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USE OF GROUND GRANULAR BALLAST SLAG (GGBS) & COPPER SLAG IN PAVEMENT QUALITY CONCRETE MIX

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Abstract - Increasing Industrialization & Infrastructure development leads to production industrial waste & increase consumption of concrete. Cement is the widely used binding material in concrete and it's over exploitation of cement has led to various harmful consequences. Similarly, the increased demand of aggregates has impact on environment as quarrying is done for aggregates. Increasing waste from industries is becoming burden to environment as it needs to be dump in lands. Instead of dumping in ground it should reuse as per their properties & uses. In this study, Pavement Quality Concrete (M40 grade) mix has been designed with the help of Ground Granulated Blast Furnace Slag (GGBS) & Copper slag (CS) which are industrial waste. GGBS is used as cement replacement and Copper slag as fine aggregate replacement due to their similar properties. Different material properties & hard concrete properties such as Workability, Compressive strength and flexural strength are tested for concrete mixes which have partial replacement of cement & fine aggregate by GGBS & Copper slag as (40%-40%, 50%-40%, 50%-50% & 60%-50%). Strength of concrete increases up to replacement of GGBS50%-CS40% after that it starts reducing the strength. Thus the alternative material GBBS and Copper slag can be partial replacement with cement and fine aggregate.

Key Words: GGBS, Copper slag, Strengths, Sustainable, Cost Effective

1. INTRODUCTION

India is a developing country. Rapid infrastructural growth plays an important role in the growth of country. Road covers large part of infrastructural growth. It helps to connect places on ground level so that transportation becomes faster and easier. So the infrastructural growth is becoming essential. It is also important to construct good quality roads with achieving economy & no harm to environment. This growth of construction industry demands large number of raw material for the construction purpose. Concrete is mainly used for construction, it is consists of cement, aggregates & water. Increasing demand of these materials is leading to increase their impacts on the environment because the process or the source of getting these materials isn't sustainable.

Cement is an unsustainable resource. Manufacture of the cement consumes a huge quantity of raw material, energy and heat. The process emits CO_2 in the atmosphere. Increasing production of cement causes increase in CO_2 emission. CO_2 is a greenhouse gas which leads to global warming. Cement industries contributes 7-9% globally in carbon emission. For aggregates quarrying is done, which leads to use of natural resources. Quarrying can be very destructive to the environment. It results in open spaces, air & sound pollution, loss of land, etc. As we know we have limited natural resources so we have to conserve them.

However, environmental sustainability is at stake both in terms of damage caused by the extraction of raw material and CO_2 emission during cement manufacture. Therefore the material with good concrete properties & sustainability need to use in concrete mix and should find their acceptability in concrete is essential. Industrialization produces waste, some part of it can be used elsewhere but a huge amount of it is not in use, which remains as waste only. Management of the waste is becoming one of the most challenging problems in the world. To solve these problems we can try to use industrial waste (Slag) as construction material. The consumption of slag in concrete not only helps in reducing greenhouse gases but also helps to making it environmentally friendly.

Studies on many different types of material such as Fly ash, Fly ash, Nano Silica, Silica fume, Steel Slag, Copper Slag, GGBS, GBFS, etc. had been carried out on the use of construction material in civil engineering field. These materials may be naturally occurring, industrial wastes or by-products that are less energy intensive & sustainable. Lately some attention has been given to the use of GGBS & Copper slag as a possible partial replacement for cement & fine aggregate. GGBS is the Ground Granular Blast Furnace slag is a by-product of the iron manufacturing industry. It is having similar chemical composition as cement so it can partially replace cement. Also Copper Slag is a byproduct from copper industry. As per the statistics, manufacturing of one ton copper leads to generate 2.25 tons of copper slag. As copper slag is less reactive we can use it as fine aggregates in pavement.

By recycling the industrial waste, we can save the environment and money to build the disposal for it. Dumping of waste materials causes natural and medical issues, so that use of industrial Slag as construction material is a good alternative. Use of these sustainable materials as construction material has many good effects as load of waste on earth is minimized, dumping problem will be solved, and use of waste will help to reduce environmental impact of conventional construction material.

2. METHODOLOGY

Pavement Quality Concrete (PQC) was designed for M40 grade. To maintain standard materials and testing of material was conducted as per IS codes. The concrete mix design for pavement grade concrete mix was done as per IRC: 44 & MORTH specifications. All the material collected and tested for their physical properties as per respective IS Codes. Then gradation had done for fine & coarse aggregate to find the right mix proportion. Using all the required data concrete mix designed was prepared.

Concrete mixes prepared for control mix & for partial replacement of Cement with 40, 50, 60% GGBS & Fine aggregates with 40 & 50% Copper slag. Fresh & hard properties of concrete tested for different mixes. By trial & error method concrete mix tested for slump. Mix with required slump filled in the mould & set for 24hrs. After 24hrs specimens were demoulded & kept for curing. Compressive specimen checked for 7th, 28th & 60th day & flexural strength of specimen checked for 28th & 60th day. Test reports of conventional mix compared with mixes using GGBS & CS.

The Experimental investigation is planned as follows.

1. Finding the properties of the materials.
2. Gradation.
3. Preparing Mix Design for PQC of M40 grade.
4. Obtaining the mix proportions for partial replacement of cement & fine aggregate with GGBS & Copper Slag such as 40% - 40%, 50% - 40%, 50% -50% and 60% - 50% respectively.
5. Preparing concrete specimens such as cubes for compressive strength, beam for flexural strength.
6. Curing of specimens.
7. Evaluating the mechanical characteristics of concrete such as compressive strength, flexural strength of specimens for 7, 28 and 60 days.
8. Comparison of the results.
9. Conclusion.

2.1 Chemical Composition of Ground Granular Ballast Slag

The main components of blast furnace slag are CaO (30-50%), SiO_2 (28-38%), Al_2O_3 (8-24%), and MgO (1-18%). In general increasing the CaO content of the slag results in raised slag basicity and an increase in compressive strength. Concrete made with GGBS cement sets more slowly than concrete made with ordinary Portland cement, depending on the amount of GGBS in the cementitious material, but also continues to gain strength over a longer period in production conditions. This results in lower heat of hydration and lower temperature rises, and makes avoiding cold joints easier

2.2 Physical Properties of GGBS & Cement

GGBS is off white in colour. Specific gravity has range of 2.85-2.95. GGBS have less specific gravity compared to cement. It is a hydraulic cement, i.e. it has the property of setting and hardening through chemical reaction with water. GGBS is very fine material. Fineness of GGBS is greater than cement. Fineness of GGBS leads to have more surface area. It helps to improve mobility of concrete. GGBS have relatively low density as compared to cement.

Table -1: Physical Properties of GGBS & Cement

SR. NO.	PROPERTIES	GGBS	CEMENT
1	Colour	Off white	Grey
2	Specific gravity	2.9	3.15
3	Fineness (by sieving on 90µm)	0.78 %	8.5 %
4	Fineness (Blain's air permeability)	386 m2/kg	302 m2/kg
5	Bulk density	1.29 gm/cm3	1.48 gm/cm3

Fig -1: GGBS

Consistency, Initial & Final Setting time & Compressive strength of mortar cubes results were checked for 40%, 50% & 60% GGBS with cement. Consistency results shows increment with increasing GGBS content but results are within the cement consistency limit. It is due to more fineness of GGBS.

Table -2: Consistency Results

Sr. No.	MIX	Consistency (%)
1	100% Cement	29.25%
2	60% Cement - 40% GGBS	30.20%
3	50% Cement - 50% GGBS	30.95%
4	40% Cement - 60% GGBS	31.75%

Use of GGBS in concrete shows increase in initial & final setting time of concrete with increasing GGBS contents. As GGBS have lower heat of hydration which indicates GGBS reacts slowly with water as compare to cement, which

influences the setting time of concrete. An extended setting time is advantageous to keep concrete workable for longer period and there will be less risk of cold joints. Small reduction in water content. Even though there is increase in consistency results, experimental study also shows reduction in water/binder ration. Reduction in water/cement ration can lead to less water consumption.

Table -3: Initial & Final Setting Time Results

Sr. No.	MIX	Avg. Initial Setting Time	Avg. Final Setting Time
1	100% Cement	117.5	254.0
2	60% Cement - 40% GGBS	139.0	267.0
3	50% Cement - 50% GGBS	147.0	285.5
4	40% Cement - 60% GGBS	164.0	312.0

Addition of GGBS in proportion with cement tends to increase compressive strength. As per results we can see that upto 50% replacement of GGBS increases it compressive strength after that it starts reducing, but all the mixes having compressive strength within the requirement.

Table -4: Compressive Test Results

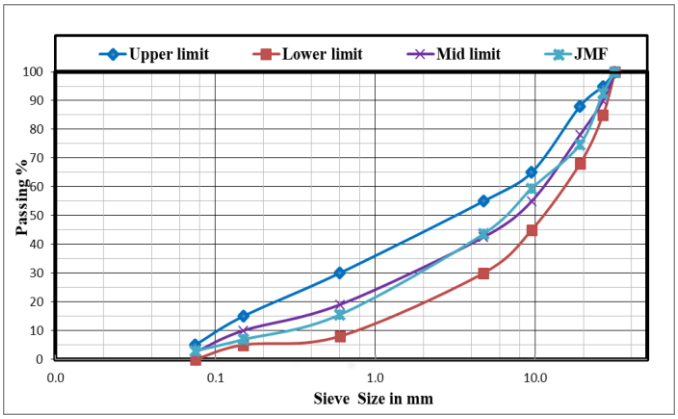
Sr. No.	MIX	3 Days	7 Days	28 Days
1	100% Cement	35.04	44.3	52.32
2	60% Cement - 40% GGBS	36.74	52.24	72.89
3	50% Cement - 50% GGBS	36.57	53.11	73.13
4	40% Cement - 60% GGBS	31.97	46.94	60.89

Fig -2: Mortar cubes for Compressive Test

2.3 Gradation

Sieve analysis for fine aggregates was done as per Table 2 of IRC 44. Copper Slag comes under zone II of fine aggregates, therefore we can use copper slag as fine aggregates. Max. nominal size of aggregate taken was 31.5mm. Aggregates taken in Proportion of 26.5mm – 20%, 20mm – 17%, 10mm – 25% & Fine aggregate – 38%. Results of Combine Gradation as per MORTH Table 600-3 shows that blending comes between upper & lower limit as per specified in MORTH.

Graph -1: Blending of Aggregates



2.4 Properties of Course aggregates

The Coarse aggregates used were from Terav quarry Chiplun. Aggregates for mixed were tested for their physical properties like AIV, Specific Gravity, Water absorption & Shape Test. As before preparing mix design properties of mix should be known.

Table -5: Physical properties of Course Aggregates

Sr. No.	Properties	Aggregate Sizes		
		26.5mm	20mm	10mm
1	Type	Crushed	Crushed	Crushed
2	Particle shape	Irregular	Irregular	Irregular
3	Specific gravity	2.850	2.815	2.794
4	AIV	13.08%		
5	Water absorption	1.652%	1.757%	1.626%
6	Combined FI&EI	27.95%		

2.5 Properties of Fine Aggregates

The Crushed Sand & Copper Slag used as fine aggregates were from Terav quarry Chiplun & Sai Enterprises, Chakan respectively. Copper Slag appears black in colour with glassy surface & irregularity of particle shape. Copper slag has similar gradation as sand, therefore it is use to replace sand. Aggregates for mixed were tested for their physical properties like Specific Gravity, Water absorption & Silt content. Result shows that Copper slag has more specific gravity compare to crush sand & less water absorption. Which means Mix having copper slag will have denser concrete & will require less water. Less water requirement is a big beneficial factor towards water conservation. Also the slit content of copper slag is less than crush sand.

Table -6: Physical properties of Fine Aggregates

Sr. No.	Properties	Crushed Sand	Copper Slag
1	Colour/Type	Crushed	Black & glassy
2	Particle shape	Irregular	Irregular
3	Specific gravity	2.651	3.19
4	Water absorption	2.686%	0.75%
5	Silt Content	3.00	1.75

Fig -3: Copper Slag

2.6 Mix Design

PQC mixes were designed for M40 grade by using necessary information. As flexural strength of pavement quality is important, mix design of PQC is based on flexural strength of concrete. First mix design was prepared with the help of IRC: 44 & MORTH for 100% cement & 100% crush sand content & then mix were prepared with percentage of GGBS & Copper slag added in the mix in proportion with cement & sand respectively. Percentage of GGBS & Copper slag used in the mix was 40% - 40%, 40% - 50%, 50% - 50% & 50% - 60% respectively.

First we prepared 100% cement mix with 0.36 w/c ratio but didn't get the required workability so we increased it to 0.38 so that will get workability for 100% cement mix. As use of GGBS &Copper slag in mix reduces water content so we used 0.36 w/c ratio for all mixes prepared with GGBS & Copper slag. Superplasticizer 1.2% was used to get desired workability for all the mixes. Cement content was taken 380kg/m^3. The mixes were prepared for low cement contents & water but good strength requirement. Proportions are given in Table 3. Using these mix proportions, mixes were prepared to cast specimens for testing compressive strength, flexural strength & Workability of all the mixes was determined. 9cubes & 6 beams of each mix were prepared to check compressive strength at 7, 28 & 60days & flexural strength at 28 & 60days respectively.

Fig -4: Preparation of Concrete Mix

Table -7: Mix Design Proportion

MIX DESIGN PROPORTIONS FOR 1 CUM										
Sr. No.	**Description**	**W/C Ratio**	**Cement (kg/m3)**	**GGBS (kg/m3)**	**Sand (kg/m3)**	**Copper Slag (kg/m3)**	**26.5 mm (kg/m3)**	**20 mm (kg/m3)**	**10 mm (kg/m3)**	**Water (kg/m3)**
1	**100% cement**	0.36	380	0	698.9	0	401.8	343.2	501.8	136.8
2	**100% cement**	0.38	380	0	691.6	0	397.7	339.6	496.5	144.4

3	**GGBS 40 - CS 40%**	0.36	228	152	417.1	352	399.7	341.4	499.1	136.8
4	**GGBS 50 - CS 40%**	0.36	190	190	416.3	351.4	399	340.7	498.2	136.8
5	**GGBS 50 - CS 50%**	0.36	190	190	347.0	439.2	399	340.7	498.2	136.8
6	**GGBS 60 - CS 50%**	0.36	152	228	346.5	438.6	398.4	340.2	497.5	136.8

3 RESULTS & DESCUSION

3.1 Workability

The PQC must have sufficient workability. For manual and fixed-form methods of laying of concrete, the workability should be around 50-60 mm of slump & if concrete is paved using a fully automatic slip-form paver, the requirement of slump is 25±15 mm. The slump value of all the PQC mixes was determined and the values are given in Table 4. The slump cone values indicate that workability of the concrete mix increases with increase in GGBS & Copper slag at all levels. Workability majorly gets affected by increase or decrease in Copper slag content as compare to GGBS.GBBS also has impact on workability but in less proportion as compare to copper slag. As to maintain workability of 100%cement we need to increase w/c ratio from 0.36 to 0.38, but all other mixes didn't require to increase the w/c ratio. Which indicates use of GGBS & Copper slag helps to reduce water content & also maintains workability at minimum w/c ratio as compare to 100% cement mix.

Table -8: Results of Slump Cone Test

SLUMP CONE TEST OF CONCRETE				
MIX DETAILS	**SLUMP**			
	Initial	**30min**	**60min**	**90min**
100% cement (0.36 w/c)	25	0	0	0
100% cement (0.38 w/c)	80	65	35	15
GGBS 40- CS 40%	95	70	40	20
GGBS 50- CS 40%	100	80	55	20
GGBS 50- CS 50%	105	85	65	30
GGBS 60- CS 50%	110	90	75	35

3.2 Compressive Strength Test

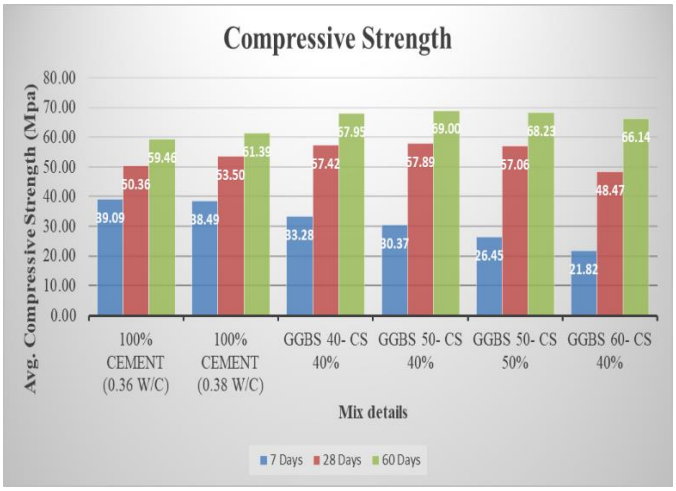
The compressive strength of the concrete cube test provides an idea about all the characteristics of concrete. Compressive strength is the ability of material or structure to carry the loads on its surface without any crack or deflection. Nine cubes of size 15 X 15 X 15cm from each mix were prepared to check Compressive strength at 7^{th}, 28^{th} & 60^{th} day.

Results are given in Table 5. It was observed that at 7^{th} day concrete mix with GGBS & Copper slag content does not gain the required strength as compare to mix of 100% cement. But results on 28 & 60^{th} day we can see there is increase in strength. Mix with 50% replacement of GGBS & 40% replacement of Copper slag gives max results as 57.89mpa at 28^{th} day & 69mpa at 60^{th} day. As GGBS & copper slag content increases compressive strength increases upto 50%GGBS & 40% Copper slag replacement then it starts reducing the strength. However, other mixes also have good strength as compare to 100% cement mix but due to further increase in GGBS & Copper slag content it increases the free water content which leads to reduction in strength. Thus, it can be concluded that, though, most optimum replacement of OPC by GGBS is 50 % & Crush Sand by 40% Copper Slag. We can replace OPC by GGBS & crush sand by copper slag without compromising the strength requirement of the mix.

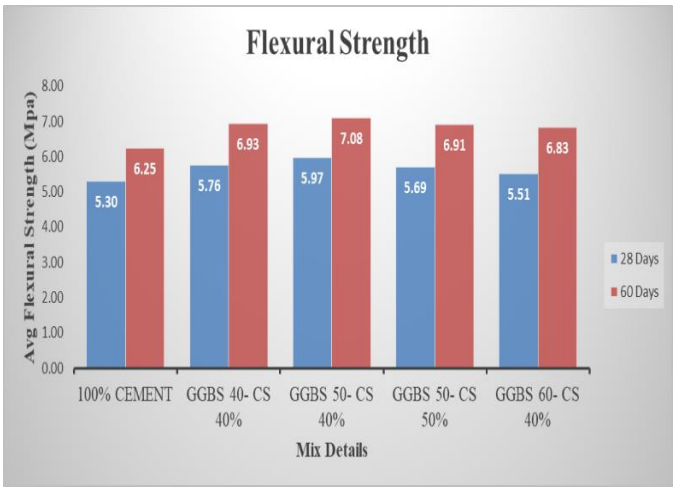
Table -9: Results of Compressive Strength Test

Sr. No.	**Mix details**	**Avg. Compressive Strength (Mpa)**		
		7 Days	**28 Days**	**60 Days**
1	**100% cement (0.36 w/c)**	39.09	50.36	59.46
2	**100% cement (0.38 w/c)**	38.49	53.50	61.39
3	**GGBS 40- CS 40%**	33.28	57.42	67.95
4	**GGBS 50- CS 40%**	30.37	57.89	69.00
5	**GGBS 50- CS 50%**	26.45	57.06	68.23
6	**GGBS 60- CS 50%**	21.82	48.47	66.14

Graph -2: Compressive Strength



Graph -3: Flexural Strength



3.3 Flexural Strength Test

Pavement slab undergoes bending due to wheel load, therefore flexural strength is important in case of pavement quality concrete. Referring to the flexural strength results shown in Table 7, it shows flexural strength of mixes increases as the percentage of GGBS & Copper slag increases upto certain limit. The maximum flexural strength of mix was 5.97MPa and 7.08MPa at 28th and 60th day respectively, which was achieved by GGBS 50% & CS 40% mix after that increase in percentage of GGBS & Copper slag shows reduction in strength. We can also see that flexural strength results for all the GGBS & Copper slag mixes were greater than the 100% cement mix. It means that use of GGBS & Copper slag in concrete mix has good impact on flexural strength.

Table -9: Results of Flexural Strength Test

Sr No	Mix details	Avg. Flexural Strength (Mpa)	
		28 Days	60 Days
1	**100% cement**	5.30	6.25
2	**GGBS 40- CS 40%**	5.76	6.93
3	**GGBS 50- CS 40%**	5.97	7.08
4	**GGBS 50- CS 50%**	5.69	6.91
5	**GGBS 60- CS 50%**	5.51	6.83

Fig -4: Cube & Beams of trail mixes.

4. CONCLUSIONS

Ground Granular Ballast slag & Copper slag both are industrial waste with good concrete material properties. So we can use them in Pavement Quality Concrete mix.

1) GGBS has less specific gravity so the less density as compare to cement. It has more fineness, therefore consistency of GGBS mix concrete is more compare to the normal concrete.
2) Initial & Final setting time increases in GGBS mix concrete due to its low heat of hydration, which may lead to low setting time but it can be beneficial in cold joints & minimizing thermal cracks.
3) GGBS mix concrete shows good compressive strength results for mortar cubes, which indicates use of GGBS improves the compressive strength.
4) Copper slag & crush sand both comes under zone II of fine aggregate. Copper slag is less reactive as it has low CaO contents. Therefore copper slag can be used as fine aggregate.
5) Copper Slag has higher specific gravity & low water absorption compare to crush sand, which indicates concrete

mix using copper slag will require less water content & concrete will have more density.

6) Concrete mix using GGBS & Copper Slag has less water demand than control mix concrete mix. It also provides required workability. Workability increases with increase in GGBS & Copper slag content in mix.
7) GGBS & copper slag mix concrete shows good strength results for compressive & flexural strength. Replacement upto 50% GGBS & 40% Copper Slag gives us higher strength results. Strength increases upto GGBS 50% - CS 40% then it starts reducing its strength, but all the GGBS & Copper slag mix shows good strength compare to 100% cement mix.
8) Use of GGBS & Copper slag also contribute to environment as use of GGBS instead of cement will reduce carbon footprints, large energy consumption, mining for raw material & use of copper slag as sand will help to conserve natural sources of sand.

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