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Comparative Study of Sisal Fibre and Glass Fibre Reinforced Concrete -A Review

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Abstract*: Concrete which is made by mixing cement with aggregates, is widely used to make structural buildings, bridges etc. but alone this mixture could not stand strong for many years. Here comes in play the natural and artificial fibres which can be added to the concrete which are known to increase its tensile strength, fire resistant properties, shock absorbing properties and durability. The natural fibres and artificial fibres affect concrete in different ways enhancing different properties. This paper presents the review of research carried out by various researches over previous years. It also presents the comparative study of different advantages and disadvantages of using natural and artificial fibres in concrete mix.

I. INTRODUCTION

Concrete is a construction material made up of a mixture of cement and aggregate, where aggregate is like sand, stone chips, gravels etc. And cement is the binding material for the aggregates. This simple concrete can now be modified into any shape as it hardens to give a stable structure for many years to come. Owing to the easy availability of raw material in abundance, concrete is economical and can be easily manufactured. It is highly durable. Moreover, its ability to withstand high temperature and non-combustible nature makes it fire proof. Though having many advantages, concrete is less ductile and lacks tensile strength as compared to other binding materials. With time and stress, concrete may develop cracks thereby exposing the internal atmosphere to acid sulphate, moisture, bromine etc. Which degrades the concrete and impair its water proofing property. Besides this, the manufacturing of concrete has a great toll on our environment. The raw material used is found abundantly in nature but are non-renewable. The continuous extraction of gravels and sand which are natural filler materials, from the water bodies results in the uprooting of plants at the banks of the riverbed. The whole process leads to soil erosion and may eventually lead to landslides. Moreover, statistically the production of 1.4 tonnes of ordinary portland cement every year contributes to 5 percent of carbon dioxide and greenhouse gases around the globe. The accumulated effect of these problems soon may be dangerous for the human race. Proper and safe methods must be implemented to safeguard our environment and enhance the properties of concrete alongside. One such method is adding fibre to the concrete mixture.

Various studies have shown that adding artificial or natural fibres to the concrete mixture adds to its tensile strength and increases thermal expansion coefficient which prevents concrete from cracking up under high stress and tension. The increase in the tensile strength depends on the type and the amount of fibre used. The use of fibres in the concrete has grown to a great range with the growing fast-track construction. The short length fibres are dispersed in the concrete mixture thus rendering tensile strength and improving the ductility of the overall mixture. Structures such as road overlays, bridge decks and airfield pavements use steel fibres. Glass fibres are used because they have a high ratio of surface area to the weight. They even render great thermal insulation by trapping air in between them. However, using glass fibres may have certain cons as they can absorb more moisture thereby, worsening the microscopic cracks and surface defects. The use of glass fibres makes concrete mixture more susceptible to chemical attacks. Moreover, artificial fibres are also the part of non-renewable sources which makes them prone to extinction. The pace in which these sources are used may lead to their complete extinction. This is where the use of natural fibres may come in handy. Since, the natural fibres are found in nature and are replenished by nature itself, the question of their extinction does not arise.

Use of natural fibres is more of a theory than the practical thing yet. The natural fibres must be preferred because of their compatibility with the environment, better durability, more strength, and biodegradable nature. Switching from artificial fibres to natural fibres is recommended because they are available in huge amount locally and are very much cheaper than the other alternatives. The natural fibres which can be used include cotton, sugarcane, bamboo, jute, sisal and palm leaf, where sisal is the most advantageous to use because of its high lignin content. Also, sisal fibre is tough due to which it exhibits great tensile strength and holds to this property even in wet conditions.

Various studies on the use of sisal fibre as the reinforcement material in the concrete mixture have shown it to be a promising opportunity. Using natural fibres altogether poses a great challenge and may solve many financial problems of developing countries if they are put to practical use.

Artificial fibres are good in tensile strength and durability but on the other hand have some disadvantages whereas, natural fibres are cheap and environmental friendly. These two types complement each other and hence can give a stronger and better concrete mixture if used together as in hybrid concrete mixture. So far, studies have been conducted on the artificial fibres and natural fibres individually and this paper presents a review on various researches conducted on natural and artificial fibres.

A. SISAL Fibre Reinforced Concrete

Worldwide researches are being carried out to produce durable, structurally safe and most importantly environmental friendly products. Natural fibres have emerged to be the most focused element to create an excellent concrete containing all the desirable properties. Many tests are being carried out to test the physical and mechanical properties of concrete mixed with natural fibres such as sisal, coconut etc. because of their low cost, easy availability, and low energy consumption. The use of sisal fibres in concrete has shown many promising results for structural applications.

The sisal fibre is derived from a plant botanically known as Agave Sisalana. Its leaves are cut, dried, brushed and palleted to form a fibre. The Agave Sisalana's leaves are cut and the inner pulp of the leaves are removed. The outer skin of the leaves thus constitutes the durable and recyclable sisal fibre. The sisal fibre does not absorb moisture and dust, hence are anti-static. They don't wear and tear easily and thus requires less maintenance. Using borax with sisal fibre render them to be fire resistant. They naturally have shock and sound absorbing properties.

Nilson in Sweden, 1971 started the study of sisal fibre reinforced concrete by cutting 10-30 mm fibres and casting them into the beam. He found an immense increase in the tensile strength and toughness when continuous fibres were used.

B. Glass Fibre Reinforced Concrete

The small short length fibres are spread in the concrete mixture of sand, cement, admixture, and water. This is how glass fibre reinforced concrete was made. The concrete thus made looks good in appearance, is light weight, strong, have high tensile strength and is fire resistant. The glass fibre mixed concrete is even acid resistant and has increased energy absorption capacity. The surface area to weight ratio of glass fibre is high which makes it more useful. The fresher and thinner fibre is, the more ductile it is. However, the glass fibre makes concrete more prone to chemical attack due to increased surface area. Since, glass is amorphous in nature using glass fibre may increase moisture absorption and worsen the microscopic cracks formed due to heavy load. Due to these disadvantages of glass fibre the focus is shifted to using another more reliable fibres for concrete. The study of natural fibres is given more preference because of their environmentally friendly nature, cost effectiveness and abundance availability.

II. LITERATURE REVIEW

The research carried out by some of the researchers over the previous years and the outcome have been briefly presented and highlighted in the paras here under. Some of the concrete properties have also been discussed.

Athiappan. K et al. (2014)[1], studied the mechanical properties like modulus of rapture, split tensile strength and compressive strength of M40 grade concrete. The cement of OPC grade 53 was used in the research work. Researchers varied the dosage of sisal fibre content in concrete from 0.1% to 0.5%, by replacing the volume of cement. The optimum length of fibre was taken as 35mm. Optimum dosage of sisal fibre was found to be 0.3% and various mechanical properties were compared with conventional concrete properties of the M40 grade. Results drawn out were: - Modulus of rapture decreases with an increase in the percentage of sisal fibre, Workability decreases with increase in percentage, Flexural strength increases with optimum percentage, Ductility index was nominally higher, Energy ductility was higher for optimum fibre specimen and Stiffness of specimen was higher than the optimum percentage fibre specimen.

P. Sathish et al. (2016)[2], focused his study on replacing the conventional concrete of M30 grade with sisal fibre and different percentage of slag. Cement used was OPC 53 grade. Cement was replaced by slag in a various dosage of 10%, 20% and 30% by weight. Sisal fibre was added at a replacement percentage of 1% by weight of cement and kept as constant. Strength performance and mechanical properties of slag blended fibre reinforced concrete was studied after 7, 14 and 28 days of curing and was compared with the performance of conventional concrete. The author found that optimum replacement of slag powder to cement was 20%. Results drawn from his study were:- Strength was low at the initial stage of curing up to 14 days but as curing period increased, strength started to increase as well. Mechanical properties like compressive, tensile and flexural strength was increased with addition of constant sisal fibre (1%) and ground granulated blast furnace slag content at an optimum dosage of 20% but it decreased with more addition of ground granulated blast furnace slag above 20%.

Abdul Rahuman et al. (2015)[3], presented his research work to check the sustainability, strength properties and workability of sisal fibre reinforced concrete. Different mix proportions and different percentage of fibre was used. Natural fibre i.e sisal fibre was examined to be used in cement concrete. No deterioration of sisal fibre in the concrete medium was observed. Sisal fibre of length 40 mm was used by the author. M20 and M25 grade mix of concrete was prepared by addition of 0.5%, 1% and 1.5% fibre by weight of cement. The degree of workability was achieved by adding 0.2% superplasticizer and water cement ratio 0.45, thus achieving the slump value of 50mm and compaction factor of 0.88. Various tests were conducted to check its compressive, tensile and flexural strength. For M20 Grade of concrete author found that there is an increase in compressive and tensile strength by 50.53% and 44.378% respectively for 1.5% addition of fibre. For M25 Grade of concrete author found that there is an increase in compressive and tensile strength by 52.51% and 36.027% respectively for 1.5% addition of fibre. Tensile strength decreased for M25 grade when compared to the M20 grade of concrete. The conclusion drawn from the study was that 1.5% addition of fibre was giving improved results.

Gaurav Tuli et al. (2016)[4], carried out the experimental study on concrete mixed with glass fibre which is proved to be the good replacing material as it is free from corrosion problem which has to be faced while using steel fibre. In this research work, glass fibre of 14micron was used. These glass fibres, varying from 0.3% to 1% by weight of cement was used to make M20 grade of concrete. Various properties like flexural and Compressive Strength, Toughness and modulus of elasticity were studied. Conclusions drawn was that there is an increase in modulus of elasticity, compressive and flexural strength by 4.14%, 37% and 5.19% respectively of glass fibre reinforced concrete at 28 days when compared to conventional concrete.

C. Selin Ravikumar et al. (2013)[5], carried out a study in which author used glass fibre of 45mm length and added to the concrete at a percentage of up to 1% by volume to determine its mechanical properties and fire resistant properties. A comparative study was done between the properties of conventional concrete and glass fibre reinforced concrete on M25 grade of conventional concrete. Various results shown were: - Compressive strength increased by 13%, split tensile strength increased by 20% and flexural strength increased by 42% when 0.5% of glass fibre was added to the conventional concrete. - Compressive strength increased by 35%, split tensile strength increased by 37% and flexural strength increased by 75% when 1% of glass fibre was added to the conventional concrete. Thus increase was 1.78 times more than that of normal concrete. For checking the fire resistant properties of concrete, the author studied the decrease in compressive strength of concrete after heating it at a temperature of 300C for 2 hours. The author noticed that the compressive strength decreased by 32%, 25% and 10% than its original strength without the addition of fibre, with 0.5% addition of fibre and 1% addition of fibre respectively.

J.D.Chaitanya kumar et al. (2016)[6], carried the study in which various test has been conducted on the concrete mixed with glass fibre at a various percentage level of 0.5%, 1%, 2% and 3% by weight of cement. PPC cement has been used in this study. M20 grade of concrete was prepared as conventional concrete in which further addition of glass fibre was done to prepare glass fibre reinforced concrete. Various results observed from the study included: - workability increases at 1% addition of glass fibre. Increase in split tensile, flexural and compressive strength for the M20 grade with 1% addition of glass fibre was noted. The compressive strength of glass fibre reinforced concrete after 28 days was 28.46N/mm^2 which is very high when compared to the M20 grade of concrete. The tensile strength of glass fibre reinforced concrete after 28 days was 2.94N/mm^2 which is very high when compared to the M20 grade of concrete. The flexural strength of glass fibre reinforced concrete after 28 days was 3.92N/mm^2 which is very high when compared to conventional concrete.

Chandramouli k et al. (2010), [7] did an experimental study on the various grade of concrete M20, M30, M40 and M50. In these grades, glass fibre was added by weight of cement and various tests were performed to check its mechanical properties. OPC of grade 53 was used in the research work. Glass fibre of 14 micron and length 12 mm was used and kept as constant for various grades of concrete. Conclusions interpreted from the study was that there was reduction in bleeding on addition of glass fibre, Surface integrity of concrete was improved and there was less probability of cracks due to improved homogeneity, The percentage increase in compressive strength of various grades of glass fibre concrete mixtures after 28 days varied from 20% to 25 whereas flexural and split tensile strength after 28 days varied from 15% to 20%.

table 1. comparison of physical properties of sisal and glass fibre

physical properties	sisal fibre	glass fibre
tensile strength(mpa)	610-720	2400
young's modulus(gpa)	9-24	73
elongation at break (%)	2-3	3
density(g/cm3)	1.34	2.55

table 2. comparisn of mixing properties of sisal and glass fibre.

sisal fibre	glass fibre
sisal fibre don't get deteriorate with time when used with conventional concrete.	glass fibre also do not get deteriorate with time when used with conventional concrete.
Sisal fibre could be mixed in concrete by hand or in a pan.	Glass fibre should not be mixed more than 1 minute in conventional concrete.
Sisal fibre does not absorb moisture.	Glass fibre can absorb moisture.
Sisal fibre can be used in various lengths like (10, 20, 25, 30, 35, 40)mm.	Glass fibre, when used in the crimped state, gives better results.

Table 2 above defines the mix properties of sisal and glass fibre that should be kept in mind while we are using those fibres in conventional concrete. Sisal and glass fibre don't get deteriorate with time when we use a low content of Portland cement and calcium hydroxide to reduce the potential aging of sisal fibre and it is important to know its deterioration pattern for the durability of these fibres in a normal concrete when used for a long time. Sisal fibre could be mixed in many proportions and at various lengths by different methods like hand mixing, pan mixing, spraying fibres and cement slurry and hand laying fibres etc. Glass fibre should not be mixed more than 1 minute otherwise it will break into pieces and it will not be suitable to work with[3]. Sisal fibre doesn't absorb moisture or attract any dust[1] but on the other hand, glass fibre easily absorbs moisture and can worsen microscopic cracks and surface defects and thus reduce tenacity. Sisal fibre when used in various lengths ranging from (10-40)mm and proportions like (0.3-1.5)% give better results but in the case of glass fibre, it was seen that crimped state of fibre give better results than straight and hooked fibres[5].

Fig (1) raw sisal fibre

Fig (2) raw glass fibres.

Table 3. EFFECT OF SISAL FIBRE AND GLASS FIBRE ON THE PROPERTIES OF FRESH AND HARDENED CONCRETE

PROPERTIES	SISAL FIBRE REINFORCED CONCRETE(SFRC)	GLASS FIBRE REINFORCED CONCRETE(GFRC)
Test on pre-hardened state of concrete i.e. fresh concrete		
Workability	Workability decreases with increase in the percentage of sisal fibre.	Workability decreases but only after a certain amount of addition of glass fibre in the concrete. Workability decreases when fibres used have high aspect ratio.
Test on hardened state of concrete i.e. after 7 and 28 days		
Compressive Strength	Compressive strength increases at an optimum dosage of sisal fibre added to conventional concrete by replacing the cement by weight.	Compressive strength increases immensely at an optimum dosage of glass fibre added to normal concrete by replacing the cement by weight.
Split Tensile Strength	Split tensile strength increases sufficiently at an optimum dosage of sisal fibre used in conventional concrete.	Split tensile strength increases immensely at an optimum dosage of glass fibre used in conventional concrete.
Flexural Strength	Flexural strength increases with increases in an optimum dosage of sisal fibre used in normal concrete.	Glass fibre possesses high flexural strength, therefore, it increased the flexural strength of normal concrete when mixed with it at an optimum dosage.
Fire Resistant strength	Treating sisal fibre with material like borax gives fire resistant properties to the concrete.	Glass fibre has good thermal insulation properties so it gives good fire resistant properties when mixed with normal concrete.

The comparison shown in Table 3 above defines the various properties of concrete when mixed with sisal and glass fibre to form Sisal Fibre Reinforced Concrete (SFRC) and Glass Fibre Reinforced Concrete (GFRC) at the pre-hardened state and hardened state. At the pre-hardened state of concrete workability decreases with increase in the percentage of sisal fibre[1] and in the case of GFRC workability increases at an optimum dosage but after that, it decreases with increase in fibre content[6][5]. At the hardened state of concrete various properties were studied like compressive strength, split tensile strength, flexural strength and fire resistant strength after 7 and 28 days of curing. The compressive strength of SFRC increases sufficiently[3] whereas the compressive strength of GFRC increases immensely because glass fibre has an amorphous structure and high tensile strength[4]. As we know concrete is stronger in compressive strength and weaker in tensile strength, SFRC and GFRC both increases the tensile strength of conventional concrete[3][2][7][5]. The flexural strength of both GFRC and SFRC was increased sufficiently but it was more in the case of GFRC because of its good physical properties as defined in Table 3[1][4]. Treating sisal fibre with borax before adding to the concrete mixture makes it fire resistant [2]. Glass fibre could trap air within them which makes them good thermal insulation material with a thermal conductivity of 0.05w/(mK) thus GFRC has good fire resistant properties.

III. CONCLUSIONS

Sisal is the natural fibre and readily available in local markets and have various eco-friendly qualities like low cost, biodegradable, recyclable and renewable but it lacks in many physical properties when compared to glass fibre like tensile strength, elongation at break and density etc. Glass fibre being artificial fibre could deplete with time and its manufacturing process is very costly. So to use them individually in concrete as a reinforcement is not a good idea. There is a need to shift out construction method techniques

towards environmental friendly techniques by using natural fibres or we should consider in making the hybrid reinforced concrete by adding both natural and artificial fibres in the normal concrete so that the deficiencies of one fibre could be fulfilled by other fibre. This method may prove to be a turning point in the field of civil engineering. The hybrid fibres can offer potential advantages in improving concrete properties as well as reducing the overall cost of concrete production.

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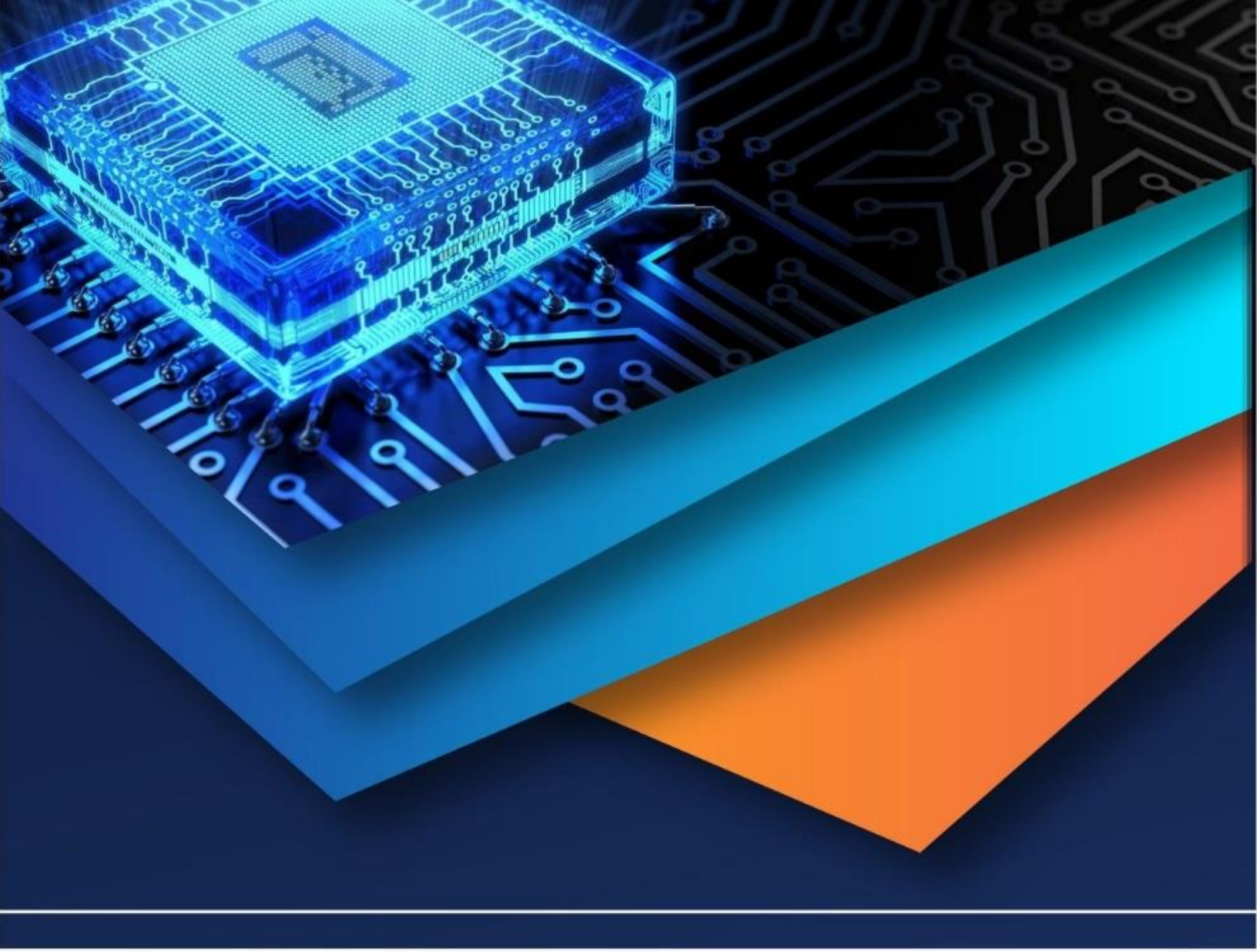

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