Materials Letters 231 (2018) 105–108

Contents lists available at ScienceDirect

Materials Letters

journal homepage: www.elsevier.com/locate/mlblue

Compressivestrength study of geopolymer mortar using quarry rock dust

T. Venu Madhav [a,*], I.V. Ramana Reddy [b], Vaishali G. Ghorpade [c], S. Jyothirmai [d]

[a] Head Department of Civil Engineering, Audisankara College of Engineering & Technology, Gudur 524101, Andhra Pradesh, India
[b] Professor, Department of Civil Engineering, S.V.U. College of Engineering, TIRUPATI – 517 502, Andhra Pradesh, India
[c] Professor, Civil Engineering Department, JNTUA College of Engineering, Anantapuram-515002, Andhra Pradesh, India
[d] Assistant Professor, Department of Civil Engineering, Audisankara College of Engineering & Technology, Gudur 524101, Andhra Pradesh, India

ARTICLE INFO

Article history:
Received 6 January 2018
Received in revised form 9 June 2018
Accepted 28 July 2018
Available online 3 August 2018

Keywords:
Geopolymer
Alkaline solution
Cement concrete
Fly ash
Slag
Sustainable technology

ABSTRACT

India is one of the Developing countries that needs to face the environmental pollution. We have many ways to reduce environmental pollution that causes by production of Portland cement and by the increasing of waste material. Geopolymer is the term used to represent the binders produced by polymeric reaction of alkaline liquid with silicon and aluminium as source materials. Common river sand is expensive due to excessive cost of transportation from natural sources. Also large-scale depletion of these sources creates environmental problems. River sand is most commonly used fine aggregate in the production of concrete poses the problem of acute shortage in many areas. In such a situation the Quarry rock dust can be an economic alternative to the river sand.

Quarry Rock Dust can be defined as residue, tailing or other non-voluble waste material after the extraction and processing of rocks to form fine particles less than 4.75 mm. This paper presents the feasibility of the usage of Quarry Rock Dust as a substitute for Natural Sand in geopolymer mortar. The by-product materials considered in this study are combination of GGBFS and Fly ash. The experimental program involves casting of geopolymer mortar cubes by using GGBFS, Flyash and Quarry rock dust and testing them at 1 day, 3 days and 7 days for compressive strength. Different parameter considered in this study is alkaline fluid to binder ratio Keeping 12-Molarity of the alkaline liquid and the ratio of sodium hydroxide to sodium meta silicate as constant (1:2).

1. Introduction

Concrete is the most widely used material all over the world after water. Portland Cement is the most important ingredient in making concrete whose production leads to severe environmental hazards [5]. The production of 1ton of cement emits about 1 ton of carbon dioxide which is the major green house gas contributing to environmental pollution [1].The contribution of ordinary Portland cement production worldwide in the emission of green house gas is approximately 7% to the total green house gas emission to the atmosphere. Hence there is a need to develop alternative binders to make concrete [6]. The concrete developed with this theme which is under research and practice now a days is geopolymer concrete. This revolutionary development in construction industry has been brought by Joseph Davidovits who proposed the that binders could be produced by polymeric reaction of alkaline liquids with silicon and aluminium in source materials of geological origin or bi-product materials of fly ash and rice husk ash [10]. He termed these polymers as geopolymers [2]. Palermo et al suggested that pozzolanos such as blast furnace slag might be activated using alkaline liquids to form a binder and hence totally replace the use of ordinary Portland cement in concrete [8]. Thus emerged the concept of geopolymer concrete.

Apart from cement, from thousands of years sand and gravel have been used in the construction industry. Today, the demand for sand continues to increase. So there is excessive in stream sand and gravel mining leading to the degradation of rivers [9]. This excessive instream sand mining is a threat to bridges, river banks and near by structures. Also the excessive depletion sand is the main reason for ecological imbalance [8]. Hence sustainable alternate material to sand has to be used in the production of concrete and mortar. One of the alternative is the use of quarry dust in replacement to sand as fine aggregate.

Hence, in scheme of reducing the environmental hazards due to the ingredients of concrete production the present research deals with the study of compressive strength of geopolymer mortar which is a combination of GGBFS & flyash (in replacement of cement), Quarry rock dust (in replacement of sand), and 12 M

* Corresponding author.
E-mail address: vtmadhav@gmail.com (T. Venu Madhav).

https://doi.org/10.1016/j.matlet.2018.07.133
0167-577X/

alkaline solution made of Sodium Hydroxide and Sodium meta silicate. The ratio of NaOH to Na_2SiO_3 considered in this study is 1:2.

2. Materials

Materials used in this research are GGBFS obtained from JSW industries ltd. Bellary, Fly ash (Table 2) from VTPS, Vijayawada and sodium meta silicate and sodium hydroxide from Dutta scientific chemicals, Bangalore. The fine aggregate used in this study is Quarry rock dust, a by- product of stonecrusher industry was procured from a local stone crusher Kandra Gudur AP. India.

As fineaggregate, quarrydust provides volume to the mix. It imparts workability, homogeneity and uniformity to the mortar/-concrete mix The sodium hydroxide is in flakes and pellets form and having about 98% purity.

These pellets were mixed with distilled water to obtain the sodium hydroxide solution of required molarity. In the present study, the molarity of the solution is kept constant at 12 M for all the experimental investigations. The chemical compositions of the materials used in this research are given in the table below (Tables 1 and 2). Also, the physical properties of quarry dust are given in the succeeding table (Table 3).

3. Experimental program

In this research combination of GGBFS and low calcium Fly ash is used as binder instead of ordinary Portland cement in the preparation of cement mortar and the sand which is generally used in preparing mortar is replaced by quarry rock dust. The mixture of GGBFS and fly ash is activated by using alkaline solution which is a combination of sodium hydroxide solution and sodium meta silicate solution. The solution is prepared 24 h in advance before the use [3]. The weight of sodium hydroxide required for preparing the solution is calculated from the molarity. The molarity is kept constant throughout the experiment i.e., 12 and the weight is calculated from the gram molecular weight of NaOH i.e., 40. The required weight thus obtained is mixed with 1 L of water to obtain 1 L of NaOH solution and the weight of sodium meta silicate required is calculated using the ratio of sodium hydroxide: sodium meta silicate [6]. The ratio used in this research is 1:2.

The required weight of sodium meta silicate thus obtained is mixed with 1 L of water to obtain 1 L of sodium meta silicate solution and the two solutions are mixed together and kept still for 24 hr before proceeding to the experiment [7].

The manufacture of geopolymer mortar is carried out using the usual methods as in case of ordinary Portland cement mortar [4]. The required quantities are weighed for a given proportion of fluid to binder ratio and binder to aggregate ratio and the materials are mixed together in pan mixture. Dry mix is carried out for 3 min followed by a wet mix for about 4 min.

The mortar thus obtained is filled in cube moulds in three layers by tamping each layer 25 times and then compacting by using vibrator. The dimensions of cube used $70.6 \times 70.6 \times 70.6$ mm. The cubes thus prepared are allowed to cure under ambient conditions.

The cube specimens prepared are allowed to self curing under ambient conditions and the compressive strength is found out after 1 day, 3 days and 7 days. The cubes are tested in "digital compression testing machine manufactured by AIMIL Limited having a capacity of 2000KN". Three cubes are tested at a time and the results are represented in graphs as average strength of the three cubes.

4. Results and discussion

In the present research the effect of quarry rock dust is studied as the complete replacement with the amount of GGBFS for different alkaline fluid to binder ratios. "Alkaline liquid to binder ratio considered in this study is 0.55, 0.5, 0.45 and 0.4. The variation of GGBS percentage in the binder is from 0 to 100% with 10% interval. Three cubes of each binder proportion is prepared and tested for strength at a particular age. The cubes are tested at 1, 3, 7, 14, 28 and 56 days. Thus for a particular binder proportion, for each fluid to binder ratio 18 cubes are prepared.

Thus, for all the binder proportions from 0 to 100% a total of 198 cubes are prepared for a particular fluid to binder ratio. Hence, for the entire investigation for 4 fluid to binder ratios considered in the study a total of 792 cubes are casted and tested for compressive strength at different ages" All the cube moulds are tested for compressive strength using the digital compression testing machine.

It evident from the present investigation "Long curing times relatively allow the formation of fairly homogeneous samples with highly compressive strength at high fluid to binder ratios, whereas breaks of the granular structure of geopolymers are observed at low fluid to binder ratios."

Table 1
Chemical Composition of GGBFS.

CONSTITUENTS	fineness (M^2/kg)	Particle Size (cumulative percent)	Insoluble Residue	Magnesia	Sulphide-Sulphur	Sulphide	Loss on Ignition	Manganese	Chloride	Glass	Moisture
PERCENT BY WEIGHT	412	94.25/100	0.23	8.73	0.54	0.29	0.17	0.06	0.010	90	0.14

Table 2
Chemical Composition of Fly Ash.

CONSTITUENTS	Silica	Aluminium	Iron oxide	Manganese	Titanium oxide	Potassium oxide	Calcium oxide	Magnesium oxide	Phosphorus	Sulphur tri oxide	Sodium oxide	Loss on Ignition
PERCENT BY WEIGHT	64.22	20.37	4.44	0.12	0.49	2.35	4.32	0.40	0.37	1.25	0.80	0.89

Table 3
Physical properties of Quarry dust.

DESCRIPTION	Specific gravity	Bulk density (loose) Kg/m^3	Bulk density (compacted) Kg/m^3	Fineness modulus	Grading zone
VALUE	2.85	1644	1756	3015	I

The results of compressive strength with increasing percentage of GGBS for different Fluid to binder ratios are presented in the Figs. 1–4.

"From the results it can be inferred that there is considerable increase in strength of geopolymer mortar with increase in age and also for an increase in the percentage of GGBS at all fluid to binder ratios. It can be observed that the strength increased in consistent manner up to 7 days and the rate of increase is more predominant at 14 and 28 days whereas at 56 days this increase is negligible as the mortar achieved maximum strength by 28 days.

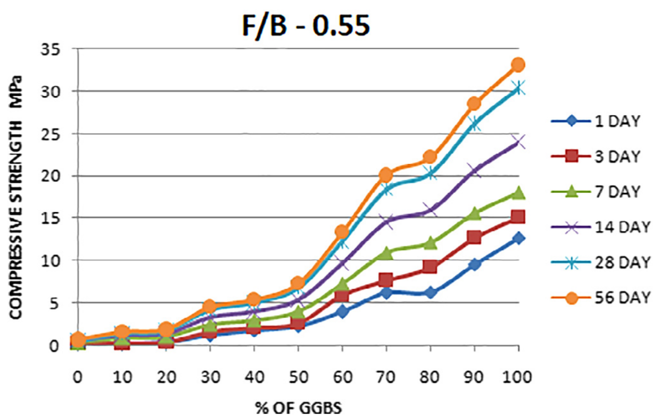

Fig. 1. Compressive strength Vs % of GGBS @ F/B –0.55.

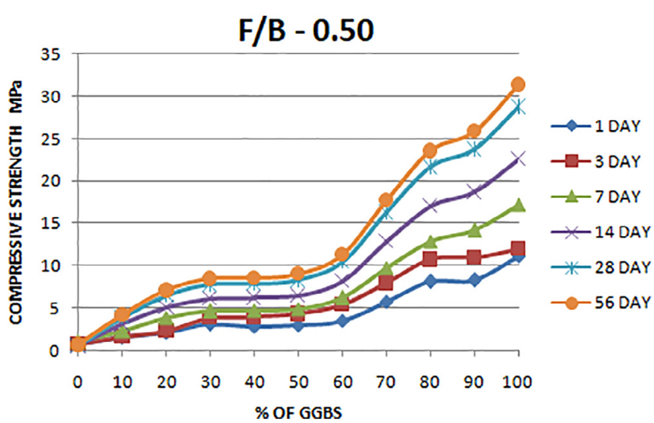

Fig. 2. Compressive strength Vs % of GGBS @ F/B –0.50.

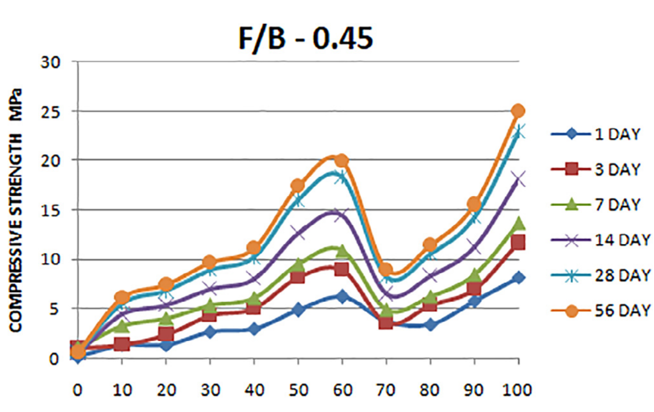

Fig. 3. Compressive strength Vs % of GGBS @ F/B –0.45.

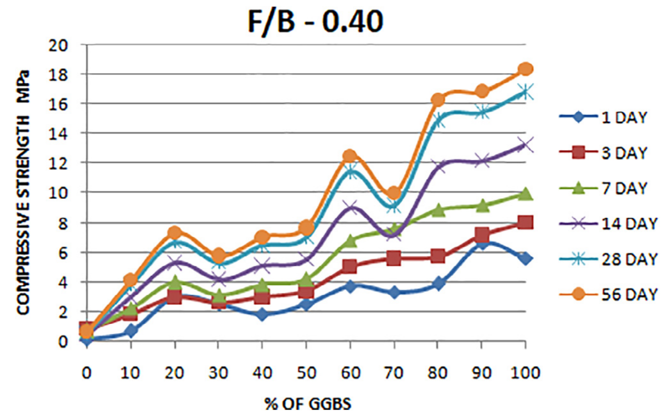

Fig. 4. Compressive strength Vs % of GGBS @ F/B –0.40.

Also, it can be seen that maximum strength is obtained for 100% GGBS in the binder for all fluid to binder ratios at all ages. The increase in strength with increase in percentage of GGBS is more predominant in the range of 70–100% as can be seen in the graphs. However the variation is in a zigzag manner at fluid to binder ratio of 0.45 and 0.40 which can be attributed to lesser amount of NaOH present in the fluid to activate flyash and GGBS. It can also be seen that the strength decrease is more from fluid to binder ratio 0.45–0.4 which can also be attributed to less reactivity of NaOH in the binder. The maximum strength obtained is 33.11 at 56 days for F/B of 0.55 at 100% GGBS in the binder. The 28 days strength of this proportion is 30.38 which is within the desired limit. From the results it can be observed that although the strength is maximum at 56 days, the 28 days strength is in the desired range from 80 to 100% of GGBS for F/B ratio of 0.55 and 0.5. The maximum strength obtained for F/B of 0.45 and 0.4 is 25.02 and 18.31 respectively at 56 days for 100% GGBS which is also acceptable range. But, the decrease can be attributed to decreased activation of the binder material."

5. Conclusion

The following conclusions can be drawn from the present experimental investigations:

- The strength increased with increase in age, increase in percentage of GGBFS and also with an increase in Fluid to Binder ratio.
- The maximum strengths obtained are 33.11 MPa, 31.34 MPa, 25.02 MPa, 18.31 MPa at 56 days for Fluid to Binder ratios of 0.55, 0.5, 0.45, 0.4 respectively at 100% GGBFS.
- Thus we can say that there is consistent increase in strength for an increase in F/B from 0.5 to 0.55 but the strength has greatly reduced when the F/B is further decreased to 0.45 and then to 0.4 which shows the scarcity of fluid cannot impart strength due to weak activation.
- The study can be extended further for better results and better strength for considering in practical approach to reduce the environmental hazards of soil erosion increase in global warming etc.

References

[1] P.K. Mehta, Mechanisms of sulphate attack on Portland cement concrete-another look, Cem. Concr. Res. 13 (3) (1983) 401–406.
[2] Joseph Davidovits, Ancient and modern concretes: what is the real difference?, Concr Int. (1987) 23–28.
[3] J. Davidovits, Properties of Geopolymer Cements, in: Kiev (Ed.), First International Conference on Alkaline Cements and Concretes, Ukraine: Kiev State Technical University, Kiev, 1994, pp. 131–149.

[4] J. Davidovits, Geopolymer Chemistry and Properties. Paper presented at the Geopolymer '88, First European Conference on Soft Mineralogy, Compiegne, France. (1988b).
[5] J. Davidovits, Green-Chemistry and Sustainable Development Granted and False Ideas About Geopolymer-Concrete, Australia, Perth, 2005.
[6] B.V. Rangan, D. Hardjito, S.E. Wallah, D.M.J. Sumajouw, Fly ash based geopolymer concrete: a construction material for sustainable development, Concr. Aust. 31 (2005) 25–30.
[7] H. Xu, J.S.J.V. Deventer, The geopolymerisation of alumino-silicate minerals, Int. J. Miner. Process. 59 (3) (2000) 247–266.
[8] J. Davidovits, (1999, 30 June – 2 July 1999). Chemistry of Geopolymeric Systems, Terminology. Paper presented at the Geopolymere '99 International Conference, Saint-Quentin, France.
[9] J. Davidovits, Geopolymers of the First Generation: SILIFACE-Process. Paper presented at the Geopolymer '88, First European Conference on Soft Mineralogy, Compiegne, France. (1988c).
[10] J. Davidovits, Geopolymeric Reactions in Archaeological Cements and in Modern Blended Cements. Paper presented at the Geopolymer '88, First European Conference on Soft Mineralogy, Compiegne, France. (1988d).