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Experimental Investigations on Thermally Treated Alumino Silicates In Concrete

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ABSTRACT

It is a well-known fact that cement production depletes significant amount of natural resources and releases large volume of CO_2.Cement production is also highly energy intensive after steel and aluminium.On the other hand coal burning power generation plants produce huge quantities of fly ash. Most of the fly ash is considered as waste and dumped in landfills.In order to address the issues mentioned above it essential that order forms binders must be developed to make concrete. The Geopolymer technology offers an attractive solution to address the problem. The present work embraces the concept of geopolymers to make thermally treated alumino silicates-fly ash in concrete

INTRODUCTION:

An important ingredient in the conventional concrete is the Portland cement. Actual production of Portland cement contributes 13.5 billion tons of carbon dioxide per year (1 ton of carbon dioxide for each ton of produced cement) which is equivalent to 7% of the total global emission of carbon dioxide to the atmosphere. Geo polymer is made out of waste materials like fly ash, therefore does not have an industry of it and does not contribute to carbon dioxide emissions. The Portland cement production process is one of the most energy consuming mass production processes. A mixture of powdered raw materials requires heating to over 1400^0 C to obtain cement powder, with its corresponding high use of fuels. Geo polymer, on the other hand, can be produced out of waste products like fly ash, or out of claimed kaolin (meta-kaolin) which consumes significantly less energy.

In Geopolymers the polymerization process involves a chemical reaction under highly alkaline conditions on Al-Si minerals yielding Si-O-Al-O bonds. The chemical composition of geopolymers similar to Zeolite, but shows an amorphous Micro-Structure. The Structural model of geopolymer material is still under investigation; hence the exact mechanism by whichgeopolymer setting and gardening occur may consists of dissolution, transportation or orientation and poly condensation and takes place through and exothermic process. The strength of geopolymer depends on the nature of source materials. Geopolymers made from calcinated sour materials, such as metakaoline (calcinatedkaoline, Fly ash, slag etc, yield higher from non-calcinated materials, such as Kaoline clay. The source is combination of sodium ore, potassium silicate and sodium ore, Potassium Hydroxide has been widely used as alkaline activator.As in the case of OPC concrete, the aggregates occupy about 75-80 % by mass, in geo polymer concrete. The silicon and the aluminium in the fly ash react with an alkaline liquid that is a combination of Sodium Silicate and Sodium Hydroxide solutions to form the geo polymer paste that binds the aggregates and other un-reacted materials.

To improve the workability, they suggested the use of admixtures to reduce the viscosity and cohesion. Metakaolin and ground blast furnace slag, they measured the setting time of the geo polymer material both at room and elevated temperature. In the elevated temperature, the measurement was done in the oven. They found that the initial setting time was very short for geo polymers cured at 60^{o}C, in the range of 15 to 45 minutes.

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LITERATURE REVIEW:

Hardjito D [1]From Curtin University Australia in 2010.He studied the properties of fresh and hardened states of GPC concrete by keeping Alkaline liquid to fly ash ratio as 0.35The comprehensive summary of the extensive studies conducted on fly ash based geopolymer concrete is presented. Test data are used to identify the effects of salient factors that influence that influence the properties of geopolymer concrete in fresh and hardened states. These results are utilized to propose a simple method for design of geopolymer concrete mixture.Rangan BV[2]This paper presents the study of effect of duration and temperature curing on compressive strength of fly ash based geo polymer concrete. Geopolymer concrete is manufactured by replacing cement fully with processed low calcium fly ash which is chemically activated by alkaline solutions like sodium silicate and sodium hydroxide. Cubes of size 150mm ×150mm×150mm were made at solution to fly ash ratio of 0.35 with 16 mole concentrated sodium hydroxide solution. All the specimens were cured in oven at 60^0c, 90ºc and 120^0c for 6,12,16,20 and 24hrs duration. Test results show that compressive strength increases with increasing duration and temperature of oven curing.

Mehrali M[3]Uses the fly ash in 1930 as a workability-improving admixture. Later on its aplication increases as people were aware about pozzolanic reactivity of flyash. It is used in the manufacture of Portland pozzolana cement (ppc), partial replacement of cement and workability-improving admixture in concrete but its utilization is limited to 20% throughout the world. An important achievement in this regard is the development of high volume fly ash (HVFA) concrete that utilizes up to 60 percent of fly ash, and at possesses excellent mechanical properties with enhanced durability performance.Palomo A[4] studied the influence of curing temperature, curing time and alkaline solution-to-flash ratio on the compressive strength. The authors confirmed that the temperature and the curing time significantly improve the compressive strength for curing at more than 60^0c. In addition, the compressive strength decreases.When the water-to-geopolymer solids ratio by mass increased. The driving shrinkage strains of fly ash based geopolymer concrete were found to be significant.The chemical reaction of the geopolymer gel is due to substantial past polymerization process at certain elevated temperature (30^0c-90^0c).Kolli.Ramujee [5]Done research to develop mix design for Geopolymer concrete in ordinary (M_{20}), medium (M_{40}) and Higher (M_{60}) grades and relative comparison is made with equivalent mix proportions of grades of opc Concretes in both heat cured and ambient cured conditions.About 7 different mixes for each grade is casted, tested and optimized and the results are in agreement with mix design reported in past literature. The design parameters like alkaline liquids to fly ash ratio and water to geopolymer solids ratio were proposed to develop the geopolymer concrete in all the three grades.

Scope of work:

The scope of present work study the properties of geopolymer concrete Compressive Strength, Split Tensile Strength and Stress Strain Behavior of geopolymer concrete of fly ash based geopolymer at different curing regime.

Constituents of Geopolymer Concrete:

Fly ash:

In the present experimental work,Class F (Flyash) (American Society for Testing and Materials 2001) dry fly ash obtained from the silos of Ramagundam thermal power station, Telangana State, which was used as the base material.ASTM-Fly ash obtained from coal burning power station. Most of the fly ash available globally is formed as a byproduct of anthracite and bituminous coal. All the coal burning power plants considered to be environmentally unfriendly.

Fly ash can be used to manufacture Geopolymer concrete when the Silica (Si) and Aluminum oxides constituted about 80%(by mass) with the Si-Al ratio of about 2.The content of iron oxide usually ranged from 10-20%(by mass) where as the calcium oxide content was less than 5%(by mass).The carbon content of fly ash, as indicated by the loss on ignition by mass, was as low as less than 2%.The particle size distribution test revealed that 80% fly ash particles were smaller than 50µm. The chemical composition of flyash in shown in Table 1.

Alkaline liquids used:

Sodium silicate

A combination of sodium silicate solution(Na_2SiO_3) and sodium hydroxide solution (NaOH) as alkaline liquid. It is recommended that the Alkaline liquid is prepared by mixing both the solution together at least 24hours prior to use. The sodium silicate is commercially available in different grades. The sodium silicate solution with SiO_2-to-Na_2O ratio by mass of approximately 2, i.eSiO_2=30.62%,Na_2O=13.39%andwater=44.01% by mass generally used. The sodium hydroxide with 97-98% purity, in flake or pellet form, is commercially available .The solids must be dissolved in water to make a solution with the required concentration. The concentration of sodium hydroxide solution can vary in the range between 8 Molar to 16 Molar; however, 8 Molar solutions is adequate for most applications. The mass of NaOH solids in a solution varies depending on the concentration of the solution. For instance, NaOH solution with a concentration of 8 molar consists of $8 \times 40 = 320$ grams of NaOH solids per liter of the solution, where 40 is the molecular weight of NaOH. The mass of NaOH solids were measured as 262 grams per kg of NaOH solution with a concentration of 8

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Molar. Similarly, the mass of NaOH solids per kg of the solution for other concentrations was measured as, 12 Molar: 361 grams, 14 Molar: 404grams and 16 Molar: 444 grams.Note that the mass of water is the major component in both the alkaline solutions. In order to improve the workability, a high range water reducer super plasticizer and extra water may add to the mixture.Chemical Composition of Sodium Silicate is shown in Table 2.

Sodium Hydroxide

Sodium hydroxide, also known as caustic soda with the molecular formula NaOH isa caustic metallic base which is a white solid available in pellets, flakes, granules, and as a 50% saturated solution. Sodium hydroxide flakes were used in the experimental program. Sodium Hydroxide pillets are shown in Fig 1.

Fig. 1: showing sodium hydroxide pillets

In the present study we have used a combination of sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) solutions. The sodium hydroxide solids were either a technical grade in flakes form (3 mm), 98% purity, or a commercial grade in pellets form with 97% purity.The sodium hydroxide (NaOH) solution was prepared by dissolving either the flakes or the pellets in distil water. The mass of NaOH solids in a solution varied depending on the concentration of the solution expressed in terms of molar, M.

Super Plasticiser

To improve the workability of the fresh geo polymer concrete, a naphthalene Sulphonate super plasticizer, **Conplast SP430** was used in the Experimental study work. Another type of super plasticizer, a polycarboxylic ether hyper plasticiser, under the brand name of Glenium 27, this type of super plasticiser was not used due to the cost.Superplasticiser should be within the limit 1.5 to 2.5% of fly ash content. Exceeding this limit compressive strength of the geo polymer concrete will be decreased.

As can be seen from the above, the interaction of various parameters on the compressive strength and the workability of geopolymer concrete is complex. In order to assist the design of fly ash- based geopolymer concrete mixtures, a single parameter called **'Water-to-geopolymer solids ratio'** by mass was devised. In this parameter, the total mass of water is the sum of the mass of water contained in the sodium silicate solution, the mass of water used in the making of the sodium hydroxide solution, and the mass of extra water, ifany, present in the mixture. The mass of geopolymer solids is the sum of the mass of flyash, the mass of sodium hydroxide solids used to make the sodium hydroxide solution, and the mass of solids in the sodium silicate solution (i.e., the mass of Na_2O and SiO_2).Tests were performed to establish the effect of water-to-geopolymer solids ratio by mass on the compressive strength and the workability of geopolymer concrete. The test specimens were 150×150 mm cubes,heat cured in an oven at various temperatures for 24 hours. The compressive strength of geopolymer concrete decreases as the water-to-geopolymer solids ratio by mass increases. This test trend is analogous to the well-known effect of water-to-cement ratio on the compressive strength of Portland cement concrete. Obviously, as the water-to-geopolymer solids ratio increased, the workability increased as the mixtures contained more water.

Experimental program:

The work plan of the present investigation is shown in Table 3 and quantities of the mix proportion is shown in Table 4.

Compressive and Split Tensile Strength:

The compressive and tensile strength tests on hardened fly-ash based geo polymer concrete were performed on a 200Tonne capacity compressive testing machine in accordance to the relevant Indian Standards. Three 150x150x150 mm concrete cubes were tested for every compressive strength test. Three 100x200 mm concrete cylinders were tested for each tensile splitting strength test.

Stress Strain Behavior of Geopolymer Concrete:

Two 100x200 mm concrete cylinders were tested for each molar and binder ratio to evaluate the maximum stress and strain at maximum stress and maximum strain. The test will conduct on compression testing machine by fix up the deflectometer and note deflection at different stress level. For this equipment the least count of deflectometer is 0.002 mm.

Results and Discussion:

Compressive and split tensile strength:

Longer mixing time produced higher compressive strength. This suggests that the extended mixing time resulted in better polymerization process and enhanced the properties of hardened concrete. The results are shown in Table to 5 and 6.

Conclusions:

As Molarity increases Compressive strength of GPC increases. As Age of curing time increases compressive strength, split tensile strength increases up to 48hrs and then it decreases from 96hrs. It is observed that the grade of concrete for 28days obtained from the results is M30 which is a satisfactory target strength which comes under standard concrete. Geoploymer concrete Split tensile strength also increases with the increase with alkali solution. The maximum Compressive strength of Geopolymer concrete he maximum compressive strength of Geopolymer concrete is found to be 39.24 N/mm^2 at 8M of NaOH. The maximum split tensile strength of Geopolymer concrete is 6.38 N/mm^2 at 8M NaOH. The ultimate stress is stress is 28.86 N/mm^2 found at 16M NaOH. The maximum strain is 0.0034 found at 16M of NaOH. It is observed that the normal consistency does not depends upon the molarities of alkaline activator while the workability and final setting time decreases on the molarity of alkaline activator increases.

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