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Past Investigations on Strength and Durability Characteristics of Natural Fibre Reinforced Cement Composites with Nano Silica

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Abstract: *Natural fibres have drawn attention from the researchers and engineers in the recent years due to their mechanical and durability characteristics comparable to the conventional synthetic fibres, steel fibres, etc, and due to their low cost, eco-friendliness and biodegradability. Enormous experimental studies are being carried out to determine the mechanical behaviour of different natural fibre types such as the modulus of elasticity, split tensile strength, flexural strength and Poisson's ratio. This review paper shall focus on strength and durability properties of the major types of natural fibre reinforced composites based on the recent experimental investigations and findings of the researchers.*

Keywords: Natural fibre, Cement composites, Nano Silica, Mechanical properties, Durability properties.

I. INTRODUCTION

Fibres are thread like materials which can be used for different purposes. Fibres delivered by plants (vegetable, leaves and wood) creatures and geological procedures are normal fibres. The pattern of research on characteristic fibre strengthened solid composite is presently expanding the increment in cost of high vitality materials and furthermore accessibility of answers for improve toughness of normal strands in concrete. Nowadays the plant fibres to replace conventional fibres as reinforcement in compositions due to environmental and ecological issues. It embraced fundamentally because the characteristics of eco-friendly like qualities, ease, and generally great properties and so on.

In present days, due to simultaneously increment on condition and energy, expanding consideration paid to be normal filaments with a high energy and protecting environmental issues. Materials like jute, sisal, coir, rice husk, flax, bamboo, banana, oil palm, sugarcane bagasse and so on, however specialists and researcher have found an alternate kind in concrete. Furthermore, it has observed the outcomes of sisal, coconut and bamboo are all the more promisingly accomplished its test condition and their low their low thickness, ease and biodegradability. Natural fibres are cheap, but it required greater skills in producing, placing and mixing does the conventional reinforced concrete and yet unproven long term performance and durability.

II. CRITICAL REVIEW ON THE INVESTIGATION OF NANO SILICA REPLACED CEMENT MORTAR

2.1 Gulzar H.Barbhuiya et.al Studied on

- This paper has enough data about using nanomaterial nano silica as partial replacement in cement this include their behavior in fresh, harden and theirphysical property.
- The setting time reduced to a extend, the mechanical property like compressive strength, split tensile strength, flexure strength and elastic modulus have improvemental behaviour like durability character but structural micropores have a reduced behaviour.
- As an overall view this addition of Nano silica reduces the content of cement used,which results in decreased release of CO2 contributing to global warming.

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2.2 D.S.V.S.M.R.K. Chekravarty et.al concluded that,

- The basic study about replacing the active nanomaterial in high graded cement toobserve their characters in both fresh and harden state by various test propertieslike mechanical and durability was examined and discussed.
- The absorption has a conclusion of using 3% Nano silica for having better response above that the properties are not that much promising.

2.3 Luciano Senff et.al investigated on,

- Durably examination for nano-silica particle were done in this.About2.5% weight was considered.
- Rheological test on viskomat PC viscometer for 75 minutes which shows low flowability.

2.4 Sakshi Gupta experimented on,

- Today's active pozzolonic material, nano-silica. Extremely fine onecomprising 1000 time smaller than cement particle.
- It provides major advantage in filling pores in cement content enhancingits maximum mechanical and durability properties.
- This nano-structured particle in mortar directly involved in theimprovement of fresh properties and compressive strength.

2.5 Pothala Vasudeva Reddy & K. Chandrasekhar Reddy discussed on:

- The novel microstructure nano-silica was examined in this study, whichare used to enhance mechanical and durability characters.
- Ultra-high resolution field strength and flexural electron microscopy (FE-SEM) and X-ray are utilized to observe fracture surface & flakes of 4.5% Nano silica .
- About 22.25%, 38.77% & 10.25% raise in compression, bending & splittensile strength of cement mortar.
- Acid resistance and salt resistance were done and noted for a weight loss as a result of durability test.

III. CRITICAL REVIEW ON THE INVESTIGATION OF FIBER REINFORCED CEMENT MORTAR

3.1 Kittipong Kunchariyakun et.al investigated that,

- The wood fibre waste (WFW) reduced the dry density, compressive andflexural strengths approximately 4-3%, 10-70% and 3-65% respectively under normal curing, low heat curing and autoclave curing.
- Compared to normal curing and low heat curing, the autoclave curing shows relatively low values of flexural-compressive strength ratio.
- The mortar with 5% of wood fibre waste by weight under normal curing at 28 days shows highest flexural-compressive strength ratio.

3.2 Mareike Thiedeitz et.al investigated on:

- Agriculture by product rice husk ash as supplementary cementitious material is tested in this study. Scanning electron microscopy (SEM) & X- ray diffraction (XRD)analysis, compressive strength and durability properties were examined, and theirresults were compared with control mix.
- Carbonization resistance and capillary suction in durability investigation have aincreased performance.
- The result from this durability is like decreased crystalline phase with XRD and lowwater absorption resulting in less capillary pores.

3.3 Kirupairaja Thanushan et.al interrogated on,

- The cement stabilized soil blocks reinforced with Banana fibre and coconutfibre were tested for compression, flexural bending, water absorption, sorptivity, acid and alkaline attack, wet drying, freezing and thawing.
- Banana fibre shows better post-peak behaviour in compression and coconut coir fibre shows better post-peak behaviour in flexural.

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- Both fibre reinforced blocks show enhanced durability against acid andalkaline attack, wet-dry weathering and freeze-thaw weathering.
- The coconut fibre shows better durability compared to banana fibre.

3.4 Sasha Rai P et.al investigated that

- The Compressive strength of palmyra fibre reinforced concrete reduced fibre content up-to 2% of varying length.
- Increase in split tensile strength, flexural strength, and shear strength withincreased fibre content.

3.5 Valeri Laverde et.al discovered that,

- The effect of fibre length on the mechanical properties of the reinforced composites.
- And the result shows that the short fibres increase the flexural, tensile and toughness of fibre-reinforced cementitious composites (FRCC).
- And also, the long fibres which are used as an external reinforcement increase the compressive strength of textile-reinforced cementitious composites (TRCC).

3.6 Chandrashekar S. Malalli et.al investigated that,

- The Natural fibre-reinforced polymer composites (NFRP) are used in medical devices and various engineering applications due to high specific strength, low thermal conductivity and biodegradability.
- Also reports that the natural fibre PALF-sisal reinforced polymer composites have better mechanical performance than the synthetic fibre reinforced polymers.

3.7 Xun Gao et.al investigated that

- The mechanical strength of the bamboo fibre is contributed by alternately arranged thin and thick layers.
- Thermoset polymer-based bamboo fibre composites give higher mechanical strength than thermoplastic- based fibre composites.
- The short bamboo fibre has a greater reinforcing effect in cement mortar than in concrete.
- Boiling bamboo fibre in distilled water, and then treating in NaOH solutiongives long term performance of bamboo fibre reinforced cement mortar composites.

3.8 Raj Govindchandrasekaran G. Ramakrishna investigated on,

- The study appreciably good flexural and split tensile strength for all the fibre (Sisal, Palmyra, coir & banana) composites compared to control mix.
- Sisal fibres with better results on workability and compressive strength compared to all other fibres.
- The proposed reinforcement scheme using natural fibre would assure economic feasibility and cost-effectiveness as the fibre are cheaper and available patently in this.

3.9 R. Borinaga-Treviño et.al investigated on,

- The physical, thermal and mechanical properties of cement mortar which isbeing reinforced with recycled brass fibres.
- Brass fibres of length 10mm, 15mm and 25mm had been used in different percentages to correlate the strength characteristics of each with the control mortar.
- The study revealed that the addition of recycled brass fibres provided a better flexural strength while the compressive strength got decreased. Also, thermal conductivity increased. It is suggested that using short fibres (10 mm) of highest percentage gave considerable flow ability. On the other hand, without considering flow ability the use of long fibres provided the largest improvement in mechanical properties.

3.10 G. Ramakrishna & T. Sundararajan investigated on,

- Highest impact strength was absorbed by reinforcing 2% of coir fibre in mortar slab.

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- Coir fibre reinforced cement mortar slab specimen gave average increase in crack resistance ratio on comparing with other fibre involved specimen suchas sisal, jute & hibiscus.
- Coir fibre reinforced slab specimens have the highest residual impactstrength ratio among the various types of natural fibres.

3.11 M. Vaishnavi et.al studied on,

- As fibre like nylon, coir, sisal and cotton have good resilience and extensibility, they show higher mechanical and durability properties.
- Comparing with other fibres nylon have opposite character, have increasingworkability with increase in fibre %.
- As per studies increase in aspect ratio decreases compressive strength.
- Addition of fibre bring out drastic change in improvement of mechanical and durability properties.

3.12 Emad Booya et.al experimented on,

- The study is based on the comparison between mechanically and chemically treated kraft pulp fibre.
- As observed the TF have less permeability character, shrinkage strain and compressive character comparing with UTF.
- This study found that these specially designed fibre (MMF and CTF) can be used for durability enhancement.

3.13 Ons Hamdaoui et.al investigated on,

- Simplified models of cement paste reinforced with Posidonia Oceania fibres for studying the thermal and mechanical properties with conventional one.
- The range of 5 – 10% of fiber reinforcing have improve mental behaviour in above mention properties and above that there is a sudden decrease in those characters.
- A noticeable increase in toughness of about 65% for 20% of fibre reinforcing.

3.14 Sandra Juradin et.al concluded that,

- The influence of harvesting time, fibre processing method, fibre length and amount of fibres on the mechanical characteristics of cement composite with Spanish broom fibre have been studied.
- The results of strength after 28 days and 56 days of curing were absorbed. Summer harvested groom gave high yield than fall harvested groom.
- Study shows it provide high flexural & tensile (980Mpa) and low compressive strength.

3.15 Sumit Chakraborty et.al showed that,

- The physical and mechanical properties of cement mortar with polymer modified alkali treated jute fibre as a reinforcing agent had been studied.
- Chopped fibres of 2-5 mm length treated in 0.5% dilute solution of sodium hydroxide and the solid polymer content in emulsion in variations between 0.0252% and 0.205% were being added in a combined state by a novel processing methodology.
- The study showed that the optimal polymer content in emulsion (0.0513%)is found to increase the compressive strength, modulus of rupture and flexural toughness respectively as compared to control mortar with a decrease in flexural modulus.

3.16 Bojan Poletanovic et.al concluded that,

- The influence of the hemp fibres, treated with sodium-hydroxide, on the properties of fly-ash based alkali-activated mortars and their durability before and after wet & dry cycles.
- The various dosages of sodium hydroxide treatments of hemp fibres lead to separation of fibre bundles and increase the fibres' surface roughness. The porosity of the specimens lowered for 15% & 26% and the water absorptioncapacity got reduced for 4% & 11%.

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- All fibre treatments lead to increase in the compressive for 24% and 43%and flexural strength for 19% and 23%, prior and after the wet/dry cycles respectively. The fibre reinforced mortar's energy absorption capacity increased for approximately 13% and 14%.

3.17 R. Sathia et.al investigated that,

- Caryota Urens (Fish Tail Palm Fibre) natural plant fibres are a sustainable concrete solution to develop high strength fibre reinforced self-compacting concrete.
- Addition of fibres is mainly to increase the mechanical strength of SCC. Fibre up-to 3% increases the compressive strength, split tensile strength and flexural strength.
- Beyond 3% fibre, increases the porosity of concrete and thereby the mechanical strength decreases.
- It reduces and avoids the stress concentration and sudden failure of concrete structures.

3.18 Markos Tsegaye Beyene et.al experimented on,

- The Ensete ventricosum (Ev) fibre reinforced cementitious composites improved the post-cracking stiffness, toughness and flexural strength with increase of fibre content of 3%, 4%, 5%. The strength increases of 260%, 274% and 396% respectively.
- The pretreatment of fibres (soaking in water for 48hrs) before reinforced inmatrix increase the mechanical performance of the Ev fibre reinforced composites.
- Sample reinforced with 5% presoaked fibre are the best mechanical capacity compared to other series of test. The strength increase of 396%compared to the unreinforced mortar specimens.

3.19 M. Vaishnavi et.al studied on,

- The strength and workability characteristics of self-compacting cement mortars which had coir and nylon fibres as reinforcement.
- Coir fibres of 1cm & 2cm and nylon fibres of 1cm were used at different percentages of 0.125%, 0.250% and 0.300% of solid weight.
- Results revealed that specimens experienced an enhancement in compressive strength in nylon fibre than coir fibre. On the other hand,the workability had brought little better in nylon fibre whereas in coir fibre, the workability decreased.

3.20 Soukaina Ajouguim et..al posted that,

- Alfa fibre with different aspect ratio (<2 & 10,20,30mm) are involved in this study, considering their character as fresh mortar and flexure & compression in harden state are examined.
- The various volumes of fibre (1%,2% & 3%) are tested, in those samples <2% fibre content containing samples having decrease in mixture workability and have delayed setting timing.
- In mechanical character they show improvement in flexure and decrease in compression characteristics. By overall this type of fibre is useful in enhancingadhesive property.

3.21 Hongwei Song et.al showed that

- The addition of Jute fibres in cementitious composites (CCs) enhance the mechanical properties as well as eco-friendly.
- The jute fibres of shorter lengths and lower volume content can increase the strength properties of CCs while the higher volume content of jute fibres degraded the strength properties of CCs.
- Shorter length up-to 20mm and lower proportions up-to 0.5% volume fraction.

3.22 Iranildo Barbosa da Silva Junior et.al investigated on,

- In this paper the composite matrix with low calcium hydroxide content replacing cement with fly-ash and metakaolin reinforced with 3 layered unidirectional sisal fibre were tested for mechanical characteristics.

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- This composite gave higher strain resistance in direct tension and lower ultimate bending strength in 4-point flexure test.
- There is a decrease in strength and strain capacity after creep observed in stereoscopic microscope. The composite with saturated fibre gave 48.2% reductionin toughness in tension creep while composite with natural humidity fibre provide 35.3% reduction.
- In overall study it is conclude that for a higher sustained load the higher is the deflection over time and the lower is the recovery rate.

3.23 Hyeonseok Choi et.al studied on,

- Comparative study between hemp and jute fibre of various dosage (0,0.25,0.5,1,2%) as natural cellulose fiber-reinforced cement. These are examinedfor their mechanical characters.
- Decrease in compressive strength & increase in setting time were observed withincrease in fibre mix proportion.
- The UPV and UPV rate over time and the heat of hydration were measured for cement composites mixed with fibres. The results showed that hemp and jute fibres delayed the hydration of cement.

3.24 S. Candamano et.al highlighted that,

- The pretreated hemp fiber reinforced cement mortar is examined using X-raydiffractometry, Fourier-transform infrared spectroscopy, thermogravimetric analysis and scanning electron microscopy is done in this study.
- The durability drying shrinkage and mechanical properties are tested and having incremental result.
- This show increasing effect in absorption capacity, shrinkage value & load carryingcapacity and reduced character in sorptivity character upto 50%.

3.24 Fotini Kesikidou and Maria Stefanidou investigated on,

- The use of recycled materials like bio-fibres as additives in cement and limemortars to study the differences in the strength, durability and other such properties.
- Three types of natural fibres such as jute, coconut and kelp fibres were combined and taken in same length as additives in 1% by mortar volume.
- The results obtained, revealed an increase in flexural strength especially due to coconut fibers and also fracture energy increased whereas under compression, there is a decrease of strength up-to 15% in cement mortars but in lime mortars, compressive strength increased by 250%.

3.25 Chunheng Zhou et.al discussed that,

- Kenaf fibre reinforced high strength cement composites (KFRHC) with three different strength grades and different water-cement ratios of 0.25, 0.3 and 0.35.
- The compressive strength of KFRHC was decreased by 12.2%-46.2% and the flexural strength was increased by 30.7%-66.9%.
- This shows the negative effect on compressive properties and positive effect on flexural properties.

3.26 Gonzalo Ruano et.al discussed on,

- The mechanical behaviour of cementitious composites reinforced withsugarcane bagasse and hemp fibres.
- The workability had reduced, and hydration process had been altered.
- Bagasse fibres provided greater flexural strength whereas hemp fibresresulted in increased toughness.

3.27 Danso H and Manu D discussed on:

- The influence of coconut fibres and lime on the properties of soil-cementmortar in which the coconut fibres of 0.2%-0.8% and lime of 0-15% were combined to prepare the cement mortars.
- The results showed that with 0.2% of coconut fibre and 5% of lime content,the soil-cement mortars achieved the optimum amount of strength in bothcompression and tension tests. The density had been recorded to be

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increased with the increase of both lime content and coconut fibre.

- Also lime content seemed to reduce the water absorption rate of the specimens providing a higher resistance to the specimens against water.

3.28 Sabrina Vantadori et.al innovated on,

- The cement-based mortar reinforced with date palm mesh (DPM) fibresincreases the ductility of mortars by increasing the fibre content.
- The decrease of flexural strength and fracture toughness is significantfor fibre content greater than 4% and 6% respectively.
- The toughening mechanisms observed are crack deflection; fibre-matrix interference de-bonding with fibre fracture.

3.29 M. Mathavan et.al discovered that,

- The addition of natural fibres (cotton, wool, silk, linen, nylon, polyester) in various proportion such as 1%, 2%, 3% increases the mechanical and durability behavior of mortar.
- Increase in water absorption in plant fibres, organic and inorganic fibres compared to conventional mix.
- Increase in compressive strength in plant fibres and organic fibres than in inorganic fibres and increase in split tensile strength in organic fibres than in plant fibre and inorganic fibres.
- Increase in flexural strength in plant fibres and inorganic fibres than in organic fibres.

3.30 Mohammed Asim et.al investigated that,

- The fibre treatments will develop high performance kenaf (KF) and pineapple leave fibre (PALF) reinforced polymer composites for industrial application.
- And also observed that the silane treated KF and PALF increased the tensile strength and interfacial stress strength than those of untreated, alkaline and NaOH silane treated.

3.31 Daniel Fernando Hincape Rojas et.al investigated on

- The changes occurred in morphology, structure, thermal properties & flexural with incorporation of 3,5 & 7% of Nano-silica was studied withmicroscop, X-ray thermogravity & mechanical test.
- Increase in resistance to bending upto 16.25% was observed with 5% addition of fibre.

3.32 Colbert Babé et.al investigated that,

- The adobes millet is characterized by mechanical, geotechnical, thermal & durability test.
- There is about 38% and 23% improvement in compressive (> 4Mpa) and thermal respectively with incorporation of 2% and 4% of millet fibre. Providing more resistance to abrasion, erosion & water on comparison with pure matrix.
- On other hand, decreasing thermal conductivity from 0 to 23% was noted.

3.33 J.M.L. Reis et.al discussed that,

- The mortars with pissava fibre as reinforcement in natural polymer and resinproduced from castor oil seeds of synthetic minerals in polymer mortars matrix was analyzed.
- The piassava fibre improves fracture toughness and stiffness especially of 1% fibre content. And also, piassava fibres contribute brittle failure.
- Castor oil polymer mortars behaves similar to epoxy polymer mortars and also the properties are significantly higher in castor oil polymer mortars compared to epoxy polymer mortars.

3.34 G. Ramakrishna and T. Sundararajan investigated on,

- The studies on the durability of natural fibres like coir, sisal, jute and *Hibiscus cannabinus* and the effect of corroded fibres on the strength of mortar.

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- The fibres are subjected to alternate wetting and drying and then immersed in three mediums (water, saturated lime, sodium-hydroxide)for wholly 60 days.
- The specimens resulted with an increase of 40-60% and 20-40% of original tensile strength in coir fibres and 60-70% in sisal fibres. Corroded fibre specimens gained lesser compressive strength 30-60% of original strength on exposure to three mediums.

3.35 Jawad Ahmad et.al experimented on,

- The addition of natural fibre up-to 2% decreases the mechanical performance of the concrete due to lack of workability.
- And also recommended that the tensile capacity of concrete can be improved by using 1%.

3.36 Jonathan Page et.al invented on,

- The coatings of flax fibres with linseed oil are tested both in fresh and hardened states of mortar. To evaluate the performance of coating the water absorption test were conducted.
- Increased workability of paste reinforced with flax fibres and linseed oil.
- In hardened state, the nature of the fibre coat increases the flexural strength beyond 90 days of curing. Linseed oil coated fibre composites areproved to be most porous.
- Flax fibres increase the mortar toughness and prevent from dehydration cracking.

3.37 Thuany E.S.Lima et.al investigated on,

- This work is based on addition of NaOH treated guaruman fibre on different 2.5, 5& 7.5% on cement mortar matrix ratio 1:1:6 OPC.
- Technical properties like mass density, consistency, incorporated air content &water retention have about 3% increase for 7.5% fibre in their fresh state. This same have an increase from 92.7% to 94.24% with treated one.
- Finally, it is concluded for the use of wall covering in civil constructions.

IV. CRITICAL REVIEW ON THE INVESTIGATION OF FIBER REINFORCED CEMENT MORTAR WITH NANO-SILICA REPLACEMENT

4.1 Afonso R.G. de Azevedo et.al investigated on,

- 3.0% of NaOH treated açaí natural fibres in mortars is recommended tobalance the technological and durability properties.
- There is an increase in nominal values in certain properties is justified in thestudy up to 5.0% addition.

4.2 Wang Yongggui et.al investigated on,

- As adding nano-silica and basalt fibre to recycled aggregate reinforced concrete, there is an increase in brittleness, slump & workability and decrease in plastic performance.
- There is a decreased behavior in mechanical property with RA replacement of recycled aggregate without addition of NS and BF.
- For considerable compressive strength and microstructure, when the replacement ratio does not exceed 50%, the optimum NS amount is 6%; when the RA replacement ratio is 100%, the optimum NS amount is 8%.

4.3 Jing Yu et.al investigated on,

- The improvement of the mechanical and fracture properties using nano-silica in fibre-reinforced high-volume fly-ash cement mortar studying the hydration, fresh, mechanical and durability properties.
- Poly vinyl alcohol (PVA) fibres were used as reinforcement with nano-silicain four dosages to study the variations in the characteristics of mortar specimens.

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4.4 R. Yu, P. Tang et.al investigated on,

- The study of multiple effects of nano-silica and hybrid fibers on theproperties of Ultra-High Performance Fiber Reinforced Concrete incorporating waste bottom ash.
- In this study, the modified Andreasen and Andersen particle packing modelis employed. The workability, porosity, flexural and compressive strengths have been analyzed. Steel and propylene fibers were used.
- This study results where the use of waste bottom ash decreased the compressive strength, workability and cement hydration. On the other hand, nano-silica and hybrid fibers improved the flexural strength andrestricted and minimized the cracks.

4.5 Mayank Gupta and Maneek Kumar investigated on,

- The study of effect of nano-silica and coir fibre on the compressive strength and abrasion resistance of concrete.
- Coir fibres with varying percentages and 2% & 3% of nano-silica along with 15% of fly ash as partial replacement of cement had been added tothe concrete mixture.

V. CONCLUSION

This review paper summarized the history of natural fibres, mechanical and durability characteristics of concrete by using different natural fibres such as hemp, pineapple, sisal, jute, palm, bamboo, etc, which were used to substitute synthetic, glass and steel fibres. The fibre addition improves the crack resistance, reduce the crack width and at the same time workability of concrete is affected. The compressive strength is not affected much upto certain natural fibre content but due to addition of fibre, there is a significant improvement in flexural strength and impact strength.

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