Strength Study of copper slag & Fly Ash With Replacement Of Aggregate's In Concrete For Roads

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Abstract - *Concrete is an extensively used material in the construction industry. Normally the concrete is made up of cement, sand and coarse aggregate at the appropriate ratio as per the requirements. The cement used in the preparation of concrete has its own detrimental effect on health and the environment. Sand is a natural building material that depletes fast due to excessive usage. Sand mining done for construction purposes has its own impact on the environment. Hence there has been a concerted effort to substitute the cement and sand through alternate technologies. Thus, the primary objective of this research is to propose optional strategies to combat the problems of excessive sand usage by industrial waste/by-products and agro wastes.*

For the experimentation purpose, the industrial by-products namely fly ash, and copper slag was used in this research work. The activation of fly ash was carried out with different concentrations of sodium hydroxide (10 M, 12 M, 14 M and 16 M) and the effect of concentration of NaOH, the different proportions of copper slag as a substitute for sand and the curing conditions were taken as the validation parameters.

The experimental investigations were conducted to examine the suitability of copper Slag as fine aggregate in High Strength Concrete flexural members (Beams). The parameter considered for this research was the replacement to natural sand by Copper Slag at 25%, 50%, 75% and 100%, in M40, M60 and M80 grades. For Rigid pavement (concrete samples of rectangular cross section were cast five boxes in each grade with similar reinforcement and of same sizes, tested under uniformly increasing static applied load at 1/3rd points. The load–deflection curve at mid-span and Moment–Curvature based on deflection under the loads and at mid-span were analysed. The load carrying capacity of the beams made of 100% copper slag as fine aggregate performed well when compared with the control concrete beam alytical modelling is developed by using Regression analysis to evaluate the strength of the geopolymer concrete with copper slag/sand.

Key Words: copper slag , Fly ash ,Aggregates ,sand etc

1. INTRODUCTION

Concrete is the most versatile and commonly used building material. Cement is a major pozzolanic constituent for concrete production, as conventional concrete typically contains 10 to 30% of cement paste and the remaining are filler material like fine aggregates and coarse aggregates (sand, gravel, crushed rock).Currently, concrete consumes a large amount of natural resources such as sand, crushed stones and limestone as filler material and binder, that leads to several environmental impacts such as deforestation, depletion of natural resources, a drastic reduction in the water retaining sand strata, and disturbance to the vegetation and aquatic life affecting the ecosystem. As per the report of National Institution for Transforming India (NITI) Aayog on the Strategy on Resource Efficiency Survey 2017, 1.4 billion tonnes of sand will be required for the construction sector by the year 2020, in India.

Hence, the consumption of a huge amount of sand may lead to the biggest ecological disasters in the environment like lowering of the water table and erratic changes in the ecology.

In recent years, rapid industrialization has led to the generation of huge solid waste, causing environmental problems such as land pollution, deforestation, and water loss. . The world's annual cement production is approximately 1.6 billion tonnes, which accounts for approximately 7% of worldwide carbon dioxide, loading into the environment . The production also consumes an enormous quantity of electricity during manufacturing and grinding process . Fly ash from coal-based thermal power plants is one of the major industrial waste/by-products that cause environmental issues by altering the patterns of land use in and around these power plants and causes air pollution. The awareness in the construction industry had risen to address the above problems. The sustainable solutions the usage of geopolymer binder triggers the fabrication and usage of environmentally friendly building products, that would significantly decrease global warm

1.1 LITRATURE AND REVIEW

Before also reduced the chloride ion penetrability.

- Rahul Sharma and Rizwan A (2019) Khan investigated the Self Compacting Concrete (SCC) with copper slag as fine aggregate, the fly ash, and silica fume as a supplementary cementitious material. The copper slag replacement was at the increment of 20%. They reported that the compressive strength and splitting strength had improved, compared to the control mix for Copper slag substitution. The Scanning Electron Microscope (SEM) micrograph study reveals the formation of uniformly distributed and compact C-S-H gel for the copper slag substituted concrete.

- Das et al. (1983) studied the geotechnical properties of copper slag and found out that the copper slag is generally similar to medium sands as far as maximum, minimum and average void ratio; permeability; and compressibility are concerned. The minimum and maximum unit weights of oven dried samples were determined in the laboratory to be 1779.4 kg/m3 and 2180.2 kg/m3 respectively. The void ratios corresponding to the maximum and minimum dry unit weights were found to be 0.468 and 0.8 respectively. The angle of friction of shearing resistance of the slag is generally higher than that of sand. This is because of the angularity of the slag particles. It is generally about 53 degrees. Based on EPA toxicity tests, it appeared that the copper slag is a non hazardous waste as far as the groundwater pollution potential is concerned as it does not contain any organic materials. Copper slag is black in colour .

- Kaniraj and Gayathri (2003) investigated the effect of cement content stabilized with fly ash at different curing period to their use as pavement base materials. For any cement content, the unconfined compressive strength (UCS) increased at a certain curing period and then decreases after. The rate of increase in strength was high till about 14 days, decreased drastically during 28–90 days, and became very small.

- Patel et al. (2007) investigated the engineering properties of copper slag mixed with different percentage of fly ash (20, 25, 30, 35 and 40%) and the CBR value was found at 32 for the mix of 80% slag and 20% fly ash. With increasing fly ash content, CBR value decreasing from 32 to 13. The mix consisting of 30% fly ash and 70% copper slag was chosen for the construction of embankment and subgrade. The cost saving in this project by using copper slag and fly ash was reported as Rs 8.22 lacs per km of road.

- Havanagi et al. (2007 and 2008) studied the geotechnical properties of copper slag- fly ash mix as a road construction material. The copper slag is also known as poor sand in grade . Its specific gravity was found to be 3.22. The copper slag was mixed with fly ash in the range of 0 to 100% with 25% interval. The result of modified proctor test and soaked CBR test are shown in Figs. 2.1 and 2.2, respectively. In the case of copper slag-fly ash mixes, the increase in CBR is predominant only after the slag content reaches 50%. The CBR value of copper slag fly ash mix with 75% copper slag content satisfied the MORTH criteria (20-30%) for use in the subbase layer of road pavement. The angle of internal friction of copper slag-fly ash mixes was determined as 390 to 360 from Direct Shear test in saturated condition.

- Toohey et al. (2013) investigated the stress-strain-strength behavior of four lime- stabilized fine grained soils subjected to 23°C (normal) and 41°C (accelerated) curing. Table 2.2 shown the comparison of different curing period. Specimens cured at 41°C reached qu values equivalent to 28 day 23°C qu after 1.8–5.9 days. The 7-day 41°C accelerated curing regime overestimates 28-day normal curing qu by 13–256%. The 5- day 41°C curing produced qu values within 0.90–1.94 of 28-day 23°C qu.

- Sinha (2009) investigated the strength properties of blast furnace slag (BFS) and granulated blast furnace slag (GBFS) under cyclic loading conditions for their use in the subbase layer of a flexible pavement. The cyclic triaxial tests were conducted at three confining pressures .At 10000 load cycles the permanent strain of BFS is very high as compared to that of GBFS.

1.2 METHODOLGY AND MATERIAL USED

In this study, the materials used for the preparation of geopolymer concrete in this research work are

- Fly ash
- Fine Aggregate
- River Sand
- Copper Slag

- Fly Ash

is an industrial by-product, which is rich in silica and alumina collected from the Tuticorin Thermal Power Plant, Tamil Nadu, India . The ash appears dark grey in colour and spherical shapes of different diameters. The chemical composition obtained by X-Ray Fluorescence (XRF) of the collected fly ash is shown in Table 3.1. It is evident that fly ash belongs to Class F category as the sum of $SiO_2 + Al_2O_3 + Fe_2O_3$ is found to be higher than 70% (As per ASTM C 618).

- Copper slag

Copper slag and sand is used as a fine aggregate. The physical properties such as specific gravity, water absorption, sieve analysis, particle size distribution and the chemical composition were analysed using XRF and are presente. The microscopic analysis was also performed to determine the shape and angularity of copper slag and sand. The mineral and crystalline characteristics of the source material were studied through the XRD analysis and reported.

- River Sand

The locally available river sand is used as the filler material, and it was partially replaced with copper slag. To remove the larger sized particles, aggregates were sieved through 4.75 mm IS sieve and it was used for the geopolymer concrete manufacturing.

- Coarse Aggregate

The hard broken granite stone of 12 mm size was used as the coarse aggregate in the manufacturing of geopolymer concrete. The specific gravity, bulk density, water absorption, and void ratio were found as 2.74, 1420 kg/m3, 0.45% and 0.95 respectively.

2. TESTS AND RESULTS

California bearing ratio (CBR)

The soaked CBR values obtained for different FAL mixes and FAC mixes after 7 days curing and 4 days soaking are given in Table The broad trends observed for CBR values and the reasons for these trends are similar to those described earlier for UCS values.

Mixes	CBR (%)	Mixes	CBR (%)
FA6L	64	FA6C	58
FA9L	89	FA8C	73

Durability characteristics

The loss of dry weight for FA6L, FA9L, FA6C and FA8C mixes are obtained as 17.1%, 16.2%, 17.8% and 16.6%, respectively. Hence, all the four mixes satisfy the criterion for the maximum permissible percentage loss in weight (= 30%) recommended by IRC: 89 (2010) for the stabilized mix to be used in pavement subbase course.

Lime (%)	Dry weight of sample (gm)			Cement (%)	Dry weight of sample (gm)		
	Initial	Final	% Loss		Initial	Final	% Loss
6	292	240	17.1	6	308	258	17.8
9	301	252	16.2	8	305	256	16.6

Durability

To ensure the minimum utilization of binder (lime and cement) the CFL mixes with maximum 6% lime and CFC mixes with maximum 6% cement which satisfied the minimum strength criteria recommended by IRC: 37-2012 were subjected to the durability tests.

The observations for the variation of durability test results with different CFL and CFC mixes are opposite to the broad trends observed for the UCS values. The higher the

UCS values the higher will be the resistance against the disintegration of the slag and fly ash particles, and the lower will be the percentage loss in dry weight. The maximum permissible percentage loss in dry weight for the cemented base materials is 14 % as per IRC: 37 (2012). The CFL mix with 6% lime content and CFC

The percentage loss in dry weight of the specimens obtained after 12 wetting and drying cycles is given in Table

Initial dry weight (gm)	Final dry weight (gm)	Loss in dry weight (%)	Mix proportions	Initial dry weight (gm)	Final dry weight (gm)	Loss in dry weight (%)
544	453	16.7	90CS-10F-4C	561	464	17.3
514	433	15.8	80CS-20F-4C	512	432	15.6
465	394	14.5	70CS-30F-4C	469	390	16.9
429	355	17.3	60CS-40F-4C	421	344	18.2
390	319	18.2	-	-	-	-
541	491	9.2	90CS-10F-6C	551	508	7.8

3. CONCLUSIONS

Engineering properties of copper slag-fly ash-lime (CFL) and copper slag-fly ash-cement (CFC) mixes were investigated for their utilization as base course material in flexible pavements. The following conclusions are drawn:

- As the fly ash percentage in the CFL and CFC mixes increases, the compressive strength increases up to the optimum fly ash content and decreases thereafter. The optimum fly ash content for CFL and CFC mixes was found to be 30% and 20%, respectively. Beyond the optimum percentage fly ash simply serves as weak filler in the mix resulting in a decrease of strength and stiffness. The variation of indirect tensile strength as well as resilient modulus follows the same trend as that of UCS for the variation in fly ash content.
- UCS values increase continuously with increase in binder (lime and cement) content.
- The gel formation increases with an increase in binder content leading to a more efficient binding of the slag particles. For a given fly ash and binder content, UCS values as well as IDT and Mr values of CFC mix were found to be lower than that of CFL mix. This may be due to the lower specific surface area of cement as compared to that of lime.
- A linear correlation between IDT and UCS was observed with a good R2 value for both the mixes. The IDT value was found to be 17.3% and 18.1% of UCS value for CFL and CFC mixes, respectively
- CFL mixes with 6% lime content and CFC mixes with 6% cement content satisfy both the UCS and durability criteria suggested by Indian Road Congress and hence, recommended for use as base course material in flexible pavement.
- Resilient modulus of all the CFL and CFC mixes was found to be increased with an increase in W-D cycles. As a result of strain hardening phenomenon Mr value increases with the increase in deviator stress. Most of the CFL and CFC mixes exhibited higher resilient modulus than WMM indicating that a lower thickness of base layer can be adopted if WMM is replaced with the CFL and CFC mixes.
- The main drawback of the two parameter model is its in capability of separating the effect of confining pressure and deviator stresses on resilient modulus for the prediction of Mr. Higher values of coefficient of determination were obtained using the three parameter model, which separates the effect of confining pressure and deviator stress on Mr values.

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