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MECHANICAL PROPERTIES OF CONCRETE BY PARTIAL REPLACEMENT OF COPPER SLAG WITH CEMENT AND SAND

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Abstract—Cement and Sand(fine aggregate) are the major constituent materials that are used in the process of construction. Due to the increasing population and rapid increase in urban population, the need for cement and sand also increased to a huge extent. The production of cement and sand led to environmental pollution and degradation of the natural resources. Copper slag is conventionally used as an alternative for cement and sand. By which economy is obtained thereby reducing the rate of pollution. The strength properties were also obtained in a good range. This paper conveys the results obtained from the test.

Keywords—sand, cement, copper slag, pollution control, economy, copper slag, alternative, increased strength.

1.INTRODUCTION

The constituents of concrete are Cement, sand(fine aggregate) and gravel(coarse aggregate). Due to rapid urbanisation and increased constructional activities, the need for the materials increased to a huge extent. The production of Cement, led to a release of large amount of CO_2 which constituted to as a major causative for air pollution. Also the need for lime which is the chief constituent of cement, increased. The lime production led to the mining of the natural resources which caused enivornmental degradation. Also river sand is a major problem in the recent years, due to the increase in demand. The sand is also obtained as a process of mining, over exploitation of sand also leads to soil erosion and the environmental hazards, which may also lead to earthquake, liquefaction and other seismic problems. To overcome these problems, a suitable alternative must be used, as it is an alarming threat. In today's era major emphasis is given on making green and sustainable development. Copper slag is one among the major land pollutant. The copper slag has many properties similar to that of cement and fine aggregate(sand). The characteristic strength is also good when compared to that obtained in a nominal mix by cement. Except the fact that, the colour of copper slag is black whereas the color of cement is in lite grey. The copper slag is the waste product that is generated in the production of copper during the smelting process. Nearly 2.2Tonnes of copper slag is generated during the manufacturing of 1Tonne of copper. This copper slag waste is always disposed as a landfill, hence this can be utilized in the manufacture of concrete, by serving as a best tool in the disposal technique. Also the use of copper slag in the concrete gives characteristic strength of concrete in a good manner(both compressive and flexural strength).Copper slag is a by-product obtained during the matte smelting and refining of copper has been reported by Biswas and Davenport (2002). The major constituent of a smelting charge are sulphides and oxides of iron and copper. The charge also contains oxides such as SiO2, Al2O3 CaO and MgO, which are either present in original concentrate or added as flux. It is Iron, Copper, Sulphur, Oxygen and their oxides which largely control the chemistry and physical constitution of smelting system of hazardous wastes are generated in the State of which nearly 42,916,982 Metric tonnes are recyclable, 128,984.214 Metric tonnes are disposable and 10,072,612Metric tonnes is incinerable waste.Copper slag in concrete was very well suited in replacement of fine aggregate even upto 100%, so it imparts greater workability in the concrete. When it is partially replaced by cement alone, the rate of hydration was also decreased to an extent and also the workability of the concrete was also increased. Copper slag is an ideal material in the replacement of cement and fine aggregate partially.

2.LITERATURE REVIEW

1. Jagmeet Singh, Jaspal Singh, Manpreet Kaur/, "Use of Copper slag in Concrete" concluded that The workability of concrete increases as CS content increases. For 20% of CS, the workability increases by 8.21%. Copper slag is suitable as a perfect partial replacement ingredient for cement at an optimum percentage of 10.

2. Suresh T, Ravikumar C "INFLUENCE OF COPPER SLAG AS PARTIAL REPLACEMENT OF SAND IN CEMENT CONCRETE" concluded that Copper slag serves as an ideal perfect disposal technique. Copper slag sounds as a perfect additive for the production of conventional concrete.

3. Sachin P. L, N. Bhavani Shankar Rao/.,"Performance Study of Concrete using GGBS & Copper Slag as a Partial Replacement for Cement & Fine Aggregates" concluded that Water absorption for optimal mix (0.25) is less when compared with conventional concrete (0.39).
The compressive strength of concrete with partial replacement of sand by copper slag by 20% & cement by GGBS can be replaced by 15% has achieved 44.58 higher strength for 28-days when compared with control mix.

4. PranshuSaxena, Ashish Simalti," SCOPE OF REPLACING FINE AGGREGATE WITH COPPER SLAG IN CONCRETE "concluded that the workability was increase up to 31.57 for 100% replacement of copper slag as a fine aggregate. Maximum compressive, tensile and flexural strength is obtained when copper slag is replaced with fine aggregate up to 40%.

5. Prof. P.A. Shirule, AtaurRehman, Rakesh D. Gupta, "Partial replacement of Cement with Marble dust powder" concluded that the compressive strength of cubes increased upto 27.4% with addition of the marble powder upto 10% and further addition resulted in decrease in its compressive strength. Also the split tensile strength of cylinders increased upto 11.5% 10 % replacement of cement with marble powder. The initial strength gradually decreases from 15 % addition of marble powder."

6.R.Chitra, S.J.Mohan"REPLACEMENT OF CEMENT AND FINE AGGREGATE BY COPPER SLAG AND CERAMIC POWDER" concluded that As cement cost is going on increasing trend and fine aggregate demand is increasing day by day, the replacement of ceramic powder and copper slag for cement and fine aggregate proves to be economical and an also provides an efficient utilization of industrial waste.

7.Er. Tanpreet Singh and Er. Anil KumarNanda,"Influence of marble powder on mechanical properties of mortar and concrete mix" concluded that there is a marked reduction in compressive strength values of mortar mix with increasing marble powder content when compared with control sample at each curing age.

3.Materials and Properties:

3.1Test results of Cement:

- Fineness of cement = 2.33 % (OPC, 43 grade)-

Consistency % of water = 29 %

-Initial setting time = 40 minutes

-Final setting time = 480 minutes

-Specific gravity = 3.10

3.2 Test results of Fine aggregate

- Fineness modulus = 3.59
- Effective size, D10 = 0.70 mm; D60 = 1.30 mm
- Uniformity co efficient= 2.17
- Confirms to Zone-I
- Specific gravity= 2.48
- Bulk density= 1.697 gm/cc
- Percentage of voids= 31.65 %

- Max. percentage of bulking = 18 %
- Water content for max. % of bulking= 5 %

3.3 Test results of Coarse aggregate

- Fineness modulus = 4.33
- Effective size, D10= 12.00 mm

D60 = 24.00 mm

- Uniformity co efficient = 2.00
- Specific gravity = 2.73

3.4 Test results of Copper slag

- Colour- Black
- Appearance – Glassy, regularly shaped angular particles
- Specific gravity = 3.8 to 4.2
- Fineness modulus = 2.5 to 4.0
- Bulk density =2.31 gm/cc
- Absorption capacity = 0.12 %
- Consistency % of water= 23.10 %
- Fineness of residue = 78 % (after grinding)
- Initial setting time = 30 minutes

3.Table – 1 Comparison of Cement and Copper slag

S. No.	Property	Cement (Sastha cement, OPC, Grade 43)	Copper slag
1	Colour	Grey	Black
2	Specific gravity	3.1	3.8 to 4.2
3	Fineness (of residue)	3 %	78% (after grinding)
4	Chemical composition (Si O2 + Al2 O3 + Fe2 O3)	> 70 %	79.28 %
5	Total sulphur	< 1.0 %	0.90 %
6	Soluble Sulfate	< 0.6 %	0.04 %
7	So3	< 5.0 %	0.04 %
8	Humidity	< 3.0 %	0.00 %
9	Consistency	29 .0 %	23.1 %
10	Initial setting time	40 minutes	30 minutes

Composition	Fe_2O_3	Fe_3O_4	S_iO_2	CaO	S
%	55-60	< 10	27-33	3.5	0.2 – 1.5

3.6 Table -2 Chemical composition of copper slag

4.METHODOLOGY:

The compressive strength test, flexural strength test and acid attack were conducted on various samples including the conventional mix(M20), Cement with 15% Copper Slag&Fine Aggregate with 35% Copper Slag, Cement with 20% Copper Slag&Fine Aggregate with 40% Copper SlagAnd Cement with 25% Copper Slag&Fine Aggregate with 45% Copper Slag. The results were calculated and compared.

5.TESTS ON CONCRETE:

5.1 COMPRESSIVE STRENGTH TEST ON CONCRETE:

In reinforced concrete construction, the strength of the concrete in compression is only taken into consideration. The tensile strength of concrete is generally not taken into consideration. But the design of concrete slab and beam is often based on the flexural strength of concrete. Therefore, it is necessary to assess the flexural strength of concrete either from the compressive strength or

Description	7 days	28 days
Conventional Concrete	13.42	20.00
Cement with 15% C.S.& F.A with 35% C.S	16.00	24.00
Cement with 20% C.S.& F.A with 40% C.S	15.51	22.66
Cement with 25% C.S.& F.A with 45% C.S	15.15	23.00

independently.As measurements and control of compressive strength in field are easier and more convenient, it has been customary to find out the compressive strength for different conditions and to correlate this compressive strength to flexural strength. Having established a satisfactory relationship between flexural and compressive strength, flexural members can be designed for a specified flexural strength value, or this value could be used in any other situations when required. It is seen that strength of concrete in compression and tension (both direct tension and flexural tension) are closely related, but the relationship is not of the type of direct proportionality. The ratio of the two strengths depends on general level of strength of concrete. In other words, for higher compressive strength concrete shows higher tensile strength, but the rate of increase of tensile strength is of decreasing order.

Fig1: Experimental Compressive strength of Concrete

Table3: Comparison of Compressive strength of Concrete in 7 and 28days in N/mm^2.

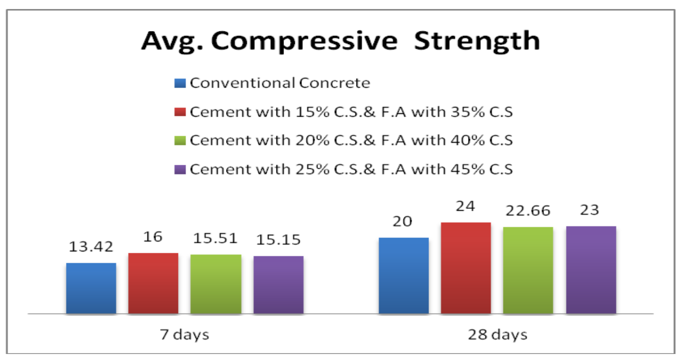

Fig2: Average Comparison of Compressive strength of Concrete in 7 and 28days in N/mm^2.

5.2 DURABILITY OF CONCRETE

In the past, only strength of concrete was considered in the concrete mix design procedure assuming strength of concrete is an all prevailing factor for all other desirable properties of concrete including durability. For the first time, this precious opinion was proved wrong in late 1930's when they found that series of failures of concrete pavements have taken place due to frost attack. Although compressive strength is a measure of durability to a great extent it is not entirely true that the strong concrete is always a durable concrete. For example, while it is structurally possible to build a jetty pier in marine conditions with 20 MPa concrete, environmental condition can lead this structure to a disastrous consequences. In addition to strength of concrete another factor, environmental condition or what we generally call exposure condition has become an important consideration for durability.

5.2 FLEXURAL STRENGTH OF CONCRETE

Experience shows that the variability of results is less in third-point loading. The results of the flexural strength tested under central and third-points loading with constant span to depth ratios of 4 were analyzed statistically and the following general relationship was obtained at Central Road Research Laboratory.

X1 = X2 + 0 .72

Where, X1 = flexural strength (MPa) of concrete under central point loading and

X2 = flexural strength (MPa) of concrete under third point loading.

In all the cases the central loading gave higher average value than the third-point loading irrespective of the size of the sample. The higher strength obtained in the case of central loading may be attributed to the fact that the beam is being subjected to the maximum stress at a pre-determined location not necessarily the weakest. In the standard methods for finding the flexural strength of concrete, the span to depth ratio of the specimen is kept at 4. If the span to depth ratio is increased or decreased, the flexural strength was found to alter a change in this ratio by one induced 3 per cent and.2.5 per cent change in strength when tested by third-point and central point loading respectively. With the increase in span to depth ratio the flexural strength decreased.

The rate of stress application was found to influence the flexural strength of concrete to a very significant extent. The strength increased up to about 25 per cent with increase in stressing rate compared to the standard rate of 0.7 MPa per minute. The increase was found more with the leaner mixes.

There are number of empirical relationships connecting tensile strength and compressive strength of concrete. One of the common relationships is shown below.

Tensile Strength = K (Compressive Strength) n

Where, value of K varies from 6.2 for gravels to 10.4 for crushed rock (average value is 8.3) and value of n may vary from 1/2 to 3/4

Further data obtained at the Laboratories of Portland Cement Association giving the relationship between compressive and tensile strength of concrete is shown in Table 4

The Indian Standard IS: 456 of 2000 gives the following relationship between the compressive strength and flexural strength.

Flexural Strength = 0.7 fck

The bond strength is also a function of specific surface of gel. Cement which consists of a higher percentage of C2S will give higher specific surface of gel, thereby giving higher bond strength. On the other hand, concrete containing more C3S or the concrete cured at higher temperature results in smaller specific surface of gel which gives a lower bond strength. It has been already pointed out that high pressure steam cured concrete produces gel whose specific surface is about 1/20 of the specific surface of the gel produced by normal curing.

Table4: Flexural Strength of Concrete

Therefore, bond strength of high pressure steam cured concrete is correspondingly low.

Durability of Concrete

In the past, only strength of concrete was considered in the concrete mix design procedure assuming strength of concrete is an all prevailing factor for all other desirable properties of concrete including durability. For the first time, this precious opinion was proved wrong in late 1930's when they found that series of failures of concrete pavements have taken place due to frost attack. Although compressive strength is a measure of durability to a great extent it is not entirely true that the strong concrete is always a durable concrete. For example, while it is structurally possible to build a jetty pier in marine conditions with 20 MPa concrete, environmental condition can lead this structure to a disastrous consequences. In addition to strength of concrete another factor, environmental condition or what we generally call exposure condition has become an important consideration for durability.

Description	Ultimate load in (kg)	Moment M=wl/4 (N.mm)	Section modules $Z=bd^2/6$ mm^3	Stress = (M/Z) mm^2
Permissible Stress				5.00
Cement with 15% C.S.& F.A with 35% C.S	1440	$2.70X10^6$	562500	4.80
Cement with 20% C.S.& F.A with 40% C.S	1230	$1.84X\ 10^6$	562500	3.28
Cement with 25% C.S.& F.A with 45% C.S	1120	$1.68X\ 10^6$	562500	2.98

Fig3: Flexural Strength Testing on Concrete-Single Point Load Test.

The flexural strength obtained by single point loading was most used when compared to the results obtained from the 3Point loading test. From the obtained results, the flexural stress of Concrete and its variation is represented in Fig4.

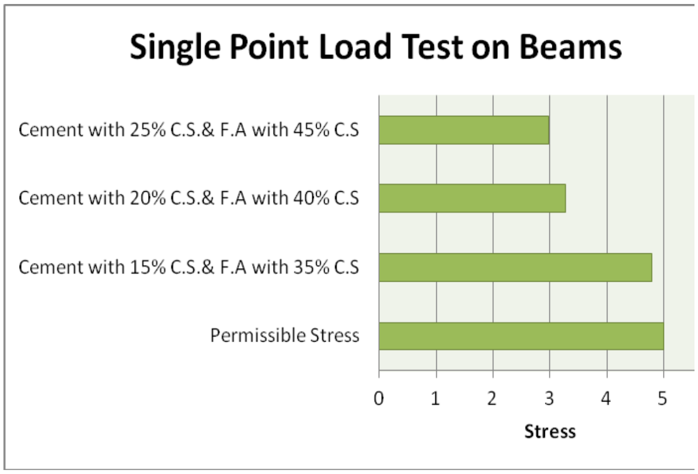

Fig4: Comparison of Single Point Load test on Beams with varying compositions used

5.3: ACID ATTACK TEST:

Concrete is not fully resistant to acids. Most acid solutions will slowly or rapidly disintegrate portland cement concrete depending upon the type and concentration of acid. Certain acids, such as oxalic acid and phosphoric acids are harmless. The most vulnerable part of the cement hydrate is Ca(OH)2, but C-S-H gel can also be attacked. Silicious aggregates are more resistant than calcareous aggregates.Concrete can be attacked by liquids with pH value less than 6.5. But the attack is severe only at a pH value below 5.5. At a pH value below 4.5, the attack is very severe. As the attack proceeds, all the cement compounds are eventually broken down and leached away, together with any carbonate aggregate material. With the sulphuric acid attack, calcium sulphate formed can proceed to react with calcium aluminate phase in cement to form calcium sulphoaluminate, which on crystallization can cause expansion and disruption of concrete.nIf acids or salt solutions are able to reach the reinforcing steel through cracks or porosity of concrete, corrosion can occur which will cause cracking.

Fig5: Acid attack Test on Concrete.

Procedure :

*Water about 8 liters taken in a bucket of 300mm diameter

*Concentrated Hydrochloric acid (HCL) is added at the rate 4% on water (ie. 320ml). Acid is stirred with water

*Concrete cube to be tested for acid attack is placed in the above bucket, after dry weight of the cube is taken.

*Weight of concrete cube after 1day, 3days, 7days, 28 days etc are taken in the Tabular form.

*The changes observed is less of weight in due course in contact with acid mixed water and the surface also eroded.

*Cement with 10% Copper Slag Cube is used

No. of Days	Weight (Kgs.)
0	8.550(Dry)
1	8.520(Wet)
3	8.565
7	8.510
28	8.495

Table5: Results of Acid Attack Test on Concrete

Conclusion:

1. The various mixes are made i)Cement with 15% Copper Slag.&Fine Aggregate with 35% Copper Slag ii)Cement with 20% Copper Slag.&Fine Aggregate with 40% Copper Slag iii)Cement with 25% Copper Slag.&Fine Aggregate with 45% Copper Slag.
2. The compressive strength was found to be 20% greater than in 15%cement replacement and 35% Fine aggregate replacement mix that of the nominal mix.
3. The flexural strength was also found to be greater in 15% Cement Replacement, 35% Fine Aggregate Mix compared to that of the nominal mix.

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