Interdependence between Structural Engineering and Construction Management
Edited by Ozevin, D., Ataei, H., Modares, M., Gurgun, A., Yazdani, S., and Singh, A.
Copyright © 2019 ISEC Press
ISBN: 978-0-9960437-6-2

MECHANICAL AND DURABILITY CHARACTERISTICS OF GGBS DOLOMITE GEOPOLYMER CONCRETE

AIKOT PALLIKKARA SHASHIKALA, PRAVEEN NAGARAJAN, SARANYA PARATHI

Dept of Civil Engineering, National Institute of Technology Calicut, Calicut, India

Production of Portland cement causes global warming due to the emission of green-house gases to the environment. The need for reducing the amount of cement is necessary from sustainability point of view. Alkali activated and geopolymeric binders are used as alternative to cement. Industrial by-products such as fly ash, ground granulated blast furnace slag (GGBS), silica fume, rice husk ash etc. are commonly used for the production of geopolymer concrete. This paper focuses on the development of geopolymer concrete from slag (100% GGBS). Effect of different cementitious materials such as lime, fly ash, metakaolin, rice husk ash, silica fume and dolomite on strength properties of slag (GGBS) based geopolymer concrete are also discussed. It is observed that the addition of dolomite (by-products from rock crushing plants) into slag based geopolymer concrete reduces the setting time, enhances durability and improves rapidly the early age strength of geopolymer concrete. Development of geopolymer concrete with industrial by-products is a solution to the disposal of the industrial wastes. The quick setting concrete thus produced can reduce the cost of construction making it sustainable also.

Keywords: Marine resistance, Setting time, Sorptivity, Strength, Sulphate resistance, Water absorption.

1 INTRODUCTION

Production of cement is harmful for environment as it is the main source for the development of green-house gases to the atmosphere (Li *et al.* 2011). Many researchers have focused their studies on the use of cementitious material as substitute for cement to protect the environment from global-warming. Later, Geopolymer concrete (GPC) was developed by Davidovits (1984), in which industrial by-products were used for the complete replacement of cement (Davidovits 1991). GPC is a sustainable concrete, which has high strength, durability and less carbon footprint (Juenger *et al.* 2011). Industrial by-products such as fly ash, Ground Granulated Blast Furnace Slag (GGBS) and metakaolin are the main source material for the development of geopolymer concrete (Duxson *et al.* 2007).

GGBS is a by-product from steel industries and its chemical composition is similar to cement. It can react with water at slow rate of hydration and can be activated with an alkali solution for producing high strength (Nath *et al.* 2014). Dolomite is a by-product from rock crushing plant. Use of dolomite powder in self-compacting concrete had been reported earlier (Barbhuiya *et al.* 2011). No work has been reported on the effects of dolomite on geopolymer concrete. In this study, effect of dolomite on strength and durability properties of GGBS geopolymer concrete was investigated.

2 MATERIALS USED

2.1 Ground Granulated Blast Furnace Slag (GGBS)

GGBS and dolomite are the by-products from steel industries and rock crushing plants respectively. Physical and chemical properties of GGBS and dolomite are shown in Table 1.

Table 1. Physical and chemical properties of GGBS, dolomite and OPC.

	Cement	**GGBS**	**Dolomite**
Source	Ultra Tech, 53 grade OPC	Mangalore Steel Industries (Pvt. Limited)	Rock crushing plant, Jaipur
Colour	Grey	Off white	Pure white
Specific gravity	3.14	2.9	2.85
Blaine's fineness (cm^2/gm)	2435	4032	3500
CaO	61.53	38.9	35.58
SiO_2	20.36	33.5	20.78
Al_2O_3	4.31	10.68	8.54
Fe_2O_3	5.98	2.35	2.45
MgO	1.36	9.45	20.58
LOI	6.46	5.12	12.07

2.2 Aggregate

The property of aggregates used in the study, satisfying IS 2386-3 (1963), is shown in Table 2.

Table 2. Properties of aggregates.

Property	**Fine aggregate**	**Coarse aggregate**
Size	Passing through 1.18 mm sieve	Maximum size 12 mm
Water absorption	1.4%	0.93%
Fineness modulus	2.75	6.8

2.3 Alkaline Solution

Combination of sodium hydroxide and sodium silicate was used as an alkaline medium for the test. Sodium hydroxide pellets having purity 97% were dissolved in water one day before casting, since it is an exothermic reaction. Sodium silicate in solution form composed of SiO_2 (27.2%), Na_2O (8.9%) and H_2O (63.9%). Solutions of sodium silicate and sodium hydroxide were mixed together at least one hour before casting (Davidovits 1991). Sulphonated naphthalene based super plasticizer also added to improve the workability.

3 MIX PROPORTIONING OF GEOPOLYMER CONCRETE

There are no proper mix design guidelines available for GGBS geopolymer concrete under ambient curing condition. Mix proportion for M60 concrete was carried out based on trial and error basis for GPC and is shown in Table 3. GPC was filled in each mould in three layers and compacted on a vibrating table. All the specimens were demolded within 24 hours and cured under ambient condition (25-28°C).

Table 3. Mix proportioning of GPC.

Sl. No	Material	Quantity (kg/m^3)
1	Binder content	400
2	Alkaline solution	175
3	Fine aggregate	618
4	Coarse aggregate	1196
5	Super plasticizer	6

4 EFFECT OF DOLOMITE ON STRENGTH PROPERTIES OF GGBS GPC

4.1 Preparation of Specimens

Specimens were prepared as per the mix proportions given Table 3. GGBS was replaced with dolomite in different proportions (Table 4).

Table 4. Proportions of GGBS (G), Dolomite (D) and OPC.

MIX	GGBS	Dolomite	Cement
G100:D0	100	0	0
G90:D10	90	10	0
G80:D20	80	20	0
G70:D30	70	30	0
G60:D40	60	40	0
G50:D50	50	50	0
OPC100	0	0	100

4.2 Setting Time

Setting time of binder was found as per IS 4031 Part IV (1988) using Vicat apparatus. Initial and final setting time of geopolymer paste with different proportions of GGBS and dolomite are shown in Table 5.

Table 5. Setting time of OPC and GPC concrete.

Mix	Initial setting time (min)	Final setting time (min)
G100:D0	47	62
G90:D10	44	58
G80:D20	42	53
G70:D30	36	47
G60:D40	34	46
G50:D50	32	41
OPC100	37	265

Initial setting time for 100 % GGBS was obtained as 47 minutes, which is 27 % more than OPC. Replacement of GGBS with dolomite reduces the initial setting time. When mix ratio of GGBS and dolomite become 50:50, the setting time was reduced by 16 % less than OPC.

4.3 Workability of GPC

Table 6 gives the slump values based on the workability tests conducted as per IS 1199:1959 (1959). GGBS geopolymer concrete has 14% more slump than OPC concrete. 38% more slump was observed in G50:D50 than that of G100:D0. As the percentage of dolomite increases, workability also increases due to the spherical shape of dolomite particles.

4.4 Compressive Strength

150 mm ×150mm × 150 mm cube concrete specimens were tested at 1, 3, 7, 14, 28 and 56 days of curing as per the procedure specified in IS 516:1959 (1959), which is shown in Table 6.

Table 6. Compressive strength of GGBS-dolomite GPC.

Mix	Slump (mm)	Compressive strength (N/mm^2)				
		1 day	3 day	7 day	28 day	56 day
G100:D0	120	42.5	57	62.8	64.5	67.8
G90:D10	132	47.5	65	67.5	68.4	69
G80:D20	145	50.4	65	69.5	70	72
G70:D30	155	53.0	63	71	72.5	73.6
G60:D40	160	45.2	52	64	65.7	68.2
G50:D50	166	30.5	48.5	58	60.4	64
OPC100	105	15.7	23.5	35.6	71.5	73

Addition of dolomite up to 30% increases the compressive strength and decreases thereafter. The optimum percentage of GGBS and dolomite is obtained as 70:30 in terms of strength. Ambient curing provided 95% of the compressive strength of geopolymer concrete within 7 days whereas the strength gaining process of OPC was completed after 28 days of curing in water.

5 TESTS FOR DURABILITY

5.1 Water Absorption

Water absorption test was done as per ASTM C 642-82 (1994) by using cubes of size 100 × 100 × 100mm. Test results are shown in Table 7.

Table 7. Water absorption test results.

MIX	Initial weight (kg)	Weight after 30 minutes (kg)	Weight after 120 hours (kg)	Initial water absorption (%)	Final water absorption (%)
G100:D0	2.62	2.645	2.675	0.954	2.09
G90:D10	2.63	2.653	2.68	0.874	1.91
G80:D20	2.62	2.641	2.65	0.802	1.14
G70:D30	2.61	2.629	2.64	0.728	1.15
G60:D40	2.64	2.66	2.67	0.776	1.13
G50:D50	2.67	2.69	2.75	0.749	2.23
OPC100	2.491	2.525	2.628	1.36	5.49

From Table 7, OPC concrete has 2.63 times more water absorption than G100:D0. Replacement of GGBS with dolomite (30%) decreases water absorption 1.82 times than that of G100:D0. G70:D30 mix has less initial water absorption compared to others, which is 1.87 times and 1.31 times less than OPC100 and G100:D0 respectively.

5.2 Sorptivity

Sorptivity refers to the rate of water absorption through capillary pores. It is measured as per ASTM C 642-82 (1994) using cylinder specimens having diameter 150mm and height 50mm (Figure 2). Sorptivity test results are given in Table 8. OPC concrete has 2.68 times more sorptivity than GGBS geopolymer concrete. Addition of dolomite makes the concrete denser than that of GGBS geopolymer concrete.

Table 8. Sorptivity of geopolymer concrete.

MIX	Sorptivity (cm/min$^{1/2}$) x 10^{-3}
G100:D0	2.45
G90:D10	2.34
G80:D20	2.13
G70:D30	2.14
G60:D40	2.12
G50:D50	2.18
OPC100	6.56

Figure 2. Test setup for sorptivity.

5.3 Sulphate Attack

Oven dried cube specimen having 100 x 100 x 100 mm size were used were immersed in a 3% sodium sulphate solution for 180 days. Loss in weight and compressive strength were measured after 180 days and are shown in Table 9.

Table 9. Acid and sulphate resistance of concrete.

MIX	Acid attack (after 180 days)		Sulphate attack (after 180 days)	
	% weight loss	% loss in compressive strength	% weight loss	% loss in compressive strength
G100:D0	1.21	10.5	0.26	6.45
G90:D10	1.51	10.6	0.20	6.28
G80:D20	1.32	9.51	0.18	6.15
G70:D30	1.47	9.45	0.12	6.18
G60:D40	1.46	9.40	0.11	6.17
G50:D50	1.58	11.58	0.11	6.78
OPC100	35.64	48.56	0.68	20.45

OPC concrete has 2.62 times more weight loss than G100:D0. GGBS-dolomite geopolymer concrete showed reduced weight loss of 2.36 times less than that of G100:D0.

5.4 Marine Attack

Artificial marine water with composition was prepared in the laboratory as per the procedure given in ASTM D1141 (2013). Loss of weight and percentage reduction in compressive strength of 100 x 100 x 100 mm cube specimens was found out after 180 days is given in Table 10.

Table 10. Marine water resistance of GGBS-dolomite GPC.

MIX	% weight loss	% loss in compressive strength
G100:D0	0.95	10.24
G90:D10	0.92	9.84
G80:D20	0.94	9.80
G70:D30	0.92	9.81
G60:D40	1.45	9.64
G50:D50	1.89	10.85
OPC100	8.21	25.78

OPC 100 has 8.6 times more weight loss than that of G100:D0 during marine water attack. 2.52 times compressive strength loss was also observed for OPC concrete than that of GPC.

6 CONCLUSIONS

- Addition of dolomite decreases the setting time of GGBS geopolymer concrete, thus reducing the total construction time.
- Maximum compressive strength was obtained at GGBS and dolomite proportion 70:30.
- GGBS-Dolomite geopolymer concrete attained 95% of its compressive strength within 7 days of ambient curing, while that of conventional concrete completed its strength gaining process after 28 days of water curing.
- GGBS-Dolomite GPC has improved water absorption, sorptivity and high resistance towards sulphate and marine attack. Hence, it can be used for construction in marine environments.

Acknowledgements

The authors thankfully acknowledge the financial support provided by Kerala State Council for Science, Technology and Environment [TDAP/01/2017/KSCSTE], Kerala, India.

References

ASTM C 642-82, Standard Test Method for Specific Gravity, Absorption and Voids in Hardened Concrete, *Annual Book of ASTM Standards*, Vol. 4.02, 1994.

ASTM-D1141-98: Standard Practice for the Preparation of Substitute Ocean Water, *Annual Book of ASTM Standards*, Vol. 11.02, 2013.

Barbhuiya, S., Effects of Fly Ash and Dolomite Powder on the Properties of Self-Compacting Concrete, *Construction and Building Materials*, 25(8), 3301-3305, 2011.

Davidovits, J., Geopolymers: Inorganic Polymeric New Materials, *Journal of Thermal Analysis and Calorimetry*, 37(8), 1633-1656, 1991.

Davidovits, Synthetic Mineral Polymer Compound of the Silicoaluminates Family and Preparation Process, *US Patent No. 4*, 172, 199, 1984.

Duxson, P., Provis, J. L., Lukey, G. C., and Van Deventer, J. S., The Role Of Inorganic Polymer Technology in The Development of 'Green Concrete', *Cement and Concrete Research*, 37(12), 1590-1597, 2007.

Juenger, M. C. G., Winnefeld, F., Provis, J. L., and Ideker, J. H., Advances in Alternative Cementitious Binders, *Cement and Concrete Research,* 41(12), 1232-1243, 2011.

IS 516-1959: Methods of Test for Strength of Concrete, *Bureau of Indian Standards*, New Delhi, P.11, 1959.

IS 1199-1959: Methods of Sampling and Analysis of Concrete, *Bureau of Indian standards*, New Delhi, P.11, 1959.

IS 2386 (Part III)-1963: Methods of Test for Aggregate for Concrete Part 3-Specific Gravity, Density, Voids, Absorption and Bulking, *Bureau of Indian Standards*, New Delhi, P.17, 1963.

IS 4031-1988: Methods of Physical Tests for Hydraulic Cement, *Bureau of Indian Standards*, New Delhi, P.1, 1988.

Li, C., Gong, X. Z., Cui, S. P., Wang, Z. H., Zheng, Y., and Chi, B. C., CO_2 Emissions Due to Cement Manufacture, *Materials Science Forum,* Trans Tech Publications, 685, 181-187, 2011.

Nath, P., and Sarker, P. K., Effect of GGBFS on Setting, Workability and Early Strength Properties of Fly Ash Geopolymer Concrete Cured in Ambient Condition, *Construction and Building Materials*, 66,163-171, 2014.