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RESEARCH ARTICLE

EXPERIMENTAL INVESTIGATION ON MECHANICAL PROPERTIES OF GEOPOLYMER MORTARS FOR REPAIR APPLICATIONS: IMPACT OF BINDER TO SAND RATIO

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Abstract

Deterioration of concrete structures made with ordinary Portland cement (OPC) as a binder is inevitable, and this requires repair or rehabilitation using appropriate repair materials. A strong and highly adhesive repair material is very important in order to ascertain the safety of damaged concrete structures. The existing repair materials, especially those that utilized conventional OPC-based materials, appear to require a certain curing condition, which prior studies have revealed to result in a weak link between the repair material and the repaired structures. Hence, an alternative material which is geopolymer mortar was utilized in this study as a repair material, and the impact of geopolymer mortars with various binder-to-sand ratios was evaluated. The physical and mechanical properties of the geopolymer mortars were assessed in addition to their performance as a repair material in terms of their bonding characteristics to conventional concrete. Findings from this study revealed that geopolymer mortar with a binder-to-sand ratio of 1:2 exhibited the highest bonding strength. In addition, geopolymer mortars with a binder-to-sand ratio of 1:3 to 3:1 exhibited better bonding strength compared to when geopolymer paste was used. NaOH& Na_2SiO_3.

Introduction:-

Geopolymers are inorganic, typically ceramic, alumino-silicate forming long-range, covalently bonded, non-crystalline (amorphous) networks. Obsidian (volcanic glass) fragments are a component of some geopolymer blends. Commercially produced geopolymers may be used for fire- and heat-resistant coatings and adhesives, medicinal applications, high-temperature ceramics, new binders for fire-resistant fiber composites, toxic and radioactive waste encapsulation and new cements for concrete. The properties and uses of geopolymers are being explored in many scientific and industrial disciplines: modern inorganic chemistry, physical chemistry, colloid chemistry, mineralogy, geology, and in other types of engineering process technologies. The field of geopolymers is a part of polymer science, chemistry and technology that forms one of the major areas of materials science.Polymers are either organic material, i.e. carbon-based, or inorganic polymer, for example silicon-based. The organic polymers comprise the classes of natural polymers (rubber, cellulose), synthetic organic polymers (textile fibers, plastics, films, elastomers, etc.) and natural biopolymers (biology, medicine, pharmacy). Raw materials used in the synthesis of silicon-based

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polymers are mainly rock-forming minerals of geological origin, hence the name: geopolymer. Joseph Davidovits coined the term in 1978and created the non profit French scientific institution (Association Loi 1901) InstitutGéopolymère (Geopolymer Institute).

Experimental Program

Materials Used

The materials such as Fly ash, GGBS, 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 manufacturing which is used as a cementitious material used in concrete.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 1:1,1:2,1:3 and3 :1. 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 8MThe proportion of binder components (i.e.) the various percentages of fly ash, GGBS is taken as 80%, 20% respectively. The ratio of Na_2SiO_3/NaOH solutions is taken as 2.5. Extra water was added 20% by weight of cementitious material to get desirable workability for 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 fine aggregate, fly ash, GGBS were dry mixed before adding the alkaline solution.

Fig 2:- Mortar cube specimens.

Mix Proportion

Table 1:- Mix Proportion.

MIX ID	Binder Ratio	Proportion of binders	Fly Ash kg/m^3	GGBS kg/m^3	Fine Aggregates kg/m^3	NaOH kg/m^3	Na_2SiO_3 kg/m^3	Alkaline Solution kg/m^3
CB	1:1	$F_{80}G_{20}$	2.592	0.648	3.24	0.4907	0.98	1.470
CG1	1:2	$F_{80}G_{20}$	1.856	0.464	4.64	0.348	0.696	1.044
CG2	1:3	$F_{80}G_{20}$	1.44	0.360	5.4	0.270	0.540	0.81
CG3	3:1	$F_{80}G_{20}$	4.32	1.08	1.80	0.486	0.972	1.458

Results and Discussion:-

Density:

Density of mortar cubes is calculated by dividing the mass by the volume of mortar cube.. Density of geopolymer mortar varies from 2084 - 2160 kg/m^3.It was seen that, binder to sand ratio increases the Density also increases at same time binder to sand ratio decreases the Density was decreases. Density values are above 2100 kg/m3 when the Sand binder increases.

Table 2:- Density of Mortar Cube Specimens

Mix ID	Binder Ratio	Proportion of binders	Density (kg/m^3)
CB	1:1	$F_{80}G_{20}$	2103.41
CG_1	1:2	$F_{80}G_{20}$	2130.25
CG_2	1:3	$F_{80}G_{20}$	2145.85
CG_3	3:1	$F_{80}G_{20}$	2160.00

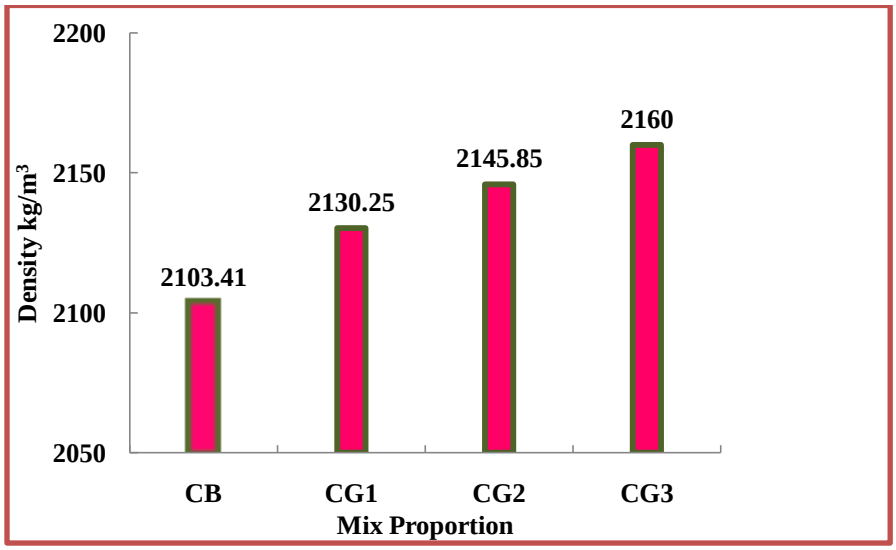

Fig 3:-Density of Mortar Cube Specimens

Compressive Strength:

The compressive strength of geopolymer mortar the Binder to sand ratio increases the strength was decreases at the same time the Binder to sand ratio increases the strength also increases. The geopolymer mortar cube specimen made of 3:1 produces the maximum strength of all the mortar specimens.The geopolymeric binder prepared using 1:3 mix proportion attained a minimum compressive strength of 33.59 N/mm^2.

Table 3:- Compressive strength of mortar specimens

Mix ID	Binder Ratio	Proportion of binders	Compressive Strength (N/mm^2)	
			7 Days	28 Days
CB	1:1	$F_{80}G_{20}$	25.2	38.04
GB_1	1:2	$F_{80}G_{20}$	22.04	36.73
GB_2	1:3	$F_{80}G_{20}$	20.29	33.59
GB_3	3:1	$F_{80}G_{20}$	27.10	40.18

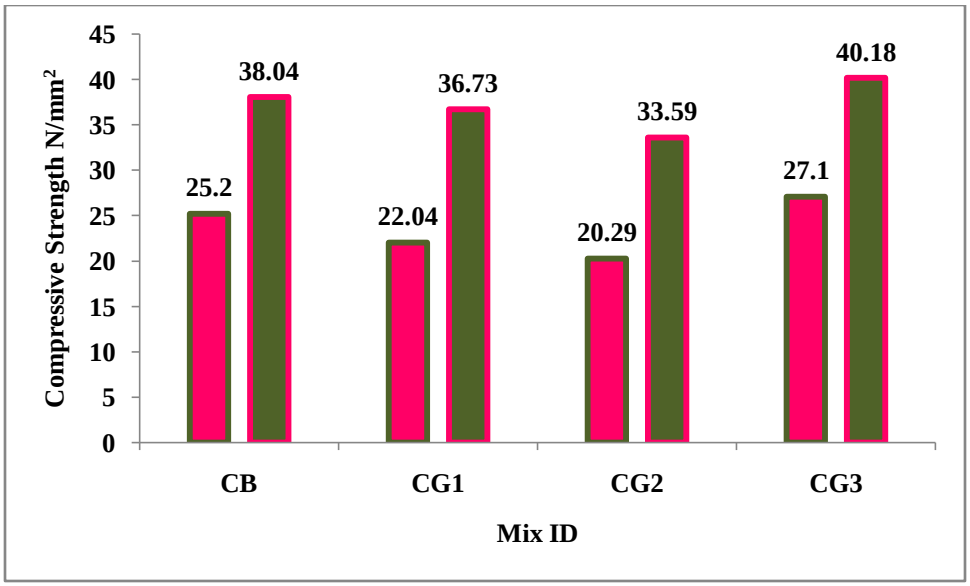

Fig 4:- Compressive Strength of Mortar Cube Specimens

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 1.8% - 4.5%. From the test results, it was found that binder to sand ratio increases the Water absorption also increases; when the binder to sand ratio decreases the water absorption also decreases.

Table 4:- Water Absorption of mortar specimens

Mix ID	Binder Ratio	Proportion of binders	Water Absorption (%)
CB	1:1	$F_{80}G_{20}$	2.0
CG_1	1:2	$F_{80}G_{20}$	3.2
CG_2	1:3	$F_{80}G_{20}$	4.5
CG_3	3:1	$F_{80}G_{20}$	1.8

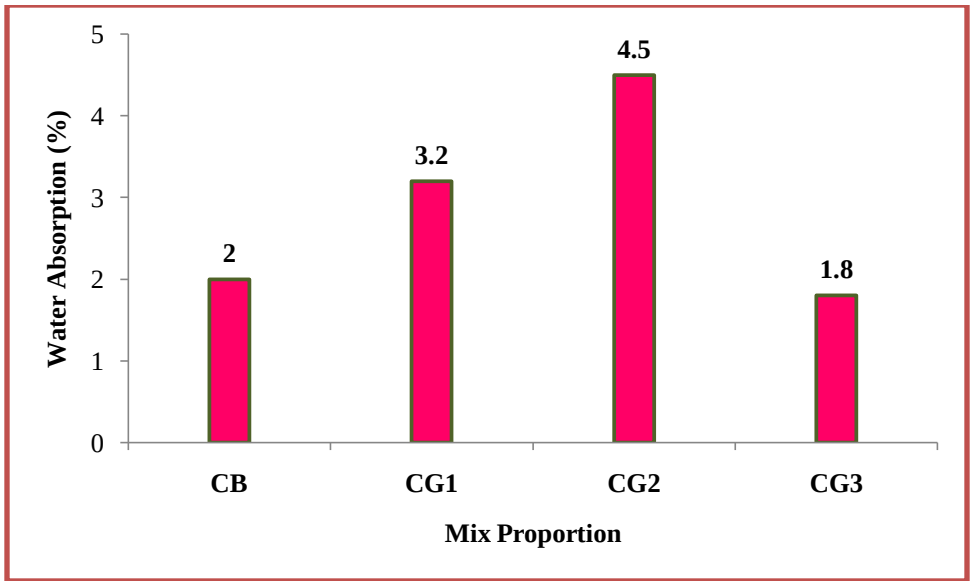

Fig 5:-Water Absorption of Mortar Cube Specimens

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 12 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 3.5 – 4.9 N/mm^2. The maximum flexural strength of 4.9 N/mm^2 is obtained for the mix 3:1 and the minimum flexural strength of 3.5 N/mm^2 is obtained for the mix 1:3 for an alkaline liquid to binder ratio of 0.45. The Binder to sand ratio increases the strength was decreases at the same time the Binder to sand ratio increases the strength also increases.

Table 4:- Water Absorption of mortar specimens

Mix ID	Binder Ratio	Proportion of binders	Flexural Strength (N/mm^2)
CB	1:1	$F_{80}G_{20}$	4.2
GB_1	1:2	$F_{80}G_{20}$	3.9
GB_2	1:3	$F_{80}G_{20}$	3.5
GB_3	3:1	$F_{80}G_{20}$	4.9

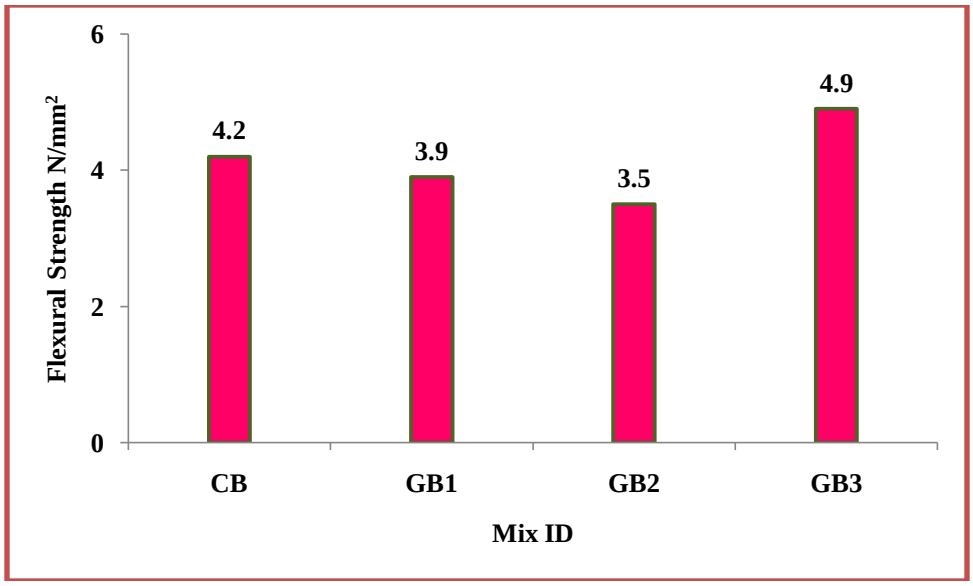

Fig 6:- Flexural strength of prism specimens

Conclusion:-

The density of mortar cube specimens is within the range of 2084 - 2160 kg/m^3. Density values are higher for higher Na_2SiO_3 / NaOH ratio and also for rich binder to sand ratios. It was concluded that, binder to sand ratio increases the Density also increases at same time binder to sand ratio decreases the Density was decreases.

The compressive strength of geopolymer mortar the Binder to sand ratio increases the strength was decreases at the same time the Binder to sand ratio increases the strength also increases. The geopolymer mortar cube specimen made of 3:1 produces the maximum strength of all the mortar specimens.

The geopolymeric binder prepared using 1:3 mix proportion attained a minimum compressive strength of 33.59 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.

The water absorption of mortar cube specimens is within the range of 1.8 - 4.5%. The water absorption value was concluded that binder to sand ratio increases the Water absorption also increases, when the binder to sand ratio decreases the water absorption also decreases

Flexural strength of prism specimens ranges from 3.5 – 4.9 N/mm^2. The Binder to sand ratio increases the strength was decreases at the same time the Binder to sand ratio increases the strength also increases.

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