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A STUDY ON RECYCLED AGGREGATE CONCRETE AS REPLACEMENT OF COARSE AGGREGATE IN CONCRETE WITH MINERAL ADMIXTURES

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ABSTRACT
Microcracks are the inherent feature of concrete and this feature also persists in recycled aggregate concrete (RAC) just like a conventional concrete. Due to external loading and chemical reactions, microcrack spreads, causing harmful species to enter the concrete causing durability of the concrete to deteriorate. In this study, the precipitations of bacterially induced CaCO3 were introduced in RAC as a strategy to repair cracks on their own. Recycled coarse aggregate (RCA) was used at the 50% and 100% levels by replacing natural coarse aggregate (NCA). In addition, 10% weight of cement was replaced in bacterial recycled aggregate concrete (BRAC) mixes with microsilica (MS) and metakaolin (MK). The competency of self-healing was assessed through compressive strength, ultrasonic pulse velocity (UPV) measurements, water permeability and microscopic inspection of crack healing. The maximum crack width of 0.63 mm was fully healed after 56 days of healing incubation. Depending on the cracking age regain in compressive strength was found to be in the range of 57% to 93% and the variation ratio (Rk) of the permeability coefficient was observed in the range of 143% to 181% in different BRAC mixes. The microstructure investigations were conducted using SEM with EDS and XRD techniques from which the morphology of bacterial precipitations and their composition were explored. Based on the results of the study, it is suggested that cracks in RAC can be self-repaired by bacterially attained self-healing phenomena and hence, its durability can be improved.

I. INTRODUCTION

Construction becomes the basic input for Socio-economic development of any country. Any construction activity requires several materials such as concrete, steel, brick, stone, glass, clay, mud, wood etc. However, the cement concrete remains the main construction material used in construction industries. Concrete is the most widely used construction material and has established itself as the most versatile construction material in all the disciplines of civil engineering owing to its high compressive strength. Moreover, natural resources are depleting remarkably due to extensive demand for new constructions. It is estimated that the construction industry in India generates about 10-12 million tonnes of waste annually. The usability of recycled aggregate in concrete is gaining popularity in all over the world due to the preservation of the environment and suitable development [1]. Hence, a number of studies have been performed by using recycled aggregate in concrete, but they always resulted in lower level of concrete strengths. This was due to the residual impurities on the surface of the recycled aggregates, which blocked the strong bond between cement past and aggregates [2]. A number of previous publications studied the mechanical behavior of concretes containing recycled aggregates. The results showed how the strength loss caused by RAC aggregates at equal water-cement ratio could be reduced if better concrete was used as coarse recycled aggregate and if a lower portion of fine recycled aggregates was added [3].
Mineral admixtures such as fly ash, silica fume, metakaolin and granulated blast slag have been utilized for many years either as supplementary

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cementations materials in Portland cement concretes or as a component in blended cement [4, 5]. Generally, due to their high Pozzolanic activity, the inclusion of fly ash and silica fume improvise the mechanical and durability properties of concrete [6]. Preliminary studies have been conducted on the mechanical and durability properties of recycled aggregate concrete made with mineral admixtures [7]. 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 [8-12]. Research & Development activities have been taken up all over the world for proving its feasibility, economic viability and cost effectiveness.

Construction waste is bulky and heavy and is mostly unsuitable for disposal by compositing. The growing population in the country and requirement of land for other uses has reduced the availability of land for waste disposal. The trend of the utilization of recycled aggregates is the solution to the problem of an excess of waste materials.

Recycled aggregates in concrete

Recycled aggregates (RA) is a poor quality due to its higher porosity resulted from cement attaching to the RA surface that hampers the potential of recycle concrete waste. Many previous research works recorded reduction in strength for concrete made with RA, thus the use of RA is mainly confirmed to low grade applications. Recycled concrete is simply old concrete that has been crushed top produce aggregate Recycled aggregates will have higher drying shrinkage than the conventional aggregates.

Concrete made with recycled coarse aggregates and conventional fine aggregates can obtain an adequate compressive strength. The use of recycled fine aggregate can result in minor compressive strength reductions. However, drying shrinkage and creep of concrete made with recycled aggregates is up to 100% higher than concrete with corresponding conventional aggregate. Therefore, considerably lower values of drying shrinkage can be achieved using recycled coarse aggregate with natural sand. As with any new aggregate source, recycled concrete aggregate should be tested for durability, gradation, and other properties.

Recycled aggregate (RA) types

RA is typically classified according to the grain size. Typically coarse RA (> 4 mm) is much easier to use in concrete production than fine RA (< 4 mm). This is because after normal concrete crushing and sieving operations the proportion of good natural aggregates is much higher in the coarse portion than in the fine portion. After advanced RA production methods, coarse RA can basically consist of natural aggregate.

The use of RA together with other recycled materials in cement based on the use of RA with Pozzolanic materials such as fly ash (FA)/classified FA/micronized FA, silica fume (SF), slag (SLG), other (recycled) powder/micronized materials, brick powder, glass powder, rock powders and even e.g. lime production waste is a way to widen the use of demolished concrete. RA can also be used to produce low strength materials, as filling materials, including ecological materials also totally without or with a minimum amount of cement.

Advantages in recycling of construction materials

- It leads to conservation of natural resources, especially in regions where aggregates are scarce.
- Use of any recycled material helps to keep that material out of landfills.
- Cost saving: - There are no detrimental effects on concrete & it is expected that the increase in the cost of cement could be offset by the lower cost of Recycled Concrete Aggregate (RCA).
- Save environment: - There is no excavation of natural resources & less transportation. Also less land is required.
- Save time: - There is no waiting for material availability.

Disadvantages in recycling of construction materials

- Less quality (e.g. compressive strength reduces by 10-30%).
- Duration of procurement of materials may affect life cycle of project.
- Land, special equipment's machineries are required (more cost).
- Very high water absorption (up to 6%).
- It has higher drying shrinkage & creep.

Fig.1.1: Three stage mixing approaches

Scope and Objective of Work

• To study the influence of parent aggregate on recycled aggregate concrete by using Pozzolanic materials (silica fume and fly ash).

To obtain the strength of RAC20 using replacement of recycled aggregate (i.e. 50%, 75% and 100%) with natural aggregate.

II. LITERATURE REVIEW

The literature review presents the current state of knowledge and examples of successful uses of alternative materials in concrete technology, and in particular the use of Recycled Concrete (RC) aggregate as a coarse aggregate fraction in nonstructural and structural concrete. Many researchers have dedicated their work to describe the properties of these kinds of aggregate, the minimum requirements for their utilization in concrete and the properties of concretes made with recycle aggregates. It also presents a review of available literature on physical, mechanical and durability properties of RC aggregates, and mechanical, durability and structural properties of RCA concrete.

Cakar.O, [1] studied on experimental analysis of properties of recycled coarse aggregate (RA) concrete with mineral additives. The author studied mineral additives used in this experimental work are silica fume (SF) and granulated blast furnace slag (GGBFS) at various ratio. The influence of SF and GGBFS with RCA hardened concrete on experimental investigation on compressive strength, split tensile strength, density of the water absorption.

The author concluded compressive strength of the specimens containing 5% and10% SF contents increases 30% and 60% GGBFS contents decreases by replacing of the NCA with RCA at 28 days. An inverse relationship between the density and the water absorption ratio is observed in RCA concrete and relation in more significant in higher amount of RCA contents.

Ann.K.Y et al, [2] studied durability on recycled aggregate concrete using pozzolanic materials. For the durability of RCA and increase the compressive strength. They use 30% PFA and 65%GGBS, it should a effective resistance of chloride ion penetrability of concrete body, measured by a rapid ion penetration test.

They concluded compressive strength of the concrete containing recycled aggregate lower than replacing with 30% PFA and 65%GGBS less effective in increasing the tensile strength at 28 days. The corrosion rate was significantly reduced by PFA and GGBS due to the restriction of cathodic reaction.

Shi-cong kou et al,[3] studied on comparisons of natural and recycled aggregate concrete prepared with the addition of different mineral admixtures .They conducted experimental work on laboratory study on the performance of natural and recycled aggregate concrete prepared with the incorporation of different admixtures including silica fumes (SF) metakoline (MK),fly ash(FA),ground granulated blast slag(GGBS).The compressive ,split tensile strength , drying shrinkage ,chloride ion penetration and UPV of the concrete mixtures were determined.

The authors concluded that the compressive strength of the concrete containing recycled aggregate at 1, 4, 7, 28 and 90 days lower than that of the control specimen, but could be compared by use of 10%SF or 15%MK.Also,it has been found that the split tensile strength of natural aggregate concrete made with SF and

MK was higher than control concrete at all test ages.

Carmine lima et al, [4] researched on physical properties and mechanical behavior of concrete made with recycled aggregate and fly ash. They studied experimental campaign is carried out on concrete, made using recycled concrete aggregate (RCA) and fly ash(FA) in partial substitutions of natural aggregates(NA) and cement are discussed. The concrete characterization by variable water-binder ratios and produced with different % of RCA and variable the content of FA have been tested.

They concluded that the replacement of normal aggregate with recycled type will significantly reduce the workability, compressive strength, bond strength of deformed steel reinforcement rebars.

Ahmed .S.F.U, [5] studied on properties of concrete containing construction and demolition wastes and fly ash. The author reports RCA is used as 25, 50, 75 and 100% replacement of NCA. The properties of concrete evaluated are the compressive strength, indirect tensile strength and water absorption test.

The author concluded the inclusion of fly ash improves the workability of the recycled aggregate concrete. The addition of 40% fly ash significantly reduce the water absorption values of all recycled aggregate concretes.

Valeria Corinaldesi et al, [6] studied on Influence of mineral additions on the performance of 100% recycled aggregate concrete. They are used materials on RAC with fly ash (RA+FA) or silica (RA+SF). They conducted on compressive strength, split tensile strength, dynamic modulus of elasticity, drying shrinkage, reinforcing bond strength.

They concluded compressive strength of RAC can be improved to equal or exceed that of virgin aggregate concrete by adding fly ash or silica fume to the mixture as a fine aggregate replacement with the aid of an acrylic-based superplasticizer.

Ali Abd Elhakam et al, [7] studied on investigate the properties of concrete made with recycled concrete coarse aggregates. Adding 10% silica fume as cement addition to recycled aggregates concrete enhanced properties of concrete. They conduct on compression and tensile strength, self-healing, two stage mixing approach.

They concluded compressive strength decreases with the increasing of % of recycled aggregate. Add 10% silica fume to recycled aggregates concrete enhances the properties of concrete. The recycled aggregate porosity to enhance its compressive strength.

Rattapon Somna et al, [8] studied on Effect of ground fly ash and ground bagasse ash on the durability of recycled aggregate concrete. The effect of ground fly ash (GFA) and ground bagasse ash (GBA) on the durability of recycled aggregate concrete. Replacement of cement 20%, 35%, and 50% by weight of binder. They conduct compressive strength, water permeability, chloride penetration depth.

They concluded Use of both ground fly ash (GFA) and ground bagasse ash (GBA) to partially replace cement at 20% by weight of binder in recycled aggregate concrete results in compressive strength similar to that of recycled aggregate concrete without GFA and GBA which is lower than that of conventional concrete (CON) by approximately 10%.Both GFA and GBA could reduce the water permeability of recycled aggregate concrete to be lower than that of CON.

III. PRELIMINARY EXPERIMENTAL INVESTIGATION

Introduction

The details of the mix proportions, casting and testing procedures of various tests carried out to investigate the properties of ingredients are presented in this chapter. There is a general cement, and the physical, mechanical and chemical properties of the aggregates.

CEMENT

The cement used throughout my thesis was ordinary Portland cement (OPC53grade) confirming to IS: 12269-1989.It was obtained from a single source MAHA Gold LTD, Visakhapatnam. The chemical and physical properties of the cement were tested as per the IS: 4031-1985 & IS: 4031- 1988 respectively.

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Consistency of cement AS per IS 4031:1988- Part IV

Normal consistency of cement is defined as the percentage of water by weight of cement which produces a consistency which permits a plunger of 10 mm diameter to penetrate up to a depth of 5mm to 7mm above the bottom of vicat mould.

- Taken 400 grams of cement and place it in an enamel tray.
- Measure 23% of distilled water by weight of cement.
- Start the stop watch the moment water is added thoroughly mixed 400g of cement sample. Filled vicat mould on non-pours glass plate when prepared past.
- The mould may be slightly shaken to expel the air and leveled the surface with the help of trowel.
- Place the prepared mould under the plunger and screw the clamp to bring the plunger just in contact in the surface and quickly released to allow in sink.
- Note down the penetrated reading from the bottom of the mould.
- The above procedure is repeated for several pastes with varying percentages of water and the test is conducted until the needle penetrated 5mm to 7mm from the bottom of the mould.

The test results are given below,

Table.3.1: Consistency of cement

S.No.	Quantity of water added, ml	Time of gauging, min	Penetration from the bottom of the mould, mm
1	92	5	42
2	100	5	39
3	108	5	36
4	116	5	24
5	124	5	13
6	132	5	6

Percentage of water required to prepare a cement paste of standard consistency,

$$P = \frac{\text{weight of water}}{\text{weight of cement}} \times 100 = 33$$

No standard values for normal consistency are specified it is necessary to determine the consistency of cement because other tests are dependent on this normal consistency.

Initial setting time As per IS 4031:1988 - Part V

Initial setting time of cement is defined as the period elapsing between the time when the water is added to the cement and the time at which needle of 1 sq-mm section fails to pierce the test block to a depth of 5-7 mm from the bottom of vicat mould.

- Take 300gms of cement and place it in an enamel tray.
- Measure quantity of water at 0.85x p x c, where p is consistency of cement and c is total weight of cement.
- Before making paste of cement fix 1 sq-mm needle fixed vicat apparatus.
- Mix the major quantity of water wet cement at simultaneously note down the time.
- Filled the vicat's mould with the cement paste and leveled the surface with the help of trowel.
- Place the test block under the needle, lower the needle shall in contact with the surface of the test block and gently released along to penetrate into the test block and observed penetration.
- Repeat the test at appropriate time till the needle take to 5mm to 7mm from the bottom of the mould to note this time.
- The period elapsing between the time when water is added to the cement and the time at which the needle fails to penetrate in to test block by 5-7mm from the bottom of the mould is determined as the initial setting time.

The test results are given below,

Quantity of water to be added = 0.85*P*

= 0.85 x 33 x 300 = 84.15ml.

Time at which water is first added (T1) = 10.50AM Table. 3.2: Initial setting time of cement

Final Setting Time As Per IS 4031:1988 Part –V

- The same procedure of initial setting time was adopted to determine the final setting time of cement.
- Replaced the needle of the Vicat's apparatus by the needle with an annular attachment.

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- The cement is considered as finally set when, upon applying the needle gently to the surface of the test block, the needle makes an impression thereon, while the attachment fails to do so.
- The period elapsed between the time when water is added to the cement and the time at which the needle makes an impression on the surface of test block while the attachment fails to do so the final setting time.

We got final setting time is 215 minutes.

Soundness of the Cement As per IS 4031:1988 - Part III

- Take 300gms of cement i.e., 100g cement taken for each sample.
- The water of quantity 0.78*P*C, where P is standard consistency of cement paste and C is quantity of cement.
- Apply oil for all sides of the mould to prevent loss of cement paste to the mould. Place the mould on a glass plate.
- Now, fill the mould with cement paste.
- Cover the mould with another piece of lightly oiled glass sheet, place a small weight on this covering glass sheet and immediately submerge the whole assembly in water at a temperature of 27±2ºC and keep there for 24hours.
- After 24hrs, measure the distance separating the indicator points to the nearest 0.5 mm.
- After measuring, bring the water to boiling, with the mould kept submerged, in 25 to 30 minutes, and keep it boiling for three hours.
- Remove the mould from the water, allow it to cool and measure the distance between the indicator points.
- The difference between these two measurements indicates the expansion of the cement.

The test results are given below,

Table.3.3: Soundness of the cement

S.No.	Time in minutes after water added	Penetration reading
1.	5	16
2.	10	25
3.	15	15
4.	20	23
5.	25	24
6.	30	24
7.	35	24
8.	40	28
9.	45	30
10.	50	31
11.	55	36
Initial setting time of cement is 55 minutes.		

3.2.4 Fineness of cement as per IS 403:1996 Part I

- The sample of cement collected 10gms of cement to remove the air lumps and 90 µ sieve with pan fitted in bottom now place the lid at top.
- Gentle shacking for 15 min motion clock wise, anti-clock wise, forward and backward.
- The retained weight indicated mass percentage (R1) of the quantity first placed in the sieve to the nearest 0.1 percent.
- Repeat the whole procedure using a fresh 10 g sample as above to obtain R2
- Then calculate the residue of the cement R as the mean of R1 and R2 as a percentage, expressed to the nearest 0.1 percent.
- When the results differ by more than 1 percent absolute, carry out a third sieving and calculate the mean of the three values.

The results are given below,

Table. 3.4: Fineness modulus of cement

DESCRIPTION	SAMPLE		
	I	II	III
Weight of sample (C)	100	100	100
Water added to the sample(0.78*P*C)	25.74	25.74	25.74
Time at which the sample is kept inwater at 27°C to 32 °C	12.15pm	12.15pm	12.15pm
Distance between the pointer ends before heating (D1), mm	38	37	32
Time of heating, hr	3	3	3
Distance between the pointer ends afterheating (D2), mm	34	35	33
Difference (D2-D1), mm	4	2	1
Average Soundness	3.5		

Specific gravity of cement

- I have taken weigh a clean and dry specific gravity bottle with its stopper (W1).
- After place a sample of cement up to one third of the flask and weight with its stopper (W2).
- Add kerosene to cement in flask remain portion weight with its stopper (W3).
- Clean the bottle thoroughly and fill the bottle with kerosene and weigh (W4).
- Finally clean the bottle fill with water and weight (W5).
- Repeat the above steps for each cement sample.

The test results are given below,

Table.3.5: Specific gravity of cement

Description	Sample
a)Weight of bottle (W1), g	34
b)Weight of bottle + 1/3 of cement (W2), g	69
c)Weight of bottle + cement + kerosene (W3), g	103
d)Weight of bottle + kerosene (W4), g	78
e)Weight of bottle filled with water (W5), g	88
f)Specific gravity of kerosene, G_k =(W4-W1)/(W5-W1)	0.81
g)Specific gravity of cement, G = [(W2-W1)G_k]/ [(W4-W1)-(W3-W2)]	3.15

Compression strength of cement As per IS 403:1988-Part VI

- Taken sample of cement and sand such that the quantity of cement and sand ratio is 1:3.
- Then add water of quantity [(P/4) + 3.0] of total mass of cement and sand, whether P is the percentage of standard consistency.
- Mix the cement and sand with a trowel for one minute and then with water until the mixture is of uniform the time of mixing shall be not less than 3min.
- Apply petroleum jelly on all sides of mould and its base plate.
- Place the assembled mould on the table of the vibration machine and hold it firmly in position by means of a suitable clamp.
- Attach a hopper of suitable size and shape securely at the top of the mould to facilitate filling and this hopper shall not be removed until the completion of the vibration period.
- Immediately after mixing the mortar, fill the entire quantity of mortar in the hopper of the cube mould and compact by vibrating. The period of vibration shall be 2 minutes at the specified speed of 12000±400 vibration per minute.
- Then placed the cube moulds in temperature of 27±2o C for 24 hours. After 24 hours removed the cubes from the mould and immediately submerged in clean water after completion of vibration.
- The cubes shall be tested on their sides without any packing between the cube and the steel plates of the testing machine.
- One of the plates shall be carried on a base and shall be self- adjusting, and the load shall be steadily and uniformly applied, starting from zero at a rate of 35N/mm2/min.

The test results are given below,

Table. 3.6: Compressive strength of cement

Description		Specimen					
		3 days			7 days		
		I	II	III	I	II	III
Weight of cement,	g	200	200	200	200	200	200
Weight standard sand,	g	600	600	600	600	600	600
Weight in g of water	g	23.4	23.4	23.4	23.4	23.4	23.4
Area	Cm^2	7.06	7.06	7.06	7.06	7.06	7.06
Load at fracture (P),	KN	80	78	85	115	95	120
Compressive stress,N/mm^2		16.05	14.04	17.95	23.07	19.95	24.07
Average strength, N/mm^2		15.7			22.0		

FINE AGGREGATES

Fine aggregate is natural sand which has been washed and sieved to remove particles larger than 4.75 mm. Sand (>0.075mm) is used as a fine aggregate in concrete. It is a granular form of silica. The locally available river sand conforming to zone-II of IS 383-1970 has been used as fine aggregate. The fine aggregate are clean, inert and free from organic matter, silt and clay. Sand used in construction purpose should passes at least 85 percent of the strength of standards and mortars of like proportions and consistency. The tests conducted on fine aggregate is as below,

Fineness Modulus of Fine Aggregate as per IS 2386:1963- Part I

- Take 1000gms of air dried fine aggregate sample. This may be achieved either room temperature or heating temperature at 1000 to 1100 C.
- Now place the sample in the set of IS sieves arranged in order 10mm,4.75mm,2.36mm,1.18mm,600µ,300µ ,150µ,75µ with 10mm sieve at the top and 75µ sieve at the bottom.
- Shake the complete assembly by giving varied motion so that each particle gets sufficient change of passing through the opening.
- The aggregate is taken in 10mm sieves and sieved for 10 minutes.
- After proper sieving fraction of sand of difference size will be retained on difference sieves.

The results obtained are shown in table below,

Table.3.7: Fineness modulus of fine aggregate

SieveNo.	Weight Retained	% of total weight retained	Cumulative % of totalweight retained	% Passing	Permissible Values as per IS 383-1970
1	2	3	4	5	6
10mm	0	0	0	0	100
4.75mm	28	2.26	2.26	97.74	90-100
2.36mm	20	2.73	4.99	95.1	75-100
1.18mm	91	11.63	16.62	83.38	55-90
600µ	327	33.83	50.45	49.55	35-59
300µ	500	46.1	96.55	3.45	8-30
150µ	20	2.56	99.11	0.89	0.1
75µ	0	0	0	0	—
Total			269.88		
Fineness Modulus = 269.88/100 = 2.69					
As per IS 383-1970, the sample confirms to Zone-II					

IV. PRESENTATION OF RESULTS

Introduction

The Normal aggregate (NA) and granulated aggregate (GA) are tested for its physical and mechanical properties. The fresh concrete properties are slump tested. And herded concrete properties are density, water absorption and compressive strength of recycled aggregate concrete and Normal aggregate concrete are presented.

Physical and mechanical properties of normal and granulated aggregates

Specific gravity

The specific gravity of demolished concrete aggregates is lower than that of natural aggregate. The average specific gravity of aggregate usually varies from 2.6 to 2.8.

Table.4.1 Specific gravity of natural and recycled aggregate.

Aggregate	20mm	10mm
NA	2.86	2.76
GA20	2.78	2.67
GA25	2.78	2.65
GA30	2.77	2.63
GA35	2.74	2.62
GA40	2.71	2.61

Water Absorption

The absorption capacity of recycled aggregates depends on the quality and quantity of adhered mortar. There was dependence between density and water absorption capacity. Recycle aggregates with adhered motor have lower density and higher water absorption capacity.

Table.4.2: Water absorption of natural and recycled aggregate

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Aggregate	20mm	10mm
NA	0.5	0.4
GA20	3.03	5.08
GA25	3.07	5.10
GA30	3.17	5.14
GA35	3.2	5.18
GA40	3.24	5.29

Bulk density

The bulk density or unit weight of an aggregate gives valuable information regarding the shape and grading of the aggregates. For a given specific gravity the angular aggregates shows a lower bulk density. Bulk density of aggregates is of interest when dealt with light weight aggregates and heavy weight aggregates. In general, the saturated surface density of recycled aggregates is lower than that of natural aggregates, due to the low density of the mortar that is adhered to the original aggregate. It depends on the strength of original concrete and size of original aggregates.

Table.4.3: Compacted Bulk Density of NA & GA

Aggregate	20mm	10mm
NA	1605	1525
GA20	1400	1310
GA25	1400	1300
GA30	1390	1290
GA35	1370	1280
GA40	1340	1280

Crushing Value of Aggregate

Aggregates used in construction, should be strong to resist crushing under loads. If the aggregates are weak, the stability of the pavement structure is likely to be adversely affected. The strength of coarse aggregate is assessed by aggregates crushing test. The aggregate crushing value provides a relative measure of resistance to crushing under a gradually applied compression load.

Impact Value of Aggregates

The aggregates should therefore have sufficient toughness to resist their disintegration due to impact. This characteristic is measured by impact value test. The aggregate impact value is a measure of resistance to sudden impact or shock, which may differ from its resistance to gradually appliedcompressive load.

Table.4.4: Crushing Values of NA & GA

Aggregate	20mm	10mm
NA	23.13	25.16
GA20	28.15	44.60
GA25	27.89	44.03
GA30	27.57	43.92
GA35	26.62	42.02
GA40	25.12	40.89

Table.4.5: Impact Values of NA & GA

Aggregate	20mm	10mm
NA	17.4	21.67
GA20	27.4	44.79
GA25	26.5	41.93
GA30	24.91	40.27
GA35	21.17	38.75
GA40	19.74	35.78

Fresh concrete properties of recycled aggregate concrete

Workability

The property of fresh concrete which is indicated by the amount of useful internal work required to fully compact the concrete without bleeding or segregation in the finished product.

Workability of the two mixes with Pozzolanic and without Pozzolanic is gradually decreased with increase in percentage of recycled aggregates. The set with 20% fly ash and 10% silica fume has more workability than without Pozzolanic material. Workability with different % of RCA (in slump value) isshown in table 4.7.

Table.4.6: Flakiness Index of NA & GA

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Aggregate	20mm	10mm
NA	12.8	21.3
GA20	13.2	22.3
GA25	14.8	24.6
GA30	16.4	25.3
GA35	17.2	29.4
GA40	18.7	32.4

Table.4.7: Slump of recycled Aggregate concrete with Pozzolanic materials

S.NO	Grade of aggregate	Slump of RAC20,mm % of replacement		
		50%	75%	100%
1	GA20	50	45	42
2	GA25	48	44	40
3	GA30	46	42	38
4	GA35	42	38	35
5	GA40	40	36	30

Hardened concrete properties of recycled aggregate concrete

Density of Recycled Aggregate Concrete

The density of concrete is a measure of its unit weight. Concrete is a mixture of cement, fine and coarse aggregates, water, and sometimes some supplementary materials like fly ash, slag, and various admixtures. A normal weight concrete weighs 2400 kg per cubic meter. That the natural air content of recycled aggregate concrete may be slightly higher than that of control concretes made with conventional concrete.

Table.4.8: Density of RAC20

S.NO	Grade of concrete	Days density of RAC20,Kg/m^3		
		50%	75%	100%
1	GA20	2471	2465	2443
2	GA25	2464	2456	2425
3	GA30	2458	2440	2405
4	GA35	2439	2435	2382
5	GA40	2416	2402	2364

Water absorption of RAC

This is due to the increase proportion of cement paste in RCA, as the quantity of attached cement paste in the concrete with 100% coarse RCA increased by three times than that of concrete with 30% coarse RCA. And also concluded that up to 30% coarse RCA had no detrimental effect on air permeability, regardless of concrete strength. However, intrinsic air permeability found to increase with RCA content beyond this level. A possible use of admixtures such as fly ash or silica fume could decrease significantly porosity and permeability of recycled aggregate (both coarse and fine aggregates) concrete.

Table.4.9: Days Water absorption of RAC20

S.NO	Grade of concrete	Days water absorption of RAC20, %		
		50%	75%	100%
1	GA20	1.8	1.89	1.97
2	GA25	1.65	1.75	1.93
3	GA30	1.6	1.72	1.88
4	GA35	1.58	1.6	1.74
5	GA40	0.87	0.88	0.97

Compressive Strength of Recycled Aggregate Concrete

The experimental results obtained after the curing of 7 days and 28 days of the compressive strength with and without Pozzolanic materials is tabulated given,

Fig.4.4.1 Compressive Strength Test of Cubes

Table.4.10:7days Compressive Strength of RAC20 with PozzolanicMaterials

S.NO	Grade of concrete	Compressive strength of 7 days, Mpa		
		50%	75%	100%
1	GA20	19.55	18.95	18.66
2	GA25	18.81	16.43	16.23
3	GA30	16.44	16.00	15.55
4	GA35	16.04	15.11	14.66
5	GA40	15.47	14.22	12.88

Table.4.11:28 days Compressive Strength of RAC20 with PozzolanicMaterials

S.NO	Grade of concrete	Compressive strength of 28 days, Mpa		
		50%	75%	100%
1	GA20	27.55	26.22	24.88
2	GA25	25.33	24.44	24
3	GA30	24.44	23.11	21.33
4	GA35	22.07	20.74	20
5	GA40	20.95	20.29	17.77

V. RESULTS AND DISCUSSION

Introduction

The Normal aggregate and Recycled aggregate are tested for its physical and mechanical properties at the different replacement levels of 50%, 75% and 100% recycled aggregate concrete. The silica fume (10%) and fly ash (20%) were used as a Pozzolanic materials. The density, compressive strength and water absorption of recycled aggregate concrete are discussed in this chapter.

Physical and mechanical properties of RAC

Specific gravity of NA and RA

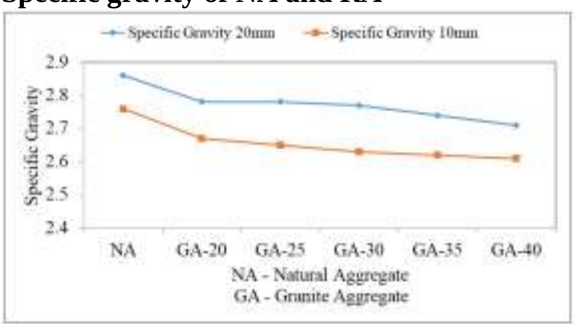

Fig.5.1: Specific Gravity of NA & GA

Specific gravity of GA is decreased as the grade of GA is increased. It is due to the density loss in GA due to adhered mortar. The decrease in specific gravity shower the granite aggregates loss its weight behaves as a floating particle. The specific gravity of 20mm recycled aggregate is more than the 10mm recycled aggregate. The percentage between NA &GA is for 20mm & 10mm is 2.8% - 5.3% and 3.3% - 5.3% respectively.

Water absorption of NA & GA

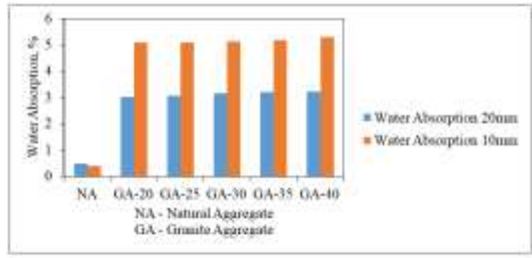

Fig.5.2: Water absorption of NA & GA

The water absorption is increased as the grade of GA is increased. Due to high amount of adhered mortar increasing when the grade is increased the air voids and the porosity will be more. 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. The absorption capacity of recycled aggregates depends on the quality and quantity of adhered mortar. There was dependence between density and water absorption capacity. Recycle aggregates with adhered motor have lower density and higher water absorption capacity.

Bulk Density of NA & GA

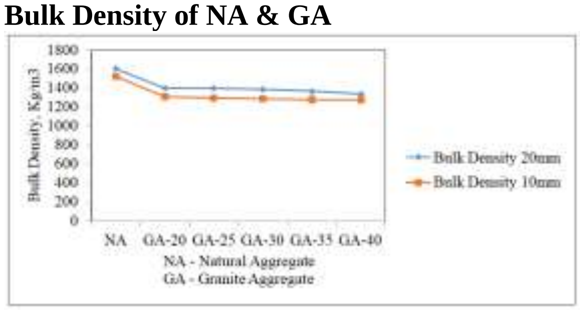

Fig.5.3: Bulk Density of NA & GA

Bulk density is decreased as the grade of GA is increased .As the high in amount of cement mortar present on GA the density per unit volume is decreased. Bulk density of aggregates is of interest when dealt with light weight aggregates and heavy weight aggregates. The density of recycled aggregate concrete reduces with smaller size of aggregates. In general, the saturated surface density of recycled aggregates is lower than that of natural aggregates, due to the low density of the mortar that is adhered to the original aggregate. It depends on the strength of original concrete and size of original aggregates. Furthermore it is concluded that by addition of silica fume to the recycled aggregate concrete and conventional concrete, reduces the density.

Flakiness Index of Granite Aggregate

It is important the shape and surface texture of the aggregate due to the amount of adhered mortar present on the GA, the aggregate behaves flaky for the desired size of aggregate to be used for production of concrete.

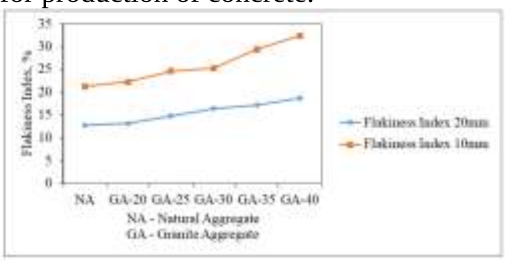

Fig.5.4: Flakiness Index of Granite Aggregate

The shape and surface texture of the coarse aggregate influence the strength of concrete by providing an adequate surface area for bonding with the paste or creating unfavorable high internal stresses. The surface texture ofaggregate contributes significantly to the development of a physical bond between aggregate and cement paste.

Aggregate Crushing Value (%)

The crushing of aggregates is to resist the load applied on the materialand to give efficient value in resisting loads but due to the adhered mortar on GA the crushing value is increased.

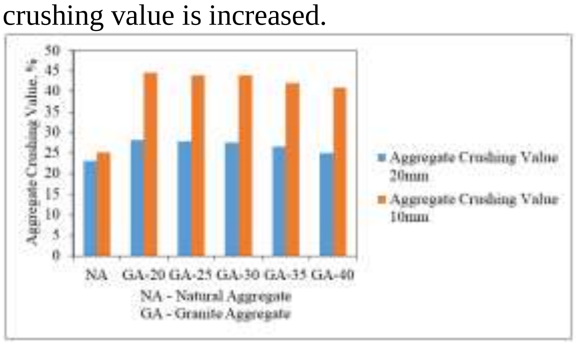

Fig.5.5: Aggregate Crushing Value (%)

Aggregate Impact Value (%)

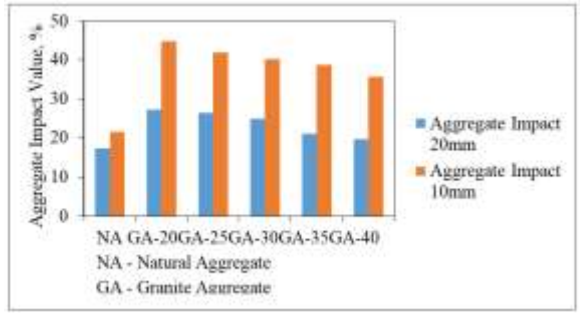

Fig.5.6: Aggregate Impact Value (%)

When compared to NA the GA of impact value is increased due the sudden or impact loads on aggregates, the adhered mortar present on the GA gets loose and removed.

VI. CONCLUSIONS

From the study following conclusion are made

- The resistance of recycled aggregate to physical and mechanical actions is lower than fresh crushed granite aggregate, the values are generally within acceptable limits.
- As the GA grade increases, the workability decreases. But, with the addition of 20% FA and 10% SF to the replacement of cement showed a better workability.
- The recycled aggregate concrete has less density than conventional concrete this may be due to the porous structure of recycled aggregate.
- The water absorption of RAC increase with increase in replacement and increase in grade of aggregate. This may be because of adhered motor attached to the recycled aggregate.
- The strength of concrete decreases with increase in the percentage of recycled aggregate, this may be because of the loose mortar around the recycle aggregate which do not allow the proper bonding between the cement paste and aggregate.
- Generally, fly ash and silica fume based concrete has the ability to develop strength over prolonged periods of time. So at a long period of run the compressive strength of RAC with fly ash and silica fume achieves similar strength of natural aggregate concrete by adding Pozzolanic materials.

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