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Behaviors of Glass Firer in Pavement under Compression and Flexural Stresses

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ABSTRACT

Concrete is weak in tension and has a brittle character. The concept of using fibers to improve the characteristics of construction materials is very old. Early applications include addition of straw to mud bricks, horse hair to reinforce plaster and asbestos to reinforce property. The modern development of fiber reinforced concrete (FRC) started in the early sixties. Addition of fibers to concrete makes it a homogeneous and isotropic material. When concrete cracks, the randomly oriented fibers start functioning, arrest crack formation and propagation, and thus improve strength and ductility.

The objective of this study is to investigate the effects on stress development in pavement and on critical design factors from substituting GFRP reinforcement for conventional steel reinforcement in pavements to determine the performance characteristics of the GFRP-reinforced concrete pavements. The results of this study target the design of pavement with GFRP rebar as an applicable reinforcement and propose feasible GFRP designs to be constructed.

The glass fibers reinforce the concrete, much as steel reinforcing does in conventional concrete. The glass fiber reinforcement results in a product with much higher flexural and tensile strengths than normal concrete, allowing its use in thin-wall casting applications. GFRC is a lightweight, durable material that can be cast into nearly unlimited shapes, colors and textures

GFRC is a specialized form of concrete with many applications. It can be effectively used to create façade wall panels, fireplace surrounds, vanity tops and concrete countertops due to its unique properties and tensile strength. One of the best ways to truly understand the benefits of GFRC is a unique compound.

1, INTRODUCTION

Concrete is weak in tension and has a brittle character. The concept of using fibers to improve the characteristics of construction materials is very old. Early applications include addition of straw to mud bricks, horse hair to reinforce plaster and asbestos to reinforce property. Use of continuous reinforcement in concrete (reinforced concrete) increases strength and ductility, but requires careful placement and labor skill. Alternatively, introduction of fibers in discrete form in plain or reinforced concrete may provide a better solution. The modern development of fiber reinforced concrete (FRC) started in the early sixties. Addition of fibers to concrete makes it a homogeneous and isotropic material. When concrete cracks, the randomly oriented fibers start functioning, arrest crack formation and propagation, and thus improve strength and ductility. The failure modes of FRC are either bond failure between fiber and matrix or material failure. In this paper, the state-of-the-art of fiber reinforced concrete is discussed and results of intensive tests made by the author on the properties of fiber reinforced concrete using local materials are reported.

The objective of this study is to investigate the effects on stress development in pavement and on critical design factors from substituting GFRP reinforcement for conventional steel reinforcement in

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CRCPs to determine the performance characteristics of the GFRP-reinforced concrete pavements. The results of this study target the designs of CRCP with GFRP rebar's as an applicable reinforcement and propose feasible GFRP-CRCP designs to be constructed.

The scope of this report includes studying the effect of GFRP reinforcing rebar's on shrinkage and thermal stresses in concrete by analytical and numerical methods as well as by experimental measurements, and proposing a series of designs for the GFRP-reinforced CRCP based on the numerical and mechanistic results. The study also reveals some areas where further studies are recommended.

2, LITERATURE REVIEW

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.

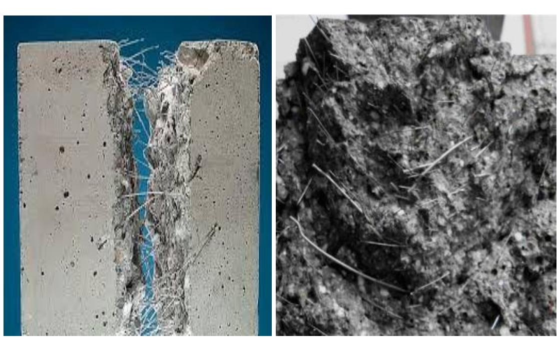

Fig : Fiber reinforcement concrete

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

3, GLASS FIBER REINFORCED CONCRETE (GFRC)

It is a composite of Portland cement, fine aggregate, water, acrylic co-polymer, glass fiber reinforcement and additives. The glass fibers reinforce the concrete, much as steel reinforcing does in conventional concrete. The glass fiber reinforcement results in a product with much higher flexural and tensile strengths than normal concrete, allowing its use in thin-wall casting applications. GFRC is a lightweight, durable material that can be cast into nearly unlimited shapes, colors and textures. There are two basic processes used to fabricate GFRC – the Spray-Up process and the Premix process. The Premix process is further broken down into various production techniques such as spray premix, cast premix, pultrusion and hand lay-up.

FRCs use textile glass fibers; textile fibers are different from other forms of glass fibers used for insulating applications. Textile glass fibers begin as varying combinations of SiO_2, Al_2O_3, B_2O_3, CaO, or MgO in powder form. These mixtures are then heated through direct melting to temperatures around 1300 degrees Celsius, after which dies are used to extrude filaments of glass fiber in diameter ranging from 9 to 17 µm. These filaments are then wound into larger threads and spun onto bobbins for transportation and further processing. Glass fiber is by far the most popular means to reinforce plastic and thus enjoys a wealth of production processes, some of which are applicable to aramid and carbon fibers as well owing to their shared fibrous qualities.

Roving is a process where filaments are spun into larger diameter threads. These threads are then commonly used for woven reinforcing glass fabrics and mats, and in spray applications.

Fiber fabrics are web-form fabric reinforcing material that has both warp and weft directions. Fiber mats are web-form non-woven mats of glass fibers. Mats are manufactured in cut dimensions with chopped fibers, or in continuous mats using continuous fibers. Chopped fiber glass is used in processes where lengths of glass threads are cut between 3 and 26 mm, threads are then used in plastics most commonly intended for moulding processes. Glass fiber short strands are short 0.2–0.3 mm strands of glass fibers that are used to reinforce thermoplastics most commonly for injection molding.

Benefits of GFRC

There are lots of good reasons to use GFRC for thin sections of concrete:

- Lighter weight: With GFRC, concrete can be cast in thinner sections and is therefore as much as 75% lighter than similar pieces cast with traditional concrete. According to Jeff Girard's blog post titled, The Benefits of Using a GFRC Mix for Countertops, a concrete countertop can be 1-inch thick with GFRC rather than 2 inches thick when using conventional steel reinforcement. An artificial rock made with GFRC will weigh a small fraction of what a real rock of similar proportions would weigh, allowing for lighter foundations and reduced shipping cost.

Large artificial rocks made with GFRC are lighter allowing rock features where real rock would be impossible. NEG America

- High strength: GFRC can have flexural strength as high as 4000 psi and it has a very high strength-to-weight ratio.
- Reinforcement: Since GFRC is reinforced internally, there is no need for other kinds of reinforcement, which can be difficult to place into complex shapes.

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- Consolidation: For sprayed GFRC, no vibration is needed. For poured, GFRC, vibration or rollers are easy to use to achieve consolidation.

PRODUCTION OF GRC

There are two main production techniques of GFRC, usually referred as spray up and premix. In the spray-up process, the mortar is produced separately from the fibers, which are mixed only at the jet of the spray gun. The glass fiber strands are cut within the spray gun to the required size, typically between 25mm (0.98inch) and 40mm (1.57inch), and are about 5% of the GFRC total weight. The subsequent compaction with a cylindrical roll guarantees the adaptation of GFRC to the form, the impregnation of the fibers with in the mortar, the removal of the air retained within the mix, and an adequate density.

Typical Range of GFRC Properties:

Property		28-day, (E)	Aged**, (A)
Density (dry)		120 to 140 (pcf)	120 to 140 (pcf)
Impact strength (Charpy)		55 to 140 (in. lb/in.^{2})	20 to 28 (in. lb/in.^{2})
Compressive strength (edgewise)		7,000 to 12,000 (psi)	10,000 to 12,000 (psi)
Flexural:	Yield (FY)	900 to 1,500 (psi)	1,000 to 1,600 (psi)
	Ultimate strength (FU)	2,500 to 4,000 (psi)	1,300 to 2,000 (psi)
	Modulus of elasticity	1.5 x 10^6 to 2.9 x 10^6 (psi)	2.5 x 10^6 to 3.5 x 10^6 (psi)
Direct tension:	Yield (TY)	700 to 1,000 (psi)	700 to 1,100 (psi)
	Ultimate strength (TU)	1,000 to 1,600 (psi)	725 to 1,100 (psi)
	Strain to failure	0.6 to 1.2 (percent)	0.03 to 0.06 (percent)
Shear:	Interlaminar	400 to 800 (psi)	400 to 800 (psi)
	In-plane	1,000 to 1,600 (psi)	725 to 1,100 (psi)
Coefficient of thermal expansion (77 to 115 F)		6 to 9 x 10^{-6} (in./in./deg F)	6 to 9 x 10^{-6} (in./in./deg F)
Thermal conductivity		3.5 TO 7.0 (Btu/in./hr/ft^2/deg F)	3.5 TO 7.0 (Btu/in./hr/ft^2/deg F)

4, EXPERIMENTAL PROGRAM

MATERIALS

The details of materials used in the present program are as follows.

Cement

Portland pozzolona cement of 43 Grade available in local market has been used in the investigation. The cement used has been tested and found to be conforming to the IS 1489 specifications. The specific gravity was 3.15.

Crushed angular aggregates from a local source were used as coarse aggregate.

Fig; Coarse aggregate to be mixed

CONCRETE MIX:

The M25 grade of concrete quantities are used in per cubic meter .The water cement has been fixed.

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.

Figure; Concrete mix

Mixture Compositions and Placing

Mixing of FRC can be accomplished by many methods. The mix should have a uniform dispersion of the fibres in order to prevent segregation or balling of the fibres during mixing. Most balling occurs during the fibre addition process. Increase of aspect ratio, volume percentage of fibre, and size and quantity of coarse aggregate will intensify the balling tendencies and decrease the workability. To coat the large surface area of the fibres with paste, experience indicated that a water cement ratio between 0.4 and 0.6, and minimum cement content of 400 kg/m[3] are required. Compared to conventional concrete, fibre reinforced concrete mixes are generally characterized by higher cement factor, higher fine aggregate content and smaller size coarse aggregate. A fibre mix generally requires more vibration to consolidate the mix. External vibration is preferable to prevent fibre segregation. Metal trowels, tube floats, and rotating power floats can be used to finish the surface.

Casting GFRC

Commercial GFRC commonly uses two different methods for casting GFRC: spray up and premix. Let's take a quick look at both as well as a more cost effective hybrid method.

5, METHODOLOGY

The tests have been performed to determine the mechanical properties such as compressive strength and splitting tensile-strength of concrete mix with steel fibers 0%, 0.5% by volume of concrete and alkali resistance glass fibers, 0.25% by weight of cement.

5.1 Compression Strength Test

The strength of concrete is usually defined and determined by the crushing strength of 150mm x 150mmx150mm, at an age of 7 and 28days. It is most common test conducted on hardened concrete as it is an easy test to perform and also most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength.

Figure ; Compression test Equipment

Steel mould made of cast iron dimension 150mm x 150mmx150mm used for casting of concrete cubes filled with steel fibres 0%, 0. 5% by volume of concrete and alkali resistance glass fibres, 0% and 0.25% by weight of cement. The mould and its base rigidly damped together so as to reduce leakages during casting.

Figure: Placing of cube

It also stated in IS 516-1959 that the load was applied without shock and increased continuously at the rate of approximately 140 Kg/sq cm/ min until the resistance of specimen to the increasing loads breaks down and no greater load can be sustained. The maximum load applied to the specimen was then recorded as per IS: 516-1959. The testing of cube and cylinders under compression.

6, GEOMETRIC AND PAVEMENT DESIGN STANDARDS

Expressway, a controlled access facility is intended to provide most efficient speedy movement of relatively high volumes of motorized traffic with higher degree of safety, comfort and economy. Alignment characteristics and parameters of physical dimensions should be such that the resulting road has inbuilt flexibility of adjustment for additional carriageways in foreseeable future without any extravagant and or wasteful provision because in a rapidly developing economy it is not always possible to forecast the traffic growth accurately. Besides, sustainability of a very high growth continuously over a very long period could also be questionable. Hence, concept of a variable traffic growth rate during the service life will also have to be developed.

Geometric and other elements should be preferably match the individual and collective requirement of traffic using the facility. Predominant vehicles should form the basis of design unit for carriageway width capacities and other design parameters like design speed etc. Geometric elements are mostly governed by the functional requirements, which are also influenced by the environmental parameters and which once built in the road systems are difficult to modify.

7, EXECUTION

A highway pavement is a structure consisting of superimposed layers of processed materials above the natural soil sub-grade, whose primary function is to support the wheel loads imposed on it from traffic moving over it. Additional stresses are also imposed by changes in the environment. It should be strong enough to resist the stresses imposed on it. The pavement structure should be able to provide a surface of acceptable riding quality, adequate skid resistance, favorable light reflecting characteristics, and low noise pollution. The ultimate aim is to ensure that the transmitted stresses due to wheel load are sufficiently reduced, so that they will not exceed bearing capacity of the sub-grade.

Two types of pavements are generally recognized as serving this purpose, they are

- Flexible pavements
- Rigid pavements.

RESULTS

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The difference between the initial and final penetration readings is taken as the penetration value.

Test load 100+_ 0.25 gms					
Test temperature 25^0c+_ 0.1^0c					
Test duration 5 seconds					
Trial no	Initial dial reading	Final dial reading	Penetration 1/10 th mm	Average value	Specification 1/10 mm
	(1)	(2)	(3)=(2) -(1)		
1	126	187	61	63	50 —70
2	125	189	64		

CONCLUSION

Pavements form the basic supporting structure in highway transportation. Each layer of pavement has a multitude of functions to perform which has to be duly considered during the design process. Different types of pavements can be adopted depending upon the traffic requirements. Improper design of pavements leads to early failure of pavements affecting the riding quality also.

More roads add on to car-dependence, which can mean that a new road brings only short-term mitigation of traffic congestion. Major modern highways that connect cities in populous developed and developing countries usually incorporate features intended to enhance the road's capacity, efficiency, and safety to various degrees. Hence we are adding the glass fibres to the concrete of a pavement.

GFRC as a material, however, is much more expensive than conventional concrete on a pound-for-pound basis. But since the cross sections can be so much thinner, that cost is overcome in most decorative elements.

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