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Partial Replacement of Cement in Concrete Mixes Using Ground Granulated Blast Furnace Slag (GGBS) as Secondary Cementitious Material (SCM)

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Abstract: ***Blast furnace slag is a byproduct of Iron & steel industry across the world. It is an industrial waste material obtained by iron and steel making process. Approx 300 kg waste slag is produced for every MT of crude steel production. Annual production of Slag is 35 MT in Odisha, 150 MT in India and approx. 2000 MT in the world. Such a huge volume of industrial waste is generated every year. Considering the physical and chemical properties of slag, it can be utilized in construction industry. Slag is used in cement industry. Slag can be used as partial replacement for sand. The production of cement has always lead to massive exploitation of natural resources. Ordinary Portland Cement being produced yearly around the globe contributes to 5 percent of greenhouse gas and 2.5% of total worldwide waste emissions from industrial sources. One effective way to reduce the environmental impact is to use mineral admixtures, as a partial cement replacement both in concrete and mortar, which will have the potential to reduce costs, conserve energy, and minimize waste emission.***
Keywords: Ground Granulated Blast Furnace Slag (GGBFS), OPC, PPC, etc.

I. INTRODUCTION

Concrete is a main constituent of the Civil Engineering structures. We cannot imagine the structures without concrete. It is becoming the backbone of infrastructural development of whole world. Concrete has capacity to enhance its properties with the help of other suitable constituents.

The main disadvantages of concrete are as follows -

Very low tensile strength

Brittleness

Less resistance to cracking

Heavy mass (density)

Shrinkage cracks

Some remedial measures can be taken to minimize some bitter properties of concrete. Waste is the one of the main challenges to dispose and manage. It has become one of the major environmental, economical and social issues. Recycling is the most promising waste management process for disposal of materials like agricultural waste and Industrial by –product like blast furnace slag, fly ash, silica fume ,rise husk, phosphor-gypsum etc. The use of above mentioned waste products with concrete in partial amount replacing sand paved a role for

Modifying the properties of the concrete

Controlling the concrete production cost

The advantageous disposal of industrial waste.

A. Blast Furnace Slag

1) Blast furnace slag is a nonmetallic by-product produced in the process of iron making (pig iron) in a blast furnace and 300kg of Blast furnace slag is generated when 1 ton of pig iron produced. 2.
2) In India, annual productions of pig iron is 70-80 million tons and corresponding blast furnace slag are about 21-24 million tons.
3) Blast furnace slag is mildly alkaline and exhibits a pH in solution in the range of 8 to 10 and does not present a corrosion risk to steel in pilings or to steel embedded in concrete made with blast furnace slag cement or aggregates.

4) The blast furnace slag could be used for the cement raw material, the roadbed material, the mineral admixture for concrete and aggregate for concrete, etc.
5) Now in India, resources of natural sand are very lacking, it is necessary that the new fine aggregate was sought. The property of blast furnance slag is similar to natural sand, the price is cheap and the output is large too, could be regarded as the substitute of the natural sand. But there is no experience about application of blast furnance slag fine aggregate in concrete and the reports about the research are also few.
6) In this investigation a series of experiments about mechanical characteristics of concrete using ground granulated blast slag (GGBS) fine aggregate would be done, and results of investigation on compressive strength, tensile strength and properties of fresh concrete could be reported.

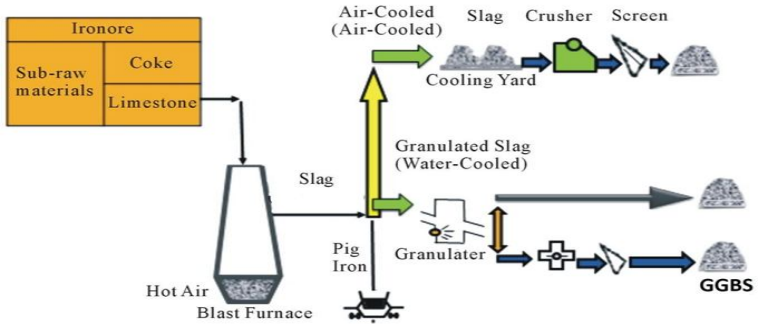

Fig 1. Process of preparation of GGBFS

Table1. Chemical Composition of Ground Granulated Blast furnace slag

TYPICAL CHEMICAL COMPOSITION			TYPICAL PHYSICAL PROPERTIES	
Calcium oxide	40%		Colour	off-white
Silica Alumina	35% 13%		Specific gravity Bulk density	2.9 1200 kg/m3
Magnesia	8%		Fineness	>350m2/kg

B. Present Practice

At present Portland Slag Cement of different brands (Dalmia, Emami, Ramco) is being used as blended cementitious materials in TSK. Since cement manufacturers blends 60-65 % GGBS during production of PSC, further blending of mineral admixture is not possible.

Recommended Practice

1) In general, all Govt. infrastructure projects across India use OPC only or OPC blended with FA/ GGBS/ Both.
2) Mix Design data collected from Infrastructure Projects/ RMC plants in Central/ Western/ Southern part of India shows that concrete mix of double blend (OPC+GGBS or OPC+FA) or triple blend (OPC+GGBS+FA) is adopted for reduction of cost.
3) The properties of proposed double blend concrete mixes shall remain identical with that of existing concrete mixes being produced with PSC.
4) The whole content of PSC in design mix will be replaced with the same combined weight of OPC43 and GGBS in same proportion of blend used in production of PSC.
5) IS 455. 2015 allows replacement of OPC with GGBS up to 70%.

C. PH Value Of Concrete With GGBS

pH value of GGBS and OPC is around 9.7 and 12.8, respectively. Hence, many are apprehensive that pH value of pore solution particularly with high percentages of GGBS, may fall below 10.0, thereby exposing the reinforcement to corrosion; fortunately, such an apprehension is found to be untrue.

Table 2: pH values of Concrete with GGBS

pH Values of concrete and Concrete with and without GGBS *					
Initial	Initial	After 7 days	After 28 days	After 56 days	After 90 days
100 % OPC with 0.4% w/c	12.8	12.4	12.3	12.2	12
40% OPC + 60% GGBS	12.4	12.4	12.3	12.3	12.2

Advantages in using SCM (GGBS) along with OPC in Odisha

1) Easy adaptation as all parameters of existing design mix will remain unchanged except use of PSC.
2) No additional infrastructure is required as all major batching plants have multiple silos.
3) GGBS is produced as secondary product of all steel plants in Odisha . So the Consistent quality of GGBS will remain secured.
4) Huge quantity of GGBS could be utilized throughout the state in construction work.
5) Carbon footprint of Iron and steel Industry would be further reduced.
6) Substantial savings of cost.

Table2. Compressive Strength Test Report:

Trial no	Grade of Conc.	Binder Content (Kg)	OPC: GGBS	Age of Cube (Days)	Cube Size	Cube Wt (Kg)	Load (KN)	Strength (N/mm²)	Avg Strength (N/mm²)
				28	150	8.634	906.5	40.29	
1	M30	370	40:60	28	150	8.6	929.2	41.3	36.79
				28	150	8.579	917.7	40.79	
				28	150	8.82	803	35.69	
2	M30	370	40:60	28	150	8.84	767	34.09	35.17
				28	150	8.92	804	35.73	
				28	150	8.55	936	41.6	
3	M30	370	35:65	28	150	8.685	908.7	40.39	34.31
				28	150	8.6	876.3	38.95	
				28	150	8.64	913.9	40.62	
4	M30	370	45:55:00	28	150	8.585	923.6	41.05	36.07
				28	150	8.51	867.1	38.54	
				28	150	8.5	900	40	
5	M30	370	40:60	28	150	8.582	910	40.44	37.13
				28	150	8.62	930	41.33	

Comparison of Test Results- M30

Binder Type	PSC	OPC+GGBS	Remarks
Trial Period	November 2021	Nov 21- June 2022	
BF Slag (SCM) Content	60%	60%	Conforms to IS-456-
Total Binder content (Kg/ Cum)	370	370	
Water Binder Ratio	0.42	0.42	
28 Days Strength (Target)	34.95 Mpa	34.95 Mpa	Assuming Standard Deviation 3 Mpa
Avg 28 days Strength obtained	35.0 Mpa	36.99 Mpa	Superior Strength obtained for concrete using SCM.

Comparison of Cost for Cementitious Materials

S.N.	Particulars	Rs/ MT	Proposed blending (%)	Cost of Cementitious Material / MT	Final Cost /MT Rs
1	Cost of PSC at Angul	5000	-	5000	5000
2	Cost of OPC at Angul (Market price)	6300	40%	2520	
3	Cost of GGBS (Conversion Cost)	1300	60%	780	
	Total Savings=				1700

S.N.	Particulars	Rs/ MT	Proposed blending (%)	Cost of Cementitious Material / MT	Final Cost /MT Rs
1	Cost of PSC at Angul	5000	-	5000	5000
2	Cost of OPC at Angul (Market price)	6300	35%	2205	
3	Cost of GGBS (Conversion Cost)	1300	65%	806	3011
	Total Savings=				1989

Cost Savings for 1 MT
For (60 : 40) = Rs 1700/ MT i.e. 34%. For (65 : 35%) = Rs 1989/ MT i.e. 40 %

This is beneficial mostly for Iron & Steel industry producing GGBS as in house product.

II. CONCLUSION & WAY FORWARD

1) For producing durable, sustainable concrete, it is necessary to use low W/B Ratio in concrete mix and also Secondary Cementitious Materials as part replacement to cement.

2) Out of various SCMs, replacement of cement by GGBS is permitted to a maximum of 70%. Therefore it helps in producing sustainable and economic concrete.

GGBS is produced by grinding of BF Slag which is a by-product of Iron Making process. Hence GGBS blended with OPC as Secondary Cementitious Material not only minimizes solid waste generation of Iron & Steel industries but also will have substantial impact on reduction of carbon footprint.

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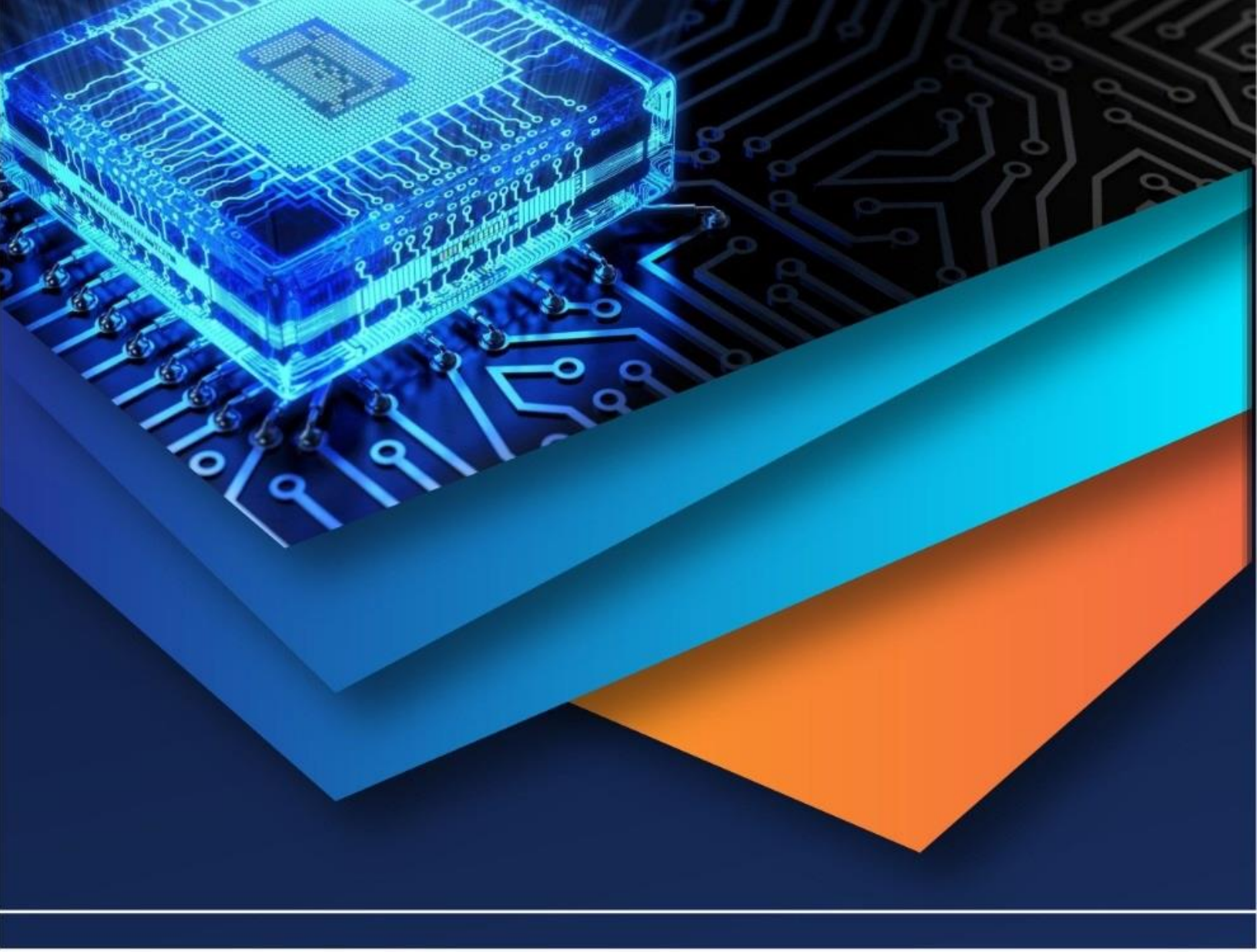

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