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Effect of Sodium Hydroxide and Different Proportions of Sodium Silicate to Sodium Hydroxide on Compressive Strength of Geopolymer Concrete

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Abstract: Sustainable building methods have undergone a paradigm change with the introduction of geopolymer concrete, a ground-breaking substitute for conventional Portland cement-based concrete. Instead of using cement, which has a large carbon footprint in the process of making concrete, geopolymer concrete uses industrial byproducts like fly ash or slag, which improves material performance while having less of an adverse effect on the environment. The effects of changing the molarity of NaOH and the proportion of sodium silicate to NaOH on specimens of simple geopolymer concrete were examined. It was shown that compressive strength raised with a rise in NaOH concentration up to 13 Molar, after which there was a minor decrease. Furthermore, because the mix cohesiveness was increased, a larger ratio of sodium silicate to Sodium silicate produced stronger compressive strength, nevertheless, going above this ratio rendered the material impracticable to deal.

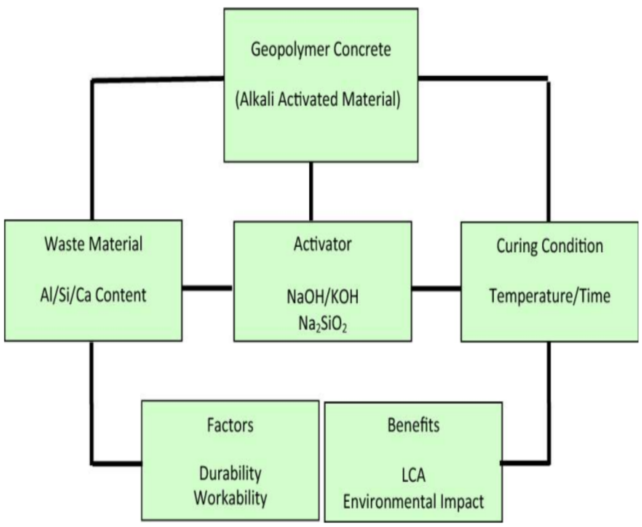
Introduction: With the use of a novel concrete technique called geopolymer, any silica and alumina-rich source material can be used in place of cement 100 percent of the time. Fly ash, rice husk ash and ground granulated blast furnace slag are useful substitutes for cement in the creation of geopolymer concrete. The simultaneous abundance of fly ash and the fly ash disposal issue are significant problems. Fly ash is a byproduct from thermal power plants. It is typically regarded as a waste product, the disposal of which has created a number of environmental and ecological issues. Davidovits introduced geopolymer in 1978. It is created by activating an alkaline solution including Na or KOH and silicate, along with high alumina silica-rich materials. It functions similarly to ceramic composites, which form the link between silica and alumina.

Mechanism of Geopolymerisation

In the process of geopolymerization, an alkaline solution (including NaOH and Na2SiO3) activates the silica and alumina content of pozzolana binding materials like fly ash and slag to produce an alumino-silicate gel structure. The crosslinked geopolymer microstructure exhibits greater resilience against external environmental factors. Alkali metal is crucial for the reaction rate and reaction products during the geopolymerization process. At high temperatures, this inorganic polymer exhibits an amorphous character. When heat is applied instead of ambient temperature curing, the rate of geopolymerization rises. The geopolymerization reaction process is depicted in Eqs. (1.1) and (1.2), from the beginning to the specimens' hardening. The geopolymerization's final products display the three-dimensional structure.

$$n(Si_2O_5,AL_2O_3) + 2nSiO_2 + 4Nh_2O + NaOH \text{ or } KOH \rightarrow Na^+, K^+n(OH)_3 - Si\text{-}O\text{-}Al^-(OH)_2\text{-}O\text{-}Si\text{-}(OH)_3 \quad (1.1)$$

$$n(OH)_3\text{-}Si\text{-}O\text{-}Al^-(OH)2\text{-}O\text{-}Si\text{-}(OH)_3 \; NaOH \text{ or } KOH \; (Na,K^+)(\text{-}Si\text{-}O\text{-}Al^{-}O\text{-}Si\text{-}O\text{-}) +$$



Properties of geopolymer concrete

- Nontoxic and there is no bleeding in this concrete
- The working life is long before stiffening.
- It is impermeable
- Higher heat resistant
- It has high strength in comparing to normal conventional concrete

Literature Reviews

In a brief review published in 2004, Hardjito D. et al. addressed the advancement of geopolymer concrete. Geopolymer concrete shown great promise as a material for the future. It had both short- and long-term durability and was environmentally beneficial. The authors claim that water was a major factor in the geopolymer concrete's workability. Workability was obtained, according to studies, by modifying the water content and maintaining a consistent H2O to Na2O ratio, which allowed geopolymer concrete to be handled without setting or losing its compressive strength for at least 120 minutes after mixing. The study verified that the curing temperature and duration had a substantial impact on the compressive strength of the concrete. The project's conclusion was a 60°C maximum curing temperature and a 48-hour maximum curing period.

Fly ash-based geopolymer concrete's manufacturing process and technical characteristics were described by Hardjito D. et al. (2005). The study made it clear that low calcium dry fly ash, a solution of sodium hydroxide and sodium silicate, additional water, fine and coarse aggregates, and extra water were required to make fly ash based geopolymer concrete. The study demonstrated that aging has zero effect on the compressive strength of geopolymer concrete. The geopolymer concrete demonstrated outstanding defense against sulfate assault. The study found that slump value dropped with longer mixing times. Longer mixing times also resulted in greater density and compressive strength. In comparison to specimens without a rest time, the report states that the compressive strength rose by 20–50% as the rest duration increased. The relationship between stress and strain was reported in the research, and it was found that the relationship was comparable to Portland cement concrete. The study came to the conclusion that fly ash-based geopolymer concrete structures may be designed by using the provisions of codes and Indian Standards for concrete structures.

In 2006, Wallah S. E. and Rangan B. V. investigated the long-term qualities of geopolymer concrete based on low calcium fly ash. Two mixes were taken into consideration in the work; mixture 1 had an 8 molar concentration of NaOH and no additional water was added. Mixture 2 had additional water in addition to a 14 molar concentration of NaOH. Workability was attained using naphthalene superplastizser and a Na2SiO3/NaOH ratio of 2.51. It was noted that the creep of geopolymer concrete based on heat-cured fly ash was minimal. After seven days, mixture 1's compressive strength was 56 MPa for seam curing and 58 MPa for oven curing. For mixture 2, the figures were 45 MPa and 36 MPa, respectively. Additionally, the research included specimens for heat curing and at room temperature, although it was noted that further basic research in this field was required because the study produced no conclusive results.

Research on the strength, bond and setting time of high calcium fly ash geopolymer concrete was conducted by Pattanapong Topark Ngarm et al. (2015). The experiment employed high Ca fly ash from the Mac Moh power station in Northern Thailand, coupled with concentrations of NaOH (10M, 15M, and 20M). A ratio of 1 to 2 for Na2SiO3/NaOH was used. The ratio of alkaline solution to fly ash was taken into consideration, and two different curing techniques were employed curings at 60 +2^{o} C for 24 hours, and room temperatures curing at 23 + 2^{o} C. The high Ca content of fly ashes was found to be the reason behind the quick setting time of 28 to 58 minutes for geopolymer concrete. For compressive strength, a concentration of 15 M NaOH was ideal, whereas a fly ash's ideal Na2O content was about 12%.

Ali A. Aliabdo et al. (2016) carried out experiments on several fly ashe based geopolymer concrete performance parameters. Initially, NaOH concentrations of 12 M, 16 M, and 18 M were employed. It was shown that compressive strength rose with increasing geopolymer concrete molarity (from 12 to 16 M) and decreased with increasing NaOH concentration (18 M). It was proposed that the ideal NaOH molarity for geopolymer concrete was 16 M. For 48 hours, the temperature for curing should be 500C. It was determined that the ratio of sodium hydroxide to sodium silicate was 0.4 and that 35 kg/m3 of more water was needed. The needed water for mixing was 10.5 kg/m3. Water absorption was shown to decrease as concentration rose from 12 M to 16 M.

METHODOLOGY

To determine the ideal fraction of hybrid fibers that meets I. S. standards, experimental work is conducted. Research is first conducted on fiber less geopolymer concrete in its basic form. Here, the NaOH's molarity is adjusted between 8 and 13 molar. Moreover, the ratios of sodium hydroxide to sodium silicate are 1, 1.5, and 2**.**

Ingredients used in Geopolymer Concrete:

The basic ingredients of the geopolymer concrete which are used in this investigation are as follows:

- Fly ash
- Coarse aggregate
- Fine aggregate
- Alkaline solutions
- Water
- Fibers

Preparation of Geopolymer Concrete

The process of making geopolymer concrete is quite similar to that of traditional concrete. The NaOH solution is ready one day before mixing. Sodium hydroxide and sodium silicate solutions are added to create an alkaline solution. To create a homogenous mix, two types of coarse aggregates first one is sand and the other one is fly ash are mixed together in a dry condition. The prepared mix solution is then added to the dry mix and vigorously stirred for three to four minutes. Fresh geopolymer concrete is discovered to be viscous, glassy, and black in hue. Standard 150 mm x 150 mm x 150 mm geopolymer concrete cubes were subjected to a cube compression test after 3, 7, and 28 days of oven curing. Figures illustrate a graphic representation of the relationship between compressive strength and other factors, including molarity and the alkaline solution ratio, over three, seven, and twenty-eight days, respectively.

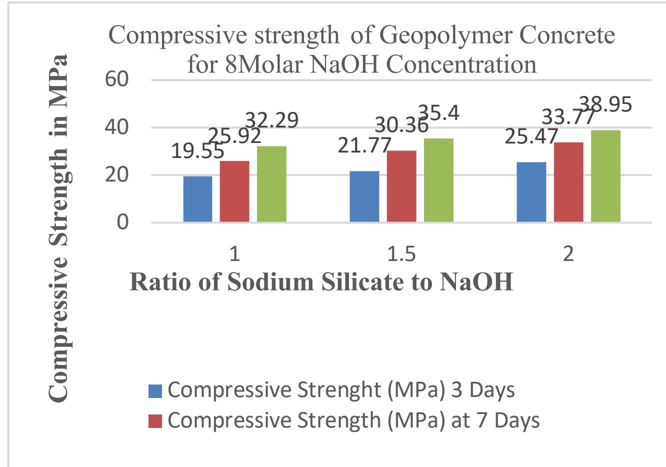
Figure 1: Testing of specimen

Results and Discussions

This research project consists of variations in the molarity of NaOH include 8M, 10M, 12M, 13M, as well as ratios of 1, 1.5, and 2 between Sodium Silicate and Sodium Hydroxide.

Compressive Strength of plain Geopolymer Concrete with varying molarity and varying ratio of $Na_2SiO_3/NaOH$:

This article discusses the compressive strength of plain



geopolymer concrete with different sodium hydroxide concentration molarities and sodium silicate to sodium hydroxide ratios. There are several concentrations of sodium hydroxide: 8M, 10M, 12M, 13M molar. The ratio of NaOH to sodium silicate can be adjusted to 1, 1.5, or 2

Table 1

Na_2SiO_3 / NaOH	Compressive Strength (MPa)		
	At 3 Days	At 7 Days	At 28 Days
1	19.55	25.92	32.29
1.5	21.77	30.36	35.4
2	25.47	33.77	38.95

Compressive Strength of cube specimen for 8 Molar NaOH Concentration:

Cube specimens are used to measure compressive strength. The strength of concrete is a measurement of its capacity to withstand loads that would otherwise cause it to compress. Table 1 displays the results for the 8 molar sodium hydroxide concentration and the sodium silicate to NaOH ratios of 1, 1.5, ands2, while above figure presents a graphical discussion of the data.

Compressive Strength of cube specimen for 10 Molar NaOH Concentration:

Eight milliliters of NaOH concentration are replaced with ten milliliters of NaOH concentration. A second mixture is made with a 10-molar quantity of NaOH. Table 2 summarizes the results for the 10 Molar NaOH concentration and the 1, 1.5, and 2 ratio of sodium silicate to sodium hydroxide, respectively. The results are also visually displayed in below Figure.

Na_2SiO_3/ NaOH	Compressive Strength (MPa)		
	At 3 Days	At 7 Days	At28 Days
1	22.81	29.33	35.7
1.5	24.9	33.77	38.81
2	28.59	35.99	43.1

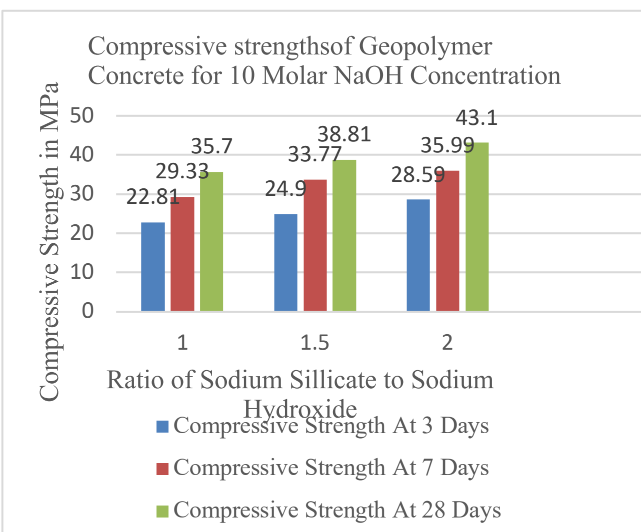


Figure: Compressive Strength for Plain Geopolymer Concrete of 10MolarNaOHConcentration

Compressive Strength of cube specimen for 13 Molar NaOH Concentration

Table 3 displays the results for the 13 Molar Sodium Hydroxide concentrations and the Na2SiO3 / NaOH ratios of 1, 1.5, ands2. It is noted that the cube specimens fail brittlely and show a little increase in strength at the concentration of 12 molar NaOH. Cube specimens are therefore cast for a concentration of 13 Molar NaOH.

Table 3

Na_2SiO_3/NaOH	Compressive Strength (MPa)		
	At 3sDays	At 7sDays	At 28Day
1s	27.99	35.4	40.20
1.5s	30.07	38.21	44.29
2s	33.77	42.51	49.33

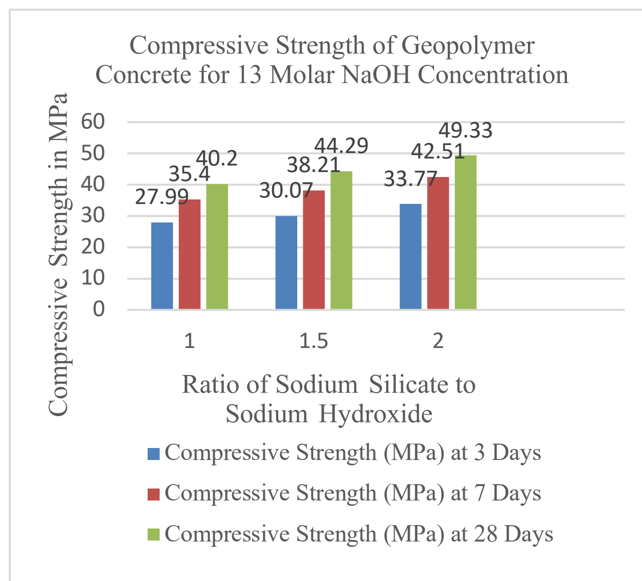


Figure: Compressive Strength of cube specimen for 13 Molar NaOH Concentration

Conclusion:

Increases in sodium hydroxide molarity are associated with increases in geopolymer concrete's compressive strength. The study comes to the conclusion that a 13 Molar NaOH concentration yields the best molarity for compressive strength. Maximum compressive strength is obtained with a cohesive mix that exhibits flow ability. Its compressive strength rises but its workability decreases as the ratio of sodium silicate to sodium hydroxide rises. The maximal compressive strength increases with sodium silicate concentration, as indicated by the sodium silicate to sodium hydroxide ratio of 2. It promotes the mix's cohesion. The ratio of sodium silicate to sodium hydroxide is limited to 2, since larger amounts result in very sticky mixtures that are impractical for an alkaline solution to fly ash ratio of 0.35.

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