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Experimental Study on Coir Fiber Reinforced Fly Ash Based Geo Polymer Concrete with 12 Molar NaOH Activator

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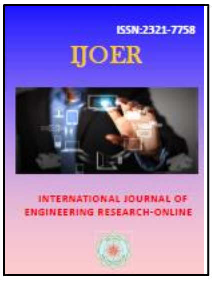


ABSTRACT

Ordinary Portland cement is a major construction material worldwide. Cement manufacturing industry is one of the carbon dioxide emitting sources besides deforestation and burning of fossil fuels. The global warming is caused by the emission of greenhouse gases, such as CO_2, to the atmosphere. Among the greenhouse gases, CO_2 contributes about 65% of global warming. The global cement industry contributes about 7% of greenhouse gas emission to the earth's atmosphere. In order to address environmental effects associated with Portland cement, there is a need to develop alternative binders to make concrete.

One of the efforts to produce more environmentally friendly concrete is the development of inorganic alumino-silicate polymer, called geopolymer, synthesized from materials of geological origin or by-product materials such as fly ash that are rich in silicon and aluminum.

In this project work, low-calcium (Class F) fly ash-based geopolymer from Vijayawada Thermal power plant has been used for the production of geopolymer concrete. The combination of sodium silicate solution and sodium hydroxide solution was used as alkaline solution for fly ash activation. Alkaline solution to fly ash ratio was varied as 0.45.The concentration of sodium hydroxide solution was maintained as 12M (Molars).The curing condition of geopolymer concrete was varied as ambient curing. The compressive strength, Flexural strength, Split Tensile Strength of the geopolymer concrete was tested at various ages such as 3, 7 and 28 days.

From the test results it was found that (a) as the alkaline solution to fly ash ratio increases, the strength of geopolymer concrete also increases. (b) The strength of ambient cured concrete. (c) Strength of concrete increases as the curing condition (ambient) at various ages

Keywords— geopolymer concrete; silicon and aluminum fly ash-based geopolymer.

INTRODUCTION

Concrete is the widely used construction material that makes best foundations, architectural structures, bridges, roads, block walls, fences furthermore, posts. The creation of one ton of Portland bond transmits roughly one ton of CO_2 into the environment. Among the nursery gasses, CO_2 contributes around 65% of an Earth-wide temperature boost. The commitment of common Portland bond (OPC) creation worldwide to ozone depleting substance emanations is assessed to be roughly 1.35 billion tons yearly or around 7% of the aggregate ozone harming substance discharges to the world's climate.. After thermal power plants and the iron and steel sector, the Indian cement industry is the third largest user of coal in the country. The industry's capacity at the beginning of the year 2008-09 was about 198 million tones. The cement demand in India is expected to grow at 10% annually in the medium term buoyed by housing, infrastructure and corporate capital expenditures. Considering an expected production and consumption growth of 9 to 10 percent, the demand-supply position of the cement industry is expected to improve from 2008-09 onwards.

Coal-based warm power establishments in India contribute around 65% of the aggregate introduced limit with respect to power era. Keeping in mind the end goal to take care of the Developing vitality demand of the nation, coal-based warm power era is relied upon to assume an overwhelming part later on as well, since coal reserves in India are expected to last for more than 100 years. The ash content of coal used by warm power plants in India changes in the vicinity of 25 and 45%. Be that as it may, coal with a powder substance of around 40% is prevalently utilized as a part of India for warm power era. As a result, a gigantic measure of fly fiery remains (FA) is produced in warm power plants,, causing several disposal-related problems. In spite of initiatives taken by the government, several non-governmental organizations and research and development organizations, the total utilization of FA is only about 50%. India produces 130 million ton of FA annually which is expected to reach 225 million ton by 2017and may exceed 300 million tons by 2020. Disposal of FA is a growing problem as only 15% of FA is currently used for high value addition applications like concrete and building blocks, the remainder being used for land filling.

Literature review

1. **Concrete and environment:** The exchanging of carbon dioxide (CO_2) outflows is a critical calculates for the ventures, including the bond enterprises, as the nursery impact made by the emanations is considered to create an expansion in the worldwide temperature that may bring about atmosphere changes. The 'tradeable emanations' alludes to the financial components that are required to help the nations worldwide to meet the discharge diminishment targets set up by the 1997 Kyoto Convention. Hypothesis has emerged that one ton of outflow can have an exchanging an incentive about US$10. The environmental change is ascribed to the an unnatural weather change, as well as to the incomprehensible worldwide diminishing because of the contamination in the climate. Worldwide darkening is related with the lessening of the measure of daylight achieving the earth because of contamination particles noticeable all around hindering the daylight. With the push to lessen the air contamination that has been taken into usage, the impact of worldwide diminishing possibly decreased, in any case it will expand the impact of a dangerous atmospheric devation. In this view, the a dangerous atmospheric devation wonder ought to be viewed as more genuinely, and any activity to lessen the impact ought to be given more consideration and exertion. The generation of concrete is expanding around 3% every year. The creation of one ton of concrete frees around one ton of CO2 to the air, as the consequence of de-carbonation of limestone in the oven amid assembling of bond and the burning of petroleum products. The commitment of Portland concrete generation worldwide to the ozone harming substance emanation is evaluated to be around 1.35 billion tons every year or around 7% of the aggregate ozone depleting substance discharges to the world's air. Concrete is additionally among the most vitality escalated development materials, after aluminum and steel. Besides, it has been accounted for that the sturdiness of common Portland bond (OPC) cement is under examination, the same number of solid structures, particularly those implicit destructive conditions, begin to decay following 20 to 30 years, despite the fact that they have been intended for over 50 years of administration life. The solid business has perceived these issues. For instance, the U.S. Solid Industry has created arrangements to address these issues in 'Vision 2030: A Dream for the U.S. Solid Industry'. The record expresses that 'solid technologists are confronted with the test of driving future advancement in a way that ensures natural quality while anticipating concrete as a development material of decision. Open concern will be capably tended to with respect to environmental change

Component	Bituminous	Subbituminous	Lignite
SiO_2 (%)	20-60	40-60	15-45
Al_2O_3 (%)	5-35	20-30	20-25
Fe_2O_3 (%)	10-40	4-10	4-15
CaO (%)	1-12	5-30	15-40
LOI (%)	0-15	0-3	0-5

coming about because of the expanded centralization of a dangerous atmospheric devation gasses. In this archive, procedures to hold concrete as a development material of decision for foundation improvement, and in the meantime to make it an earth well disposed material for the future have been delineated. With a specific end goal to deliver earth amicable cement, Mehta (2002) proposed the utilization of less characteristic assets, less vitality, and limit carbon dioxide emanations. He arranged these fleeting endeavors as 'mechanical environment'. The long haul objective of decreasing the effect of undesirable by-results of industry can be accomplished by bringing down the rate of material utilization. In like manner, McCaffrey (2002) recommended three other options to decrease the measure of carbon dioxide (CO2) discharges by the bond businesses, i.e. to diminish the measure of asserted material in bond, to diminish the measure of bond in cement, and to diminish the quantity of structures utilizing concrete.

2. **Fly ash:** As per the American Solid Establishment (ACI) Committee 116R, fly fiery debris is characterized as 'the finely separated buildup that outcomes from the ignition of ground or powdered coal and that is transported by pipe gasses from the burning zone to the molecule expulsion framework' (ACI Board of trustees 232 2004). Fly fiery debris is expelled from the ignition gasses by the clean accumulation framework, either mechanically or by utilizing electrostatic precipitators, before they are released to the environment. Fly cinder particles are regularly circular, better than Portland bond and lime, extending India meter from under 1 am to close to 150 am.

3. **The use of fly ash in concrete:** One of the endeavors to create all the more ecologically friendly concrete is to diminish the utilization of OPC by in part supplanting the measure of bond in cement with by-items materials, for example, fly powder. As a bond substitution, fly slag assumes the part of a counterfeit pozzolona, where its silicon dioxide content responds with the calcium hydroxide from the concrete hydration procedure to shape the calcium silicate hydrate gel. The circular state of fly fiery debris regularly enhances the workability of the crisp cement, while its little molecule estimate additionally plays as filler of voids in the solid, thus to create thick and strong cement (CS-H) gel.. Generally, the effective amount of cement that can be replaced by fly ash is not more than 30%.An important achievement in the use of fly ash in concrete is the development of high volume fly ash (HVFA) concrete that successfully replaces the use of OPC in concrete up to 60% and yet possesses excellent mechanical properties with enhanced durability performance. HVFA concrete has been proved to be more durable and resource-efficient than the OPC concrete. The HVFA technology has been put into practice, for example the construction of roads in India, which implemented 50% OPC replacement by the fly ash.

METHODOLOGY

1. **Source materials**

a. Fly ash: The combustion of ground or powdered coal which results the residue of finely divided particle is known as fly ash. The combination of oxides of Calcium (CaO), Aluminum (Al_2O_3), Silicon (SiO_2), and Iron (Fe_2O_3), are the chemical compositions, where the percentage of Titanium, Sodium, and Magnesium, Potassium, Sulphur are present in lesser amount. Fly ash preferred is Low-calcium (ASTM Class F).The fly ash used in this study was obtained from Ennore Thermal power plant. It falls in the category of class F grade and its chemical composition. The physical properties of fly ash were determined as per IS: 1727-1967 and given in Table 3.1.

Fig 3.1: Showing Fly ash

The Ca-bearing minerals are orthite, gehlenite, akermanite and different calcium silicates and calcium aluminates indistinguishable to those found in Portland concrete can be distinguished in Ca-rich fly fiery remains. The mercury substance can achieve 1 ppm, however is for the most part incorporated into the range 0.01 - 1 ppm for bituminous coal. The groupings of other follow components differ also as indicated by the sort of coal combusted to frame it. Truth be told, on account of bituminous coal, with the striking exemption of boron, follow component fixations are for the most part like follow component focuses in unpolluted soils.

Class F fly ash: The consuming of harder, more seasoned anthracite and bituminous coal ordinarily delivers Class F fly fiery debris. This fly cinder is pozzolanic in nature, and contains under 20% lime (CaO). Having pozzolanic properties, the lustrous silica and alumina of Class F fly slag requires a solidifying operator, for example, Portland bond, snappy lime or hydrated lime blended with water to respond and deliver cementitious mixes. On the other hand, including a substance activator, for example, sodium silicate (water glass) to a Class F slag can frame a geopolymer.

Class c fly ash: Fly fiery remains delivered from the consuming of more youthful lignite or sub-bituminous coal, notwithstanding having pozzolanic properties, additionally has some self-solidifying properties. Within the sight of water, Class C fly fiery remains solidifies and gets more grounded after some time. Class C fly powder by and large contains over 20% lime (CaO). Dissimilar to Class F, self-solidifying Class C fly powder does not require an activator. Soluble base and sulfate (SO4) substance are by and large higher in Class C fly ashes.US maker has declared a fly fiery debris block containing up to half Class C fly cinder. Testing demonstrates the blocks meet or surpass the execution guidelines recorded in ASTM C 216 for regular earth block. It is likewise inside the admissible shrinkage limits for solid block in ASTM C 55, Standard Detail for Solid Building Block. It is assessed that the creation technique utilized as a part of fly slag blocks will lessen the typified vitality of stone work development by up to 90%.[9] Blocks and pavers were relied upon to be accessible in business amounts some time recently.

Table 3.2: showing chemical composition of ennore fly ash is reported as follows

components	SiO_2	Al_2O_3	Fe2o3	TiO_2	CaO	MgO	Na_2O	K_2O	Loss On Ignition
% by mass	56.77	31.88	2.82	2.77	0.78	2.39	0.68	1.96	0.93

Alkaline Liquids: The most widely recognized basic fluid utilized as a part of geopolymerisation is a mix of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate or potassium silicate (Davidovits 1999; Palomo etal. 1999; Barbosa et al. 2000; Xu and van Deventer 2000, Swanepoel and Strydom 2002; Xu and van Deventer2002). The utilization of a solitary basic activator has been accounted for (Palomo et al. 1999; Teixeira-Pinto et al. 2002), palomo et al (1999) inferred that the kind of antacid fluid assumes a critical part in the polymerization procedure. Responses happen at a high rate when the antacid fluid contains solvent silicate, either sodium or Potassium silicate, contrasted with the utilization of just basic hydroxides. Xu and van Deventer (2000) affirmed that the expansion of sodium silicate answer for the sodium hydroxide arrangement as the soluble fluid improved their activity between the source material and the arrangement. Promote more, after an investigation of the geo-polymerization of sixteen normal Al-Si minerals, they found that for the most part the NaOH arrangement brought on a higher degree of disintegration of minerals than the KOH arrangement.

Sodium hydroxide: For the most part the sodium hydroxides are accessible in strong state by methods for pellets and chips. The cost of the sodium hydroxide is primarily changed by the virtue of the substance. Since our geopolymer cement is homogenous material and its principle procedure to actuate the sodium silicate, so it is prescribed to utilize the most reduced cost i.e. up to 94% to 96% immaculateness. In this examination the sodium hydroxide pellets were used. Whose physical and chemical properties are given by the manufacturer is shown in Table 1 and 2.

Fig 3.2: Sodium hydroxide flakes form

Table 3.3: Chemical properties of sodium hydroxide

Sodium silicate

Assay	97%	Min
Carbonate(Na_2CO_3)	2%	Max
Chloride(Cl)	0.01%	Max
Sulphate (SO_2)	0.05%	Max
Lead (Pd)	0.001%	Max
Iron (Fe)	0.001%	Max
Potassium(K)	0.1%	Max
Zinc (Zn)	0.02%	Max

Sodium silicate is also known as water glass or liquid glass, available in liquid (gel) form. In present investigation sodium silicate 2.0 (ratio between Na2O to SiO2) is used. As per the manufacture, silicates were supplied to the detergent company and textile industry as bonding agent. Same sodium silicate is used for the making of geopolymer concrete. The chemical properties and the physical properties of the silicates are given the manufacture is shown in Table 3.Sodium hydroxide pellets are taken and dissolved in the water at the rate of 16 molar concentrations. It is strongly recommended that the sodium hydroxide solution must be prepared 24 hours prior to use and also if it exceeds 36 hours it terminate to semi solid liquid state. So the prepared solution should be used within this time.

Fig 3.3: Sodium silicate in gel form

Table 3.4: Physical and chemical properties of sodium silicate

Assay	97%	Min
Carbonate(Na_2CO_3)	2%	Max
Chloride(Cl)	0.01%	Max
Sulphate (SO_2)	0.05%	Max
Lead (Pd)	0.001%	Max
Iron (Fe)	0.001%	Max
Potassium(K)	0.1%	Max
Zinc (Zn)	0.02%	Max

Sodium Hydroxide solution (NaOH):

Considering 12M concentration, where in the solution consists of 44.4% of solids (flakes) and 63.5% of water.

Mass of solids = (44.4/100) ×(45.06) = 20.00 Kg

Mass of water = 45.06 - 20.00 = 25.06 Kg

Sodium Silicate Solution (Na_2SiO_3):

The water content in the silicate solution is observed as 63.5%.

So, the

Mass of Water = (63.5/100) × (112.64) =71.52 Kg

Mass of solids = 112.64 – 71.52 = 41.11 Kg

Total mass of water:

Mass of water in NaoH solution + Mass of water in Na2SiO3.

Solution = 25.60 + 71.52 = 96.58 Kg.

Total mass of solids:

Mass of solids in NaoH solution + Mass of solids in Na2SiO3solution + Mass of Fly ash =

20.00 + 41.11 + 394.28 = 455.39Kg.

Ratio of water to Geopolymer Solids: Ratio = (96.58) / (455.39) = 0.21.

Course aggregates

Locally available crushed granite stone aggregate of 20mm maximum size was used as coarse aggregate. The coarse aggregate passing through 20mm and retaining 4.75mm was used for experimental work. The following properties of coarse aggregates were determined as per IS: 2386- 1963 and given in Table3.3.

Fine aggregates

The locally available river sand, passing through 4.75 mm was used in this experimental work.

Latex Rubber

Latex is the stabled persion(emulsion)of polymer micro particles in an aqueous medium. Latex may be natural orsynthetic. It can be made by polymerizing a monomer such as styrene that has been emulsified with surfactants. Latex as found in nature is a milky fluid found in10%ofall flowering plants. It is a complex emulsion consisting of proteins, alkaloids, starches, sugars, oils, tannins, resins, and gums that coagulate on exposure to air. It is generally exuded after tissue injury. In most plants, latex is white, but some have yellow, orange, or scarlet latex. Latex is a polymer of micro particles in an aqueous medium. It is either in natural or in synthetic form. Latex in nature is milky fluid. Latex consists tannins, sugars, gums, alkaloids, oils, proteins, resins, and starches that coagulate on exposure to air. Naturally available latex is white, but in some plants latex is scarlet latex, orange, or yellow.

Fig 3.8: Latex adhesive liquid

Composite preparation

The coir fiber is chopped to 25mm. The chopped fibers are allowed to soak in sodium hydroxide for 48hours for chemical treatment. After 48hours the treated coir fibre is washed repeatedly and allowed to dry for 24 hours. The dried fibers are then resin with latex compound which is prepared by the mixing of 70% of latex, 10% of sodium hydroxide solution and 20% of water to achieve thee homogenization and allowed to dip for 15 minutes and dried for 24 hours.

Fig 3.4: soaked of coir fibre in NaOH solution before casting

Fig 3.5: after soaking washing of coir fibre with normal water

Fig 3.6: Drying of fibers for 24hrs

MIXING, CASTING AND CURING

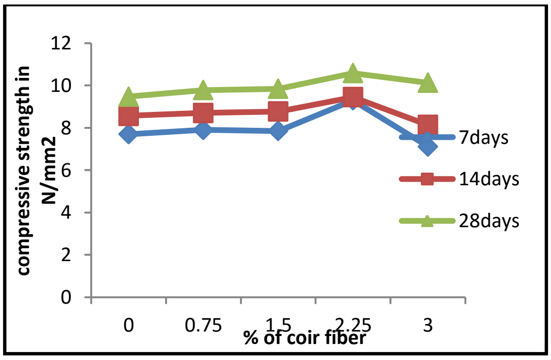
In this work, low-calcium (ASTM Class F) fly ash-based geopolymer is used as the binder, instead of

Portland or other hydraulic cement paste, to produce concrete. The fly ash-based geopolymer paste binds the loose coarse aggregates, fine aggregates and other un-reacted materials together to form the geopolymer concrete, with the presence of admixtures Geopolymer concrete can be manufactured by using the low-calcium (ASTM Class F) fly ash obtained from coal-burning power stations. Most of the fly ash available globally is low-calcium fly ash formed as a by-product of burning anthracte or bituminous coal. Coir pith and other undesirable materials are separated from the coir fiber. It is then chopped to about different length of 25mm subjected to chemical treatments. Coir fibers are soaked in sodium hydroxide solution for 48 hours. Fiber were taken out, repeatedly washed with water and dried in the air. Latex compound is prepared by mixing 70% of natural rubber,latex and 10% of sodium hydroxide solution and 20% of water. The latex compound and the resin solution were agitated to achieve homogenization. Then the coir fiber is dipped in the mixture about 15minutes and dried. The Na_2SiO_3 and NaOH are mixed one day before to get polymerization which is perfectly suitable as the binding agent. All the materials are mixed manually. Fly ash and aggregate are mixed for one minute and the binding agent is added with small amounts and the mixing is done for 2 minutes. Now the treated fibers are added to the mixture with the slow increment and mixing is done thoroughly. For compressive test cube specimens of 150*150*150mm, for split tensile test cylindrical specimens of 150mm dia and 300mm height specimen and for flexural strength beam specimens 100*100*500mm^3 were casted. Curing is done under ambient conditions.

Curing conditions: The effect of curing conditions on the compressive strength of geopolymer concrete for various alkaline solutions to fly ash ratios are depicted in Figures 4.4 to 4.6. The compressive strength of oven cured specimens was more than that of ambient cured specimens irrespective of age, alkaline solution to fly ash ratio and concentration of sodium hydroxide solution. The test results revealed that compressive strength of oven cured specimens at 0.45 ratio was 4.5 and 1.25 times more than that of ambient cured specimens at 7 and 28 days respectively. In ambient curing, compressive strength significantly increases with age up to 28 days. In ambient curing, compressive strength at 28 days was about 3 times and 1.4 times higher than 7 and 14 days respectively.

Results and discussions

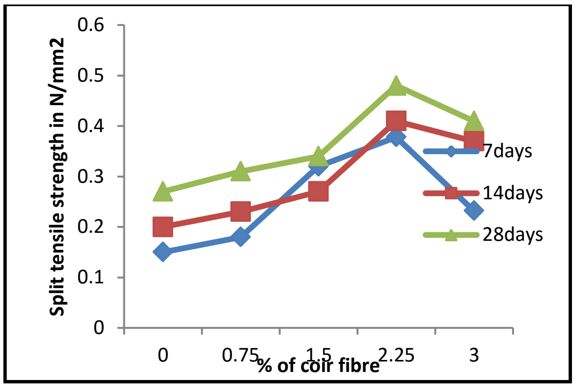
1. Compressive test: The compressive strength test on hardened fly ash based geopolymer concrete was performed on standard compression testing machine of 3000kN Capacity, as per IS: 516-1959. Totally 81 number of cubical specimens of size 100mm x 100mm x 100mm was casted and tested for the compressive strength at the age of 7days, 14days and 28days. The compressive strength test was performed as shown in Figure 3.6. Each of the compressive strength test data corresponds to the mean value of the compressive strength of three test concrete cubes. The graph 1 shows that the strength of the specimen increases upto a level and then the strength falls down. For 7 days, the maximum strength obtained is 7.3 N/mm^2. For 14 days 9.45 N/mm^2 is the maximum strength. And for 28 days 10.58 N/mm^2 is the maximum strength. This shows that optimum percentage of coir fiber is 2.25 for all.



Graph 4.1: Shows the compressive strength parameter

SPLIT TENSILE TEST

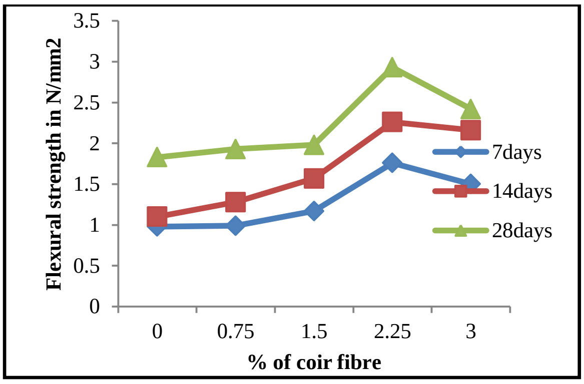
Split Tensile strength is defined as resistance of concrete to radial loading. Cylinders were placed in Universal Testing Machine (U.T.M), and load was applied. The readings on dial gauge were recorded and tensile strength was calculated. The graph 2 shows that the strength of the specimen increases upto a level and then the strength falls down. For 7 days the maximum strength obtained is 0.378 N/mm^2. For 14 days 0.41 N/mm^2 is the maximum strength. And for 28 days 0.48 N/mm^2 is the maximum strength. This shows that optimum percentage of coir fiber is 2.25 for all.



Graph 4.2: Shows the split tensile strength parameter

FLEXURAL STRENGHT

The graph3 shows that the strength of the specimen increases upto a level and then the strength falls down. For 7 days the maximum strength obtained is 1.76 N/mm^2. For 14 days,2.26 N/mm^2 is the maximum strength. And for 28 days,2.93 N/mm^2 is the maximum strength. This shows that optimum percentage of coir fiber is 2.25 for all.



Graph 4.3: Shows the flexural strength parameter

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