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Mechanical properties of fly ash and blast furnace slag based alkali activated concrete using high silica modulus activator

*Dr.G.V.V.*Satyanarayana[1], *Kaparaboina* Greeshma[2]

[1] Professor of Civil Engineering Department, GRIET, Hyderabad.
[2] M. Tech student Department of Civil Engineering, GRIET, Hyderabad

Abstract: The alternative to cement is grabbing attention of inventors due to the numerous advantages with their usage. Fly Ash (FA) and Blast furnace slag (BFS) are abundantly available in bi product form. There is heavy problem in disposal and land availability for industries. So many studies are going on to reduce these problems by usage as cementitious materials in concrete adding advantages towards green concrete. It is developed that Alkali activated flyash concrete has high strength, high acid resistance and heat resistance where as Alkali activated slag concrete has rapid setting time, high strength, impermeable and improved fire resistance. In this study FA and BFS are activated with high silica modulus activator with different activator/binder ratios and binder contents. The alkali activated FA-BFS concrete is verified for workability, compressive strength, split tensile strength, and flexural strength.
Keywords Fly Ash (FA) and Blast furnace slag (BFS) based alkali activated concrete (AAC), High silica modulus, Activator/binder ratio, Mechanical properties, ambient curing.

1 Introduction

Cement is the primarily used constituent material for binding material in conventional concretes so its usage and demand is higher since so many decades. Manufacture of cement contributes to negative impact on environment mainly depletion of ozone layer and different raw materials like lime stone and sand. On this aspect the researchers are finding solution to protect natural resources. Alkali activated concrete is one of the response towards this environmental concern. Alkali activated binders such as inorganic polymers alkali-bonded ceremics, geopolymers are environmental friendly materials. Alkali activated binder reduced the effect of deplication of raw materials along with advantages of high compressive strength, fire resistance, rapid setting time, low shrinkage, resistance of alkali aggregate reaction, freeze-thraw resistance and markable durability. Generally Fly Ash (FA) and Blast furnace slag are mostly used binders.

Shah, Syed Farasat Ali, et al [1] studied on the impact of slag content, activator, retarder content and curing effects on the fresh and hardened properties of AAFSC. Compressive strength and flexure strength results indicated that curing condition governed that strength of alkali activated mortars. SEM conformed improved geo polymerization reaction at heat curing leads to increase in early strength. Dr.G. V. V Satyanarayana, and C. Saikiran [2] stated that increase in compressive strength was observed upto 50% of fine aggregate replacement with copper slag. The split tensile strength and flexural strength decreased due to less interlocking space between concrete ingredients. Zhou, Xianyu, et al [3] studied that AAM'S are alternatives for Portland cement but the problem of shrinkage and cracking of these binders is deduced by adding basalt and PP reinforced fiber in concrete in this investigation. With increase in basalt fibre dosage and its length compressive strength increased initially later it decreased where as split tensile strength, flexural strength increased with increasing fiber dosage later there was decrease in split tensile strength. Kishore and Kamal, et al [4] concluded when GGBS is partially replaced by metakaolin with NaOH and Na_2SiO_3 the setting time increased whereas compressive strength decreased. Fang and Guohao, et al [5] studied the mechanism of microstructural evolution of interfacial transition zone in AAFSC using SEM. For one day quick reaction of activator/binder leads to increase in formation of reaction products, for seven days the dissolved species increases along with high Ca C-(N)-A-S-H and C-A-S-H. For 28 days compact dense Ca C-(N)-A-S-H microstructure with rich Si, Al is formed. Bhardwaj and Bavita, et al [6] concluded that by replacing foundry sand in GPC and AASC workability decreased. In GPC 100 % replacement gave maximum strength of 43% of 28 days, where as AASC on replacing 40-60% with foundry sand achieved more than 77% compared to GPC. Tensile strength is same as compressive strength. Marjanovic and Natasa, et al [7] studied AAFSC for varing proportions of Fly Ash, blast furnaces slag and activator concentration. And stated that compressive strength depends on composition of blend of flyash, blast furnaces slag and the water/binder ratio whereas the setting time depends on activator concentration. Fly Ash alkali reaction in binding face influence flexural strength where as blast furnaces slag alkali reaction influence the compressive strength. Chi, Maochieh, and Ran Huang [8] studied AAFSC was produced with silica modulus 1 where Na_2O concentration of 4% and 6% with liquid/binder the results showed that Flyash/slag ratio and dosage ratio are influencing factor of binding mechanism and properties of AAFSC. The compressive strength and flexural strength are higher compared to OPCC. FA need curing at elevated temperatures whereas BFS has rapid setting time to eradicate these problems combination of FA and BFS with high silica modulus of 2.91 is used as activator. In this article three different activator/binder ratio with FA-BFS binder content of 500 Kg/m^3 are prepared to conducted compressive strength, split tensile strength, and flexural strength.

2 Materials

The combination of FA and BFS are used as binders. The specific gravity of FA and BFS are 2.6 and 2.8 respectively. The mineralogical composition of FA and BFS are in Table 1. The fine aggregate is the river sand with maximum size of 2.5mm. The coarse aggregate is of maximum size 20mm. High silica modulus sodium silicate solution is used as activator. This neutral activator with SiO_2:Na_2O ratio 2.91 used without any admixtures.

Table 1: Mineralogical composition of FA and BFS

Chemicals	FA (wt%)	BFS (wt%)
CaO	6.9	42.3
Na_2O	0.63	0.34
SiO_2	50.2	35.9
Al_2O_3	23.2	12.8
MgO	1.2	6.03
Fe_2O_3	4.92	0.53
K_2O	1.32	0.321
SO_3	1.49	1.79
TiO_2	1.4	0.70

Concrete mixture

In this study a total of six mixes were prepared and tested. The six mixes has constant binder content of 500kg/m^3. The ratio of FA and BFS are 70:30 and 50:50. The activator/binder ratio of 0.6, 0.65 and 0.7 are considered. A total of 114 specimens are casted and tested. The details of concrete mix proportion are in table 2

Table 2: Mix proportions

Mix	M1	M2	M3	M4	M5	M6
Binder content (kg/m^3)	500	500	500	500	500	500
FA (%)	70	50	70	50	70	50
BFS (%)	30	50	30	50	30	50
Activator/binder	0.6	0.6	0.65	0.65	0.7	0.7
Fine aggregate (kg/m^3)	765.2	765.2	753.1	753.1	742.6	742.6
Coarse aggregate (kg/m^3)	935	935	921	921	907	907
Activator (kg/m^3)	300	300	325	325	350	350

3 Experimental procedure

The normal consistency, initial setting time and final setting time tests are conducted for alkali activated FA BFS using vicat's apparatus similar to that of cement test. The test are done adding activator in place of water. The workability of FA-BFS based concrete for six mixes using slump cone test is conducted to ensure proper flowability of concrete. In this study to obtain mechanical properties of FA-BFS based AAC the trail based mix design proportions are shown in Table 2. The preparation of FA-BFS based AAC involved dry mixing of FA, BFS, fine aggregate and coarse aggregate. Then the activator is added and mixed for more 5 -7 minutes till homogenous material is obtained. The specimens are casted, vibrated for 10 seconds and allowed to dry for 24 hours and then demoulded. The specimens are cured at ambient temperature and strengths are determined.

4 Results and Discussions

The normal consistency test of FA and BFS is comparable to cement. The normal consistency of FA and BFS achieved at 28% and 38% respectively. The initial setting time of FA was obtained at 30±5 minutes and for BFS it is 40±5 minutes. The final setting time of FA, BFS are 240, 300 minutes respectively. The slump of FA-BFS based concrete has higher values compared to conventional concrete. With increase in activator/binder

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ratio the slump values increased. For 500kg/m^3 the slump of six mixes are between 80-200mm. Figures 1 and 2 shows casted and cured specimens. The compressive strength for the specimens of size 100 mm x 100mm x100 mm are conducted and the strength obtained for 3, 7, 28 days are in figure 3. The split tensile strength for the specimens of diameter 100 mm and height 300 mm are casted. The split tensile strength is measured for 3, 7and 28 days results are in figure 4. The prisms of size 500 mm x 100 mm x 100 mm are casted and cured . The specimens are tested for 7 and 28 days the results are indicated in figure 5.

Fig 1: Casted specimens of AAC

Fig 2: Ambient curing of AAC.

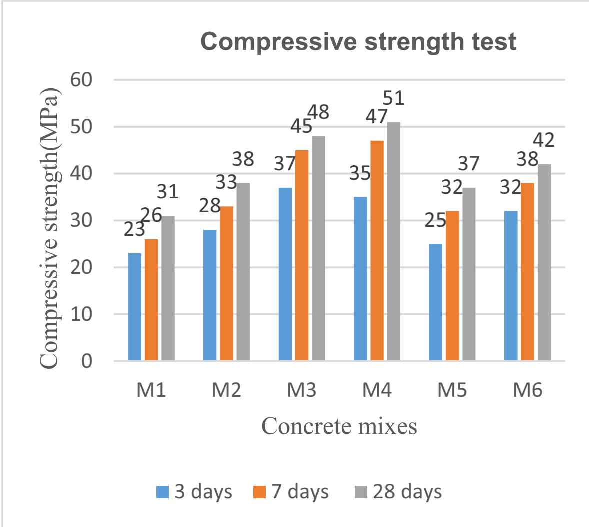

Fig 3: Results of compressive strength for 3, 7 and 28 days.

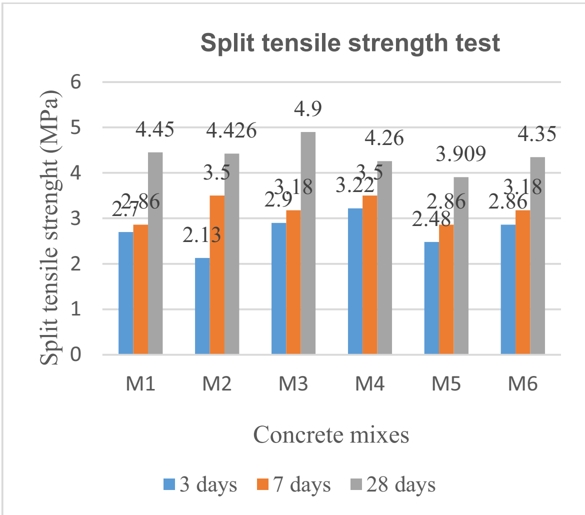

Fig 4: Results of split tensile strength for 3, 7 and 28 days

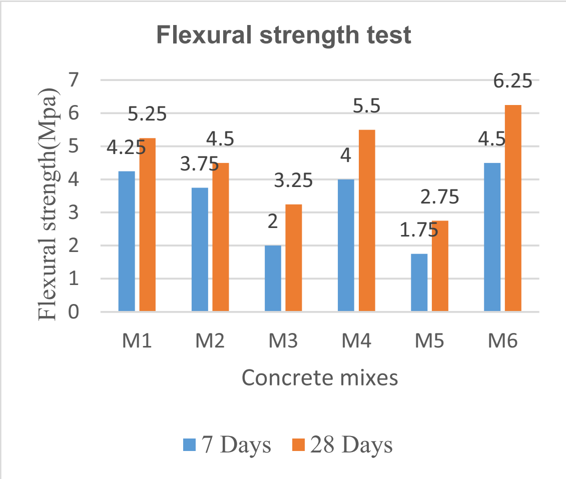

Fig 5: Results of Flexural strength for 7 and 28 days

5 Conclusions

1. The normal consistency of FA and BFS with High silica modulus activator showed satisfactory results. The workability of FA-BFS based AAC is higher compared to conventional concrete.
2. The outcomes of combined use of FA-BFS with sodium silicate activator reduced Rapid setting time of BFS and also gained strength without curing at elevated temperatures.
3. The compressive strength for Mix M4 with 0.65 activator/binder ratio and 50% FA and BFS is higher. Activator/binder greater than 0.65 showed less compressive strength.
4. The split tensile strength is maximum at M3 mix where the flexural strength showed failure.
5. The flexural strength gained better performance at mix M6 where the compressive strength and split tensile strength showed decreased strengths.

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