Experimental Investigation of Concrete with Ggbs, Quarry Dust and Steel Slag Waste

Gopireddy Madan and G. Vimalanandan

Abstract-The use of alternative materials in production of concrete is being well accepted, since it leads to several possible improvements among in the concrete composites, additionally besides general economy. This paper gives laboratory investigation report about the utilization of ground granulated blast furnace slag (GGBS) as partial replacement of cement, quarry dust (QD) as partial replacement of fine aggregate (FA) and steel slag waste (SSW) as partial replacement of course aggregate (CA). The partial replacement of cement , sand and coarse aggregate were done in different trail mix for M40 grade of concrete separately. The mix trail with different percentage of GGBS, SSW and QD by 0%, 10%, 20%, 30%, 40%, 50%, 60% and 70% in order to find the optimum percentage use in concrete. From these trial mixes, percentage optimization of GGBS, SSW and QD used in concrete for the further investigation. It was found that 40%, 50% and 60% replacement of GGBS, QD and SSW respectively gives maximum strength to concrete.

***Keyword*: GGBS; Steel slag waste; quarry dust; Replacement; Optimum; Concrete.**

I. INTRODUCTION

Concrete is an important construction material consisting of ingredients such as CA, FA and binding materials (cement or lime). Cement is the binder in used as plain concrete, reinforced concrete. In this investigation GGBS used as a partial replacement of cement,QD as a partial replacement of FA, SSW as a partial replacement of CA. Steel slag is a byproduct of steel making processes in steel industry. QD is a waste from the stone crushing units. This QD which is released directly into environment can cause environmental pollution. To reduce the impact to environment and humans, this waste can be used to produce a new product by partially replacing FA with quarry dust in concrete. GBBS is obtained by rapidly chilling the molten ash from the furnace with the help of water. During this process, the slag gets fragmented and transformed into amorphous granules. The granulated slag is ground to desired fineness for producing GGBS [1-3].

II. MATERIAL USED

OPC of 53 grade having specific gravity 3.15 in compliance with IS 12269 was used. Locally available river FA, confirming to grading zone II of IS 383:1970. FA was screened at site to remove deleterious materials and tested as per IS 2386:1968 (part-3), which was used as FA in this investigation. The physical properties of FA tested in laboratory are listed in Table 1.

Table 1 Physical properties of FA

S.No.	Properties	Values
1.	Specific gravity	2.6
2.	Fineness modulus	2.50
3.	Bulk density (kg/m^3)	1559

The aggregate confirming to size 20mm in dry condition was used CA in concrete preparation, confirming to IS 383: 2016. The physical properties of coarse aggregate are listed in Table 2.

Table 2 Physical properties of CA

S. No.	Properties	Values
1.	Specific gravity	2.70
2.	Water absorption (%)	0.35
3.	Aggregate impact value (%)	9.52
4.	Bulk density (kg/m^3)	1680
5.	Flakiness index	15
6.	Elongation index	12

As per IS 456-2000, potable water was used for casting and curing of concrete specimen.

2.1. Ground Granulated Blast Furnace Slag (GGBS)

Ground granulated blast furnace slag is a by-product, which is obtained from the iron making industries as the growing of industrialization and urbanization is more creating the manufacturing of iron is more and obtaining by products from the industries is also more. By utilising this by-products in concrete as partial replacement of OPC is very useful in creating the high quality concrete [2].

Fig. 1 Collected GGBS

The physical and chemical properties of GGBS [4] are listed in Table 3 and 4.

Table 3 Physical properties of GGBS [4].

S. No.	Properties	Values
1.	Specific gravity	2.6
2.	Colour	White
3.	Surface moisture	Nil
4.	Averageparticle size; shape	4.75mm; down, round

Table 4 Chemical composition of GGBS [4].

S. No.	Constituent	GGBS(%Wt.)
1.	Aluminium oxide	14.42
2.	Calcium oxide	37.34
3.	Sulphide sulphur	0.39
4.	Magnesium oxide	0.02
5.	Silica	37.73
6.	Manganese oxide	8.71
7.	Iron oxide	1.11

2.2. Steel Slag Waste

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Steel slag waste which is obtained from the iron and steel industries as a by product and it is having a glassy shade of stones. By using this waste by-product material as partial replacement of CA, environmental pollution can be reduced and it also gives high strength properties of concrete [5]. SSW used in this research was collected from Bollineni Castings and steel Ltd., Suryapalem (village), Nellore, Andhra Pradesh, India as shown in Figure 2 (a). After collection it was crushed into size of 20mm as shown in Figure 2 (b).

Fig.2 (a)Steel slag waste at site (b)Crushed steel slag waste

Typical SSW physical properties and chemical composition [5] are shown Table 5.

Table 5 Physical properties and chemical composition of Steel slag waste [5]

Physical properties		**Chemical composition**	
Properties	**Values**	**Constuient**	**Composition (%)**
Loss angels abrasion (%)	20-25	CaO	40-52
Specific gravity	2.0	SiO_2	10-19
Water absorption (%)	1.05	FeO	10-40
Flakiness index (%)	8.5	MnO	5-10
Elongation index	4.50	Al_2O_3	1-3
Impact strength	19.50	P_2O_5	0.5-1
Crushing strength (%)	19	Metallic Fe	1 -10

2.3 Quarry Dust

Quarry dust is obtained asa by-product from the quarrying activities of granite rocks for specific sizes of construction activities or pavement activities. This material having specific gravity of 2.61, as shown in Figure 3 having similar to the normal river sand and which is having high strength granules of stones. QD can be used as replacement material of sand to produce high strength concrete [3].

Fig. 3 Collected QD

Many countries have started to find the replacing material for river FA and they have taken mainly quarrying activities waste QD can be best suitable for constructions, road works, building materials etc. In this investigation mainly this quarry dust was used as partial replacement to get high strength concrete, this can reduce environmental pollution and also saves the natural resources.

III. METHODOLOGY

In this investigation M40 grade of concrete was taken with mix ratio of 1:1.52:2.69:0.45. The percentage replacement of GGBS as cement were 10%, 20%, 30%, 40% and 50%;QDs a replacement of fine aggregate by weight were 10%, 20%, 30%, 40%, 50% and 60%; and SSW as coarse aggregate were 10%, 20%, 30%, 40%, 50%, 60% and 70%. After casting and partial replacement testing of specimen optimum percentage of all materials were obtained.

IV. EXPERIMENTAL STUDY

A. Testing program and specimen details

According to the mix ratio the ingredients were mixed in the mixer, the mixed concrete was placed in their respective moulds as shown in Figure 4. After demoulding, concrete samples were placed for curing for 7 and 28 days.Thesizes of moulds were was 150mm ×150mm×150mm and the cylinders of 300mm length and 150mm as diameter as per IS 516-1959. Compressive strength test as shown in Figure 5 and split tensile strength test as shown in Figure 6 were conducted on their respective specimens in compression testing machinehaving 2000KN capacity. Tests were conducted after 7 and 28 days of curing.

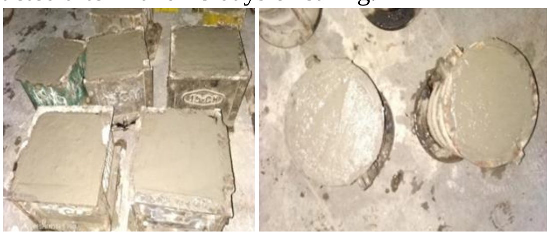

Fig. 4 Casted cubes and cylinder specimens


Fig. 5 Compression test (a)Testing of specime in CTM (b) Failed specimens

Fig. 6 Split tensile test (a) Split tensile test in CTM (b) Failed specimen

V. RESULT AND DISCUSSION

The mechanical properties of concrete such as compressive strength and split tensile strength of conventional concrete with GGBS, QD and SSW.

A. Compressive strength

Compressive strength test of conventional and replaced material for OPC, CA and FA with GGBS, SSW and QDrespectively were done. After the different trail mixes the optimized percentage was obtained as 40% replacement of OPC with GGBS, 60% replacement of CA with SSW and 50% replacement of FA with QD. The trail test results are shown in table 6, 7 and 8.

B. Splitting tensile strength

Split Tensile Strength test of conventional and replaced material for OPC, CA and FA with GGBS, SSW and QD respectively were done. After the different trail mixes the optimised percentage was obtained as 40% replacement of OPC with GGBS, 60% replacement of CA with SSW and 50% replacement of FA with QD [8]. The trail test results are shown in table 6, 7 and 8.

Table 6 Optimization of GGBS for OPC replacement

% replacement of GGBS	Compressive strength (N/mm^2)		Splittensile strength (N/mm^2)	
	7 days	28 days	7 days	28 days
0	37.30	40.30	2.44	2.73
10	31.10	35.70	2.31	2.42
20	32.10	37.80	2.42	2.58
30	35.50	38.40	2.59	2.71
40	40.20	42.80	2.71	2.99
50	37.60	39.20	2.53	2.78

Table 7 Optimization of QDfor FA replacement

% replacement Ofquarry dust	Compressive strength (N/mm^2)		Split tensile strength (N/mm^2)	
	7 days	28 days	7 days	28 days
0	37.30	40.30	2.44	2.73
10	33.30	34.60	2.22	2.31
20	33.50	36.30	2.41	2.40
30	34.80	37.80	2.52	2.59
40	36.90	39.70	2.62	2.75
50	39.80	41.70	2.69	2.92
60	37.90	38.80	2.51	2.80

Table 8 Optimization of SSW for CA replacement

% replacement of steel slag waste	Compressive strength (N/mm^2)		Split tensile strength (N/mm^2)	
	7 days	28 days	7 days	28 days
0	37.30	40.30	2.44	2.73
10	0.80	31.20	1.92	2.08
20	32.10	32.80	2.08	2.12
30	33.80	34.50	2.19	2.29
40	34.50	36.70	2.31	2.41
50	36.90	38.90	2.49	2.62
60	39.20	41.20	2.64	2.90
70	38.10	38.50	2.48	2.78

C. Compressive strength and Split tensile strength for optimised % of GGBS, QD and SSW

As from the different trial mixes for OPC, FA and CA by GGBS, QD and SSW, the optimized percentage for the maximum strength was decided. Table 9 demonstrate the compressive strength for combined optimized percentage for GGBS, QD and SSW.

Table 9 Compressive strength and tensile strength for optimised % of GGBS, QD and SSW

Conventional concrete				Optimised % of GGBS, QD and SSW combined concrete			
Compressive strength (N/mm^2)		Split tensile strength (N/mm^2)		Compressive strength (N/mm^2)		Split tensile strength (N/mm^2)	
Days							
7	28	7	28	7	28	7	28
37.3	40.3	2.44	2.73	38.80	43.60	2.81	3.2

VI. CONCLUSION

From the present research work carried out on partial replacement of GGBS, SSW and QD the following conclusions were drawn:

- Workability of concrete increases while GGBS, SSW and QD is replaced for cement, coarse aggregate and fine aggregate respectively.
- 40% replacement of cement with GGBS is the optimum level to get maximum compressive strength and split tensile strength.
- 50% replacement sand with QD is the optimum level to get maximum compressive strength and split tensile strength.
- 60% replacement of CA with SSW is the optimum level to get maximum compressive strength and split tensile strength.
- The compressive strength increases by 6.40%, 2.90% and 2.22% and the split tensile strength increases by 9.52%, 6.95% and 6.10% for cement, fine aggregateand CA replacement by GGBS, QD and SSW respectively when compared to conventional concrete.
- For Optimised % of GGBS, QD and SSW the

compressive strength increases by 8% and splittensile strength increases by 17.5%compared to conventional concrete.

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REFERENCES

1. Tamilrasan V.S, Perumal P and Maheswaran, International Journal of Advanced Research in Engineering and Technology, 3, 11 (2012)
2. Dabhekar K.R, Nagarnaik P.B and Pawade P.Y, International Journal of Civil Engineering and Technology, 8, 418 (2017)
3. Prasanna k, Anandh K.S and Kiruthiga K, International Journal of Civil Engineering and Technology, 8, 1502 (2017)
4. Adisekhar G and B. Sarath C.K, International Journal of Civil Engineering and Technology, 8, 175 (2017)
5. Suri N and Babu Y.A, International Journal of Civil Engineering and Technology, 7, 322 (2016)
6. IS 456: 2000, Indian Standard for plain and reinforced concrete - Code of practice, New Delhi, (2000)
7. Prakash M, and Narayanaswamy P, Rasayan Journal of Chemistry, 10, 442 (2017), DOI:10.7324/RJC.2017.1021689
8. Gunasekaran K, Annadurai R and Kumar P.S, Construction and Building Materials, 28,208 (2012), DOI: 10.1016/j.matdes.2013.03.022

AUTHORS PROFILE

Gopireddy Madanis currently doingM-Tech in Structural Engineering at SRM Institute of Science and Technology, Chennai, India. He received his B. Tech degree in Civil Engineering from
Visvodaya Engineering College,Kavali (M), Nellore (Dt)

Mr.G.Vimalanandan
Currently Assistant Professor in Civil Engineering Department at SRM Institute of Science and Technology, Chennai, India. He received his M. Tech. in Structural EngineeringPRIST University, Thanjavur, 2012