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A Review on Self curing Geopolymer Concrete by Using Lime and Cement with Recycled Aggregates

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Abstract:
Geopolymer concrete containing fly ash and recycled aggregate is a new concrete which can reuse the by-products of power station and waste concrete. Most of the studies employed heat curing for setting and hardening of fly ash geopolymer mixtures. Heat curing process requires special arrangements which is energy-consuming. This paper presents a review on fly ash based geopolymer concrete cured in ambient temperature without additional heat. To achieve self-curing of GPC, a small amount of lime and OPC were added with fly ash. The inclusion of lime and OPC with fly ash significantly enhanced the early age properties. Setting time reduced to reasonable values and compressive strength increased to enable early de-moulding of specimens. The reviews suggest that suitable geopolymer mixtures can be designed for ambient curing with fly ash, lime and OPC as optimum replacement with recycled aggregates.
Keywords: *GPC, Self-curing, ambient temperature, lime and OPC, recycled aggregates.*

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I. INTRODUCTION

The demand of concrete is increasing day by day for satisfying the need for the development of infrastructure facilities. The cement production is held responsible for CO2 emissions, which pollute the atmosphere. Hence, it is inevitable to find an alternative material to OPC. Geopolymer concrete is an innovative, eco-friendly construction material which is made by reacting aluminate and silicate bearing materials with a caustic activator. In several types of GPC, the fly ash-based geopolymer concrete is a better option. But the need of heat curing prevents the wide application of fly ash based geopolymer concrete. Usually the geopolymer systems are subjected to heat curing for hours or even days at a temperature higher than 50 °C. In order to improve the self-curing of GPC the incorporation of calcium sources such as cement and lime were found to play an important role to shorten the setting time and improve the mechanical properties. The use of recycled aggregates in geopolymer concrete provides an eco-friendly alternative for the construction industry. Utilising concrete waste from demolition sites and crushed test specimens that would otherwise be disposed of into landfill, as a source of aggregates offers a potential environmental and economic benefit. Used together, lime and cement added geopolymer concrete with recycled aggregates, eliminate the need for Portland cement and makes use of waste materials.

II. LITERATURE REVIEW

The focus is to produce a geopolymer concrete with the use of lime and OPC under ambient curing and to improve the properties of GPC thereby to eliminate the need of heat curing in the concrete.

2.1 LIME POWDER ADDED GEOPOLYMER CONCRETE

Namagga and Atadero (2009)- investigated that, the replacement of high-lime fly ash in concrete generally increases the ultimate strength of concrete. Replacement of cement with high-lime fly ash reduces the rate of strength development beyond the optimal limits obtained for 25–35% fly ash mixes.

Temuujin et al (2009)- studied that, the addition of the calcium compounds CaO and $Ca(OH)_2$ improves mechanical properties of the fly ash based GPC with ambient temperature. $Ca(OH)_2$ is considered to be a more beneficial than CaO.Desired properties of ambient cured GPC increased with 3% CaO and 3% $Ca(OH)_2$ addition.

Dutta and Ghosh (2012)- studied that, the pore sizes get a reduction after addition of limestone dust into the geopolymer paste. This phenomenon influences water absorption and compressive strength.

Incorporation of limestone dust up to 15% increases the compressive strength of paste specimens about 44%. The reduction in compressive strength due to lower curing temperature may be compensated by incorporation of calcium compound which can accelerate the rate of polymerization even at low temperature.

Prakash Vora et al (2013)- studied that, with increase in the curing temperature in the range of 60°C to 90°C, the compressive strength of the geopolymer concrete also increases. The compressive strength of the geopolymer concrete increases with increase in the curing time. However, the increase in strength beyond 24 hours is not much significant. 1-day rest period increases the compressive strength of the geopolymer concrete as compared to that for the concrete without the rest period.

Patankar et al (2013)- observed that, the workability as well as compressive strength of geopolymer mortar increases with increase in concentration of sodium hydroxide in terms of molarity.13-molar solution of sodium hydroxide is recommended. Test results show that the flow of geopolymer concrete increases with increase in the water-to-geopolymer binder ratio and vice versa. The compressive strength is inversely proportional to water to geopolymer binder ratio and 0.25 to 0.35 is the suitable range.

Jamkar et al (2013) - investigated that, the compressive strength results show that the fly ash fineness plays a vital role in the activation of geopolymer concrete. An increase in the fineness increased both workability and compressive strength. It was also observed that finer particles resulted in increasing the rate of reaction needing less heating time to achieve a given strength. The mass density of GPC increased with increasing flyash fineness. The alkalinity of geopolymer concrete was slightly affected by the flyash fineness.

Jain et al (2016)- investigated that, the compressive strength goes on increasing with the increase in the rest period of geopolymer concrete with addition of 10% of lime and it is cured at normal room temperature. The maximum compressive strength was achieved at the completion of 28 days of rest period thereby giving it a wide scope. The compressive strength achieved by grade M30 of geopolymer concrete cured at normal room temperature at a rest period of 7 days is higher than the compressive strength achieved by ordinary concrete for similar rest period.

Andi Arham Adam et al (2016)-The test result shows 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 but decreases the setting time. There is a certain value where the increase of Na_2O dosage decrease setting time. However, beyond the level, further increase in Na_2O dosage will increase setting time.

Hake et al (2018)- articulate that, the compressive strength of geopolymer concrete of grade M30 goes on increasing with the addition of 5% and 10% of lime. Addition of 15%, 20%, and 25% of lime in geopolymer concrete of grade M30 makes the concrete harsh which adversely affects its workability as well as its compressive strength. The compressive strength goes on increasing for an M30 grade of geopolymer concrete with 10% lime addition, as the rest period increases, where the maximum strength is achieved at the completion of 28 days of the rest period.

Sandeep L. Hakea and Damgirb (2019)- Observed that Out of the three type of lime i.e. Slaked, Hydrated and Quick lime. The slaked lime shows improved results in the sense of compressive and tensile strength. 10 to 50 % increasing trend has been found out. Addition of lime up to 15% shows improved compressive strength as well as tensile strength. The addition of more than 15% lime shows decreasing trend of workability. The 10% addition of slaked lime shows improved and stable results with workable concrete.

Kalaivani et al (2019)- studied that the strength properties of fly ash – GGBS based GPC assessed with different replacements of a chemical additive such as quick lime under ambient curing was determined. The requirement of curing by heat of GPC can be eradicated by the addition of a chemical additive. Even 8M concentration of NaOH, the GPC specimens with 5% lime shows better performance.

Shaswat Kumar Das et al (2020)- investigated that the influence of lime and silica fume on the properties of fly ash based geopolymer was evaluated in this study. Results from this study showed that the incorporation of lime as a replacement of FA can be used to reduce the workability and setting time of GPC, while silica fume can be used to increase these properties. The compressive strength results also indicate the strength is enhanced up to the use of lime and silica fume as partial replacement of 7.5 and 2% respectively

According to this study, the influence of lime on the properties of fly ash based geopolymer was evaluated. Results from this study showed that the incorporation of lime as a replacement of fly ash can be used to reduce the workability and setting time of geopolymer concrete.

2.2 OPC ADDED GEOPOLYMER CONCRETE

Pradip Natha and Prabir Kumar Sarke (2014)- studied that the presence of OPC, accelerated the reaction of geopolymerisation and helped achieve setting time comparable to that of traditional cement concrete. Increase of OPC in the fly ash based geopolymer mixture reduces the workability and setting time. However, the workability and setting time increased when alkaline liquid content was increased. Mixtures having alkaline activator solution with sodium silicate to sodium hydroxide ratio of 2.5 resulted in reduced setting time and less slump than those with 1.5 and 2.0 Inclusion of OPC as little as 5% in the total binder achieved compressive strength more than 50 MPa for mortar samples and about 40 MPa for concrete samples at 28 days. Compressive strength decreased when alkaline solution content was increased from 35% to 45% of total binder. Variation of sodium silicate to sodium hydroxide ratio from 1.5 to 2.5 caused negligible change in compressive strength. Concrete and mortar samples cured in room temperature developed strength gradually over the age up to 28 days. The strength development after this age was small.

Ankur Mehta and Rafat Siddique (2017)- observed that the compressive strength of low-calcium fly ash based geopolymer concrete increased with the inclusion of OPC as fly ash replacement up to 20% at all ages. The inclusion of OPC up to 20% as fly ash replacement reduced the permeation properties such as sorptivity, porosity, and water absorption.

Mahya Askarian et al (2018)- studied that the Increasing OPC content decreased workability of one-part geopolymer concrete mixes. The geopolymer concrete mix (GP0) obtained the highest slump (122 mm) while the mix containing 60% OPC (GP60) achieved the lowest value of 30 mm. The decrease in slump value with increasing OPC could be due to the rapid reaction of OPC with the alkaline activator. By incorporating OPC in the mixes with potassium carbonate, both the initial and final setting times were significantly decreased as the presence of OPC accelerated the geopolymerisation reaction.

Tamer Ahmed (2019)-The use of OPC as a replacement ratio of fly ash in geopolymer concrete containing recycled coarse aggregate, works to reduce the setting time of geopolymer concrete, as a result of increased calcium content in the mixture, which speeds up the setting and hardening of concrete. The initial and final setting times of geopolymer mixtures with OPC are between 20-32 min and 49-69 min,respectively. . The additional of Ca amounts in the mixtures enhanced the geopolymerization process. The best mechanical properties obtained were achieved when OPC is replaced fly ash by 15% by weight and using 25% of recycled aggregate as a substitute for virgin aggregate.

Samuvel Raj and Prince Arulraj (2020)- Compressive strength of geopolymer concrete was found to be maximum at 20 % replacement level. The maximum value of compressive strength was found to be 49.7N/mm2 which is 38.54% more than that of the control specimen. The impact strength of specimens with 20% OPC was 2.3 times more than that of the control mix. At higher percentages of OPC, the geopolymer mix became stiff and the workability decreased.

This study intended to eliminate the necessity of heat curing for producing fly ash based geopolymer concrete. Fly ash based geopolymer concrete mixtures were designed with the addition of ordinary Portland cement in order to improve the early age properties in ambient curing condition. This study concludes that, the presence of OPC accelerated the reaction of geopolymerisation and helped achieve setting time. Increase of OPC in the fly ash based geopolymer mixture reduces the workability and setting time.

2.3 GEOPOLYMER CONCRETE WITH RECYCLED AGGREGATES

Benjamin Galvin and Natalie Lloyd (2011)- observed that compressive strength decrease in geopolymer concrete mixtures with the partial replacement of natural coarse aggregate with RCA. This demonstrates that strengths for nominal grade 32 MPa concrete can be developed by geopolymer concrete containing up to 30 percent RCA with no change to the mix design and higher strengths may be able to be produced with minor changes to the mix design, analogous to adjusting the water to cement ratio, by adjusting the water to geopolymer solids ratio.

Shi et al (2012)- observed that the compressive strengths of GRC with different RA contents are significantly higher than that of the corresponding RAC. With more RAs, the compressive strengths of RAC and GRC are decreased. The influence of RA on the strength is greater on GRC than that on RAC in this case.

Shi Xiao-shuang et al (2012)- studied that the increasing RA replacement ratio, the density, elastic modulus, Poisson's ratio and compressive strength of the concretes decreased. The influence of RA content is greater on GRC than that on RAC. The compressive strength of GRC is higher than that of RAC during the full testing time, especially at the early stage.

Peem Nuaklong et al (2015)-The results indicate that recycled concrete aggregate can be used as a coarse aggregate in high calcium fly ash geopolymer concrete. The obtained strengths and durability were slightly lower than those containing crushed limestone. However, geopolymer concrete containing recycled concrete aggregate still possessed sufficiently high compressive strength of 30.6-38.4 MPa or approximately 76-93% of the same geopolymer concretes containing crushed limestone.

Deepa Raj et al (2017)- conducted many experiments to find the optimum percentage of recycled aggregates and found that an optimum replacement of 40% recycled aggregates shows good workability and properties. They also concluded that strength behaviour is more compared with conventional concrete and they recommended as a sustainable and environment friendly construction material.

Chau-khun ma et al (2018)- concluded that the replacement of coarse aggregates with recycled aggregates and by replacing cement with many by-products gives much strength reducing in greenhouse gases and have better structural properties compared with conventional concrete.

Jianhe Xie et al (2018)- concluded that the combination of GGBS and fly ash can provide excellent synergetic effects on workability and mechanical performance for the geopolymer concrete with recycled coarse aggregates. Replacing OPC matrix by fly ash/GGBS based geopolymer can improve the strength of recycled aggregates in concretes. As expected, the compressive strength of GRAC increased with the decrease of W/B ratio.

Hadi Nazarpour and Milad Jamali (2019)- The results of the compressive strength of the samples indicates that the increase in material by two times nearly increased the compressive strength about five times. The compressive strength also decreased by increasing the replacement level of recycled aggregates. With the replacement of 20% of coarse aggregates with RCA, the compressive strength of mix designs at different ages decreased between 4 and 11%.

Balaji and Shanthini (2019)-From the compressive strength test results it is observed that the 10% replacement mix has high strength than the other mixes (0% and 20%) in the 28th day test. We observe that the strength parameters of the concrete are reduced with increase in replacement proportion of the aggregates. With increase in replacement proportion the weight of the geopolymer concrete decreases. Thus it can be used for light weight concreting.

From this study we can understand that, the increasing recycled aggregate replacement ratio, the density and compressive strength of the concretes decreased.The influence of recycled aggregate content is greater on geopolymer concrete than that on ordinary cement concrete.

III. CONCLUSION

Following are the major conclusions derived from the literature study,

- Geopolymer concrete offers environmental friendly and protects the natural resource by utilizing the waste/by-products from the industry which is harmful to the environment. It has several excellent benefits like high compressive strength and simple guidelines for mix design.
- This study presents the overview of geopolymer materials, characterizations and economic benefits, instead of the traditional Portland cement to make concrete.
- It was inferred that the inclusion of lime and opc in geopolymer concrete increases the overall performance of concrete under ambient temperature.
- The use of recycled concrete aggregates as coarse aggregates in the geopolymer composite causes a reduction in strength and an increase in permeability. At the same time, it also increases the workability of fresh concrete. The influence of RA content is greater on geopolymer concrete than that on ordinary Portland cement concrete.

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