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Study Of Sisal Fibre As Concrete Reinforcement Material In Cement Based Composites

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Abstract-In last around 30 years, a great concern is created worldwide on the potential applications of natural fibre reinforced cement based composites. Investigations have been carried out in many countries on various mechanical properties, physical performance and durability of cement based matrices reinforced with naturally occurring fibres including sisal, coconut, jute, bamboo and wood fibres. These fibres have always been considered promising as reinforcement of cement based matrices because of their availability, low cost and low consumption of energy. The general properties of the composites are described in relation to fibre content, length, strength and stiffness in this work. The development of sisal fibre reinforced, cement based matrices is discussed here and studied of experimental works of different investigator on performance of sisal fibre reinforced cement composites. A brief description on the use of these composite materials as building products has been included. The influence of sisal fibres on tensile, compressive and bending strength in the hardened state of mortar mixes is discussed. The durability of natural fibres in cement based matrices is of particular interest and is also highlighted.

1. INTRODUCTION:-

Fibres have been used to toughen bricks and pottery since the very beginning of civilization, but only since last 30 years, the principles of fibre reinforcement of brittle matrices started in practice. The experimental studies showed that the stress at which a brittle matrix will crack can be slightly increased by using high modulus fibres. The fibres bridge across the cracks and so provide post-cracking ductility. The increase in the tensile strain at rupture, resulting in a tough material with high resistance to impact loading is observed. A wide variety of fibres have thus been used with cement based matrices. They include metallic fibres, polymeric fibres, mineral fibres and vegetable fibres. The cement matrices can consist of paste, mortar or concrete. Most of the developments with fibre reinforced concrete involve the use of ordinary Portland cement. However, high alumina cement, cement with additives such as fly ash, slag, silica fume, etc. have also been used generally to improve the durability of the composite or to minimize chemical interactions between the fibres and matrix.

Fibres can be added to cement based matrices as primary or secondary reinforcement. Fibres work as primary reinforcement in thin products in which conventional reinforcing bars cannot be used. In these applications, the fibres act to increase both the strength and the toughness of the composite. In components such as slabs and pavements, fibres are added to control cracking induced by humidity or temperature variations and in these applications they work as secondary reinforcement. Vegetable fibres, including sisal, coconut, jute, bamboo and wood fibres, are prospective reinforcing materials and their use until now has been more empirical than technical.

The natural fibres have been tried as reinforcement for cement matrices in developing countries mainly to produce low-cost thin elements for use in housing schemes. Vegetable fibres require only a low degree of industrialization for their processing and in comparison with an equivalent weight of the most common synthetic reinforcing fibres, the energy required for their production is small and hence the cost of fabricating these composites is also low. In addition, the use of vegetable fibres in cement matrices requires only a small number of trained personnel in the construction industry.

2. BEHAVIOR OF CEMENT BASED COMPOSITES

In cement based composites the two major roles played by the fibres are to improve the toughness and the post-cracking performance of the matrices. There are also some changes created to the pre-cracking behaviour of the hardened matrix, which help to define the composite action.

To increase the strength of the composite over that of the matrix by providing a means of transferring stresses and loads across the cracks

To increase the toughness of the composite by providing energy absorbing mechanisms related to the debonding and pull-out processes of the fibres bridging the cracks.

Knowledge of fibre properties is important for design purposes. Fibre tensile strength is usually higher than the matrix strength and becomes influential in post-cracking behaviour only when long fibres are used or when the matrix is of high strength and a small volume fraction of fibres is used. A high ratio of fibre modulus to matrix modulus facilitates stress transfer from the matrix to the fibre. Compressive strength is generally unaffected by the inclusion of a low fraction (< 0.5%) of low modulus fibres (Ef/Em< 1). At a volume fraction of 2% to 3% the compressive strength can be reduced by about 25% to 30%. However, for Ef/Em> 1 there is generally some increase in compressive strength.

For volume fractions of steel fibres up to 1.5% compressive strength increases of up to 25% have been recorded for normal concrete. This increase of strength results from the high stiffness of the fibres and the internal lateral stiffness of fibres.

Except at very high fibre contents, the tensile strength of the composite is dominated by the matrix strength. Stiff fibres produce some increase in strength, while soft fibres usually have little effect on the composite. After first cracking, load is transferred to the fibres at the crack site and one of several types of behaviour may then ensue, depending on the strength, volume fraction and length of fibres.

3. NATURAL FIBRE REINFORCEMENT COMPOSITES

The need for economical, sustainable, safe, and secure shelter is an inherent global problem and numerous challenges remain in order to produce environmentally friendly construction products which are structurally safe and durable.

In recent years, a great deal of interest has been created worldwide on the potential applications of natural fibre reinforced, cement based composites.Investigations have been carried out in many countries on various mechanical properties, physical performance and durability of cement based matrices reinforced with naturally occurring fibres including sisal, coconut, jute, bamboo and wood fibres. These fibres have always been considered promising as reinforcement of cement based matrices because of their availability, low cost and low consumption of energy.

Fibbers such as sisal, jute and coconut have been used as reinforcement of cementitious matrices in the form of short filament fibres. Short filament geometry composites presented a tension softening behaviour with low tensile strength, resulting in products which are more suitable for non-structural applications. Pulp fibres derived from wood, bamboo and sisal have also been used as reinforcement. The later composites presents two major drawbacks: i) the process for pulp dispersion in water is very time and energy consuming ii) the matrix is a cement paste which presents high consumption of cement, hence, elevated emission of CO2 to the atmosphere and high shrinkage. Such composites are being proposed to be used in non-structural applications.

Vegetable fibre cement composites produced with ordinary Portland cement matrices undergo an aging process in humid environments in which they may suffer a reduction in post cracking strength and toughness. This durability problem is associated with an increase in fibre fracture and decrease in fibre pull-out due to fibre mineralization. Efforts to develop durable cement composite laminates reinforced by long sisal fibres for structural purposes has shown much promising results. A matrix with a low Calcium Hydroxide content increases the long term durability of the natural fibre with a low cement content (only 50% as compared to conventional systems) that helps reduce CO2 emissions and cost, resulting in a sustainable alternative.

4. SISAL PLANT

Sisalisastrongleaf-fibreobtainedfromtheleavesoftheplant *Agavesisalana*.Theplantisamonocotyledonousperennial shrubthatgrowsinthetropicalandsub-tropicalregionsofthe world.Itisoneofthemostextensivelycultivatedhardfibrein the world due tothe ease of cultivation of sisalplants, and is quiteeasytogrowinallkindsofenvironments.Themajor producerofsisalfibresareMexico(120ktons),Brazil(125 ktons),Tanzania(26ktons),Kenya(22ktons),Madagascar (10ktons),China(25ktons)perannum.InIndia,itismainly grownorcultivatedinthearidandsemi-aridregions of AndhraPradesh,Bihar,Orissa,Karnataka,Maharashtraand West Bengal.

Thesisal plant looks like an overgrown pineapple plant with a pineapple-like bole (ashort,stockytrunk)fromwhichthe leavesextend.Foramaturedplant,thebowlisabout50cmin heightandabout20cmindiameter (fig. a).Theleavescanattaina lengthofupto2m, the leaveswhichmaybeasbroadas12cmaretippedwithsharp, highlylignifiedspinesofabout1.0-1.5cmlong. Theoutside ofthesisalleafconsistsofawell-developedepidermiswitha waxysurface. This epidermis contains cutin, waxes and carbohydrates. Initially,allleavesgrowverticallyontheplant but with age, theyfan out gradually.Thematuredleavesarethoseclosesttothegroundcontaining thecoarsestandthelongestfibres.

5. SISAL FIBRE REINFORCED CEMENT BASED COMPOSITES

The use of sisal, a natural fibre with enhanced mechanical performance, as reinforcement in a cement based matrix has shown to be a promising opportunity. The cement matrices can consist of paste, mortar or concrete. Most of the studies on sisal fibre concrete involve the use of ordinary Portland cement. However, high alumina cement, cement with additives such as fly ash, slag, silica fume have also been used to improve the durability of the composites.

Studies of sisal fibre reinforced concrete were started in Sweden in 1971 by Nilsson (1975). Cut fibres with a length of 10- 30 mm were cast into beams and an improvement in the tensile strength in bending was observed for fibre reinforced specimens. It was found that toughness increased markedly when continuous fibre was used. In 1977 the Building

Research Unit (BRU) in Dar es Salaam (Sweden) started collaboration on the development of roof sheets on natural fibre reinforced concrete with the Swedish Cement and

Concrete Research Institute (1979). Test sheets were manufactured for durability experiments. A special roof sheet profile was developed and several buildings have been provided with sisal fibre reinforced concrete roofs. The use of sisal fibre as reinforcement in cement paste and concrete has been reported by Swift and Smith. Their results on the flexural static strength and toughness of beams made of cement based matrices reinforced indicated that remarkably high strengths can be achieved using suitable mixing and casting techniques with optimum fibre volume fraction, although the modulus of rupture is found for different ages.

6. STRENGTH OF SISAL FIBRE REINFORCED CEMENTBASED COMPOSITES

In order to produce a composite reinforced with natural fibres that present tension hardening behaviour, long sisal fibres are employed and a textile composite is developed. Such family of composites is defined as textile reinforced concrete (TRC). The TRC allows the design of thin walled elements with high strength in tension and compression. These composites can be used in various fields of applications such as permanent formworks, tanks, pipes, long span roofing elements, strengthening of existing structures and structural building members.

Recent advances on the mechanical behaviour of durable sisal fiber reinforced cement composites in terms of direct tensile tests performed in the composites. The crack spacing during tension was measured by image analysis and correlated to strain. Local and global deformation was addressed. To demonstrate the high performance of the developed composite in long term applications, its resistance to tensile fatigue cycles was investigated. The composites were subjected to tensile fatigue load with maximum stresses ranging from 4 to 9.6 MPa at a frequency of 2 Hz. These stress levels represents approximately 30% and 80% of the UTS, respectively. The fatigue tests were stopped either at 10^6 cycles or complete failure of the composite, whichever occurred first. Composites that survived 10^6 cycles are tested under monotonic tension to establish its residual strength.

7. CONCLUSION:-

1. Use of continuous sisal fabrics that are formed by aligning and stitching the fibres in a multilayer cement composite system present a new perspective for the use of natural fibre reinforced composites in the construction industry. A matrix with a low content of Portland cement and calcium hydroxide was used to reduce the potential aging of sisal fibres.
2. From the hysteresis stress-strain curves it was noticed no signs of degradation for maximum stress level.
3. For maximum stress levels, there was an increase in the hysteresis area and decrease in the Young´s modulus.
4. The impact response of sisal fibre-reinforced cement composites under a three-point bending configuration. Test results were evaluated to determine the flexural impact behaviour in terms of maximum flexural stress, maximum deflection, energy dissipated by specimen, and crack patterns of the specimens.
5. A comparison with AR glass fabric-reinforced composites indicates that sisal fibre-reinforced cement composites present a more ductile behaviour under impact loads.
6. Glass fabric composites presented strain rate dependence with regard to ultimate strength.
7. The damage morphology consisted of matrix cracking and de-lamination. The damage process was initiated by the formation and distribution of flexural cracks.

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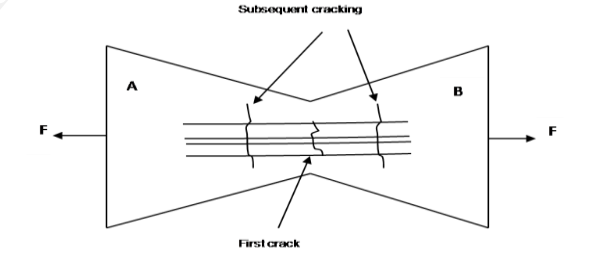

Figure 1 Cracking Mechanism in fibre reinforced Composites

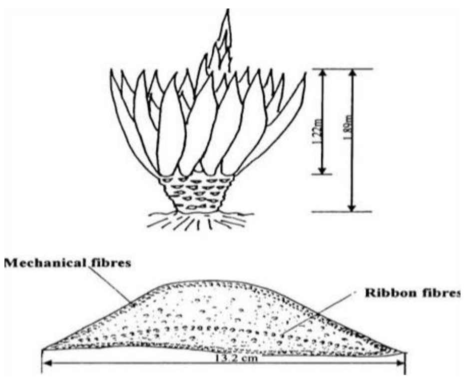

Figure 2 Sisal Plant and Leaf dimensions

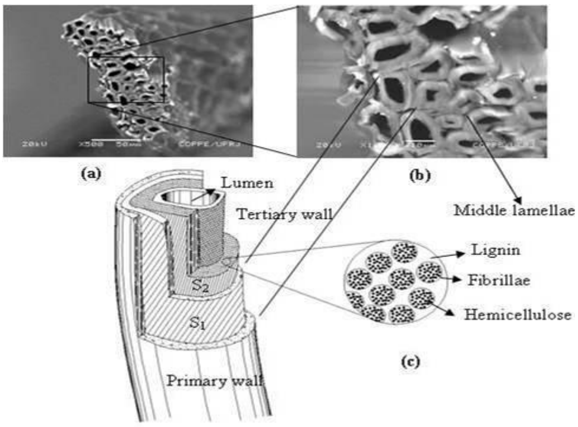

Figure3: Sisal Plant Internal structure and fibre content[5]

Table 1 Physical and Mechanical Properties of sisal Fibre[6]

Fibre tenacity (ghex)	40-45
Tensile strength (MPa)	0.4-0.7
Young's modulus (GPa)	9.0 - 20.0
Elongation at break (%)	2.5-4.5
Moisture regain (%)	11
Density (g/cc)	1.45
Porosity (%)	17
Fibre diameter (μm)	100-300