to the natural aggregate (1.15%). It was found that compressive strength of concrete made from the recycled aggregate is about 76% of the strength of concrete made from natural aggregate for normal strength concrete (M40). Flexural strength of the recycled aggregate concrete is almost 85% and 80% of natural aggregate concrete.

K.Poongodi.et.al. (2019), in this paper, the author found the relationship between flexural strength and compressive strength for RCA concrete as well as conventional concrete. The recycled concrete aggregate used was that passing through IS sieve 40mm and retained on IS sieve 4.75mm. For conventional concrete the natural stone chips of same nominal size was used in making concrete. If required a dose of superplastizer [Conplast SP 430SRV from fosroc chemicals India pvt.ltd] was also added to ordinary tap water to obtain desired degree of workability. In this study, 6 mixes were prepared i.e. replacement of natural aggregates by 0%, 10%, 20%, 30%, 40% and 500% RCA. The strength was tested at 28 days maturity of casted concrete. It was observed that recycled concrete aggregate has lower value of specific gravity and moderately high values of water absorption, crushing value, impact value and abrasion value. And moreover, similar to concrete containing natural aggregate, tensile strength of recycled aggregate concrete containing recycled concrete aggregate mainly depends on compressive strength.

Sayyam D. Raigandhi, et.al. (2015), this study aimed to evaluate physical properties of concrete using recycled coarse aggregate. In this research, concrete waste from demolished structure has been collected and coarse aggregate of different percentages is used for preparing fresh concrete (0%, 25%, 50%, & 75%). Various physical properties were found For RCA such as specific gravity, water absorption, impact value etc. the specific gravity for RCA as 2.31 where as for NCA 2.67 and water absorption test as 1.53% for NCA whereas 6.38% for RCA that shows higher water absorption capacity for RCA due to adhered mortar and bulk density as 1465.8 kg/m^3 for NCA and 1330.93 kg/m^3 for the RCA with a crushing value as 19.5 & 20.5% for NCA and RCA also impact value as 8.3 and 8.9% for NCA and RCA respectively. The compressive strength of recycled coarse aggregate (RCA) is found to be higher than the compressive strength of normal concrete when used up to a certain percentage. Recycled aggregate concrete is in close proximity to normal concrete in terms of flexural strength. The slump of recycled aggregate concrete is more than the normal concrete. At the end, it can be said that the RCA up to 50 % can be used for obtaining good quality concrete.

Dr. J. Venkateswara Rao, et.al (2018) studied an experiment on the effective use of recycled concrete aggregates in rigid pavements investigated that possibility of replacing a NCA with RCA in conventional concrete used in rigid pavements the various combinations of RCA and NCA i.e 0%, 10%,20%,& 30% are considered in M40 concrete mix. The optimum percentage of replacement of NCA with RCA was determined. In the later stage the combination of both RCA and Recycled fine aggregate (RFA) in various proportions (0:100, 25:75, 50:50, 75:25) is investigated and found the optimum as 20% and 25% for RCA and RFA respectively i.e based on the economic feasibility and they have said that The physical and mechanical properties of natural coarse aggregate are superior to recycled coarse aggregate however they are within the limits as per IS: 2386 - 1963 - Part 4 and said that in previous studies the optimum percentage for RCA is 30% with they have concluded that reduction of 6.35% in the cost of concrete production per cubic meter if natural aggregates are replaced with optimum percentage of recycled coarse and fine aggregates.

3. PROBLEM STATEMENT

Mix proportions in pavement concrete works the guidelines of IRC-44 (2008) are used for obtaining the mix proportions, the grades of concrete examined in the previous works are ranging from M25 - M40.The percentage of replacements of coarse aggregate by recycled aggregate is varied between 0 to 30%. And the percentage replacement of fine aggregate by recycled fine aggregate is varied between 0% to 25%, for building construction mix proportions of concrete used as per guidelines of IS-456(2000), the grades of concrete ranging from M15 -M30, and The replacement of recycled aggregates ranging from 0% to 25%. In that point of view in pavement quality concrete works for determining tensile strength of plain concrete by flexural strength test and for compressive strength test of pavement we had replaced natural aggregates to recycled aggregates in higher extent i.e 0%, 30%, 70% and 100% to find the exact optimum percentage replacement and we are performing the experiment with high strength concrete i.e with M40 Grade concrete due as applicable in pavement because that needs to resist higher strength by means of compressive stresses, tensile stresses due to number of rotations of wheels by the heavy vehicles movement. In this project work we have selected a M40 grade concrete as high strength concrete in pavement works and to find the optimum percentage of replacement by trialing a different ratios of replacement of

natural coarse aggregates to the recycled coarse aggregates, i.e for 0%,30%,70%, and for 100% replacement.

4. MATERIALS USED

Cement: It is used for the binding of concrete I have used OPC of 43 grades having specific gravity of 3.1.

Coarse aggregates: Coarse aggregates passing through sieve size of 20 mm & retains on 10 mm were used & RCA had transported from waste management industry having a size passing through 20 mm & retains on 10 mm were used.

Fine aggregates: Fine aggregates were used in this study that is from zone two and having the specific gravity of 2.725.

Water: Portable tap water is used for the preparation of concrete mix.

Admixture: Admixture used that Sikaplast 3001 NS with desirable dosage.

5. MIX DESIGN OF CONCRETE

The nominal mix was prepared as per IS :10262-2019,and the specimens were prepared for a grade of M40 after finding the final mix proportion, i.e based on the obtained test results table 1 shows the partial replacement of NCA with RCA the conventional concrete was designated as RCA0, where "0" represents the percentage of RCA addition in the concrete and desired quantity of superplastizer was added to maintain the workability of RCA added to conventional concrete the w/c ratio was maintained as 0.4.

Table -1: Mix proportion of M40 grade PQC.

Mix Designation (%)	Cement (kg/m³)	Sand (kg/m³)	CA (kg/m³)	RCA		W/C	Water (l/m³)	SP (%)
				(%)	(kg/m³)			
RCA0	450	650	1232	0	0	0.4	186	1.0
RCA30	450	650	862.4	30	369.6	0.4	186	1.0
RCA70	450	650	369.6	70	862.4	0.4	186	1.0
RCA100	450	650	0	100	1232	0.4	186	1.0

5.1 Preparation of Specimens

The preparation of cubes and beams are prepared to achieve 28 days characteristic strength as per the Indian standard code IS: 10262-2019. Fresh concrete was casted into 150 mm cube moulds after mixing in a concrete mixer, addition of concrete ingredients into the mixer was performed strategically by firstly adding dry ingredients and thereafter adding water to prevent escaping of cement particles, and the sizes of moulds for cubes and beams are as cubes (150mm*150mm*150mm)&beams(150mm*150mm*700mm). The standard specimens were casted and kept on vibrating machine for proper compact surface & finish of concrete specimen and day after casting the moulds are removed & kept for curing till 28 days and specimens were tested for evaluation of compressive strength and flexural strength test.

6. PHYSICAL PROPERTIES OF BOTH NCA AND RCA

Table -2: Physical properties of aggregates.

Physical Property	Tests	Results of NCA	Results of RCA	Limits as per (IS: 2386 - 1963 - Part 4)
Specific gravity	Specific gravity test	2.9	2.52	2.6 to 2.8
Water absorption	Water absorption	1%	3%	0.1 to 2%
Strength	Crushing value	25%	30%	< 30%
	Aggregate Impact value	18%	19.50%	< 30%
	Los Angeles Abrasion test	12%	32.4%	< 35%

7. MECHANICAL PROPERTIES

7.1 Compressive strength test

The concrete cube of size 150mm*150mm using normal aggregate are 3 no's and recycled aggregates for different proportions are 9 no's are tested as per IS 516:1959(Reaffirmed 1999) the results of compressive strength at the end of 28 days are taken and compressive strength of natural and recycled aggregates are mentioned in table 3 & 4 also graphical figure 1 shown below.

Table -3: Compressive Strength results for 100% NCA and RCA

Serial No	Mix	Specimen no.	Compressive strength at 28 days (N/mm²)
1	100% NCA	1	48
		2	42
		3	40
		Average	43.33
2	100% RCA	1	35
		2	36
		3	35
		Average	35.33

Table -4: Compressive strength of proportions.

Serial No	Mix	Specimen no.	Compressive strength at 28 days (N/mm²)
1	70% NCA + 30% RCA	1	45
		2	36
		3	40
		Average	40.33
2	30% NCA + 70% RCA	1	38
		2	42
		3	35
		Average	38.33

7.2 Flexural Strength Test

Flexural strength was investigated with 150mm*150mm*700mm size prisms of 4 no's for natural aggregates and 12 no's for recycled coarse aggregates, test was conducted as per IS: 516-1959 in a single point loading and the results are shown in figure 2 graphically and values are shown in table 5 & 6 below.

Table -5: Flexure strength results for 100% NCA and RCA

Serial no.	Mix.	Specimen no.	Flexural strength at 28 days. (Mpa)
1	100% NCA	1	6
		2	5.5
		3	5.8
		4	5.9
		Average	5.8
2	100% RCA	1	4.5
		2	4.0
		3	4.2
		4	3.9
		Average	4.15

Table -6: Flexural strength results for mix proportions

Serial no.	Mix	Specimen no.	Flexural strength at28 days.(Mpa)
1	70% NCA + 30% RCA	1	5.5
		2	6
		3	4.9
		4	5.6
		Average	5.5
2	30% NCA + 70% RCA	1	4.8
		2	4.5
		3	5
		4	4.4
		Average	4.675

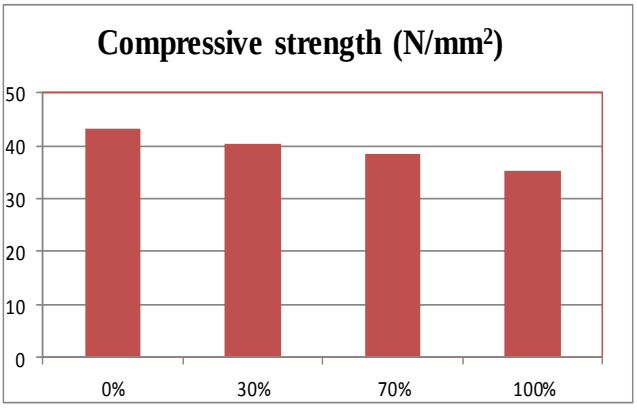

Fig -1: compressive strength results for different proportions.

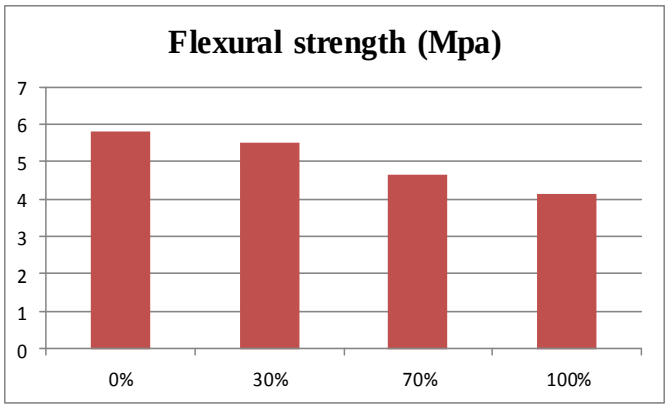

Fig -2: Flexural strength results for different proportions.

8. RESULTS AND DISCUSSION

8.1 Workability of Concrete

The slump cone test was carried out on recycled and conventional concrete in order to know the workability of concrete, the slump of concrete with natural aggregates is found to be 32mm for conventional concrete, while adding the RCA the slump get reduced due to its absorption capacity slump became reduced with increasing the content of RCA finally for full replacement of RCA the slump obtained as 8mm, but the use of superplastizer the mixes was made workable.

8.2 Compressive Strength Test

Compression strength of pavement quality concrete test was conducted as per IS 516:1959 using compressive testing machine, the insignificant reduction of compressive strength was noticed when conventional coarse aggregate was replaced by RCA. In the meantime 28 days target strength of designed concrete was considered as threshold limit in strength of the concrete. The substitution of RCA is not achieved the target strength of M40 as per the design stipulation, also the results obtained from 70% of RCA added PQC was noticed lower value then target strength and 100% of RCA in PQC had shown lower than the target value of concrete at 28 days curing period. The strength reduction may be attributed due to the improper bonding between cement paste and RCA content in the concrete.

As per results it was found that the compressive strength for conventional concrete increased to more than characteristic strength but not achieved a target mean strength and for 30% RCA is slightly reduction of strength was found and significant reduction of compression strength was observed for increased replacement ratio of recycled coarse aggregates and finally demolished concrete aggregates gives us a lower strength as compared to natural coarse aggregates.

8.3 Flexural Strength Test

Flexural strength of all the mixes prepared using natural and RCA's was determined using hardened concrete prism specimens of size 150mm*150mm*700mm. and values are determined as per IS:516 (1959) at the age of 28 days, Recognized that the concrete mix containing only NCA developed maximum flexural strength followed by replacement of RCA.

As per the results the flexural strength was found that the reduction of strength to maximum extent from conventional concrete the flexural strength was found that as 5.8 Mpa as average value from all the specimens, and by increasing the RCA to extent of 30% it was found that reduction of strength as 5.5 Mpa and for 70% replacement that was reduced to 4.675 Mpa and for 100% replacement the strength was found that 4.15 Mpa so, here I have noticed that low tensile strength of plain concrete was observed by increasing the replacement ratio of recycled coarse aggregates.

9. CONCLUSIONS

Based on the investigation, the following inferences were drawn:

- The workability of pavement quality concrete was gradually decreased while adding RCA instead of natural coarse aggregates obtained from the test results of slump cone test.
- As per our design 48 N/mm^2 is the target mean strength but here significant reduction of strength was noticed up to 100% substitution of RCA. Meantime, the results of compression strength for 0%, 30% , 70% & 100% RCA as 43.33 N/mm^2, 40.33 N/mm^2 , 38.33 N/mm^2 & 35.33 N/mm^2 respectively was observed i.e similar in flexural strength test also lesser values obtained than target mean strength at 28 days curing period.
- The insignificant reduction on flexural strength of the PQC was detected after the addition of 30% RCA.
- The significant linear increase in water absorption of PQC was observed while increasing the replacement of conventional aggregate by Recycled coarse aggregates.
- With the help of results, it is resolved that the RCA could be used up to 40% as CA for PQC works.
- Due to use of recycled aggregate in construction, energy & cost of transportation of natural resources & excavation is significantly saved. This in turn directly reduces the impact of waste material on environment.

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