Analysis of Polymer fiber reinforced concrete pavement

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***Abstract*: Road transport is the lifeline of any nation and its development is a crucial concern. The traditional bitumen pavements and there needs for continuous maintenance and rehabilitation operations points towards the scope for cement concrete pavement. There are several advantages of cement concrete pavement over bituminous pavements. This paper explains a "Polymer Fibre Reinforced Concrete Pavement" which is a recent advancement in the field of reinforced concrete pavement design. FRC pavements prove to be more efficient than conventional RC pavements.**

Introduction

A pavement consists of various layers/grades upon which vehicles travel. It have two purposes, to provide a comfortable and durable surface for vehicles, and to reduce stresses on underlying soils. In India, the bituminous pavements are widely used for the construction of roads or Highways.

Easily available cement concrete is a better substitute to bitumen which is the by product in distillation of imported petroleum crude. It is a clear fact that petroleum and its by-products are declining day by day. When we think of a road/Highway constructions in India it is taken for granted that it would be a bituminous pavement and there are very less chances of thinking about an alternatives e.g: like concrete pavements Fibre reinforced pavements. Within two to three decades bituminous pavement would come to an end and then there is a much need for an alternatives. Then the solution will be POLYMER FIBER REINFORCED CONCRETE PAVEMENTS, as it satisfies two of the much demanded requirements of pavement materials, economy and reduced pollution. It also has several other advantages like longer life, low maintenance cost, fuel efficiency, good riding quality, increased load carrying capacity and impermeability to water over flexible pavements.

***"FRC is defined as composite material consisting of concrete reinforced with discrete randomly but uniformly dispersed short length fibers."* The fibers may be of steel, polymer or natural materials. FRC is considered to be a material of improved properties and not as reinforced cement concrete whereas reinforcement is provided for local strengthening of concrete in tension region. Fibers generally used in cement concrete pavements are steel fibers and organic polymer fibers such as polyester or polypropylene.**

Fibre Reinforced Concrete

FRC (Fiber Reinforced concrete) is defined as a composite material which consist of mixtures of cement, concrete with discontinuous, discrete, uniformly dispersed suitable fibers. Tyre, woven fabrics and long wires or rods are not considered to be discrete fibers.

Fiber reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibers that are uniformly distributed and randomly oriented. Fibers may generally be classified into two: organic and inorganic. Inorganic fibers include steel fibers and glass fibers, whereas organic fibers include natural fibers like coconut, sisal, wood, bamboo, jute, sugarcane, etc and synthetic fibers based on acrylic, carbon, polypropylene, polyethylene, nylon, Aramid, and polyester. Within these different fibers the character of fiber reinforced concrete changes with varying concretes, fiber materials, geometries, distribution, orientation and densities. Fibers are usually used in concrete pavement surface to control plastic shrinkage cracking and drying shrinkage cracking. Fibers also help in lowering the permeability of concrete and also reduces bleeding of water from concrete. Some types of fibers produce greater impact, abrasion and shatter resistance in concrete. Fiber reinforced concrete is the best alternative to WBM in the near future as the petroleum sources are declining at a very fast spped.Fibers with a non-circular cross section use an equivalent diameter for the calculation of aspect ratio. If the modulus of elasticity of the fiber is higher than the matrix (concrete or mortar binder), they help to carry the load by increasing the tensile strength of the material. Fibers which are too long tend to " ball" in the mix and create workability problems.

Polymer Fibre Reinforced Concrete

The polymeric fibers commonly used are polyester, Recron 3s, Tyre fibres and polypropylene. Various types of recycled materials/ fibers like plastic, disposed tires, carpet waste and wastes from textile industry, can also be used in fiber reinforcements. These fibers act as crack arresters, restricting the development of cracks and thus transforming a brittle material into a strong composite with superior crack resistance, improved ductility and distinctive post cracking behavior prior to failure. Concrete pavements may be weak in tension and against impact, but PFRC is a suitable material which may be used for cement concrete pavement as it possesses extra strength in flexural fatigue and impact etc. reduced surface water permeability of concrete. It reduces the risk of plastic settlement cracking over rebar. It enables easier and smoother finishing. It also helps to achieve reduced bleeding of water to surface during concrete placement, which inhibits the migration of cement and sand to the surface and the benefits of the above will be harder, more durable surface with better abrasion resistance. A uniform distribution of fibers throughout the concrete improves the homogeneity of the concrete matrix. It also facilitates reduced water absorption, greater impact resistance, enhanced flexural strength and tensile strength of concrete. The use of polymer fibers with concrete has been recognized by the Bureau of

Indian Standards (BIS) and Indian Road Congress and is included in the following Standard documents:

Vision: 2021 By Ministry of Road Transport and Highway New Delhi

IS:456:2000 – Amendment No.7, 2007 IRC:44-2008 – Cement Concrete Mix Designs for Pavements with fibers . Polymer Fiber Reinforced concrete has been approved by National as well as State bodies like:

- Central Public Works Department(CPWD)
- Airport Authority of India
- J&K Irrigation and Flood Control.

Steel Fibre Reinforced Concrete

Reinforced concrete is basically concrete in which steel bars desirable magnitude are introduced in the casting stage so that the resulting composite material resist the stresses developed due to the external loads.Steel fibers have been used for a long time in construction of roads and also in the construction of buildings, particularly where heavy wear and tear is expected. Steel reinforcement are mostly used in the construction of bridges. In a work where steel fiber reinforced concrete was used for overlays just like flooring, the following nomenclature can be adopted for concreting of small thickness. Second item of fibers was provided separately as “Providing and mixing steel fibers of dia 0.45 mm in cement concrete duly cut into pieces not more than 25 mm in length.”Though the item of steel fiber reinforced concrete has been provided with a design mix of concrete, which is almost of 1:2:2 grading, it can now be used of mix like M30 or M35.

Strength Properties of Steel fibre and Glass fibre Composites:

OBJECTIVE OF THE STUDY:

The main objective of this study is to determine the optimum percentage of steel fibre and glass fibre for split tensile strength and flexural strength and to find out the maximum percentage increase of split tensile strength and flexural strength.

EXPERIMENTAL INVESTIGATION:

Materials Used

Cement, fine aggregate, coarse aggregate, water and fibres were used. Cement: the cement used was Arco Super grade PPC Cement with a specific gravity of 2.7.Initial and final setting time was 60min and 460 min respectively.

Fine Aggregate: M-Sand, conforming to zone II with specific gravity 2.50 and water absorption 1.43 %was used, conforming to IS 383:1970 .

Coarse Aggregate: Crushed angular metal of specific gravity 2.93 and water absorption0.35% conforming to graded aggregate of nominal size 20 mm as per IS 383:1970 [7]was used in this experimental study.

Water: Potable water was used in this experiment. Water should be free from acids, oils, alkalies or other organic impurities.

Steel Fibre: Crimped steel fibre of length 50 mm, diameter 1 mm and aspect ratio 50 was used. Steel fibres of 0.6%, 0.70% and 1% of volume of concrete were used. Fig.7 shows the dimension of the steel fibre used for the experimental work.

Glass Fibre: Alkali-Resistant glass fibre of 12 mm length was used. Glass fibres of 0.10%, 0.20% and 0.25% weight of cement were considered in this study.

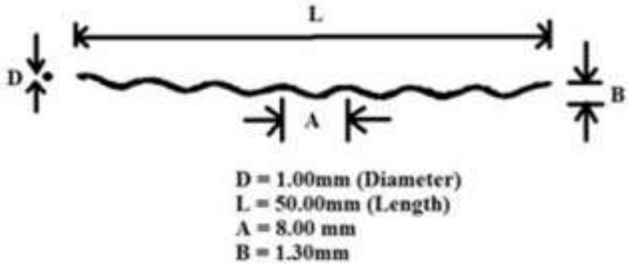

Fig.1: Dimensions of a crimped steel fibre

Fig.2: Alkali–Resistant Glass Fibre

Concrete Mix Proportion:

The mixture proportioning was done according to IS1 0262:2009 and with reference to IS 456:2000. The target strength for mix proportioning for M25 grade concrete was 31.6N/mm^2. The water –cement ratio was kept constant as 0.5 .Cement, fine aggregate and coarse aggregate were properly mixed together in the ratio 1:1.47:2.78. Table shows the details of quantity of constituent materials.

TABLE 1: Details of quantity of constituent materials

Material	Quantity	Proportion
Cement	420kg/m^3	1
FineAggregate	617.843kg/m^3	1.47
CoarseAggregate	1168.07kg/m^3	2.78
Water	210l/m^3	0.5

Crimped steel fibres of 0.5%,0.75% and 1% by volume of concrete and alkali-resistant glass fibres of 0.10%,0.20% and 0.25% weight of cement a reconsidered in this study. Table 2shows the proportion of steel fibre and glass fibre used in the experimental work.

TABLE 2:Proportion of steel fibre and glass fibre

Specimen	SteelFibre(%byvolumeofconcrete)	GlassFibre(%byweightofcement)
S1	0	0
S2	0.6	0.16
S3	0.6	0.25
S4	0.5	0.25
S5	0.75	0.15
S6	0.75	0.20
S7	0.75	0.25

METHODOLOGY

The tests have been performed to determine the mechanical properties such as split tensile strength and flexural strength of concrete mix with hybrid fibre content.

Split Tensile Strength Test:

The test was conducted as per IS5816:1999[10]. For tensile strength test, cylindrical specimen dimension 150 mm diameter and 300 mm length were cast. The specimens were demoulded after 24 hours of casting and were transferred to curing tank where in they were allowed to cure for 28 days. The load shall be applied with out shock and increased continuously at anominal rate within the range 1.2N /(mm^2/min) to2.4N/(mm^2/min). Maintain the rate, once adjusted, until failure. In each category, three cylinder were tested and their average value was reported. Split tensile strength was calculated as follows:

$$\text{Split Tensile Strength (MPa)}=2P/\pi DL \qquad (1)$$

Where, P=Failure Load(N)

D=Diameter of Specimen (mm)
L= Length of specimen (mm)

Fig.3: Shows the split tensile testing of cylinder.

Flexural Strength Test:

The test was conducted as per IS 516:1959 [11]. The bed of the testing machine shall be provided with two steel rollers, 38 mm in diameter, on which the specimen is to be supported, and the rollers shall be so mounted that the distance from centre to centre is 40 cm for 10 cm specimens. The load shall be applied without shock and increasing continuously at a rate such that the extreme fibre stress increases at approximately 7kg/sqcm/min. i.e., at a rate of loading of 400kg/min for the 15 cm specimen and at a rate of 180kg/min for the 10 cm specimens, The load shall be increased until the specimen fails, and the maximum load applied to the specimen during the test shall be recorded.

$$\text{Modulus of rupture}, \sigma_r = Pl/bd^2 \quad (2)$$

Where,

b=measured width in cm of the specimen,
d=measured depth in cm of the specimen at the point of failure,
l=length in cm of the spanon which the specimen was supported, and P=maximum loading applied to the specimen

Fig.4: Flexural strength testing of beams

EXPERIMENTAL RESULTS

Split Tensile Strength of Cylinders

Split tensile strength of cylinder s at 28 days of curing was tested and the results obtained are tabulated in Table 3.

Fig.5shows the average value of split tensile strength of cylinder s of different proportions.

TABLE 3: Split tensile strength of different proportions

Mix	SplitTensileStrength(N/mm^2)			AverageSplitTensileStrength (N/mm^2)
	1	2	3	
S1	2.263	2.433	2.230	2.308
S2	2.659	2.617	2.716	2.664
S3	2.688	2.758	2.800	2.748
S4	2.829	2.971	3.000	2.933
S5	3.140	3.280	3.270	3.230
S6	3.466	3.508	3.320	3.430
S7	2.801	2.971	2.716	2.829
S8	2.857	2.688	2.758	2.767

The split tensile strength was increased by 48.61% for S6 specimen. i.e., by the addition of 0.75% volume of concrete of steel fibre and 0.2% weight of cement of glass fibre.

Flexural Strength of Beams:

Flexural strength of beams at 28 days of curing was tested and the results obtained are tabulated in Table 4.

TABLE 4: Flexural strength of different proportions

Mix	Flexural Strength(N/mm^2)			AverageFlexural Strength(N/mm^2)
	1	2	3	
S1	3.30	2.700	3.400	3.10
S2	3.350	3.700	4.100	3.700
S3	4.000	4.320	3.840	4.050
S4	4.800	4.480	4.320	4.530
S5	5.350	5.050	5.780	5.400
S6	6.350	6.250	6.050	6.200

PAVEMENT DESIGN:-

The base coarse of Dry Lean Concrete (DLC) serves as working platform for supporting PFRC slabs which by slab action distributes the wheel load to larger area. The DLC base layer rests on granular sub-base which rest on sub grade.

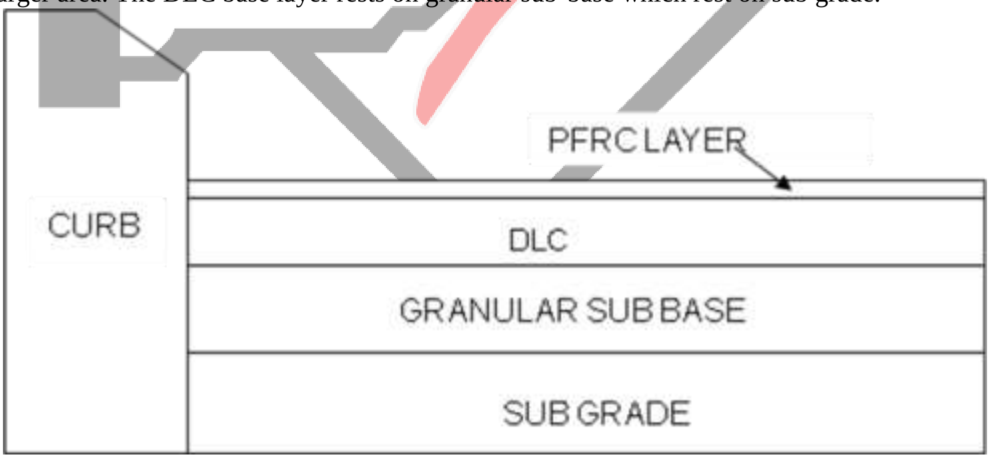

Fig 5: Cross section of a typical PFRC pavement

Over the well compacted sub grade Granular Sub base is constructed using big stone boulders and mud. Over that the Dry Lean Concrete of mix 1:4:8 is made, which is compacted, leveled and floated. Surface of DLC is also corrected for road camber. An antifriction separation membrane of 125 micron thickness is spread over the DLC surface so as to impart free movement of the upper slab caused due to temperature warping stresses. The separation membrane may be stuck to the lower layer with patches of adhesives or appropriate tape or concrete nails with washer so that polythene sheet does not move during placement of concrete.

CURING:
Membrane curing is applied with the help of texture-cum-curing machine. The resin based curing compound is used at the rate of 300 ml per square meter of the slab area. After about 1.5 hours moist Hessian cloth is spread over the surface covered with curing compound spray. Water curing by keeping the Hessian moist by sprinkling water is ensured for 3 days.

11 CONCLUSION AND FUTURE SCOPE :

PFRC can be used comfortly over normal concrete pavement. Polymeric fibers such as polyester or polypropylene are being used due to their cost effective as well as corrosion resistance. PFRC requires specific design considerations and construction procedures to obtain optimum performance. This may lead to early development of the country at very fast rate and at low cost as compared to the other costly pavement materials,and also resources can be saved for the future generations. PFRC material is not much costly and is also available locally at any place , so it becomes an excellent option for the construction of road pavements in the developing countries.

FUTURE SCOPE

- The present research work leaves a wide scope for future investigators to explore many other aspects of such hybrid composites. Some recommendations for future research include
- The other properties of composites such as moisture absorption, fatigue and tri biological behavior may be determined using extensive experimentation.
- The experiments can be extended to other machining processes such as milling , reaming etc

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