ANALYSIS ON FIBER REINFORCED EPOXY CONCRETE COMPOSITE FOR INDUSTRIAL FLOORING – A Review

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Abstract.

Fiber composites are the having an good scope in construction industry as they are light in weight, durable, economic, and resistant to temperatures. Many researchers concentrate on the composites for the industrial flooring with the fibers. The main objective of this paper is to review the fiber reinforced epoxy for industrial flooring. Epoxy can be used as flooring elements in industries as they deliver good performance. Since, natural and synthetic fibres can be used with filler matrices, which are very much cheaper than the conventional steel fibres reinforced composite concrete flooring and other type of composites here fibre is considered for reinforcing with epoxy or polymer concrete filler matrix. Fibre-polymer and fibre-concrete composite properties has been reviewed for testing procedure for flexural test, bending test, tensile test and based on the results, it is clear that the fibre-polymer concrete composite, which has good mechanical properties and performance than the mentioned composites, can be made for industrial flooring.
1. Introduction

Industries are the places which are specially customized for all type of dynamic and static loads. Here the loads act from movable elements and mainly from the service loads of all elements of the industry. The loads (static and dynamic) acting in an industry are service loads of equipments and machineries, trucks, trolley, conveyors dead and live loads, load from labours, loads of stored units, vibrations from working machineries and service loads of structures.

The others factors considered while selecting the type of flooring in an industry are cost, site conditions, temperature conditions, self-weight of flooring elements and installation and maintenance type and cost in future. The commonly used industrial flooring systems are steel fibre reinforced concrete, semi reinforced concrete, plain reinforced concrete, polyurethane flooring, and smoothing concrete and mesh concrete.

In general, steel fibre reinforced concrete is mostly used as it is convenient to cast in site and has better mechanical performance than the other types. Polyurethane flooring is a modern method of flooring and has a smooth top surface, which is necessary in industries as oil spills occur often and smooth top surface helps in wiping out the oil spills easily. Generally, tiles which are used in residential and commercial buildings is not prefered in industry floorings because of their light weight, durability, less mechanical strengths and poor performance for industries.

Composite is a term used for mentioning the element or substance combining two or more basic substances of different characteristics. Fibre is reinforced with other materials such as polymers, cement paste or mortar, etc. The polymers or cement mortar acts as filler matrix and fibers as reinforcements. Fibres are lengthy, thin substances which are obtained naturally from plants, waste organic materials, coir, etc. Also the fibers can be made artificially such as nylon, aramid and acrylic.

Polymers are the chemical compounds which are continuous chains of ether groups and are adhesive in nature. They are generally used as matrices while using fibers as reinforcements. The commonly used polymers are epoxy and polypropylene. Hardeners are used as catalysts during the process of making fiber composites.

2. Literature Review

[1] Tested acrylic, polyester and aramid fibers in uniaxial tension and used 2 to 6.5% of synthetic fibres to perform splitting tensile test, four point beam bending test and toughness test. They found the stresses in flexural test and tensile test for the reinforced beam is significantly greater than the non-reinforced beam and [2] mentioned fibre reinforced concrete, at time of mixing the fibre gets randomly mixed and improve concrete properties in all directions, as fibers transfer load to the internal micro
cracks. They stated that FRC has excellent flexural strength, resistance to spitting, impact resistance, permeability and frost resistance and FRC increases toughness, shock resistance, resistance to plastic shrinkage cracking of mortar and freeze thaw resistance. They [3] stated fibers have always been considered promising as reinforcement of cement based matrices because of their availability, low cost and low consumption of energy. They used sisal fibre and found sisal fibre reinforced cement composites present a more ductile behavior under impact loads and [4] mentioned fibrous materials tend to increase both mechanical and thermal properties such as tensile strength, flexural strength, flexural modulus, heat deflection temperature, creep resistance and impact strength of thermoplastics. They used 10%, 20%, 30% fiber with polypropylene and conducted that viscosity of PP increases with fiber content and elastic behavior of matrix decreases with fiber content at 180° C because fiber acts as filler at this temperature. [5] They mentioned that synthetic fibers are used as reinforcement in concrete and soil to improve their properties and used recycled fibers for low cost raw materials and resource utilisation. They concluded 2.6 volume % fiber reinforcement has good flexural properties. [6] They developed oil palm press fibre reinforcement composites. They used 5 wt% to 30 wt% oil palm fibre and concluded that 20 wt% shows optimum tensile, flexural and impact strength. Alkali treatment further increases the strength of the composite. They [7]used M30 mix concrete and plastic fibers from 0% to 3% by volume. The optimum tensile and compressive strength was observed at 1%, thereafter reductions in strength were observed. [8]M20 mix concrete and polythene fibers from domestic waste plastics. They concluded 0.5% addition increases compressive strength and split tensile strength. [8]Turmeric fibers with polyester to enhance the bonding between fibres, they treated the fibre with NaOH, KMnO4 and H2SO4. They stated that tensile strength increases up to 22.38% Vf and further increase in Vf results in decrease in tensile strength. [9] Kenaf fibers with polypropylene. They stated 20% Kenaf fiber addition exhibit significant increase in the initial modulus or stiffness of the composite. They functionalized PP and concluded that modified matrix have superior mechanical properties by improved adhesion and enhanced polar interactions. [10] Researched on the effects of process parameters on tensile strength of jute and polypropylene composites. They developed matrix composites by hot compression technique for percentages such as 5%, 10% and 15* by weight. They stated tensile strength increases with increase in the fiber size and fiber percentage. They concluded that 10% wt additions of 2mm fibers have good tensile strength. [11] Analyzed properties of fiber reinforced polymer concrete by using epoxy resin, fly ash as filler, cellulose fibers. They concluded that increase in rein dosage increases split tensile strength and for same dosage of epoxy, compressive strength and split tensile strength can be attained to maximum by increasing the fly ash content up to 12.8%. A review on sisal fiber reinforced polymer composites. They analysed various polymers and natural fibers and concluded sisal fibre reinforced polymer composites can be made on constant
research and experiments. [12] An attempt to improve the impact property of coconut fibre reinforced epoxy composites using sodium lauryl sulfate treatment. They concluded that fiber length and SLS increase the impact strength. [13] Analyzed the use of fibers in concrete industrial ground floor slabs and reviewed various type of fibers as a replacement to steel-fabric reinforcement in industrial ground floors. They concluded synthetic fibers can be made as replacement to steel reinforcement in flooring. [14] Analyzed the mechanical properties of polymer concrete. They concluded that polymer concrete has better mechanical properties and durability by addition of 15% fly ash, 0.5% moisture content, seven day curing and resin dosage in range of 10-20%. [15] Analyzed the mechanical behavior of coir reinforced polyester composites. They concluded woven coir composites have good mechanical strengths than the untreated coir. [16] Studied on effects of short coir fiber reinforcement on flexural properties of polymer matrix. They used coir and polypropylene in various percentages and concluded 20% coir reinforcement at 4mm thickness has good flexural strength and elongation.

3. Test

The properties and performance of the composites can be analysed only by performing tests. The fibre-polymer composite and fibre-cement mortar were subjected to flexural (bending) test, toughness test and tensile test for various proportions of fibre and filler matrix. They were compared to analyse the fibre-polymer concrete composite.

3.1. Tensile test:

Tensile test is needed to find the tensile strength of the fiber-matrix composite. The tensile strength of the composite is expressed in MPa or N/mm². The tensile strength of fiber-cement paste or concrete filler is given in Table 1. The tensile strength of the fiber-polymer filler is given in Table 2.

| SL. NO. | FIBRE USED | TENSILE STRENGTH IN MPa |
|---------|------------|-------------------------|
| 1       | Acrylic    | 2.5                     |
| 2       | Acrylic+   | 3.3                     |
| 3       | Nylon      | 2.7                     |
| 4       | Nylon+     | 2.2                     |
| 5       | Plastic fibers | 3.87                |

+ At fibre volume fraction Vf 2.4%
Figure 1: Tensile strength for Fiber – concrete composites

[7] The plastic pet fibers and concrete composite is efficient with 1% addition of plastic fibres. Hence, tensile strength of 1% addition of plastic fiber is mentioned here. [1]Nylon fibres and acrylic fibres mixed with 2-4.5% wt. with the cement paste. On the addition of 0.5% of polythene bags fibres [8] and the tensile strength of the composite is increased to 1.63% when comparing to conventional concrete. On the addition of natural fibres with concrete, 1.78% increment is observed [2]on comparison with the ordinary concrete.

Table 2: Fiber-polymer composite

| SL. NO. | FIBRE USED | TENSILE STRENGTH IN MPa |
|---------|------------|-------------------------|
| 1       | Oil palm   | 50                      |
| 2       | Coir       | 40.83                   |
| 3       | Sisal      | 31.12                   |
| 4       | Turmeric   | 34.76                   |
| 5       | Kenaf      | 28.4                    |
The coir has different tensile strength values as 30 MPa, 44.1 MPa, 46.83 MPa, 43.98 MPa, 26.8 MPa, 29.7 MPa for various patterns and treatments. [15] The tensile strength for Kenaf fibre is 26.9 MPa when 20% kenaf fibre is added with polypropylene. [16] Turmeric fibre addition is efficient until the addition is 22.38% and tensile modulus at 22.38% addition is as high as 744.3 MPa. The tensile strength of sisal is taken for 30% of fiber content.

3.2. Bending test:

In need to find the flexural strength of the composite element, bending test is done. The flexural strength is given in MPa or kN/m². The flexural strength of fibre-cementious filler composite is given in Table 3 whereas the flexural strength of fibre-polymer filler composite is given in Table 4. Artificial fibre and natural fibre composites were considered. Flexural strength depends on the orientation and type of fibre used.

Table 3: Fiber-concrete composite

| SL. NO. | FIBRE USED   | FLEXURAL STRENGTH IN MPa |
|---------|--------------|--------------------------|
| 1       | Acrylic      | 3.0                      |
| 2       | Acrylic+     | 2.4                      |
| 3       | Nylon        | 2.7                      |
| 4       | Nylon+       | 2.0                      |
| 5       | Polypropylene| 3.74                     |
| 6       | Carpet waste | 3.64                     |

+ continuous filaments used in the longitudinal direction.
Figure 3: Flexural strength for Fiber-concrete composite

Nylon fibres and acrylic fibres can be mixed with 2-4.5% wt. with the cement paste as mentioned

Table 4: Fiber-polymer composite

| SL. NO. | FIBRE USED | FLEXURAL STRENGTH IN MPa |
|---------|------------|--------------------------|
| 1       | Kenaf      | 60                       |
| 2       | Oil palm   | 2.4                      |
| 3       | Coir       | 58-66                    |

Figure 4: Flexural strength for Fiber-polymer composite

The flexural strength given above for coir is for 4mm thickness as stated and variation in flexural strength is given in coir based on the thickness of the composite is analysed. On the addition of natural fibres with concrete, 25-30% increment in flexural strength is observed on comparison with
the ordinary concrete whereas on addition of polymer fibres, 30% increase in flexural strength is observed.

3.3. **Toughness test:**

Toughness of the composite is found by conducting toughness test. Toughness of a composite is expressed in terms of toughness index. The toughness index of fibre-cementitious filler is given in Table 5. And fibre-polymer matrix's toughness index is given in Table 6.

**Table 5: Fiber-cement composite**

| SL. NO. | FIBRE USED   | TOUGHNESS INDEX |
|---------|--------------|-----------------|
| 1       | Acrylic      | 79.1            |
| 2       | Acrylic+     | 19.0            |
| 3       | Nylon        | 57.7            |
| 4       | Nylon+       | 43.0            |
| 5       | Nylon*       | 37.6            |
| 6       | Aramid       | 125             |
| 7       | Polypropylene| 6.33            |
| 8       | Carpet waste | 4.21            |

+fibres arranged perpendicular to load direction

* fibres arranged parallel to load direction

![Figure 5: Toughness for Fiber-cement composite](image-url)
Nylon fibres and acrylic fibres can be mixed with 2-4.5% wt. with the cement paste[1]. The carpet waste and polypropylene fibres are added [5] for 0.5-2% by volume and the length of the fibre used is 12-25mm. Above values show, usage of Aramide fibre has good toughness index.[2] Addition of polymer fiber increases toughness upto 15%.

**Table 6: Fiber-polymer composite**

| SL. NO. | FIBRE USED | TOUGHNESS INDEX       |
|---------|------------|-----------------------|
| 1       | Kenaf      | 114.8-145.8           |
| 2       | Oil palm   | 24.82 HRV             |

Figure 6: Toughness for Carpet waste

Figure 7: Toughness for kenaf
From the above test results, it is clear that the addition of fibres (natural and fiber) with either polymer matrix or cementious substance can produce good properties and mechanical performance. Hence, it is expected to obtain better results on producing fibre-polymer concrete composite, which can retain combined properties of fibre-polymer composite and fibre-cementious matrix polymer.

4. Conclusion

The above discussions give a brief portrait about the usage of fibre reinforced epoxy concrete for industrial flooring. Moreover, the combined properties and characteristics of fiber-epoxy composite and fiber-cement composite is expected in the fiber-epoxy concrete composite tile. This type of composite tile with fiber, epoxy, and cement matrix can be used for industrial flooring, as they have better mechanical performance and predominantly better composite properties and are convenient for installation and maintenance. The fibers can be provided in the epoxy or polymer concrete matrix as continuous filaments in longitudinal direction or in directions perpendicular or parallel to the loading directions. From the results of various fibre used composites, it is clear that synthetic and artificial fibres exhibit more improvements in the properties and performance of the concrete when compared to the natural bio-fibers. This variation occurs due to the presence of weak bonds, less adhesion between fibres, presence biological element i.e. cellulose and legumes in the natural fibers which make the artificial synthetic fibers superior. This can be improved by performing certain preliminary chemical treatments for the natural fibers. Other than strengthening the fibers, the usage of saline coupling agents can enhance the mechanical properties of the polymer concrete. The
fibre-polymer concrete composite tile should be made with a smooth top surface so that the oil spills can be easily wiped out in industries.

References

[1] Wang Y 1999 Utilization of recycled carpet waste fibers for reinforcement of concrete and soil Polym. Plast. Technol. Eng. 38 533–46

[2] Rai A and Joshi Y P 2014 Applications and Properties of Fibre Reinforced Concrete J. Eng. Res. Appl. www.ijera.com ISSN 4 123–31

[3] Mandal A and Nigam M K 2018 E-R E-R E-R E-R 1 46–54

[4] Joseph K, Tolêdo Filho R D, James B, Thomas S and Carvalho L H de 1999 a Review on Sisal Fiber Reinforced Polymer Composites Rev. Bras. Eng. Agrícola e Ambient. 3 367–79

[5] Wang Y, Backer S and Li V C 1987 An experimental study of synthetic fibre reinforced cementitious composites J. Mater. Sci. 22 4281–91

[6] Obasi H., Iheaturu N C, Onuoha F., Akanbi M N and Ezeh V O 2014 Influence of Alkali Treatment and Fibre Content on the Properties of Oil Palm Press Fibre Reinforced Epoxy Biocomposites Am. J. Eng. Res. 117–23

[7] Nibudey R N, Nagarnaik P B, Parbat D K and Pande A M 2013 Strengths prediction of plastic fiber reinforced concrete (M30) Int. J. Eng. Res. Appl. 3 1818–25

[8] Kandasamy R and Murugesan R 2012 Fiber reinforced self compacting concrete using domestic waste plastics as fibres J. Eng. Appl. Sci. 7 405–10

[9] Vella Durai S C, Kumar E, Indira R and Muthuraj D 2020 Preparation and investigations of structural, optical and conductivity properties of polyaniline/titanium dioxide nanocomposites J. Ovonic Res. 16 345–53

[10] Rashid H, Islam M and Rizvi F 1970 Effects of Process Parameters on Tensile Strength of Jute Fiber Reinforced Thermoplastic Composites J. Nav. Archit. Mar. Eng. 3 1–6

[11] Barbuta M and Harja M 2008 Properties of Fiber Reinforced Polymer Concrete Bull. Polytech. Inst. Jassy, Constr. Archit. Sect. LIV (LVIII 13–22

[12] Karthikeyan A, Balamurugan K and Kalpana A 2013 The new approach to improve the impact property of coconut fiber reinforced epoxy composites using sodium laurlyl sulfate treatment J. Sci. Ind. Res. (India). 72 132–6

[13] Labib W and Eden N 2006 An investigation into the use of fibres in concrete industrial ground-floor slabs 3rd Int. Built a. Hum. Environ. Res. Week 466–77

[14] Pang X F and Deng B 2008 Investigation of changes in properties of water under the action of a magnetic field Sci. China, Ser. G Physics, Mech. Astron. 51 1621–32
[15] Srinivasababu N, Rao M M and Kumar J S 2010 Tensile properties of turmeric fibre reinforced polyester composites *Indian J. Fibre Text. Res.* **35** 324–9