AN EXPERIMENTAL INVESTIGATION ON GEOPOLYMER MADE OF NATURAL FIBER REINFORCED FLY ASH.

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ABSTRACT

In the scenario where demand of concrete is a continuous growing sector, it has become necessary to research for the options of cement concrete replacement with the material that offers same compressive strength. Geo- polymer is one of those alternatives that can replace concrete suitably and also they are very effective in handing environmental threats like fly-ash is a very efficient manner. Geo-polymers are the binding materials made by mixing fly- ash (pozzolanic material) with alkaline solution (activator) in a proper proportion. Also to provide flexural strength to the material under observation, we have induced it with naturally occurring sisal fiber in 0.5%, 1%, 1.5%, 2% and 2.5% of fly- ash. On applying tests for compressive and flexural strength, 2% of sisal fiber by weight of fly-ash has given the optimum results. Furthermore conclusions have been drawn in the study.

Keyword: - *Fly-Ash, Alkaline Solution, Activator, Fiber Reinforcement, Sisal Fiber, Compressive Strength, Flexural Strength.*

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1. INTRODUCTION

1.1 Geo-Polymer

Geo-polymer is a novel binding material produced from the reaction of fly ash with an alkaline solution. In geo-polymer Portland cement is not utilized at all. It has the potential to replace OPC in concrete manufacturing and produce fly ash based geo polymer concrete, low calcium with excellent physical and mechanical properties.

In order to produce geo polymer low calcium fly ash needs to be activated by an alkaline solution to produce polymeric Si-O-Al bonds. Geo polymer concrete has the potential to reduce greenhouse gas emission from the concrete industry by 80%.

1.2 Need for Geo-Polymer

Geo-polymer concrete is proven to have excellent engineering properties with a reduced carbon footprint. It not only reduces the greenhouse gas emissions (compared to Portland cement based concrete) but also utilizes a large amount of industrial waste materials such as fly ash and slag. Due to these positive attributes, it is becoming an increasingly popular construction material.

In reinforced concrete, the second highest source of the carbon emission is the steel reinforcement. By combining synthetic fiber and reinforcement and geo-polymer technology, it is possible to remove Portland cement and steel reinforcement from structural concrete to produce a new generation of structural concrete with potential benefits of improved durability and reduced carbon content.

1.3 Fibre Reinforced Concrete

Concrete is weak in tension and has a brittle character. The concept of using fibers to improve the characteristics of construction materials is very old. Early applications include addition of straw to mud bricks, horse hair to reinforce plaster and asbestos to reinforce pottery. Use of continuous reinforcement in concrete (reinforced concrete) increases strength and ductility, but requires careful placement and labor skill.

When concrete cracks, the randomly oriented fibers start functioning, arrest crack formation and propagation, and thus improve strength and ductility. The failure modes of FRC are either bond failure between fiber and matrix or material failure.

1.4 Types of Fibers

1. Steel Fibers: - Straight, crimped, twisted, hooked, ringed, and paddled ends. Diameter range from 0.25 to 0.76 mm.
2. Glass Fibers: - Straight Diameter ranges from 0.005 to 0.015mm (may be bonded together to form elements with diameters of0.13 to 1.3mm).
3. Natural Organic and Mineral Fibers: - Wood, asbestos, cotton, bamboo, and rock wool. They come in wide range of sizes.
4. Polypropylene Fibers: - Plain, twisted, fibrillated, and with buttoned ends.
5. Other Synthetic Fibers: - Kevlar, nylon, and polyester. Diameter ranges from 0.02 to 0.38mm.

1.5 Fibre Reinforced Geo-polymer Concrete

The use of geo-polymer binder and synthetic fibers in place of Portland cement and steel reinforcement to produce fiber reinforced geo-polymer concrete (FRGC) provides a lower carbon alternative to conventional concrete by combining synthetic fiber reinforcement and geo-polymer technology, it is possible to remove Portland cement and steel reinforcement from structural concrete to produce a new generation of structural concrete with potential benefits of improved durability and reduced embodied carbon content

Geopolymer concrete reinforced with randomly distributed discrete fibers resembles the fiber reinforcement concrete in many of its properties. Generally the discrete fibers are simply added and mixed with the fly ash, much the same as cement, lime or any other additives. Fiber reinforced geopolymer concrete was found to outperform the control mix with regard to flexural strength, durability and shrinkage whilst reducing carbon emissions by approximately 70%.

1.6 Natural Fiber as Geo-polymer Reinforcing Material

Natural fibers, as reinforcement, have recently attracted the attention of researchers because of their advantages over other established materials. They are environmentally friendly, fully biodegradable, abundantly available, renewable, and cheap and have low density. Plant fibers are light compared to glass, carbon and aramid fibers.

Natural fibers are prospective reinforcing materials and their use until now has been more traditional than technical. They have long served many useful purposes but the application of materials technology for the utilization of natural fibers as the reinforcement in concrete has only taken place in comparatively recent years.

1.7 Natural Fiber Sisal as Reinforced Material

In recent time plant fibers have been receiving considerable attention as substitutes for synthetic fiber reinforcements. Unlike the traditional synthetic fibers like glass and carbon these lignocellulosic fibers are able to impart certain benefits to the composites such as low density, high stiffness, low cost, renewability, biodegradability and high degree of flexibility during processing. Cellulosic fibers like sisal, coconut (coir) and bamboo in their natural form as well as several waste cellulosic products such as shell flour, wood flour and pulp have been used as reinforcing agents of different thermosetting and thermoplastic composites.

Sisal Fiber is one of the most widely used natural fiber and is very easily cultivated. It is obtain from sisal plant. These plants produce rosettes of sword-shaped leaves which start out toothed, and gradually lose their teeth with maturity. Each leaf contains a number of long, straight fibers which can be removed in a process known as decortication. During decortication, the leaves are beaten to remove the pulp and plant material, leaving the tough fibers behind. The fibers can be spun into thread for twine and textile production, or pulped to make paper products.

2. OBJECTIVE OF THE STUDY

The prime aim of the present investigation is to assess the usefulness of sisal fiber as reinforcement in geo-polymer concrete. The present investigation has been limited to the following studies:

- To study the effect of percentage of fiber content on strength characteristics of geo-polymer concrete,
- To study the effect of length of fiber on strength behaviour of geo-polymer concrete,
- To study the influence of sisal fiber inclusion on compressive strength and flexural strength of geo polymer concrete,

3. LITERATURE REVIEW

3.1 From Ancient Concrete to Geopolymer

Davidovits (1993) presented the study of development of geo-plymeric material in ancient period by using the archaeology as a data bank & explained the mystery behind the resistance of ancient Egyptian & Roman mortars. This paper provides an answer to the question that how the structures made of Egyptian & Roman mortars like Great Pyramid Blocks and Saint Sofia Church of Constantinople are still standing even after thousands of years since their construction. He explained that reactive ingredients combine with lime, leaving the excess lime as inert. The makeup of the mortars varies according to the archaeological site that is according to its geological environment. A mortar will be good if components are selected from an appropriate site. He was able to demonstrate that geo-polymer have the same strength than natural rock by showing the granular structure of OPC and GPC mortar.

3.2 Fly-Ash Based Geo-Polymer Concrete: Engineering Properties

Hardjito et al. (2005) presented the study of parameters which cover certain aspects of manufacture of fly ash-based geopolymer concrete. In this paper it is described that after casting, some specimens were left at room temperature until the start of curing. On the other hand, some specimens were placed in an oven during the rest period. The oven temperature on the first day of rest period was 32ºC; on other days of the rest period, the temperature was 40ºC. This variation in temperature simulated the ambient variations during the rest period.

From the experimental results findings described below as a, b & c were concluded.

- Longer mixing time yielded lower slump of fresh concrete, and higher compressive strength and higher density of hardened concrete. This suggests that the extended mixing time resulted in better polymerization process, and hence enhanced properties of hardened concrete.
- The term „rest period" is used to indicate the time taken from the end of casting to start of curing at an elevated temperature. The compressive strength of specimens increased with a rest period of one day or more after casting. The extent of strength gain is significant, in the range of 20 to 50 % compared to the compressive strength of specimens with no rest period.
- The measured stress-strain relations of fly ash-based geopolymer concrete, both the ascending and the descending parts, agree well with the predictions of equation developed originally for Portland cement concrete.

3.3 Influence of types of curing on strength of geo-polymer concrete

Vijai et al. (2010) presented the study of influence of curing types on strength of geopolymer concrete. It was concluded from the experimental results that the compressive strength of hot cured concrete is much higher than that of ambient cured concrete

During experimental procedure concrete specimens were prepared with particular design mix & after casting the specimens, they were kept in rest period for five days and then they were demoulded. At the end of the rest period, six test specimens were kept under ambient conditions for curing at room temperature while the remaining six specimens were kept at 60 ºC in hot oven for 24 hrs.

Fig. 1: Experimental procedure concrete specimens

A graphical representation of variation of compressive strength for 7 days and 28 days of curing is shown. Compressive strength of hot cured specimens was more than that of ambient cured specimens both in 7 and 28 days. 28 days compressive strength of hot cured specimens was 2 times more than that of ambient cured specimens.7 days compressive strength of hot cured specimens was 7 times more than that of ambient cured specimens. In ambient curing, the 28 days compressive strength is about 4.5 times 7 days compressive strength. In hot curing, the 28 days compressive strength is about 1.2 times 7 days compressive strength.

3.4 Natural fiber as cost effective materials

J. Bharanichandar et al. presented the study of Natural fiber in Building and construction industry as a cost effective material is used in panels for partition and false ceiling, partition boards, wall, floor, window and door frames, roof tiles, mobile or pre- fabricated buildings which can be used in times of natural calamities such as floods, cyclones, earthquakes, etc. For Storage device like post-boxes, grain storage silos, bio-gas containers, etc. In the range of Furniture: chair, table, shower, bath units, etc. Natural fiber as an Electric devices include electrical appliances, pipes, etc. For Everyday applications like lampshades, suitcases, helmets, etc. And for Transportation uses automobile and railway coach interior, boat, etc.

Natural fiber in the automotive industry which have a large varieties of application that resembles with the low density which may lead to a weight reduction of 10 to 30%.

3.5 Natural Fiber as a substitute of synthetic fiber

Begum K. et al. begun to focus attention on Natural fiber in response to the increasing demand for environmentally friendly materials and the desire to reduce the cost of traditional fibers (i.e., carbon, glass and aramid) reinforced polymer composites. Besides ecological considerations natural fibers exhibit many advantageous properties which promote the replacement of synthetic fibers in polymer composites. They are a low-density material yielding relatively lightweight composites with high specific properties and therefore natural fibers offer a high potential for an outstanding reinforcement in lightweight structures.

Natural fibers are derived from a renewable resource and do not have a large energy requirement to process, and are biodegradable. These fibers also offer significant cost advantages and therefore the utilization of lightweight, lower cost natural fibers such as jute, flax, hemp, sisal, abaca, coir offer the potential to replace a large segment of the synthetic fibers in numerous applications.

3.6 Natural Fiber into concrete

Dr. N.R. Krishna Murthy et al. experimental study in which the Ordinary Portland Cement of 53 grades is used. The better coarse aggregates of 20mm and 12mm from the nearby quarry and the fine aggregate are used. SNF based super plasticizer is used. Natural Organic fiber – Jute, Sisal, Hemp, Banana, Pine apple are used The work on M30 grade of concrete as per IS:456-2000 for fiber-cement ratios 0.5%, 1%, 1.5% are carried out with fiber length of 6mm-10mm chopped. All the fibers has shown much better increase in strength than plain concrete for 0.5% fiber-cement ratio and little increase than plain concrete for 1% fiber-cement ratio and with further increase of fiber-cement ratio to 1.5% the strength is decreased than plain concrete but sudden failure is resisted. It is expected that the decrease of strength may be due to decrease in slump and increase of fibers in concrete leads to voids It is observed that there is more bulging in concrete with added fibers than in plain concrete. Also the failure is not sudden and with increase in fiber-cement ratio, the cracks at failure load are observed to be very less Slump is decreasing with the addition of fibers. More the fiber- cement ratio more is the decrease in slump due to absorbency of water by fibers. Hence the use of proper super plasticizer which does not affect other properties except workability is recommended for higher fiber-cement ratios.

3.7 Machining characteristics of natural fiber reinforced polymer

S. Veerapuram et al. research showed that the natural fibers are replacing the synthetic fibers due to their superior qualities; it has become very essential to optimize the machining parameters of the natural fiber based composites for enhancing its performance in the machining applications. In a study, the researchers have reported the optimization of machining parameters in drilling hemp fiber rein-forced composite to maximize the tensile strength using design experiments. Taguchi and ANOVA analysis were used to determine the factors and the combination of factors that affect the delamination and tensile strength of the drilled hemp fiber composite. The feed rate and cutting speed were found to contribute maximum to affect the delamination and tensile strength properties. In another study, the researchers had reported the optimization of polyester composite reinforced with jute fabric. A comparison of machinability of the composites with untreated and treated fiber was done. ANOVA analysis was performed and found that delamination factor was reduced slightly due to alkali treatment. It has also been observed that the alkali treatment have reduced the push down delamination more than the peel up delamination. Though the natural fiber composites are considered as a superior material for the structural application due to their inherent properties.

3.8 Mechanical characterization of sisal fiber reinforced polymer

M. Das et al. studied that, in case of other natural fiber composites, the mechanical properties and the fracture behavior of Sisal fiber reinforced polymer were also significantly influenced by the fiber/matrix interfacial adhesion. A good fiber/matrix interfacial adhesion yields superior mechanical properties of Sisal fiber reinforced polymer. Many research works have been done for improving the sisal fiber/matrix interfacial adhesion. The sisal fiber is hydrophilic in nature. So, in order to improve the interfacial adhesion, the surface of the sisal fiber needs to be modified. The polar groups present in the natural fiber reinforced thermosetting composites are the main reason behind the good adhesion be-tween the fiber and the matrix. But, on the other hand, no reaction can take place between the fiber and matrix in the case of the thermo-plastic composite, and thus, surface modification of fibers are needed to be done. The researchers have reported the effect of fiber treatment, both chemically and physically, on the mechanical behavior of the sisal fiber reinforced polymer.

The heat treatment of fibers increased the crystallinity of the fiber and thus increased the stiffness of the composite.

3.9 Electrical characterization of sisal fiber reinforced polymer

P.A. Sreekumar et al. reported the effect of the fiber surface treatment, variation of frequency, fiber loading and fiber length on the electrical properties of the composite. With the fiber surface permanganate ($KMnO_4$) treatment, hydrophilic nature of the fiber got reduced and thus resulted in the reduction of the di-electric constant and also increased the volume resistivity of the composite. Also, it was reported that the dielectric constant increased with an increase in fiber loading and decreased with the increase in fiber length and frequency. With the increase in fiber loading, the orientation and the interfacial polarization increase due to the presence of polar group of cellulose in fiber and thus the dielectric constant and conductivity got increased.

3.10 Thermal characterization of sisal fiber reinforced polymer

J. Rachasit et al. reported that in comparison to the synthetic fibers like glass fibers, carbon fibers, etc., the thermal stability of natural fibers is low. This relatively lower thermal stability of the natural fibers caused limitation of natural fiber reinforced composite in the higher temperature application. At high temperature, the natural fiber composite undergoes thermal degradation and loses its weight. In a study, the researchers have reported that the unidirectional reinforcement of the sisal fiber in rubber seed oil (RSO) based polyurethane composite has resulted in an improvement of thermal stability than that of RSO-polyurethane matrix [69]. Though the thermal stability was improved, it was however lesser than the sisal fiber.

3.11 Environmental benefits of eco-friendly natural fiber reinforced materials

M. Sivapragash et al. presented that the, efficient utilization of plant species and utilizing the smaller particles and fibers obtained from various lignocellulosic materials including agro wastes to develop eco-friendly materials is thus certainly a rational and sustainable approach. Any lignocellulosic waste matter can, therefore, be turned into composite products through appropriate R & D work and development in technological aspects. Resilience property which makes plastics ideal for many applications like food industries, packaging, construction field and sanitation products etc. petroleum-derived plastics can lead to waste disposal problems, as these materials are not readily biodegradable and because of their resistance to microbial degradation, they accumulate in the environment.

Biodegradable plastics and polymers were first introduced in 1980s. There are many sources of biodegradable plastics, from synthetic to natural polymers. Natural polymers are available in large quantities from renewable sources, while synthetic polymers are produced from non-renewable petroleum resources. Biodegradation takes place through the action of enzymes and/or chemical deterioration associated with living organisms. Biodegradability depends not only on the origin of the polymer but also on its chemical structure and the environmental degrading conditions.

Bio-based polyesters such as PLA and poly- hydroxyalkanoates (PHA"s) have begun to be more accepted since they are prepared from renewable feedstock rather than petroleum and are biodegradable. PLA in particular is finding wider application in areas such as textile, carpet making and food packaging industries.

4. MATERIAL

1. Fly-Ash

The fly ash from Satpura Thermal Power Plant, Sarni, and District–Betul is selected for the experimental procedure. This Fly ash was named as R3 fly ash in CSIR-AMPRI Bhopal. It is the largest coal fired Power station generating about 1400 megawatt in Madhya Pradesh, contributing to approximately 70% of total electricity supply of the state.

The typical fly ash was chosen for concrete component because of its local availability and excellent reactivity. The collection of Fly ash was done by means of electrostatic precipitators at the thermal power station.

2. Aggregates

A) Coarse Aggregate
The aggregates most of which retained on 4.75 mm sieve and contains only so much finer material as permitted by IS:383- 1970 is termed coarse aggregate. Aggregate used for making concrete shall be well graded with maximum size of 20 mm and 10 mm. Basalt coarse aggregates of nominal size of 20 mm and 10 mm were selected to use in this study.

B) Fine Aggregate
IS 383-1963 defines fine aggregate as the aggregate most of which will pass 4.75 mm sieve. Locally available river sand which was obtained from river Narmada & called Narmada sand, having a lower size of about 0.07 mm or little less was used as fine aggregates.

C) Activated Alkaline Solution
This solution was prepared from dissolution of alkali chemicals in water & used for activation of Fly ash. This was

specifically with special care & protection in laboratory.

D) Water

Simple Tap water supplied in laboratory was used for preparation of activated solution which was later used for preparation of geo polymer concrete.

E) Sisal fiber

Sisal fiber is creamy white in color and lustrous. It can measure up to 1 meter in length with a diameter of 200 to 400 microns. The sisal fiber is a coarse hard fiber which is strong, durable, and stretchable and does not absorb moisture easily, does not deteriorate in salt water and has affinity for dyestuff. Agricultural twine and ropes is still one of the largest markets for sisal fiber, while the highest fiber grades are used for manufacturing of rugs and home furnishing.

Fig. 2: Sisal Fiber

Sisal as natural fiber is used in the experimental procedure. It is used because of its bulk availability and naturally occurring fiber. Sisal Fiber is exceptionally durable and it is recyclable also.

A standard length of 1 cm with a diameter of 200 to 400 microns is taken for the whole study and experimental work. The length is so assumed because to avoid the balling problem during mixing. The fiber is chopped or cut in the length of 1 cm for the experimental procedure.

5. METHOD

- Identification of raw materials such as Fly ash, sisal fiber, alkaline activator, fine aggregate & coarse aggregate for concrete preparation.
- Characterization properties of fly ash, fine aggregate & coarse aggregate and sisal fiber.
- Process for preparation of standard size cube specimens of optimized mix for compressive strength and flexural strength.
- Filling & compaction of concrete mix into moulds for making the proposed concrete components.
- Heat treatment of concrete components by optimized curing procedures.

A. Experimental Procedure Adopted

- The experimental procedure involves the evaluation of the compressive and flexural strength of the geo-polymer concrete reinforced with the sisal fiber. The % of the sisal fiber varies from 0.5%-2.5% of dry fly ash. The length of the sisal fiber is taken as 1 cm (say that the sisal is taken in the chopped form), in the geo-polymer mix prepared in the lab.
- Different set of specimen (composition varying with the % of sisal fiber, fly ash and alkali activator) were casted for the experimental purpose. One set of reference specimen is also made of geo-polymer concrete (optimized mix).
- Two curing regime condition involved in the experiment which includes the curing at ambient temperature with external exposure and outdoor ambient condition for 48 hrs. and thermal curing at 600 C for 48 hrs.

(oven method).

- 18 moulded samples (cube) of size 15cm x 15cm x 15 cm and 1 moulded sample (beam) of size 70cm x 15cm x 15cm casted in every set of experiment. And total 6 (19 specimen in each) set of moulded samples were made which include the 5 set of mix of geo-polymer concrete reinforced with sisal fiber (sisal % varies in every set) and one set of reference i.e., unreinforced geo-polymer concrete mix for comparative studies.
- Out of 19 specimen 9 samples (15cm x 15cm x 15 cm) were cured in the ambient temperature with external exposure and outdoor ambient condition which involves no energy consumption, the specimen after casting were left on laboratory floor (indoor) & outside the laboratory on the uncovered ground, under outdoor ambient conditions.
- These specimens de molded as soon as they attain size wise stability and were left again in ambient conditions. These were tested after 3, 7 & 14 days for compressive strength, and rest 9 sample (15cm x 15cm x 15 cm) and 1 sample (70cm x 15cm x 15cm) were cured in the oven for 48 hours with the curing temperature was kept constant at 60°C.
- At the end of the curing period(48 hrs), the specimens were taken out from the oven and were left undisturbed in laboratory at ambient conditions until these were tested for compressive strength for 3 ,7, & 14 days and flexural strength for 28 days.
- This was resulted into finding out the increase or decrease in the compressive strength and flexural strength of the mix with the reference mix. By analysis of results compressive strength and flexural strength within both curing conditions were evaluated.

B Mix Proportioning

- The geopolymer concrete mix was the optimized design mix developed for M-20 Grade concrete.
- Our work is to reinforced the optimized mix by natural fiber and evaluate the compressive strength and flexural strength when compared with the optimized design mix called as reference mix or unreinforced mix.
- The design mix for preparation of 18 no cube samples of size 15cm x 15cm x 15cm presented in table.

Fiber (Sisal) Reinforced Geopolymer Mix (2% of FA)			
Material		Unit	Quantity
Fly ash		kg	27
Aggregate	20 mm	kg	36
	10 mm	kg	54
Sand		kg	45
Alkali activator	Chemical activator-1 + Chemical activator-2	kg	6.6
Water		lts	8.4
Fiber Used (2% of FA)	(Sisal)	gms	540
Slump		mm	150
Solution Left		ml	0

Table 1: Mix proportion of fiber (sisal) reinforced geo- polymer (Optimized 2%)

6. RESULT

A) Compressive Strength (Mpa) of reference geo-polymer concrete, tested after 3, 7 and 14 days

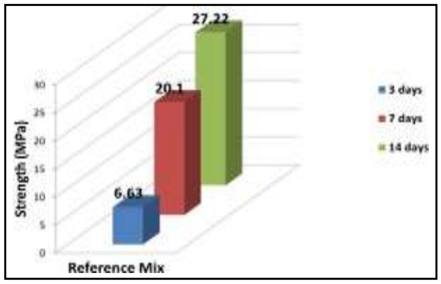

Fig. : When Ambient Cured

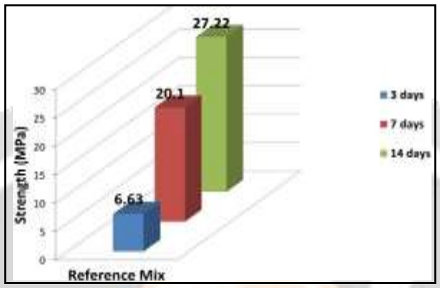

Fig. : When cured thermally at 600 for 48 hours

B) Compressive strength of Fiber Reinforced Geopolymer Concrete (Sisal-0.5%) tested after 3, 7 and 14 days Compressive Strength

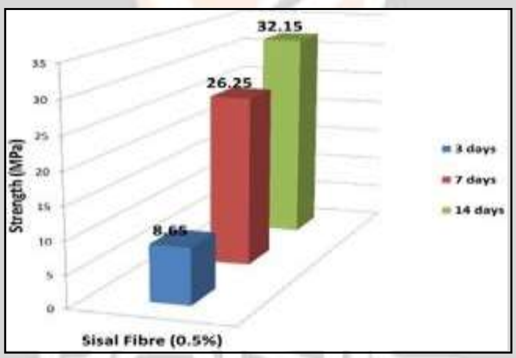

Fig. : When Ambient Cured

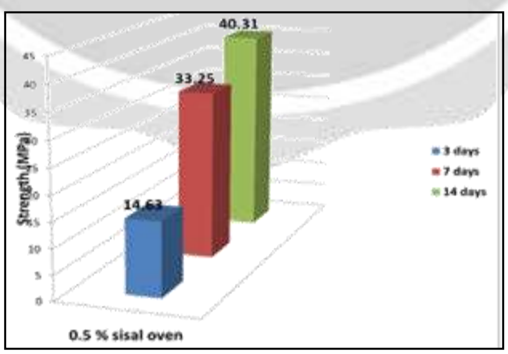

Fig. : When cured thermally at 600 for 48 hours

C) Compressive strength (MPa) of Fiber Reinforced Geo- polymer Concrete (Sisal-1%), tested after 3, 7 and 14 days

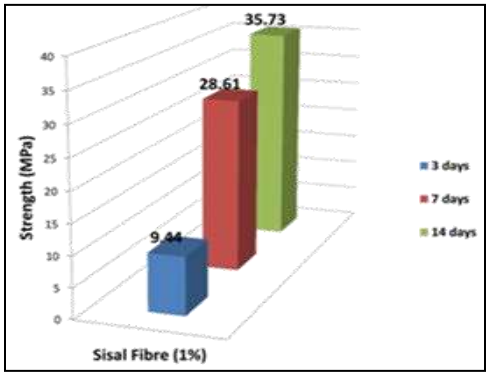

Fig.: When Ambient Cured

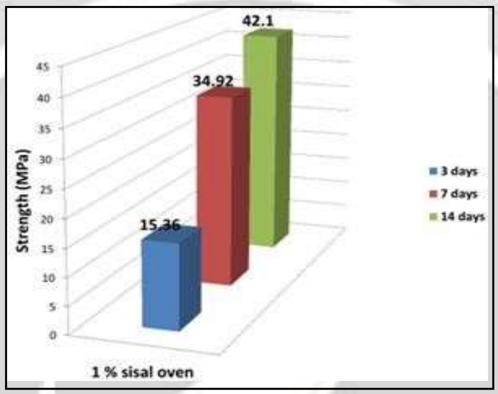

Fig. : When cured thermally at 600 for 48 hours

D) Compressive strength (MPa) of Fiber Reinforced Geopolymer Concrete (Sisal- 1.5%), tested after 3, 7 and 14 days.

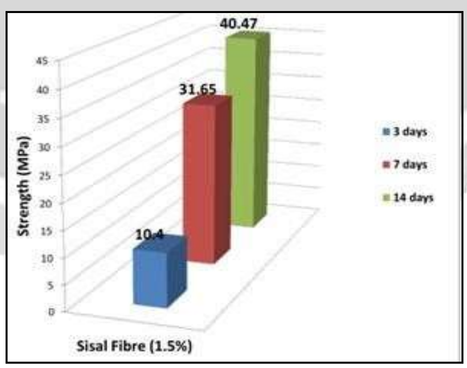

Fig. : When Ambient Cured

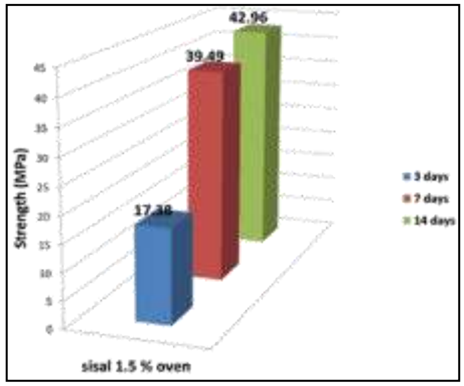

Fig. : When cured thermally at 600 for 48 hours

E) Compressive strength (MPa) of Fiber Reinforced Geopolymer Concrete (Sisal-2%), tested after 3, 7 and 14 days

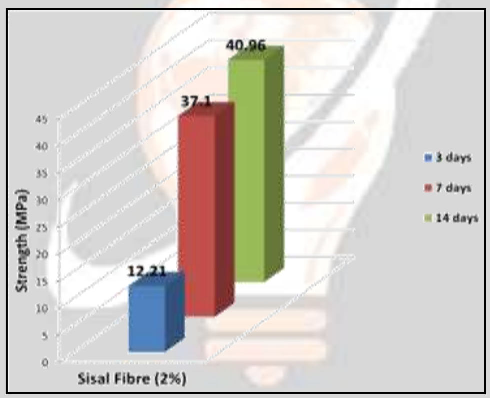

Fig. When Ambient Cured

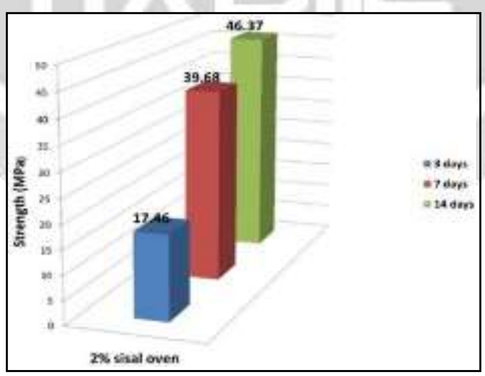

Fig. : When cured thermally at 600 for 48 hours

F) Compressive strength (MPa) of Fiber Reinforced Geo- polymer Concrete (Sisal- 2.5%), tested after 3, 7 and 14 days

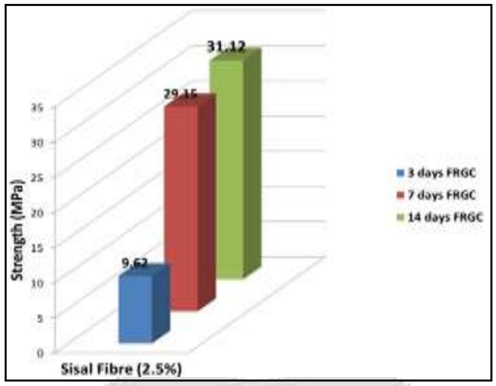

Fig. 12: When Ambient Cured

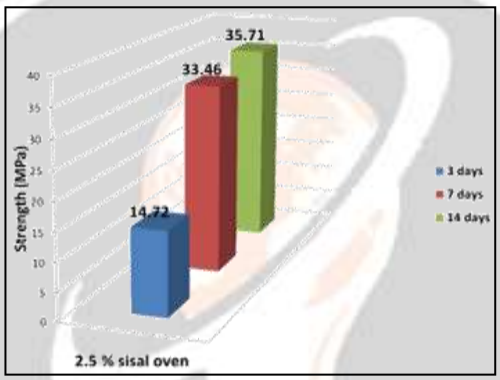

Fig. 13: When cured thermally at 600 for 48 hours

S. No.	Percentage (Sisal Fiber)	Weight (kg) of 15 x 15 x 70 cm Beam	Flexural Strength (MPa)
1	Reference	43.27	3.3
2	0.50 %	41.29	3.6
3	1.00 %	40.81	3.5
4	1.50 %	40.75	3.9
5	2.00 %	40.86	4.5
6	2.50 %	40.08	2.8

Table 2: Flexural strength at different percentage of sisal fiber, thermal cured at 600 C for 48 hrs and tested after 28 days

7. CONCLUSION

- A Fresh Geopolymer Concrete is made using the design mix developed as a reference mix for the experimental program.
- For experimental program the percentage of sisal fiber of length 1 cm is taken in the range of 0.5%, 1%, 1.5%, 2%, 2.5% w/w of flyash.

- The compressive strength of the Reference mix, in case of ambient curing at temperature of 35-40ºC was 27.22 MPa at 14 days and in case of curing at controlled temperature in a hot air oven for 48hrs. At the temperature of 60ºC was 37.15 MPa at 14 days.
- The flexural Strength of Reference Mix in case of curing at controlled temperature in a hot air oven for 48 hrs. At the temperature of 60ºC was 3.3 MPa at 28 days.
- The concept of using natural fiber as reinforcing material in geopolymer concrete leads to engineering properties.
- The compressive and flexural strength gradually increases with the increase in the percentage of the sisal fiber in the fiber reinforced geo-polymer concrete up to 2%.
- The optimized percentage of the sisal fiber is 2%, which shows the optimum compressive and flexural strength compared to the reference mix.
- After the optimized ratio of sisal 2%, the compressive and flexural strength both decreases.
- The compressive strength of the sisal fiber reinforced geo-polymer concrete (SFRGC) is increased as compared to the reference geo-polymer concrete mix.
- The maximum compressive strength in case of ambient curing obtained at temperature of 35-40ºC reinforced with optimized percentage of sisal was 40.96 MPa at 14 days.
- The maximum compressive strength in case of curing at controlled temperature in a hot air oven for 48hrs obtained at the temperature of 60ºC reinforced with optimized percentage of sisal was 46.37 MPa at 14 days.
- The compressive strength of fiber reinforced geopolymer concrete (with optimized sisal i.e. 2%) have increased about 1.8 times in ambient curing and about 1.4 times in the controlled hot curing (60ºC) with respect to the reference geopolymer concrete.
- The flexural strength of sisal fiber reinforced geopolymer concrete is increased significantly as compared to the reference geopolymer concrete.
- The maximum flexural strength in case of curing at controlled temperature in hot air oven for 48 hrs. (at 60ºC), reinforced with optimized percentage of sisal was 4.5MPa at 28 days.
- The flexural strength of fiber reinforced geopolymer concrete (with optimized sisal i.e. 2%) have increased about 1.5 times in controlled hot curing (60 ºC) with respect to the reference geopolymer mix.
- The maximum compressive strength in case of curing at controlled temperature in a hot air oven for 48hrs obtained at the temperature of 60ºC reinforced with optimized percentage of sisal was 46.37 MPa at 14 days.
- The compressive strength of fiber reinforced geopolymer concrete (with optimized sisal i.e. 2%) have increased about 1.8 times in ambient curing and about 1.4 times in the controlled hot curing (60ºC) with respect to the reference geopolymer concrete.
- The flexural strength of sisal fiber reinforced geopolymer concrete is increased significantly as compared to the reference geopolymer concrete.
- The maximum flexural strength in case of curing at controlled temperature in hot air oven for 48 hrs. (at 60ºC), reinforced with optimized percentage of sisal was 4.5 MPa at 28 days.
- The flexural strength of fiber reinforced geopolymer concrete (with optimized sisal i.e. 2%) have increased about 1.5 times in controlled hot curing (60 ºC) with respect to the reference geopolymer mix.
- The reaction of fly ash was extremely slow during ambient temperature condition, hence initial thermal curing was necessary that can improve the geo- polymerization.
- It is observed that the average flexural and compressive strength of heat cured test specimens was higher than that of ambient air curing.
- Sisal fiber reinforced geo-polymer concrete can be used as the pavement quality concrete (PQC) since it shows sufficient flexural strength as per requirement lay down by the IRC-15-2002.
- The sisal fiber shows the better result with the geo- polymer concrete and can be used as the reinforcing material
- The concept of using fly ash as a cementitious material results in the bulk utilization of waste and solving the environment problems (Air pollution, Ponding, Ground water pollution & Soil pollution etc.)

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