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Performance of Recycled Aggregate Concrete for M25 Grade

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ABSTRACT:

Recycled aggregate are comprised of crushed, graded inorganic particles processed from the materials that have been used in the construction and demolition debris. One of the major challenges of our present society is the protection of environment. The use of aggregates from construction and demolition debris (wastes) is showing prospective application in construction as alternative to primary (natural) aggregates. Although there is a critical shortage of natural aggregate, the availability of demolished concrete for use as RECYCLED CONCRETE AGGREGATE (RCA) is increasing. Using the waste concrete as RCA can provide cost savings. The aim of this project is to determine the strength characteristics of recycledaggregates for application in high strength structural concrete, which will give a better understanding on the properties of concrete with recycled aggregates, as an alternative material to coarse aggregate in structural concrete. Further, this work is to determine and compare the workability, compression strength, indirect tensile strength, flexural strength and modulus of elasticityof recycled aggregate concrete with that of natural aggregate concrete.Toattain the planned objectives of the

Present investigation, M25 grade concrete is taken and the replacement values via, 0%, 25%, 50%, 75%, 100% were considered. These five replacement ratios mix design are done by using IS 10262-2009 method. A total of 60 cubes, 40 cylinders, 10 beams were casted to determine the properties mentioned as above.The development of compressive and tensile strengths of recycled aggregate concrete at the age of 7and 28 days; the development of flexural strength and static modulus of elasticity at the age of 28 days are investigated. The parameters which were investigated for recycled aggregate concrete and compared with natural aggregate concrete as per BIS specifications found to be decreasing gradually as the percentage of recycled aggregate are increased

Keywords: Recycled aggregates, M25 garde, flexural strength, static modulus of elasticity.

1. INTRODUCTION

Concrete is a composite construction material composed primarily of aggregate, cement and water. It has been proved to be a leading construction material for more than a century. It is estimated that the global production of concrete is at an annual rate of 1m^3 (approximately 2.5 tones) per capita (Neville 2003). The global consumption of natural aggregate (NA) will be in the range of 8-12 billion tones after 2020. Over 1 billion tones of construction and demolition wastes(C&DW) is generated every year worldwide (Anon 2004). The large scale depletion of NA and the increased amounts of C&DW going to landfill sites are causing significant damage to the environment and developing serious problems denting the public and the environmentalist's aspirations for a waste-free society.

Fig 1:Recycled Aggregates

In the past, almost all materials which are used in the construction industry were entirely natural and all waste from demolished buildings was disposed of in landfills and partially in unauthorized places. The utilization of the recycled aggregates created from processing C&DW in new construction has become more important over the last two decades. There are many factors contributing to this, from the availability of new material and the damage caused by the quarrying of NA and the increased disposal of costs of waste materials. C&DW are generated mainly from demolished concrete and masonry structures. Due to advances in manufacturing of crushing industry, machinery and recycling process, it became possible to scale or crush down large masses of C&DW into smaller particles to produce recycled aggregate (RA) at acceptable cost.

The quality of the recycled aggregates has been improved significantly during the last decade as a result of good deconstruction practice and advances in stationary or transportable crushing machinery, as well as the recycling process itself*i.e* .screening and separation. As a result, improved quality aggregates are available now-a-days, at prices competitive to NA. However, despite the enhanced quality of the recycled aggregates, the uptake of this alternative is still in fact too low(Dhir 2001; Wrap 2007).this limited use is largely due to the past experience formed when low strength cements and low quality recycled aggregates were used as well as the restrictions imposed by standards. Therefore, in view of current concreting technologies and advances in materials production, there is a need to reform the negative impression, prevalent for a relatively longtime, to increase the use of recycled aggregates in construction.

a. Need for the Present Work:

Concrete is the most favorite choice used in construction industry. This is due to its basic ingredients (cement, coarse aggregate, fine aggregate, water) are easily to find, little maintenance service, easily to handle, most economical material, good in compression, durable and good fire resistance etc. Because of these factors, there is scarcity that natural sources like coarse aggregate will diminish. Thus, to preserve this source, the application of Recycled Aggregate (RA) for producing concrete is taken into consideration.

On the other hand, construction and demolition waste is being increased day by day. To make use of this demolition waste, the strength properties are to be known particularly for higher-grade applications. The successful production of RAC, with the help of these materials, could lead to large scale use of recycled aggregates for various structural applications, rather than prevailing low value uses. This is deemed possible when the strength and performance of RAC is improved to compete with NAC.

Fig 1: jaw crusher

b. Applications of Recycled Aggregate:

(a) Concrete production - The Standing Committee of Concrete Technology (SCCT) recommends that recycled aggregates can be used for concrete production up to Grade 35 until further tests have demonstrated that concrete with higher strength can be consistently produced with satisfactory performance in long-term durability.

(b) Granular materials for fill, filters, drainage layer, etc.;

(c) Road sub-base materials;

(d) Concrete paving blocks or similar block works

(e) Rock fills replacement for sea wall, infill to gabion walls, etc.

Most probably recycled aggregate is used as landfill. Depending upon the needs and priorities of a country usage of recycled aggregate changes.

2. LITERATURE REVIEW

Tavakoli (1996), the strength characteristics of recycled aggregate concrete were influenced by the strength of the original concrete, the ratio of coarse aggregate to fine aggregate in the original concrete, and the ratio of top size of the aggregate in the original concrete in the recycled aggregate. He also mentioned that water absorption and Los Angeles abrasion loss will influence the water cement ratio and top size ratio for the strength characteristic of recycled aggregate.

Ramamurthy and Gumaster (1998), the compressive strength of recycled aggregate concrete was relatively lower and variation was depended on the strength of parent concrete from the obtained aggregate.

Limbachiya and Leelawat (2000) found that recycled concrete aggregate had 7 to 9% lower relative density and 2 times higher water absorption than natural aggregate. According to their test results, it shown that there was no effect with the replacement of 30% coarse recycled concrete aggregate used on the ceiling strength of concrete. It also mentioned that recycled concrete aggregate could be used in high strength concrete mixes with the recycled concrete aggregate content in the concrete.

Mandal (2002) stated that adjusted the water/cement ratio when using recycled concrete aggregate during the concrete mixing can improved the strength of the recycled aggregate concrete specimens. From the obtained result, recycled aggregate concrete specimens had the same engineering and durability performance when compared to the concrete specimens made by natural aggregate within 28days design strength.

Sagoe, Brown and Taylor (2002) stated that the difference between the characteristic of fresh and hardened recycled aggregate concrete and natural aggregate concrete is relatively narrower than reported for laboratory crush recycled aggregate concrete mixes. There was no difference at the 5% significance level in concrete

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compressive and tensile strength of recycled concrete and control normal concrete made from natural aggregate.

4. METHODOLOGY

COMPARSION OF NATURAL AGGREGATE AND RECYLED AGGREGATE

Property	Natural aggregate	Recycled aggregate
Texture	Natural aggregate is smooth and rounded compact aggregate.	Recycled aggregate has the rough – textured, angular and elongated particles. The rough – texture, angular and elongated particles require much water
Quality	The quality of natural aggregate is based on the physical and chemical properties of sources sites.	The quality of recycled aggregate is depended on contamination of debris sources.
Density	Natural aggregate has higher density compared to recycled aggregate.[11]	Recycled concrete aggregate have lower density because of the porous and less dense residual mortar lumps that is adhering to the surfaces.
Strength	Strength of natural aggregate is higher than recycled aggregate.	The strength of recycled aggregate is lower than natural aggregate. This is due to the weight of recycled aggregate is lighter than natural aggregate. This is the general effect that will reduce the strength of reinforcement concrete.
Location	Natural aggregate are derived from a variety of rock sources. The processing plant for natural aggregate depends on the resource. It usually occurs at the mining site and outside the city.	Recycled aggregate are derived from debris of building constructions and roads. The locations of recycling plants are depended on where the structures are demolished. The recycling process is often located in the urban area.

➢ Materials

Cement: cement is a binding material invented by Joseph Aspdin in 1824. It is manufactured from calcareous materials, such as limestone or chalk, and argillaceous material such as shale and clay.

Coarse Aggregate: If the size of aggregate is bigger than 4.75 mm, then the aggregate is considered as coarse aggregative: Stone, ballast, gravel, brick ballast.

Fine Aggregate: According to IS 383, most of the aggregate which will pass through 4.75 mm IS sieve and entirely retained on 75 µ sieve is considered as fine aggregate. Eg: Sand crushed stone, ash or cinder and surkhi.

Water:

Mix Design is carried out in B.I.S Method (Bureau of Indian Standards) As per IS 10262:2009

Stipulation of proportioning

1. grade designation= M-25
2. type of cement = OPC 53 grade
3. maximum nominal size of aggregates = 20mm
4. water/cement ratio = 0.47 (mild-M25)

Target mean strength for mix proportioning

[f' ck = f ck + 1.65s]

1. target mean strength = 25+1.65 x4=31.6N/mm^2
2. characteristics strength at 28 days = 25Mpa

Selection of water content

1. Max. water content = 186lts(at 50mm slump)
2. corrected water content = 186+(186 x 6/100)

W=197lts.

Calculation of cement content

1. water/cement ratio = 0.47
2. cement content = 197lts/0.47

C=419kg/m^3

- **calculation of coarse and fine aggregate**

From (table 3 IS 10262:2009) zone I and coarse (20mm) at w/c ratio 0.5

Volume of coarse aggregate = 0.6

- **corrected volume** = 0.01/0.05 x 0.03=0.006

= 0.6+0.006

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Coarse aggregate = $0.606m^3$
Fine aggregate = $1-0.606=0.394m^3$

Calculations
Volume of concrete = $1m^3$

- absolute vol.0f cement = 19/3.13 x 1/1000
  = $0.133m^3$
- volume of water = 197 /1000
  = $0.197\ m^3$
- volume of materials (except aggregates) = 0.113+0.197 = $0.33\ m^3$
- absolute total aggregates = 1-0.33 = $0.67\ m^3$
- ➢ weight of coarse aggregate = 0.67 x 0.606 x 2.77 x 1000
  = $1125kg/\ m^3$
- ➢ weight of fine aggregate =0.67 x 0.394 x 2.6 x 1000
  = $686.3kg/\ m^3$
- ➢ Total density = cement + coarse aggregate + fine aggregate + water
  = $2427kg/\ m^3$

	% of Replacement				
	0	**25**	**50**	**75**	**100**
Cement	419	419	419	419	419
Fine Aggregate	686	686	686	686	686
Coarse Aggregate	1125	844	562.3	281	0
Recycled aggregate	0	49	497	746	944.75
water	197	197+9	197+18	197+26	197+35

Quantity Of Material in Different Proportions per m^3

MIX RATIO:- Cement: fine aggregate: coarse aggregate = 1:1.63:2.68

5. RESULTS AND ANALYSIS

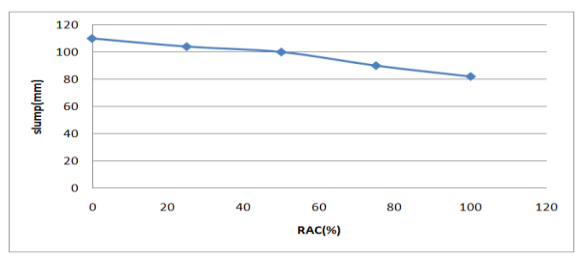
Tests on Fresh Concrete

1. SLUMP TEST:

Slump test is the most commonly used method of measuring workability of concrete which can be employed either

in laboratory or at site of work. It is not a suitable method for very wet or very dry concrete.

	RAC 0%	RAC 25%	RAC 50%	RAC 75%	RAC 100%
Slump @ 0Min	110mm	104mm	100mm	90mm	82mm
Slump @ 30Min	98mm	98mm	94mm	88mm	75mm



2 .COMPACTING FACTOR TEST:

The compaction factor test is designed primarilyfor use in the laboratory. It is more precise and sensitive than theslump test and is mostly useful for very low workability concrete mixes.

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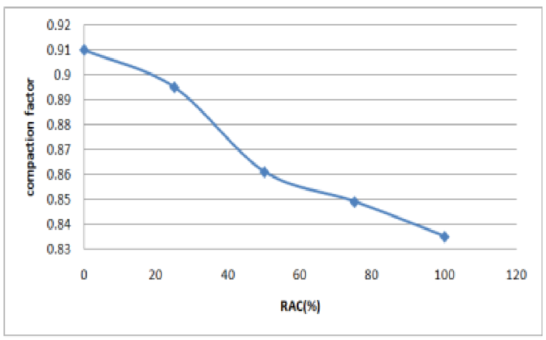
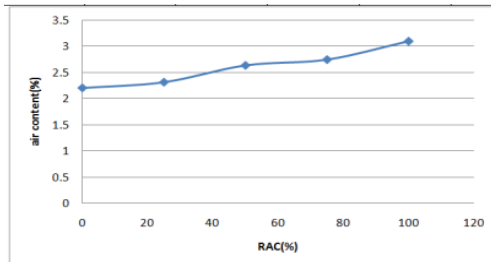
RAC	0%	25%	50%	75%	100%
Compaction factor	0.91	0.895	0.861	0.849	0.835



3 .AIR CONTENT

RAC	0%	25%	50%	75%	100%
Air Content (%)	2.2	2.31	2.63	2.74	3.09



4 .COMPRESSION TEST:

Compression test is the most common test conducted on hardened concrete because most of the desirablecharacteristic properties are qualitatively related to its compressive strength.

RAC	Density(kN/m3)	Compressive strength(N/mm2)	
		7 Days	28 Days
0%	2374	22.6	31.46
25%	2352	21.7	29.2
50%	2345	20.2	27.98
75%	2338	19.09	25.15
100%	2315	17.34	23.9

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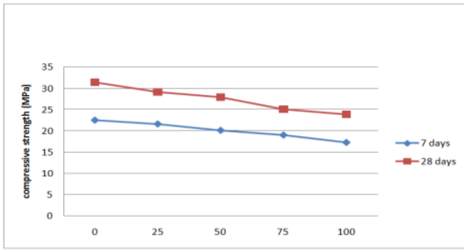
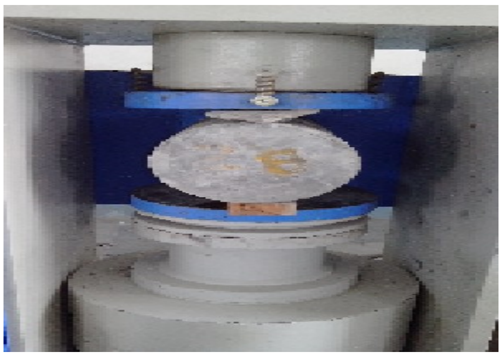
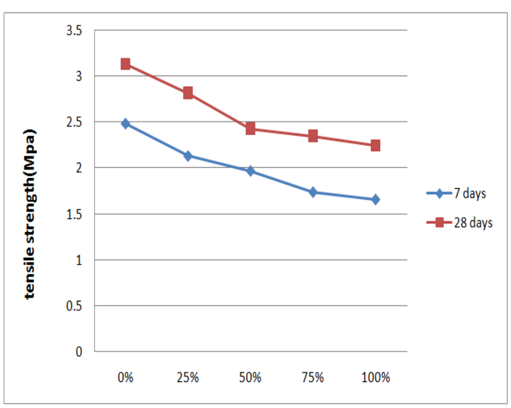


5 .SPLIT TENSILE TEST :

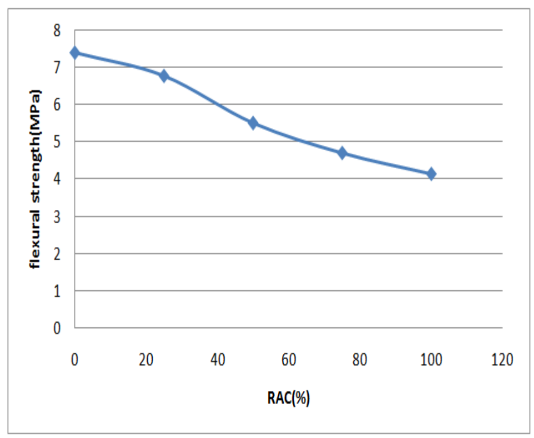


RAC	Density (28days)KN/ m^3	Tensile strength (2P/πDL) (MPa)	
		7 Days	28Days
0%	22.54	2.48	3.13
25%	22.40	2.13	2.815
50%	22.23	1.969	2.425
75%	22.10	1.74	2.345
100%	22.00	1.66	2.24



6 .FLEXURAL STRENGTH:

RAC	Density (KN/ m^3)	Flexural strength (Mpa)
0%	23.74	7.38
25%	23.52	6.76
50%	23.45	5.5
75%	23.38	4.7
100%	23.15	4.14



7 .RUPTURE MODULUS:

RAC	Density (KN/ m^3)	Compressive Strength (Mpa)	Rupture modulus (Mpa)
0%	22.54	30.5	3.864
25%	22.40	29	3.765
50%	22.23	28.3	3.72
75%	22.10	25.3	3.515
100%	22.00	24.2	3.44

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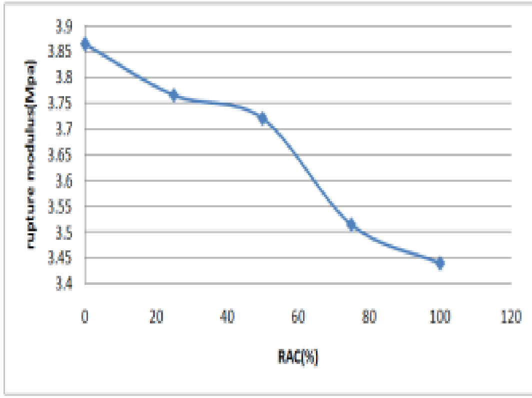
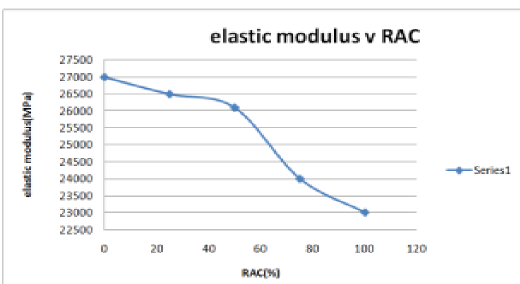


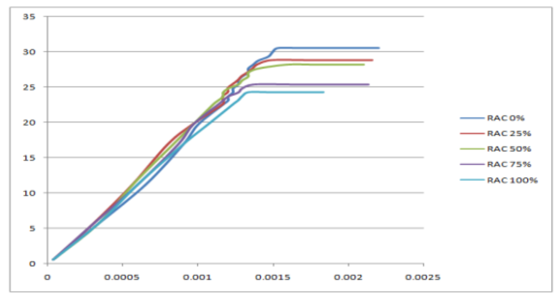
8 .ELASTIC MODULUS:

RAC	Compressive strength at28days (MPa)	Elastic modulus (5000√fck) (GPa)
0%	31.46	27000
25%	29.2	26500
50%	27.98	26100
75%	25.15	24000
100%	23.9	23000



9 .Determination of Young's Modulus by Stress-Strain Parameters

RAC	Load (T)	Area (mm²)	Stress (Mpa)	Change in length	Length	Strain	Young's modulus (Mpa)
0%	54	17671.5	30.55	0.46	300	0.00152	0.2×10^5
25%	51	17671.5	29	0.45	300	0.00146	0.198×10^5
50%	50	17671.5	28.3	0.44	300	0.00145	0.194×10^5
75%	45	17671.5	25.3	0.41	300	0.00136	0.185×10^5
100%	43	17671.5	24.2	0.40	300	0.00134	0.18×10^5



6. CONCLUSIONS:

Research on the usage of waste construction materials is very important due to the materials waste is gradually increasing with the increased of population and increasing of urban development. The reasons that many investigations and analysis had been made on recycled aggregate are because recycled aggregate is easy to obtain and the cost is cheaper than virgin aggregate.

Virgin aggregate need to mine but recycled aggregate can ignore this process. This on-going research project is to determine the strength characteristics of recycled aggregate for potential application in the high concrete structural concrete. According to the results which are obtained that the workability is been decreasing by increasing the RAC% and the air content increased which indirectly relates to the decrease of bulk density .The various tests performed on hardened concrete such as compressive strength, flexural strength , split tensile tests results are clearly states to be decreasing by increasing the RAC%.

From the observation of the results we can conclude that the replacement of virgin aggregate by recycled aggregate about 50% is been recommended since it attains the similar strength compared to normal concrete .Further replacement above 50% can be done by introducing some admixtures to maintain the workability .

Recommendations for Further Studies

Further testing and studies on the recycled aggregate concrete is highly recommended to indicate the strength characteristics of recycled aggregates for application in high strength concrete.

Below are some of the recommendations for further studies:

1. Although by decreasing the water/cement ratio, recycled aggregate can achieve high strength concrete. But the workability will be very low. Therefore, it is recommended that adding admixtures such as super plasticizer and silica fume into the mixing so that the workability will be improved.

2. More investigations and laboratory tests should be done on the strength characteristics of recycled aggregate. It is recommended that testing can be done on concrete slabs, beams and walls. Some mechanical properties such as creep, durability and abrasion were also recommended.

3. More trials with different sizes of recycled aggregate(10mm,16mm…etc) and percentage of replacement of recycled aggregate are recommended to get different outcomes and higher strength characteristics in the recycled aggregate concrete.

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