Experimental Investigation on Development of Compressive Strength of High-Strength Geopolymer Concrete Containing M-Sand

Gaurav Jagad, C. D. Modhera, and Dhaval Patel

Abstract The serious issue related to more consumption of cement-based concrete because of the CO_2 emission, while manufacturing of the cement. The Portland cement manufacturing causes the emissions of pollutants in atmosphere. By use of industrial by products in construction industry will reduce these harmful effects. The incorporation of Ground Granulated Blast Furnace Slag (GGBS) in construction field is the best suitable solution to utilize waste as a binder. Also, the demand of river sand is so high and the resources of natural river sand going to over and become costly and finally become expensive and rare. Because of these illegal excavations of river sand have occur and natural resources will be destroyed. To overcome this issue in eco-friendly aspect, in this research, the incorporation of manufactured sand instead of river sand can be the better solution in construction industry. The ultimate objective of this study is to incorporate the locally available material in high-strength geopolymer concrete like GGBS as a binder and manufactured sand as a fine aggregate.

Keywords High-strength geopolymer concrete · Manufactured sand · Ground granulated blast furnace slag

1 Introduction

Geopolymer concrete is considered very strong in nature and can withstand harsh conditions and existing temperatures. Compared with steel fiber, GGBS in low-calcium geopolymer concrete exhibits particularly high-pressure resistance and toughness [1]. Facts have proved that, compared with Portland cement concrete, low-calcium fly ash-based geopolymer concrete is extremely cost-effective and eliminates greenhouse gases harmful to sustainable development. Concrete is the main constructing material which is the second highest consumption by human after the water and the main component of concrete is Portland cement. In a new aspect,

G. Jagad (✉) · C. D. Modhera · D. Patel
Sardar Vallabhbhai National Institute of Technology, Surat, India

B. Kondraivendhan et al. (eds.), *Sustainable Building Materials and Construction*, Lecture Notes in Civil Engineering 222,
https://doi.org/10.1007/978-981-16-8496-8_3

the biggest risk facing humans on earth today is global warming and environmental pollution. Cement production refers to the production of pollution caused by carbon dioxide emissions during the production process. To reduce construction costs, improve construction efficiency and increase the compressive strength of concrete, the industrial waste can be converted into usable building materials [2]. Every ton of cement produced will produce a ton of carbon dioxide, which will pollute the environment [3]. Therefore, the use of geopolymer concrete is best suitable solution for eco-friendly concrete.

Concrete is made of natural sand as fine aggregate. Due to the depletion of natural resources, the scarcity of natural sand, and due to environmental considerations, concrete manufacturers have to seek suitable alternative for fine aggregates [3]. One such alternative is "Manufactured sand," and it is made by sieving natural stone powder or crushed granite stone to adapt to the particle size of natural sand, to be used as fine aggregate [4].

The objectives of the present research study are to find the feasibility study on high-strength geopolymer concrete made with M-sand as fine aggregate. To determine the workability of wet concrete, the slump cone test was carried out and after that concrete has placed in 15 cm × 15 cm × 15 cm cube mold for 24 h. After 24 h, concrete demolding of cast concrete carried out and placed ambient curing for 7 days.

2 Experimental

2.1 Material and Mix Proportions

2.1.1 GGBS

GGBS is created by the method of quenching, which is the method of sudden ion slag cooling from a blast furnace using water or flux. A glassy, granular substance is obtained at the end of the process, and then dried and grinded into fine powder. GGBS is a form of off-white cement. It's often referred to as slag cement by the United Kingdom which it has used in Europe, United States and Asia. GGBS is a binding material which is used mainly in ready-mix concrete with a ratio of 30–70% to create an eco-friendly concrete [5]. GGBS used as the main binder material in this article and the chemical composition of GGBS in Table 3.

2.1.2 Alkaline Solution

For the geopolymerization process, alkaline solution plays main role. The combination of NaOH and Na_2SiO_3 was used as an alkaline solution. The sodium silicate (Na_2SiO_3) solution was purchased from Sadguru Chemicals, Veraval, Rajkot.

Table 1 Chemical composition of GGBS

Particulars	(SiO_2)	(Al_2O_3)	(Fe_2O_3)	(CaO)	(MgO)	(K_2O)	(Na_2O)	(TiO_2)
GGBS	32.19	8.59	2.8	38.09	5.5	0.4	0.26	8.89

Table 2 Properties of an aggregate

Size	Specific gravity	Impact value
20 mm	2.75	20%
10 mm	2.65	24%

Table 3 Sieve analysis of river sand and manufactured

Sieve size	10 mm	4.75 mm	2.36 mm	1.18 mm	600 micron	300 micron	150 micron	75 micron	Pan
River sand	100	99.8	93.3	55.95	33.8	11.9	5.7	0	0
M sand	100	100	97.8	90.7	70.4	16.95	12.2	0.5	0

2.1.3 Aggregate

Coarse Aggregate

Aggregates that were locally available has been used for the experiment work. Properties of aggregate are mentioned in following Table 4.

Fine Aggregate (River Sand and Manufactured Sand)

M-sand is nothing but artificial sand made by crushing rocks or granite for construction purposes. The physical and mineralogical properties of M-sand are different from those of natural river sand. Nowadays, due to environmental degradation, natural sand sources (such as river sand, pit sand, stream sand, sea sand and other sand used as concrete aggregates) have become scarce and depleted. The driving need for alternative aggregates in construction has given the source to M Sand. Sieve analysis and physical properties of both sand tabulated as in Tables 1 and 2, respectively (Tables 3 and 4).

Table 4 Physical properties of river sand and manufactured sand

	Fineness modulus	Specific gravity	Water absorption (%)	Loose density (kg/m^3)	Rodded density (kg/m^3)	Grading zone	Voids (%)	Moisture content (%)
River Sand	2.8	2.66	1.8	1.7	1.83	Zone II	36.09	1.9
M Sand	2.9	2.536	5.544	1.71	1.84	Zone II	32.57	0.15

3 Experimental Program

Concrete mix was prepared using GGBS as a binder and alkaline liquid. Alkaline solution has been prepared one day before casting. A solution with a Na_2O/SiO_2 ratio by mass of approximately 2 (say, $Na_2O = 14.7\%$, $SiO_2 = 29.4\%$, and water = 55.9%) is recommended. Sodium hydroxide with 98% purity, in pellet form, was used. The concentration of NaOH in terms of molarity was 16M. In this study river sand as well as M-sand used as a fine aggregate content and as a coarse aggregate 20 mm as well as 10 mm sized aggregates were used. The wet mix was then placed in a mold and vibrated on a table vibrator. The mix proportions of geopolymer concrete as given in following Table 5.

3.1 *Methodology*

The ratio of Na_2SiO_3 to NaOH has taken as 3, in terms of Molarity concern 16M concentration has been selected. Binder to solution ratio taken as 0.5. River sand has completely eliminated by manufactured sand. GGBS used as a main binder content and 1% plasticizer used for better workability. Ambient curing for 24 h and then after demolding and applied only free air curing for cast concrete specimens [6] (Figs. 1, 2, 3, 4, 5 and 6).

Table 5 Mix proportion

Constituent	GGBS	Sand	Coarse aggregate	NaOH solution	Na_2siO_3	Extra water	SP
Quantity (kg/m^3)	480	625	1216	59	175	92.21	4.8

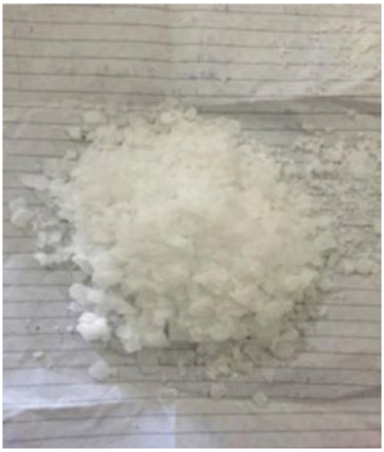

Fig. 1 NaOH flex

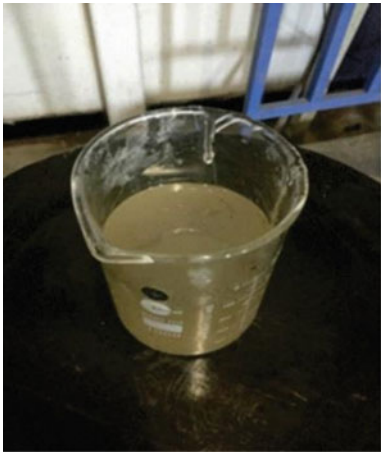

Fig. 2 Na_2SiO_3 solution

Fig. 3 Alkaline solution

Fig. 4 Machine mixing

Fig. 5 Measuring slump

4 Results and Discussion

The workability and compressive strength of high-strength geopolymer concrete have been carried out and the results shown in Figs. 5 and 6 as under.

Fig. 6 Compression test

- Workability of high-strength geopolymer concrete containing river sand is high as compared to high-strength manufactured sand concrete because the moisture content is already present in the river sand, and manufactured sand is free from moisture. Moreover, the river sand particles are rounded and manufactured sand particles are angular, and these angular shape particles make concrete denser.
- While using manufactured sand in concrete workability has been decreased. This issue can be overcome by incorporating superplasticizer content more than 1.5% or 2% in wet concrete mix.
- In compressive strength of both concrete seems good but as compared to river sand, manufactured concrete gave higher strength because of the angular particles of manufactured sand the bonding between subsequent particles is good (Figs. 7 and 8).

5 Conclusions

From the experimental study and investigations performed, the following conclusions were made,

- The improvement of compressive strength in M-sand concrete is approximately 10% at 7 days. So, it can be noted that the M-sand is the best alternative as a natural sand.
- The wet concrete mix of M-sand has low workability, because its particle shape is angular, which can be compensated by adding superplasticizer to the mixture.

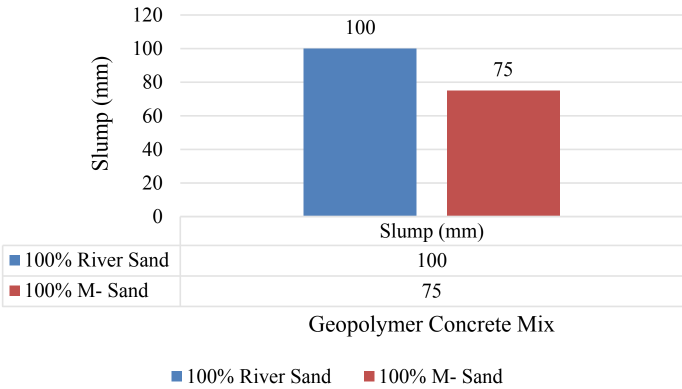

Fig. 7 Slump test results

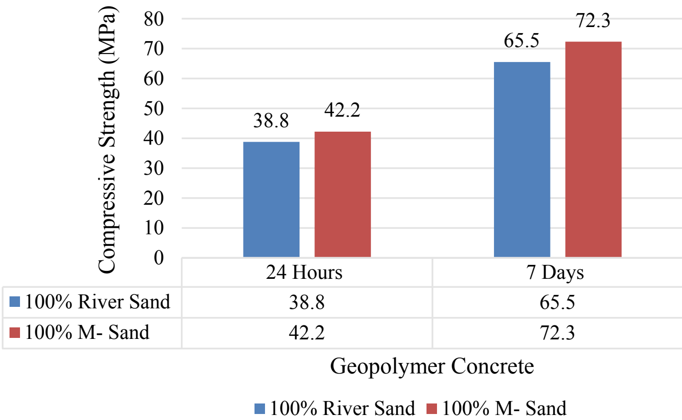

Fig. 8 Compression test results

- The water requirement of M-sand geopolymer concrete is high because of free moisture of M-sand is almost zero as compared to river sand.

References

1. Sashidar C et al (2015) Fresh and strength properties of self compacting geopolymer concrete using manufactured sand. Int J Chemtech Res 8(7): 183–190. ISSN: 0974-4290
2. Gomathi J, Doraikannan J (2016) Study on geopolymer concrete using manufactured sand. Int J Adv Res Trends Eng Technol (IJARTET)
3. Janani R, Revathi A (2015) Experimental study of geopolymer concrete with manufactured sand. Int J Sci Eng Technol Res (IJSETR) 4(4)
4. Abdul Aleem MI, Arumairaj PD (2013) Pollution free geopolymer concrete with m-sand

5. Nagajothi S, Elavenil S (2016) Strength assessment of geopolymer concrete using m-sand. Int J Chem Sci 14(S1): 115–126. ISSN 0972-768X
6. Topark-Ngarm P, Chindaprasirt P, Sata V (2014) Setting Time, strength, and bond of high-calcium fly ash geopolymer concrete. https://doi.org/10.1061/(ASCE)MT.1943-5533.0001157. © 2014 American Society of Civil Engineers