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PHYSICAL AND MECHANICAL PROPERTIES OF RECYCLED AGGREGATES AND TREATED RECYCLED AGGREGATES

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Abstract: ***Construction and Demolition(C&D) waste is the major production of total solid waste production in the world and it is most of them used in landfills. After enormous research work by various researchers made on reusing (C&D) waste, proposals are made for the possibility of reusing such waste as aggregates in new concrete with and without suitable treating. In this paper, an attempt is made on the possibility of using C&D waste for concrete in place of natural coarse aggregates known as recycled coarse aggregate (RA). A brief overview and comparison studies are made on physical and mechanical properties of recycled aggregate with and without treatment for maximum utilization of recycled aggregate in concrete. Recycled aggregate was treated with epoxy resin to reduce the water absorption. Control concrete mix is prepared by using natural coarse aggregate and test concrete mixes are prepared replacing natural aggregate by recycled coarse aggregates with and without treatment in different percentages (20%, 30%, 40% and 50%). Tests are conducted on all concrete mixes for determining workability of fresh concrete and mechanical properties of hardened concrete like compressive strength, split tensile strength, flexural strength. The tests results are analyzed and presented.***

Key words: Natural Aggregates; Recycled Aggregate; Treated Recycled Aggregate; Epoxy Resin; Compressive Strength.

1. INTRODUCTION

Concrete is proved to be a leading construction material for the last century. It is estimated that the global production of concrete is at an annual rate of 2.4 billion metric tons in the year 2017. Worldwide consumption of natural aggregate is 48 billion tons in the year 2016. Over 3 billion tons of construction and demolition waste (C&D) is generated every year worldwide. The large-scale depletion of natural aggregate and the increased amounts of C&D going to landfill sites are causing significant damage to the environment and developing serious problems to the world. The public and the environmentalist's aspirations for a waste-free society. Pappu, Saxena et al., [1] presented 14.5 million tones/year C&D waste in India. CPCB (central pollution control board) estimated the solid waste generation in India 48 million tonnes per annum in the year 2000, out of which waste from construction industry accounted for about 12 to 14.7 million tones/ year, in 2016 total C&D waste produced was 23.75 million tonnes.

Construction demolition waste is now becoming a source of aggregates for new concrete production. The use of the recycled aggregates created from the processing of construction and demolition waste in new construction has become more important for the last two decades. There are many factors contributing to the availability of a new material and the damage caused by the quarrying of natural aggregate to the increased disposal costs of waste materials. Recently recycled aggregates(RA) started to be used for intermediate utility applications, such as foundations for buildings and roads. The advantages of recycling of construction and demolition waste are (1) reduction in the amount of construction and demolition waste entering landfill sites; and (2) reduction of utilization of natural resources for construction purposes (3) Contribution to the environment to providing a renewable source of construction material The advantages of recycling construction using demolition waste are (1) reduction of amount of construction and demolition waste entering landfill sites; and (2) reduction of utilization of natural resources in construction (3) Contribution to the environment, providing a renewable source of construction material, and, (4) reduction of haulage costs if used in-situ. There has been a growing global interest in maximizing the use of recycled aggregates in construction from economical and environmental reasons.

Preliminary study was conducted by chi-sun poon et al. [2] to investigate the possibility of using crushed brick and tile aggregate derived from construction and demolition waste stream as a replacement of fine aggregate in concrete. The effects of the using fine crushed brick and tile aggregate with 20 wt% replacement of natural sand on the fresh and mechanical properties are presented in his work. Kiyoshi Eguchi et al. [3] reported that as the replacement ratio increases, the compressive strength and elastic modulus decreases, and the drying shrinkage strain increases. However, by estimating the decrease in quality by the relative quality values and adjusting the replacement ratio, the quality required for the concrete can be secure. Wai Hoe Kwan et al. [4] stated about replacement level of the natural coarse aggregate with the RCA would reduce the compressive strength of the concrete. However, the replacement up to 30% is still acceptable to achieve the target strength and water absorption value is directly proportional to the level of the RCA replacement. A. Djerbi Tegguer [5] concluded that the water absorption coefficient of recycled aggregates for 24 h of soaking produces about 60% and 70% of the total water absorption obtained after 85h and 110 h of soaking for 12.5– 20 mm fraction and 5–12.5 mm fraction. P.Saravana kumar et al. [6] conducted studies on treated recycled aggregates and reported that the surface treatment by presoaking the recycled aggregates in acids significantly improves the properties of RA .The strength development of recycled aggregate concrete with treated RA was better than untreated RA. Ngoc Kien Bun et.al. [7] made comparision studies were made with 100% coarse recycled concrete aggregate and untreated RAC where improved results were reported with compressive strength up to 33–50%, splitting tensile strength 33–41%, and elastic modulus 15.5–42.5%. Shahiron Shahidan et al. [8] worked on recycled aggregates treated with epoxy resin and found to reduce water absorption and improve the fresh and hardened properties of recycled aggregate concrete. W.P. Lokuge et al. [9] has reported improvement in the compressive strength and flexural strength when various resin types (vinylester and epoxy) were used.

2. MATERIALS AND METHODS

2.1 Materials

Following materials are used in the present investigation:

2.1.1 Cement

Ultra tech Ordinary Portland cement of 53 grade were used in this project work. The physical properties of cement are given below table.1.

Table.1 Physical Properties of Cement Used

Property	**Results**
Standard Consistency	33%
Initial Setting Time	52 min
Final Setting Time	280 min
Specific Gravity	3.13
Fineness Modulus	3.2%

2.1.2 Aggregates

Natural coarse aggregates (NA) and recycled coarse aggregates (RA) are used in the concrete mixes. Crushed stones of Natural aggregates with a maximum size of 20mm are used in this project. RA was obtained by crushing locally available old concrete demolished structures waste . The physical properties of both NA and RA are shown in table.2. River sand is used as fine aggregate in this work. Specific gravity and bulk density of fine aggregates is 2.63 and 1673kg/m^3.

Table.2 Physical properties of NA and RA

Property	**Natural Aggregates(NA)**	**Recycled Aggregates(RA)**
Specific Gravity	2.80	2.53
Bulk Density	1535kg/m^3	1380kg/m^3
Water Absorption	0.75%	4.58%
Crushing Value	13.83%	29.12%
Impact Value	11.32%	25.46%

2.1.3 Epoxy Resin

Epoxy resin is used as the main binder material in polymer concrete and also used as a curing agent. Epoxy resin has two parts one part is resin and another part is hardener. Resin was based on Bisphenol A and hardener was epichlorohydrin. Epoxy resins are produced from combining bisohenol A and epichlorohydrin to give bisphenol A diglycidyl ether. These resin and hardener are fully mixed together for uniform molecular structure. The properties of epoxy resin in table.3.

Table .3 Properties of Epoxy Resin

Property	**Epoxy Resin values**
Viscosity	10000-12000mPa.s
Density	1.15-1.20gm/cc
Tensile Strength	35-38 kg/mm^2
Flexural Strength	45-50kg/mm^2

2.2. Treatment of Recycled Aggregates

Crushed C&D waste of aggregates is not directly used in new concrete because it has a porous structure. Due to this porous structure aggregates has more water absorption and less desirable physical properties of RA compared to the NA. To improve physical properties and reduce water absorption, RA are treated with epoxy resin. Initially, epoxy resin should be mixed together before treating of RA. Then aggregates are immersed into epoxy resin and dry it and then treated aggregates are directly used in concrete. The physical properties of treated RA are as shown in table. 4.

Table.4 Properties of treated Recycled Aggregates

Property	**Results**
Bulk Density	1450kg/m^3
Specific Gravity	2.58
Water Absorption	1.0%
Crushing Value	21.32%
Impact Value	20.43%

2.3. Mix proportions and preparation of specimens

2.3.1 Mix Proportions

Concrete Mix design as per IS:10262-2009 was adopted in this work for preparing nine mixes. Initially one conventional mix was prepared i.e. Mix-1 and reaming mixes were prepared with replacement of NA with RA (M-2 to M-5) and NA with treated RA (M-6 to M-9) in different percentages i.e. 20%, 30%, 40%, 50%. Here laboratory tests for workability of mix concrete with treated RA and without treated RA, and the hardened properties Compressive Strength, Split Tensile Strength , Flexural strength and water absorption ratio were tested. The mix proportions are shown in table.5.

Table.5 Mix proportions

Materials	**M-1**	**Without treated RA**				**With treated RA**			
		M-2 (20%)	**M-3 (30%)**	**M-4 (40%)**	**M-5 (50%)**	**M-6 (20%)**	**M-7 (30%)**	**M-8 (40%)**	**M-9 (50%)**
Cement(kg/m^3)	435	435	435	435	435	435	435	435	435
Water(kg/m^3)	197	197	197	197	197	197	197	197	197
FA(kg/m^3)	685	685	685	685	685	685	685	685	685
NA(kg/m^3)	1135	908	795	681	567.5	908	795	681	567.5
RA(kg/m^3)	_	227	340	454	567.5	_	_	_	_
Treated RA(kg/m^3)	_	_	_	_	_	227	340	454	567.5

2.3.2 Preparation of Specimens

Specimens were prepared as per IS: 519 (1959) for finding Compressive Strength and Flexural Strength. 150mm X 150 mm X150mm cubes for Compressive Strength and 100mm X 100 mm X 500mm beams for flexural strength were cast. Specimens of 150mmX 300mm cylinders were cast as per IS: 5816(1999) for determining Split Tensile Strength. For finding water absorption 150mm X 150 mm X 150mm cubes were used. All the specimens were cured for 28 days and then tested.

3. RESULTS AND DISCUSSION

Table.6 shows the test results on concrete specimens using recycled aggregates(RA) without and with treatment

Table .6 Fresh and Hardened Properties of Concrete

Test	M-1	RA without treatment				RA with treatment			
		M-2	M-3	M-4	M-5	M-6	M-7	M-8	M-9
Workability(slump value) (mm)	75	50	30	25	12.5	65	60	40	30
Compressive Strength(MPa)	47.7	42.4	41.1	38.9	37.4	45.2	43.9	41.9	40.1
Tensile Strength (MPa)	4.25	3.76	3.44	3.18	3.05	4.00	3.63	3.45	3.26
Flexural Strength (MPa)	5.36	4.38	3.92	3.03	2.97	4.63	4.02	3.52	3.05

3.1 Workability

Slump values of all concrete mixes are shown in table.6. The slump values are observed to decrease with increasing percentage of RA when compared to conventional concrete mix. The slump values of treated RA are better than those mixes with untreated RA. The variation of slump values are shown graphically in the below fig.1.

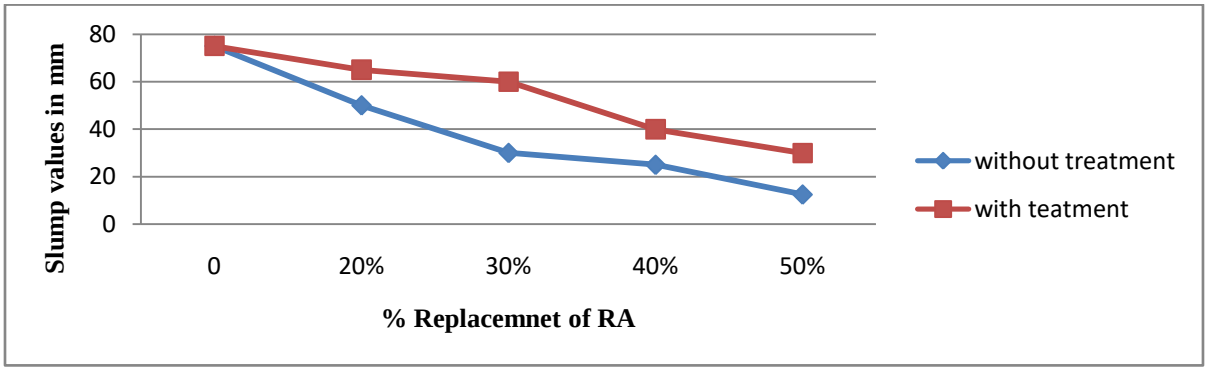

Fig.1 Variation of slump values with % replacement of RA

3.2 Compressive Strength

Compressive strength of conventional concrete is 47.70 MPA. Compressive strength of mixes with replaced of RA is found to be less than the mixes with natural aggregates. Fig.2. shows variation of Compressive Strength with % replacement of RA. 50% replacement of untreated R.A shows the reduction of the Compressive Strength up to 27%. But with 50% replacement of treated RA in mixes has reduced strength upto 18 %. The Compressive Strength of treated RA has increased from 7% - 10%.

3.3 Split Tensile Strength

The results of split tensile strength of NA and with untreated RA and treated RA are shown in fig.3. It can be observed that the concrete mixes made with RA are lower strength. The strength reduces by 8% - 40% with maximum replacement of 50% RA. Treated RA strength reduces by 6% - 30% with maximum replacement of 50% treated RA.

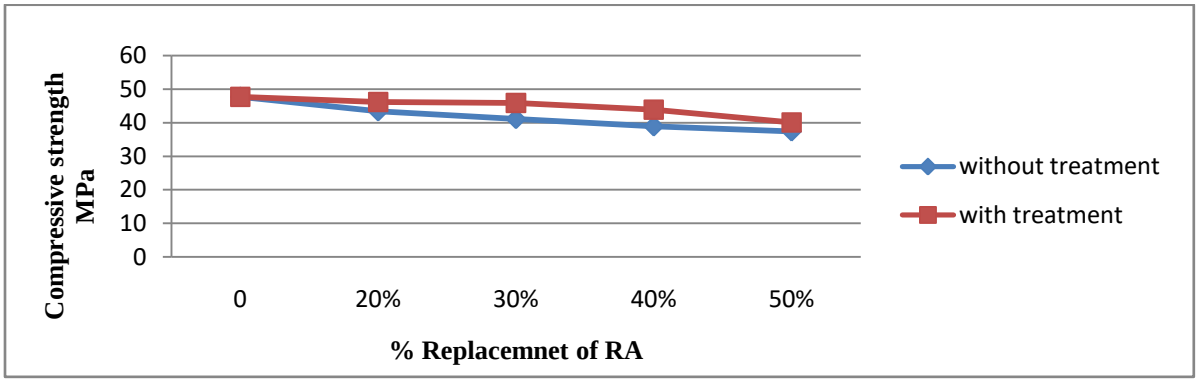

Fig.2 Variation Compressive Strength with % replacement of RA

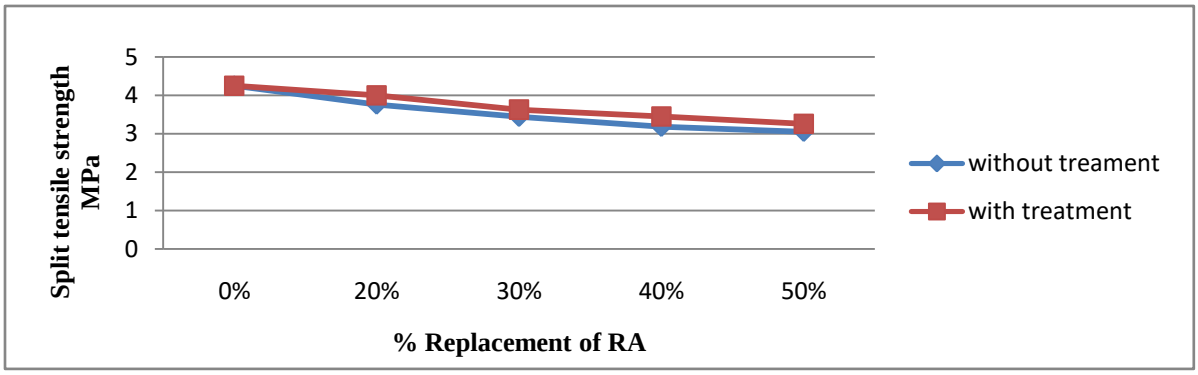

Fig.3 Variation of Split Tensile Strength with % replacement of RA

3.4 Flexural Strength

After 28 days of curing Flexural strength for conventional concrete is 5.36MPa. Variation of Flexural strength with percentage replacement of RA is shown in fig.4. The Flexural Strength is gradually decreasing with increase in percentage of RA. Concrete mix with treated RA has shown more flexural strength compared to untreated RA with a variation of 5 % to 12 %.

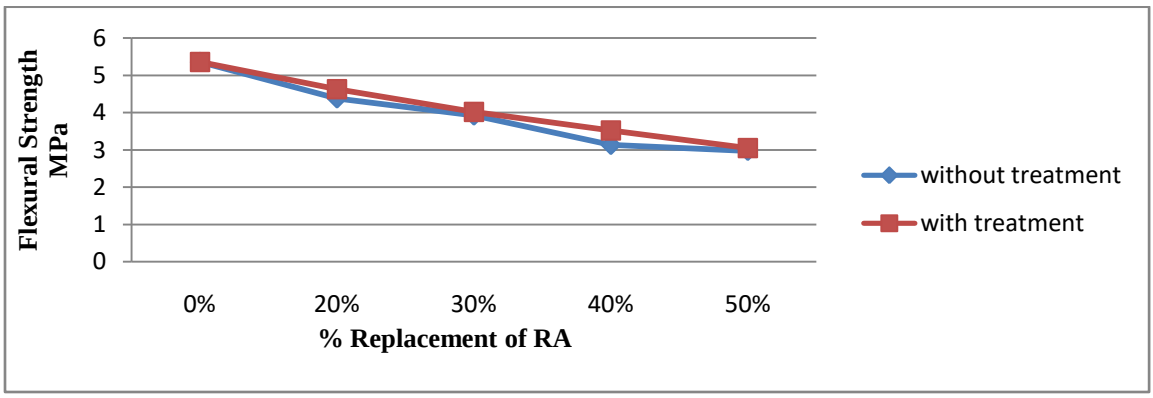

Fig.4 Variation of Flexural Strength with % replacement of RA

4. CONCLUSIONS

In this experimental study comparison of the physical and mechanical properties of recycled aggregates with and without treatment are made. The following are the concluding remarks are drawn:

1. Surface treatment of RA improves the physical properties like Specific Gravity, Bulk Density, Crushing Value, Impact Value and Water Absorption.
2. Effect is not reflected in Compressive Strength with 20% to 30% replacement of untreated RA and 40% replacement of Treated RA. Compressive Strength of treated RA is better than untreated RA but lower than NA.
3. The variation of Split Tensile Strength and Flexural Strength using untreated RA and treated RA is varying from 8% to 12%.

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