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Experimental Investigation on the Influence of Micronized Biomass Silica in the Recycled Aggregate Concrete

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***Abstract*—The use of recycled aggregate concrete in structural application is restricted due to the high strength reduction and higher water absorption. In this study, Micronized biomass silica (MBS) a pozzolanic material produced from rice husk was used as a partial replacement of cement to improve the performance of the recycled aggregate concrete. Recycled aggregate concrete with and without MBS has been investigated and the results of the mechanical and durability properties such as compressive strength, split tensile strength, flexural strength, rapid chloride permeability and water absorption were compared with conventional concrete. The test results showed that recycled aggregate concrete without MBS was inferior to conventional concrete but with MBS showed similar results like conventional concrete. Thus, the drawbacks in the use of recycled aggregates in concrete for structural application can be overcome by using MBS as cement replacing material.**

***Key Words*— Recycled aggregate concrete, Micronized Biomass Silica, Mechanical properties, Durability properties.**

I. Introduction

Construction industry is the one which consumes large amount of natural resources in world wide. The use of natural aggregates in the construction industry is more nowadays because of the advanced development of infrastructure. The global annual consumption of natural aggregate in construction industry (NA) will be in the range of 8-12 billion tonnes which generally occupy 60% to 75% of the concrete volume [1, 2]. So there will be a critical shortage for natural aggregate in future. On the other hand, the amount of construction & demolition waste (C&D wastes) has been increased due to the rapid increase of population and economic development. Construction and demolition waste consists mostly of inert and non-biodegradable material such as concrete, plaster, metal, glass, wood, plastics etc. These wastes are usually dumped in unauthorized landfills which will not only affect the landfills but also affects the environment.

The potential depletion of resources, and high energy consumption rates in the process of production, increases the necessity of recycling. Recycling of aggregate material from the construction demolition waste may reduce the demand of natural aggregate. The use of recycled aggregate obtained from C&D Wastes in new concrete is a solution for effective utilization of construction demolition wastes [3]. The sustainability can be achieved by using recycled aggregate in the concrete. Using recycled aggregate concrete creates cost savings in the transportation of aggregate and waste products, and waste disposal. There are many advantages in recycling the waste concrete construction and its demolition into aggregates, including from protecting the natural resources as well as saving ecological environment.Even though recycled aggregate is a good alternative to natural aggregate, there are some drawbacks by using recycled aggregates in concrete for structural application. Thus, this paper presents a brief review of the recycled aggregates in concrete, use of pozzolanic material (MBS) by improving the properties of recycled aggregate concrete and experimental investigations on the influence of MBS in recycled aggregate concrete.

II. Literature Review

Aggregates are the important constituents in concrete. Earlier aggregates are considered as inert material but now it has been identified that some of the aggregates exhibit chemical bond at the interface of the aggregate and paste. So it plays an important role in strength and durability of concrete performance. Since the demand for natural aggregate getting increased, recycled aggregates will become a good alternative material if it was properly processed [4]. Recycled aggregate has been produced from construction & demolition waste material as coarse or fine aggregate. Concrete made using such aggregates is referred to as recycled aggregate concrete (RAC) [5].

The physical properties of the recycled aggregates are inferior to the natural aggregates. The strength of the concrete made with recycled aggregates mainly depend on the amount of the adhered mortar attached to the original aggregate and the strength of the parent concrete [6]. The properties of the recycled aggregates could be improved by various methods like heating and rubbing method, acid treatment method [7, 8]. In fresh concrete, it was observed that the use of dry recycled aggregates in concrete mix greatly reduces its workability due to its more water absorption capacity. This can be rectified by using recycled aggregates in saturated condition i.e. presoaking the recycled aggregates in water before casting [9].

Many authors concluded that there was a strength reduction when natural aggregates are fully replaced by recycled aggregates and they have compared the variation of the compression strength of concrete made with 100% of recycled aggregates with respect to conventional concrete. Weerachart Tangchirapat et. al (2008)[10] reported that the compressive strength of the recycled aggregate concrete decreases up to 6% and Etxeberria et. al (2007) [11] concluded that there is a decrease in recycled aggregate concrete up to 20-25% compared to conventional concrete. Bhashya et.al (2012)[12] has done experimental investigation on recycled aggregate concrete by using laboratory concrete wastes as coarse aggregate and observed that there was a 21% reduction in compressive strength when compared to conventional concrete. Weerachart Tangchirapat et. al (2008) [10] found the splitting tensile strength of recycled aggregate concretes was not much different from the concrete made from normal aggregates. Padmini et.al (2009) [6] concluded that there is a slight difference in the split tensile strength. Durability quality of the recycled aggregate concrete is reduced with increase in the quantities of recycled aggregate in concrete [13].

It was observed from the previous research, the major problem of recycled aggregate concrete was high strength reduction and more water absorption compared to that of conventional concrete. Due to these qualities, recycled aggregate concrete made with recycled aggregate will give lesser strength and poor durability properties. The most effective way is to increase the performance characteristics of the recycled aggregate concrete (RAC) by the incorporation of other materials to substitute or supplement those conventionally used in concrete mixes. Mineral and chemical admixtures are among the materials which could lead to improved quality of RAC [10, 14].

In the present study, MBS is selected as a pozzolanic material and it is used as a partial replacement of cement to improve the properties of RAC. Micronized biomass silica is a byproduct of agricultural waste which is obtained by burning rice husk in rotary furnace at 500 – 600 degree Celsius, contains high content (90% - 95%) of silica and thus is an excellent pozzolanic material. and then it was micronized by using jar mill for about one hour to reduce the particle size diameter. Suitability of MBS mainly depends upon the chemical composition of the ash and content of silica content and its mineralogical structure depend upon the combustion time, temperature and turbulence during combustion. The cost of MBS was five times lesser than the silica fume. Some of the advantages when MBS was incorporated in concrete (a) Lowers heat of hydration and prevents the formation of cracks during casting (b) Reduces permeability and reduces the penetration of chloride and sulphates [15].

Due to these advantages, MBS can be used in concrete industry for structural applications. However, the major uses of MBS in natural aggregate concrete and the use of recycled aggregate concrete did not receive much attention, may be due to the limited use of RAC itself. Hence, investigation on the influence of MBS in recycled aggregate concrete is necessary. With the utilization of MBS, the inferior performance of using recycled aggregate concrete expected to be compensated, and will support the structural application of recycled aggregate in construction industry. When MBS used to replace cement, MBS could, indirectly reduce the carbon emission linked to cement production. Recycled aggregate concrete with MBS is obviously more sustainable than conventional natural aggregate concrete.

III. Research Significance

For economical and environmental reasons, there has been a growing global interest in maximizing the use of recycled aggregates in construction. The concrete wastes and agricultural wastes can be used in a useful way to produce a good quality of recycled aggregates concrete. This will help to reduce the consumption of natural resources and also protect the environment by reducing the disposal of wastes in the landfill. When proved successful, this recycled aggregate concrete with micronized biomass silica having similar performance characteristics to natural aggregate concrete, can be substituted for natural aggregate concrete in much application.

IV. Experimental Investigation

A. Materials

Ordinary Portland cement of Grade 53 was used in this study confirming to 12269-1987 [16]. The specific gravity of cement was found by using Le-Chatelier flask which was reported in the table 1. The initial and final setting time of cement was 132 min and 330 min. Fine aggregate and natural coarse aggregate used in this experiment was confirming to IS: 383-1970 specifications [17]. Water used for mixing and curing is fresh potable water, conforming to IS: 3025 – 1964 part 22, part 23 and IS: 456 – 2000. Conplast SP430 Sulphonated Napthelene Formaldehide (SNF) based type SP was used in this investigation. The other materials used in this investigation have been detailed below.

B. Micronized biomass silica

Micronized biomass silica, an agricultural waste by product bought from N.K Enterprises, Orissa, India, for this study. The specific gravity of micronized biomass silica was found by using Le-Chatelier flask which was given in the Table I.

TABLE I. PHYSICAL PROPERTY OF CEMENT & MBS

Property	**Cement**	**MBS**
Specific gravity	3.145	2.192

C. Recycled aggregate

Recycled aggregates used in this study was prepared by crushing the construction demolition wastes in to smaller stones by using hammer and then jaw crusher was used to prepare 20mm and 10mm recycled aggregates. Heating and Rubbing method [7] is applied to the recycled aggregate to

TABLE II. WEIGHT REDUCTION OF RECYCLED AGGREGATE AFTER THE APPLICATION OF HEATING AND RUBBING METHOD

Treated recycled aggregate	20 mm	10 mm
Weight reduction after treatment (%)	36.40	18.33

TABLE III. PHYSICAL PROPERTIES OF AGGREGATES

Properties	Natural Aggregate	Recycled Aggregate	Treated Recycled Aggregate
Specific Gravity	2.70	2.44	2.63
Water Absorption, %	0.62	3.82	1.31
Bulk Density (Loose) kg/m^3	1483.65	1240.70	1442.91
Bulk Density (Rodded) kg/m^3	1651.73	1442.91	1583.99

remove the mortar content and it was named as treated recycled aggregates. The amount of mortar content removed in the recycled aggregate by the application of heating and rubbing method was listed in the Table II. The results showed that by the application of heating and rubbing method, more mortar content was easily removed, if the size recycled aggregates was more. The physical properties of recycled aggregates, treated recycled aggregates are compared with natural aggregate which was given in the Table III. From the table 3 it was observed that all the physical properties of the recycled aggregates are inferior to the natural aggregate. This is because of the adhered mortar attached to the aggregate [6]. The physical properties of the treated recycled aggregates also inferior to natural aggregate but better than the recycled aggregate. This was mainly due to the less amount of adhered mortar content in the treated recycled aggregates.

D. Concrete Mixes

Prameetthaa et.al (2012) [18] has done investigation on the Cement paste and cement mortar by replacing different percentages of cement 0%, 4%, 8% and 12% by MBS as cement replacement material and reported that the optimum percentage of MBS was to be 8%. This optimum percentage of MBS was used in the recycled aggregate concrete to improve its performance. In this study, four concrete mixes were prepared and IS 10262: 2009 [19] method was adopted as design mix for these concrete mixes. Table IV shows the mix proportion for concrete mixes. The mixes M1, M2, M3, M4

TABLE IV. CONCRETE MIXES

Mix	Cement Kg/ m^3	MBS Kg/ m^3	W/B ratio	Coarse aggregate Kg/m^3			FA	SP in %
				NA	RA	TRA		
M1	309	-	0.55	1054	-	-	843	0.6
M2	309	-	0.55	-	953	-	843	0.7
M3	309	-	0.55	-	-	1027	843	0.7
M4	284	25	0.55	-	-	1027	843	0.9

denoted for control concrete, Recycled aggregate concrete, Treated recycled aggregate concrete and Treated recycled aggregate concrete with optimum percentage of MBS. The target strength of concrete at 28 days is 20 MPa, and its water-binder ratio is 0.55. Superplasticizer have been used to maintain the slump value is designed for 30-70 mm for the concrete. Mixing and Curing of the concrete specimens were performed as per IS standards.

E. Testing

A 100 mm x100mm cubes were tested at the age of 7, 28 days to compare the compressive strength of all the mixes and 100x200 mm concrete cylindrical specimens were tested at the age of 28 days to study the split tensile strength of all the mixes. Four point bending test was conducted on the plain concrete prism of size 100mmx100mmx500mm to compare the flexural strength of all the mixes. A cutting machine is used to prepare100x50 mm concrete cylindrical specimens at the age of 28 days to study the rapid chloride permeability and water absorption capacity for above mentioned four mixes. Testing of mechanical properties of the concrete specimens were tested as per IS 516-1959 standards and the durability properties of the concrete specimens were performed as per ASTM C642-13 and ASTM C1202 standards.

V. Results and Discussion

A. Compressive Strength

Compressive strength of various concrete mixes at the age of 7 and 28 days were reported in the Table 5. It was found that the compressive strength of concrete containing 100% recycled coarse aggregate (Mix M2) at the age of 28 days was 33.26 MPa which was 13.09% lesser than the strength of the control concrete. Based on the previous studies, the reason behind the reduction of the strength of the recycled aggregate was due to the influence of higher content of adhered mortar present in the aggreagates which is having higher porosity than the natural aggregates [6, 20]. From the Table V, it can observed that compressive strength of the treated recycled aggregate concrete (M3) was 7.04% higher than the recycled aggregate concrete (M2). This may be due to the removal of adhered mortar content by heating and rubbing method, but still it was 6.98% lesser than the control concrete. The compressive strength of the treated recycled aggregate concrete having 8% MBS (M4) was 13.45% higher than the treated recycled aggregate concrete (M3) and also which is 5.54% more than the control concrete. This indicated that the MBS increased the compressive strength of the recycled aggregate concrete by pozzolanic reaction. The silica content present in the MBS react with calcium hydroxide (CaOH2), which is a cement hydration product and it foms an additional CSH gel. This gel has an ability to fill the pores present in the recycled aggregate concrete, thus results in the higher compressive strength of the recycled aggregate [21].

B. Split tensile strength

The variation of split tensile strength of the various concrete mixes at the age 28 days was listed in the Table V.

TABLE V. MECHANICAL PROPERTIES

Mix	**Compressive strength MPa**		**Split tensile strength,**	**Flexural strength, MPa**
	7 day	***28 day***		

			MPa	
M1	32.82	38.27	3.06	4.61
M2	28.6	33.26	2.55	4.37
M3	30.12	35.6	2.95	4.54
M4	35.55	40.39	3.22	4.59

From the experiments, it was observed that the split tensile strength of the recycled aggregate concrete was lesser than the control concrete. Through visual inspection, it was observed that the failure in the control concrete and recycled aggregate concrete occurred along the interfacial zone between the cement mortar and natural aggregate but in the recycled aggregate concrete the failure occurs earlier than the control concrete. This may be due to the weak bond between the recycled aggregate, adhered mortar and new mortar. Treated recycled aggregate concrete gave better strength than the recycled aggregate concrete but still it was lesser than the control concrete. Treated recycled aggregates concrete having 8% MBS gave higher split tensile strength than all the mixes including control mix. This may be due to the additional CSH gel formation due to pozzolanic reaction which makes the weak interfacial transition zone between recycled aggregate, adhered mortar and new mortar strong. This was the reason behind the high split tensile strength for the mix M4.

C. Flexural Strength

Flexural strength test was carried out at the age of 28 days. The test conducted as per IS method. Table V shows the result of the flexural strength of all the mixes M1, M2, M3 and M4. The test results showed that the flexural strength of the recycled aggregate concrete was inferior to the conventional concrete. The cause for the lesser strength was due to the weak interfacial bond between recycled aggregate, adhered mortar and new mortar. But it was improved when treated recycled aggregate in the concrete mix. This was further improved when MBS was used in the mix. While doing experiment, the similar pattern of failure was observed for both control concrete and recycled aggregate concrete.

D. Rapid chloride permeabity

This test has been used to measure the rate of transport of Chloride ions in concrete. The chloride permeability test was conducted on all the mixes according to ASTM C1202-12[22]. Table VI shows the chloride permeability of all the mixes. The chloride permeability for the recycled aggregate concrete is more compared to the conventional concrete. This was mainly due to the porosity of adhered mortar present in the recycled aggregate concrete. The chloride permeability for treated recycled aggregate was better than the untreated recycled aggregate concrete. The MBS present in the recycled aggregate concrete mix was less permeable to chloride than the other mixes expect control concrete because of the filler effects of the MBS. As Ramezanianpour et.al [20] told, physical effect i.e filler effect of the MBS increase the packing of the solid material by filling the micro pores present in the recycled aggregate concrete. However, chloride permeability for all the mixes was moderate. So recycled aggregate concrete can be used in the chloride prone areas.

TABLE VI. CHOLORIDE PERMEABILITY

Mix	Charges Passed in amperes	Chloride Permeability
M1	2356	Moderate
M2	3764	Moderate
M3	3420	Moderate
M4	2973	Moderate

E. Water Absorption

Water absorption test were carried out on cylinder specimen according to ASTM C642-13[23]. The test results of all the mixes were shown in the Fig 1 and the variation of porosity of all the concrete mixes are shown in the figure 2. It was observed that the recycled aggregate concrete showed higher water absorption and more porosity than the control concrete. This was mainly due to the porosity of the adhered mortar attached to the aggregate. The water absorption of the treated recycled aggregate concrete was less compared to the recycled aggregate concrete. The reason behind this was less amount of adhered mortar present in the treated recycled aggregate. The water absorption of the mix M4 was lesser than M3. This was because of presence of MBS in the mix M4 which was acts as filler. Since it was a fine powder it can fill the micro pores present in the recycled aggregate concrete mix. This results reduction in the water absorption for the mix M4.

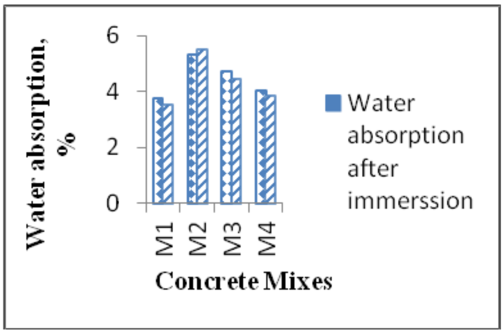

Fig. 1. Water absorption after immersion and after immersion and boiling

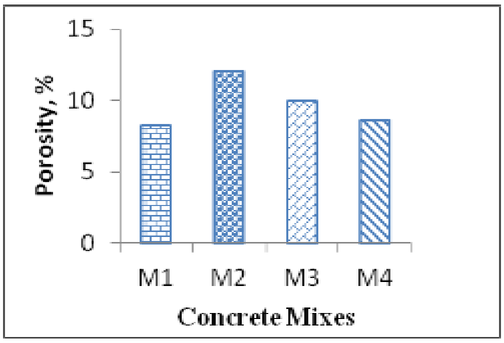

Fig. 2. Porosity of all the concrete mixes in percentages.

IV. SUMMARY

The study has shown the potential usage of waste material s like recycled aggregates from C&D wastes and micronized biomass silica (MBS) to produce a concrete similar to conventional concrete. The conclusion made from this research works are as followed.

1. The mechanical and durability properties of the recycled aggregate concrete were inferior to the conventional concrete.
2. Treated recycled aggregate concrete gave better performance than the recycled aggregate concrete. This was due to the less amount of mortar present in the treated recycled aggregate concrete.
3. Recycled aggregate concrete containing MBS gave higher strength than that of recycled aggregate concrete without micronized biomass silica.
4. MBS has an ability to lower the water absorption and chloride permeability of recycled aggregate concrete. This may be due to the filler effect of the MBS.

Thus, this study has been concluded that the drawbacks of the recycled aggregate concrete can be overcome by the incorporation of MBS in the recycled aggregate concrete as a cement replacement material.

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