International Journal of Advanced Technology in Engineering and Science
Vol. No.08, Issue No. 04, April 2020
www.ijates.com
ijates
ISSN 2348 - 7550

A brief over view of strength and durability studies of Geopolymer concrete

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Abstract

Cement is most consumed material on earth after water. Process of cement production releases huge amount of co_2 into the atmosphere. Construction industry enhancing the alternate binders to fully or partially to demote the environmental pollution with supplements like fly ash, rice husk ash, metakaoline, silica fume, GGBFS etc.,. Fly ash is produced in huge volume from thermal power plants and part of it is utilized in the cement industry, low laying area filling, embankments and roads. Yet balance fly ash is disposal problem hence it is exigent to construct the suitable methodologies for disposals. The past research indicates rich silica content in fly ash is chemically activated with alkali solutions to form geo polymer concrete.

The present paper is thorough survey on various elements of geo polymer concrete. To study the mechanical and along term properties with prominences on compressive strength, split tensile strength, stress-strain behavior, acid resistance, impact strength and flexural strength conductivity.

Gaurav Nagalia(1) et al, examines role of concentrations of alkali hydroxide on the micro structure and compressive strength of geo polymer concrete with fly ash. Further identified that, early polymerization in geo polymer concrete depends on sodium hydroxide solution (NaOH), concentration and also exhibit highest compressive strength.

Key Words: Fly ash, GGBFS, Cement, NaOH, Na_2SiO_3, Polished stone dust, Etc.,

INTRODUCTION

Cement is most widely used construction material. The production of cement worldwide increases by 9% for every year approximately. One ton of OPC production approximately emits one ton of CO_2 into atmosphere which is increasing the pollution and causing greenhouse effect. The up going demand for the sustainable material like cement rejuvenate researchers to identify the new materials for sustainable development of cement less concrete to reduce the severe exhaustion of CO_2 .

The use of recycled or waste materials is same as means of viable development. Construction industry is one where bulk utilization of waste material can be effectively done without any compromise on quality and performance.

A French scientist Joseph Davidovits developed concept of Geopolymers which are the network molecules of mineral linked with covalent bond. Geopolymerization consists of dissolution, polymerization, reorganization and hardening. The pozzolonic materials contain rich silica and alumina which can be used to produce geobinder when mixed with alkali solutions such as NaOH, KOH, Na_2SiO_3 and K_2 SiO_3.

Fly ash exhibits significantly different particle morphology and chemistry which affects mechanical properties of resulting geopolymer concrete properties which include high early strength, low shrinkage, free-thawing resistance, sulphate and corrosion resistance. The structural behavior of geo-polymers concrete was similar or superior to OPC concrete. The geo-polymers are an inorganic binder is viable alternative to OPC.

MATERIALS IN GEOPOLYMER CONCRETE

- Pozzolonic materials
- Alkaline liquids
- Water
- Aggregates

Pozzolonic materials

Pozzolons are very finer materials which will fill voids between the sand particles. The pozzolons size would be preferred as 90 microns. The Fly ash, Rice husk ash, GGBFS, Metakaoline, Silica fume etc., are used, as they are rich in silica and alumina. Among all, fly ash is mostly used as pozzolonic materials as it would be the wastage from coal burnt power plants which are available in huge quantity and there is problem regarding its disposals.

Alkaline liquids

The alkaline liquids play a vital role in geo-polymer concrete as they react with the silica and alumina in the pozzolonic materials. NaOH or KOH and Na_2SiO_3 or K_2SiO_3 are recommended as alkali liquids. NaOH, Na_2SiO_3 are widely used as they are economical than KOH, K_2SiO_3. The concentration of NaOH will directly influence the compressive strength. Ratio of NaOH solution to Na_2SiO_3 solution varies according to the application since it influences the mechanical properties of GPC.

Water

Water has no role in chemical reaction which takes place between silica and aluminous liquids. The geo-polymer concrete will be stiffer than ordinary Portland cement hence the water is added to have better properties. Adding excess water causes shrinkage and cracks in the process of drying as the water particles are expelled from the GPC. It is advised that water quantity should be as low as possible or completely avoided by adding the super plasticizer.

Aggregate

The aggregate is the major constituent in the geo-polymer concrete. The role of aggregate in GPC would be same as the ordinary concrete. For obtaining good or high mechanical properties low graded aggregates would be used.

Curing

The polymerization process is a chemical reaction between the silica and alumino liquids that occur as covalent bond. The formation of covalent bond occurs at high temperature. Hence oven or steam curing is adopted for 24 hours at 70^{o} or higher. The ambient curing may be possible by adding small percentage of calcium materials such as lime, GGBFS etc., so that there would be internal heat development for the formation of covalent bond.

William Gustavo[(2)] Valencia saavend ra et al, evaluated performance of geo polymer concrete using binary mixture of fly ash (FA) with blast furnace slag in 80 to 20 ratio and with activated solution mixture of silicate and sodium hydroxide. Specimens were immersed for 360 days in 5 % sodium silicate and magnesium sulfate solutions by weight, volumetric expansions and mechanical resistance loss were measured and reactions are characterized by XRD &SEM. It is observed that geo polymer concrete material offer high resistance to sulfates.

Supratic Gupta[(3)] et al. presented the efficiency factor by conducting durability tests. The efficiency factor is one with which compressive strength of GPC can be compared with OPC concrete. The results of durability test show that there is considerable amount of increase with increase of fly ash percentage.

p. vignesh[(4)] et al, investigated strength properties of geo-polymer concrete with low calcium fly ash replacing slag with five different percentages viz.. 0, 5, 10, 15 and 20% etc., from experimental results it is proved that 30 % GGBFS and 70% fly ash produced maximum strength.

RB khadiranikar[(5)] et al, focused on stress- strain, poison's ratio and modulus of elasticity of geo-polymer concrete with NaOH and Na_2SiO_3 ratio as 2.5. The result reveals that poison's ratio range was 0.20 to 0.24 and modulus of elasticity was 27 to 29 $N/mm^{2.}$ N Ganeshan[(6)] et al, examined effect of confinement on OPC & GPC behavior. Results revealed that stress- strain behavior is more or less similar for both GPC &PCC. Though

GPC mixes have shown improved stress values at ascending portion of stress- strain curve but there were wide variations in descending portion of stress- strain curve.

Pattanapog Topak-Ngam[7] et al, investigated setting time, strength and bond of high calcium fly ash based geo- polymer concrete. The NaOH solution used in molarities of 10, 15 and 20. The ratio between NaOH to Na_2SiO_3 is considered as 1.0 and 2.0.The optimum molarities obtained for 16M gives good mechanical properties.

Pradip nath[8] et al, focused on the usage of GGBFS with local calcium fly ash geo polymer concrete. The GGBFS ratio adopted in the percentage of 10, 20 & 30 NaOH to Na_2SiO_3 ratio is 2.5. The experimental results show that the fresh properties of GPC is more stiffer than natural GPC with increase in fly ash, workability gets reduced in geo polymer mixture. Setting time is improved by adding 30% GGBFS which gives optimum compressive strength.

A marina Rajesh[9] at et al, experimentally investigated effect of geo polymer concrete by replacing cement. The GGBFS is added to improve the curing process. The 12M of NaOH solution used in GGBFS reduces risk of damage caused due to alkali silica reaction. The experimental results show that 40% replacement of GGBFS with fly ash is optimum.

U R kawade[10] et al, studied combination effect of sodium hydroxide and sodium silicate (Na_2SiO_3)with 2.5 ratio. M_{40} grade is chosen in investigation with increase in molarities from 12M to 14M to 16M., it revealed samples with higher molarities of NaOH increased compressive strength.

B. Vijay rangan[11] described results of tests conducted on large scale reinforced geo polymer concrete members & explained geo polymer applications. Class F fly ash is used. And results reveal that longer curing time, improved polymerization process resulted in higher compressive strength. It has excellent sulphate resistance and exhibit good long term properties.

K parthiaban[12] et al, observed increased compressive strength of GPC with increment in GGBFS percentage and also with increase in sodium silicate solution, in which concentration of sodium hydroxide in aqueous solution is fixed at constant achieved in just 7 days.

Madheswaram C.K[13] et al, presented the details of studies carried out on development of strength for various grades of geo polymer concrete with varied molarities 3M,5M,7M.NaOH & Na_2SiO_3 have been used alkaline solutions the results exhibits increase in compressive strength with increasing concentration in NaOH .

S. kumaravel[14] et al, focused on the performance of GPC in the sulphate curing by immersing them for 30 days .Different molarities have been used to cast the specimens compared with normal OPC the 12 Molarities NaOH specimen which shows excellent resistance to acids and salts.

Neetu singh[15] et al., studied the effect of immersion of geo polymer concrete specimens in sulphates such as Na_2SO_4 & $MgSO_4$. The influences of sulphuric acid and sulphates are different in both GPC & OPC. Compressive strength, structural and mineralogical changes are calculated and confirmed with XRD. GPC has excellent resistance against chloride attack and sulphuric acid.

Shankar H sami[16] et al investigated performance of geo polymer concrete under severe environmental conditions with NaOH to Na_2SiO_3 at a ratio of 2.5 to 3.50 the specimens are immersed in 10% solutions of Sulphuric acid and Magnesium sulphate separately. The results have been analyzed and composed with OPC which clearly exhibit more strength than GPC.

FINDINGS AND INFERENCES:

- Geo polymer concrete has unmarred design except a few strong recommendations in adopting NaOH to Na_2SiO_3, and aggregate ratio.
- In the entire world huge volume of fly ash is of low calcium and hence it is required to develop a good geo polymer concrete with locally available fly ash.

- With increase in sodium hydroxide concentration, compressive strength increases. The 10M NaOH will be economical to produce good workable GPC.
- The compressive strength is a function of ratio of NaOH to Na_2SiO_3, curing temperature, concentration of NaOH and solids to liquid ratio.
- The mechanical properties of GPC are found to be very good in the short term curing but for the long term curing the behavior of geo polymer concrete is still unknown.
- GPC has good sulphate resistance than the OPC.
- The downfall of stress-strain curve is not gentle, and it is more fluctuating and hence detail study is needed to understand the behavior of GPC.
- Durability properties of GPC are yet unpredictable except the sulphate resistance; hence there would be a huge scope to determine the chloride resistance freezing and thawing effect and impact strength of GPC.
- The application of GP material now a day is also used for precast members.
- Extension of GPC at in-situ works is not recommended, perhaps because of its setting time.
- Advantages of GPC will reach the common users only when the same is economical and also used at in-situ.

Present work on geo polymer concrete is research subject. By and large the geopolymer concrete is made with flyash. Now it is aimed to either reduced or totally replaced the flyash with polished stone dust, and all the physical properties are tested. So far much has been done on fly ash and it would be better to replace the same with the dust that is generated in the cutting of polished slabs at Bethamcherla in Kurnool district. This dust is simply used for land filling or else dumped, which causes higher environmental and land pollution. This particular dust also will be as good as fly ash since this dust is from lime stone and the likes. Previous studies and experts suggest that increase in molarities of sodium hydroxide, will increase concrete strength.

The objective of project is to replace the cement to the maximum possible extent since the manufacturing of the same is associated with heavy pollution. Moreover the dust that is

preferred is a byproduct and it also causes pollution when dumped. So the work will be a double edged one.

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