A Research Article on "Geopolymer Concrete"

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ABSTRACT: Concrete is used more than any other man-made material in the world, in fact it is the second most consumed substance in the world after water. The production of concrete is the reason for the emission of 5% of total global CO_2 emission. This is high time to think for an alternative to cement since the production of cement is the main reason for CO_2 emission. There are considerable attempts which have taken place in order to replace cement other materials. One of those is Geo-Polymer Concrete (GPC), which is successful enough to fully replace the cement but with certain limitations. These limitations are making it unpopular among the practicing engineers. Hence, an attempt has been made to consolidate the research works carried out by the researchers in the area of geopolymer concrete. The limitations of geopolymer concrete are also presented.

Key words –Geopolymer concrete, Co_2 emission, greenhouse gases

INTRODUCTION

Production of cement results in emission of greenhouse gases which are harmful to the environment and humans. It is need of the hour to find alternative binding materials which are less harmful and ecofriendly. Geopolymer concrete is synthesized from waste materials like fly ash, rice husk, silica fume etc. along with binding solution and is free of cement. The main constituent of geopolymer concrete is silicon and aluminium which are provided by thermally activated natural materials (e.g. Kaolinite) or industrial byproducts (e.g. Fly ash) and an alkaline activating solution which polymerizes these materials into molecular chains and networks to create hardened binder. It is also called as alkali-activated cement or inorganic polymer cement.Curing temperature is an important factor from the strength point of view in geopolymer concrete. The main polymerization process or the chemical reaction of geopolymer concrete takes place with the temperature imposed to it during the curing period. Longer curing time will enhance the polymerization process and will result in a higher compressive strength. However with the elevated curing temperature, setting time decreases.The study of the literature reviews brings before us some specific areas which need to be addressed in order to overcome the limitations and make the geopolymer concrete a widely usable one. These areas are as follows, Curing methodology of the concrete, Molarity of the alkaline solutions, Uses of fly ash and other materials, Variation in incubation period and incorporation of cement as partial replacement. If only these areas are understood clearly then the geopolymer can come out as a noble and ecofriendly invention which can be used practically at larger scale.

CURING METHODOLOGY

Ukesh Praveen P and Srinivasan K **(2017)** made a review of literature pertaining to self-compacting of geopolymer concrete and reported that the contribution of GGBS helps the self-compacting geopolymer concrete attain high compressive strength at ambient room temperature. GGBS at ambient curing condition had more compressive strength rather than Fly ash based self-compacting geopolymer concrete. It is recommended that sodium hydroxide and sodium silicate solutions should be prepared at least 24 hours before use.

Manimaran, E and Mohankumar, G (2017) carried out an investigation on influence of sodium hydroxide concentration on the strength of fly ash based geopolymer concrete andreported that the strength of ambient cured specimens is always less and about 95% to 97% of the hot cured concrete irrespective of the molarity of NaOH solution. Under specified concentration of NaOH, the required strength of Geopolymer concrete can be achieved by ambient curing itself and hot curing is not at all required under laboratory condition. Hot curing may be employed in case of fabrication of precast units.

Patankar S.V et al. (2018) studied effect of duration and temperature curing on compressivestrength of fly ash based of geopolymer concreteand observed while finding effect of concentration of sodium hydroxide on fly ash based geopolymer concrete that the compressive strength of geopolymer concrete increases with increase in the concentration of sodium hydroxide solution for all temperatures but the rate of gain of strength at and above 60∘C is not very significant.

Deepa Balakrishnan S. et al (2013) examined the properties of fly ash based geopolymer concrete and stated that the strength gain in geo-polymer concrete is significant when heat cured for 72 hours also the strength of heat cured specimen is found to be almost equal to the corresponding strength of 90 day ambient cured specimens or almost two times as that of the 28 day strength.

Satpute Manesh B. et al (2012) studied the effect of duration and temperature curing on compressive strength of fly ash based of geopolymer concrete and reported that curing temperature and its duration are important in the activation of geopolymer concrete. Curing time, in the range of 6 to 24 hours, produces higher compressive strength. However, the increase in strength beyond 20 hours is not significant.

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B. V. Rangan (2008) in his research report on Fly ash based geopolymer concrete highlighted that longer curing time improves the polymerization process resulting in higher compressive strength. The rate of increase in strength is rapid up to 24 hours of curing time; beyond 24 hours, the gain in strength is only moderate. Therefore, heat-curing time need not be more than 24 hours for all practical applications.

Sandeep L. Hake et al. (2015) made an investigation on the method of curing and found that most of researcher used only oven heat curing for geopolymer concrete. They reported that many studied only for different curing temperature in oven curing, but only few researchers experimented with steam, membrane curing and no work was reported on accelerated curing, as well as comparison on steam, accelerated, membrane, natural and oven curing. So there is scope for research on method of curing of geopolymer concrete.

Zhang H.Y. et al. (2018) based on theirexperimental results on the bond behaviour between geopolymer concrete and rebarreported that Geopolymer concrete exhibits significant temperature induced degradation in bond strength, when exposed to temperatures above 300˚C also Bond strength of geopolymer concrete was found to decrease at the same rate as that of splitting tensile strength with temperature, but this degradation is at a higher pace than that of the compressive strength

MOLARITY

Manimaran E and Mohankumar G (2017) reported while finding the influence of sodium hydroxide concentration on the strength of fly ash based geopolymer concrete that the higher concentration of NaOH reduces the slump value and extra water is needed for workability. The equivalent characteristic strength of GPC even 3% more than that is easily obtained with the lowest molarity (8M) of NaOH both in hot and ambient curing.

Phoo-ngernkhamT (2017) investigated the effects of combinations of sodium hydroxide and sodium silicate solutions (SH, SHSS, and SS) on the strength development of fly ash and Portland cement based Geopolymer Mortar (GM)also the GM made from SHSS solution can be used as a sustainable repair binder and its application is veryattractive.

Patankar S.V. et al. (2018) studied effect of various concentrations of sodium hydroxide solution in terms of molarity at solution to fly ash ratios of 0.30, 0.35, and 0.40 on workability in terms of flow in plastic state and effect of degree of heating on compressive strength. They reported that the workability as well as compressive strength of geopolymer mortar increases with increase in concentration of sodium hydroxide solution in terms of molarity and they recommended, 13-molar solution of sodium hydroxide is recommended on the basis of workability and compressive strength.

Oyebisi S et al. (2018) investigated the utilization of both corncob ash and ground granulated blast furnace slag as source materials activating with both sodium hydroxide (NaOH) and sodium silicate (Na2SiO3) solutions in the production of geopolymer concrete and reported that the geopolymer concrete with 12 M sodium hydroxide shows a higher compressivestrength when compared with the Portland cement concrete. Comparing with the Portland cement concrete, the optimal replacement level of both ground granulated blast furnace slag and corncob ash for optimum strength is obtained at 60% and 40% respectively.

Lăzărescu A et al. (2018)investigated on the parameter affecting the mechanical property of fly ash based geopolymer concrete while keeping the alkaline liquid to fly ash mixing ratio constant, they varied the $Na_2SiO_3$to NaOH solution ratio and the NaOH solution concentration, Results showed that by increasing the sodium silicate solution content in the mixtures, a significant increase in the compressive strength can be obtained.

USES OF FLY ASH AND OTHER INDUSTRIAL WASTES

Geopolymer concrete doesn't use cement but uses industrials wastes like flyash, GGBS etc. Out of all the usable industrial wastes flyash is the most commonly used material.

Deepa Balakrishnan S et al (2013) reported that the fly ash content is much significant when the geo-polymer concrete is cured in ambient temperature. However, the change in strength of heat cured specimen is nominal with the variation of fly ash content is varied from 395 to 425 kg per cubic meter of concrete. They reported that the fly ash geo-polymer concrete is a sustainable material for future construction works. However, design methodologies are to be developed for geo-polymer concrete prior to actual use in worksite.

B. V. Rangan (2008) reported that heat-cured low-calcium fly ash-based geopolymer concrete offers several economic benefits over Portland cement concrete. The price of one ton of fly ash is only a small fraction of the price of one ton of Portland cement. Therefore, after allowing for the price of alkaline liquids needed to the make the geopolymer concrete, the price of fly ash-based geopolymer concrete is estimated to be about 10 to 30 percent cheaper than that of Portland cement concrete.

Adam A. A. et al. (2016) investigated on the effect of lime addition on the setting time strength of ambient cured fly ash based geopolymer concrete and reported that the setting time of the class F fly ash based geopolymer paste can be controlled by adding a small proportion of slaked lime. The addition of lime increases the strength and decreased the setting time.

Ma C. K. et al. (2018) assessed the performance of geopolymer concrete,both in material and structure. It was found that there are about 6 groups of geopolymer concrete based on alumina silicate sources. They are fly ash-based, metakaolin-based, slag-based, rice husk ash-based, high calcium wood ash-based and combination of either two of the earlier mentioned aluminosilicates. Among these types, fly ash-based geopolymer concrete is the most popular and widely tested alsothrough review of papers found that geopolymer is suitable for structural elements. It was also found that the full scale tests are still lacking especially for non-Fly Ash based geopolymer concrete.

Albitar M et al. (2017) while evaluating the durability of geopolymer and conventional concretereported thatSulphuric acid has a more detrimental impact on OPC concrete with a reduction in compressive strength of 26.6% compared to 10.9% reduction of fly ash in geopolymer concrete compressive strengths respectively.

Al-Majidi M. H. et al. (2016) investigated the development of geopolymer mortar under ambient curing temperature for in situ applications and stated that the geopolymer mixes with increased GGBS content had considerably improved flexural and direct tensile strength, even without any heat curing treatment.

INCORPORATION OF CEMENT AS PARTIAL REPLACEMENT

Only limited work is available in the literature on incorporation of cement as partial replacement in GPC.

Mehta A and Siddique R (2017) reported thatthe compressive strength of low-calcium fly ash based geopolymer concrete increased with the inclusion of OPC as a replacement to fly ash up to 20% at all ages.

Askarian M et al. (2018) reported thatthe developed one-part hybrid OPC-geopolymer concrete could be a suitable material for on-site operation as the need for heat curing and the use of highly alkaline solutions have been eliminated. The setting time, workability, compressive strength and microstructure properties can be controlled by adjusting the OPC content and activator concentrations.

DURABILITY AND ENVIRONMENTAL CONSIDERATION & RESULTS

Albitar M et al. (2017) while investigating on the durability of geopolymer and conventional concrete reported that theOPC concrete suffers more deterioration than geopolymer concretes due to sodium sulphate exposure with a reduction magnitude of 15.4% compared to the 13.4% reduction magnitude of fly ash geopolymer concrete.

Daniel A. Salas et al. (2018) while assessing the life cycle of geopolymer concrete reported thatthe production of geopolymer concrete entails a potential environmental advantage over cement concrete if sodium hydroxide is produced with solar salt while considering an electricity mix with a high share of hydropower. The global warming potential of geopolymer concrete under these conditions is 64% lower than that of cement concrete. However, geopolymer concrete performs worse in the ozone depletion category due to CFC emissions during the chlor-alkali process (due to the use of carbon tetrachloride), which are not present in cement production.

WATER TO GEOPOLYMER SOLID RATIO

Ferdous M.W. et al. (2013) proposed a method for selecting the mix proportions of fly ash based geopolymer concrete and their experimental results showed that the compressive strength of the fly ash based geopolymer concrete decreased linearly with increase in the water to geoploymer solids ratio.

Sudhakarreddy K et al (2018) reported that at 6% of replacement of cement in fly ash of geopolymer concrete yields the betterresults in flexural strength of beams. They also reported that higher replacement percentage in fly ash of geopolymer concrete increasesthe strength of concrete.

Fan F et al. (2017) carried out an experimental investigation on the thermo-mechanical properties of geopolymers prepared using a class F fly ash, KOH and Na_2SiO_3solutions. They reported that the compressive strength of the geopolymer with the water/ash ratio of 0.25 and 0.3 are very close, and the residual strength of the geopolymer matrix after 500C heating with the water/ash ratio of 0.3 is higher than that for the water/ash ratio of 0.25, which indicates that the water/ash ratio of 0.3 might be the optimal mixture ratio.

CONCLUSION

A detailed review of literature on geopolymer concrete has been carried out and consolidated. It is found that fly-ash is the most widely used material for making geopolymer concrete. The optimum time of curing for fly-ash based geopolymer concrete is reported to be 20 to 24 hours. From the literature it is found that 8M to 16M sodium hydroxide solutions are often used for making GPC. Few have attempted to use lime or cement as partial replacement to fly-ash. It is reported that replacement of fly-ash with 20% of ordinary Portland cement gives higher compressive strength than geopolymer concrete. The concept of addition of ordinary Portland cement in geo-polymer concrete is a good idea since the heat of hydration could be used for curing. The authors coins the term “Semi Geo-polymer Concrete” for geopolymer concrete in which fly-ash is partially replaced with cement.

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