ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Studies on Resistance of GGBS Based Geopolymer Concrete to Sulfuric Acid Attack



S.Pradeep Kumar
Lecturer,
Department of Civil Engineering,
Sri Krishnadevaraya University.

V.G.Kiran Kumar
Lecturer,
Department of Civil Engineering,
Sri Krishnadevaraya University.

K.Yuva Pallavi
Lecturer,
Department of Civil Engineering,
Sri Krishnadevaraya University.

Abstract:
Concrete is the most commonly used construction material. its usage by the communities across the globe is second only to water. Customarily, concrete is produced by using the Ordinary Portland Cement (OPC) as the binder. The usage of OPC is on the increase to meet infrastructure developments. The world-wide demand for OPC would increase further in the future. It is well-known that cement production depletes significant amount of natural resources and releases large volumes of carbon-dioxide. In recent years, new alkali activated inorganic cementitious compositions were commercially introduced into the US market by the American cement manufacturer Lone Star Industries, Inc - under the brand name PYRAMENT® blended cements - which resulted from the development carried out on inorganic alumino-silicate polymers or geopolymers [Davidovits, 1985; Heitzmann, 1987; Blumenthal, 1988], resulting from the geopolymeric reaction.

These alumino-silicate binders are called inorganic geopolymeric compositions, since the geopolymeric cement obtained results from an inorganic polycondensation reaction, a so-called geopolymerisation yielding three dimensional zeolitic frameworks, unlike traditional hydraulic binders in which hardening is the result of the hydration of aluminates of calcium and silicates of calcium [Davidovits, 1990, 1991] The amorphous to semi-crystalline three dimensional geopolymeric silico-aluminate structures are of the types poly(sialate), poly(sialate-siloxo) and poly(sialate-disiloxo) . This research resulted in patent applications disclosing alkali-activation of coal fly-ashes and inducing some processes in order to manufacture low-CO2 cement. On the other hand, coal burning power generation plants produce huge quantities of fly ash. The volume of fly ash would increase as the demand for power increases.

Most of the fly ash is considered as waste and dumped in landfills. In order to address the issues mentioned above, it is essential that other forms of binders must be developed to make concrete. The geopolymer technology developed by Davidovits in the 1980s offers an attractive solutio . From 2001 onwards so many researches were continuing with embraced Davidovits original concept of geopolymers to make fly ash-based geopolymer concrete. The Present Experiment is to Ascertain the durability effect of GGBS on Low calcium Fly ash(ASTM Class-C) (Which is obtained from Rayalasema Thermal Power Plant Muddanur) based Geopolymer Concrete . The 24 hours of oven curing at 600 C,28 days of air drying and 30,60,90 days of sulfuric acid and water curing. To find Compressive strength and Water Absorption are found by Replacing the Fly ash with GGBS by 0%, 2.5%, 5%, 7.5% & 10% by mass of Fly ash.

Keywords:
GGBS, SULFURIC ACID, GEOPOLYMER CONCRETE.

Introduction:
In today's architecturally complex world, the "regular shape" requirement of precast pretensioned concrete is often times not possible. In order to meet these architecturally challenging applications while still providing a durable concrete structure, designers specify cast-in-place construction. Cast-in-place construction allows the engineer the flexibility to meet any geometric floor plan and to use varying section dimensions resulting in the most economical solution for the concrete application. Using post-tensioned reinforcement in cast-in-place construction affords the engineer an even more improved economical solution by reducing the depth of the structural elements.

This reduction in depth optimizes the quantity of concrete required and also can reduce the overall weight of a structure which saves foundation costs and can reduce the overall height of a building saving in exterior cladding costs .Overall, a post-tensioned cast-in-place concrete solution for either a slab-on-ground application or a high-rise building floor system affords the owner, architect, and engineer the most cost-effective solution to meet today's challenging construction environment.

General over view on admixture:

According to Richard G.Mielang, admixture is defined as a material other than water, aggregate and cement that is added as an ingredient of concrete or mortar either immediately before or during the process of mixing to modify certain desired properties of the normal fresh or hardened concrete or mortar for the grout. The most common reason for adding admixtures are to alter the workability, improve the rate of gain of strength, increase the strength itself, improve the impermeability and durability and also to improve the appearance. Sometimes many admixtures affect more than one property of concrete. There are wide variety and very large number of admixtures available in the construction market. The admixtures are classified mainly into following groups as according to the type of materials constituting the admixture or characteristic effect of the use.some admixtures are listed below:Air entraining agents,Accelerators,Retarders Pozzolanas,Gas forming agents, Air-detraining agents Alkali aggregate expansion inhibitors, Damp proofing and permeability reducing agents, Workability agents Grouting agents, Corrosion inhibiting agents Bondingagents,Coloringagents,Fungicidal, germicidal and insect Cal agents Miscellaneous agents.

NEED OF THE PRESENT INVESTIGATION:

Concrete is the most commonly used construction material; its usage by the communities across the globe is second only to water. Customarily, concrete is produced by using the Ordinary Portland Cement (OPC) as the binder. The usage of OPC is on the increase to meet infrastructure developments. The world-wide demand for OPC would increase further in the future. It is well-known that cement production depletes significant amount of natural resources and releases large volumes of carbon-dioxide.Cement production is also highly energy-intensive, after steel and aluminium. On the other hand, coal burning power generation plants produce huge quantitiesof fly ash. The volume of fly ash would increase as the demand for power increases. Most of the fly ash is considered as waste and dumped in landfills. In order to address the issues mentioned above, it is essential that other forms of binders must be developed to make concrete. The geopolymer technology developed by Davidovits in the 1980s offers an attractive solution (1, 2). In 2001, the authors embraced Davidovits original concept of geopolymers to make fly ash-based geopolymer concrete.

Concrete as a sink for CO2? During hardening, the Portland cement paste reacts with atmospheric CO2. Theoretically, it could be possible to keep a certain amount of concrete to re carbonate itself. This chemical re absorption of CO2 which is actually very slow, taking decades to fulfill, has been accelerated in CO2 enriched precast concrete products. However, this concept is not always desirable, for any re carbonation in calcium carbonate will reduce the pH level of the cement and prevent the beneficial passivation of the iron reinforcement bars taking place and protect them against corrosion. Yet, intensive CO2-precast manufacture could be a partial solution to some Portland cement plants.

Natural pozzolans:

True pozzolans are vitreous pyroclastic materials produced by violent eruptive volcanic action. The Ancient Romans used natural pozzolans for producing their famous Roman Cement, obtained by blending lime and pozzolan. Properties of blended cements obtained by replacing a certain amount of Portland cement with natural zeolitictuffs, have been studied for over thirty years in several laboratories and in use in some countries. China, for example, is presently producing 70 million tonnes of cement containing 10% to 30% of zeolitic material, mostly clinoptilolite. The extraction of 15-20 million tonnes of zeolites in China equals the Portland cement production of the United Kingdom. In terms of mechanical strength the highest replacement is in the 30% range. Coal Fly Ash:from a technological point of view, and in terms of strength properties, a certain amount of power plants coal fly ash, up to 25% by weight, may be blended with Portland cement. In the year 1988world production of electricity generated 290 million tonnes of coal fly ash, from which only 10% to 15% have been used in blended cements. There are several reasons for the relatively low percentage of fly ash used in cements. The most relevant is the failure to provide a uniform quality product.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

The tendency in world electricity production is not directed towards implementing more and more coal-fuelled power plants. It is exactly the opposite which is happening. The carbon- dioxide emissions are strongly associated with the production of electricity in coal-fuelled plants. In certain countries, for instance Poland, coal-fuelled power plants were emitting 54% of the national carbon-dioxide emission. The freezing of carbon-dioxide emission at 1990 level definitively means the freeze of electricity production based on this technology and the stagnation at present level of fly ash quantities suitable for Portland cement replacement. Even, if power plants are successfully tackling the quality issue, in the scenario discussed above until year 2015 a maximum amount of 290 million tonnes of fly ash would be available for cement applications. This represents, at most, 8% of the cement world market.

GEO POLYMERS:

The term 'Geo polymer' was first introduced by Davidovits in 1978 to describe a family of mineral binders with chemical composition similar to Zeolites but with an amorphous microstructures

PROPERTIES OF GEO POLYMER:

Previous studies have reported that geopolymers possess high early strength, low shrinkage, freeze-thaw resistance, sulfate resistance, corrosion resistance, acid resistance, fire resistance, and no dangerous alkali-aggregate reaction. Based on laboratory tests, Davidovits (1988b) reported that geopolymer cement can harden rapidly at room temperature and gain the compressive strength in the range of 20 MPa after only 4 hours at 20oC and about 70-100 MPa after 28 days. Comrie et.al, (1988) conducted tests on geopolymer mortars and reported that most of the 28-day strength was gained during the first 2 days of curing. Geopolymeric cement was superior to Portland cement in terms of heat and fire resistance, as the Portland cement experienced a rapid deterioration in compressive strength at 300oC, whereas the geopolymeric cements were stable up to 6000C (Davidovits, 1988b; 1994b). It has also been shown that compared to Portland cement, geopolymeric cement has extremely low shrinkage. The presence of alkalis in the normal Portland cement or concrete could generate dangerous Alkali-Aggregate-Reaction. However the geopolymeric system is safe from that phenomenon even with higher alkali content. As demonstrated by Davidovits (1994a; 1994b), based on ASTM C227 bar expansion test, geopolymer cements with much higher alkali content compared to Portland cement did not generate any dangerous alkali-aggregate reaction where the Portland cement did. Geopolymer cement is also acid-resistant, because unlike the Portland cement, geopolymer cements do not rely on lime and are not dissolved by acidic solutions. As shown by the tests of exposing the specimens in 5% of sulfuric acid and chloric acid, geopolymer cements were relatively stable with the weight lose in the range of 5-8% while the Portland based cements were destroyed and the calcium alumina cement lost weight about 30-60% (Davidovits, 1994b). Some recently published papers (Bakharev, 2005c; Gourley& Johnson, 2005; Song et. al., 2005a) also reported the results of the tests on acid resistance of geopolymers and geopolymer concrete. By observing the weight loss after acid exposure, these researchers concluded that geopolymers or geopolymer concrete is superior to Portland cement concrete in terms of acid resistance as the weight loss is much lower. However, Bakharev and Song et. al has also observed that there is degradation in the compressive strength of test specimens after acid exposure and the rate of degradation depended on the period of exposure. Tests conducted by U.S. Army Corps of Engineers also revealed that geopolymers have superior resistance to chemical attack and freeze/thaw, and very low shrinkage coefficients.

FLY ASH BASED GEOPOLYMER CONCRETE:

Past studies on reinforced fly ash-based geopolymer concrete members are extremely limited. Palomo et.al (2004) investigated the mechanical characteristics of fly ash based geopolymer concrete. It was found that the characteristics of the material were mostly determined by curing methods especially the curing time and curing temperature. Their study also reported some limited number of tests carried out on reinforced geopolymer concrete sleeper specimens. Another study related to the application of geopolymer concrete to structural members was conducted by Brookeet al. al (2005). It was reported that the behavior of geopolymer concrete beam column joints was similar to that of members made of Portland cement concrete.

2.7 USE OF FLY ASH IN CONCRETE:

Fly ash has been used in the past to partially replace Portland cement to produce concretes. 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 yet possesses excellent mechanical properties with enhanced durability performance.

The test results show that HVFA concrete is more durable than Portland cement concrete (Malhotra 2002).Recently, a research group at Montana State University in the USA has demonstrated through field trials of using 100% high-calcium (ASTM Class C) fly ash to replace Portland cement to make concrete. Ready mix concrete equipment was used to produce the fly ash concrete on a large scale. The field trials showed that the fresh concrete can be easily mixed, transported, discharge, placed, and finished (Cross et al 2005).

Properties of Low calcium Fly ash Based Geo polymer concrete

The Report presented information on heat-cured fly ash-based geopolymer concrete. When Low-calcium fly ash (ASTM Class F) is used as the source material, instead of the Portland cement, to make concrete. Low-calcium fly ash-based geopolymer concrete has excellent compressive strength and is suitable for structural applications. The salient factors that influence the properties of the fresh concrete and the hardened concrete have been identified. Data for the design of mixture proportions are included and illustrated by an example. The elastic properties of hardened geopolymer concrete and the behavior and strength of reinforced geopolymer concrete structural members are similar to those observed in the case of Portland cement concrete. Therefore, the design provisions contained in the current standards and codes can be used to design reinforced low-calcium fly ash-based geopolymer concrete structural members. Heat-cured low-calcium fly ash-based geopolymer concrete also shows excellent resistance to sulfate attack, good acid resistance, undergoes low creep, and suffers very little drying shrinkage. The Report has identified several economic benefits of using geopolymer concrete

General Mixture Proportions of Geopolymer Concrete

The primary difference between geopolymer concrete and Portland cement concrete is the binder. The silicon and aluminum oxides in the low-calcium fly ash reacts with the alkaline liquid to form the geopolymer paste that binds the loose coarse aggregates, fine aggregates, and other un-reacted materials together to form the geopolymerconcrete. As in the case of Portland cement concrete, the coarse and fine aggregates occupy about 75 to 80% of the mass of geopolymer concrete.

This component of geopolymer concrete mixtures can be designed using the tools currently available for Portland cement concrete. The compressive strength and the workability of geopolymer concrete are influenced by the proportions and properties of the constituent materials that make the geopolymer paste. Experimentalresults (Hardjito and Rangan, 2005) have shown the following:• 1 Higher concentration (in terms of molar) of sodium hydroxide solution results in higher compressive strength of geopolymer concrete. Higher the ratio of sodium silicate solution-to-sodium hydroxide solution ratio by mass, higher is the compressive strength geopolymer concrete.•The addition of naphthalene sulphonate-based super plasticizer, up to approximately 4% of fly ash by mass, improves the workability of the fresh geopolymer concrete; however, there is a slight degradation in the compressive strength of hardened concrete when the super plasticizer dosage is greater than 2%.• The slump value of the fresh geopolymer concrete increases when the water content of the mixture increases.• As the H2O-to-Na2O molar ratio increases, the compressive strength of geopolymer concrete also increases 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 low-calcium fly ash-based geopolymer concrete mixtures, a single parameter called 'water-to-geopolymersolidsratio' 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 in the sodium hydroxide solution, and the mass of extra water, if any, added to the mixture. The mass of geopolymer solids is the sum of the mass of fly ash, the mass of sodium hydroxide solids, and the mass of solids in the sodium silicate solution(i.e. the mass of Na2 O and SiO2). 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 100x200mm cylinders, heat-cured in an oven at various temperatures for 24 hours. The results of these tests show that the compressive strength of geopolymer concrete decreases as the water to-geopolymer solids ratio by mass increases (Hardjito and Rangan, 2005). 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.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Mixing, Casting, and Compaction of Geopolymer Concrete

Geopolymer concrete can be manufactured by adopting the conventional techniques used in the manufacture of Portland cement concrete. In the laboratory, the fly ash and the aggregates were first mixed together dry in 80-litre capacity pan mixer (Figure 2.1) for about three minutes. The aggregates were prepared in saturated-surface-dry (SSD) condition, and were kept in plastic buckets with lid (Figure 2.2).The alkaline liquid was mixed with the super plasticiser and the extra water, if any. The liquid component of the mixture was then added to the dry materials and the mixing continued usually for another four minutes (Figure2.3). The fresh concrete could be handled up to 120 minutes without any sign of setting and without any degradation in the compressive strength. The fresh concrete was cast and compacted by the usual methods used in the case of Portland cement concrete (Hardjitoand Rangan, 2005; Wallah and Rangan, 2006; Sumajouw and Rangan, 2006). Fresh fly ash-based geopolymer concrete was usually cohesive. The workability of the fresh concrete was measured by means of the conventional slump test (Figure2.5).

Slump Measurement of Fresh Geopolymer Concrete (Hardjito and Rangan, 2005)

The compressive strength of geopolymer concrete is influenced by the wet-mixing time, as illustrated by the test data. The test specimens were 100x200 mm cylinders, steam-cured at60oC for 24 hours and tested in compression at an age of 21 days. Figure 8 shows that the compressive strength significantly increased as the wet-mixing time increased. The slump values of fresh concrete were also measured. These results showed that the slump values decreased from 240 mm for two minutes of wet-mixing time to 210 mm when the wet-mixing time increased to sixteen minutes.

Curing of Geopolymer Concrete

Heat-curing of low-calcium fly ash-based geopolymer concrete is generally recommended. Heat-curing substantially assists the chemical reaction that occurs in the geopolymer paste. Both curing time and curing temperature influence the compressive strength of geopolymer concrete.. The test specimens were 100x200 mm cylinders heat-cured at 60oC in an oven. The curing time varied from 4 hours to 96hours (4 days).

Longer curing time improved the polymerization process resulting in higher compressive strength. The rate of increase in strength was rapid up to 24 hours of curing time; beyond24 hours, the gain in strength is only moderate. Therefore, heat-curing time need not be more than 24hours in practical applications.Higher curing temperature resulted in larger compressive strength. Heat-curing can be achieved by either steam-curing or dry-curing. Test data show that the compressive strength of dry-cured geopolymer concrete is approximately 15% larger than that of steam-cured geopolymer concrete (Hardjito and Rangan, 2005). The temperature required for heat-curing can be as low as 30oC.

In tropical climates, this range of temperature can be provided by the ambient conditions. The required heat-curing regime can be manipulated to fit the needs of practical applications. In laboratory trials (Hardjito and Rangan , 2005), precast products were manufactured using geopolymer concrete; the design specifications required steam-curing at 60oC for 24 hours. In order to optimize the usage of formwork, the products were cast and steam-cured initially for about 4 hours. The steam- curing was then stopped for some time to allow the release of the products from the formwork.

The steam-curing of the products then continued for another 21 hours. This two-stage steam-curing regime did not produce any degradation in the strength of the products. A two-stage steam-curing regime was also used by Siddiqui (2007) in the manufacture of prototype reinforced geopolymer concrete box culverts. It was found that steam curing at 80 °C for a period of 4hours provided enough strength for de-moulding of the culverts; this was then followed by steam curing further for another 20 hours at 80°C to attain the required design compressive strength. Also, the start of heat-curing of geopolymer concrete can be delayed for several days.

Tests have shown that a delay in the start of heat-curing up to five days did not produce any degradation in the compressive strength. In fact, such a delay in the start of heat-curing substantially increased the compressive strength of geopolymer concrete (Hardjito and Rangan, 2005). This may be due to the geopolymerisation that occurs prior to the start of heat-curing. The above flexibilities in the heat-curing regime of geopolymer concrete can be exploited in practical applications and prototype products can be manufactured ready for use within 24 hours after casting.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

General Design of Geopolymer Concrete Mixtures

Concrete mixture design process is vast and generally based on performance criteria. Based on the information given in above Sections, some simple guidelines for the design of heat-cured low calcium fly ash-based geopolymer concrete are proposed. The role and the influence of aggregates are considered to be the same as in the case of Portland cement concrete. The mass of combined aggregates may be taken to be between 75% and 80% of the mass of geopolymer concrete. The performance criteria of a geopolymer concrete mixture depend on the application. For simplicity, the compressive strength of hardened concrete and the workability of fresh concrete are selected as the performance criteria. In order to meet these performance criteria, the alkaline liquid-to-fly ash ratio by mass, water-to-geopolymer solids ratioby mass, the wet-mixing time, the heat-curing temperature, and the heat-curing time are selected as parameters. With regard to alkaline liquid-to-fly ash ratio by mass, values in the range of 0.30 and 0.45 are recommended. Based on the results obtained from numerous mixtures made in the laboratory over a period of four years, the data given in Table 3 are proposed for the design of low-calcium fly ash-based geopolymer concrete. Note that wet-mixing time of 4 minutes, and steam-curing at 60oC for 24 hours after casting are proposed.

The data given in the reference 2 may be used as guides to choose other curing temperatures, wet-mixing times, and curing times. Sodium silicate solution is cheaper than sodium hydroxide solids. Commercially available sodium silicate solution A53 with SiO2-to-Na2O ratio by mass of approximately 2, i.e., Na2O = 14.7%, SiO2 =29.4%, and water = 55.9% by mass, and sodium hydroxide solids (NaOH) with 97-98% purity are recommended. Laboratory experience suggests that the ratio of sodium silicate solution-to-sodiumhydroxide solution by mass may be taken approximately as 2.5 (Hardjito and Rangan, 2005). The design data given in Table 3 assumes that the aggregates are in saturated-surface-dry (SSD) condition. In other words, the coarse and fine aggregates in a geopolymer concrete mixture must neither be too dry to absorb water from the mixture nor too wet to add water to the mixture. In practical applications, aggregates may contain water over and above the SSD condition. Therefore, the extra water in the aggregates above the SSD condition must be included in the calculation of water-to geopolymer solids ratio given in Table.

Water-to-geopolymer solids ratio, by mass	Workability	Design compressive strength (wet-mixing time of 4 minutes, steam curing at 60oC for 24 hours after casting), MPa
0.16	Very Stiff	60
0.18	Stiff	50
0.20	Moderate	40
0.22	High	35
0.24	High	30

The fineness modulus of combined aggregates is taken to be in the range of 4.5 and 5.0. When cured in dry-heat, the compressive strength may be about 15% larger than the above given values.When the wet-mixing time is increased from 4 minutes to 16 minutes, the above compressive strength values may increase by about 30%.Standard deviation of compressive strength is about 10% of the above given values.

Illustrated Example of Geopolymer concrete:

Mixture proportion of heat-cured low-calcium fly ash-based geopolymer concrete with design compressive strength of 45 MPais needed for precast concrete products.Assume that normal-density aggregates in SSD condition are to be used and the unit-weight of concrete is 2400 kg/m3. Take the mass of combined aggregates as 77% of the mass of concrete, i.e. 0.77x2400=1848 kg/m3. The combined aggregates may be selected to match the standard grading curves used in the design of Portland cement concrete mixtures. For instance, the aggregates may comprise 277 kg/m3(15%) of 20mm aggregates, 370 kg/m3 (20%) of 14 mm aggregates, 647 kg/m3 (35%) of 7 mm aggregates, and 554 kg/m3 (30%) of fine sand to meet the requirements of standard grading curves. The fineness modulus of the combined aggregates is approximately 5.0 The mass of low-calcium fly ash and the alkaline liquid = 2400 – 1848 = 552 kg/m3. Take the alkaline liquid-to-fly ash ratio by mass as 0.35; the mass of fly ash = 552/(1+0.35) = 408 kg/m3 and the mass of alkaline liquid = 552 – 408 = 144 kg/m3. Take the ratio of sodium silicate solution-to-sodium hydroxide solution by mass as 2.5; the mass of sodium hydroxide solution = 144/ (1+2.5) = 41 kg/m3, the mass of sodium silicate solution = 144 – 41 =103 kg/m3.Therefore, the trial mixture proportion is as follow:

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

combined aggregates = 1848 kg/m3, low calcium fly ash = 408 kg/m3, sodium silicate solution = 103 kg/m3, and sodium hydroxide solution = 41 kg/m3.To manufacture the geopolymer concrete mixture, commercially available sodium silicate solution A53with SiO2-to-Na2O ratio by mass of approximately 2, i.e., Na2O = 14.7%, SiO2 = 29.4%, and water =55.9% by mass, is selected. The sodium hydroxide solids (NaOH) with 97-98% purity is purchased from commercial sources, and mixed with water to make a solution with a concentration of 8 Molar. This solution comprises 26.2% of NaOH solids and 73.8% water, by mass .For the trial mixture,

water-to-geopolymer solids ratio by mass is calculated as follows: In sodiumsilicatesolution,water = 0.559x103 = 58 kg, and solids = 103 – 58 = 45 kg. In sodium hydroxidesolution, solids = 0.262x41 = 11 kg, and water = 41 – 11 = 30 kg. Therefore, total mass of water =58+30 = 88 kg, and the mass of geopolymer solids = 408 (i.e. mass of fly ash) +45+11 = 464 kg. Hencethe water-to-geopolymer solids ratio by mass = 88/464 = 0.19.Using the data given in Table 3, for water-to-geopolymer solids ratio by mass of 0.19, the designcompressive strength is approximately 45MPa, as needed. The geopolymer concrete mixtureproportion is therefore as follows:20 mm aggregates = 277 kg/m3, 14 mm aggregates = 370 kg/m3, 7 mm aggregates = 647 kg/m3, finesand = 554 kg/m3, low-calcium fly ash (ASTM Class F) = 408 kg/m3, sodium silicate solution (Na2O =14.7%, SiO2 = 29.4%, and water = 55.9% by mass) = 103 kg/m3, and sodium hydroxide solution (8Molar) = 41 kg/m3(Note that the 8 Molar sodium hydroxide solution is made by mixing 11 kg ofsodium hydroxide solids with 97-98% purity in 30 kg of water). The geopolymer concrete must be wet-mixed at least for four minutes and steam-cured at 60oC for 24hours after casting. The workability of fresh geopolymer concrete is expected to be moderate. If needed, commercially available super plasticizer of about 1.5% of mass of fly ash, i.e. 408x (1.5/100) = 6 kg/m3 may be added to the mixture to facilitate ease of placement of fresh concrete. Numerous batches of the Example geopolymer concrete mixture have been manufactured and tested in the laboratory over a period of four years. These test results have shown that the mean 7th day compressive strength was 56 MPa with a standard deviation of 3 MPa.The mean slump of the fresh geopolymer concrete was about100 mm. .The above Example is used to illustrate the effect of alkaline liquid-to-fly ash ratio by mass on the compressive strength and workability of geopolymer concrete.

When the Example is reworked with different values of alkaline liquid-to-fly ash ratio by mass, and using the data given in Table 2.2 the following results are obtained

Alkalin Liquid/Fly ash by mass	Water/geopolymer solids, by mass	Workability	Compressive strength MPa
0.30	0.165	Stiff	58
0.35	0.190	Moderate	45
0.40	0.210	Moderate	37
0.45	0.230	High	32

Curing of Geopolymer Concrete

Heat-curing of low-calcium fly ash-based geopolymer concrete is generally recommended. Heat-curing substantially assists the chemical reaction that occurs in the geopolymer paste. Both curing time and curing temperature influence the compressive strength of geopolymer concrete.. The test specimens were 100x200 mm cylinders heat-cured at 60oC in an oven. The curing time varied from 4 hours to 96hours (4 days). Longer curing time improved the polymerization process resulting in higher compressive strength. The rate of increase in strength was rapid up to 24 hours of curing time; beyond24 hours, the gain in strength is only moderate. Therefore, heat-curing time need not be more than 24hours in practical applications. Higher curing temperature resulted in larger compressive strength. Heat-curing can be achieved by either steam-curing or dry-curing. Test data show that the compressive strength of dry-cured geopolymer concrete is approximately 15% larger than that of steam-cured geopolymer concrete (Hardjito and Rangan, 2005). The temperature required for heat-curing can be as low as 30oC. In tropical climates, this range of temperature can be provided by the ambient conditions. The required heat-curing regime can be manipulated to fit the needs of practical applications. In laboratory trials (Hardjito and Rangan , 2005), precast products were manufactured using geopolymer concrete; the design specifications required steam-curing at 60oC for 24 hours. In order to optimize the usage of formwork, the products were cast and steam-cured initially for about 4 hours. The steam- curing was then stopped for some time to allow the release of the products from the formwork.The steam-curing of the products then continued for another 21 hours. This two-stage steam-curing regime did not produce any degradation in the strength of the products.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

A two-stage steam-curing regime was also used by Siddiqui (2007) in the manufacture of prototype reinforced geopolymer concrete box culverts. It was found that steam curing at 80 °C for a period of 4hours provided enough strength for de-moulding of the culverts; this was then followed by steam curing further for another 20 hours at 80°C to attain the required design compressive strength. Also, the start of heat-curing of geopolymer concrete can be delayed for several days. Tests have shown that a delay in the start of heat-curing up to five days did not produce any degradation in the compressive strength. In fact, such a delay in the start of heat-curing substantially increased the compressive strength of geopolymer concrete (Hardjito and Rangan, 2005). This may be due to the geopolymerisation that occurs prior to the start of heat-curing. The above flexibilities in the heat-curing regime of geopolymer concrete can be exploited in practical applications and prototype products can be manufactured ready for use within 24 hours after casting.

Materials used for Fly ash Based Geopolymer Concrete Low Calcium Class- F fly ash

The Low Calcium class –F Flt ash was procured from Rayalaseema Thermal Power Station –Muddanur, Kadapa (Dist), Andhra Pradesh as a source Material. The following are the Chemical composition of Fly Ash.

Oxides	% by Wt in the Fly ash of RTPP, Muddanur	Requirement as per IS 3812-2003
Sio_2	58.80 %	> 35 %
Al_2O_3	24.10 %	-
Fe_2O_3	5.18 %	-
Tio_2	1.64 %	-
CaO	1.0 %	
MgO	0.38 %	< 5.0%
Na_2O	0.66 %	< 1.50%
K_2O	0.62 %	< 1.50%
P_2O_5	0.60 %	-
SO_3	0.25 %	< 2.750%
Loss of Ignition (LOI)	6.25 %	< 12.00%
Total of SiO_2,Fe_2O_3,Al_2O_3, % by weight	> 70 %	88.08 %

Alkaline Solutions:

The alkaline liquid used was a combination of Sodium Silicate solution and sodium hydroxide solution. The sodium silicate solution (Na2O – 13.7%, SiO2 – 29.4%, and water – 55.9 % by mass) was purchased from a local supplier in bulk. The sodium hydroxide (NaOH) in flakes or pellets from with 97% - 98% purity was also purchased from a FUSION CHEMICALS, LIMITED & PRODUCTS, HYDERBAD in bulk. The NaOH solids were dissolved in water to make the solution.

Specific Gravity	1.49 to 1.51
Viscosity 30^0 C (by B4 Cup)	45 sec to 75 sec
Na_2O %	13.5 to 14.5
SiO_2 %	27 to 29
Weight Ratio	1:200 to 1:2.40
Mole Ratio	1:2.06 to 1:2.47

Mineral Admixtures

GGBS (Ground Granulated Blast Furnace Slag)

The GGBS (Ground Granulated Blast Furnace Slag) was procured from Sai Vishnu Saravan Enterprises, Vishakhapatnam in Andhra Pradesh and it is then grinded to get fine powder form of GGBS. The chemical Moduli for this material.

CaO+MgO+SiO2 - 78.26
(CaO+MgO)/SiO2 - 1.18
CaO/SiO2 - 1.02

Properties of GGBS:

Particulars	Test Results
Fineness (m2/kg)	387
Initial setting time (min)	170
Loss on ignition (% mass)	0.03
Magnesia content (% mass)	8.97
Sulphidesulphur (% mass)	0.42
Manganese content (% mass)	1.02
Chloride content (% mass)	0.018

Table Properties of GGBS

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Water :

Deionized water, which is free from concentration of acid and organic substances was used for mixing the concrete

Super Plasticizer:

In order to improve the workability of fresh concrete, high range water-reducing naphthalene based super plasticizer was added to the mixture.

Mix Proportions:

The manufacture of low-calcium fly ash based geo-polymer concrete. The mixture proportions per m3 for concrete are given below table. In mixture the concentration of the sodium hydroxide solution was 8 Molars (M), and extra added water. With this mix proportion Replacement of Fly ash by 0%, 2.5%, 5.0%, 7.5%and 10.00% of GGBS by mass, the Specimens are prepared for testing the compressive strength and water absorption (Change in weight) of dimensions 100mmX100mmX100mm are casted.

Material		Mass Kg/m^3
Coarse Aggregate	20 mm	841
	10 mm	360
Fine Sand		647
Fly ash (Low Calcium ASTM Class F)		408
Sodium silicate solution (SiO2/Na2O=2)		41
Sodium Hydroxide solution		102
Super Plastizer		6
Extra Water		45
GGBS (Ground Granulated Blast Furnace Slag		0

Concrete Mix Proportions per Kg/m3

Manufacture of Test Specimen:

Preparation of Liquids: The sodium hydroxide (NaOH) solids were dissolved in water to make the solution. The mass of NaOH solids in a solution varied depending on the concentration of the solution expressed in terms of Molar; M. for instance, NaOH solution with a concentration of 8M consisted of 8x40=320 gm of NaOH solids in flake or pellets form per liter of the solution, where 40 is the molecular weight of NaOH. The mass of NaOH solids was measured as 262 grams per kg of NaOH solution of 8M concentration.The sodium silicate solution and the sodium hydroxide solution were mixed together at least one prior to prepare the alkaline liquid.

On the day of casting of the specimens, the alkaline liquid was mixed together with the super plasticizer and the extra water to prepare the liquid component of the mixture.

Manufacture of Fresh Concrete and Casting:

The fly ash and the aggregate were first mixed together in pan mixer for about 3 minutes. The liquid component of the mixture was then added to the dry materials and the mixing continued for further about 4 minutes to manufacture the fresh concrete The fresh concrete was cast into the moulds immediately after mixing, three layers in specimens. For compaction of the specimen each layer and then vibrated for 15 seconds on a vibrating table.

Curing of Test Specimens:

After casting, the test specimens were kept in oven cured at 600C for 24 hours. After demoulding, the specimens were left to air-dry in the laboratory for 28 days.

Acid resistance test:

After completion of 28 days the acid resistance test was conducted on geo polymer concrete. Because no universal or widely accepted standard procedures for acid resistance test exist, the type and concentration of the acid solution to which the specimen were exposed varied.Sulfuric acid is one type of acid solution that is frequently used to simulate the acid attack in sewer pipe systems. In such systems, sulfuric acid attack is a particular problem as it is generated bacterially from hydrogen sulfide. To test the acid resistance of geopolymer concrete, Hime (2003) suggested that the specimen be exposed to sulfuric acid solution with a concentration of pH- 1. This value of pH was also used by Gourley& Johnson (2005) to simulate the acid attack on sewer pipes. Mehta (1985) and Li and Zhao 2003 used 1% and 2% sulfuric acid concentration to simulate the sulfuric acid attack on concrete. Based on those past studies, to evaluate the acid resistance of fly ash based geopolymer concrete, the specimen were soaked in sulfuric acid solution with selected concentrations ranging from 0.25 % to 2 % with the measured pH ranges from about 0.9-2.1 up to 90 days of exposure. The test specimen were immersed in sulfuric acid solution in a container, the ratio of the volume of the acid solution to the volume of the specimen was 4. The solution was stirred every week. And some specimens were immersed on water for up to 90 days. The acid resistance and water absorption of geopolymer concrete was then evaluated the compressive strength and the change in mass after acid and water exposure.

Test parameters:

The test specimens for acid resistance and water absorption test on fly ash based geopolymer concrete, replacement of fly ash with 0%, 2.5%, 5.0%, 7.5%, and 10.0% of GGBS were 100x100x100 mm cube size for compressive strength and change in mass. The test parameters are summarized in below table was used for all tests and the specimens were oven cured at 600 C for 24 hours, after demoulded the specimens left to 28 days in air drying and 30,60,and 90 days immersed on Sulfuric acid& water. The scope of present investigation is to study and determining the Acid Resistance effect of replacement of fly ash by various percentages of GGBS (2.5%, 5 %, 7.5%, and 10%) with Sodium Hydroxide Molarity as 8M for ascertaining the compressive strength for geo polymer concrete. The acid resistance of Geopolymer concrete with immersion of specimens for 30days, 60days and 90days and find the compressive strength.To find the water absorption effect of geo polymer concrete with the replacement of fly ash by various percentage of GGBS MATERIAL

OBJECTIVES OF THE PRESENT STUDY

The objective of the present study is to investigate the durability characteristics of fly ash based Geo polymer concrete replacement of (2.5%, 5 %, 7.5%, and 10%) percentage of GGBS To find out the compressive strength of fly ash based geo polymer concrete by replacing the fly ash by various percentages of GGBS (2.5%, 5%, 7.5% and 10%). Specimen were cured along with moulds in an oven for a period of 24 hours at 600C remolded and allowed it to 28 days air drying and after air drying cubes are immersion on sulfuric acid for 30,60,& 90 days To estimate the change in weight of fly ash based Geo polymer concrete by replacing the fly ash by various percentages of GGBS (2.5%, 5%, 7.5% and 10%). Specimen were cured along with moulds in an oven for a period of 24 hours at 600C remolded and allowed it to 28 days air curing and 30,60 & 90 days by curing on water .

SCOPE OF STUDY

The scope of present investigation is limited to find out the compressive strength of fly ash based Geo polymer concrete by replacing the fly ash by various percentages of GGBS (2.5%, 5%, 7.5% and 10%) specimens are oven cured at 600 C for 24 hours, 28 days of air dry curing and 30,60,& 90 days immersion on sulfuric acid by compressive strength testing machine. Further the scope of present investigation is limited to estimate the change in weight of fly ash based Geo polymer concrete by replacing the fly ash by various percentages of GGBS (2.5%, 5%, 7.5% and 10%). Specimen are Oven cured along with moulds at 600 C for 24 hours, remolded and allowed it to 28 days air curing and 30,60 & 90 days by curing on water.

TEST PROGRAMME

To evaluate the effect of replacement of fly ash by various percentages of GGBS (2.5%, 5%, 7.5% and 10%) fly ash basedconcrete with alkaline liquid is taken as follows ratio of activator solution to fly ash by mass in the range of 0.35 & 0.4. Ratio of sodium silicate solution to sodium hydroxide solution, by mass of 2.5. This ratio was fixed at 2.5 for mixtures. At 24 hours oven cured along with moulds at 600C, 28 days of air curing and The required specimens are immersion in solution of 5 % sulfuric acid and required specimens are in water up to period of 30, 60& 90 days compressive strength and water absorption (weight Loss) for fly ash based Geo polymer concrete, for all mixes same type of coarse aggregate i.e., machine crushed, river sand and the same proportions of fine and total aggregate is used, fly ash used also same for all mixes. GGBS is also collected from company is grinded and sieved through 90μ sieve.

The parameters planned to studies are:

Compressive strength – Replacement of Fly ash with various percentages of GGBS (2.5%, 5%, 7.5% and 10%). with water binder ratio of 0.5. Water Absorption – Replacement of Fly ash with various percentages of GGBS (2.5%, 5%, 7.5% and 10%).with water binder ratio of 0.5.

For each percentage of GGBS 18 cubes of size 100mmX100mmX100mm were casted for determining the water absorption (change in weight) and compressive strength. In that 3 cubes for 30 days, 3 cubes for 60 days and 3 cubes for 90 days.

WORKABILITY OF GEO POLYMER CONCRETEThe

workability tests such as Slump tests were conducted on fresh concrete mixes with different percentages of GGBS and tabulated as follows

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

S. No	% of GGBS (by Mass of Fly Ash) in Geo polymer Concrete	Slump value
1	0%	40
2	2.5%	40
3	5.00%	42
4	7.5%	45
4	10.00%	45

Variation of workability with Replacement of Fly Ash with GGBS

Cubes are immersed on Sulfuric acid (5 % of H2SO4) Change in Compressive Strength

The sulfate resistance was evaluated based on the change in compressive strength of the specimens after various periods of sulfate exposure. Tests were conducted on 100mmX100mmX100mm cubes of different Percentages of GGBS in Geo Polymer Concrete, curing at 24 hours oven curing, 28 days of air drying, and 30, 60, 90 days immersion on Sulfuric acid test results are tabulated as follows.

% GGBS	Sample No	30 Days Average Strength N/mm²	60 Days Average Strength N/mm²	90 Days Average Strength N/mm²
0%	Sample 1	23.2	19.2	19.8
2.50%	Sample 2	24.2	22.6	20.4
5%	Sample 3	27.3	24.8	21.5
7.50%	Sample 4	28.6	26.1	25.4
10%	Sample 5	29.8	28.4	27.4

Water Absorption:

This test was conducted on the change in mass of specimens (100mmX100mmX100mm) soaked in Sodium sulfate solution up to 30, 60, 90 days period of different percentages of GGBS in Geopolymer Concrete. Test results are tabulated below.

Absorption (%) = (w2 – w1)/ w1 x100

Where W1 = weight of specimen after complete drying at 105°C

W2 = final weight of surface dry sample after immersion in water at 30 days , 60 days and 90 days.

The results of this study for all the concretes are presented in table presents a typical variation of absorption with time for the Geopolymer Flyash based concrete with GGGBS as admixture in 0%,2.5%,5.0%,7.5% and 10%, The final absorption results of these mixes shows that the geopolymer concretes were having lower absorption rate compared to normal concretes, and also decreasing with increasing percentage of GGB.

	Sample No	30 Days Average Weight Loss in %	60 Days Average Weight Loss in %	90 Days Average Weight Loss in %
0 %	Sample 1	1.45	1.70	1.95
2.50%	Sample 2	1.55	1.75	1.99
5.0%	Sample 3	1.59	1.81	2.16
7.50%	Sample 4	1.61	1.89	2.36
10.0%	Sample 5	1.65	1.92	2.44

CONCLUSIONS:

Based on the results obtained from this study, the following Conclusions seems to be valid. The increase in percentage replacement of Fly Ash with GGBS from 0% to 10.00% causes increase in Slump value up to 5% and beyond that slump is decreased. This shows workability is reducing as percentage of GGBS increased beyond 5%. Hence, 5% replacement of Fly ash with GGBS is suitable from workability point of view.

The increase in percentage replacement of Fly ash with GGBS from 0% to 10% causes increase in compressive strength of concrete from 23.2MPa to 27.4MPa, when specimens are soaked in sulfuric acid up to 90 days of exposure. In case of specimens soaked in water increase in percentage replacement of Fly ash with GGBS from 0% to 10% causes increase in compressive strength from 28.3MPa to 35.6MPa. Hence replacement of Fly Ash with 0 to 10 % of GGBSis advisable increase the compressive strength beyond the 10%. The increase in percentage replacement of Fly ash with GGBS from 0% to 10% causes decrease in mass of specimens, soaked in sulfuric acid up to 90 days of exposure. The decrease in mass is approximately 1.2 % The increase in percentage replacement of Fly ash with GGBS from 0% to 10% causes increase in water absorption of specimens, soaked in Water up to 90 days of exposure. The increase in Water absorption approximately 1.5 %. Finally, it can conclude Keeping in view of the workability, compressive strength and change in mass in mind, beyond the 10% replacement of Fly ash with GGBS is recommended for use in GEO POLYMER CONCRETE for ascertaining the further durability study.

SUGGESTIONS FOR FUTURE WORK

In spite of a long-term recognition of the problem of sulphuric acid corrosion in concrete sewer pipes this issue has not been satisfactorily resolved. Geopolymer binders have been reported as being acid resistant and thus are a promising and alternative binder for sewer pipe manufacture.Experiments can be conducted for estimating the Long Term properties of Plian Geopolymer concrete Experiments can be conducted for short Term /Long Term Properties of Reinforced Geo polymer concrete Experiments can be conducted on long term properties of columns Experiments can be conducted on for fibre reinforced Geo polymer concrete

Experiments can be conducted for sulphuric acid resistence of Geo polymer concrete Experiments can be conducted for other durability tests like Resistance to acid attack test, high temperature resistance test on both plain Geo Polymer Concrete concrete as well as Fibre and Glassfibre reinforced concrete with Geo Polymer Concrete as admixture. Experiments can be conducted for producing plain Geo Polymer Concrete self compacting concrete as well as Fibre reinforced and Glass fibre reinforced self compacting Geo polymer concrete

BIBLIOGRAPHY:

Davidovits J. "Chemistry of Geopolymeric Systems, Terminology.": Joseph Davidovits R. James C, editors. Geopolymer '99 International Conference; 1999 June 30 to July 2, 1999; France; 1999. p. 9-40.

Davidovits J. "Properties of Geopolymer Cements. " In First International Conference on Alkaline Cements and Concretes; 1994; Kiev, Ukraine, 1994: SRIBM, Kiev State Technical University; 1994. p. 131-149.

Xu H, van Deventer JSJ. "The Geopolymerisation of Alumino-Silicate Minerals" international Journal of Mineral Processing " 2000;59(3):247-266.

Xu H, van Deventer JSJ. "Geopolymerisation of Multiple Minerals". Minerals Engineering 2002; 15(12):1131-1139.

Swanepoel JC, Strydom CA. "Utilization of fly ash in a geopolymeric material". Applied Geochemistry 2002; 17(8):1143-1148.

Barbosa VFF, Mackenzie KJD, Thaumaturgo C. "Synthesis and Characterization of Materials Based on Inorganic Polymers of Alumina and Silica": Sodium Polysialate Polymers. International Journal of Inorganic Materials 2000;2(4):309-317.