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Review on Industrial Waste Materials as a replacement for Construction Material.

Rupali Thanage[1], Kunal Pawar[2]

[1]M.tech, Department of civil Engineering, Sandip University Nashik
[2]Assistant Professor, Department of civil Engineering, Sandip University Nashik

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Abstract – *Infrastructure development leads to increase consumption of concrete. Concrete is commonly used in construction industry. As a result the concrete industry demands large number of construction materials. Concrete mix is consist of 70-75% of aggregates, 10-15% of cement & remaining will be water & air entrained. Cement is a binding material. Cement performs a vital role in the construction industry due to its strength and other properties; therefore it is very important construction material. The cement manufactured by a complex process involving multiple ingredients, but this process leads to consume more energy & also effect on environment as it releases Co2 gas. Hence an alternative material for cement is required which will lead to the decrease in the production of CO2 & energy consumption. Similarly, the aggregates have impact on environment as quarrying is done for aggregates. As we have limited natural sources we need to conserve them. This requirement is drawn the attention of investigators to explore new replacements of ingredients of concrete. The present technical report focuses on investigating characteristics of concrete with partial replacement of cement with Ground Granulated Blast furnace Slag (GGBS) & sand with Copper Slag. Ground Granular Ballast Slag & Copper Slag is the industrial waste.*

Key Words: **Cement, GGBS, Copper slag, Strengths, Sustainable.**

1. INTRODUCTION

Construction industry is growing rapidly with the development of country. Now a days use of concrete is increased everywhere. So the material require for concrete mixture i.e. Cement, aggregates, water are in very much demand. Cement is the main constituent in concrete as it plays the role of binding material. Also aggregates cover a large part of concrete mix. But cement & aggregates are unsustainable material as mining is done for raw material used in cement manufacturing industry & for aggregates too. Manufacture of the cement consumes a huge quantity of raw material, energy and heat. This 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. Therefore, the material with great cement & aggregates properties & which is sustainable too needs to study as cement replacement or by partially replacing it with cement & aggregates. GGBS & copper slag being a waste material, it needs proper method for disposal. So incorporating this waste material in concrete can reduce the depletion of conventional concrete components such as cement & aggregate.

1.1 Ground Granular Ballast Slag

Ground granular ballast slag is an industrial by-product from iron industry. Normally it is designated as 'GGBS'; it can also be referred to as 'GGBFS' i.e. *Ground Granular Ballast furnace Slag*. GGBS is obtained by quenching molten iron slag. Ground-granulated blast furnace slag is highly cementitious and high in CSH (calcium silicate hydrates) which is a strength enhancing compound which improves the strength. Blast-furnaces operate at temperatures of about 1,500°C and are fed with a carefully controlled mixture of iron ore, coke and limestone. The iron ore is reduced to iron and the remaining materials form a slag that floats on top of the iron. This slag is quenched by using water jets; the quenching optimizes the cementitious properties and produces granules similar to coarse sand. This 'granulated' slag is then dried and ground to a fine powder known as *Ground Granular Ballast Slag* (GGBS).

1.2 Cement

Cement is used from many years in construction industry. Cement is finely ground powders that, when mixed with water, it becomes hard. Hardening of cement is due to heat of hydration. Cement is strong in compression. Portland cement consists essentially of compounds of lime (calcium oxide, CaO) mixed with silica (silicon dioxide, SiO_2) and alumina (aluminum oxide, Al_2O_3). Cement is good in compressive stress.

1.3 Copper Slag

Copper slag is a by- product from copper industry. It is a black glassy and granular in nature and has similar particle size range like sand. When copper is manufactured it settles down due to its density but impurity stays in above layer. This slag is then quenched in water which produces angular granules which are further crushed to use or disposed of as waste.

2. LITERATURE

Khalifa S. Al-Jabri, Makoto Hisada, Salem K. Al-Oraimi & Abdullah H. Al-Saidy (2009), studies the effect of copper slag by replacing copper slag with fine aggregate in HPC (High Performance Concrete). Eight concrete mixes were prepared, by replacing 0% - 100% of sand with copper slag in mix. Effect on workability, density, strength of concrete studied. Workability increases with increasing CS percentages. Density also increases with increasing CS percentages as CS has more specific gravity than sand. Water absorption for CS is less so it demands less water in mix. It leads to free water content in mix which increases workability of mix. With increasing CS% upto 40% surface water absorption decreases, after that it increases rapidly. All the strength parameter shows good results when sand is replaced with 50% of copper slag. [1]

M. Pavan Kumar & Y.Mahesh (June 2015), studies the behavior of concrete, when cement & fine aggregate replaced with GGBS & CS. Study is done for M25 mix with 0.45 w/c ratio. Replacement of cement with GGBS (10%, 20%, 30% and 40%) and fine aggregate with CS (5%, 10%, 15% and 20%) was done in mix and properties of fresh & hard concrete were tested. Result shows that replacement of GGBS & CS by 30 & 15% gives higher strength but replacement by 40 & 20% also provides good strength results than control mix for compressive, split tensile & flexural strength. [2]

Zine Kiran Sambhaji & Prof.Pankaj B. Autade (June 2016), Study of workability, durability & strength of copper slag has been done by replacing sand in M25 grade concrete mix by different percentages of copper slag from 0 to 100%. As per results 30 & 50% of copper slag replacement shows higher results. Also we can replace sand upto 100% by copper slag as results are higher than conventional concrete mix result. Durability checked results in loss in strength for some mixes. Pulse velocity & the modulus of elasticity of copper slag added concrete was gradually increased up to 50% replacement and then decreases. As copper slag is a waste material and shows good results so it can be used in concrete mixes. [3]

Ishwar Chandra Thakur, Prof. Sheo Kumar (Aug 2016), Prof. J.P.Singh, Studies effect of Portland cement in combination with GGBS & mortars cubes with varying percentage of GGBS (0%, 10%, 20%, 30%, 40%, 50%, 60% and 70%). it is observed that the standard consistency increases by 0 to 20%, as fineness of mix increases as the content of GGBS increases. IST & FST increases with increasing percentages of GGBS in cement. Rate of increment of IST is greater than that of FST. The soundness decreases slowly as the percentage of GGBS increases. Compressive strength of mortar shows decrease in strength for 3 & 7 days but strength increases for 28 days. 40% & 50% GGBS replacement shows max compressive strength. [4]

P.Gopal, G. and Manohar Reddy (Jan 2017), studies about use of GGBS in M20 grade concrete with partial replacement of cement using five fractional GGBS substitution proportions 0%, 10%, 20%, 30%, and 40% respectively. Mix design is prepare as per: Is 10262-1982. 20mm was the max aggregate size and 0.5 w/c ratio. Different mixes were prepared using batch mixing. Curing period was 7, 14 & 28days. The compressive strength, flexural strength, tensile strength & split tensile strength were checked for all mixes. This study says that 30% replacement of cement with GGBS gives us good results for the tests.[5]

Ashwini T Bhosale (Jan 2017), Studies concrete of grade M30 made with various percentages of GGBS. Study shows GGBS replacement enhances lower heat of hydration, higher durability and higher resistance to sulphate and chloride attack. It also reduces the temperature rise and helps to avoid early-age thermal cracking. Using GGBS water demand reduces by 2-3%. Setting time seems to be increases by use of GGBS in mix. It gives higher ratio of Flexural to Compressive strengths when compared with normal ordinary concrete. [6]

Sachin P. L & N. Bhavani Shankar Rao (May 2017), studies behavior of M30 grade concrete mix when cement & fine aggregate replaced with GGBS & Copper Slag. Cement was replaced with 10, 15, 20 & 30% GGBS & fine aggregates with 20% CS in concrete mix. Specimens were tested for compressive strength & split tensile strength. Results show gradual increase in strength. 15%GGBS & 20%CS replacement shows higher results in strength & has less water absorption. Higher strength is due to development of C2S in GGBS & toughness of CS. [7]

Rahul Morampudi, Korrapati Anil Kumar, Dr. Shaik Yajdani (Sep 2017), studies replacement of fine aggregate with Copper slag in M20 and M35 grades of concrete. Percentage of replacement was 10%, 20%, 30%, 40%,50% of Copper slag by weight of sand. To check workability slump study was conducted with and without admixture. Slump seems to increase as the water absorption capacity of Copper Slag is less. With increasing copper slag the compaction factor also increases & vee-bee time decreases which shows the increase in workability. To evaluate harden Concrete Properties Compressive strength, split tensile strength and flexural strength tests were performed at ages of 7,28,56,91 days. For up to 50% replacement of copper slag we get higher results than conventional concrete & at 40% replacement we get max strength of concrete cube with copper slag. [8]

Divya Krishnan K., P.T.Ravichandran and V. K. Gandhimathi (2017), had done experimental study on concrete using GGBS & CS as a partial replacement for cement & fine aggregate. M30 grade concrete mix was designed for partial replacement of cement with GGBS (0%, 10%, 20% and 30%) and fine aggregate with CS (0%, 10%, 20%, 30% and 40%). And results with only GGBS and combination of both were compared. For replacement of cement with GGBS compressive strength decreases as GGBS% increases, but for combination use of 30% GGBS & 30%CS shoes improvement in compressive strength by 16N/mm2. Also for split tensile strength & flexural test both GGBS & combination of GGBS & CS shows good result with

increasing percentages. Study suggests the use of 30% GGBS & 30%CS in concrete mix is preferable. [9]

Binod Kumar, L. Sengupta, L. R. Manjuatha (Dec 2018), studies effect of ground granular ballast slag on properties of concrete pavement. Tests were conducted on different mixes prepared using 10, 20, 30, 40, 50, 60% of GGBS instead of cement. Results show that we can use 40 to 50% replacement of cement with GGBS. Also 40% replacement gives more strength and 50% gives us strength same as conventional mix. Workability, compressive & flexural strength, abrasion resistance, drying shrinkage of all mixes was tested & their effects on pavement thickness, concrete joints, shrinkage cracks. [10]

Gowram Iswarya & V.Viharika Reddy (2018), studies use of CS & GGBS was done by replacing it with fine agg. & cement respectively. M40 grade of concrete was designed with 0.4 w/c ratio. Sand was replaced with Copper slag in 0%, 10%, 20%, and 30% with fine aggregates in mix and tested. Then cement was replaced with GGBS by 0%, 5%, 10% and 15% in mix and tested. Concrete mixes were prepared, tested and analyzed regarding compressive, flexural, split tensile strength and durability of concrete with the conventional concrete. Maximum results were found for replacement of cement by 15% of GGBS and sand by 30% of copper slag. [11]

Ramprasad Kumawat(2019), chose concrete grade M30 for mix. 0 - 60% replacement of fine aggregate was done with CS. CS comes under zone II as per gradation. Fresh & hard concrete properties of concrete were tested. Prepared mix was tested after 3, 7 & 28 days of curing period. Test results shows that strength of concrete increases as CS content increases up to 40% after that it starts reducing due to free water in mix, which increases workability & reduction in strength & cohesion. Concrete with copper slag has lesser in resistance to the H2So4 & HCL solution, therefore weight loss of concrete specimen increases & compressive strength decreases. CS concrete has the resistance against Na2So4 solution. [12]

3. DISCUSSION

Study shows Ground Granular Ballast Slag & Copper Slag both are studied for concrete mix of different grades, from low to High performance concrete. Copper Slag was tried to partially replace with sand from 0-100%, where as highest level of replacing cement with GGBS was 70%. Study of materials physical & Chemical properties has been done. Also to check hard & fresh concert properties destructive & non-destructive testing methods are performed. Results of hard concrete mostly checked for 7,28,56 & 91 days.

3.1 GGBS Chemical Composition

The chemical composition of a slag varies considerably depending on the composition of the raw materials in the iron production process. GGBS has the same main chemical constituents as ordinary Portland cement, but with different proportions. The main components of blast furnace slag are CaO (30-50%), SiO2 (28-38%), Al2O3 (8-24%), and MgO (1-18%). Due to similar chemical constituents of GGBS is used as partial replacement of cement.

Table -1: Chemical composition of GGBS

Sr. No.	Chemical Composition	GGBS
1	CaO	37.63
2	SiO_2	34.81
3	Al_2O_3	17.92
4	MgO	7.80
5	Fe_2O_3	0.66
6	SO_3	0.20
7	Cl	0.004
8	Mn_2O_3	0.21
9	Glass Content	96.85

3.2 Physical Properties of GGBS

GGBS is off white in colour. Specific gravity has range of 2.85-2.95. 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. It helps to improve mobility of concrete. GGBS have relatively low density as compared to cement.

Table -2: Physical Properties of GGBS

Sr. No.	Properties	Results
1	Colour	Off white
2	Specific gravity	2.85-2.95
4	Fineness (by sieving on 90µm)	0-3%
5	Surface area (Blain's air permeability)	385-600 m^2/kg
6	Bulk density (loose)	1.0-1.1 $tons/m^3$
7	Bulk density (Vibrated)	1.2-1.3 $tons/m^3$

3.3 Concrete Properties of GGBS

GGBS has been studied for different concrete proper. Consistency results of GGBS mix concrete shows increment

in results with increasing GGBS content but results are within the cement consistency limit.. Use of GGBS in concrete shows increase in initial & final setting time of concrete. The setting time of concrete is influenced by many factors, in particular temperature and water/cement ratio. An extended setting time is advantageous to keep concrete workable longer 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. Soundness of concrete i.e. volume change in concrete mix. It shows that the soundness of partially replaced OPC with GGBS decreases slowly as the percentage of GGBS increases. This is due to the decreasing proportion of free lime (or unreacted lime) after hydration of cement mixed with GGBS. Therefore GGBS in cement produce more sound cement than conventional cement.

Thermal cracking in thick-section pours happens due to reactions involved in the setting and hardening of concrete. This reaction generates significant heat and produce large temperature rises, particularly in thick-section pours. By replacing Portland cement with GGBS reduces the temperature rise and helps to avoid early-age thermal cracking. The greater the percentage of GGBS, the lower will be the rate at which heat is developed and the smaller the maximum temperature rise. GGBS replacement enhances lower heat of hydration, higher durability and higher resistance to sulphate and chloride attack when compared with normal ordinary concrete.

Due to the consistent fineness, particle shape of the GGBS and from its slightly lower relative density fresh concrete containing GGBS has better mobility characteristics than concrete made with Portland cement. These improvements arise the smoother surface texture and glassy surface of GGBS particles also helps to improve workability. This improved workability of concrete is useful for its easy placement concrete & compaction.

Concrete with different properties can be made by varying the proportions of GGBS. Use of GGBS has shown increase in Compressive, Split & Flexural strength parameters of hard concrete. Up to 40-50% of GGBS replacement shows good results as compared to Ordinary Portland Cement. Higher replacement level i.e. more than 50% of GGBS shows lower strength results. Desire scaling results depended on the level of GGBS usage, the curing regime and the cement brand.

GGBS mix concrete can also be done in Rigid pavement construction as it fulfills the concrete requirement for pavement grade concrete. Compressive & flexible strength are important parameter of design of pavement grade concrete, GGBS shows improved results for the same. GGBS concrete being strong in bearing strength will resist crushing of concrete under dowels thereby significantly reducing faulting and spalling of joints and resulting in better performance of joints. The drying shrinkage of the concrete decreases with increase of GGBFS content. A lesser value of drying shrinkage is always desirable for PQC mixes to maintain higher level of aggregate interlocking at joints of concrete pavement and also to avoid shrinkage cracking. Abrasion resistance of concrete improves generally with the improvement of compressive strength of concrete, therefore as compressive strength increases with GGBS mix abrasive resistance will increase too. Thickness design of pavement slab is based on the flexural strength of concrete, therefore Higher the flexural strength of concrete will lower the required thickness of pavement slab to sustain through the design life. Therefore we can use partially replace cement with GGBS.

3.4 Copper Slag Chemical Composition

Chemical composition of copper slag is shown in table-3. Copper slag content varies as per quality of raw material used in manufacturing of copper. Copper slag has high concentrations of SiO_2 and Fe. It has low CaO contents, that means it is chemically less reactive & can be used as sand.

Table -3: Chemical composition of Copper Slag

Element/ Compound	Analysis Rang
Cu	0.6-0.7
Fe	55-60
Sio_2	26-30
Al_2O_3	1-3
S	0.2-0.3
CaO	1-2
MgO	0.8-1.5
Fe_3O_4	1-2
Co	0.01-0.03
Cr	0.02-0.04
Zn	0.2-0.4
Ni	0.005-0.008
W/s. Chloride	0.001-0.002

3.5 Physical Properties of Copper Slag

Copper Slag appears black in colour with glassy surface & irregularity of particle shape. Copper slag has gradation same as sand, therefore it is use to replace sand. As specific gravity of copper slag is high, it will result in much denser concrete than control mix concrete. which will result in good strength. Less water absorption of copper slag would

demand less water for concrete mix than that required by sand in the concrete mix.

Table -4: Physical Properties of GGBS

Sr. No.	Properties	Results
1	Colour	Black and glassy
2	Particle shape	Irregular
3	Specific gravity	3.4-3.98g/cm^3
4	Fineness modulus	2.5-3.8%
5	Water absorption %	0.15-0.8
6	Bulk density	1.9-2.15kg/m^3

3.6 Concrete Properties of Copper Slag

Workability of concrete is checked by different methods such as Slump cone method, Vee-bee method & compaction factor method. In slump cone test due to less water absorption property of copper slag free water content in concrete mix increases & so the workability of concrete. Compaction Factor test shows reduction in compaction factor so the increases the Workability. Workability in terms of Vee-Bee method the Vee-Bee time decreases which shows the increase in workability. With the increasing percentage of copper slag workability will increase more. Surface water absorption decrease as the copper slag quantity increased up to 40% replacement. Beyond that level of replacement, the absorption rate increases rapidly.

Concrete with copper slag gives good strength results for compressive strength, flexural split tensile strength. Addition of up to 50% of copper slag as sand replacement yielded comparable strength with that of the control mix. However, further additions of copper slag caused reduction in the strength due to an increase of the free water content in the mix.

Using ultrasonic pulse velocity method(a non destructive method) checked the homogeneity of the concrete, presence of cracks, voids and other imperfections, changes in the structure of the copper slag mixed concrete which may occur with time, the quality of the concrete grading in relation to standard requirements. The quality of concrete is that comparatively higher velocities are obtained when the quality of concrete in terms of density, homogeneity and uniformity is good. Density and modulus of elasticity of aggregate also significantly affect the pulse velocity. The result of ultrasonic pulse velocity is greater for up to 50% replacement after that they starts to reduce.[3]

Copper slag mix concrete shows increase in Modulus of elasticity up to 50% replacement after that decreases in accordance with an increase of replacement of natural sand by copper slag.

The percentage weight loss is observed to be increasing in correspondence with time for test of acid attack resistance on Copper Slag using 10% H2So4 solution and 10%HCl solution.

Copper slag has number of favorable mechanical properties for aggregate use, including excellent soundness characteristics, good abrasion resistance and good stability therefore copper slag can be used as sand replacement.

Both Copper slag & GGBS are good alternatives for sand & cement respectively. Due to their good strength characteristics & material properties. As they are waste from industry, use of them will be help to make a sustainable concrete mix.

4. CONCLUSIONS

Ground Granular Ballast slag & Copper slag both are industrial waste with good concrete material properties. Both contribute in improving workability of concrete. As well as GGBS mixed concrete or copper slag mix concrete shows good strength results for compressive, flexural & split tensile strength up to replacement of 40-50% we can use them in our concrete mixes from lower to higher grads. Use of these waste material will 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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