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The Use of Plant-Based Natural Fibers in Reinforced Cement Composites

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***Abstract*—**Plant-based natural fibers are used more increasingly in construction materials. It is done to reduce the pressure on the built environment, which has been increased dramatically due to the increases world population and their needs. Plant-based natural fibers are abundant in many countries. Despite the low-cost of such environmental friendly renewable material, it has the ability to enhance the mechanical properties of construction materials. This paper presents an extensive discussion on the use of plant-based natural fibers as reinforcement for cement-based composites, with a particular emphasis upon fiber types; fiber characteristics, and fiber-cement composites performance. It also covers a thorough overview on the main factors, affecting the properties of plant-based natural fiber cement composite in it fresh and hardened state. The feasibility of using plant-based natural fibers in producing various construction materials; such as, mud bricks and blocks is investigated. In addition, other applications of using such fibers as internal curing agents as well as durability enhancer are also discussed. Finally, recommendation for possible future work in this area is presented.

***Keywords*—**Cement composites, plant fibers, strength, mechanical properties.

I. Introduction

SUSTAINABILITY was addressed by World Commission of Environment and Development (WCED) to be a concept whereby the requirements of the current generation are fulfilled in a way that enables the following generations to fulfill their own requirements [1]. However, due to surges in global populations, there has been a rapid accumulation of burden on the existing environment. It was corroborated in a study by Melbert [2] that considered the built infrastructure and the construction industry to be the primary causal factors contributing to waste production in addition to energy and resource expenditure. In addition to consuming land, energy resources, and raw materials, it was seen that construction businesses greatly contribute to environmental pollution through the emission of greenhouse gases (GHSs). An effective way of elevating the level of sustainability in construction materials is to utilize the by-products of the industrial processes and make use of renewable materials for the purpose of construction.

Concrete reinforcement makes use of three variations of natural fibers. These are namely plant-based, animal-based and mineral-derived fibers. Plant-based fibers are inclusive of jute, cotton, sisal, hemp, flax and specialty-fibers that are processed using wood or other plant-based materials whereas, animal fibers, comprising specific proteins, include silk, wool, and hair fiber and mineral-derived fibers include asbestos, wollastonite and palygorskite. Cementitious material characteristics may be significantly enhanced via use of plant fiber reinforcements. Natural fibers are relatively advantageous as compared to man-made fibers due to the fact that they are procured from renewable sources and have a cost-effective availability. Incorporating plant-based natural fibers in cement-based composites present a variety of advantages in the form of resource, energy and environmental conservation.

The aim of this study is to present existing research pertaining to the reinforcement of short and pulp fibers derived from plant sources in cement mortar and paste. A special emphasis would be laid on the fresh and hardened characteristics of composites. Furthermore, the performative abilities of these fibers in the form of mechanical efficacy and durability are greatly addressed. Additionally, current and future implications of the utilization of such fibers have been highlighted.

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II. Types of Plant-Based Natural Fibers

Plant-based natural fibers exist in a variety of forms. These are highlighted below.

A. Bast Fibers

The extraction of bast fibers is commonly carried out from sources such as the external bark of plant stems. Bast fibers of flax, kenaf, jute and abaca are commonly recognized.

B. Leaf Fibers

Leaf fibers are greatly characterized through their distinctive properties of coarseness and hardness. These fibers are procured from leaf tissues through mechanical extraction. Additionally, leaf fibers can be obtained by beating and retting the leaf tissues followed by scraping by hand. The distinctive strength of these fibers means that they can be widely utilized for making mats, fabrics, carpets and ropes. Commonly recognized examples of these fibers are pineapple, sisal, henequen and caroa.

C. Seed Fibers

Coconut husks are common sources for obtaining seed fibers. The distinctive strength and low weight of these fibers makes them ideal candidates in the manufacture of sacks, brushes, mats and ropes. Such seed fibers can additionally be obtained from the pods of plant seeds. Seed fibers that are obtained in this manner are inclusive of milkweed floss, kapok and cotton.

D. Stalk Fibers

Common sources for obtaining stalk fibers are corn, eggplants, sunflowers, sugarcanes and wood. Additionally, stalk fibers may be extracted from a variety of grains such as rice, wheat and barley.

E. Grass and Other Fiber Crop Residue

This category of fibers may be obtained from tall grasses such as bamboo, elephant grass, rye grass and switch grass.

F. Wood and Specialty Fibers

Trees form a common source for the procurement of wood fibers. These trees may be classified into two categories of interest, which are namely hardwood and softwood trees. A primary distinction between these two categories is that softwood fibers are more elongated than hardwood fibers. Fig. 1 denotes the six groups of plant fibers discussed. The following section caters to the process of fiber extraction for these abovementioned categories.

Fig. 1 Types of plane-based natural fibers from left to right: bast fibers, leaf fibers, seed fibers, stalk fibers, grass fibers and wood fibers

III. Fiber Extraction Processes

Following the process of retting, most of the plant-based strand fibers are collected either by decorticators or through separation via mechanical and manual means. Additionally, the minimization of wood chips or fiber strands into separate fibers is carried out via a pulping mechanism [3]. The mechanical process of pulping involves grinding the wood chips or fiber strands in three primary modalities, which are: steaming (thermo-mechanical pumping); steaming or chemical pretreatment (chemi-thermo-mechanical pulping), and; no use of steam.

With regard to the chemical pulping process, the separation of bundled fiber strands and wood chips is carried out through the use of heat or chemical processes. The aim of the heating and chemical treatment is to eliminate the presence of lignin from the fiber strands and wood chips. It is to be noted that although mechanical pulping processes present greater advantages with regard to the amount of pulp generated, chemical pulping processes succeed in producing fibers with a relatively greater strength, brightness and elongation. Following the chemical pulping process, mechanical beating and bleaching of the fibers may be carried out based on the purpose for which the fibers are to be utilized.

IV. Mechanical, Chemical and Hygric Fiber Structures

The composition of the plant-based fibers is in the form of lignin, ash, cellulose, and hemicellulose components. The proportions of these components are largely dependent on a variety of factors that are inclusive of age, plant location, fiber type, extraction, processing, and growth condition. Table I illustrates the chemical structural variations for some specified fibers of interest [4]-[6].

TABLE I
Chemical Composition of Plant-Based Natural Fibers

Grouping	Fiber	Cellulose	Hemicellulose	Lignin	Extractives	Ash
Bast	Jute	33.4	22.7	28.0	–	–
	Hibiscus	28.0	25.0	22.7	–	–
	Banana trunk	31.48	14.98	15.07	4.46	8.65
	Banana	60–65	6–8	5–10	–	4.7
Stalk	Sorghum	27.0	25.0	11.0	–	–
	Bagasse	32–48	19–24	23–32		1.5–5
	Bagasse	41.7	28	21.8	4	3.5
Straw	Wheat	33–38	26–32	17–19	–	6.8
	Rice	28–36	23–28	12–14	–	14–20
	Barley	31–45	27–38	14–19	–	2–7
Leaf	Sisal	38.2	26.0	26	–	–
	Sisal	73.11	13.33	11.0	1.33	0.33
	Banana	25.65	17.04	24.84	9.84	7.02
	Pineapple	70–82	18.0	5–12	–	0.7–0.9
	Corn stover	38–40	28.0	7–21	–	3.6–7
Seed	Coir	36–43	0.15–0.25	41–45	–	2.7–10.2
	Coir	33.2	31.1	20.5	–	–
	Coir	21.46	12.36	46.48	8.77	1.05
	Coconut tissue	31.05	19.22	29.7	1.74	8.39
Wood	Eucalyptus	41.57	32.56	25.4	8.2	0.22

The existence of hydroxyl groups and hemicellulose components contribute to the hydrophilic nature of the abovementioned natural fibers. This was corroborated by studies conducted by Alvarez et al. [7] that linked the ability of plant fibers to absorb moisture with the elevated levels of hydroxyl groups in their cellulose structures. The presence of porous cell walls, hydroxyl groups and open lumens greatly contributes to plant dimension instability due to high moisture absorption. An additional study by Farul et al. [8] highlighted that fiber mechanical properties and performative abilities in composite materials is greatly associated with the moisture absorption of plant fibers.

Existing research pertaining to this discussion highlighted that the chemical makeup of the plant fibers heavily influences their mechanical characteristics, due to the presence of lignin, cellulose and hemicellulose. These components greatly affect the bonding and fiber degradation of these fibers in composite materials. Corresponding studies by Li et al. [9] affirmed this relationship by discussing the vital role of cellulose and microfibril orientation within the cell wall in contributing to the stiffness and strength of these fibers. It is to be noted that the chemical makeup and mechanical characteristics of these fibers is affected by the method used for fiber extraction. Table II illustrates the mechanical characteristics of selected plant fibers of interest [8]. As may be seen from this table, the fiber tensile strengths are at reasonably high values even though the modulus of elasticity is low, and the strength values show a high degree of variation. Due to the low levels of density and cost-effectivity of these fibers, they may be utilized in cement composite materials so as to reinforce them.

TABLE II
MECHANICAL PROPERTIES OF SELECTED FIBERS [8]

Grouping	Fiber source	Tensile strength (MPa)	Young Modulus (GPa)	Elongation at break (%)	Density (g/cm3)
Bast	Abaca	400	12	3–10	1.5
	Flax	345–1035	27.6	2.7–3.2	1.5
	Jute	393–773	26.5	1.5–1.8	1.3
	Hemp	690	70	1.6	1.48
	Kenaf	930	53	1.6	–
	Ramie	560	24.5	2.5	1.5
	Bamboo	140–230	11–17	–	0.6–1.1
Leaf	Sisal	511–635	9.4–22	2–2.5	1.5
	Curaua	500–1150	11.8	3.7–4.3	1.4
	Pineapple	400–627	1.44	14.5	0.8–1.6
Seed/fruit	Coir	175	4–6	30	1.2
	Oil palm	248	3.2	25	0.7–1.55

V. FIBER-CEMENT COMPOSITE PROPERTIES AND PERFORMANCE

Cement properties are subject to changes due to the hardening process. Therefore, these properties are different prior to the hardening process and following the hardening process. Fresh cement properties are noted prior to the hardening process. The most prominent fresh properties are consistency, setting time and plastic shrinkage.

A. *Consistency*

Mansur and Aziz [10] observed an overall reduction in the workability of cement was observed, with the fiber's content and length increasing when compared to the fiber-less mixture. The cement's composite's decreased workability has also been observed by Savastano et al. [11] when it is reinforced with coir, eucalyptus pulp or eucalyptus pulp mixed with sisal fibers. Reduction in workability has been reported here to be an outcome of the moisture being absorbed by fibers.

They may be resolved through the use of a fiber pre-treatment that aids in the reduction of the fiber chemical components having water-absorption properties. Additionally, the fibers could undergo through a pre-wetting process prior to being incorporated in the mixture. Fiber-reinforced cement mixtures demonstrating reasonable workability may additionally be manufactured by taking into account the properties of water absorption of these fibers.

B. *Setting Time*

It was indicated by some studies that plant fibers are detrimental to cement composite hydration. In a study by Bilba et al. [12], it was discussed that water-soluble sugars that arise due to lignin alkaline hydrolysis and hemicellulose partial solubilization greatly contribute to prolonged setting time and decreased heat of hydration in bagasse-reinforced cement composites. This was corroborated by additional studies by Sudin and Swamy [13] that suggested causal factors for delayed setting time in bamboo-reinforced cement mixtures to be in the form of a high level of sugar present in the fibers. Their dissolution results in the formation of compounds of calcium in the cement mixture that result in a decrease in the hydration temperature and delayed production of hydration products in the cement mixture.

Additional studies by Sedan et al. [14] corroborated these findings by observing that setting time delays in hemp-reinforced cement composites are attributed to pectin that works as a calcium silicate hydrate (CSH) growth inhibitor in the fibers. Recent research by Fan et al. [15] highlighted that the presence of hemicelluloses and carbohydrates in wood contribute to decreased cement hydration in wood-reinforced cement composites. This was corroborated by a study conducted by Vaickelionis and Vaickelioniene [16] that attributed hydration delays to the soluble sugar concentration in the cement mixture. It was suggested by the study that adding Pozzolan aids in the reduction of hydration delays. Furthermore, using pre-treated fibers that contain reduced levels of lignin in the cement mixture may alleviate hydration delays. It was further suggested that elevated curing temperatures and use of chemical accelerators may aid in the improvement of early hydration. Other factors that may aid in this process include the use of supplementary materials having a wide surface area.

C. *Plastic Shrinkage*

When water evaporates from fresh cement-based mixtures' exposed surfaces, there is a chance that plastic shrinkage cracking will occur. Research demonstrates that the tensile stresses created in plastic cement mixtures can be relieved through the addition of various plant-based fibers. Research by Sanjuán and Tolédo Filho [17] shows that low volume coconut and sisal fibers not only effectively controlled cracking in mortars but also seemed to slow down the beginning of reinforcement corrosion in samples. In another study, Toledo Filho and Sanjuan [18] saw that low volume sisal fiber, especially was quite effective in at decreasing crack development and free plastic shrinkage in cement mortars. Toledo Filho et al. [19] also researched the influence of low volume fraction of short coconut and sisal fibers on the shrinkage of both hardened and fresh mortar matrices. They observed that both of these fibers were able to decrease free plastic shrinkage and also delay initial cracking when it came to restrain plastic shrinkage. This improvement in plastic shrinkage resistance was caused by greater elastic modulus of fibers, as well as to the crack abridgment they would induce [18], [19]. Research by Boghossian and Wegner [20] demonstrated that low volume fraction of short flax fibers effectively decreased restrained plastic shrinkage cracks in cement mortar. Figs. 2 and 3, adapted from [20], demonstrate that maximum crack area and crack with both decreased as the mixtures' flax fiber content rose. There was a 99.9% reduction in total crack area relative to the reference mixture and a 99.5% reduction in maximum crack width at a fiber volume fraction of 0.3% and a fiber length of 10 mm. This improvement in plastic shrinkage resistance is probably due to hydrophilic flax fibers inducing an enhanced fiber-matrix bond [20]. It is also possible that the lowered bleeding of the fibers as well as the reduced rate of settlement of particles played a factor in the plastic shrinkage resistance. According to Soleimani et al. [21], the number of cracks and crack width in mortar mixtures that included 0.25 to 0.75% estabragh (*Asclepias procerais*) fiber experienced a reduction of 67% and 90% respectively, compared to the reference mixture, this decrease in plastic shrinkage was credited to crack abridgment by the fibers.

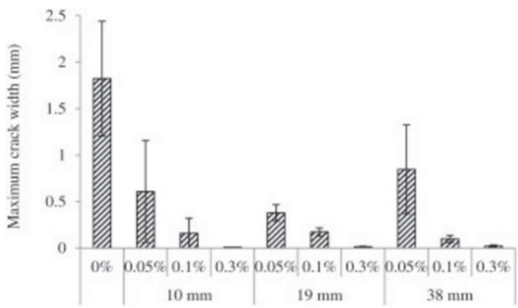

Fig. 2 L Flax Fiber Length and Volume [20]

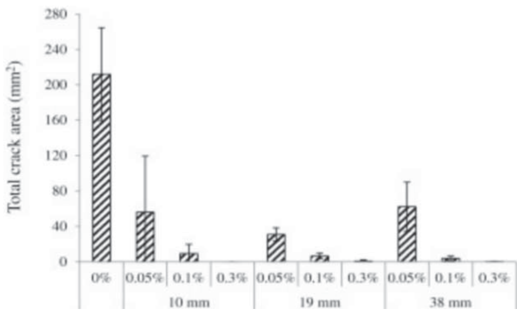

Fig. 3 Flax Fiber Length and Volume [20]

The properties undergo changes, as follows.

D.Drying Shrinkage

Drying shrinkage problems, both restrained and free will regularly occur in hardened cement-based mixtures. According to some research [19]-[22], these problems could not be resolved when plant based natural fibers were added to cement mortar. In fact, the volume addition of coconut fibers and sisal fibers caused cement mortars' drying shrinkage to rise by 2 to 3%, according to research conducted by Filho et al. [19]. The report also observed that the composites including sisal fiber experienced more drying shrinkage than the ones with the coconut fiber; since sisal fiber's surface is less smooth and its water absorption is higher. These findings are matched by research by Silva et al. [22] which studied cement matrix reinforced by sisal fiber, and reported high drying shrinkage. This occurrence was due to the higher porosity of samples. It therefore appears that a combination of factors affects the drying shrinkage tendencies of cement mortar that has been fortified with plant-based natural fiber, including fiber volume fraction, fiber characteristics and the resultant effect on the matrix pore structure.

E. Mechanical Strength

It was seen by studies that the incorporation of synthetic fibers within cement composites aids in the improvement of qualities such as ductility, toughness and impact resistance [3]-[6]. Fig. 4 shows the results obtained by Ramakrishna and Sundararajan [23] with regard to the impact resistance tests.

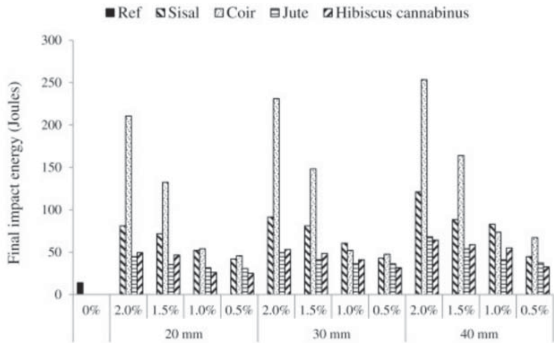

Fig. 4 Flax Fiber Length and Volume [23]

As may be seen, the plant-reinforced mortar slabs demonstrated an impact resistance that was 3-18 times greater than that observed for the mortar slabs that were not reinforced with plant fibers. It was additionally seen that there was a directly proportional relationship between the impact resistance and the volume length and fraction of the fibers. The greatest level of impact resistance was noted for coir fiber reinforced slabs. This may be due to its properties of extensive elongation at break (as shown in Table II) relative to the other investigated fibers. It was suggested by Munawar et al. [24] that coconut fiber demonstrates the most toughness in natural fibers, where their capacity for strain was noted to be 4-6 times higher than the other investigated fibers. Coir fibers are seen to demonstrate great ductility that aid in the reduction of brittleness that is so often seen in cement composites. Table III depicts an overview [25]-[29] of the mechanical characteristics of air cured cement composites that are reinforced with a variety of pulp fibers. As may be seen, the mechanical strength of cement paste that was reinforced with strand sisal fibers was less as compared to sisal pulp fibers. The greater mechanical strength of the cement composites that are reinforced with sisal pulp fibers may be attributed to the elevated levels of fiber surface area and decreased stiffness, due to which there is an improvement in fiber-matrix interaction. Fiber-matrix interactions may further be affected by pulp refinement via beating and elevated levels of fiber aspect ratio, as was seen in the case of abaca fiber-reinforced

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cement composites. Table III additionally illustrates that there are different patterns for toughness and flexural strength. Although, toughness increases with an increase in composite fiber volume, it is seen that optimum fiber content with regard to flexural strength stands at 8-10%.

TABLE III
28D MECHANICAL STRENGTH OF CEMENT COMPOSITES REINFORCED WITH DIFFERENT VEGETABLE FIBERS

Cement matrix	Fiber type	Fiber volume	Fiber aspect ratio	Flexural strength	Flexural toughness
Paste	–	0	–	11.8 ± 3.7	0.04 ± 0.01
	Refined softwood kraft pulp	4	53	19.2 ± 1.9	0.64 ± 0.09
		8		23.5 ± 0.8	1.32 ± 0.11
		12		25.0 ± 2.1	1.93 ± 0.42
	Unrefined waste sisal kraft pulp	4	122	16.5 ± 0.6	0.39 ± 0.06
		8		21.5 ± 1.6	0.92 ± 0.13
		12		20.3 ± 1.4	1.41 ± 0.20
	Unrefined Banana kraft pulp	4	127	15.5 ± 1.3	0.21 ± 0.03
		8		19.5 ± 1.4	0.53 ± 0.08
		12		20.1 ± 2.5	1.01 ± 0.15
	Unrefined Eucalyptus kraft pulp	4	61	15.6 ± 0.8	0.29 ± 0.04
		8		21.4 ± 0.9	0.82 ± 0.11
		12		22.2 ± 1.3	1.50 ± 0.18
	Sisal strand	4	89	14.4 ± 1.0	0.58 ± 0.17
	Refined bamboo kraft pulp	2	–	10.9 ± 1.5	0.07 ± 0.01
		4		12.1 ± 1.3	0.15 ± 0.02
		6		16.2 ± 1.0	0.23 ± 0.02
		8		17.4 ± 0.9	0.32 ± 0.03
		10		18.6 ± 1.2	0.45 ± 0.07
		12		19.2 ± 1.5	0.54 ± 0.05
		14		21.8 ± 1.7	0.70 ± 0.06
	Refined abaca kraft pulp	2	400	17.5 ± 2.0	0.47 ± 0.10
		4		21.8 ± 2.1	0.93 ± 0.24
		6		26.3 ± 1.6	1.76 ± 0.48
		8		27.3 ± 3.2	2.08 ± 0.33
		10		24.7 ± 3.9	2.19 ± 0.78
Mortar	Unrefined Sisal kraft pulp	0.5		9.2 ± 0.7	0.25 ± 0.02
		1		9.9 ± 0.8	0.45 ± 0.03
		1.5		11.3 ± 0.8	0.62 ± 0.07
		2		12.7 ± 1.2	0.84 ± 0.08
		4		15.9 ± 1.2	1.64 ± 0.17
		6		16.7 ± 1.0	2.05 ± 0.29
		8		18.3 ± 1.3	2.49 ± 0.47
		10		15.0 ± 1.7	2.47 ± 0.46
		12		10.3 ± 1.6	3.07 ± 0.58

It was discussed earlier that the level of moisture greatly affects the mechanical strength of plant-reinforced cement mixtures. Table IV shows the variation in percentage with regard to toughness and flexural strength in cement composites as a result of water absorption. It was seen that the level of water saturation resulted in 18-51% decrease in flexural strength. It was additionally noted that composite toughness demonstrated a significant elevation. Studies pertaining to this regard highlighted that the hydrogen bonds present between fibers or between the matrix and fibers are greatly destroyed due to water absorption [30]. Subsequently, it was seen that there was a reduction in the composite flexural strength with softened fibers and weak fiber-cement matrix bonding. Conversely, enhancement in toughness levels may be contributed to elevated levels of frictional stress and pull-out force due to the swelling of the fibers [31]. Furthermore, studies pertaining to this regard highlighted the strong influence of specimen moisture content in changing the failure mechanism and mechanical strength of the cement composites [32]. It was reported that mortar reinforced with oven-dried pulp fibers resulted in reduced levels of toughness and greater flexural strength as compared to wet cured or air cured specimens. It may therefore be seen that the performance of composites is greatly dependent on regulation of moisture absorption in these fibers.

TABLE IV
THE EFFECT OF 48 H WATER SATURATION ON MECHANICAL STRENGTH

Cement matrix	Fiber type	Fiber volume	Flexural strength	Flexural toughness
Paste	Refined abaca	2	−32.6	+100.0
		4	−29.4	+223.7
		6	−40.7	+156.8
		8	−45.8	+130.3
		10	−51.0	+87.7
Mortar	Flax – 510 CSF	2	−26.4	+26.3
		4	−17.6	+108.8
		6	−22.4	+95.8
		8	−22.4	+107.1
		10	−26.1	+80.7
	Flax – 555 CSF	2	−22.4	+30
		4	−27.7	+62.2
		6	−27.6	+101.2
		8	−25.2	+84.8
		12	−35.1	+44.4
	Flax – 555 CSF	2	−23.5	+11.1
		4	−31.0	+5.7
		6	−23.4	+87.3
		8	−31.7	+81.3
		10	−38.7	+70.3
		12	−44.7	+68.3

F. Influence of Fiber Degradation on Cement Composite Durability

Durability is considered to be an important factor in cement composite design due to its influence on their long-term resistance to damaging substances. It was discussed in studies that fiber reinforced cement composites demonstrate high susceptibility to cement matrix deterioration as a result of water absorption and weakening of alkaline pore solution in these fibers. Furthermore, composite deterioration is accelerated by weathering. A primary causal factor for plant fiber deterioration in cement mixtures may be attributed to lignin dissolution in addition to hemicellulose linkage of the separate fiber cells using alkaline pore solution [33]. The degradation may additionally be accelerated through fiber de-polymerization by alkaline hydrolysis, where the disruption of linked glucose molecules and shortening of the chain length of the molecules may be noted [33], [34].

It was suggested by studies that the cellulose's fibrillary morphology and crystallinity are factors upon which the degradation rate is dependent [35]. Therefore, the rate of degradation is noted to be inversely proportional to the cellulose crystallinity. As per the study by Ramakrishna and Sundararajan [4], there was a decrease in the levels of cellulose, hemicellulose and lignin in hibiscus, coir, jute, sisal and jute fibers that were exposed to saturated lime, water and solutions of sodium hydroxide (NAOH). Incorporating these corroded fibers as part of cement mortar resulted in a decrease in the mechanical strength of the specimen.

A study by Filho et al. [33] conducted an exploration of the loss in strength in coconut and sisal fibers that were exposed to alkaline solutions and the effect on durability when such fibers are added to cement mortar composites. It was seen in this study that the alkaline exposure of these fibers contributed to a loss in their flexibility. Furthermore, the mortar composites were seen to undergo a great loss in toughness. According to an additional study by Mohr et al. [36], the mechanical strength noted for kraft pulp fiber reinforced cement paste underwent a great decrease after being exposed to 25 dry or wet cycles. Furthermore, Romia Jr. et al. [18], [37] studied the mechanical characteristics of cement roof tiles that were reinforced using eucalyptus and sisal fibers and suggested that the toughness of these composites underwent a substantial reduction on being exposed to weathering. It is thus apparent that the ineffective resistance of plant fibers to weathering and alkaline solutions greatly constrains their applicability in cement composites. Therefore, a variety of methods have been investigated with regard to the alleviation of fiber degradation in cement composites.

VI. Recent Developments and Future Trends

A. Reinforcing the Cellulose Fabric

Augmentation of the composites of cement with fiber fabrics is a promising emerging method. The reinforcement of fiber fabric could increase the fiber content of composites negating the need of fiber dispersion troubles that are usually faced in discrete plant-based fiber composites that are reinforced. There were a lot of studies that did some investigation that the conduction of the synthetic fiber did augment the composites of cement [38]-[42]. A very minor number of studies have shown that the cement composites go through reinforcing by a mechanical presentation [43]-[45].

B. Internal Curing Agent

An arisen technology for the design of outstanding performing cement composites with lessened internal cracking potential is internal cutting. Several studies have been exploring the internal curing ways of superabsorbent polymers (SAP) and also the pre-wetted fine light-weight aggregate (LWA) in materials that have cement found in them [46]-[52]. A few of these studies [53]-[56] tend to show that the fibers that are saturated cellulose can eventually act as internal curing agents in mortar and pastes made of cement. Further research on the influence of fiber horrification, fiber content, fiber type, desorption mechanism and fiber types are a requirement. A comprehensive list of details on fiber dispersion, a design mixture and the consequence of fiber properties that are based on new and strengthened performance of the composites of cement that have been cured internally with cellulose fibers that are saturated and this is also a requirement.

C. Durable Enhancing

For achieving infrastructures that are sustainable, novel and affordable methods that reduce the degrading of processes that helps in impairing the service and function of cement composites were implemented. These degradation processes include corroding, curling and the permeability of chloride and water. In comparison with a plain slab that is reinforced, Banthia et al. [57]-[60] came out with a latest studies that report on lessened cracking and curling in slabs that are concrete and incorporate a volume fraction (0.3%) of cellulose fiber of specialty Therefore, in comparison to different approaches to reduce the curling of flatworks, for instance as the usage of more thick end sections, the surplus synthetic fibers and the ongoing reinforcements within slabs, usage of the low fraction volume cellulose fibers is recommended by this present study to be a more economical approach.

D. Nano-Reinforcing Cellulose

Nano-manufacture of a huge variety of high-performing composites and materials is getting a large interest among many industries. Cellulose Nano-Crystals and Cellulose Nano-Fibers (CNFs) are both high surface and strength particles, that can get isolation from cellulose fibers using acid hydrolyses and mechanical fibrillation. Also, CNCs and CNFs, both being Nano-sized are distinct in their chemical compositions and dimensions. The amorphous cellulose that contains CNFs forms an interlined connection of fibers, with each fiber that measures between a range of 2-5 μm in length and the more crystalline and short CNCs mostly measure a small hundred 20 nanometers in length. A lot of studies have been investigating the probability of the extraction of CNF and CNC from different plant and wood sources [61]-[69].

VI. Future Implications Regarding Plant-Fiber Reinforced Cement Composites

Aside from the role played by plant fibers in traditional cement composites, there is a variety of additional applications presented by them in the construction industry. In a study by Bergado et al. [70], it was suggested that there is widespread applicability of synthetic fiber geotextiles in embankment stabilization with a high rate of efficacy. This may be utilized in situations where there is a long-term requirement for ground enhancement and sustainability regarding construction. Furthermore, using such plant fibers is highly pertinent with regard to the manufacture of biodegradable fabrics and fibers. An amalgamation of plant fibers that have undergone chemical treatment may be utilized for soil stabilization over a long period of time. Sarsby [71] suggested that the temporary sub-soil and sub-base separation required in road construction, embankment support and erosion regulation may be carried out relatively better by well-designed plant fibers such as sisal, flax and coir as compared to synthetic geotextiles. Additional studies highlighted that flax-fiber reinforced soil cement composites demonstrated a significant enhancement with regard to ductility [72]. Studies pertaining to discussions of cost-effective energy conservation and building construction suggested the use of plant-reinforced fibers for building purposes. In a study by Aggarwal [73], it was highlighted that the durability and mechanical characteristics of bagasse-cement composites were in accordance with ISO: 8335-1987 and BS: 5669: Part 4: 1989 standards and could therefore be utilized as external and internal elements in construction processes. According to Binici et al. [74], conventional mud bricks were heavier than fiber reinforced mud bricks. Furthermore, the compressive strength in the fiber-reinforced bricks was seen to be greater than their conventional counterparts. According to an additional study, Binici et al. [75] discussed the role of straw fiber in enhancing the thermal insulator capability of mud bricks, resulting in energy conservation within buildings. Whereas, Khedari et al. [76] highlighted that coir-fiber reinforced soil cement blocks weighed less than unreinforced specimens and demonstrated lower levels of thermal conductivity. Likewise, Goodhew and Griffiths [77] highlighted that unfired bricks that were reinforced using straw, paper or wool demonstrated thermal conductivities that were lower than the limits prescribed by the United Kingdom Building Regulations. Shehata et al. conducted two studies that emphasized the role of saturated cellulose pulp fibers in the surface curing of concrete structures in addition to them being used as durability improvers and internal curing agents in cement composites [78], [79].

VII. CONCLUSION

It was discussed that plant-reinforced cement composites have undergone a rapid evolution due to the rising requirement for sustainability in applications; such as cost-effectivity, raw material use, strength, lower densities and availability of the fibers. However, it was seen that the property of moisture absorption in these fibers in cement composites has adversely impacted their durability and mechanical characteristics and led to a reduction in their level of utilization. However, it was seen that there are a few applications; such as hot-weather concretion where this property may be seen as an advantage. Furthermore, these fibers are unable to resist a cement environment that has a high Ph, due to which their usage has been seen to be reduced. It is essential that further research should be conducted to investigate the percussions of fiber pre-treatment methodologies and alternatives based on the composite performance over a long period of time. Future studies are additionally needed to study the effects of using such fibers on cement matrix pore structures, crack abridgement and chloride and water permeability. Additionally, it is essential that novel approaches should be studied to investigate the water retention capabilities of these fibers with regard to producing high-performance cement composites.

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