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Investigation on Replacement of Fine and Coarse Aggregate by Waste Materials in Concrete

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ABSTRACT:- *This paper investigates the properties of waste materials in concrete of strength M25 using cuddapah waste aggregate as partial replacement of conventional coarse aggregate and copper slag as partial replacement of fine aggregate by focusing on its ability for compressive strength. For this purpose, seven mixes were prepared with different replacement ratio (0,10,20,30,40,50 and 100) by weight of cuddapah waste aggregate with coarse aggregate, and five mixes were prepared with different replacement ratio (20, 40, 60, 80 and 100) by weight of copper slag with fine aggregate. Tests were conducted on fresh and hardened concrete after a curing period of 7 and 28 days. The evaluation of concrete quality had done by Destructive and Non-Destructive tests. The results of experimental had been conducted that the 40% replacement of cuddapah waste aggregate and copper slag instead both conventional aggregate is achieved the target strength as well as combined waste aggregate concrete. The use of cuddapah waste aggregate or copper slag or both in concrete provide potential environmental as well as economic benefits for all related industries, particularly in areas where a considerable amount of both are produced.*

1. Introduction

Concrete which contains waste products as aggregate is called ‘Green’ concrete. Use of hazardous waste in concrete-making will lead to green environment and sustainable concrete technology and so such concrete can also be called as ‘Green’ concrete (1). The increasing demand for green concrete has been spurred by demand for high quality concrete products, desire of nations to reduce green-house gas emission, need for conservation of natural resources and limited landfill spaces (2). Green’’ or ‘‘eco’’ concretes have less impact on the environment, help in solving the problem of construction and industrial waste disposal, and contribute to the conservation of natural resources (3) . A modern lifestyle, alongside the advancement of technology has led to an increase in the amount and type of waste being generated, leading to a waste disposal crisis (4). On the one hand, there would be an economic and environmental saving because it would not need to deposit waste in landfills. On the other hand, there would be a further economic and environmental saving because it would reduce the need for natural aggregate (5). Cement, fine aggregate, coarse aggregate and water are important constitutes of concrete that are obtained naturally. So we can replace new materials instead of natural sources such as M Sand, fly ash, Metakaolin, etc (6). The investigation shows that the tested types of green concrete can be evaluated using the same accept criteria as for ordinary types of concrete (7). Copper slag, which is produced during pyrometallurgical production of copper from copperores contains materials like iron, alumina, calcium oxide, silica etc. For every tone of metal production about 2.2 ton of slag is generated. Dumping or disposal of such huge quantities of slag cause environmental and space problems. During the past two decades attempts have been made by several investigators and copper producing units all over the world to explore the possible utilization of copper slag. The favourable physico-mechanical characteristics of copper slag can be utilized to make the products like cement, fill, ballast, abrasive, aggregate, roofing granules, glass, tiles etc. apart from recovering the valuable metals by various extractive metallurgical routes (8). Copper slag is a by-product obtained during matte smelting and refining of copper. The common management options for copper slag are recycling, recovering of metal, production of value added products such as abrasive tools, roofing granules, cutting tools, abrasive, tiles, glass, road-base construction, railroad ballast, asphalt pavements. Despite increasing rate of reusing copper slag, the huge amount of its annual production is disposed in dumps or stockpiles to date. One of the greatest potential applications for reusing copper slag is in cement and concrete production (9). 40 wt% of copper slag can used as replacement of sand in order to obtain HPC with good strength and durability properties (10). The replacement of coarse aggregate by waste Shabath stone over the concrete had attained the good strength compared to that of conventional concrete (11). Construction industry has been conducted various researches on the utilization of waste products in concrete in order to reduce the utilization of natural resources. Layer stone (Cuddapah slab) is utilizing for roof and floor works. During processing of finished product, waste is generating and this waste is dumping in and around the places where they are cut as per customer’s requirements. Concrete production achieves innovations in substitution of different materials in the place of natural coarse and the fine aggregates

(6). Shabath (Cuddapah) is the slate rock which is metamorphic rock of greenish blue color and is used for the flooring of corridors (12).

2. Experimental programme

The experimental programme comprises the following three stages
1. Physical properties of cuddapah waste aggregate is found out by conducting series of tests.
2. Physical properties of copper slag is found out by conducting series of tests.
3. Optimization ratio of cuddapah waste aggregate instead of coarse aggregate in concrete and copper slag instead of river fine aggregate in concrete is arrived by conducting the series of tests . The experiment also studied the physical properties by conducting destructive and non-destructive tests, to find combined concrete mix between both replaced.

3. Materials

3.1 Cuddapah waste aggregate
Cuddapah slab wastes are normally big to be put into a crushing machine. They were broken into small pieces of about 100–150 mm sizes by a hammer. These small pieces are then put into a jaw crusher to get the required 20 mm to 12.5 mm size after sieved (Fig. 1).
3.2 Copper slag
Copper Slag (Fig. 2) is a industrial waste obtained from smelting and refining process of copper from Sterlite Industries Ltd (SIL), Tuticorin, Tamil Nadu, India. SIL is producing Copper slag during the manufacture of copper metal.
3.3 Other concrete mix components
The portland pozzolana cement (PPC) 53 grade conforming to IS 8112-1989 [13], locally available river sand and conventional coarse aggregate of maximum size 20 mm conforming to IS 383-1970 [14], superplasticizer (Tec MIX 550) conforming to IS 9103-1999 [15] .
3.4 Mix proportions
A concrete mix of strength M25 has been designed as per the procedure given in IS 10262:2009 [16]. The mix proportion of designed (1: 1.48: 2.54) with water-cement ratio of 0.45, the chemical admixture, superplasticizer which is 8 ML by weight of cement is added to the concrete .

The concrete mixes were labelled as M_1 (Control mix), six cuddapah waste aggregate concrete mixes were partially replaced with conventional coarse aggregate in ratio (10%, 20%, 30%, 40%, 50% and 100%) in five mixes (M_{c2}, M_{c3}, M_{c4}, M_{c5}, M_{c6} and M_{c7}) and five copper slag concrete mixes were partially replaced with fine aggregate in ratio (20% , 40%, 60%, 80% and 100%) in five mixes (M_{f1}, M_{f2}, M_{f3}, M_{f4}, and M_{f5}) as shown in Table 1, by optimized replacement for cuddapah waste aggregate instead of coarse aggregate in concrete and copper slag instead of river fine aggregate in concrete made combined concrete mix M.
3.5 Test details
The physical and mechanical properties of the cuddapah waste aggregate, copper slag, conventional coarse aggregate and fine aggregate were determined as per IS 2386 (Part I–VIII)-1963 [17].
To check the workability of cuddapah waste aggregate concrete, conventional coarse aggregate and copper slag concrete, slump test was conducted as per IS 7320-1974 [18]. For each mix, six cubes of size 150 mm were cast to determine compressive strength, the compressive strength with compression testing machine (CTM) was conducted as destructive at the age of 7 days and 28 days as per IS 516-1959 [19] and non-destructive (Ultrasonic pulse velocity test (UPVT) as per IS 13311 (Part 1)-1992 [20] and Rebound hammer as per IS 13311 (Part 2)-1992 [21]) was conducted at the age of 28 days for the greatest compressive strength of partially replaced cuddapah waste aggregate concrete as well as copper slag concrete and combined waste materials concrete. The specimens were demoulded 24 h after casting and were cured under water until the test age.

4 Results and discussion

4.1 Properties of materials
4.1.1 Properties of cuddapah waste aggregate
The properties of cuddapah waste aggregate are shown in Table 2. The surface texture of the cuddapah waste aggregate was found to be smoother than that of conventional coarse aggregate. In general, cuddapah waste aggregate showed properties close to those of conventional coarse aggregate.
4.1.2 Properties of copper slag
The properties of copper slag are shown in Table 3, the specific gravity of copper slag is about 3.4 g/cm^3, that means copper slag is denser than of river fine aggregates. In general, water absorption of copper slag is very low.

4.2 Properties of mixes concrete

4.2.1 Test on fresh concrete

The freshly prepared concrete mixes were tested for its workability by slump test , the tested were preformed as per IS 1199:1959. The slump of concrete mix M_1 (control mix) is 70 mm .

4.2.2 Tests on hardened concrete

In the present investigation, mechanical properties such as unit weight, quality of concrete and compressive strength by destructive (Compression Testing Machine-CTM) and non-destructive (Ultrasonic pulse velocity test (UPVT) and Rebound hammer test) were determined as per relevant Indian standards.

4.2.3 Destructive Test on hardened concrete

Table 4 presents the average of the compressive strength with compression testing machine (CTM) for concrete mixes at the age of 7 and 28 days of curing.

The compressive strength for concrete mix M_1 (Control mix) was found to be 18.8 MPa and 35.21 MPa at the age of 7 and 28 days respectively, The compressive strength of cuddapah waste aggregate concrete varied from 20.25 to 36.83MPa after curing period 28 days. Therefore, the compressive strength is increased gradually as the percentage of cuddapah waste aggregate is increased up to 40% (M_{c5}) of it then getting decreased, The compressive strength of copper slag concrete varied from 25.20 to 36.9MPa after curing period 28 days. The compressive strength is increased gradually as the percentage of copper slag is increased up to 40% (M_{f2}) of it then getting decreased. Hence the replacement of 40% cuddapah waste aggregate as well as copper slag are found to be optimized and effective to attain the strength of concrete , the compressive strength of combined concrete (M) was 31.1MPa and 38.6 MPa after curing period of 7and 28 days respectively. The promotion in compressive strength of concrete specimen at 28 days was found to increase by 4.32%, 4.58% and 17.8% for M_{c5}, M_{f2} and M respectively in comparison to control mix $M_{1.}$

4.2.4 Non-destructive Test on hardened concrete

A non-destructive testing method is a very unique method for evaluating the strength and integrity of concrete structure, without causing any deterioration. In this investigation, the following two methods are adopted (a) Ultrasonic pulse velocity test (UPVT) and (b) Rebound hammer test were conducted to M_1 (Control mix) , M_{c5} the highest compressive strength of cuddapah waste aggregate replaced by conventional coarse aggregate, M_{f2} the highest compressive strength of copper slag replaced by river fine aggregate and combined of replacement aggregate concrete M.

4.3.3.1 Ultrasonic pulse velocity test (UPVT)

In this investigation the measurement of pulse velocity is through surface transmission technique for the three concrete mixes are shown in Table 5. The pulse velocity of mixes M_1, M_{c5} and M were above 4.5 km/sec at 28-day curing, hence the concrete quality grading was 'excellent'. However for concrete mix M_{f2} the pulse velocity was 3.8 km/sec at 28-day curing, hence the concrete quality grading was 'good'. The qualities of cube specimen of all concrete mixes were found to be within the permissible limits as specified in relevant IS codes (IS 13311 (Part 1)-1992).

4.3.3.2 Rebound hammer test

The compressive strength was then obtained corresponding to the rebound number from The graph .In total 15 trial readings were taken on each specimen and their average was recorded, after a curing period of 28 days .

The compressive strength of concrete mixes were found to be as shown in Table 5 after 28-day curing period. Therefore, the basic trend in the behavior of waste aggregate concrete M_{c5}, M_{f2} and M are not significantly different from that of the conventional coarse aggregate concrete M_1.

4.3.4 Comparison of different types of concrete mix

Table 5 presents the results of destructive, non-destructive (Ultrasonic pulse velocity test (UPVT) and Rebound hammer test), unit weight and slump test. The promotion in compressive strength of concrete specimen at 28 days was found to increase by 5.2%, 5.5% and 17.8% for M_{c5}, M_{f2} and M respectively in comparison to control mix M_1. Non- destructive are shown no significantly different between values of mixes as well as unit weight of cube. M_{f2} and M were more cohesive and workable than $M_{1,}$ M_{c5}. This is due to the lower water absorption and smooth surface texture of the copper slag.

5. Conclusion

The following observation and conclusion can be made on the basis of the experimental results:

Cuddapah waste aggregate proves to be a good alternative to conventional coarse aggregate, the properties of cuddapah waste aggregate are well within the range of the values of concrete making aggregates.

The replacement 40% of coarse aggregate by cuddapah waste aggregate over the concrete has attained the good strength when compared to that of the conventional concrete.

The characteristics of copper slag has a good effective on fresh concrete and hardened concrete.

The compressive strength for higher percentage of copper slag i.e., 40%. It is almost higher result to conventional concrete mix. This is attributed that copper slag has high density than sand, so self-weight of concrete is increased.

Combined concrete mix has proved that it is given good results compared to others concrete mixes.

Table 1. Replacement proportion of waste materials in concrete mixes

Concrete mixes	Cement kg/m^3	Fine aggregate kg/m^3	Copper slag kg/m^3	Coarse aggregate kg/m^3	Cuddapah waste aggregate kg/m^3
M_1 : 0	438.13	651.1	0	1115.42	0
M_{c2}: 10	438.13	651.1	0	1003.88	111.54
M_{c3}: 20	438.13	651.1	0	892.34	223.08
M_{c4}: 30	438.13	651.1	0	780.79	334.63
M_{c5}: 40	438.13	651.1	0	669.25	446.17
M_{c6}: 50	438.13	651.1	0	557.71	557.71
M_{c7}: 100	438.13	651.1	0	0	1115.42
M_{f1}: 20	438.13	520.88	130.22	1115.42	0
M_{f2}: 40	438.13	390.66	260.44	1115.42	0
M_{f3}: 60	438.13	260.44	390.66	1115.42	0
M_{f4}:80	438.13	130.22	520.88	1115.42	0
M_{f5}:100	438.13	0	651.1	1115.42	0
M	438.13	390.66	260.44	669.25	446.17

Table 2. Properties of conventional coarse aggregate and cuddapah waste aggregate

Properties	Cuddapah waste aggregate	Conventional coarse aggregate
Water absorption 24h %	0.5	0.3
Specific gravity	2.65	2.73
Maximum size	20	20
Fineness modulus	8.19	7.89
Impact value %	10.78	8.03
Crushing value %	21.78	19.86
Bulk density kg/m^3 - Compacted	1490	1468
Bulk density kg/m^3 -Loose	1500	1580
Voids – loose %	43.56	46.23
Voids – Compacted %	42	42.12

Table 3. Properties of fine aggregate and copper slag

Properties	Fine aggregate	Copper slag
Specific gravity	2.60	3.4
Water absorption, %	0.80	0.14
Moisture Content, %	0.50	0.21
Fineness modulus	2.55	2.68
Bulk density, g/cm^3	1.67	2.97
Grading Zone	Zone II	Zone II

Table 4. The compressive strength of all concrete mixes

Concrete mixes	Average strength of 7 days (MPa)	Average strength of 28 days (MPa)
M_1: 0	18.8	34.98
M_{c2}: 10	16.34	28.83
M_{c3}: 20	17.87	27.94
M_{c4}: 30	21.14	30.37
M_{c5}: 40	24.93	36.83
M_{c6}: 50	21.44	30.63
M_{c7}: 100	18.93	20.25
M_{f1}: 20	22.5	35
M_{f2} : 40	24.62	36.9
M_{f3} : 60	23.20	34.70
M_{f4} :80	22.10	30.40
M_{f5} :100	18.60	25.20
M	31.1	38.6

Fig. 1. Cuddapah waste aggregate

Fig. 2. Copper slag

Table 5. The results of Non-Destructive tests of optimized proportion

Specimen 150mmxl50mmxl50mm - Cube	M_1	M_{c5}	M_{f2}	M
Avg of Rebound hammer no	20.27	20.13	20.8	21.2
UPV (km/sec)	4.51	4.53	3.8	4.57
Compressive strength (N/mm^2)	34.98	36.83	36.9	41.2
Weight (gm)	8460	8500	8490	8540
Slump test (cm)	70	60	100	90

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