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"CRITICAL REVIEW ON INFLUENCE OF CURING ON PROPERTIES GEOPOLYMER CONCRETE USING INDUSTRIAL WASTE."

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Abstract - Concrete is the world's most versatile material and reliable construction material, which required large quantities of Ordinary Portland Cement production. Ordinary Portland Cement Concrete is the second only to the automobile as major generator of carbon dioxide. 5 to 8% of world's manmade greenhouse gas emission is from cement industry itself. To overcome it, in recent years, researchers have focused on finding an alternative to Ordinary Portland Cement to reduce carbon footprint. Natural material will be scarce in future, to find alternative solution by using such waste and also decrease the scarcity of landfill space. This paper is consist of critical review based on various literature. The different research already taken place in this particular area of the commercially available superplasticizer based concrete improves the workability of fresh concrete. The work on setting time of Geopolymer concrete was also studied. The Geopolymer concrete have short initial setting time of about 20 minutes. The Geopolymer with mrtacolin seen good workability but deterioration in same environment is reported. Studies related to effect of various molarity in different types of curing method using various industrial waste is one of the area which still undiscovered for geopolymer concrete. Such type of review is also helpful in explore current status of research in the domain of geopolymer concrete.

Keywords— Geopolymer Concrete, Alkaline Solution, Pozzolanic Materials, Molarity, Curing.

I. INTRODUCTION

The term geopolymer was first introduced by Davidovits in 1978-1979 is the one who termed these 3-dimensional alumino-silicates as geopolymer (GP). He states that, supplementary cementing materials such as coal and lignite fly ash, rice husk ask, buggash ash, palm oil fuel ash GGBFS, silica fume, limestone, metakaolin and natural pozzolana can produce geopolymer.

Geopolymer composites have emerged as an environmental friendly alternative to OPC composites. Many researchers have reported as geopolymers composites possess high early strength and better durability. Recently several researchers have used different bu-products as cement, fine aggregate and coarse aggregate replacement materials in production of concrete.

The geopolymer is synthesized by activating one or more supplementary cementing materials with help of activatorsolution (AS). Activator solution can be prepared using silicates and hydroxides of sodium or potassium. Most commonly used are sodium silicate (SS) and sodium hydroxide (SH). Sodium hydroxide solution (SHS) of known molar concentration is prepared and mixed with sodium silicate solution (SSS) to form the activator solution (AS).

Polymerization process involves a substantially fast chemical reaction under alkaline condition on Si-AL minerals, resulting in a three-dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds. Geopolymer concrete gains about 60-70 % of the total compressive strength within 7 days.

In this paper attempt has been made to explore the current status of research done in the one of the latest area of geopolymer concrete. This critical review on geopolymer concrete narrated the variety of materials used for the production of geopolymer concrete. It also provide the information about current methodology and its effect on the properties of geopolymer concrete. Based on this study one can decide the undiscovered area of research in the domain and planned their research work to explore more unknown aspects of geopolymer concrete.

II. LITERATURE REVIEW

Many researchers and technocrats had put their sincere and elaborate efforts about effect of various materials on geopolymer concrete and its properties. Research papers and related studies were reviewed. Some journal papers were also reviewed. This literature review provides in depth information and database related to the current trends in geopolymer concrete.

M. I. Abdul Aleem and P. D. Arumairaj was introducing geopolymer concrete which is an innovative construction material and also it shall be produced by the chemical action of inorganic molecules. Geopolymer concrete shall be produced without using any amount of ordinary Portland plain cement concrete. Geopolymer concrete gives 7.5 times more compressive strength than Ordinary Portland cement concrete for the same mix and also give same workability to Ordinary Portland cement concrete. Geopolymer concrete can be used for bridges, precast structural elements, slab for paving, bricks, decks, precast pipes & pavers, infrastructure works, beam-column junction of reinforced concrete structure and repair & rehabilitation work. For precast industries, huge production is possible in short duration and breakage during transportation shall also be minimized due to the high early strength Geopolymer concrete. No landfills are required to dump the industrial waste. The government can make necessary steps to extract sodium hydroxide and sodium silicate solution from the waste materials of chemical industries, so that the cost of alkaline solution required for the Geopolymer concrete shall be reduced.

F. Nurhayat Degirmenci was studied to investigate the engineering properties and mix design of Geopolymer mortar. Geopolymer mortar made using fly ash, natural zeolite and ground granulated blast furnace slag as source material and combination of sodium hydroxide and sodium silicate as alkaline activator. It was observed that compressive strength of Geopolymer mortar increase in GGBS context and molarity of alkaline solution in ambient curing.

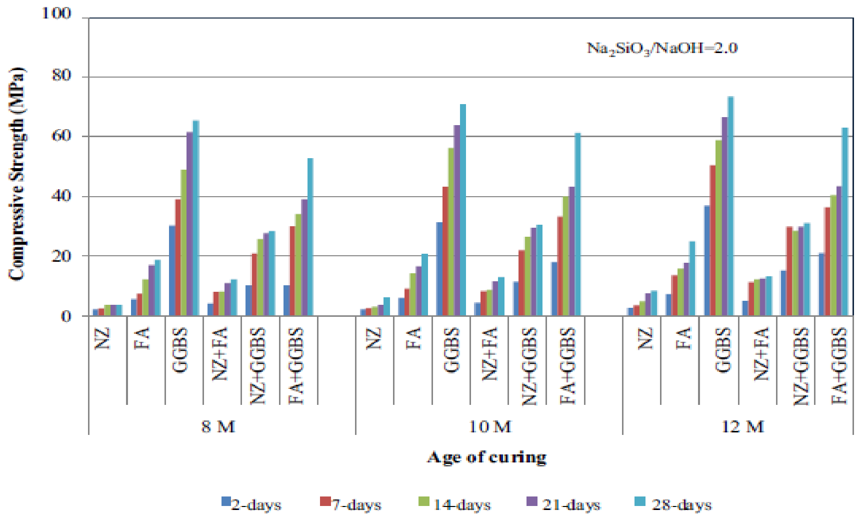

Fig. 1 effect of sodium hydroxide concentration on compressive strength of Geopolymer mortar.

Using Fly Ash and N_2 in Geopolymer mortar, it gives moderate compressive strength respectively at the all ages. The compressive strength of Geopolymer mortar increase with increase of sodium silicate to sodium hydroxide ratio and concentration of sodium hydroxide solution.

Madheswaran C. K, Gnanasundar G and Gopalakrishnan was studied on development of strength for various grade and different molarity for Geopolymer concrete. The alkaline liquids used in this study for the geopolymerization are sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3). Different molarities of sodium hydroxide solution (3M, 5M and 7M) are taken to prepare different mixtures. The study also carried out workability and various mechanical properties of Geopolymer concrete. The measured compressive strength of Geopolymer mix is in the range from 45 Mpa to 60 Mpa and maximum of 60 Mpa for 100 GGBS. The GPCs utilize the industrial wastes for producing the binding system in concrete. There are both environmental and economical benefits of using fly ash and GGBS.

Badami Bhavin, Prof. Jayeshkumar Pitroda and Prof.J.J.Bhavsar was carried out on the topic of geopolymer concrete technology which is widely used in USA, Europe and Australia for railway sleepers, electric poles, road pavements, marine structure, etc. In India, Geopolymer concrete has been used in Delhi metro project. Based on laboratory test, Geopolymer concrete can harden rapidly at room temperature and gain to compressive strength in the range of 20 Mpa after only 4 hour at 20° C and about 70-100 Mpa after 28 days. Geopolymer concrete stable up to 600° C when ordinary portland cement concrete is stable up to 300°. Geopolymer concrete posses high early strength, heat resistance, fire resistance, freeze-thaw resistance, sulphate resistance, corrosion resistance, acid resistance, low shrinkage and no dangerous alkali aggregate reaction. From this study, they concluded that Geopolymer concrete is economic them ordinary portland cement concrete. However, it was also concluded that the compressive strength of Geopolymer concrete is greater than ordinary portland cement concrete.

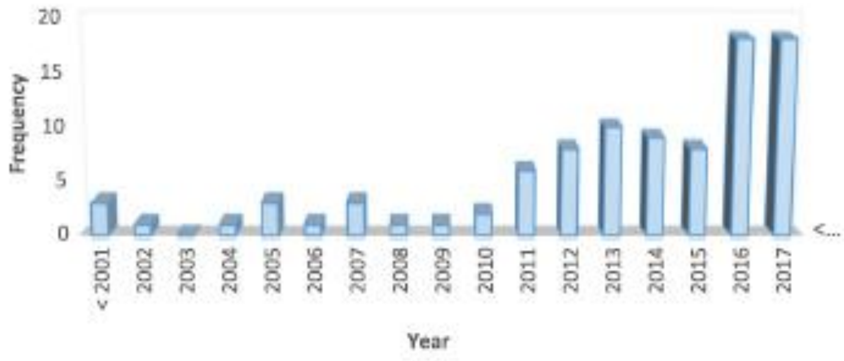

Fig. 2 Research trend in Geopolymer concrete

Chau-Khun Ma, Abdullah Zawawi Awang and Wahid Omar was studied on performance in material and structure are discussed and taxonomy in the field of Geopolymer concrete studies. The research lacking in this area was discussed. Barriers to the wide spread use of Geopolymer concrete in construction industry are critically analyzed. It was found that Geopolymer is suitable as structural elements and the fill scale test are still lacking especially for non-FA based Geopolymer concrete.

Mithanthaya I.R., Shriram Marathe, N B S Rao and Veena Bhat was carried out to make GPC using a suitable mix of industrial waste materials like Fly ash, Ground Granulated Blast Furnace Slag (GGBS), glass powder, and aggregates. In the present work, waste glass powder in the form of reactive silica is used instead of sodium silicate solution for the production of conventional GPC. Required quantity of sodium hydroxide solution having 8 M has been used. It was observed that use of naphthalene-based super plasticizer improve the fresh and harden behavior of Geopolymer concrete. Test on Geopolymer concrete cubes prepared and cared at room temperature only indicate the development of compressive strength up to M40 can be achieved corresponding to the selected optimum replacement of fly ash, by GGBS and glass powder.

Behzad Nematollahi and Jay Sanjayan was carried out in his study the effect of two different activators (NaOH solution and multi-compound activator with Na_2Sio_3/NaOH ratio of 2.5) and six different superplasticizers (three modified poly carboxilate based, 2 napthalene and one melamine based superplasticizers). Workability and strength of fly ash based Geopolymer have been evaluated. The fly ash paste activated by activators (Na_2SiO_3/NaOH =2.5) had higher relative slump and compressive strength. Workability and strength of fly ash based Geopolymer concrete directly depend on the type of activators and super plasticizers.

R. Prasanna Venkatesan and K. C. Pazhani was presented an experimental study on the strength and durability properties of Geopolymer concrete prepared using Ground Granulated Blast Furnace slag (GGBS) and Black Rice Husk Ash (BRHA). The Geopolymer concrete was prepared with GGBS and BRHA at various proportions. The effect of GGBS and BRHA on durability and mechanical properties was analyzed. It was concluded that it is possible to produced Geopolymer concrete possessing substantial strength and durability using GGBS and BRHA. Oven cured specimens showed higher compressive strength than the ambient cured specimens. The test result showed that there was decrease in sorptivity about BRHA replacement in compression with the control specimens. The Geopolymer concrete specimens showed good resistance to chloride permeability. The incorporation of BRHA in Geopolymer concrete increases its corrosion resistance. Addition of BRHA beyond 20 % is not beneficial in Geopolymer concrete. It aids the utilization of alternate materials like GGBS and BRHA to produce binder. Since these materials are essentially industrial by-products, it also means a solution to their disposal problem.

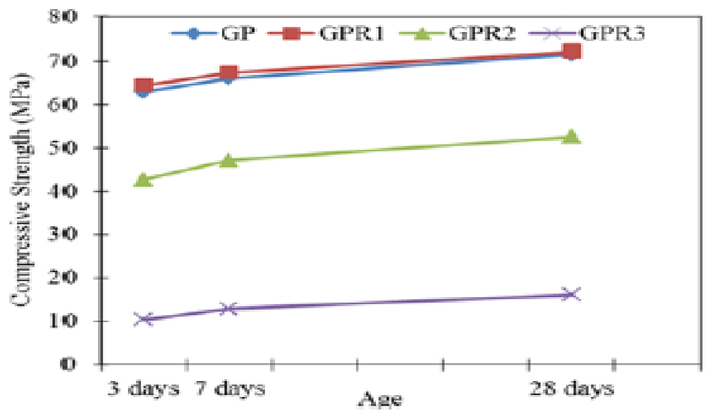

Fig. 3 Compressive strength of Geopolymer concrete cured at 90º C at different ages with different BRHA content

M.R. Karim, M.M. Hossain, M.F.M. Zain and M. Jamil[4], F.C. Lai was studied on Non-cement binder concrete which produced using Slag, Rise husk Ash and palm Oil Fuel Ash (POFA) with NaOH (Sodium hydroxide) at 2.5 molarity. Strength, water absorption and porosity of mortar were determine. Water absorption and porosity were found as 8.1 % and 16.3 % respectively at 28 days. Water absorption and porosity of non-cement mortar can be reduced by improving its compressive strength.

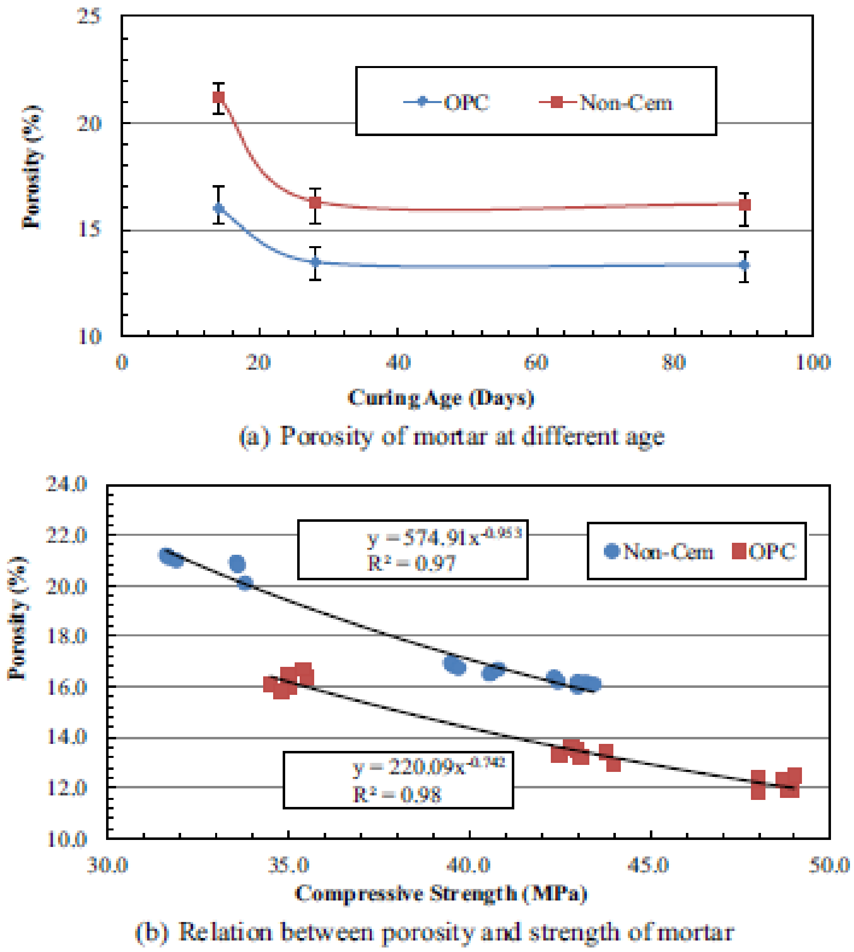

Fig. 4 Porosity of OPC and non-cement mortar at different ages

David Wiyonoa, Antonia and Djwantoro Hardjitoa was studied surface durability to improve its durability by applying Geopolymer coating paste. Class-f Fly Ash calcined volcanic mud with different partials size are used. The NaOH and sodium silicate solution was used. Appling Geopolymer paste coating, reduced the coefficient, lowering the chloride ion penetration and improves the durability of concrete. 50% pozzolanic material content show better durability in acid environment compared to ordinary portland cement.

Bavita Bhardwaj and pardeep kumar was studied on waste foundry sand in concrete. Waste foundry sand enhanced mechanical and durability performance of concrete. Waste founder sand is best alternative of natural sources such as river sand and gravels. Waste founder sand can be used as partial replacement and complete replacement of regular sand in concrete. Increase in substitution of waste foundry sand leads to decrease in unit weight of concrete. Mostly of waste foundry sand are categorized as non-hazardous waste and its give good durability. Beyond 50% replacement there was drastic increase in water demand of concrete. Sand from ferrous foundries performs better than non-ferrous foundries. Up to 30 % used of waste foundry sand gives large C-S-H gel formation. Beyond that C-S-H formation was low, but it's increased the strength. Co_2 reducing the number of pores. Up to 30 % use of waste founder sand is improved modulus of elasticity and abrasion resistance of concrete.

Thiruvenkitam Manoharan, Dhamothiran Laksmanan, Kaliyannan Mylsamy, Pandian Sivakumar and Anirbid Sircar is made by partial replacement of foundry sand with natural sand. Foundry sand is best alternative of natural sand because of concrete are generally made by river sand, which is scarce, high cost and excavation of river sand that promote environmental degradation. It was found that compressive strength, flexural strength and modulus of elasticity were approximate constant up to 20% use foundry sand and decrease with further addition compare to control mix. Split tensile strength was increased after 20% addition of foundry sand , but it affect other property of concrete, so it is recommended that the replacement should not exceed 20%.

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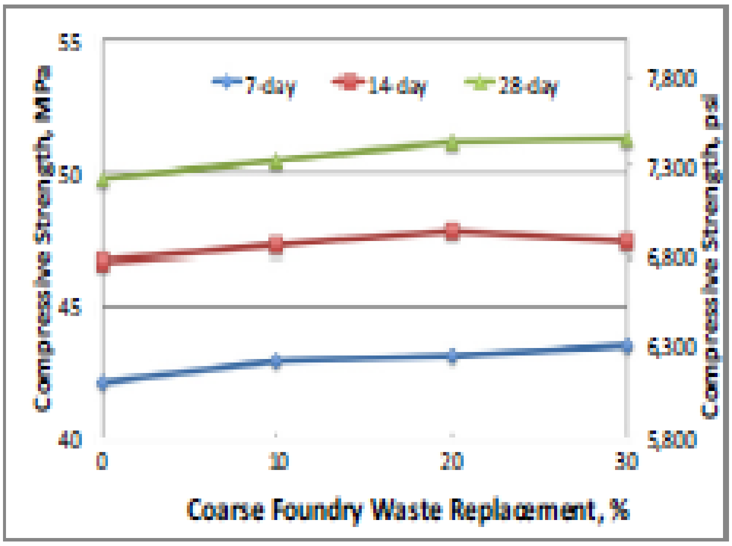

Fig. 5 Compressive strength in relation to coarse foundry waste replacement and curing age

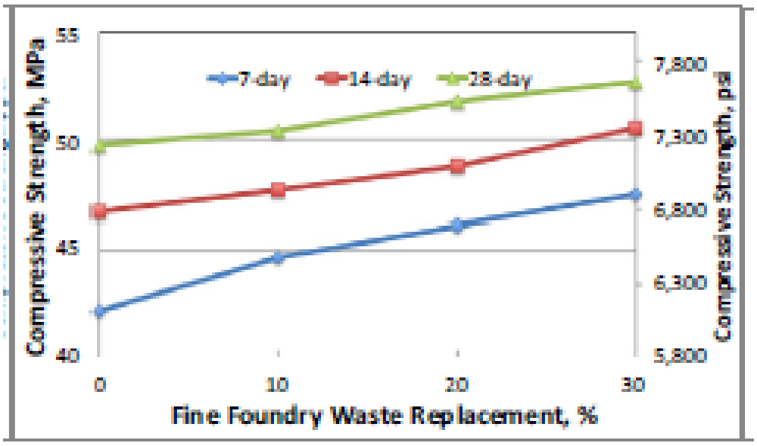

Fig. 6 Compressive strength in relation to fine foundry waste replacement and curing age

Anthony Torres, Laura Bartlett and Cole Pilgrim was studied on the concrete are made using waste fine and course foundry sand with partial replacement of natural sand and aggregate. The compressive strength, tensile strength, flexural strength and modulus of elasticity are studies and they are not affected up to 30% replacement. Using combination of both decrease compressive, tensile strength, flexural strength and modulus of elasticity above a 20% replacement which is save the natural sources and increase the amount of foundry waste solution annually.

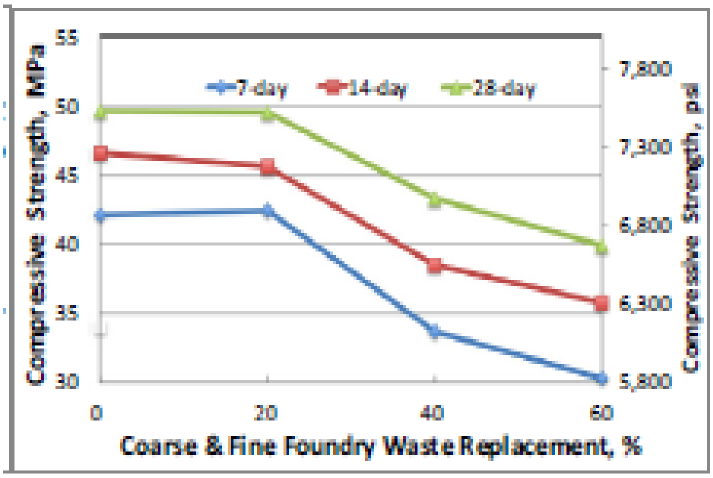

Fig. 7 Compressive strength in relation to coarse & fine foundry waste replacement and curing age

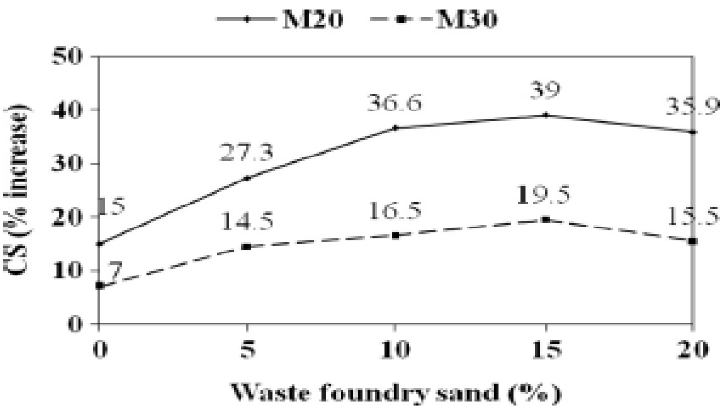

Fig. 8 Compressive strength verses waste foundry sand at 91 days.

Rafat Siddique, Gurpreet Singh, Rafik Belarbi, Karim Ait-Mokhtar and Kunal was carried out in this paper the waste foundry sand is used as a partial replacement with natural sand of 0 %, 5 %, 10%, 15%, 20% with M20 and M30 grade of concrete. The strength properties and permeability was studied.

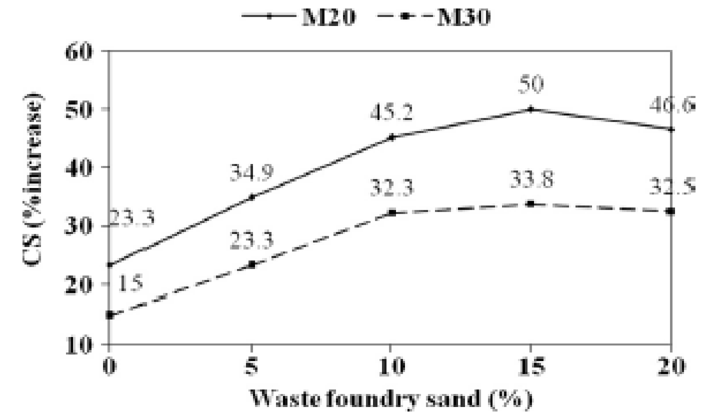

Fig. 9 Compressive strength verses waste foundry sand at 365 days

It gives 28 days compressive strength of 40 Mpa. The compressive strength, split tensile strength, modulus of elasticity, chloride permeability and ultra sonic pulse velocity up to the age of 365 days are conduced. Ultra sonic pulse velocity value increased with the increase in spent foundry content in both types of concrete. The influence of foundry sand is more prominent on M20 grade in strength and durability properties better then M30 grade of concrete. Foundry sand is chloride permeability resistance of concrete.

Visalakshi Talakokula, R. Singh and K. Vysakh was reported the results of an experimental study on the effect of delay time and duration of steam curing on the compressive strength and microstructure development of fly ash based Geopolymer concrete specimens prepared by thermal activation of fly ash with sodium hydroxide and sodium silicate solution. The experimental results concluded that fly ash based Geopolymer specimens has greater compressive strength for a steam curing cycle of 2 hour delay followed by 3 hour curing at 100° C as compared to steam curing cycle of 2 hour delay followed by 18 hour curing at the same temperature. When the curing period is prolonged the fly ash particles were found to be broken.

Sundeep Inti, Megha Sharma and Vivek Tandon was to evaluate the feasibility of using low molarity (4M) sodium hydroxide in Geopolymer mortar. The compressive strength, tensile strength and NDT were performed to identify the influence of curing regime on the gain in strength and moduli of low molariry Geopolymer. It was observed that Geopolymer mortar prepared at a lower molarity of sodium hydroxide (4M NaOH) achieved a compressive strength of 46.6 Mpa after 1 day of curing at 80° C with a standard deviation of 0.86 Mpa. The increase in temperature leads to rapid geo-polyme-rization and evaporation of moisture from the mortar resulting in higher strength and modulus. The increase in the curing temperature initially increased the strength as well as moduli. This study recommends a curing duration that will evaporate water around 70 % from the specimen.

Musaad Zaheer Nazir Khan, Faiz uddin Ahmed Shaikh, Yifei Hao and Hong Hao was producing Geopolymer which is made by using low calcium fly ash, slag, ultra-fine fly ash. It was also studied on effect of strength and microstructure of fly ash Geopolymer concrete. Effective porosity was reduced with the addition of ultrafine fly ash and slag. Additional C-S-H and N-A-S-H gels was produced by using of slag and fly ash.

Pradip Nath and Prabir Kumar Sarker was carried out study about Geopolymer design adding fly ash and GGBS up to 30 % of total binder. Test specimens were cured in ambient temperature at 20°-23° C instead of heat curing. GGBS gives early strength at ambient condition. Workability and setting time reduced with increase of GGBS and decrease of alkaline liquid. The activating liquid was a mixer of sodium silicate and sodium hydroxide solutions. No extra water or super plasticizer was added to the mixer. The workability and setting time increased when alkaline liquid content was increased, with reduced compressive strength.

Moruf Olalekan Yusuf, Megat Azmi Megat Johari, Zainal Arifin Ahmad and Mohammed Maslehuddin was study that the effect of different curing methods on the alkaline activated ground steel/ ultrative plam oil fuel ash (AAGU) mortar. Using plam oil, slag, NaOH, alkaline activated binder, materials the compressive strength, mechanical and effect of curing are studied. Three curing method, oven, room and water-ponding adopted when NaOH is in 4 to 16 molarity. Strength of AAGU concrete is increases with concentration of NaOH in 4 to 16 molarity.

III. SILENT POINTS FROM LITERATURE REVIEW

1. Geopolymer concrete is an innovative construction material which shall be produced by the chemical action of inorganic molecules.
2. Geopolymer concrete shall be produced without using any amount of ordinary Portland plain cement concrete.
3. Geopolymer concrete gives 7.5 times more compressive strength than Ordinary Portland cement concrete for the same mix and also gave same workability to Ordinary Portland cement concrete.
4. For precast industries, huge production is possible in short duration and breakage during transportation shall also be minimized due to the high early strength Geopolymer concrete.
5. No landfills are required to dump the industrial waste.
6. The government can make necessary steps to extract sodium hydroxide and sodium silicate solution from the waste materials of chemical industries, so that the cost of alkaline solution required for the geopolymer concrete shall be reduced.
7. The compressive strength of Geopolymer mortar increase with increase of sodium silicate to sodium hydroxide ratio and concentration of sodium hydroxide solution.
8. The GPCs utilize the industrial wastes for producing the binding system in concrete. There are both environmental and economic benefits of using GGBS.
9. Geopolymer concrete stable up to 600° C when ordinary portland cement concrete is stable up to 300°C.
10. Geopolymer concrete is economic them ordinary portland cement concrete and also the compressive strength of Geopolymer concrete is greater than ordinary portland cement concrete.
11. Geopolymer is suitable as structural elements and the fill scale test are still lacking especially for non-FA based Geopolymer concrete.
12. Geopolymer concrete can be cured by three curing methods: Ambient curing, Steam curing and oven curing.
13. Geopolymer design adding GGBS up to 30 % of total binder.
14. Foundry sand is chloride permeability resistance of concrete.
15. Foundry sand is best alternative of natural sand coz of concrete are generally made by river sand, which is scarce, high cost and excavation of river sand that promote environmental degradation.
16. Waste foundry sand enhanced mechanical and durability performance of concrete.
17. Waste founder sand is best alternative of natural sources such as river sand and gravels.
18. Waste founder sand can be used as partial replacement and complete replacement of regular sand in concrete.
19. Increase in substitution of waste foundry sand leads to decrease in unit weight of concrete.
20. Mostly of waste foundry sand are categorized as non-hazardous waste and its give good durability.

IV. CONCLUSIONS

Based on the critical literature review, it has been understand that vast opportunity exist for further research work in the area of the geopolymer concrete. Many critical areas are still undiscovered for production of geopolymer concrete. Various waste material which possesses pozzolanic properties are capable of utilized for production of geopolymer concrete. Apart from that some waste materials can also utilized for replacement of aggregates in geopolymer concrete. This type of research work in the area of geopolymer concrete can drastically change properties of geopolymer concrete in positive side and ultimately helpful in protection of environment by utilization of waste material in substantial amount.

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