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FOUNDRY SAND BASED GEOPOLYMER CONCRETE

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Abstract - ***Portland cement concrete is the key construction material of all the development or construction activities in the world. The construction industry is the largest consumer concrete i.e. natural resources i.e. rocks, sand, and water. Hence it is important to find any other alternative material to the cement. Fly ash is a byproduct of coal, which is obtained from thermal power plant and is being used to produce a Geopolymer concrete. Next waste material is Foundry sand, which is a byproduct of ferrous and nonferrous metal casting industries. Land filling of used foundry sand not only causes significant economic burden to the foundries but is also a loss of energy and natural resources. So we need to find out beneficial applications of foundry sand in Geopolymer concrete. It is also rich in silica and alumina so it is used as a partial replacement of fine aggregate in conventional concrete.***

The objective of present work is to study the effect of fly ash based Geopolymer concrete with replacement of foundry sand by different percentages. For a specific mix design more than 30 MPA, Different mix proportions shall be prepared by using different molarity of sodium hydroxide solution, and then replace with the foundry sand in the different proportion. Tests will be performed for the compressive strength of concrete, Compressive strength test will be performing for at 7 and 28 days. Of course, several further experimental works is necessary to study the system from environmental point of view.

Key Words: *Byproduct1, Fly ash2, Foundry sand3, Geopolymer concrete4*

1. INTRODUCTION

Usage of concrete around the world is second only to water. Ordinary Portland cement is normally used as the primary binder to produce concrete. There is serval environmental issues which are directly or indirectly related to the production of OPC are well known. The amount of the CO2 released during the manufacture of Ordinary Portland cement by the calcinations of limestone and burning of fossil fuel is in the order of one ton for every ton of Ordinary Portland cement produced.

On the other hand, the abundant availability of fly ash worldwide creates opportunity to utilize this by-product of burning coal, as a substitute for OPC to manufacture concrete, when used as a partial replacement of OPC, in the presence of water and in ambient temperature.

Ferrous and non ferrous metal casting industries produce several million tons of byproduct in the world. Waste foundry sand is major byproduct of metal casting industry and successfully used as a land filling material from many years. But waste foundry sand for land filling is becoming a problem due to high disposal cost. In an effort to use the waste foundry sand in large volume, research is being carried out for its possible large scale utilization in making concrete as partial replacement of fine aggregate in Geopolymer concrete.

1.1 Geopolymer concrete

Geopolymer is a material resulting from the reaction of a source material that is rich in silica and alumina with alkaline solution. Geopolymer concrete is totally cementing free concrete. In Geopolymer, fly ash act as binder and alkaline solution act as an activator. Fly ash and alkaline activator undergo geopolymerization process to produce alumino silicate gel. Alkaline solution used for present study is combination of sodium hydroxide (NaOH) and sodium silicate (Na2SiO3). For GPC, Portland cement is not used as a binding material. Therefore, the primary difference between GPC and conventional concrete is that of their binders. Instead of Portland cement, industrial by-product materials rich in Silicon (Si) and Aluminum (Al) such as fly ash, rice-husk ash, silica fume, slag and other similar materials are added to react with highly alkaline liquid (typically a combination of sodium silicate and sodium hydroxide solution) to produce binders.

Davidovits represent a broad range of materials characterized them by chains or networks of inorganic molecules. There are 9 different classes of Geopolymer, but these classes have a great potential application for transportation infrastructure are incorporation of aluminosilicate materials that may be used to completely replace Portland cement in concrete construction.

These Geopolymer depend on thermally activated natural materials (e.g., kaolinite clay) or industrial byproducts (e.g., fly ash ,foundry sand or slag) to provide a source of silicon (Si) and aluminum (Al), which is to be dissolved in an alkaline solution, which is a activator and afterwards polymerizes into molecular chains and networks, to create the hardened binder. Many times, such systems are referred to as alkali-activated cements or inorganic polymer cements. Water is not included in the chemical reaction and instead of expelled during heat curing and afterwards drying. This is in different to the hydration reactions that take place when Portland cement is to be mixed with water, which produces the primary hydration products calcium silicate hydrate and calcium hydroxide. This difference has a outstanding impact on the mechanical and chemical properties of the resulting Geopolymer concrete also contributes to more resistant to heat, water ingress, alkali–aggregate reactivity and other types of chemical attack.

1.2 Geopolymer Concrete Developments

Geopolymer concrete is a concrete which does not utilize any Portland cement in its production. Rather, the binder is produced by the reaction of an alkaline liquid with a source material that is rich in silica and alumina. Geopolymer were developed as a result of research into heat resistant materials after a series of catastrophic fires. The research yielded non-flammable and non-combustible Geopolymer resins and binders. Geopolymer is being studied extensively and shows promise as a greener alternative to Portland cement concrete. Research is shifting from the chemistry domain to engineering applications and commercial production of Geopolymer. It has been found that Geopolymer concrete has good engineering properties.

The use of fly ash has additional environment advantages. Presently the annual production of Fly Ash in India is about 170 million tonnes of which only 30 million tonnes are utilized in beneficial ways; principally for the partial replacement of Portland cement development of geopolymer technology and applications would see a further increase in the beneficial use of fly ash, with the use of fly ash in concrete and other building materials.

Possible Opportunities for Applications of Fly Ash based GPC

The following important opportunities are being claimed in literature for fly ash based GPC.

- High-volumes recycling of fly ash in cement-based construction industry wherever available in abundant for the replacement of portland cement binder.
- Geopolymer concrete gives a glossy appearance hence gives a beautiful appearance if used in constructing floors and walls.
- Manufacturing of more durable concrete as there is absence of transition zone in GPC
- Strength remains almost independent of the age.
- Manufacturing of precast segmental units with high compressive and flexural strength, lower drying shrinkage, increased resistance to sulphate and acid attack and high resistance to chloride ingress.
- The ratio of compressive to tensile strength of fly ash based geopolymer concrete is very high unlike portland cement concrete indicating significant reduction in brittleness of concrete. In other way, this concrete can withstand more tensile stress without requiring much reinforcing steel.
- Geopolymer concrete can be very suitable for the construction of underwater structures where early strength and rapid setting is required.
- For quick repair and rehabilitation of distressed civil infrastructures.
- Lesser construction period as curing period is substantially shorter than conventional concrete.

1.3 Environment impact of Geopolymer concrete

Use of fly ash in concrete imparts several environmental benefits and thus it is ecofriendly. It saves the cement requirement for the same strength thus saving of raw materials such as limestone, coal etc required for manufacture of cement. Manufacture of cement is an energy intensive industry. In the manufacturing of one tonne of cement, about 1 tonne of CO2 is emitted which goes to atmosphere. Less requirement of cement means less emission of CO2 resulting in reduction of greenhouse gases emission.

Significant increases in cement production have been observed and are anticipated to increase due to the massive increase in infrastructure and industrialization in India, China and South America. It has been used to produce precast railway sleepers and other pre-stressed concrete building components. The early-age strength gain is a characteristic that can best be exploited in the precast industry where steam curing or heated bed curing is common practice and is used to maximize the rate of production of elements. Recently Geopolymer concrete has been tried in the production of precast box culverts with successful production in a commercial precast yard with steam curing. Since, GPC does not require either Portland cement, or water for curing, hence, it is claimed to be more eco-friendly and sustainable than conventional concrete.

1.4 New Waste Material in Geopolymer Concrete

The development of sustainable construction and building materials with reduced environmental footprint in both manufacturing and operational phases of the material lifecycle is attracting increased interest in the construction industry worldwide. Recent innovations have led to the development of geopolymer concrete, which combines the performance benefits and operational energy savings, emissions reductions obtained through the use of waste materials like foundry sand. We will partially replace the sand with foundry sand.

Foundry sand is high quality silica sand with uniform physical characteristics. It is a byproduct of ferrous and nonferrous metal casting industries, where sand has been used for centuries as a molding material because of its thermal conductivity. Foundry sands consist of green sand and resin sand. Green sands typically comprise of high-quality silica sand, 5-10 percent bentonite clay, 2 to 5 percent water and less than 5 percent sea coal. The green sand process constitutes upwards of 90 percent of the molding materials used.

2. LITERATURE REVIEW

Paragraph Rafat Siddiquea et al. [1] reported that the results of an experimental investigation, which is to be carried out to evaluate the mechanical properties of concrete mixtures. In this study fine aggregate i.e. regular sand was partially replaced with used-foundry sand. Replacement of fine aggeregates was done by weight with three percentages (10%, 20%, and 30%) of used-foundry sand. Different tests were performed for the properties of fresh concrete. Different test on hard concrete, Compressive strength, splitting-tensile strength, flexural strength, and modulus of elasticity were performed for 28, 56, 91, and 365 days. These test results shows that a slight increase in the strength properties of plain concrete by including used-foundry sand as partial replacement of fine aggregate and it can be effectively used in making good quality concrete and construction materials.

Rakesh Kumar et al. [2] reported that recycling of industrial and post-consumer by-products combined with recent development in concrete technology for producing sustainable concrete. Geopolymer concrete reduces or eliminates the need for large amounts of raw materials for the manufacture of cement and provides great potential for recycling of Al- and Si-rich by-products materials. Low-calcium fly ash with Si and Al constituent of about 80% by mass and Si to Al ratio about two has been widely used for making Geopolymer concrete, As this concrete does not require cement, or water for curing, but utilizes by-product materials, it is more eco-friendly and sustainable. Used foundry sand can be used to replace 35% of regular concrete sand for structural concrete.

B. Vijaya Rangan et al. [3] presented sa comprehensive study conducted on fly ash-based Geopolymer concrete. Tests are conducted to find out the effects of salient factors that influence the properties of the Geopolymer concrete in the fresh and hardened states. These results are to be utilized to propose a simple method for the design of Geopolymer concrete mix. The economic merits of the Geopolymer concrete are also mentioned presented information on fly ash-based Geopolymer concrete. Low-calcium fly ash (ASTM Class F) is used as the source material, instead of the Portland cement to make concrete. It can be concluded that Low-calcium fly ash-based Geopolymer concrete has excellent compressive strength and is good for structural applications.

properties and behavior of hardened Geopolymer concrete and strength of reinforced Geopolymer concrete structural members are similar to Portland cement concrete. so that, the design standards in the current codes can be used to design reinforced low-calcium fly ash-based Geopolymer concrete. Heat-cured low-calcium fly ash-based Geopolymer concrete also shows very good resistance to sulfate attack, good acid resistance, undergoes low creep, and suffers very little drying shrinkage.

Mohd Mustafa Al Bakri et al. (2011) [4] summarizes the different properties of fly ash-based Geopolymer, which make it better when it compared to normal concrete. Fly ash reacts with alkaline solution, which is containing high amount of silica and alumina helps to produce aluminosilicate gel that binds the aggregate to make a good concrete. This reaction is depends on a few parameters such as shape and size of aggregates, chemical composition of fly ash, amount of vitreous phase in fly ash, nature, amount of activators and pH of activators. Usually sodium silicate was mixed with sodium hydroxide to produce the alkaline solution and the molarity (M) of alkaline solution is 7 to 10 M and the optimum sodium silicate to sodium hydroxide ratio was in range of 0.67 to 1.00. Meanwhile, the concentration of sodium hydroxide between 10 and 20 M give small effect on the strength. By increasing of temperature, polymerization become fast and the concrete can gain 70% of its strength within 3 to 4 h of curing. It was studied that an increase in sodium hydroxide and sodium silicate concentration will reduce the flow of mortar. For improving the workability of mortar, superplasticiser or extra water can be added. Compressive strength is an important property for concrete and it depends on curing time and curing temperature. When the curing time and temperature increase, the compressive strength will also increase. Curing temperature ranges from 60 to 90ºC and time 24 to 72 h, the compressive strength of concrete can gain about 400 - 500 kg/cm2. The compressive strength was increase when the fineness of fly ash increases. The highest compressive strength was obtained by using a of sodium silicate solution as an activator (n = 1.5; 10% Na_2O). Strength of Geopolymer concrete under high temperature curing may influenced by the sizes of aggregates. The aggregate with larger aggregate (>10 mm) are more stable and smaller sized (<10 mm) could lead to extensive spalling cracking.

M. I. Abdul Aleem et al. [5] reports that Geopolymer concrete is a new construction material; it is produced by the chemical action of inorganic molecules. Fly Ash, which is a waste product of coal obtained from the thermal power plant is available in large amount worldwide. Silica and alumina content are very high in Fly ash which reacts with alkali solution and produce aluminosilicate gel. It acts as the binding material for the concrete ingredients. It is a very innovative and good construction material to the existing cement concrete. Geopolymer concrete is to be prepared by without usage of ordinary Portland cement. Authors briefly review the constituents of Geopolymer concrete and its strength parameters.

As we have studied that high early strength of Geopolymer Concrete, it shall be very good in producing precast industries, so that huge production is possible in less time and less breaking during transportation shall also be reduced. The Geopolymer Concrete shall be successfully used for the junction of beam column in a reinforced concrete structure. Geopolymer Concrete can also be used in the Infrastructure works. In addition to that the Flyash shall be effectively used. We don't require landfills to dump the fly ash. The government can make necessary steps to take out sodium hydroxide and sodium silicate solution from the waste materials of chemical industries, so that the cost of alkaline solutions required for the geopolymer concrete shall be minimized.

Tarun R. Naik et al. [6] reported that this research was carried out to determine the effects on strength and durability of concrete by fly ash and used foundry sand. Two types of experiments (Series 1 and Series 2) were performed. All concrete mixes were produced in the manufacturing unit of a precast concrete products producer. Concrete mixes produced were used in produce the precast concrete panels. Tests were conducted on normal & air-entrained fly ash concrete. Concrete test specimens were assessed for different test like compressive strength test, abrasion resistance test, salt-scaling resistance test, freezing and thawing resistance test, and chloride-ion penetration resistance test. On the basis of durability and strength evaluations, it can concluded that both normal and air-entrained concrete mixes were developed in this study are appropriate for manufacturing of high-quality, high-durability precast concrete by using used foundry sand and fly ash.

Dushyant R. Bhimani et al. [7] Studies about the opportunities for sustainable and economical concrete. Foundry sand Used in various engineering applications that can solve the problem of dumping of foundry sand and other purposes. Used foundry-sand properties vary due to the type of equipment used for foundry processing, the types of additives, the number of times the sand is reused, and the type and amount of binder. Use of Foundry sand in concrete is to make better strength and other durability factors. Effect of foundry sand replacement as fine aggregate on the compressive strength M20 grade of concrete was studied. The percentages of fine aggregate replacements were 0%, 10 %, 20% and 30 % by weight. Tests were conducted for compressive strength for all replacement of foundry sand at different curing periods (28-days & 56-days). As per test conducted conclusion says in 1m3 of concrete M20 grade usage of fine aggregate is 538.45 kg they replace fine aggregate by 162 kg of foundry sand for 1m3 of concrete M20 grades. So, we can say that for sustainable and economic development, up to 30% foundry sand can be utilized.

P. Yellaiah et al. [8] studied the effect of basic parameters of Geopolymer technology such as activator to fly ash ratio and curing temperature on tensile strength development of geo-polymer mortar using low calcium fly ash is investigated. Samples of Geopolymer mortar specimens are made for varied alkaline activator to fly ash ratio with constant proportion of fly ash to sand. Laboratory tests are conducted on Geopolymer mortar specimens for compressive strength, direct tensile strength and flexural strength. The results reveal that Increase in alkaline activator to fly ash ratio of Geopolymer mortar increases the tensile strength and modulus of rupture. Moreover increase in curing temperature also increases the tensile strength and modulus of rupture. Average direct tensile strength is found to be 0.12 times the compressive strength whereas the average flexural strength is found to be 0.18 times the compressive strength of Geopolymer mortar.

Sohail Md et al. [9] reported that In this paper author investigate the strength properties of concrete mixes of grade M30. The present fine aggregate (river sand) is to be replaced with Waste Foundry Sand. Fine aggregate will be replaced with percentages (10%, 20%, 30%, 40%, 50%,60%,70%,80%,90%,100%) of WFS by weight.. Tests were performed for compressive strength, split tensile strength and flexural strength tests for all replacement of foundry sand at different curing period (7-days,28 days & 56-days). This experiment clearly indicate that 50% replacement of sand with waste foundry sand concrete can gain full strength at the end of 7 days, maximum compressive strength can be achieved with 50% replacement and increase in flexural strength of concrete but decreases after 50%Thus, sand replaced with waste foundry sand up to 70% is suitable in the construction works.

Prakash R. Vora et al. [10] analyzed the Various parameters which may affect the Geopolymer concrete that is alkaline liquid to fly ash ratio, concentration of NaOH, sodium silicate to sodium hydroxide ratio, time of curing, curing temperature range, amount of super plasticizer, rest period time and additional amount of water in the mix have been researched. As per test result it can be concluded that compressive strength increases with the curing time increase, high curing temperature, rest period time, concentration of NaOH solution and decreases with increase in the water to Geopolymer solids by mass ratio & doses of admixture, respectively and naphthalene based super plasticizer improves the workability of Geopolymer concrete. It was further studied that in the Geopolymer concrete mix amount of water plays noteworthy role in achieving the desired compressive strength.

Raijiwala et al. [11] conducted research to study the different properties of Geopolymer concrete using fly ash and the other components locally available. For different mix proportions Potassium Hydroxide and sodium Hydroxide solution were used as alkali solutions. Commercial grade Potassium Hydroxide in pallets form (97%-100% purity) and sodium Hydroxide solution

(Na2O=18.2%, SiO2=36.7%, Water = 45.1%) were used as the alkali activators. mass of distilled water is the prime element in both the alkali solutions. For improving the workability of the concrete superplasticiser was used. Different mix proportions prepared by using different molarity of Potassium Hydroxide solution (8M,10M,12M, 14M,16M), the specimens were cured at two different temperature 250C and 600C for 24 hours in the oven. As per different tests compression, flexure, pull out , split tensile conducted ,it can concluded that Geopolymer concrete can gain 1.5 times more compressive strength than controlled,M-25 achieves M-45,Split Tensile Strength increases by1.45 times, flexural Strength increases by 1.6 times and in Pull Out test, Geopolymer concrete increases over controlled concrete by 1.5 times.
Further good structural properties can be achieved with increase in polymerization temperature along with prolonged curing period in oven. At 12% molarities of KOH the cost per cu.M of Geopolymer concrete reduces by 12% over the controlled concrete.

3. CONCLUSIONS

Concentrating on a number of research papers related to Geopolymer technology several facts still remain a bit obscure. Foundry sand is not used yet in Geopolymer concrete. Lack of equivalent concrete standards and specifications, it include concretes other than OPC concrete, or special standards are written for Geopolymer concrete. Geopolymer concrete will be usually restricted to non-structural or low-performance structural applications. The quality of fly ash, binder-to-aggregate ratio, molarity of the activator solution, fine aggregate type, curing conditions influence the strength development in Geopolymer concrete for the improvement the workability, Superplasticiser or extra water can be added. A slight increment in strength of concrete by partial replacement of fine aggregate. By using this we can produce good quality concrete and construction materials. If some of the materials are found suitable in concrete making not only cost of construction can be put down, but also safe disposal of waste materials can be achieved.

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BIOGRAPHIES

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