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INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI:10.21474/IJAR01/18388
DOI URL: http://dx.doi.org/10.21474/IJAR01/18388

RESEARCH ARTICLE

MECHANICAL PROPERTIES OF GREEN TERNARY- BLENDED - GEOPOLYMERS BINDER

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Manuscript Info

Manuscript History
Received: 05 January 2024
Final Accepted: 09 February 2024
Published: March 2024

Key words:-
Geopolymer Mortar, Fly Ash, GGBS, Brick Kiln Dust, Binder, Alkaline activators and Strength

Abstract

Many industrial-wastes/clays, such as **fly ash (FA), ground granulated blast-furnace slag (GGBS), brick kiln dust (BDK),** are employed in developing geopolymeric materials used in the constructionsector. Accordingly, this work aims to find a green approach to benefit from the synergistic impacts of the precursors in developing ternary-blended geopolymers (GGBFS/FA/BKD) having multifunctional engineering applications. Five mixes were prepared: the control specimen and the others contained different portions from GGBS, FA, and BKD. All mixes were cured in high humidity for up to 28-days. The various combinations of fly ash, ggbs and brick kiln dust considered are 80%, 20%, & 0%; 70%, 20% & 10%; 60%, 20% & 20%; 50%, 20% & 30%; respectively. The ratio of binder to sand and Na_2SiO_3/NaOH is taken as 1:2 and 2.5 respectively. It was concluded that the compression strength,flexural strength, and density decreases when the quantity of brick kiln dust increases.

Introduction:-

Cement is a traditional manmade raw material in cementitious construction materials, which has the largest consumption in all kinds of binding materials . For every human being, almost a ton of cement has been produced each year. Therefore, it is an urgent need to develop a new applicable binding material to substitute the traditional cement in construction industries against environmental pollution by minimizing the emission of CO2, the other pollutive gases and waste dust. new aluminosilicate material with three-dimensional reticular structure named with Geopolymer was first introduced by Davidovits in 1979, which was composed by the base materials containing affluent aluminium and silicon that was activated by adopting alkaline solution to serve as a binder. The geopolymer is ceramic-like and similar to the zeolite in terms of its chemical structure, however has an amorphous structure. In other words, geopolymers are formed as a product of alkali activation of aluminosilicate materials, including base materials, such as fly ash, granulated blast furnace slag, etc. The alkaline solution used for geopolymer preparation often includes water glass or sodium silicate (Na2SiO3), sodium hydroxide, and potassium hydroxide (NaOH and KOH). Therefore, the geopolymer has significant application prospect as a kind of binding material in construction materials to replace the Portland cement.

Experimental Program

Materials Used

The materials such as Fly ash, GGBS, Brick kiln Dust, Fine aggregate And Alkaline activators are mixed together for making geopolymeric binder. Fly ash is an non-combustible matter in coal. GGBS is an by- product of iron

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manufacturing which is used as a cementitious material used in concrete. The brick kiln was taken as the dust which have been passed through the 150mm sieve.The fine aggregate sieved on standard sieve. The fine aggregate passed over 4.75 mm are used. The alkaline activator is the combination of Sodium Hydroxide, Distilled water and Sodium Silicate.

Fig 1:- Materials Used.

Mix Proportion

The density of mortar is 2100 kg/m³. The ratio of binder to fine aggregate is mixed as 1:2. By assuming the alkaline liquid to binder ratios as 0.45 and by knowing the density of mortar the amount of binder, fine aggregate and quantity of alkaline liquids were determined. The molarity of sodium hydroxide concentration is kept as 8M. The different parameters considered in this study are proportion of binder components, ratio of Na2SiO3/NaOH and alkaline liquid to binder ratio. The proportion of binder components (i.e.) the various percentages of fly ash, GGBS and Brick kiln dust is taken as 80%, 10%, & 0%; 70%, 20% & 10%; 60%, 20% & 20%; 50%, 20% & 30%; 40%, 20% & 40%; 30%, 20% & 50% respectively. The ratio of Na2SiO3/NaOH solutions is taken as 2.5. Extra water was added 20% by weight of cementitious material to get desirable workability for the all the mixes.

Mixing of mortar

To prepare 8 molarity concentration of sodium hydroxide solution, 320 grams (molarity x molecular weight) of sodium hydroxide flakes was dissolved in distilled water and makeup was done to one litre. The sodium hydroxide solution thus prepared is mixed with sodium silicate solution one day before mixing the mortar to get the desired alkaline solution. Distilled water is used to dissolve the sodium hydroxide flakes to avoid the effect of contaminants in the mixing water. The sand, fly ash, GGBS and Brick kiln dust were dry mixed before adding the alkaline solution.

Fig 2:- Mortar cube specimens.

Mix Proportion

Table 1:- Density of mortar specimens.

MIX ID	Proportion of binders	Fly Ash kg/m^3	GGBS kg/m^3	Brick kiln Dust kg/m^3	Fine Aggregates kg/m^3	NaOH kg/m^3	Na_2SiO_3 kg/m^3	Alkaline Solution kg/m^3
Binder to Sand ratio 1:2, Na_2SiO_3 / NaOH = 2.5								
A	$F_{80}G_{20}B_0$	1.85	0.46	0	4.64	0.29	0.72	1.01
B	$F_{70}G_{20}B_{10}$	1.62	0.46	0.23	4.64	0.29	0.72	1.01
C	$F_{60}G_{20}B_{20}$	1.39	0.46	0.46	4.64	0.29	0.72	1.01
D	$F_{50}G_{20}B_{30}$	1.16	0.46	0.69	4.64	0.29	0.72	1.01
E	$F_{40}G_{20}B_{40}$	0.92	0.46	0.92	4.64	0.29	0.72	1.01
F	$F_{30}G_{20}B_{50}$	0.69	0.46	1.16	4.64	0.29	0.72	1.01

Results and Discussion:-

Density

Density of mortar cubes is calculated by dividing the mass by the volume of mortar cube. The density of mortar cube specimens for various mix proportions.Density of geopolymer mortar varies from 1933 - 2122 kg/m3.

Table 2:- Density of mortar specimens.

Mix ID	Proportion of binders	Density (kg/m^3)
A	$F_{80}G_{20}C_0$	2122.27
B	$F_{70}G_{20}C_{10}$	2084.54
C	$F_{60}G_{20}C_{20}$	2056.25
D	$F_{50}G_{20}C_{30}$	2032.67
E	$F_{40}G_{20}C_{40}$	1999.65
F	$F_{30}G_{20}C_{50}$	1933.63

Density values of mortar cube specimens.It was seen that, density values decreases, with an increase in quantity of Brickl Kiln dust content.Density values are below 2100 kg/m3 when the Brick kiln dust content goes beyond 10%.

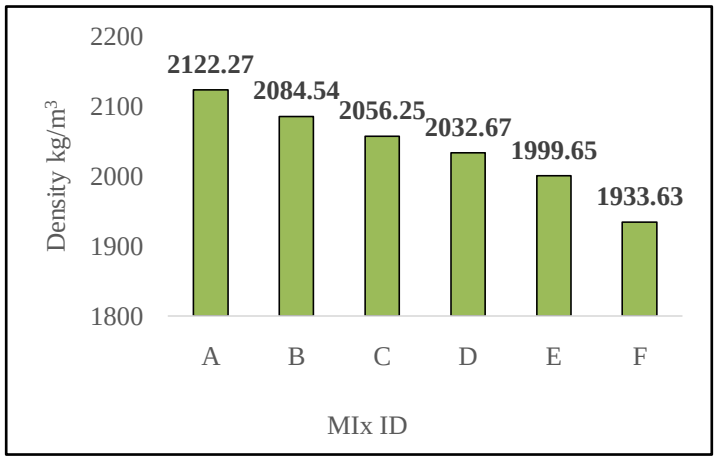

Fig 3:- Density of mortar cube specimens.

Compressive Strength

The compressive strength is the ratio of the maximum load to the surface area of mortar cube. Three cubes were tested for each mix ratio and the average of three specimens is taken as the compressive strength it was tested by Compression Testing Machine of Capacity 2000 kN. The specimens were subjected to a compressive force at the rate of 132 kN per minute. The geopolymer mortars were tested for compressive strength at the age of 7 days and 28 days.

Table 3: Compressive strength of mortar specimens.

Mix ID	Proportion of binders	Compressive Strength (N/mm^2) at 7 days	Compressive Strength (N/mm^2) at 28 days
A	$F_{80}G_{20}B_0$	19.65	35.26
B	$F_{70}G_{20}B_{10}$	18.71	33.99
C	$F_{60}G_{20}B_{20}$	18.20	31.84
D	$F_{50}G_{20}B_{30}$	17.44	28.42
E	$F_{40}G_{20}B_{40}$	17.02	26.58
F	$F_{30}G_{20}B_{50}$	16.52	24.94

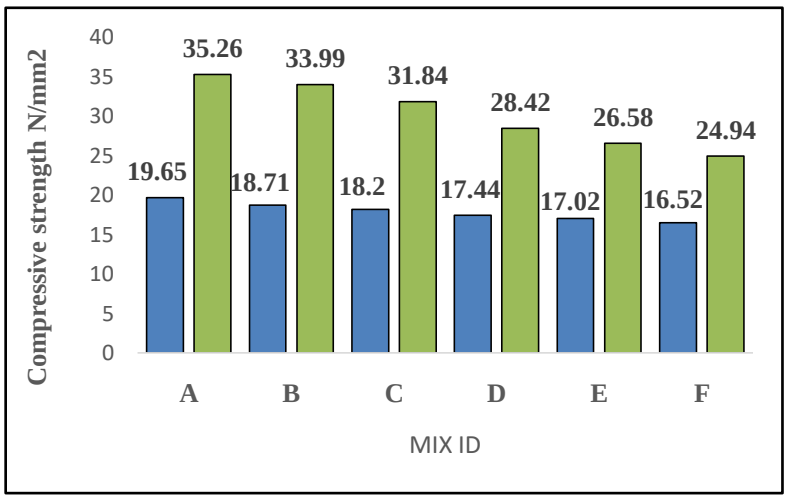

Fig 4:- Compressive strength of mortar cube specimens

Water Absorption

Water absorption was measured using cube specimens of size 70.7 mm x 70.7 mm x 70.7 mm. Water absorption test are carried out as per BIS: 2185-2005. The dry weight of mortar cube was measured and noted as weight (W1). Then dry mortar cubes were completely immersed in water at room temperature for 24 hours. After 24 hours the mortar cubes are removed from the water and the water is allowed to drain for 1 min by placing on a wire mesh, removing visible surface water with a damp cloth. Then this saturated weight was measured and noted as wet weight (W2). The water absorption values for geopolymer mortar ranges from 2.8% - 5.5%. From the test results, it was found that for specimens without Brick kiln dust the water absorption values are comparatively lower as compared to with addition of Brik kiln dust specimens. It was also observed that, water absorption increases with increase in Brick kiln dust content.

Table 4:-Water Absorptionof mortar specimens.

Mix ID	Proportion of binders	water absorption (%)
A	$F_{80}G_{20}B_{0}$	2.8
B	$F_{70}G_{20}B_{10}$	3.1
C	$F_{60}G_{20}B_{20}$	3.6
D	$F_{50}G_{20}B_{30}$	4.1
E	$F_{40}G_{20}B_{40}$	5.1
F	$F_{30}G_{20}B_{50}$	5.5

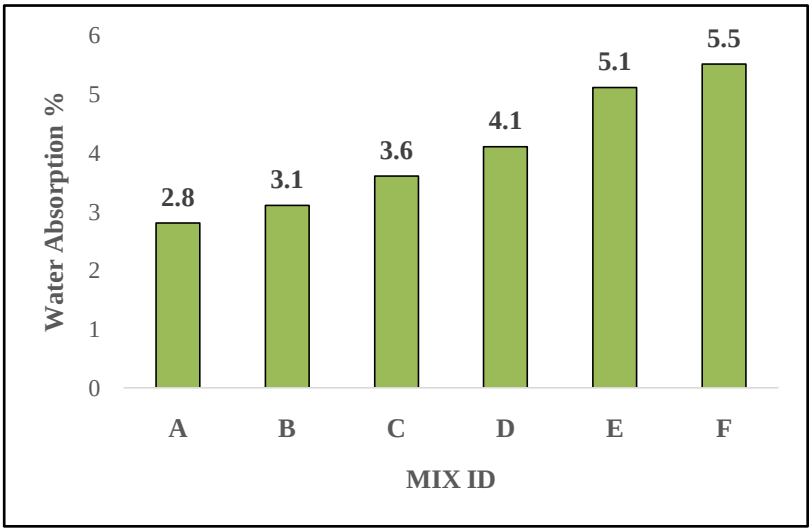

Fig 5:- Water absorption of mortar cube specimens.

Flexural Strength

Flexural strength is determined by testing the prisms in bending according to ASTM standard. Flexural strength was obtained using 160 mm x 40 mm x 40 mm prismatic specimens. Three prism specimens were tested for each mix ratio and the average of three specimens is taken as the flexural strength it was tested by Flexural Testing Machine of Capacity 100 kN. Totally 18 number of prisms were cast and tested after 28 days. Prisms were subjected to single point loading. Flexural strength of ambient cured geopolymer mortar ranges from 0.9 – 3.4 N/mm2 .The maximum flexural strength of 3.4 N/mm2 is obtained for the mix F80 G20 B0 and the minimum flexural strength of 0.9 N/mm2 is obtained for the mix F30 G20 B50 for an alkaline liquid to binder ratio of 0.45. Flexural strength decreases with an increase in quantity of Brick kiln dust content.

Table 5:- Flexural strength of mortar specimens.

Mix ID	Proportion of binders	Flexural Strength (N/mm^2)
A	$F_{80}G_{20}B_0$	3.4
B	$F_{70}G_{20}B_{10}$	2.7
C	$F_{60}G_{20}B_{20}$	2.1
D	$F_{50}G_{20}B_{30}$	1.7
E	$F_{40}G_{20}B_{40}$	1.3
F	$F_{30}G_{20}B_{50}$	0.9

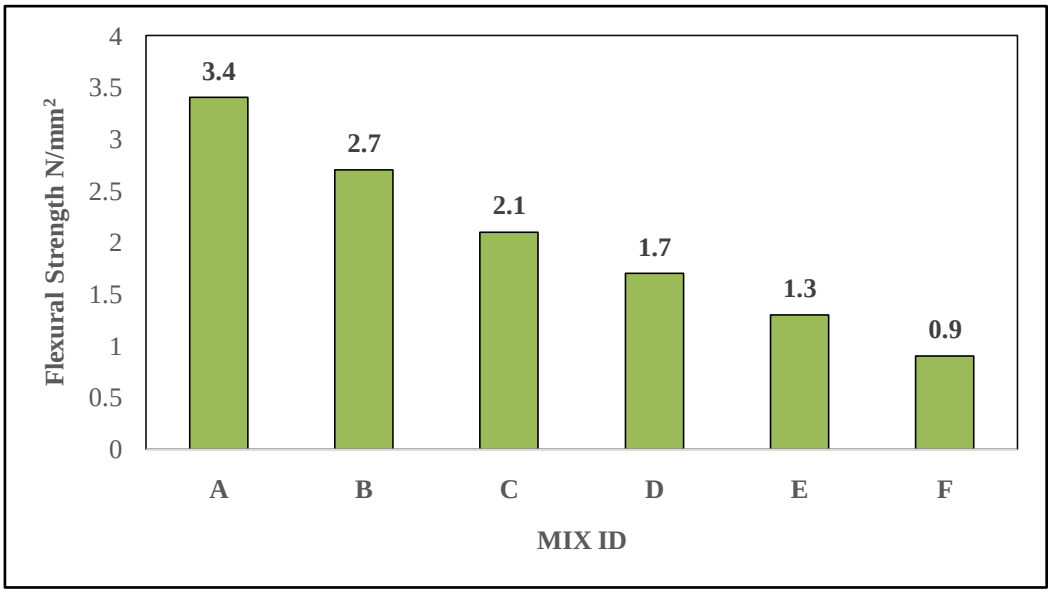

Fig 6:- Flexural strength of prism specimens.

Conclusion:-

1. The density of mortar cube specimens is within the range of 1933 - 2122 kg/m^3. Density values are higher for higher Na_2SiO_3 / NaOH ratio and also for rich binder to sand ratios. Density values decreases with increase in Brick kiln dust content. Geopolymer mortar cube specimens having higher density results in high strength.
2. The compressive strength of geopolymer mortar decreases with increases in quantity of Brick kiln dust content. The geopolymer mortar cube specimen made of F_{80} G_{20} C_0 produces the maximum strength of all the mortar specimens.
3. The water absorption of mortar cube specimens is within the range of 2.8 – 5.5%. The water absorption value increases as the percentage of Brick kiln dust is increased. As the age of mortar increases, water absorption of mortar also decreases for all the mixes.
4. Flexural strength of prism specimens ranges from 0.9 – 3.4 N/mm^2. As the percentage of the Brick kiln dust increases, the flexural strength of the geopolymer mortar decreases.
5. The compressive strength, flexural strength decreases when the quantity of Brick kiln dust increases.
6. The geo polymeric binder prepared using 1:2 mix proportion attained a minimum compressive strength of 24.94 N/mm^2. These geopolymeric binder is applicable in inner plastering work of chimney and cooling tower, bedding joints, lining of pipe and fittings, repair of defective or damaged area of linings, damp proof course, reinforced brick work and pointing work.
7. Utilization of Brick Kiln Dust as a replacement material for cement is a possible alternative solution for the safe disposal of Brick kiln dust wastes.

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