Indexed in
Scopus Compendex and Geobase Elsevier,
Geo-Ref Information Services-USA, List B of Scientific
Journals, Poland, Directory of Research Journals

International Journal of Earth Sciences and Engineering

www.cafetinnova.org

ISSN 0974-5904, Volume 09, No. 03

June 2016, P.P.411-414

Effects of Domestic Rawsewage on Mechanical Properties of Concrete Incorporating GGBS (Ground Granulated Blast Furnace Slag)

SHILPA S RATNOJI[1], PRAVEEN S MALLAPUR[1], SHASHANK KANAVALLI[1] AND K B PRAKASH[2]
[1]Dept. of Civil Engineering, Manipal Institute of Technology, Manipal, Karanataka, India
[2]Government Engineering College, Haveri, Karnataka, India
***Email:** shilpa_5sr@yahoo.co.in, praveenm3720@gmail.com, shashankkanavalli@gmail.com, Kbprakash04@gmail.com*

Abstract: Concrete is generally used as the main component for the construction of wastewater treatment units. The raw sewage containing chlorides, sulphates, biogenic sulphates, and being acidic in nature has a significant effect on the strength properties. Supplementary cementitious material GGBS are being used in increasing quantities in concrete and have shown to provide concrete with increased strength properties in this particular environment. The experimental analysis was done with a total of 9 different concrete mixes which were prepared with partial replacement of cement with GGBS at various proportions of 0%, 5%, 10%, 15%, 20%, 25%, 30%, 35% and 40% and cured in normal tap water for 28days and then immersed in wastewater for 90days. The specimens were tested for compressive, split tensile and flexural strength for the purpose to identify the optimum dosage of GGBS that performs better in wastewater environments. The test results proved that the concrete mixtures containing GGBS at proportions 25-30% in replacement of cement had not much effect on strength properties and can perform better in such wastewater environments compared to other mixes when tested for respective 28 and 90days strength.

***Keywords:** Curing, compressive strength, split tensile strength, flexural strength, mix design*

1. Introduction

As most of the sewer lines, Drainages, Sewer treatment plants (STP's) are constructed of concrete structures which are directly in contact with the raw sewage and highly exposed to waste water environments such as pH, chloride attack, Sulphate attack, sulphuric acid attack, Biogenic sulphuric acid attack etc.[1-2]which results in the deterioration of the concrete structure due to reduction in various strength properties of concrete which in turn effects the performance of the concrete structure for the intended purpose [3]. It has been well known that ground granulated blast-furnace slag (GGBS) can increase the abilities to prevent water penetration and chloride penetration, and can improve the durability of concrete structures [4]. Also, the use of GGBS for concrete material contributes to the saving the natural resources and energy in cement manufacturing process and to reducing CO_2 emissions and environment impact. So in order to have better performance concrete and to mitigate the effects of raw sewage on concrete structures an approach is made incorporating GGBS (Ground Granulated Blast Furnace Slag) in partial replacement of cement [5-6]. GGBS means the ground granulated blast furnace slag is a by-product of the manufacturing of pig iron. Iron ore, coke and Lime-stone are fed into the furnace and the resulting molten slag floats above the molten iron at a temperature of about 1500^oC to1600^oC. This molten slag has a composition close to the chemical composition of Ordinary Portland cement. After the molten iron is tapped off, the remaining molten slag, which consists of mainly siliceous and aluminous residue is then water-quenched rapidly, resulting in the formation of granulate. This glassy granulate is dried and ground to the required size, which is known as ground granulated blast furnace slag (GGBS). As it is the residue left in steel manufacturing industry and has finer size than cement and chemical properties similar to that of cement can be effectively made use in concrete in replacement of cement to various proportions in order to produce the effective concrete which can withstand the effects of raw sewage on the strength properties of concrete and also the disposal of the GGBS and its various effects on environment are eliminated by making effective use of GGBS in concrete structures.

2. Methodology

This study was carried out to analyze the effects of domestic raw sewage on strength properties of concrete and an approach is made to have the better performance concrete in wastewater environments. For this purpose the total of 9 different concrete mixes specimens were prepared in replacement of cement with various proportions of GGBS, and tests were carried out as per IS code for this proposed investigation work. For successful investigation the tests were conducted on normal concrete and GGBS concrete with proportions 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40% cement replacement. To study and compare the effects of raw sewage on concrete, a set of specimens were cured in fresh water for 28days and their respective strength results were taken and thereafter they were immersed in wastewater to take concurrent strengths of 90 days for the successful investigation of the study.

Following methodology was followed for proposed work:

- Collection, review of journals and articles to get an idea to carry out the proposed research work.
- Studying the properties of cement and GGBS as per IS standards.
- Mix design of concrete is done for preparation of concrete as per IS10262:1983.
- Carrying out tests on raw sewage characteristics as per IS: 10500-1991 in which the concrete specimens are immersed so as to identify the various parameters effectingthe strength properties of concrete.
- UTM is used to conduct the tests. Test procedure is used as per IS 516.
    1. Compression test-For this test cubes of standard size of 150mmX150mmX150mm were used.
    2. Flexural tensile strength- It was measured by testing beams under two point loading of beam size 100mmX100mmX500mm.
    3. Split tensile strength-For this test cylinders of standard size of 150mmX300mm were used.
- Wastewater characteristics such as pH, sulfates, chlorides, iron content, nitrates, fluorides, acidity, and alkalinity were experimentally determined in which the concrete specimens were immersed.

For the analyses the specimens were cured in fresh water for 28 days and immersed in waste water thereafter for 90 days and their respective strengths results were taken to study and compare the effects of raw sewage on Normal concrete and GGBS incorporated concrete.

3. Material Properties

3.1 Cement

The cements used in this experimental works are ordinary Portland cement having specific gravity 2.71, fineness modulus 7.06 and water absorption of 0.6%. All these properties of cement are tested by referring IS Specification for Ordinary Portland cement.

3.2 GGBS (Ground Granulated Blast Furnace Slag)

The chemical composition of blast furnace slag was similar to that of cement. This was used as the raw material in partial replacement of cement having chemical composition (CaO-40%, SiO_2-35%, Al_2O_3-10%, MgO-8%). GGBS was procured from Jindal steels pvt.Ltd. Located at Bellary taluk, Karnataka, India, for this study.

3.3 Water

Potable water available in laboratory was used for mixing and curing of concrete.

3.4 Fine Aggregates

Natural sand from river confirming to IS 383 is used. Various tests such as specific gravity, water absorption, impact strength, crushing strength analysis etc. have been conducted on fine aggregates to know their quality and grading.

3.5 Coarse Aggregates

Crushed angular basalt rock type coarse aggregate passing through 20mm retained on 4.75mm sieve were used confirming to IS 383-1970.

3.6 Mix Design

Total of nine different concrete mixes were done by replacing Ordinary Portland cement with GGBS (Ground Granulated Blast Furnace Slag) at various proportions of 0%, 5%, 10%, 15%, 20%, 25%, 30%, 35% and 40% keeping the w/c ratio, Fine aggregates and course aggregates ratio constant.

***Table 4.1** – Mix proportion for Normal Concrete*

Mix Design	Normal Concrete
Cement Kg/m^3	413
GGBS Kg/m^3	0
Fine Aggregate Kg/m^3	706
Coarse Aggregate (20mm Down) Kg/m^3	1117
Water Kg/m^3	186
W/C Ratio	0.45

4. Results and Discussion

A set of cubes of size 150mmX150mmX150mm immersed in normal water and another set of size immersed in wastewater for curing are tested for Compressive strength at 28 days and 90 days respectively using compression testing machine (CTM) of capacity 2000 KN.

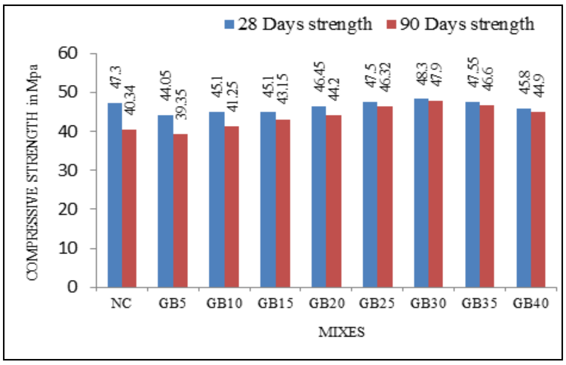
Similarly a set of beams of size 100mmX100mmX500mm and a set of cylinders of size 150mmX300mm immersed in normal water and another set immersed in wastewater were tested for Flexural strength and split tensile strength at 28days and 90 days strength respectively using Universal testing machine (UTM) of capacity 40tones.

4.1 Compression Test

A cube compression test was performed for all 9 different mixes at various proportions of GGBS in replacement using CTM. The following table shows the compressive strength results.

Table 4.2- *28 and 90 Days Compressive strength test results*

Mixes	CS in Mpa 28days	CS in Mpa 90 days	% strength Reduction
NC	47.30	40.34	13.71
GB5	44.05	39.35	10.66
GB10	45.10	41.25	8.53
GB15	45.65	43.15	6.49
GB20	47.45	44.20	5.17
GB25	47.50	46.32	2.48
GB30	48.30	47.90	0.82
GB35	47.55	46.80	1.57
GB40	45.80	44.90	1.96

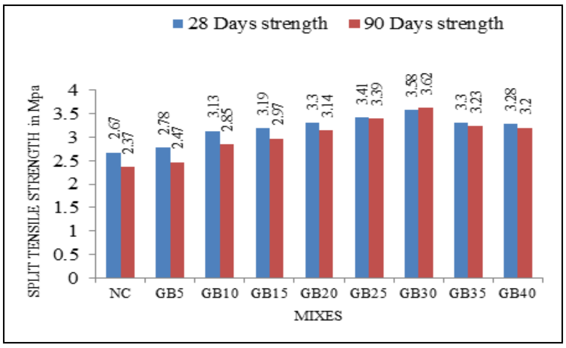


4.2 Split Tensile Strength Test

Split tensile strength test was performed on the different concrete mixes that are taken for the study. The following table shows the split tensile strength results.

Table 4.4- *28 and 90 Days split tensile strength test results*

Mixes	Split tensile strength Mpa 28 days	Split tensile strength Mpa 90 days	% strength Reduction
NC	2.67	2.37	11.23
GB5	2.78	2.47	11.15
GB10	3.13	2.85	8.91
GB15	3.19	2.97	6.89
GB20	3.3	3.14	4.84
GB25	3.41	3.39	0.58
GB30	3.62	3.58	1.10
GB35	3.3	3.23	2.12
GB40	3.28	3.20	2.43



4.3 Flexural Strength Results

The experimental flexural strength of the beam specimen was computed by the following equation from theory of strength of materials. Strength of concrete beam specimen was calculated as:

$$F_b = 3P \text{ x } a/bd^2 \text{ if } a<20$$

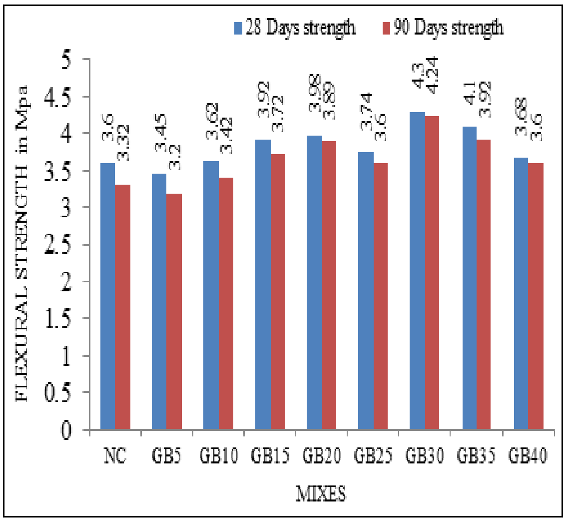
Where,

F_b=flexural stress, MPa,
b=measured width in cm of the specimen
d=depth in mm of the specimen.
l=length in mm of the span on which the specimen was supported and
p=maximum load in kg applied to the specimen.

The following table shows the flexural strength results.

Table 4.4 *28 and 90 Days Flexural strength test results*

Mixes	Flexural strength in Mpa 28 days	Flexural strength in Mpa 90 days	% Strength Reduction
NC	3.6	3.32	11.11
GB5	3.45	3.20	7.24
GB10	3.62	3.42	5.52
GB15	3.92	3.72	5.01
GB20	3.98	3.89	3.74
GB25	3.74	3.60	2.26
GB30	4.30	4.24	1.39
GB35	4.10	3.92	2.17
GB40	3.68	3.60	2.74



4.4 Waste Water Characteristics

The wastewater characteristics analysis was done as per IS: 10500-1991 specifications in which the concrete specimens were immersed in order to study and determine the effects of various parameters that have large influence on mechanical strength properties of concrete. The following table shows the results of various parameters of wastewater.

Table4.5 *Raw sewage characteristics in which concrete specimens were immersed*

Substance or characteristic	Amount of substance
pH	5.45
COD	112 mg/l
Sulphates	270 mg/l
Chlorides	155.80mg/l
Iron content	2 mg/l
Nitrates	4.8mg/l
Fluoride	0.4mg/l
Alkalinity	38.16 mg/l
Acidity	229.2mg/l

5. Conclusion

1) The domestic raw sewage in which the specimens were immersed to investigate the effects of raw sewage on concrete is slightly acidic in nature having pH 5.45, with high suphate i.e., 270mg/l and chloride i.e., 155.80mg/l content. This led to the significant reduction in the strength properties of the concrete with variations of GGBS in different concrete mixes that are taken for the study. The strength results are discussed in detail below.
2) The 90 days compressive strength of the concrete specimens which were immersed in raw sewage has led to decrease in the strength when compared with that of the 28 days strength achieved. And At replacement of cement with 35% of GGBS had shown less strength reduction compared to other concrete compositions.
3) In case of split tensile and flexural strength similar kind of strength reduction was noticed to that of compressive strength. The 90 days split tensile strength when compared with that of the 28 days strength achieved has shown better performance and less strength reduction when immersed in waste water at replacement of cement at 25-30% of GGBS.

References

[1] European Communities, “Pollutants in urban wastewater and sewage sludge” , Final Report, Office for Official Publications of the European Communities, Luxembourg, 2001, ISBN 92-894-1735-8.

[2] Mori T, Nonaka T, Tazaki K, Koga M, Hikosaka Y, Noda S.,“Interactions of nutrients, moisture and pH on microbial corrosion of concrete sewer pipes”, *Water Research1992*,26(1), 29–37.

[3] De Belie N, Monteny J, Beeldens A, Vincke E, Van Gemert D, Verstraete W. ,“Experimental research and prediction of the effect of chemical and biogenic sulfuric acid on different types of commercially produced concrete sewer pipes”, *Cement Concrete Research 2004*, 34(12):2223–36.

[4] Ramezanianpour, A. A. and Malhotra, V. M. (1995) "Effect of curing on the compressive strength, resistance to chloride-ion penetration and porosity of concretes incorporation slag, fly ash or silica fume" *Cement. Concrete Composite*, pp.125-133.

[5] Osborne GJ.” Durability of Portland blast-furnace slag cement concrete”, *Cement Concrete Composite*1999; 21(1):11–21.

[6] Gopalakrishnan S, Balasubramanian K, Krishnamoorthy TS, Bharatkumar BH. “Investigation on the flexural behaviour of reinforced concrete beams containing supplementary cementitious materials”., *ACI Mater J2001*:645–63.

[7] MegatJohari MA, Brooks JJ, Kabir S, Rivard P., “Influence of supplementary cementitious materials on engineering properties of high strength concrete”, *Construct Build Mater 2011*, 25(5):2639–48.

[8] Gollop RS, Taylor H F W. “Microstructural and microanalytical studies of sulfate attack: comparison of different slag blends”, *Cement Concrete Research 1996*; 26(7):1029–44.

[9] Brown PW, Taylor HFW. “The role of ettringite in external sulfate attack”, In: Marchand J, Skalny J, editors. Proceedings, seminar on sulfate attack mechanisms, Quebec, Canada, 1999.

[10] Attiogbe E. K., Rizkallai S. H., “Response of concrete to sulfuric acid attack”, *ACI Mater J 1988*,85(6):481–8.