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COMPARISON OF PROPERTIES OF FINE AGGREGATE OBTAINED FROM RECYCLED CONCRETE WITH THAT OF CONVENTIONAL FINE AGGREGATES

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ABSTRACT

Urbanization growth rate in India is very high due to industrialization. Rapid infrastructure development requires a large quantity of construction materials, land requirements & site. Therefore, it needs to be taken into consideration given the view that demolished materials are dumped on land & not used for any purpose. Such situations affect the fertility of land. As per report of Central Pollution Control Board (CPCB) Delhi, India, 48 million tons solid waste is produced out of which 14.5 million ton waste is produced from the construction waste sector alone. Out of the total construction demolition waste, 40% is of concrete, 30% ceramics, 5% plastics, 10% wood, 5% metal, & 10% other mixtures. For production of concrete, 70-75% aggregates are required. Out of this 60-67% is of coarse aggregate & 33-40% is of fine aggregate. This paper results of an experimental study on some of the physical and mechanical properties of Recycled Fine Aggregate (RFA) as compared to those of the Conventional Fine Aggregate (CFA). Further, concrete was prepared with CFA and RFA and tests on workability were performed. The comparative results show that the physical and mechanical properties RFA and CFA were quite comparable. Further, it shows that concrete made with RFA is less workable and maximum strength achieved was at w/c ratio 0.50.

Keywords: Recycle, construction material, fine aggregate, compressive strength, workability

I. INTRODUCTION

Any construction activity requires several materials such as concrete, steel, brick, stone, glass, clay, mud, wood, and so on. However, the cement concrete remains the main construction material used in construction industries. For its suitability and adaptability with respect to the changing environment, the concrete must be such that it can conserve resources, protect the environment, economize and lead to proper utilization of energy. To achieve this, major emphasis must be laid on the use of wastes and by-products in cement and concrete used for new constructions. The utilization of recycled aggregates is particularly very promising as 75 % of concrete is made

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of aggregates. The enormous quantities of demolished concrete are available at various construction sites, which are now posing a serious problem of disposal in urban areas. This can easily be recycled as aggregate and used in concrete. Research & Development activities have been taken up all over the world for proving its feasibility, economic viability and cost effectiveness.

II. LITERATURE REVIEW

Marios N. Soutsos had undertaken a study at the University of Liverpool to determine the potential use of recycled fine aggregates for the purpose of future construction practices and has has investigated the potential for using construction and demolition waste (C&DW) as fine aggregate in the manufacture of a range of precast concrete products, i.e. building and paving blocks and pavement flags.[1]

Topcu et al. concluded in his research work that the specific gravity of Waste Concrete Aggregates (WCA) was lower than normal crushed aggregates. The reason for this was thought to be the fact that there was a certain proportion of mortar over these aggregates.[2]

Hansen et al. found that the water absorption is 8.7% for the material that is 4–8mm in size, 3.7% for the material that is 16-32mm in size and the absorption capacity of recycled aggregate increased with a higher amount of adhered mortar.[3]

Bairagi et al. concluded in his project regarding the use of recycled aggregates for construction in future that very rapid rates of absorption are observed for recycle aggregates. Nearly 75% of the 24hour absorption capacity was attained in the first 30 minutes of the soaking period. Ravindraraja further demonstrated that the average value of water absorption in recycled aggregate was 6.35%, where as in natural aggregate it was 0.9%.[4]

Nelson in his research work said It has been found that workability of concrete with natural and recycled aggregate is almost the same if water saturated surface dry recycled aggregate is used. Also, if dried recycled aggregate is used and additional water quantity is added during mixing, the same workability can be achieved after a prescribed time.[5]

III. METHODOLOGY

The research was conducted in the laboratory of Sharda University, Greater Noida.

The Research Paper deals with evaluation of the aggregate properties and focuses on evaluation of concrete mixture utilizing 100% recycled fine aggregate.

The waste concrete for the purpose of research work was collected from the sites of demolished structures near Kalindi Kunj Park and Mayur Vihar-1, New Delhi. Collected material was then made to be crushed by the means of mechanical jaw crusher to reduce their sizes into smaller fraction. The aggregate passing through 4.75 mm IS sieves were used for the research work.

On these separated fine aggregates various tests were conducted in laboratory as per Indian Standard codes to determine the physical and mechanical properties and their results were compared with natural fine aggregates.

The nominal mix of M20 grade of concrete was produced with 100% replacement of recycled fine aggregate with varying water-cement ratio of 45%, 50% and 55% and tests were conducted on these concretes including

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slump, vee-bee, compaction factor and compressive strength are also determined. The compressive strength of recycled concrete was found out at 7 and 28 days and results were compared with natural aggregate concrete.

IV. RESULTS AND ANALYSIS

4.1 Physical and Mechanical Properties of Fine Aggregates.

In this study, the recycled aggregate obtained from crushed concrete were tested for various physical and mechanical properties. The results from the experiments are tabulated as follows.

Table 1: Comparison of Properties of RFA and Natural Fine Aggregates

S. NO.	Properties	Recycled Fine Aggregate	Natural Fine Aggregate
1	Particle Size Distribution	Well Graded	Gap Graded
2	Specific Gravity	2.37	2.92
3	Water Absorption	4.09	3.95
4	Fineness Modulus	2.058	2.89
5	Bulking% of aggregate	14.15	18.13
6	Silt Content	8.072	7.5988
7	Zone	III	III

From Table-1, it is implied that the recycled fine aggregates are reduced to various sizes during the process of crushing, which gives the better particle size distribution as compared to natural fine aggregates. The Recycled fine aggregate showed a well graded graph as opposed to Natural Aggregate which showed a gap graded graph. Specific Gravity test on aggregates is carried as per IS 2386(Part IV). It is found that the average specific gravity of Recycled Fine Aggregate was found to be 2.37 which is lower as compared to natural aggregates with a value of 2.62.This is because of mortar adhered to the surface of crushed concrete which is light in weight. The specific gravity of an aggregate is considered to be a measure of strength or quality of the material. Stones having low specific gravity are generally weaker than those with higher specific gravity values. Hence, the density of concrete will be higher for natural aggregates as compared to recycled fine aggregate. Conversely a lower specific gravity of fine recycled Aggregate will result in lower density of concretes. Moreover, the specific gravity of aggregates normally used in road construction ranges from about 2.5 to 3.0 with an average of about 2.68. Therefore, conventional sample can be used in road construction whereas recycled fine aggregate can be used in road construction but quality will not be good as compared to conventional sample.

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Water absorption test was carried out as per IS 2386(Part IV). The water absorption for recycled fine aggregate comes out to be 4.09%, which is much higher than that of the natural aggregates with a value of 3.95%.This is due to mortar adhered to the surface of concrete that results in more absorption of water to obtain saturated surface dry condition.

Bulking test was conducted as per IS 2386(Part IV). The bulking percentage of Natural Fine Aggregates (NFA) is 18.13, which is much higher as compared to those of Recycled Fine Aggregates (RFA). This may be due to the fact that RFA possess much higher moisture content which forms a film around each particle. These films of moisture exert a force, known as Surface Tension, on each particle. Due to this Surface Tension, each particle will move away from each other. Because of this, no direct contact is possible among individual particles and this causes Bulking of the Concrete. Due to the effect of Bulking, Recycled Fine Aggregates will not be able to produce durable concrete; the strength of the concrete made up of Conventional Aggregate is much higher as compared to those of the Recycled Fine Aggregate. Hence, it is advisable to explore various techniques to reduce the moisture content of Recycled Aggregates as higher moisture content is one of the factors responsible for the Bulking of aggregate.

Silt content test was carried out as per IS 2386. It is found out that Average silt content in Recycled Fine Aggregate is 8.07 which is much higher as compared to those of conventional aggregates of 7.5. Compressive strength also decreases with increase in the content of silt. Furthermore, chloride content penetrability will be much higher in Recycled Fine Aggregates as compared to that of Conventional Fine Aggregate.

Average fineness modulus for Recycled Fine Aggregates is 2.058 as compared to the value of 2.89 of Conventional Aggregate which implies both the values are in the recommended range prescribed for Fineness Modulus which is 2.0 to 3.0. Furthermore, both Recycled Fine Aggregates and Conventional Recycled Aggregates lies in Zone 3 of Gradation.

It was further noted that recycled fine aggregates was a little weaker in comparison to the natural fine aggregates, however, properties of both the aggregates were more or less comparable. Hence, Recycled fine aggregates can be used for the production of concrete.

4.2 **Properties of Concrete.**

The workability of Recycle aggregate concrete and Natural aggregate concrete was determined in accordance with Indian Standards. Tests conducted for determining the workability were Slump test, Compaction Factor test and Vee-bee Consistometer test. The experiments were conducted at water-cement ratio of 0.45, 0.50 and 0.55. The results for the experiments conducted are tabulated as follows:

Table 2: Comparison of slump of Recycle aggregate concrete (RAC) and Natural Aggregate concrete (NAC)

Water-cement ratio	Slump (mm)	
	CFA	**RFA**
0.45	74.33	56
0.50	83	76
0.55	112.33	96.6

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The slump is taken for each mixing of concrete at water-cement ratio of 0.45, 0.50 and 0.55. It may be due to the fact during the mixing process of cement and paste, high amount of water was absorbed which then resulted in the low slump for Recycled fine aggregates. On the other hand, less amount of water was absorbed during the formation of cement and paste as a result the slump of concrete made with natural aggregates at different water-cement ratio was higher as compared to concrete made with recycled fine aggregates.

Table 3: Comparison of Compaction Factor of Recycle Aggregate Concrete (RAC) and Natural Aggregate Concrete (NAC)

Water-cement ratio	Compaction Factor	
	CFA	**RFA**
0.45	0.843	0.798
0.50	0.932	0.885
0.55	0.942	0.915

The compaction factor test for both Recycled aggregate concrete and Natural aggregate concrete shows an increasing trend with corresponding increase in water-cement ratio. However the values of compaction factor for concrete made with natural fine aggregate is found to be higher than concrete made with Recycled Fine aggregate. This indicates high workability and self-compaction property of natural aggregate concrete over Recycled aggregate concrete, making it suitable for piling operations etc.

Table 4: Comparison of Compaction Factor of Recycle aggregate concrete (RAC) and Natural Aggregate concrete (NAC)

Water-cement ratio	Vee-Bee time (seconds)	
	CFA	**RFA**
0.45	17	17.7
0.50	12.7	11.3
0.55	6.7	7

This test measures the relative effort required to change mass of concrete from one definite shape to another. While comparing the Vee-Bee time of concrete made recycled fine aggregate and concrete made with natural aggregate, it is found that due to high absorption of water by Recycle fine aggregate, it has low workability and with increase in water –cement ratio it can be overcome but it will also affect the strength of concrete.

4.3 Compressive strength of Concrete

Compressive strength is defined as the maximum resistance of a concrete cube to axial loading. Testing of specimens was carried out after curing. Specimen dimensions were measured before testing. Clean and surface dried specimens were placed in the testing machine. The platen was lowered and touched the top surface of the specimen. The load was applied gradually and maximum load was recorded.

The Compression strength Tests were conducted for nominal M20 grade of concrete made with 43 grade of OPC cement.

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On the basis of test results it can be inferred that the strength of concrete depends upon the water-cement ratio taken. The maximum strength that could be achieved on 7 days curing was for water-cement ratio 0.50. The graph for 7 days curing is showing an upward trend as we increase water-cement ratio. However, if the water cement ratio is increased further from 0.50, it shows a downward trend. Initially the strength of concrete increases with increase in water-cement ratio but eventually it subsides if we continue to increase the water-cement ratio.

Furthermore it can also be implied that the strengths of both recycled aggregate fine concrete and natural aggregate concrete are comparable at varying water-cement ratios implying that various properties of concrete such as workability, durability etc will be more or less the same. Both the aggregates lie in the permissible range of IS specifications. Hence, recycled fine aggregates can be used as an alternative for conventional fine aggregates.

Table 5: Table 5 [I] Comparison of Compressive Strength of Recycle Aggregate Concrete (RAC) and Natural Aggregate Concrete (NAC).

Water Cement Ratio W/C%	Average 7days Strength (N/mm^2)		Average 28 days Strength (N/mm^2)	
	NAC	**RAC**	**NAC**	**RAC**
45	12.64	11.83	17.9	16.4
50	16.02	15.38	18.3	17.82
55	13.77	15.4	19.66	21.205

Table 5: Table 5 [II] Comparison of Average Weight of Recycled Aggregate Concrete (RAC) and Natural Aggregate Concrete (NAC)

Water Cement Ratio W/C%	Average 7days Weight(kg)		Average 28 days Weight (kg)	
	NAC	**RAC**	**NAC**	**RAC**
45	7.22	7.85	7.85	7.83
50	7.57	7.58	8.02	7.5
55	7.35	7.5	8.37	8.06

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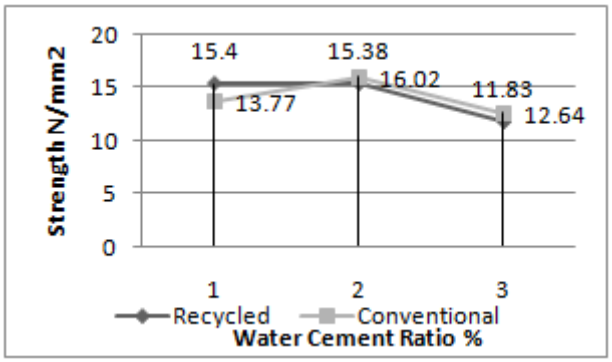

Figure 3:Characteristic strength (MPa) at 7 days

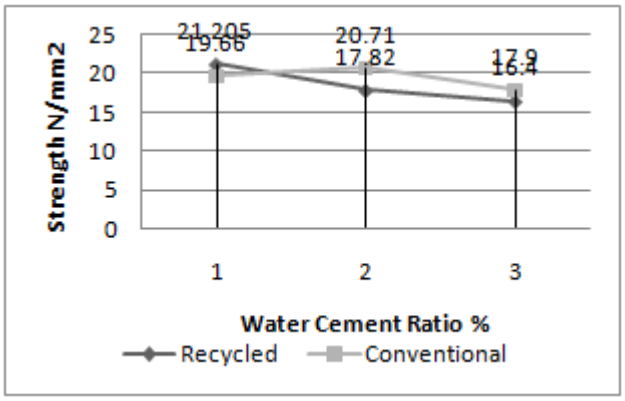

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Figure 4:Characteristic strength (MPa) at 28 days

V. SUMMARY OF RESULTS

1. The recycled aggregate showed a well graded graph as opposed to natural aggregate which showed a gap graded graph.
2. It is found that the Average specific gravity of Recycled Fine Aggregate was found to be 2.37, which is much lower as compared to natural aggregates with a value of 2.62. The specific Stones having low specific gravity are generally weaker than those with higher specific gravity values. Hence, the density of concrete will be higher for natural aggregates as compared to recycled fine aggregate. Conversely a lower specific gravity of fine recycled Aggregate will result in lower density of concretes.
3. The specific gravity of aggregates used in road construction ranges from about 2.5 to 3.0 with an average of about 2.68. Therefore, conventional sample can be used in road construction whereas recycled fine aggregate can also be used in road construction but quality will not be good as compared to conventional sample.
4. The water absorption for recycled fine aggregates is 4.09, which is much higher than that of the natural aggregates with a value of 3.95. As the water absorption characteristics of recycled aggregates are higher, it is advisable to maintain saturated surface dry (SSD) conditions of aggregate before start of the mixing operations.
5. The bulking percentage of Recycled Fine Aggregates is 18.13, which is much higher as compared to those of Conventional Recycled aggregates of 15.45, implying that RFA possesses much higher moisture content which forms a film around each particle. The lower value of bulking percentage of RFA may be attributed to

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it's his higher porosity. These films of moisture exert a force, known as Surface Tension, on each particle. Due to this Surface Tension, each particle will move away from each other. Because of this, no direct contact is possible among individual particles and this causes Bulking of the Concrete.

6. Average fineness modulus for Recycled Fine Aggregates is 2.058 as compared to the value of 2.89 of Conventional Aggregate which implies prescribed for Fineness Modulus which is 2.0 to 3.0.
7. On comparing the compressive strengths between aggregates, it is found out that compressive strengths of both aggregates show a similar trend at varying water-cement ratio. However, the strengths of both the concretes show a downward spiral as the water-cement ratio is increased further from 0.50.
8. On comparing some of the mechanical properties of recycled fine aggregate with that of natural fine aggregate, it is found that Recycled fine Aggregate is aggregate is relatively weaker than the natural aggregate but still it is satisfactory for Concrete Production as the values are in the permissible range as per Indian Standard Code.

VI. CONCLUSION

On the basis of our comparative analysis of test results of physical and mechanical properties of RCA and basic properties of concrete made with RCA at three different percentages of water-cement ratio (0.45, 0.50 and 0.55) the following conclusion are made.

Test results of RFA and CFA show that both the aggregates comply with Indian Standard Specifications while some properties of RFA do not.

Furthermore, test results for compressive force for both the aggregates also are comparable at varying water-cement ratio with the value of compressive force being the highest at water-cement ratio of 0.50.

VII. FUTURE SCOPE

Recycling and reuse of building wastes may well prove to be an appropriate solution to the problems of dumping hundreds of thousands tons of debris accompanied with shortage of natural aggregates. The usage of Recycled Fine Aggregates in concrete proved to be a valuable building material in technical, environment and economical respect. However, more research and initiation of pilot project for application of RFA is needed for modifying our design codes, specifications and procedure for use of recycled aggregate concrete. The subject of use of RFA in construction works in India should be given impetus, because of big infrastructural projects are being commissioned including the construction and planning of 100 smart cities in the country and because Recycled Fine Aggregates are in compliance with Indian codal provisions.

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