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An Investigation on Design Procedure and Operations of Polymer Fibre Reinforced Concrete Pavements

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ABSTRACT

Road transportation is undoubtedly the lifeline of the nation and its development is a crucial concern. The traditional bituminous pavements and their needs for continuous maintenance and rehabilitation operations points towards the scope for cement concrete pavements. There are several advantages of cement concrete pavements over bituminous pavements. This paper explains on POLYMER FIBRE REINFORCED CONCRETE PAVEMENTS, which is a recent advancement in the field of reinforced concrete pavement design. PFRC pavements prove to be more efficient than conventional RC pavements, in several aspects, which are explained in this paper. The design procedure and paving operations of PFRC are also discussed in detail. A detailed case study of Polyester fiber waste as fiber reinforcement is included and the results of the study are interpreted. The paper also includes a brief comparison of PFRC pavements with conventional concrete pavement. The merits and demerits of PFRC pavements are also discussed. The applications of PFRC in the various construction projects in Kerala are also discussed in brief.

Key words- *Fiber Reinforced Concrete, Pavement,*

1. INTRODUCTION

In a developing country such as India, road networks form the arteries of the nation. A pavement is the layered structure on which vehicles travel. It serves two purposes, namely, to provide a comfortable and durable surface for vehicles, and to reduce stresses on underlying soils. In India, the traditional system of bituminous pavements is widely used.

Locally available cement concrete is a better substitute to bitumen which is the by product in distillation of imported petroleum crude. It is a known fact that petroleum and its by-products are dooming day by day. Whenever we think of a road construction in India it is taken for granted that it would be a bituminous pavement and there are very rare chances for thinking of an alternative like concrete pavements. Within two to three decades bituminous pavement would be a history and thus the need for an alternative is very essential. The perfect solution would be POLYMER FIBER REINFORCED CONCRETE PAVEMENTS, as it satisfies two of the much demanded requirements of pavement material in India, 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.

Fiber reinforced concrete pavements are more efficient than ordinary cement concrete pavement. *"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.

This is an environment friendly approach in the field of pavement construction as almost all sorts of polymer waste can be recycled and used as a reinforcing admixture in the concrete pavements. As waste polymers which are produced in large quantities are non bio degradable they can cause immense environmental issues. Instead of disposing it we can efficiently make use of its properties in the pavement construction.

2. FIBER REINFORCED CONCRETE

Concrete is well known as a brittle material when subjected to normal stresses and impact loading, especially, with its tensile strength being just one tenth of its compressive strength. It is only common knowledge that, concrete members are reinforced with continuous reinforcing bars to withstand tensile stresses, to compensate for the lack of ductility and is also adopted to overcome high potential tensile stresses and shear stresses at critical location in a concrete member.

Even though the addition of steel reinforcement significantly increases the strength of the concrete, the development of micro-cracks must be controlled to produce concrete with homogenous tensile properties. The introduction of fibers was brought into consideration, as a solution to develop concrete with enhanced flexural and tensile strength, which is a new form of binder that could combine Portland cement in bonding with cement matrices.

Fibers are generally discontinuous, randomly distributed throughout the cement matrices. Referring to the American Concrete Institute (ACI) committee 544, in fiber reinforced concrete there are four categories namely

1. SFRC-Steel Fiber Reinforced Concrete
2. GFRC-Glass Fiber Reinforced Concrete
3. SNFRC-Synthetic Fiber Reinforced Concrete
4. NFRC-Natural Fiber Reinforced Concrete

Fiber Reinforced concrete can be defined as a composite material consisting of mixtures of cement, mortar or concrete with discontinuous, discrete, uniformly dispersed suitable fibers. Continuous meshes, 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 to control plastic shrinkage cracking and drying shrinkage cracking. They also lower the permeability of concrete and thus reduce bleeding of water. Some types of fibers produce greater impact, abrasion and shatter resistance in concrete.

The amount of fibers added to a concrete mix is measured as a percentage of the total volume of the composite (concrete and fibers) termed volume fraction (V_f). V_f typically ranges from 0.1 to 3%. Aspect ratio (l/d) is calculated by dividing fiber length (l) by its diameter (d). 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.

2.1 POLYMER FIBER REINFORCED CONCRETE (PFRC)

Polymeric fibers are gaining popularity because of its properties like zero risk of corrosion and cost effectiveness. The polymeric fibers commonly used are polyester, Recron 3s, and polypropylene. Various forms of recycled fibers like plastic, disposed tires, carpet waste and wastes from textile industry, and Forta Econo net, can also be used as 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. The usage of fibers in combination with concrete also results in a mix with improved early resistance to plastic shrinkage cracking and thereby protects the concrete from drying shrinkage cracks. It accomplishes improved durability and 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:

IS: 456:2000 – Amendment No.7, 2007

IRC: 44-2008 – Cement Concrete Mix Designs for Pavements with fibers

IRC: SP: 76:2008 – Guidelines for Ultra Thin White Topping with fibers

Vision: 2021 by Ministry of Surface Transport, New Delhi

Polymer Fiber Reinforced concrete has been approved by National bodies like:

1. Central Public Works Department (CPWD)
2. Airport Authority of India
3. Military Engineering Services
4. Defence Airfields
5. NF/Southern Railway
6. ISRO, Bangalore

3. MATERIALS

The two components of PFRC are concrete mix and polymer fibers.

3.1 CONCRETE MIX

Cement used shall be OPC 43 grade. Coarse sand of fineness modulus 2.42, washed and stone aggregate of 10 mm size with minimum fineness modulus of 5.99 shall be used. PFRC has been provided with a design mix of 1:2:2 grading. The concrete shall have a flexural strength of 40 kg/m² at 28 days. Water cement ratio shall be as per IS specification mentioned for M30 or M35 grade concrete. Fly ash and ground granulated blast furnace (GGBF) slag is added along with OPC in concrete mixes because they prolong the strength gaining stage of concrete.

The code IRC: 44-2008 is followed for cement concrete mix designs for pavements with fibers.

Fig.1.concrete mixing plant (ref:http://cebd.asce.org/cgi)

3.2 POLYMER FIBERS

The various polymer fibers that are manufactured specially for improving the properties of concrete that are used for construction of pavements and other construction works are:

- Recron 3S
- Polypropylene
- Forta ferro
- Forta econo net

Polymer fiber waste can also be recycled and used for the pavement construction. Waste polymer fibers commonly used are:

- Plastic
- From carpet industry
- From textile industry
- From disposed tires

Polymeric fibers normally used are either polyester or poly propylene. It should be 100% virgin synthetic fiber size 12mm long and 0.45 mm diameter. It shall be mixed at the rate of 900 gms per cum of concrete. Other fibers used are acrylic, aramid, carbon etc. These fibers reduce plastic shrinkage and substance cracking. This increase the toughness and post cracking integrity. Fibers named Fiber mesh and Recron 3S are now produced by FIBERCOM-CF Company Ltd USA and in India Fibers like polypropylene and Recron 3S are manufactured by Reliance Industries Ltd.

Polypropylene is one of the cheapest and abundantly available polymers. Polypropylene fibers are resistant to most chemical attacks. Its melting point is high (about 165 degrees centigrade). So that it can withstand a working temp, as (100 degree centigrade) for short periods without detriment to fiber properties.

Polypropylene fibers being hydrophobic and can be easily mixed. Polypropylene short fibers in small volume fractions between 0.5 to 15 commercially used in concrete.

Polyester fibers

Polypropylene fibers

Nylon fibers

Recycled plastic fibers

Tire fibers

Polymeric fiber (Fiber mesh)

Fig 2. Various polymer fibers used in concrete (ref:http://cebd.asce.org/cg)

4. 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.

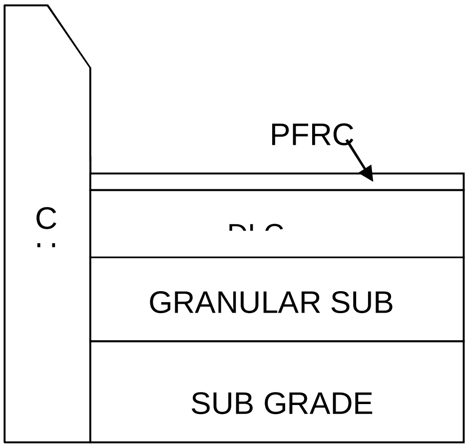

Fig 3. Cross section of a typical PFRC pavement (ref:http://cebd.asce.org/cgi)

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.

Many of the thickness design methods for cement concrete pavement adopted internationally derive their origin from the method evolved by Portland Cement Association (PCA). In this technology thickness of the pavement is assumed on trial basis.

When dewatered concrete is provided on lean concrete, it has no problem of water being coming out on surface during compaction process but when it is done over WBM, a considerable amount of water is soaked by WBM and thus the concrete loses the water to WMB and the water which comes out during dewatering/ compaction process is not in same quantity as in case of lean concrete. It appears that it is better to provide base concrete than WBM as the base.

Due to repeated application of flexural stresses by the traffic loads, progressive fatigue damage takes place in the cement concrete slab in the form of cracks especially when the applied stress in terms of flexural strength of concrete is high. The ratio between the flexural stress due to the load and the flexural strength is termed as the stress ratio (SR).

The following table shows the experimental results relating repetitions and SR.

Table1. Stress ratio and Allowable Repetitions in cement concrete

SR	Allowable Repetitions	SR	Allowable Repetitions
0.45	6.279E7	0.67	4410
0.47	5.2E6	0.69	2531
0.49	1.287E6	0.71	1451
0.51	4.85E5	0.73	832
0.53	2.29E5	0.75	477
0.55	1.24E4	0.77	274
0.59	4.08E4	0.79	157
0.61	2.34E4	0.81	90
0.63	1.34E4	0.83	52
0.65	7700	0.85	30

If the SR is less than 0.45, the concrete pavement is expected to sustain infinite number repetitions. As the SR decreases the no. of load repetitions required to cause cracking increases. This is also considered in the design of pavement.

5. PAVING OPERATION

5.1 FULLY MECHANIZED PAVEMENT CONSTRUCTION

Mechanized construction of PFRC pavement is necessitated for achieving a faster pace of construction and better riding qualities which are otherwise could not be achieved by manual laying techniques.

Use of highly sophisticated electronic sensors controlled by slip form paving machines consist of power machines, which spreads compacts and finishes the paving concrete in continuous operation. Concrete shall be placed with slip form pavers with independent unit design to spread, consolidate, screed and float finish, texture and cure the freshly placed concrete in one complete pass of the machine in such a manner that a minimum of hand finishing will be necessary so as to provide a dense and homogenous pavement in conformity with the plans and specifications.

Fig 4. Fully mechanized pavers (ref:http://cebd.asce.org/cgi)

It is imperative from the studies that PFRC should be laid in panels, or else grooves should be provided, so that concrete acts like in panels. Cutting grooves is easy as it can be made after casting of concrete. But it should not be delayed for long and should be made before concrete achieves its desired strength. The size of panels may be kept around 4m x 4m which is obtained from comparative studies.

Cutting of dummy contraction joints of 3mm width after the final set of concrete while partly removing the covering material should be commenced preferably 3-4 hours after paving in summer and 6-8 hours in winter. The work of sawing joints in green concrete should continue even at night so that concrete does not become very hard and thus drying shrinkage cracks may not occur. The is subsequently widened to 8mm width up to a depth of 26 mm to receive the sealant after 28 days curing. The joint groove is to be protected from ingress of dirt or any foreign matter by inserting performed neoprene sealant.

5.2 REQUIREMENTS FOR PAVING OPERATIONS

(1) Use of microfilm or antifriction layer of 125 micron in between PFRC and DLC layers.

(2) The DLC layer is to be swept clean of all the extraneous materials before applying microfilm which may be nailed to the DLC layer without wrinkles and holes.

(3) Concreting work in hot weather should be carried out in early or later hours.

(4) The laying temperature of concrete should always be below 35degreeCelsius.

5.3 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.

Fig 5. Completed PFRC pavement (ref:http://cebd.asce.org/cgi)

5.4 PROTECTION AND MAINTANANCE

The joint groove is to be protected from ingress of dirt or any foreign matter by inserting performed neoprene sealant. To exercise a very stringent quality control the test are to be conducted on fine and coarse stone aggregates, water cement, granular sub base, DLC etc as per standards and specification published by Indian roads congress.

No vehicular traffic should be allowed to run on the finished surface of a new cement concrete pavement until the completion of 28 days of curing, sealing of joints and completion of paved shoulder construction.

6. A CASE STUDY – POLYESTER FIBER WASTE IN PFRC

This involves a feasibility study on use of polyester fiber waste as reinforcing admixture in concrete for use in road works. In this, concrete pavement slabs of size 3.5m x 3.5m, with thickness of 10cm and 15cm were cast with plain cement concrete (PCC) and polyester fiber reinforced concrete (PFRC). The slabs were subjected to load deflection test using Falling Weight Deflectometer (FWD). Concrete cube specimens were also subjected to abrasion resistance test. Further, cube specimens were tested under compression and for their Ultrasonic Pulse Velocity after a period of 2 years. The polyester fibers used in this study is primarily a waste product from textile industry and, are non bio-degradable.

6.1 EXPERIMENTAL DETAILS

A) Methodology

A preliminary study on compressive strength and abrasion resistance using different proportions of polyester fibers resulted in an optimum fiber dosage of 0.25 percent by weight of cement. In the present study, experimental concrete slabs of size 3500mm x 3500mm, in thickness of 100mm and 150mm, both with PCC (control concrete) and optimum PFRC (OPFRC) with experimental fibers were cast and tested for deflection by FWD after 28 days of curing. Tests were also conducted for abrasion resistance and long term compressive strength. The long term compressive strength test was carried out to study if there is any reduction in strength due to possible degradation of the fibers in the concrete's alkaline environment.

B) Materials

Ordinary Portland Cement (OPC) of grade 53 conforming to IS: 12269 was used for the studies. Locally available quartzite aggregate with a maximum size of aggregate (m.s.a) of 10mm and 20mm, and a pit sand (locally known as badarpur sand), were used as coarse aggregate and fine aggregate, respectively. A high range water reducing admixture, conforming to IS: 9103 was used to improve the workability of concrete. The discrete polyester fibers of 6 mm length, used in the study were tested for salient properties and the test results are presented in the Table 2. A photograph of the fibers is presented Fig 6.

Table 2. Salient properties of the polyester fibers

Properties	Test Data
Diameter (D), mm	0.0445
Length (l), mm	6.20
Aspect Ratio (l/D)	139.33
Tensile Strength MPa	308
Specific Gravity	1.33

Fig 6. Polyester fibers used in the study. (ref:http://cebd.asce.org/cgi)

C) Preparation of PCC and OPFRC mixes

A PCC mix was designed for a compressive strength of 40.0 MPa as per IRC 44. The mix proportions are presented in Table 3.

Table 3. Mix proportions of pavement quality concrete (PQC) and dry lean concrete (DLC)

Sl. No	Mix Constituents	Quantity, kg/ m³	
		PQC	DLC
1	Cement	400 (674.16)	190 (320.24)
2	Fine Aggregate	689 (1161.3)	672 (1132.65)
3	Coarse Aggregate	20-10mm	12.5-25mm
		(0.787-0.394 in)	(0.5-1.0 in)
		552 (930.39)	387 (652.28)
		10-4.75mm	< 12.5mm
		(0.394-0.187 in)	(< 0.5 in)
		552 (930.39)	870 (1466.37)
4	Water	178 (300)	146.2 (256.42)
5	Super plasticizer	0.4 percent by weight of cement	

The FRC mix was prepared by adding 0.25 percent (by weight of cement) fibers of 6 mm length to PCC mix. The fibers were added to the dry mix first and then water was added as this method appeared to produce a uniform FRC mix. The PCC and OPFRC mixes were used for laying the Pavement Quality Control (PQC) slabs, for preparation of test specimen for abrasion resistance test and for long term compressive strength.

D) Laying of experimental pavement slabs

Before laying the pavement slabs, the sub grade (alluvial type of soil) was duly prepared by compacting to its maximum dry density at optimum moisture content. The California Bearing Ratio (CBR) value of the soil was 3.5

kg/cm2/cm. Since a sub-grade with CBR less than 6.0 kg/cm2/cm is considered as weak, it was strengthened with a base course. A Dry Lean Concrete (DLC) mix was designed for a minimum compressive strength of 10.0 MPa at 7 days, as per IRC: SP-49 and its mix proportion are given in table. The thickness of DLC was kept uniform at 100 mm. A total of 4 PQC slabs, each of 3500 mm x 3500 mm size comprising of 2 PCC and 2 OPFRC slabs were laid over the DLC base course. A cross-section of the concrete slab structure is shown in fig 7. No separation layer was provided between the DLC and PQC layers. The slabs were cast side by side with a small gap in between without any dowel or tie bars.

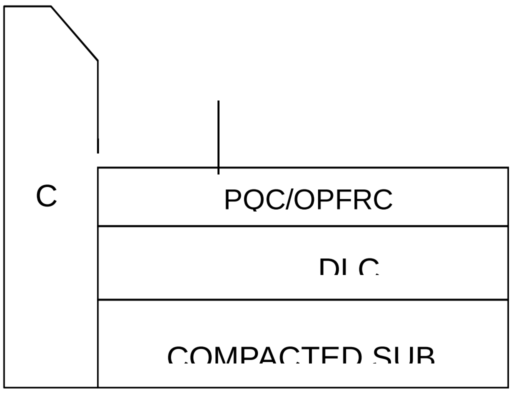

Fig 7. Typical cross section of the experimental slab.

6.2 TESTS AND RESULTS

A) Some salient properties of OPFRC from laboratory study

OPFRC exhibited increase in 28 day compressive and flexural strength by about 21 percent and 6.4 percent, respectively, as compared to control mix. It also exhibited a significant reduction in drying shrinkage. The drying shrinkage of control concrete was 0.062 percent while that of the FRC was 0.03 percent. The shear bond strength of FRC mix with old concrete was 3.3 MPa indicating that the OPFRC was suitable for repair work.

B) Pavement slab deflection

The pavement slabs were tested for deflection under load applied through Dynatest 8000 FWD. The deflection of pavements was measured as per ASTM D 4695-1996 at four impact loads viz. 4000kgf, 5000kgf, 8000kgf and 12000kgf, at three locations on each slab, i.e. centre, edge and corner. The deflections of PCC slabs at centre for thickness of 100 mm and 150mm were observed to be 180 im and 149 im respectively. The corresponding deflection values for FRC slabs are 207 im and 157 im respectively. The deflections are well within maximum deflection limit of 1250 im suggested by the IRC: 58.

C) Abrasion resistance of concrete

The abrasion resistance test was carried out on 100 mm concrete cube specimens in pneumatic sand blasting cabinet conforming to IS: 9284-1979, which involves impinging the test specimen with standard sand (abrasive charge) driven by air pressure at 0.14 MPa. The FRC mix exhibited an abrasion loss of 0.15 percent while the PCC mix resulted in an abrasion loss of 0.20 percent. The test results indicate that addition of fibers to PCC mix increases the abrasion resistance by 25 percent.

D) Long term compressive strength

OPFRC cube specimens of 150mm size were also cast at the time of laying of the slabs. The cubes were water cured for 28 days and then left exposed to the laboratory environment. The cubes were tested for compressive strength as per IS: 516 after 24 months. The average of three test specimens was calculated. The ultrasonic pulse velocity (UPV) of the OPFRC specimen was tested as per IS: 1311-Pt 1 at the respective ages of 28 days and 24 months. The OPFRC cube specimens yielded compressive strength of 60.0 MPa and 60.4 MPa, respectively, when tested at an age of 28 days and 24 months, indicating that there is no reduction in compressive strength of FRC. The test specimen exhibited UPV of 4.81 and 4.41 km/sec at the age of 28 days and 24 months.

E) Physical inspection of concrete slabs

A visual inspection of slabs after 24 months revealed satisfactory condition of the surface with no cracks or any other defects. The 24 months duration included one summer and one winter season. The peak summer day temperature was about 45 degree C and the lowest temperature during winter was around 2 degree

C. This indicates that there has not been any surface degradation of FRC slabs.

6.3 INFERENCES OF THE STUDY

The following inferences are made from this study on FRC made with polyester fibers of 6mm length:

1. The polyester FRC in thicknesses of 100mm or more can be used for pavements or other similar applications.
2. The use of polyester fibers increases the abrasion resistance of concrete by 25 percent making it more suitable for pavements.
3. The polyester fibers are resistant to the strong alkaline conditions in concrete. There is no decrease in long term compressive strength or UPV of PFRC.
4. The results of this study promote effective disposal of these non bio-degradable synthetic fibers.

7 ADVANTAGES AND DISADVANTAGES

7.1 ADVANTAGES

(1) Water logging is a major reason for potholes in roads. WBM and Asphalt roads are permeable to water which damages the road and sub grade. But PFRC roads are highly impermeable to water so they will not allow water logging and water being coming out on surface from sub grade.

(2) Implementation of sensors in roads will be easier while using polymer fibers for concrete.

(3) Environmental load of PFRC pavement was found to be significantly lower than the steel fiber reinforced pavement.

(4) Maintenance activities related to steel corrosion will be reduced while using PFRC.

(5) In fresh concrete polymer fibers reduces the settlement of aggregate particles from pavement surface resulting in an impermeable and more durable, skid resistant pavement.

(6) Fibers reduce plastic shrinkage and substance cracking. Fibers also provide residual strength after cracking occurred.

(7) The use of PFRC produces concrete of improved abrasion resistance and impact resistance.

(8) PFRC also enhances ductile and flexural toughness of concrete.

(9) The use of fibers in concrete can result in cement saving up to 10% and in the presence of fly ash, savings may be up to 35%.

(10) All these advantages result in overall improved durability of concrete.

7.2 DISADVANTAGES

(1) The use of PFRC, being a relatively new technology poses a threat of a high initial cost of construction.

8. COMPARISONS BETWEEN PFRC AND NORMAL CONCRETE

Sl. No	Properties	Gain over Normal Concrete	Test Agency
	Compressive Strength	+ 12 to 16 %	IIT Madras, IPRI Punjab, CRRI – New Delhi, Al – Futtaim, Bodycote Dubai
	Flexural Strength	+ 7 to 14 %	CRRI – New Delhi, Al – Futtaim, Bodycote Dubai, IPRI Punjab
	Split Tensile Strength	+ 7 to 14 %	GERI Baroda, IPRI Punjab, SVNIT Surat, KCT Coimbatore
	Impact Resistance	+ 40 to 140 %	IIT Roorkee, IPRI Punjab, Visvesvaraya Engg. College, Bangalore University

	Abrasion resistance	+ 25	IIT Madras
	Drying Shrinkage	-48 to 80%	CRRI – New Delhi, IIT Madras
	Water Percolation	-44 to 60	CRRI – New Delhi, Al – Futtaim, Bodycote Dubai
	Permeability K, cm/sec	Nil	IPRI – Punjab, IIT Madras
	Fatigue Life (cycles)	Higher by 230 %	M.S University Baroda
0	Damping under dynamic load)	26 %	SVNIT Surat
1	Energy absorption	55 %	SVNIT Surat, Gujarat
2	Young's Modulus	23.7 %	SVNIT Surat, Gujarat
3	Concrete Strength – NDT by Rebound Hammer	+ 22.2 %	CRRI. New Delhi
4	Bond strength of old concrete	At par with new concrete	CRRI. New Delhi
5	Durability in terms of strength of FRC	At par with control concrete after 30 cycles of heating/cooling	CRRI, New Delhi
6	Checks expansion stress	Significant in crack control	Al – Futtaim Bodycote, Dubai

9. APPLICATIONS OF PFRC

- Slab On Grade: All types of pavements and overlays, industrial floors, roads, taxi ways, hangars, etc.
- Structural Concrete: Foundations (deep and shallow), machine foundation, slabs, column beams and lintel, bridge decks and girders etc.
- Water retaining Structures: RCC retaining walls, water tanks, cross drains, swimming pools, hydel projects, check dams, canal lining, ETPs, jetties, ports, spillways etc.
- Water proofing in rooftops, sunken toilets, etc.
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10. KERALA BASED PROJECTS USING PFRC

- ICTT Vallarpadam: Jetty Construction 8000 cub mtr concrete slab/Simplex infra
- Cochin Port Trust: Mattanchery Warf, NCB, UTL etc
- CIAL Airports: Turning Pad Concrete, New Arrival Bldg, Cargo storage complex
- MES: GE Air Force – Tvm Projects, DGMAPs projects Kochi
- Southern Railway: Platforms at Quilon, Kochuveli, etc
- Kerala PWD: Store Purchase of 5000kg – Building and bridges projects
- KITCO: Cargo Complex & Arrival bldg of CIAL Airport
- Harbour Engineering Dept: Vipin Jetty wearing coat
- IT Parks: Leela IT Park TVM, Techno park Phase 3 & Techno park Quil.

11. CONCLUSION

PFRC can be used advantageously 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. The higher initial cost by 15-20% is counterbalanced by the reduction in maintenance and rehabilitation operations, making PFRC cheaper than flexible pavement by 30-35%. In a fast developing and vast country like India, road networks ensure mobility of resources, communication and in turn contribute to growth and development.

Resistance to change though however small disturbs our society; hence we are always reluctant to accept even the best. It's high time that we overcome the resistance and reach for the peaks. PFRC opens a new hope to developing and globalizing the quality and reshaping the face of the "True Indian Roads".

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