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Performance Evaluation of Concrete Containing Recycled Aggregates with Surface Modification

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ABSTRACT

The main aim of that research work is recycling of construction & demolition waste (C&DW), namely concrete. After crushing and sorting, such recycled concrete aggregate (RCA) will be used for production of new concrete. The use of RCA helps to save natural aggregate sources and thus contributes to environmental protection.

The most negative properties of recycled aggregate, comparing the natural one are roughness of its surface and high water absorptivity. Because of those properties it's create a complications during concrete production technology mainly they have negative impact on the amounts of cement and mixing water and also on the final properties of concrete. Using laboratory techniques, the 20 mm and 10 mm size of RCA was prepared for experiments aimed on the enhancement of surface quality and performance of such aggregate. To modify the surface properties of RCA, cementitious material was used in different ways. The first one is the coating of RCA by cementitious slurry, then drying under ambient conditions and finally application into concrete mixture. The second one is coating directly during mixing of concrete, using so called "triple stagemixing".

During study, properties of concretes will be compared and analyzed in terms of workability, compressive strength, flexural strength and tensile strength.

KEYWORDS

Recycle Aggregate, Surface modification, workability, strength

INTRODUCTION

Large quantities of construction and demolition wastes (C&DW) are produced during the construction and demolition of buildings and civil engineering works. Yet, despite the limited space available for disposal to landfill, the depletion of resources such as wood, metal and aggregates, and the embodied energy of construction materials, significant quantities of these materials are landfilled, without any previous treatment. This is despite widely available and environmentally effective alternative methods of waste management, such as reuse and recycling. Therefore it can be seen that there are considerable opportunities for improving current C&DW management practices from an environmental point of view.

In the European Union's 27 member countries, approximately 46% of the construction and demolition waste is recycled. It is estimated that the construction industry in India generates about 10-12 million tons of waste per year. Among them in India 25% of the construction and demolition west is recycled. They contain three types of recycled aggregates (RA) classifying them according to the compounds they are formed of: concrete (RCA), mixed (MRA) and ceramic (CRA).

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Fig 1: Recycle aggregate

Residual adhered mortar on aggregate is a main factor affecting the properties of density, porosity, and water absorption of RCA. The density of RCA is generally lower (approximately 7–9 %) than natural aggregate (NA) density, due to the adhered mortar that is less dense than the underlying rock. Porosity and water absorption are related aggregate characteristics, also attributed to residual mortar. NA generally has low water absorption (up to 2.5%) due to low porosity, but the adhered mortar on RCA has greater porosity (approximately 4 -6 %) which allows the aggregate to hold more water in its pores than NA.

Over last decade a significant volume of research in the area of recycled aggregate concrete (RAC) and its possible application in the construction industry was performed. Here, as recycled aggregate concrete is understood a concrete in which a part or a total amount of natural aggregate (NA) is replaced by recycled concrete aggregate. Published test results vary in relatively wide limits depending mostly on the quality of the RCA used. However, general conclusion is that RAC has lower properties than corresponding natural aggregate concrete (NAC) and that this decrease is proportional to the replacement level of NA with RCA.

It is important to improve the interface between cement matrix and coarse aggregate of low-quality recycled aggregates to promote their application in concrete mixes. Qualitative improvement will in turn enhance the mechanical performance such as the modulus of elasticity and strength, so surface modification was done for RCA.

In our study, recycled concrete aggregates, which surfaces had been modified, were used to produce the experimental concrete samples. On these samples workability, Compressive strength, Split tensile strength and Flexural strength were examined and then these properties of concrete made with RCA with others made with NA were compared.

Materials

As we all knows in production of concrete basically four martials were used cement, natural coarse aggregate, fine aggregate and water. We use PPC 53 grade jklakshmi brand cement, two different size ofCA 10mm and 20mm, then fine aggregate of Zone-II and at last a drinking water but without those basic thing we also use other material like recycled aggregate and modified recycled aggregate in place of natural CA.

When structures made of concrete are demolished or renovated, concrete recycling is an increasingly common method of utilizing the waste stones. Recycled aggregate is produced by crushing waste stones (concrete and sometimes asphalt) to reclaim the aggregate.

In modified recycle aggregate to modify the surface properties of RCA geopolymer material based on coal fly ash in different ways was used.The first one “Solo” modification was the coating of RCA by geopolymer slurry. Geopolymer slurryconsisted of coal fly ash, 10M NaOH solution, cement and water. After coating the aggregates at ambient conditions for 14 days were cured. Finally, modification RCA into concrete mixture, similar like natural aggregate or starting RCA were applied. The second one was coating directly during

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mixing of concrete, using so called “triple stage mixing”. First, RCA was coated by geopolymer slurry and it was curing. After 30 minutes the concrete mixing continued,gradually the other components were added. After a careful mixing of the all components concrete samples were prepared. Here the only solo modification method was applied.

Table 1. Components and composition of geopolymer slurry

Component	Composition (%)
Coal fly ash	55
Cement	15
10M NaOH solution	10
Water	20

Fig 2: Modified recycle aggregate

Mix Design

Concrete mix design may be defined as the art of selecting suitable ingredients of concrete and determine their relative proportion with the object of producing concrete of certain minimum strength and durability as economically as possible.

Objective of mix design

- To achieve the designed /desired workability in the plastic stage.
- To achieve desired minimum strength in the hardened stage.
- To achieve the desired durability in the given environmental condition.
- To produce the concrete as economically as possible.

Table 2 shows the design proportions of M25 grade of concrete for $1m^3$ concrete.

Table 2. Design proportions

Water	Cement	Coarse aggregate		Fine aggregate
		10mm size	20mm size	
206.488	516.22	554.51	369.67	710.07
Ratio				
0.4	1	1.07	0.7	1.38

Nine series of mixes in our study were considered. The first series was a control mix containing 100% NA, then after continuous 5%, 10%, 15% and 20% NA was replaced by recycled concrete aggregate. At last,

modified RCA was replaced in place of NA with 5%, 10%, 15% and 20%.Table 3 shows all detail of all replacement.

Table 3. Detail of replacement

Sample	Natural aggregate	Recycled aggregate	Modified recycled aggregate
V0	100%	0%	0%
V1	95%	5%	0%
V2	90%	10%	0%
V3	85%	15%	0%
V4	80%	20%	0%
V5	95%	0%	5%
V6	90%	0%	10%
V7	85%	0%	15%
V8	80%	0%	20%

RESULTS AND DISCUSSION

(A) Slump test

The concrete slump test measures the consistency of fresh concrete before it sets. It is performed to check the workability of freshly made concrete, and therefore the ease with which concrete flows. It can also be used as an indicator of an improperly mixed batch.The slump test is used to ensure uniformity for different loads of concrete under field conditions.

Fig 3: Slump test

Table 4. Results of slump test

Sr. No.	Sample	Slump Value (mm)
1	V0	82
2	V1	74
3	V2	76
4	V3	73
5	V4	74
6	V5	79
7	V6	80
8	V7	82
9	V8	80

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According to data we can easily see that the slump value of modified RCA concrete is quite similar than the normal concrete with NA. Slump value of recycled aggregate concrete is less because recycled aggregate have more water absorption than the natural aggregate and also than the modified recycled aggregate.

(B) Compressive strength test

The compressive strength of any material is defined as the resistance to failure under the action of compressive forces. Especially for concrete, compressive strength is an important parameter to determine the performance of the material during service conditions. For compressive strength cube size of 150mm x 150mm x 150mm is required.

Table 5. Compressive Strength of RCA concrete after 7 days

Sr. No.	Replacement of Natural aggregate by RCA	Compressive Strength (N/mm2)			
		7 Days			
		Spe. 1	Spe. 2	Spe. 3	Average
1	0%	22.65	21.98	22.34	22.32
2	5%	27.09	19.04	23.99	23.37
3	10%	31.54	26.01	28.15	28.57
4	15%	35.01	27.25	29.88	30.71
5	20%	30.14	27.62	29.58	29.11

Table 6. Compressive Strength of Modified RCA concrete after 7 days

Sr. No.	Replacement of Natural aggregate by Modified RCA	Compressive Strength (N/mm2)			
		7 Days			
		Spe. 1	Spe. 2	Spe. 3	Average
1	5%	19.41	22.16	18.78	20.12
2	10%	29.24	29.07	29.2	29.16
3	15%	30.06	30.12	29.98	30.04
4	20%	29.82	29.6	29.9	29.78

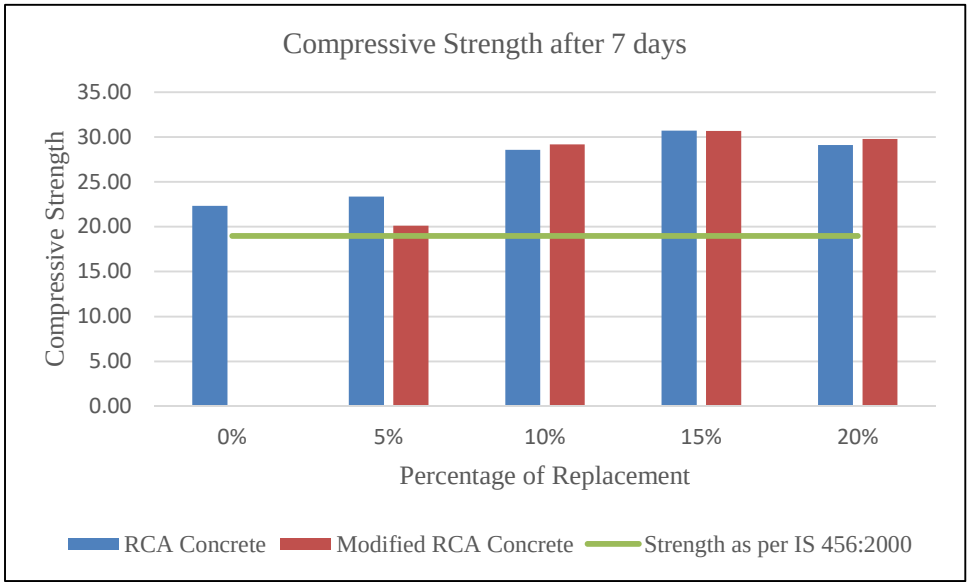

Fig 4: Compressive Strength after 7 Days

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From above graph we see that strength of concrete contain modified RCA have the higher strength then the recycled aggregate concrete. According to Is 456:2000 for M25 grade concrete after 7 daysrequired strength was about 18.96 N/mm^2.

Table 7. Compressive Strength of RCA concrete after 28 days

Sr. No.	Replacement of Natural aggregate by RCA	Compressive Strength (N/mm2)			
		28 Days			
		Spe. 1	Spe. 2	Spe. 3	Average
1	0%	36.52	34.21	35.02	35.25
2	5%	35.85	39.39	38.08	37.77
3	10%	35.19	44.57	41.14	40.30
4	15%	44.6	45.78	39.77	43.38
5	20%	32.77	35.35	38.08	35.40

Table 8. Compressive Strength of Modified RCA concrete after 28 days

Sr. No.	Replacement of Natural aggregate by Modified RCA	Compressive Strength (N/mm2)			
		28 Days			
		Spe. 1	Spe. 2	Spe. 3	Average
1	5%	35.72	35.84	36.02	35.86
2	10%	41.2	40.98	41.08	41.09
3	15%	44.25	43.98	44.12	44.12
4	20%	37.12	37.45	37.32	37.30

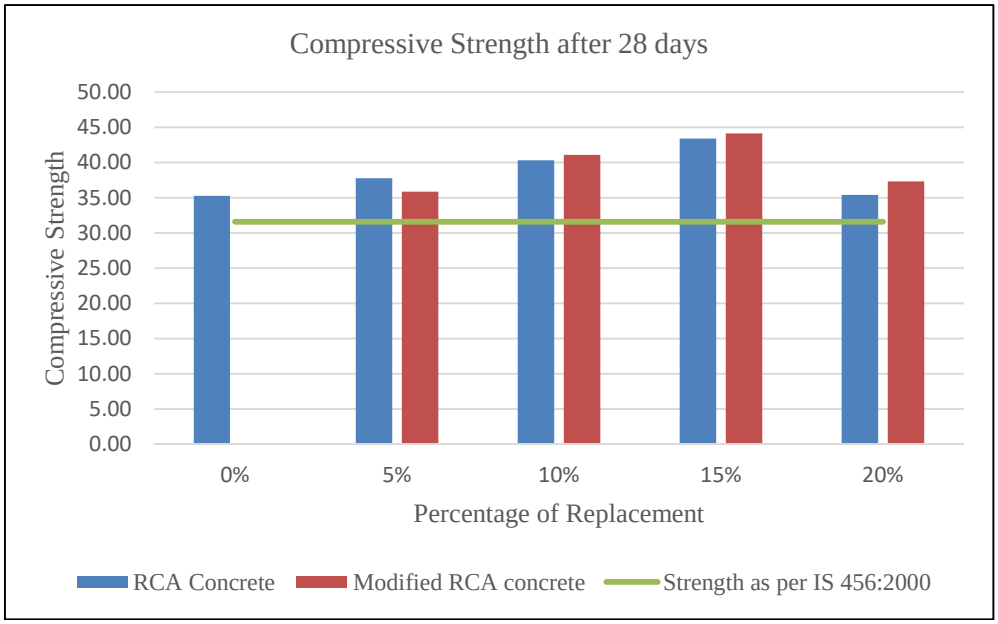

Fig 5: Compressive Strength after 28 Days

As per above data after 28 days strength of concrete is reduced after 15% replacement of RCA. In modified RCA concrete at 5% replacement we got less result than the RCA concrete but after that we got higher compressive strength as per 7days results.

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(C) Split tensile Strength Test

The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack. For tensile strength of concrete cylinder size 150mm diameter and 300mm height was casted.

Table 9. Split tensile Strength of RCA concrete after 7 days

Sr. No.	Replacement of Natural aggregate by RCA	Split tensile Strength (N/mm2)			
		7 Days			
		Spe. 1	Spe. 2	Spe. 3	Average
1	0%	4.32	4.35	4.74	4.47
2	5%	5.73	5.36	5.92	5.67
3	10%	6.02	6.34	6.5	6.29
4	15%	8.52	7.19	7.71	7.81
5	20%	6.87	7.79	7.45	7.37

Table 10. Split tensile Strength of Modified RCA concrete after 7 days

Sr. No.	Replacement of Natural aggregate by Modified RCA	Split tensile Strength (N/mm2)			
		7 Days			
		Spe. 1	Spe. 2	Spe. 3	Average
1	5%	6.17	5.29	6.11	5.86
2	10%	5.85	6.45	6.81	6.37
3	15%	7.81	8.02	7.71	7.85
4	20%	7.35	7.62	7.44	7.47

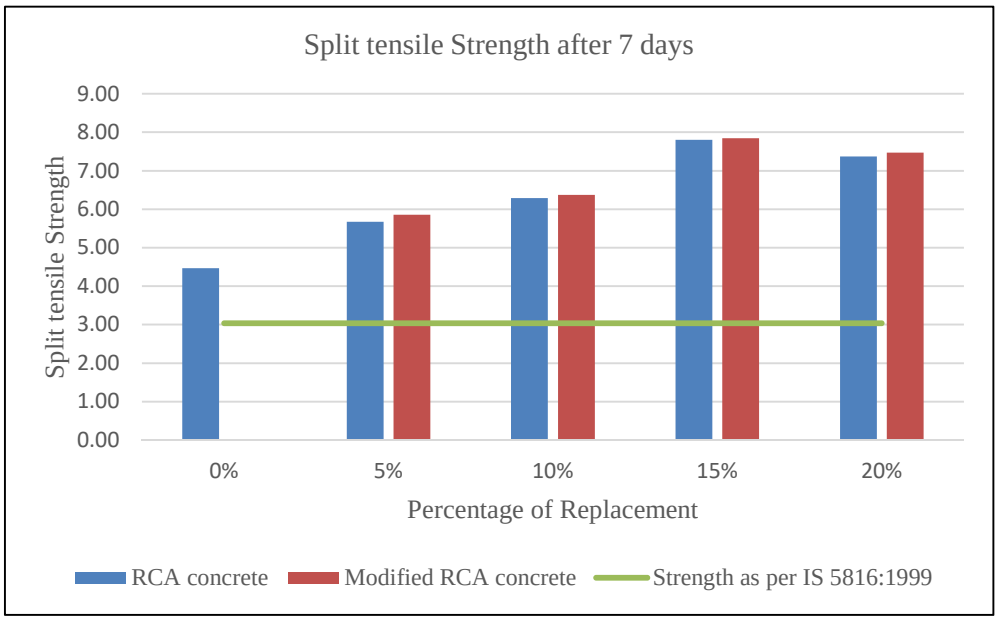

Fig 6: Split tensile Strength after 7 Days

From above graph tensile strength of concrete with modified RCA concrete have a better strength then the concrete contain RCA. We also got the strength more than IS required.

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Table 11. Split tensile Strength of RCA concrete after 28 days

Sr. No.	Replacement of Natural aggregate by RCA	Split tensile Strength (N/mm2)			
		28 Days			
		Spe. 1	Spe. 2	Spe. 3	Average
1	0%	7.46	7.24	7.02	7.24
2	5%	8.1	8.08	9.3	8.49
3	10%	9.58	11.33	10.07	10.33
4	15%	10.41	10.97	10.54	10.64
5	20%	10.14	10.05	10.25	10.15

Table 12. Split tensile Strength of Modified RCA concrete after 28 days

Sr. No.	Replacement of Natural aggregate by Modified RCA	Split tensile Strength (N/mm2)			
		28 Days			
		Spe. 1	Spe. 2	Spe. 3	Average
1	5%	8.78	8.45	9.3	8.84
2	10%	10.45	10.98	10.07	10.50
3	15%	10.84	10.97	10.59	10.80
4	20%	10.56	10.82	11.04	10.81

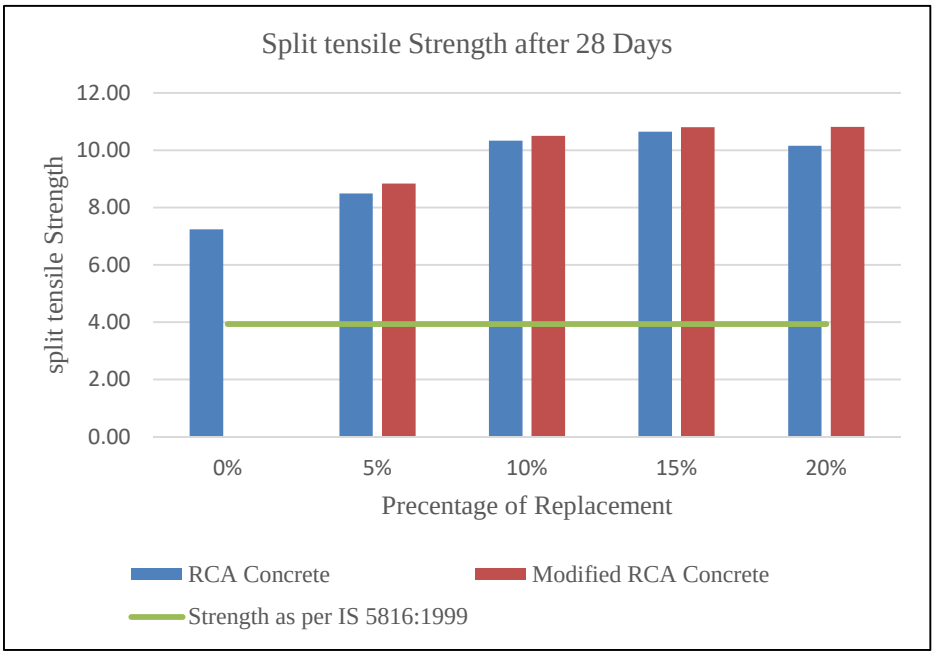

Fig 7: Split tensile Strength after 28 Days

Graph shows the tensile strength of M25 grade concrete after 28 days. As per graph the tensile strength of modified RCA was also increased in 20% replacement.

(D) Flexural Strength Test

Flexural strength is one measure of the tensile strength of concrete. It is a measure of an unreinforced concrete beam or slab to resist failure in bending. Flexural Strength of Concrete is about 10 to 20 percent of

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compressive strength depending on the type, size and volume of coarse aggregate used.Beam size 150mm X 150mm X 700mm was casted for flexural strength of concrete

Table 13. Flexural Strength of RCA Concrete after 7 Days

Sr. No.	Replacement of Natural aggregate by RCA	Flexural Strength (N/mm2)			
		7 Days			
		Spe. 1	Spe. 2	Spe. 3	Average
1	0%	3.8	4.42	3.74	3.99
2	5%	4.37	4.51	4.48	4.45
3	10%	4.48	5.14	5.24	4.95
4	15%	3.81	4.67	3.73	4.07
5	20%	3.85	3.66	3.88	3.80

Table 14. Flexural Strength of Modified RCA Concrete after 7 Days

Sr. No.	Replacement of Natural aggregate by Modified RCA	Flexural Strength (N/mm2)			
		7 Days			
		Spe. 1	Spe. 2	Spe. 3	Average
1	5%	3.02	3.82	3.32	3.39
2	10%	3.48	3.16	3.9	3.51
3	15%	3.62	3.52	3.59	3.58
4	20%	3.73	3.35	3.55	3.54

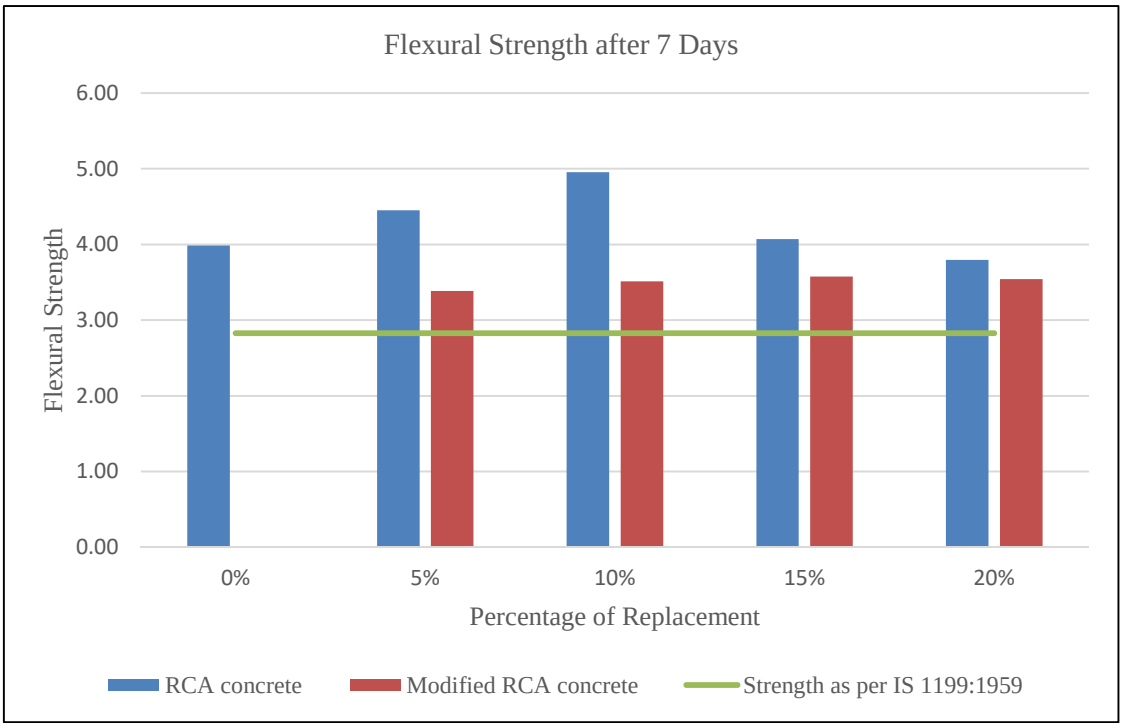

Fig 8: Flexural Strength after 7 Days

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Table 15. Flexural Strength of RCA Concrete after 28 Days

Sr. No.	Replacement of Natural aggregate by RCA	Flexural Strength (N/mm2)			
		28 Days			
		Spe. 1	Spe. 2	Spe. 3	Average
1	0%	5.24	4.46	5.86	5.19
2	5%	6.88	6.46	5.78	6.37
3	10%	5.96	6.63	6.66	6.42
4	15%	5.23	6.08	6.56	5.96
5	20%	5.36	5.55	5.48	5.46

Table 16. Flexural Strength of RCA Modified Concrete after 28 Days

Sr. No.	Replacement of Natural aggregate by Modified RCA	Flexural Strength (N/mm2)			
		28 Days			
		Spe. 1	Spe. 2	Spe. 3	Average
1	5%	5.36	5.76	5.49	5.54
2	10%	5.96	5.63	5.66	5.75
3	15%	5.47	5.08	5.22	5.26
4	20%	5.2	5.24	4.96	5.13

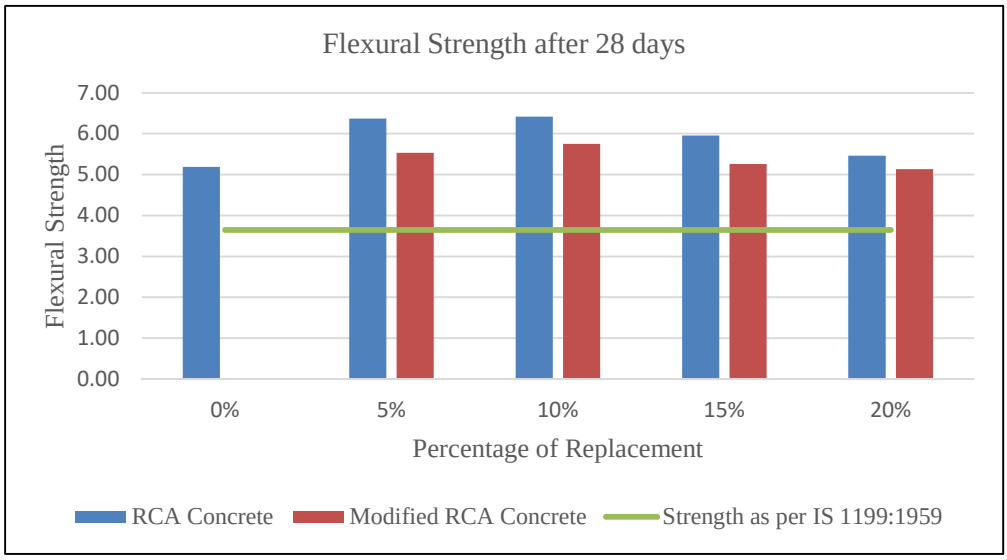

Fig 9: Flexural Strength after 28 Days

Conclusion

The main aim of my study was improved surface of recycled concrete aggregate by geopolymerslurry and then prepared experimental concrete samples with using these activated RCA. There was two methods available for surface modification of RCA. First was “solo modification” and other one “triple stage mixing” among these we adopt only solo modification method.

The most important property of fresh concrete is workability. To find workability, slump test was performed. We got true slump by performing slump test on fresh concrete.

Concrete is strong in compression and weak in tension, so compressive strength has more importance in concrete. Fro compressive strength test the testing intervals were 7 and 28 days. Based on the results we can conclude that the compressive strength of both concrete RCA concrete and Modified RCA concrete are more than IS Values. Compressive strength of Modified RCA concrete was higher than RCA concrete. The value of compressive strength was increased till the 15% replacement of natural aggregate by both RCA and Modified RCA.

Tensile strength also played an important role in design of a concrete structure. According to results of Split Tensile Strength same as compressive strength modified RCA concrete have greater strength than the RCA concrete. Here, tensile strength was reduced at 20% replacement of RCA but on other side Tensile Strength Remain almost equal for Modified RCA.

Flexural strength opposed cracks in to the concrete. According to test results Flexural Strength of RCA was higher than Modified RCA.

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