TO STUDY THE PROPERTIES OF CONCRETE BY PARTIAL REPLACEMENT OF FINE AGGREGATE FROM BOTTOM ASH

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ABSTRACT

Concrete is the most widely used artificial construction material in the World and it is second to water as the most utilized substance on the planet. A Tremendous infrastructure development has taken place in the country (Throughout the world) and making of the concrete for higher strengths and Higher durability to cater to the requirements are significant.

Admixtures are the chemical compounds in concrete other than Cement, water, fine aggregate and coarse aggregate and mineral additives that are added to the concrete immediately before or during mixing to modify the Properties of the concrete. The addition of the admixture will improve the Properties of the concrete and also it should be taken care that it should not Adversely affect the performance of the concrete. By the addition of Admixtures, the workability of the concrete is improved, the durability and Strength of the concrete is improved, the initial setting time of the concrete is Increased and sometimes it retards the initial setting time of the concrete etc.

Based on the literature review, it was observed that the admixtures Such as bottom ash, etc., put in Combination, will give better high performance and multi component concrete Which can be used in the most adverse conditions. And based on various and Repeated trials, it was observed that by the replacement of the admixtures in The followiPrepared and laboratory tests have been performed to determine the various Important properties of the concrete. The importance of the various Admixtures such as bottom ash. The optimum percentage of admixtures that gave Good mechanical and durability properties results based on trial and error method was selected

INTRODUCTION

Concrete is a material synonymous with strength and longevity. It has emerged as the dominant construction material for the infrastructure needs of the twenty-first century. In addition to being durable, concrete is easily prepared and fabricated from readily available constituents and is therefore widely used in all types of structural systems. The challenge for the civil engineering community in the near future is to realize projects in harmony with the concept of sustainable development and this involves the use of high performance materials and products manufactured at reasonable cost with the lowest possible environmental impact. Energy is the main backbone of modern civilization of the world over, and the electric Power from thermal power stations is a major source of energy, in the form of electricity. In India, over 70% of electricity generated in India, is by combustion of fossil fuels, out of which nearly 61% is produced by coal-fired plants. This results in the production of roughly 100 ton of ash. Most of the ash has to be disposed off either dry, or wet to an open area available near the plant or by grounding both the fly ash and bottom ash and mixing it with water and pumping into artificial lagoon or dumping yards. This causes the pollution in water bodies and loss of productive land.

CONSTRUCTION AND DEMOLITION 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.

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

BOTTOM ASH

Bottom ash is part of the non-combustible residue of combustion in a furnace or incinerator. In an industrial context, it usually refers to coal combustion and comprises traces of combustibles embedded in forming clinkers and sticking to hot side walls of a coal-burning furnace during its operation. The portion of the ash that escapes up the chimney or stack is, however, referred to as fly ash. The clinkers fall by themselves into the bottom hopper of a coal-burning furnace and are cooled.

BOTTOM ASH GENERATION PROCESS

In a conventional water impounded hopper (WIH) system, the clinker lumps get crushed to small sizes by clinker grinders mounted under water and fall down into a trough from where a water ejector takes them out to a sump. From there it is pumped out by suitable rotary pumps to dumping yard far away. In another arrangement a continuous link chain scrapes out the clinkers from under water and feeds them to clinker grinders outside the bottom ash hopper. More modern systems adopt a continuous removal philosophy. Essentially, a heavy duty chain conveyor submerged in a water bath below the furnace which quenches hot ash as it falls from the combustion chamber and removes the wet ash continuously up to a de-watering slope before onward discharge into mechanical conveyors or directly to storage silos. These days bottom ash can be extracted, cooled and conveyed using dry ash technology from various companies. Dry ash handling has many benefits. When left dry the ash can be used to make concrete and other useful materials. There are also several environmental benefits. Existing dry ash handling systems include: MAC Ash Cooler System, DAP Dry Ash Processor, DRYCON system, and Vibratory Ash Extractor. Bottom ash may be used as raw alternative material, replacing earth or sand or aggregates, for example in road construction and in cement kilns (clinker production). A noticeable other use is as growing medium in horticulture (usually after sieving).

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 SiO_2 (both amorphous and crystalline), aluminium oxide (Al_2O_3) and calcium oxide (CaO), the main mineral compounds in coal-bearing rock strata.

MATERIAL STUDY AND MIX DESIGN

Effective production of high strength concrete is achieved by carefully selecting, controlling and proportioning all ingredients. In order to achieve high strength concrete, optimum proportion must be selected, considering the characteristics of cementitious materials, aggregate quality, paste proportion, aggregate paste interaction and meticulous care in mixing and handling. Following are the details of the materials used in this investigation and its properties.

Cement

Cement is the most important ingredient in concrete. One of the important criteria for the selection of cement is its ability to produce improved microstructure in concrete. Cement OPC of 53 Grade locally available is used in this investigation. The Cement is tested for various properties as per the IS: 4031–1988 and found to be confirming to various specifications of IS: 12269–1987.

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 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.

Fine aggregate	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	2	2	2	2	2	2
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**	**8**	**8**	**8**	**8**	**8**	**8**

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

Fine aggregate	C	FA	CA	RCA	W
(%)	(kg)	(kg)	(kg)	(kg)	(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.

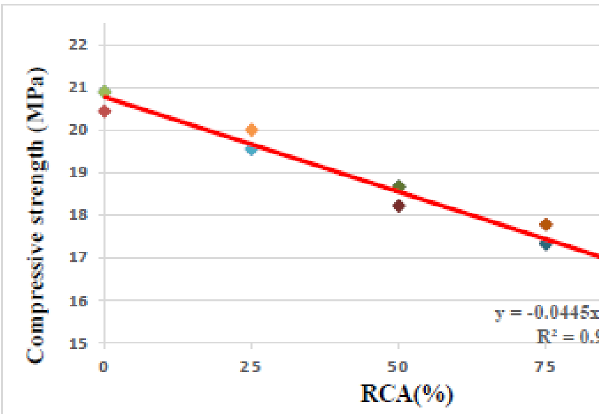
Performance of RCA Based Concrete

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	21.07
	8.564	460	21.44	
	8.425	470	20.89	
25	8.316	440	19.56	20.1
	8.458	440	19.56	
	8.413	450	20.0	
50	8.228	420	18.67	18.5
	8.393	410	18.22	
	8.396	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

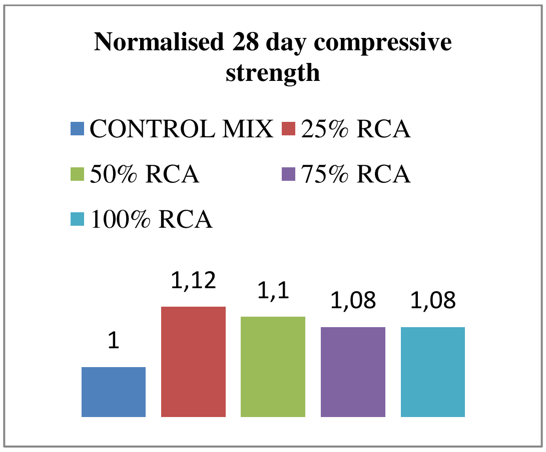
Nearly 20% decrease in strength is observed for 100% RCA based concrete. Attempts were made to achieve strengths of 100% RCA based concrete either equal to or more than that for the case of 0% RCA based concrete, with the following two approaches:

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

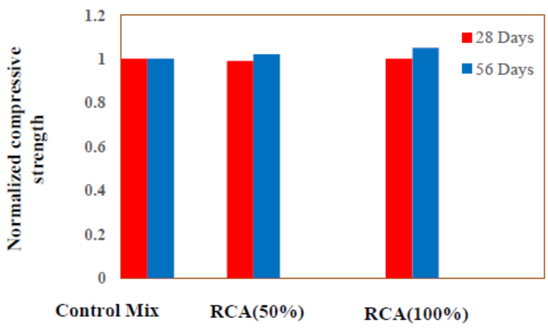
Following tables present the results of compressive strength of RCA based concrete for 28days and 56 days of curing.

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

- Bottom ash can be used as an effective replacement of natural sand.
- In the compressive strength bottom ash replaced concrete shows good results compared

with the normal conventional concrete.

- The average maximum compressive strength obtained is 31.5 N/mm^2 in 28 days and is found to be 3.96% more than the conventional concrete.
- The average maximum split tensile strength obtained is 3.34 N/mm^2 and is found to be 4.3% more than the conventional concrete.
- The average maximum flexural strength obtained is 3.35 N/mm^2 and is found to be 3.3% more than the conventional concrete.
- The maximum ultimate load by the coventional beam is 59.5KN and the bottom ash concrete beam withstands a maximum of 61 KN.
- In the durability property study the weight loss due to acid, suplahte and chloride are more in conventional concrete than the bottom ash concrete. Also the strength decreases in the conventional concrete than in the bottom ash concrete,
- The ductility factor of the bottom ash concrete beam is 1.06 times larger compared to the conventional beam.
- The energy absorption capacity of the bottom ash concrete beam is greater than that of the conventional beam.
- 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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