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Mechanical Properties of Concrete with Substitution of Fine and Coarse Aggregate by Waste Materials in Concrete

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***Abstract**: Paper Construction industry has been conducted various studies on the utilization of waste materials in concrete productions in order to decrease the usage of natural resources. This research paper exhibits the evaluation and the effective reuse of waste construction materials and industries, such as cuddapah waste aggregate as partial replacement of conventional coarse aggregate and copper slag as partial replacement of river sand (fine aggregate). Experiments were conducted to find out the mechanical properties of concrete such as compressive, splitting tensile, flexural strengths and the modulus of elasticity of concrete for waste materials aggregate concrete and to compare them with those of conventional aggregate concrete. Results appear that waste materials in concrete have the potential to produce good quality concrete mixtures.*

Keywords: Aggregate; cuddapah waste aggregate; copper slag; mechanical properties.

I. INTRODUCTION

The importance of sustainability and recycling has become mandatory in academia and industry over the last several years. Recycling construction and use of debris waste is one of the avenue that supply a great chance to prevent waste material from entering landfills and decrease the construction manufacture reliance on reducing natural resource supplies [1].The increasing request for green concrete has been stimulated by request for good quality concrete products, desire of nations to decrease green-house gas emission, necessity, for conservation of natural resources and insufficient landfill spaces [2]. Green'' or ''eco'' concretes have less effect on the environment, help in solving the problem of industrial tailing disposal and construction, and contribute to the protection of natural resources [3]. The waste materials can be reused in concrete manufacture like plastics, glass, and demolished .it can preserve natural resources, moreover helps solve a rising waste disposal crisis. The investigation exposed that the three types of waste materials can be recycled successfully as partial instead of coarse or sand aggregates in concrete mixtures [4]. Coarse aggregate, fine aggregate, cement and water are the main components of concrete that are obtained naturally. So we can replace some materials instead of natural sources such as M sand, copper slag, fly ash, etc [5]. Despite increasing amount of recycling copper slag, the large quantity of its annual production is rid in landfills or stockpiles until now. One of the most potential applications for recycling copper slag is in concrete manufacture and cement. The usage of copper slag in cement and concrete manufacture can be provided economic benefits as well as potential environmental for all related industries. [6]. Copper tailing was observed that It could be utilized for the partial substitution as fine aggregate (river sand) up to 60% replacement, with w/c 0.4, 0.45 and 0.50. The copper slag waste concrete (up to 60% substitution) exposed good durability and strength characteristics. [7]. Layer stone (Cuddapah slab) is using for floor works and roof. While processing of finished product, waste of cuddapah slab is producing and this waste is to be in and around the places that they are cut as per requirements. Concrete manufacture achieves innovations in replacement of various materials instead of natural fine and coarse aggregates [5]. The 40% replacement of cuddapah waste aggregate and copper slag instead both conventional aggregates is achieved the target strength as well as combined waste aggregate concrete. [7]

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II. EXPERIMENTAL PROGRAM

2.1. Materials

The portland pozzolana cement (PPC) of grade 53 is used for the experiments conforming to IS 8112-1989 [9]. The river sand was used as fine aggregate with specific gravity 2.60, fineness modulus 2.55 and water absorption 0.8%. The water absorption and specific gravity of coarse aggregates are 0.3% and 2.65, fineness modulus 7.89. The coarse and fine aggregates are obtained from the local area conforming to IS 383-1970 [10].

Cuddapah waste aggregate obtained from the remain of products cuddapah slab which were broken into small pieces about 100–150 mm by a hammer then put into a jaw crusher to get the required size 20 - 12.5 mm after sieved and are used to replace the conventional coarse aggregate . Figure [1] shows the process of preparation of cuddapah waste aggregate. The specific gravity and fineness modulus of cuddapah waste aggregate was 2.65 and 8.19, and water absorption 0.5% of cuddapah waste aggregate conforming to IS 383-1970 [10].

The copper slag is a by-product obtained through the manufacture of copper in copper industries. This copper slag sample is gathered from one copper manufacture located in Tuticorin, Tamil nadu, India. (Chemical compositions given in Table [1]) The specific gravity of copper slag used was 3.4, bulk density 2.97 g/cm^3 and moisture content 0.21% conforming to IS 383-1970 [10].

Figure1. Preparation of cuddapah waste aggregate

Table 1 Chemical composition of copper slag

S.No	Chemical Tests	Test Sample Result
1	SiO_2 %	32.81
2	Fe_2O_3 %	58.64
3	Al_2O_3 %	5.28
4	CaO mg/kg	544
5	MgO mg/kg	235
6	K_2O %	0.81
7	Na_2O %	0.52

2.2. Mix design and method

In this investigation was adopted concrete M25. The percentage replacement of waste materials (cuddapah waste aggregate as partial substitution of conventional coarse aggregate and copper slag as partial substitution of river sand fine aggregate) by weight of conventional aggregates. Concrete mixes proportioning is mentioned in the table [2]. The mix was designed as per IS 10262:2009 [11]. The mix ratio of M25 is (1: 1.48: 2.54) and w/c ratio is 0.45, the chemical admixture conforming to IS 9103-1999 [12], superplasticizer which is 8 ML by weight of cement was added to the concrete mixture.

Table 2 Replacement proportion of waste materials in concrete mixes

Concrete mixes	Fine aggregate %	Coarse aggregate %	Copper slag %	Cuddapah waste aggregate %
M_1 (Control mix)	100	100	0	0
M_2	100	60	0	40
M_3	60	100	40	0
M_4	60	60	40	40

2.3. Sample preparation and testing procedure

The four concrete mixes with different types of aggregate are described in Table [3]. The materials of concrete mixture were mixed in a concrete mixer. The total mixing time was around 6 min. the mixes were compacted using vibrator table. The slump test for the fresh concrete was carried out as per IS 7320-1974 [13]. The specimens were demoulded after 24 h, and then cured in water at the room temperature to keep them at the required age for hardened concrete tests. Six cubes of size (150 mm x 150 mm x150 mm) were prepared for every mixture to determine the compressive strength, and three specimens were tested after 7 and 28 days of curing. Three cylinders of size (150 mm diameter and 300 mm long) were cast for every mixture to find out the 28-days modulus of elasticity ,three cylinders of size (100 mm diameter and 200 mm long) were prepared for every mixture in order to find out the 28-days tensile (splitting) strength of concrete and three prisms of size (100 mm x 100 mm x 500 mm) were prepared and tested after 28-days of curing to find out the flexural strength (modulus of rupture).

All tests were performed as per IS 516-1959 [14] to determine compressive strength, flexural strength, splitting tensile strength and modulus of elasticity for all the mix proportions.

Table 3 Concrete mix proportions per cubic meter of concrete

Concrete mixes	Cement kg/m^3	Sand kg/m^3	Copper slag kg/m^3	Coarse agg kg/m^3	Cuddapah waste kg/m^3	Water kg/m^3	SP dosage Ml/kg
M_1	438.13	651.1	0	1115.42	0	197	8
M_2	438.13	651.1	0	669.25	446.17	197	8
M_3	438.13	390.7	260.4	1115.42	0	197	8
M_4	438.13	390.7	260.4	669.25	446.17	197	8

III. RESULTS AND DISCUSSION

The Properties of concrete mixes are presented in table [4]. The results presented in the table are the average of six tests.

3.1 Workability

The workability of concrete was assessed based on the measured slump of fresh concrete. It is shown from table [4] that the workability of concrete mixes contained copper slag (M3, M4) was increased in the workability compared to other concrete mixes.

3.2 Compressive Strength

Compressive strength results of concrete mixes at the age of 7 and 28 days of water curing age are illustrated in Figure [2]. The strength values are the average of three test samples. Compressive strength of all concrete mixes varied between 34.98 MPa and 41.2 MPa at 28 days, concrete mixes containing cuddapah waste aggregate partially replacement with conventional coarse aggregate M2 or copper slag partially replacement with fine aggregate M3 or both M4 are showed comparable with control mix M1 .

Table 4 Properties of concrete mixes

Concrete mix	Slump Test (mm)	Unit weight		Compressive strength		Splitting tensile strength MPa	Flexural Strength MPa	Modulus of elasticity GPa
		7 days (kg)	28 days (kg)	At 7 days (MPa)	At 28 days (MPa)			
M_1	70	8.270	8.460	18.8	34.98	2.39	4.8	22.62
M_2	60	8.450	8.500	24.93	36.83	2.39	4.4	18.2
M_3	100	8.420	8.490	24.62	36.9	3.34	8.4	19.8
M_4	90	8.510	8.540	31.1	41.2	3.12	6.8	22.1

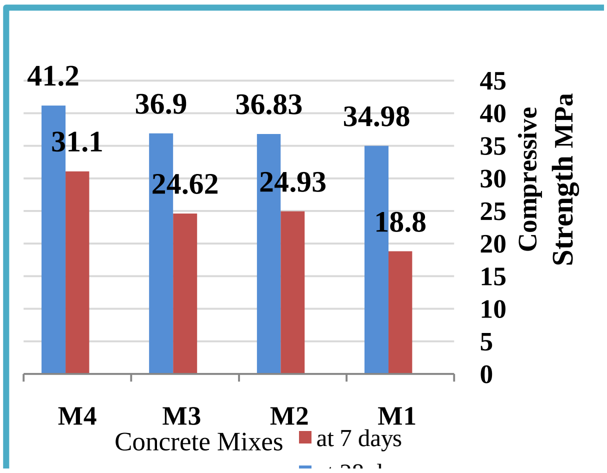

Figure 2 Compressive Strength

3.3 Splitting Tensile Strength

The results of splitting tensile strength are presented in Table 4 and Figure 3.The splitting tensile strength of cuddapah waste aggregate concrete (M2) was similar that of the control concrete mix (M1), but the value of splitting tensile strength of copper slag concrete (M3) and cuddapah waste aggregate with copper slag concrete (M4) as combined waste aggregate concrete were more than that of the control concrete mix. As presented in table [4].

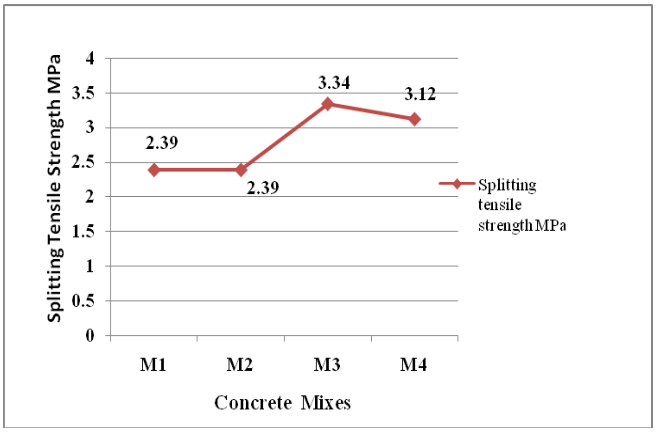

Figure 3 Splitting Tensile Strength

3.4 Flexural Strength

The results of flexural strength are presented in Table 4 and Figure 4. The flexural strength varied from 4.4 to 8.4 MPa. The flexural strength of cuddapah waste aggregate concrete (M2) was less than the other concrete mixes, but the flexural strength of concrete mixes contained copper slag (M3), (M4) were found to increase by 29.4% and 42.8% than the conventional concrete (M1).

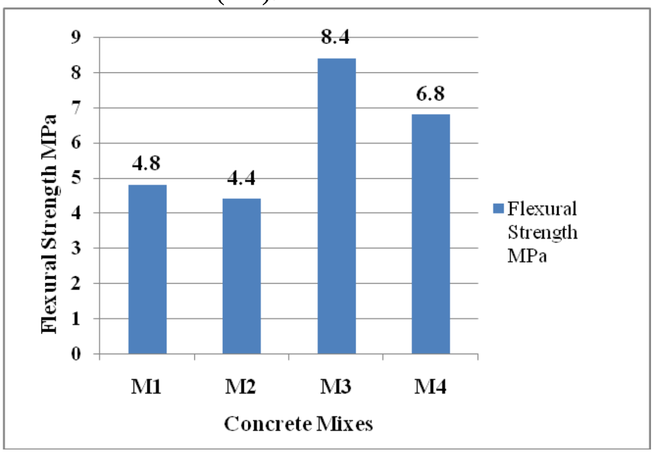

Figure 4 Flexural Strength

3.5 Modulus of Elasticity

The modulus of elasticity of concrete mixes varied from 17.6 to 22.62 GPa. The waste aggregate concrete M2, M3, M4 Lower than the control concrete mix M1 are 19.9%, 12.4%, 22.1% respectively.

IV. CONCLUSION

Based on the results obtained from the experiments the following conclusions are drawn:

Copper slag has been given more cohesive and workable in concrete, this is due to the lower water absorption and smooth surface texture of the copper slag.

The compressive strength of cuddapah waste aggregate concrete, copper slag concrete and combined waste aggregate concrete were achieved excellent strength of M25, they were increased by 32.1%, 32.2% and 39.3% respectively. It can be recommended that 40 wt% of cuddapah waste aggregate and 40 wt% of copper tailing can be used as instead of conventional coarse aggregate and river sand in order to obtain good properties.

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