A Review on Strength and Durability characteristics of Alkali Activated Binders

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Abstract - The exploitation of cement causes the pollution to the environment and reduction of raw materials. Moreover, the need of structural performance of members led to the development of new techniques of construction and materials. This led to the development of utilization of supplementary cementitious materials (SCM's) for development of alternative binding materials replacing the traditional cement. Supplementary cementitious materials may be the bi-product or waste from the industry which may have binding property with alkaline activator solution (AAS). The various types of materials like Ground granulated blast furnace slag (GGBFS), Fly ash (FA), Nano silica (NS), Alccofine, Rice Husk ash (RHA) are used in developing alternative binding materials. This paper present a overview on research done over past few decades considering the role of supplementary cementitious materials and their influence on properties like strength and durability either by partially replacing or fully replacing the traditional ordinary Portland cement.

Key Words: **GEOMORTARS, GGBFS, FA, AAS**

1. INTRODUCTION

Cement industry in India is one of the major contributors to the GDP.With increase in infrastructure development in India the need of cement also had increased extensively. But the main problem is cement industry is extremely energy intensive approximately 4GJ per tonne of energy (Parshwanath and Raja mane et.al, 2001).The production of Portland cement leads to release of significant amount of carbon dioxide one of the green house gas. The production of 1 ton of cement releases of about 1 ton of carbon dioxide into the atmosphere (J.Davidovits et.al, 2008).Therefore an alternative need of material in place of conventional Portland cement came into existence. Therefore, a novel binder called as "geopolymer' was given by Davidovits. Geopolymers are inorganic polymeric materials which posses similar chemical composition as zeolites but possessing amorphous structure. They can be produced by reacting solid aluminosilicates with highly concentrated aqueous alkali hydroxide or silicate solution (J.Davidovits et.al, 1994).The source materials there by used must be rich in silica and aluminium.They may be from natural sources such as kalonite, clay or industrial bi- products such as Fly ash, ground granulated slag, silica; rice husk ash could be used. The alkali activator solution used for geopolymerization process maybe of sodium or potassium based hydroxide and silicates of sodium or potassium (Nanavati and Sujay et.al, 2017).

2. MATERIALS

2.1. FLY ASH

The finely divided residue that results after the combustion of coal that is transported by flue gases and get collected by cyclone separators or electrostatic precipitator (IS 3812-part1, 2013).Coal is one of the natural sources available abundantly in India. Most of the electricity generation in India is based on thermal power plants. About 70% of total electricity produced is alone from thermal power plants. Indian coal is of low calorific value and higher ash content varying from 55-60% on an average value it can be taken as 35-40% (U.C.Mishra, 2004).

Fly ash production is expected nearly to increase up to 241MT by 2022 with present condition of installed power plants. But the major drawback here by considering the utilization of fly ash was only up to 67.13% of total production and remaining ash content is dumped into land masses and water bodies causing serious environmental problems and ecological imbalance. So, now there is an urgent need of carrying out research studies for 100% of utilization of fly ash production (Rajiv satykam et al, 2020).

2.2. GROUND GANULATED BLAST SLAG

Ground granulated blast furnace slag is by product of iron and steel making industries (Chandrasekaran et. al, 2017).The chemical composition of GGBFS contains 35-45% of silicon dioxide and up to 45% of calcium oxide which is near to ordinary Portland cement. Utilization of GGBFS in concrete not only reduces the emission of green house gases but also it improves the strength and resistance of concrete to corrosion and sulphate attacks (Khan, Asaf & Fareed et. al, 2018).

3. REVIEW OF UTILIZATION OF FLYASH

Sandeep L.Hake et al.., (2019) had carried out studies on properties of GPC with the addition of an alkaline solution and Different types of fly ash. In this study they considered four parameters as kinds of curing, temperature, curing time and rest period. Out of these four parameters three were kept constant and other was considered as a factor. They concluded that GPC is dependent on the form of NaOH activator, fineness of fly ash influence the compressive quality of geopolymer concrete. The effect of different curing was considered and found that 18hours of time period is required for polymerization and results better characteristic strength and 90 degree Celsius for both oven and membrane curing.

Rupesh D. Musmade and Sandeep L. Hake (2019) had carried out studies on fly ash based geopolymer concrete with lime. The materials used in the study are Fly ash, Lime powder (Slaked, Hydrated and quick); Na2SiO3: NaOH ratio as 2.5 and coarse and fine aggregates. The GPC is done by varying lime percentages and molarities. They concluded that 10% addition of slaked lime powder with 13M alkaline activator solution is increasing compression and split tensile strength of M30 grade and increases with age period.

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Sandeep L.Hake et al.., (2018) had carried out studies on the temperature effect of lime powder in geopolymer concrete. In the present study fly ash of low calcium class F – processed fly ash by Dirk India private limited by the name of Pozzocrete, P60 had been utilized. The production of Geopolymer concrete needs heat for polymerization process. So, the addition of lime powder is done for giving better results for GPC without heat. The materials used in the study are Pozzocrete, Lime powder, Sodium hydroxide and Sodium Silicate as Alkaline activators, Fine and coarse aggregates. The addition of Lime powder is varied as 0%, 5%, 10%, 15%, 20% and 25%. They concluded that an optimum dosage of 10% of lime powder in fly ash gives better results in compressive strength when compared to ordinary concrete.

T.Nagendra and N.srujana (2017) had investigated on fly ash based geopolymer concrete. The materials used in the study are Fly ash, Metakaolin, Activator solution of Sodium hydroxide and sodium silicate, coarse and fine aggregates. They concluded that strength of GPC increases with molarity of the solution.

Francis N. Okoye et al.., (2017) had investigated the effect of silica fume on durability aspects of fly ash based geopolymer concrete. He utilized low calcium fly ash and sodium based alkaline activators along with sulphonate.He conducted tests on the resistance of samples under sulphate and chloride environment considering 2% H_2SO_4 and Nacl solution with mixes of silica fume varying from 0% to 20% and had concluded that 20% silica fume had excellent durability under chemical attack.

Abhilash et al.., (2017) had investigated the utilization of low calcium based fly ash in concrete and had performed experimental studies on concrete with low calcium fly ash, residual slag as fine aggregate and coarse aggregates were replaced by up to 70% crushed stone and 30% of coal washeries rejects. He conducted experimental work to evaluate the resistance of geopolymer concrete subjected to acidic environment. He concluded that there was considerable reduction in compressive strength of specimen up to 0.61% but when compared to cement concrete it was 0.69% and the specimen are durable in acidic environment.

Nisha Jain et al .., (2016) had carried out experimental investigation on geopolymer concrete with low calcium processed fly ash (Pozocrete,P60) , sodium hydroxide and sodium silicate as alkaline activators with 16M concentration and fine and coarse aggregate as conventional concrete on two grades M3O and M45 grade and concluded that compression strength in both grades is increasing with an optimum percentage replacing fly ash by 10% with cement and no of curing days regime also increases the strength of geopolymer concrete.

Shafiq et al.., (2012) have investigated on durability aspects and long term performance of mortar cubes made with partial replacement of fly ash in cement and concluded that specimens made from partial replacement of cement by fly ash exhibits 10 to 15% of lower permeability and also resulted in 6 to 8 % increase in compression strength of mortar specimens.

Amaranth et al.., (2012) studied the influence of partially replacing cement with fly ash on strength properties of cement mortar and found that 10% fly ash is the optimum dosage for maximum strength in case of mortar.

Karim et al.., (2011) had done experimental work on determination of strength development of mortar and concrete with partial replacement of fly ash at optimum dosage is having the same or higher when compared to OPC at 7days and increases at later age of the specimens.

Beth brueggen et al.., (2010) had carried out studies of utilization of grinding fly ash and its effects of using in concrete. He concluded that grinding of fly ash and its usage improves concrete properties.

Vidivelli and Mageswari (2010) had carried out studies on concrete with partially replacing 10% and 20% of cement content by fly ash and conducted SEM (scanning electronic microscope) studies and concluded that these partially replaced concrete specimens have dense microstructure than that of ordinary concrete specimens and exhibits higher strength.

Md.moinul Islam and Md. Saiful Islam (2010) carried out experimental work on modified mortar by replacing cement in conventional mortar by partial replacement of fly ash in various percentages ranging as 10%, 20%, 30%, 40%, 50%, and 60% by weight of cement. They concluded that both compressive strength and tensile strength of mortar specimen were increased when compared to conventional cement mortar specimen up to an optimum value then if exceed the optimum value decreases. They concluded that the optimum percentage of cement replacement in mortar is 40% which improved 14% higher compressive strength and 8% higher tensile strength as compared to conventional mortar.

4. REVIEW OF UTILIATION OF GGBS

G.Mallikarjuna Rao and R.Srujan et al., (2017) had done experimental studies on the "Effect of GGBS on age of Fly ash and GGBS based geopolymer mortar". The materials use in the study were Fly ash, GGBS and alkaline activators(NaOH & Na_2Si0_3).The samples were prepared of different proportions of Fly ash and GGBS (100%GGBS-0%FA, 75%GGBS-25%FA, 50%GGBS-50%FA, 25%GGBS-75%FA and 0%GGBS-100%FA) and ratio of alkaline activator solution was taken as 2.5.They concluded that compression strength of geopolymer mortar increases with increase in content of GGBS replacing Fly ash content. The minerals identified in 100%GGBS were albite, microcline and maximum strength was observed to this proportion due to formation of N-A-S-H and C-A-S-H formation.

Mallikarjuna Rao Goriparthi and Gunneswara Rao T.D (2017) had done experimental studies on "Effect of Fly ash and GGBS combination on mechanical and durability properties of GPC".The materials used in this study were Fly ash and GGBS binders and solutions of Sodium silicate and sodium hydroxide as alkaline activators. The proportions considered are 70% FA-30%GGBS, 50%FA – 50%GGBS. They concluded that compression strength of concrete increases with increase in percentage of GGBS content.

Padmanaban M S & Sreerambabu J (2018) had investigated on Geopolymer concrete with GGBS.The use of 100% of replacement of GGBS by mass in cement, alkaline activators, coarse and fine aggregates were done. They concluded that compression strength of Geopolymer concrete is more than that of conventional concrete.

Matri Mapa and Hemalatha et al., (2015) had made investigations on Mechanical properties of GGBS and Silica incorporated cement mortar. The effect of partial replacement of cement with various percentages of GGBS on mechanical properties was examined. The materials used in the study were GGBS, Silica, Alkaline activator solution (NaOH & Na_2Si0_3). The compression strength of silica and GGBS added mortar mixes have compressive strength better than conventional cement control mixes.

Huseien, Ghasan & Mirza et al.., (2016) had made investigations on "Properties of geopolymer mortar incorporating ceramic and slag wastes". The Geopolymer mortar (GPM) with ceramic waste and varying of GGBFS is used in the study. They concluded that replacing of 50% GGBFS in ceramic waste resulted in higher strength compared to OPC mortar.

Ling (Bill), Tung-Chai & Hussin, M. et al.., (2012) had done experimental studies on "Strength properties on self compacting mortars mixed with GGBFS".In the study GGBFS is used as an alternative to high volume of cement in self compacting repair mortar(SCRM) and the effects of both fresh and hardened stages were investigated. Compressive strength of SCRM incorporating with 50% of GGBFS resulted in excellent development of long term compressive strength.

Huseien, Ghasan & Mirza et al.., (2016) had made investigations on "Effect of Different binder to aggregate ratio on workability and bending stress of multiple blend geopolymer mortar". In this study they utilized GGBS, Fly ash, Ceramic powder waste (CP), Glass powder waste (GP), Sodium hydroxide and Sodium silicate solution, Fine aggregate. The binder consists of GGBS-55%, FA-15%, CP-15%, GP-15%. They concluded that geopolymer mortar prepared with binder to aggregate ratio of 1.5 can achieve high early compressive strength.

Phoo-ngernkham, Tanakorn & Maegawa et al .., (2015) had done Investigations on "Effects of sodium hydroxide and sodium silicate solutions on compressive and shear bond strengths of FA-GGBS geopolymer".In this study they had made three types of geopolymer pastes (FA,FA+GGBS,GGBS) were tested under influence of NH,NS,NS-NH alkaline solutions. They concluded that increase in GGBS content enhanced compression strength microstructure of geopolymer paste due to formation of additional CSH.

5. CONCLUSIONS

From the past extensive research work done we can conclude some points that

1. In case of utilization of calcium rich materials, Blast furnace slag is more reactive material used for alkali activation increase in content improves the mechanical properties.
2. In case of utilization of low calcium materials, Fly ash and metakaolin are the more reactive material used for alkali activation.

3. Increase in percentage of GGBS improved the strength and durability properties of geopolymer binder.
4. Utilization of silica fume improved durability aspect of the geopolymer binder and resistance to sulphate and chloride attacks.
5. In case of using alkaline activator solutions of hydroxides and silicates based of sodium or potassium the molarity of solution plays a prominent role in enhancing the properties of Binder.
6. The geopolymerization process at ambient curing regime requires more time period than oven curing and other types of curing.
7. The particle size of admixture plays a prominent role in improving mechanical properties and also from microstructure point of view denser the material and decreases the porosity.
8. The workability of material gets affected by increase in content of slag proportion and extra water had to be added to achieve the required slump is limited to only 10%.

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