PERFORMANCE ENHANCEMENT OF RECYCLED COARSE AND FINE AGGREGATE

Mr. Absham.C.M
Dept. of Civil Engineering
Excel Engineering College
talktoabu15@gmail.com

Dr.S.Christian Johnson ,Ph.D.,
Professor and DEAN
Dept. of Civil Engineering
Excel Engineering College, Kumarapalayam

Abstract : In this work, an attempt is made to study the performance of concrete using water soaked Recycled Cycled Coarse Aggregates (RCA) in replacement levels of 0%, 25%, 50%, 75% and 100% to that of Natural Coarse Aggregates (NCA). Experiments were designed and conducted to study the performance of RCA based concrete and also to use suitable performance enhancement techniques to RCA based concrete, to achieve compressive strength at least equal to or more than that for no RCA based concrete (control concrete). Four techniques attempted to achieve this objective include soaking RCA in cement slurry for 24 hours, replacing 15% of OPC by Silica Fume (SF), replacing 30% OPC by Fly Ash (FA) and 70% of OPC by Ground Granulated Blast furnace Slag (GGBS). For blended concretes the curing of specimen were done for 28 days and 56 days. Performance enhancement study is reported here for 50% and 100% RCA based concretes. All four techniques attempted have given favourable results encouraging viability of using RCA based concretes with full replacement levels, to adopt RCA based concrete in structural applications, without any kind of concern. Further attempts have also been made to use Recycled Fine Aggregates (RFA) with appropriate modifications to serve as fine aggregates in mortar and concrete. Using RFA blended with river sand fractions as well as RFA with Iron Ore Tailings (IOT) fractions, have given good results to serve as fine aggregates in mortars and concretes.

Key Words: Recycled Cycled Coarse Aggregate, Silica Fume, Recycled Fine Aggregates, Iron Ore Tailings

INTRODUCTION

Due to high demand for construction activities in recent years in India and all over the world, the natural aggregates resources are remarkably waning day by day. On the other hand, millions of tonnes of construction and demolition (C&D) residues are generated. The amount of construction and demolition waste has increased enormously over the last decade in the entire world. Construction and demolition disposal has also emerged as a problem in India. India is presently generating construction and demolition (C&D) waste to the tune of 23.75 million tonnes annually and these figures are likely to double fold in the next 7 years. C&D waste and specifically concrete has been seen as a resource in developed countries. Therefore, the recycling of waste concrete is beneficial and necessary for the environmental preservation and effective utilization of natural resources. The use of recycled coarse aggregate obtained from construction and demolition waste in new concrete is a solution for effective waste utilization.

The management of construction and demolition waste is a major concern due to increased quantity of demolition rubble, continuing shortage of dumping sites, increase in cost of disposal and transportation and above all the concern about environment degradation. Although a substantial portion of construction materials could be substituted by re-processed construction waste material, these options are not exercised in developing countries due to lack of knowledge and insufficient regulatory frameworks resulting in waste getting piled up causing disposal problems. The increasing problems associated with construction and demolition waste have led to a rethinking in developed countries and many of these countries have started viewing this waste as a resource and presently have fulfilled a part of their demand for raw material. Since concrete composes 35% of the waste as per the survey conducted by Municipal Corporation of Delhi, India may also have to seriously think of reusing demolished rubble and concrete for production of recycled construction material. Such recycling operations have the added benefit of reducing landfill disposal, while conserving primary resources and reducing transport costs.

Though utilization of recycled aggregates (RA) in concrete has become more common practice all over the world, it is generally used for lower-grade applications. Higher-grade activities are rarely reported, because of its effects on workability, strength and durability. Work on recycled concrete has been carried out at few places in India but waste and quality of raw material produced being site specific, several inputs are necessary if recycled material has to be used in construction for producing high grade concrete.

CONSTRUCTION AND DEMOLITION (C & D) WASTES

Construction and demolition waste is generated whenever any construction/demolition activity takes place, such as, building roads, bridges, flyover, subway, remodelling etc. It consists mostly of inert and non-biodegradable material such as concrete, plaster, metal, wood, plastics etc. While retrievable items such as bricks, wood, metal, titles are recycled, the concrete and masonry waste, accounting for more than 50% of the waste from construction and demolition activities, are not being currently recycled in India. Recycling of concrete and masonry waste is, however, being done abroad in countries like U.K., USA, France, Denmark, Germany and Japan. Concrete and masonry waste can be recycled by sorting, crushing and sieving into recycled aggregate.

C&D waste needs to be focused upon in view of

∟ The potential to save natural resources

∟ Its bulk which is carried over long distances for just dumping

∟ Its occupying significant space at landfill sites

∟ Its presence spoils processing of biodegradable as well as recyclable waste

Many developed countries have been recycling C&D waste and using it for construction works. In Scotland about 63% of the C&D waste was recycled in 2000.The Government there is working out specifications and code of practice for recycling of C&D waste. U.K uses 49-52% of the C&D wastes and Australia reuses 54% of the wastes generated. Belgium has a higher recycling rate (87%) and uses majority of C&D for recycling purposes. Japan is one of the pioneer countries that recycle C&D waste.85 million tonnes of C&D waste was generated in 2000, of which 95% of concrete was crushed and reused.

In India, there is not much development in this field. In the international experiences sited above, there is considerable emphasis on recycling of C&D in India.

RECYCLED COARSE AGGREGATE (RCA)

The requirements of natural aggregates are not only required to fulfill the demand for the upcoming projects, but also are the needs of the extensive repairs or replacements required for the existing infrastructure and dilapidated buildings built few decades back. The use of Recycled Coarse Aggregate can fill a part of this gap. Figure shows recycled aggregate.

Recycled Aggregate

Works on recycling have emphasized that if old concrete has to be used in second generation concrete, the product should adhere to the required compressive strength. Literature survey reveals that compressive strength primarily depends upon adhered mortar, water absorption, Los Angeles abrasion, size of aggregates, and strength of parent concrete, age of curing and ratio of replacement, interfacial transition zone, moisture state, impurities present and controlled environmental condition. Some of the studies have suggested the mix design procedure for recycled aggregates in concrete, yet a simple and cost effective method of using demolished concrete, taking into account % adhered mortar and thus calculating mix composition needs to be developed. Figure shows recycled coarse aggregate.

Recycled coarse aggregate

Since the recycled aggregates has the potential to replace natural resources and in the process address the issue of sustainability and environmental degradation many countries outside India have been using the product satisfactorily. However this requires upgrading the waste material to normal standards and reducing it to proper size to attain the desirable properties. Works have shown that aggregates from different sources, exhibit different engineering properties. Aggregates also are the key ingredients in concrete making up 70-80% of volume in concrete and dictating the strength and density relationship. Hence using recycled concrete as aggregate will require checking the quality of the aggregates, since they are collected from different sources, grades of concrete and age. Works on recycled concrete have emphasized that the basic material properties, such as shape, texture, specific gravity, absorption, moisture content, permeability, strength characteristics, deleterious substance, resistance to freeze–thaw, etc., need to be thoroughly evaluated before it is used to produce concrete. Aggregate"s properties greatly affect the properties of a concrete. It would also be necessary to assess the effect of recycled material on final concrete and work out optimum composition of recycled aggregate to produce concrete of desirable quality.

RECYCLED FINE AGGREGATE (RFA)

The uncontrolled consumption of natural sands has led to situations of exhaustion of availability of these aggregates, with various warnings that it is going to happen in several regions. Resorting to crushed sands has shown to be unviable given the cost (fundamentally energy related) associated to its production as well as the fact that the shape of these particles in not the most suitable to achieve the best workability for concrete. On the other hand the extraction of sands in coastal areas brings along deterioration of the ecosystems with unpredictable long term repercussions, such as the elimination of local species and consequent unbalances.

Even though advances reached in the study of concrete using RCA have been enough to reliably say that, it is possible to make concrete with RCA with perfectly acceptable characteristics for current use, the use of RFA is still limited. One of the most important lines of research currently being developed is related to the possibility of using RFA from C&D waste as replacement (either partially or totally) of natural sands in concrete. This goal serves a greater environmental purpose, as it fights abiotic resources depletion, namely by reducing river banks and coastal sand extraction. Investigations on this matter have been set aside mostly because some early attempts on the use of these materials proved to be excessively detrimental to concrete's performance. The main causes for this weak performance of RFA were the low particle's density, and high water absorption capacity, that hinders the mixing.

MINERAL ADMIXTURES

Silica fume

Silica fume is a byproduct of producing silicon metal or ferrosilicon alloys. One of the most beneficial uses for silica fume is in concrete. Because of its chemical and physical properties, it is a very reactive pozzolan. Concrete containing silica fume can have very high strength and can be very durable.

Fly ash

Fly ash, is one of the coal combustion products, composed of the fine particles that are driven out of the boiler with the flue gases. Ash that falls in the bottom of the boiler is called bottom ash. In modern coal-fired power plants, fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys. Together with bottom ash removed from the bottom of the boiler, it is known as coal ash. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amount SiO2 (both amorphous and crystalline), aluminium oxide (Al2O3) and calcium oxide (CaO), the main mineral compounds in coal-bearing rock strata.

Ground Granulated Blast furnace Slag (GGBS)

The Ground Granulated Blast furnace Slag is a waste of industrial materials. It is relatively more recent pozzolanic material that has received considerable attention in both research and application. It is a non-metallic product consisting essentially of silicates and alumino silicates of calcium's developed simultaneously with iron in a blast furnace and is granulated by quenching the molten material in water or steam, and air.

Iron Ore Tailings (IOT)

The iron and steel industry is one of the major industries in India. While it has produced great economic benefits, it has also resulted in the generation of a huge amount of industrial by-products. The value of using some byproducts, such as slag which is used to produce blended cements and concrete, has already been widely recognized, but most hazardous materials like iron ore tailings have been discarded as waste. This has led to a serious environmental deterioration. Official statistics in 2008 showed that the annual discharge of iron ore tailings in China was 0.6 billion tons and only less than 7% had been recycled as resources. These untreated tailings not only occupy large amounts of land, pollute water resources and the air but also pose threat to human beings safety.

MATERIAL AND METHODS

Recycled Coarse and Fine Aggregates

The recycled coarse and fine aggregates were obtained from the concrete cubes cast and cured for 28 days. They are extracted from the above 28 day old concrete considered here as construction and demolished waste, by using the hydraulic machine to break it into smaller pieces of 20mm to 40mm by loading up to failure. These fragmented pieces will be having a high content of mortar attached to them. Separation of this adhered mortar was the main challenge in obtaining good quality RCA and RFA. These should have properties closer to that of fresh/natural aggregates after processing. To achieve, this objective, fragmented pieces were processed by rotating them in the Los Angeles abrasion testing machine. The advantage of using this machine is that, the mortar which is not as hard as the coarse aggregate will be broken down into smaller pieces as they fall over the machine and hit the steel balls. These fragmented concrete pieces were processed using 12 steel balls, approximately 48mm in diameter and each weighing 390 to 445 grams and rotated for a total of 15 minutes, at the rate of 330 rpm. For each batch, total weight of 5 kg, of demolished concrete is processed. Material was discharged from the machine and sieved to size of 20mm down and 10mm holding 10mm passing 4.75mm holding as coarse aggregate, 4.75mm passing 2.36 holding, 2.36mm passing 1.18 holding, 1.18mm passing 600μ holding as fine aggregate. Material finer than 600μ had issues of forming clay lumps with water and hence not used. Later the sieved material was washed manually with water properly, to remove the dust particles sticking to the surface of the aggregates. The physical appearance of the RCA and RFA after this method was very similar to those of natural coarse and fine aggregates. The washed material was sun dried and stacked in the laboratory before use in the subsequent experiments. The coarse aggregates were soaked in water for 24 hours before being used in producing RCA based concrete.

Sieve analysis Coarse aggregate

Sieve size (mm)	% Finer	
	NCA	RCA
20	100	100
16	68.5	71.5
12.5	32.1	27.7
10	0.7	0.5

Properties of recycled coarse aggregates

Sl. No.	Property	Results
1	Specific gravity	2.59
2	Water absorption	2.69%

Regards to the use of RFA, two types of hybrid FA, are attempted. Nearly 20% of the material in river sand (control) is finer than 600μ. River sand based RFA, meant RFA fractions taken exactly same as river sand up to 1.18mm and mixed with proportionate river sand fractions for 600μ, 300μ, and 150μ. Iron ore tailings based RFA, meant RFA fractions taken exactly same as river sand up to 1.18mm and mixed with proportionate iron ore tailings fractions for 600μ, 300μ, and 150μ.

Sieve analysis fine aggregates

Sieve size (mm)	% Finer	
	NFA	RFA
4.75	93.9	95.0
2.36	90.7	92.5
1.18	58.3	65.0
600μ	16.3	22.3
300μ	5.5	8.6
150μ	0.0	2.0

Properties of recycled fine aggregates

Sl.No.	Property	Results
1	**Specific gravity**	**2.6**
2	**Water absorption**	**6.52%**

NOMINAL MIX

Cement used for the test procedure was 53 Grade Ordinary Portland cement. The nominal mix proportion used is 1:1.5:3. The river sand used has a specific gravity of 2.62 and belonged to zone I. Water cement ratio of 0.50 was chosen. The concrete was mixed in a concrete mixer and poured into cube moulds of size 150mm. They were given adequate vibration to achieve required compaction. The cubes were de-moulded after 24 hours and cured for 28 days in water. Cubes were taken out of the curing tank after 28 days and air dried before crushing them to generate Construction and Demolished (C&D) waste from which RCA and RFA shall be extracted.

Concrete using cement slurry coated RCA with the same mix proportion of 1:1.5:3, w/c = 0.5, was produced to study the performance enhancement. Mixing, placing, demoulding and curing followed are the same.

Concrete blended with SILICA FUME was made with the same mix proportion of 1:1.5:3, w/c = 0.5, was produced to study the performance enhancement. 15% of cement was replaced with SILICA FUME. Mixing, placing, demoulding and curing followed are the same as discussed above.

Concrete blended with FLY ASH was made with the same mix proportion of 1:1.5:3, w/c = 0.5, was produced to study the performance enhancement. 30% of cement was replaced with FLY ASH.

Concrete blended with GGBFS was made with the same mix proportion of 1:1.5:3, w/c = 0.5, was produced to study the performance enhancement. 70% of cement was replaced with GGBFS.

METHODOLOGY FOR OBTAINING RECYCLED COARSE AGGREGATE

∟ To cast nominal mix (1:1.5:3) cubes of 150mm, 100 no"s to produce Construction and Demolition (C&D) waste.

∟ After 28 days curing, the specimen were crushed to failure using compression testing machine and the broken concrete is re-processed for recycling into RCA based concrete.

∟ Processing involved subjecting C&D waste to Los Angele"s machine, sieving, washing and sun drying.

∟ Test cubes of 150 mm RCA based concrete were cast for nominal mix proportion of 1:1.5:3, with w/c = 0.5. The recycled aggregates were all water soaked for 24 hours before being used, except the cement slurry coated case, wherein soaking in cement slurry was done for 24 hours.

∟ The specimen of RCA concrete is tested after 28 days of curing.

∟ The specimen of RCA concrete blended with silica fume, fly ash, and GGBS are tested after 28 days and 56 days of curing.

Mixing method

As the water absorption of the RCA was high it may absorb the water which is added for the concrete mixing. This will lead to less effective w/c ratio and less workability. Adding water to compensate for the absorption will also create problems as the effective w/c ratio will be very high and it will give high workability. Moreover the concrete will not be in a uniform condition as the mortar paste will be much dilute and chances of bleeding will be high. Hence the RCA was soaked for 24 hours in water prior to mixing. The RCA was taken out after 24 hours of soaking and allowed for air drying of 30 minutes before the mixing. This prevented further absorption of water by the RCA. It helped to attain the workability of moderate level without plasticizers.

Slump tests

Initial experiments are conducted to get a slump of at least 75 -100 mm without super plasticizers. Standard slump cone apparatus is used for measuring the value of slump. During the slump tests it was found that the workability of fresh concrete made with 100% replacement of RCA had slump value close to zero mm. With increase in percentage of RCA in concrete the workability was getting lower and lower. This was mainly due to the high absorption rate (2.7%) of the RCA as compared to the fresh coarse aggregate (0.5%). Adding water to compensate for this absorption was not a good option as exact amount could not be ascertained. So it was decided to soak the RCA for 24 hours before use so that it does not absorb water during the process of mixing.

Table 3.16 shows a test matrix for compressive strength performance and enhancement.

RCA	Concrete cubes							
	For performance	For performance enhancement						
%	OPC based	OPC, RCA cement slurry treated	85% OPC & 15% SF based		70% OPC & 30% FA based		30% OPC & 70% GGBS based	
			28 d	56 d	28 d	56 d	28 d	56 d
0	3	3	3	3	3	3	3	3
25	3	3	-	-	-	-	-	-
50	3	3	3	3	3	3	3	3
75	3	3	-	-	-	-	-	-
100	3	3	3	3	3	3	3	3
Total	**15**	**15**	**9**	**9**	**9**	**9**	**9**	**9**

The mix proportions of the OPC concrete used is shown in Table 3.17. The water cement ratio was taken as 0.5. Mixes were with 0%, 25%, 50%, 75%, and 100% RCA by weight.

Mix proportion per cubic meter for OPC based concrete

RCA (%)	C (kg)	FA (kg)	CA (kg)	RCA (kg)	W (kg)
0	400	600	1200	-	200
25	400	600	900	300	200
50	400	600	600	600	200
75	400	600	300	900	200
100	400	600	0	1200	200

Similar test matrix were used for other four performance enhancement techniques attempted. However the dosage of chemical admixture (CONPLAST SP 430) has been suitably used to give workability slump range of 75-100 mm. The details of chemical admixture dosages for various compositions are as follows;

OPC based concrete with 24hrs soaked RCA- 0 ml/kg of cement for all replacement levels of RCA.

OPC based but RCA treated in cement slurry- RCA 0% - 0 ml/kg, 25% - 0 ml/kg, 50% - 0 ml/kg. 75% - 4 ml/kg and 100% - 8 ml/kg.

OPC – 85% and SF- 15% blended concrete- RCA 0% - 8 ml/kg, 50% - 9 ml/kg. and 100% - 12 ml/kg.

OPC – 70% and FA- 30% blended concrete- RCA 0% - 0 ml/kg, 50% - 0 ml/kg. and 100% - 0 ml/kg.

OPC – 30% and GGBS -70% blended concrete- RCA 0% - 0 ml/kg, 50% - 6 ml/kg. and 100% - 6 ml/kg.

METHODOLOGY FOR OBTAINING RECYCLED FINE AGGREGATE

∟ The same material from which RCA has been extracted, is passed through 4.75 mm sieve, is washed and sun dried. The fractions finer than 600μ are removed for the reason explained earlier, but substituted with either river sand or IOT fractions.

∟ RFA mortar blended with river sand and iron ore tailings with nominal mix (1:3), cubes of 50cm2 with recycled fine aggregate in proportions 0%, 50%, 100%, 3 no‟s each, by weight are cast.

∟ RFA concrete blended with river sand and iron ore tailings with nominal mix with nominal mix (1:1.5:3), cubes of 150mm x 150mm x 150mm, w/c ratio 0.5 with recycled concrete aggregates in proportions of 0%, 50%, 100% 3 no‟s each, by weight were cast.

Experiments were planned to test the compressive strength of River sand, RFA based river sand and RFA based IOT, mortar cubes for 3, 7, and 28 days of curing in water. Table 3.18 shows the test matrix for testing compressive strength of different mortar compositions.

Test matrix for compressive strength of mortar cube

Fine aggregate	3 Day	7 Day	28Day
All River Sand	3	3	3
RFA & River Sand Fines	3	3	3
RFA & IOT Fines	3	3	3

Experiments were planned to test the compressive strength of River sand, RFA based river sand and RFA based IOT, based concrete cubes for 28 days of curing in water. Table 3.19 shows the test matrix for testing compressive strength of concrete.

Test matrix for compressive strength of concrete cubes

Fine aggregate adopted	28Day
All River Sand	3
RFA & River Sand Fines	3
RFA & IOT Fines	3

COMPRESSIVE STRENGTH

Strength of concrete is the most important, although other characteristic may also be critical and cannot be neglected. Strength is an important indicator of quality because strength is directly related to the structure of hardened cement paste. Even though strength is not a direct measure of durability or dimensional stability, it has a strong relationship with the water to cement ratio of the concrete, which in turn influences durability, dimensional stability and other properties of concrete.

The strength measured in concrete depends on some factors including the age, degree of hydration, rate of loading, method of testing, specimen geometry, and the properties and proportions of the constituent materials. Mostly, concrete strength improves with the increase of age. The strength of saturated specimen may have lower strength than dry specimen. Compressive strength measured in impact loading will be higher than that in a normal rate of loading. Cube specimen may result higher strength than cylinder specimen. The properties of constituent materials such as the quality of aggregate, the quality of cement paste, and the bond between aggregate and cement paste, influence the strength of concrete.

The concrete samples with RCA are tested for 28 day strengths in the case of OPC and 28 day &56 day strengths in the case of SF, FA and GGBS blended concretes. The testing of the cubes was done in a 200T capacity compression testing machine.

Testing of cubes for compressive strength

RESULTS AND DISCUSSION

The result of the tests performed on recycled concrete includes the variation in compressive strength by two performance enhancement techniques to achieve the strength of recycled concrete to be equal to or more than the strength of no recycled aggregate concrete.

Compressive strength testing of all specimen were carried out as per IS: 516-1959. The load was applied without shock at a rate of 140 kg/cm2/min. A set of three cubes were tested for all six mixes, for each percentage of replacement. Average of three specimen were taken, provided the individual variation in strength 50 was not more than ±15% of the average, and the results were tabulated and interpreted.

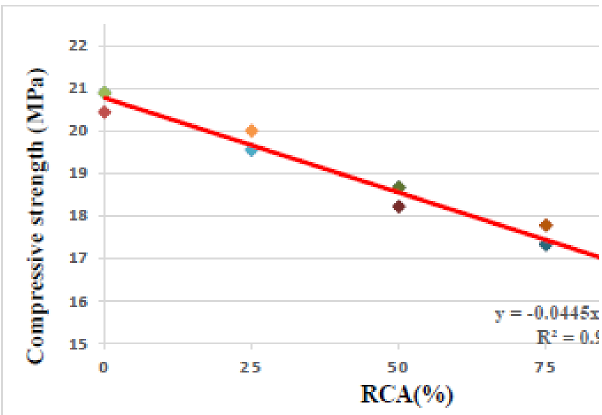
Performance of RCA Based Concrete

The results of the compressive tests for OPC specimen are shown in the table below. It can be noticed that the compressive strength of the cubes goes on decreasing as the percentage of the RCA replacement gets This can be attributed to the less bonding between the RCA and the mortar as it is having the old mortar sticking to it.

Compressive strength results for different proportions of RCA

RCA (%)	Wt of cubes (Kg)	Failure load (kN)	Compressive strength (N/mm2)	Average compressive strength (N/mm2)
Control mix 0	8.343	470	20.89	20.7
	8.439	460	20.44	
	8.425	470	20.89	
25	8.316	440	19.56	19.7
	8.379	440	19.56	
	8.413	450	20.0	
50	8.228	420	18.67	18.5
	8.393	410	18.22	
	8.388	420	18.67	
75	8.336	390	17.33	17.5
	8.402	390	17.33	
	8.455	400	17.78	
100	8.373	360	16.00	16.3
	8.358	370	16.44	
	8.345	370	16.44	

Note: RCA used have been soaked in water for 24 hours



Compressive strength (MPa) variation with RCA for OPC based mixes

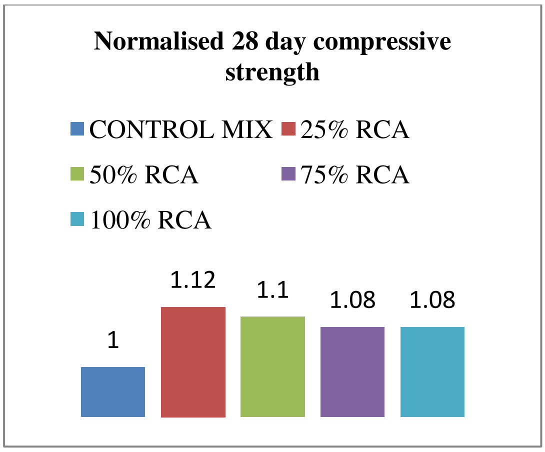
Nearly 20% decrease in strength is observed for 100% RCA based concrete. Attempts were made to achieve strengths of 100% RCA based concrete either equal to or more than that for the case of 0% RCA based concrete, with the following two approaches:

Use of cement slurry coated RCA

Experiments were planned to study the performance enhancement of cement slurry treated RCA based concrete

Compressive strength results for cement slurry treated RCA based concrete

RCA %	Wt of cubes (Kg)	Failure load (kN)	Compressive strength (N/mm2)	Avg compressive strength (N/mm2)	Normalized 28d compressive strength (N/mm2)
0	8.343	470	20.89	20.7	1
	8.439	460	20.44		
	8.425	470	20.89		
25	8.287	520	23.11	23.1	1.12
	8.194	530	23.56		
	8.229	510	22.67		
50	8.124	510	22.67	22.8	1.10
	8.026	510	22.67		
	8.383	520	23.11		
75	8.336	510	22.67	22.4	1.08
	8.402	500	22.22		
	8.455	500	22.22		
100	8.328	500	22.22	22.4	1.08
	8.365	510	22.67		
	8.365	500	22.22		



Compressive strength results for cement slurry treated RCA based concrete

It is clear from Fig. 4.2, that this method of RCA treatment is very effective as strength achieved for RCA based concrete is equal to or more than that for no RCA based concrete or Normal Aggregate Concrete (NAC), for all levels of RCA replacement.

Adopting 15% OPC replacement by silica fume

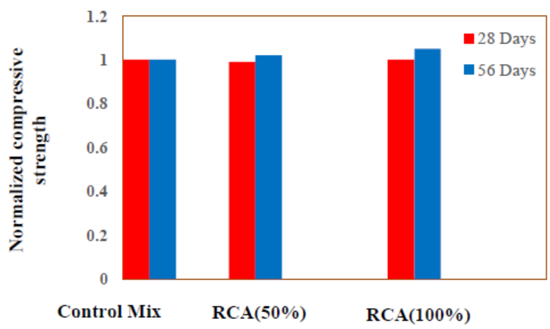
Following tables present the results of compressive strength of RCA based concrete for 28days and 56 days of curing.

28 day compressive strength results for silica fume blended concrete

RCA (%)	Weight of cubes (Kg)	Failure load (kN)	Compressive strength (N/mm2)	Average 28dcompressive strength (N/mm2)	Normalized 28d compressive strength (N/mm2)
Control mix 0	8.343	470	20.89	20.7	1
	8.439	460	20.44		
	8.425	470	20.89		
50	8.318	450	20.0	20.4	.99
	8.426	470	20.9		
	8.290	460	20.4		
100	8.336	470	20.9	20.7	1
	8.345	470	20.9		
	8.405	460	20.4		

56 day compressive strength results for silica fume blended concrete

RCA (%)	Weight of cubes (Kg)	Failure load (kN)	Compressive strength (N/mm2)	Average 56dcompressive strength (N/mm2)	Normalized 56d compressive strength (N/mm2)
Control mix 0	8.345	460	20.44	20.9	1
	8.429	470	20.89		
	8.355	480	21.30		
50	8.349	490	21.8	21.3	1.02
	8.405	480	21.3		
	8.295	470	20.9		
100	8.305	490	21.8	21.9	1.05
	8.419	500	22.2		
	8.396	490	21.8		



Normalized compressive strength results for silica fume blended RCA based concrete

It is clearly seen that for both levels of RCA usage i.e., 50% and 100% replacement to NCA, the obtained 56 days strength is higher than that for NCA based concrete.

CONCLUSIONS

- As the degree of processing gets better and better the RA tends to be closer to NA. Hence RA after processing shows better results than unprocessed RA.
- Quality of recycled aggregate plays a vital role in the strength of RCA based concrete.
- RCA could be incorporated into many concrete structures with proper processing and treatment. However, RCA that has an unknown origin should be tested to ensure that the RCA was not from a structure that was suffering from alkali-silica reaction, alkali-aggregate reaction, sulphate attack, or some other harmful reaction. Such RCA could affect the strength and durability of the concrete and may be harmful.
- A maximum reduction of about 21% was noticed in compressive strength when the entire natural coarse aggregate was replaced with RA.
- The two methods adopted to enhance performance of RCA based concrete have given favourable result, so as to consume/use 100% recycled coarse aggregate in concrete. For the cases of blended concrete with SF, curing period of 56 days is a must.

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