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# STUDY & ANALYSIS OF DURABILITY OF FIBER REINFORCED CONCRETE

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## ABSTRACT

Concrete is the premier construction material across the world and the most widely used in all types of civil engineering works, including infrastructure, low and high-rise buildings, defence installations, protection of the environment and local/domestic developments.

There is a growing awareness of the advantages of Fibre Reinforcement Concrete techniques of construction all over the world. One such development of improving or modifying the brittle characteristics of concrete is by supplementing the concrete matrix with Fibre Reinforcement. In the recent times, there is a growing interest on the use of various types of Fibres in structural applications due to their light weight, low cost and sustainability.

The present work shows the effects of fibres on the behaviour of plastic and hardened concrete varies depending on the concrete materials, mix proportions, fibre type and length, and quantity of fibre added. The present experimental shows the study of composite concrete with varying percentage of fibres ranging from 0.10%, 0.20%, 0.30% & 0.40% & M20 grade concrete were adopted. Sizes of beam (10*10*50 cm) were used for testing. Flexural test of the beam is carried out with different types of fiber. This material can help us to develop intelligent infrastructure with elegantly integrated sensing.

The objective of present work is to use fibre as reinforcement in concrete for a better durability, workability & resistance to cracking of structure. The present work is concerned with the tensile behavior of FRC specimens (100 Beams) with 60 days of normal water curing and 60 days curing by sulphate & chloride.

The bending stress is largely determined by the Fibre orientation which depends on the mixing method. FRC controls cracking and deformation under impact load much better than plain concrete. About 15 MPa bending stress found at 0.40% fibre concentration when beams were cured in plain water & about 18 MPa bending stress found at 0.40% fibre concentration when beam samples were cured in NaCl & $MgSO_4$ mix water. As compare with other fibres such as GFRC, AFRC & SFRC, NFRC had maximum bending stress which is about 18MPa at fibre concentration of 0.40%. These sustainable improvements or modifications can be easily adopted by the common man in their regular constructions.

**KEYWORDS:** Fibre Reinforced Concrete (FRC), Glass fibre reinforced concrete (GFRC), Steel fibre reinforced concrete (SFRC), Natural fibre reinforced concrete (NFRC), Artificial fibre reinforced concrete (AFRC), Bending Stress, Chloride & Sulphate.

## INTRODUCTION

Concrete is weak in tension and has a brittle character. The concept of using Fibers is 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 pottery. Use of continuous reinforcement in concrete (reinforced concrete) increases strength and ductility, but requires careful placement and labour skill. 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 me on the properties of fiber reinforced concrete using local materials are reported.

Concrete is a construction material composed of cement as well as other cementatious materials such as fly ash and slag content, aggregate (generally a coarse aggregate such as gravel, limestone, or granite, plus a fine aggregate such as river sand), water, and chemical admixtures. Concrete shows several desirable properties like High Compressive

Strength, Stiffness and Durability. Apart from its excellent properties, concrete shows a rather low performance when subjected to tensile stress. These shortcomings are generally overcome by reinforcing concrete with fibres because fibre reinforcement is one of the effective ways of improving the properties of concrete.

The concept of using fibres as reinforcement is not new. Fibres have been used as reinforcement since 1908. Early applications include addition of straw to Mud bricks, Horse hair to Reinforce Plaster. Addition of fibres to concrete makes it a homogeneous and isotropic material. When concrete cracks, the randomly oriented fibres start functioning, arrest crack formation and propagation, and thus improve strength and ductility.

Fibre reinforced concrete (FRC) is a concrete in which small and discontinuous Fibres are dispersed uniformly. The fibres used in FRC may be of different materials like Steel, G.I., Carbon, Glass, Aramid, Asbestos, Polypropylene, Jute etc. The addition of these fibres into concrete mass can dramatically increase the compressive strength, tensile strength, flexural strength and Impact strength of concrete. FRC has found many applications in Civil Engineering field. Comparing the result of FRC with plain grade concrete, this validated the positive effect of different fibres with percentage increase in compression and splitting improvement of specimen at 14days, analyzed the sensitivity of addition of fibres to concrete with different strength.

## OBJECTIVE

To analyses the durability of all four categories of fibres & comparison between them so that its use can be made simple and economical for concrete composites & constructional work in India.

## SCOPE OF WORK

- To minimize the hair cracking, micro cracks, fracture energy & chemical effect of concrete by addition of fibres.
- To provide applications, use & implementation of different fibres on a single place and also their comparison so that best one can be choose which fulfills the requirement.
- To minimize the cost of materials like – reinforcement & cement.
- To enhance tensile strength, low post cracking capacity, brittleness and low ductility, limited fatigue life & toughness

## METHODOLOGY

Methodology behind the research is as follows:
Cement Concrete is characterized by brittle failure. This characteristic, which limits the application of the material, can be overcome by the inclusion of a small amount of short randomly distributed fibers (steel, glass, synthetic and natural) and can be practiced among others that remedy weaknesses of concrete, such as low growth resistance, high shrinkage cracking, low durability, etc. Fibre reinforced concrete (FRC) is a concrete in which small and discontinuous fibres are dispersed uniformly. The fibres used in FRC may be of different materials like Steel, G.I., Carbon, Glass, Aramid, Asbestos, Polypropylene, Nylon, Coir, Jute etc. The addition of fibres into concrete mass can dramatically increase the compressive strength, tensile strength, flexural strength and Impact strength of concrete.

**FIBRE TYPES**

***i)*** ***Steel Fibres***- straight, crimped, twisted, hooked, ringed and paddled ends. Diameter range from 0.25 to 0.76 mm.

***ii)*** ***Glass Fibres***- straight. Diameter ranges from 0.005 to 0.015 mm (may be bonded together to form elements with diameters of 0.13 to 1.3mm).

***iii)*** ***Artificial (Nylon) Fibres***- kevlar, nylon and polyester. Diameter ranges from 0.02 to 0.38 mm.

***iv)*** ***Natural (Coir) Fibres-*** wood, asbestos, cotton, coir, bamboo, and rockwool. They come in wide range of sizes.

**Aspect Ratio**: Aspect Ratio is the **ratio of length of the fibre to the diameter of its cross-section**. Typical aspect ratio ranges from about **20 to 150.**

**Aspect Ratio = Length (L) / Diameter (D)**

| Fibre | Length (mm) | Diameter (mm) | Aspect Ratio |
|---|---|---|---|
| Steel | 30 | 0.50 | 60 |
| Glass | 60 | 0.60 | 100 |
| Coir | 50 | 0.80 | 60 |
| Nylon | 60 | 0.50 | 120 |

***Preparation of Beams:***

Through mixing of the material is essential of the production of uniform concrete. The mixing should ensure that the mass becomes homogenous in color and consistency. The Beam size 500mm x 100mm x 100mm is adopted in this research. 100 beam specimens of **M20** (1:1.5:3 mix by weight) grade of concrete were casted for testing of durability.

***Curing of Beams:***

Curing process is adopted to keep the concrete moist and warm enough so that the hydration of cement can continue at an atmospheric temperature. The method adopted for water curing is **PONDING.** In this concrete beam were immersed in water pond for **60 days**.

For durability check of concrete beams, beams were immersed in NaCl and $MgSO_4$ mix water for period of 60 days, which have maximum effect on concrete. Generally the amount of chemical added is 2 – 8%. In present work 3% of each chemical is used with respect to the quantity of Water.

**Water = 150 litres (approx.)**
**$MgSo_4$ = 4.5 Kg.**
**NaCl = 4.5 Kg.**

***Bending Stress:***

The flexural tensile strength at failure or the modulus of rupture is determined by loading a prismatic concrete beam specimen. The results obtained are useful because concrete is subjected to flexural loads more often than it is subjected to tensile loads.

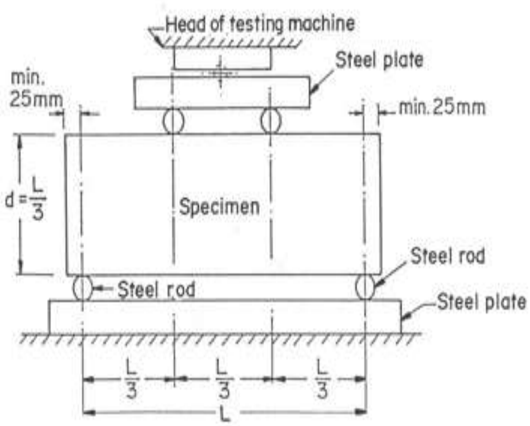


***Fig: Flexural testing Machine Layout***

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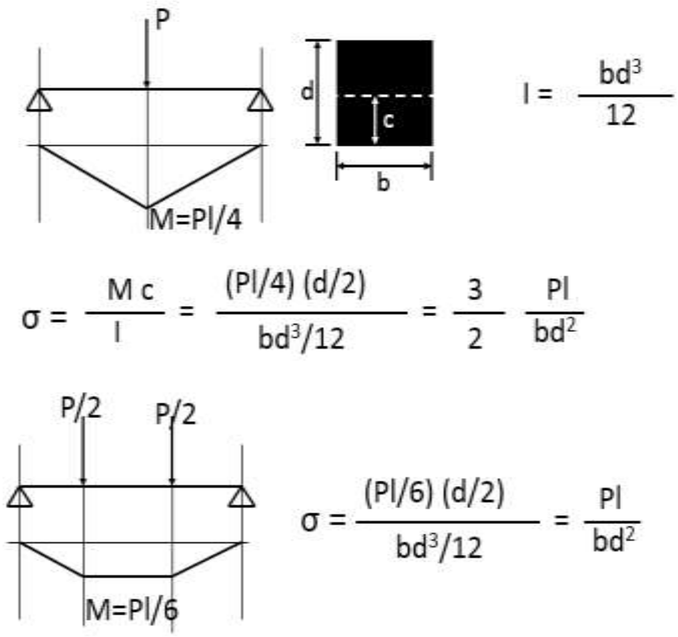


*Fig: Layout for calculation of Bending stress*

- Bending Stress of all beam samples were measured by flexural testing machine.
- Results are compared between plain water cured FRC beam samples and NaCl and $MgSO_4$ mix water cured FRC beams.
- By this comparison of bending stress we will get to the durability of concrete effected by NaCl and $MgSO_4$ mix water.

## RESULTS

To estimate the bending stress of FRC beams, which were prepared. For the FRC beam samples pounded in plain water for 60 days, flexural test has given following results-

| | GFRC | | | SFRC | | | NFRC | | | AFRC | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Fibre content %** | **Bending Stress ($N/mm^2$)** | | | **Bending Stress ($N/mm^2$)** | | | **Bending Stress ($N/mm^2$)** | | | **Bending Stress ($N/mm^2$)** | | |
| **0.10%** | **10.25** | **11** | **11.15** | **10** | **11** | **11.25** | **11** | **11.5** | **11.7** | **9.5** | **9.6** | **9.8** |
| | **10.8** | | | **10.75** | | | **11.4** | | | **9.63** | | |
| **0.20%** | **12.25** | **12.5** | **12.7** | **11** | **11.75** | **12.1** | **12.25** | **13** | **13.25** | **9.9** | **10.5** | **10.8** |
| | **12.48** | | | **11.61** | | | **12.91** | | | **10.4** | | |
| **0.30%** | **12.5** | **13** | **13.25** | **12.25** | **13** | **13.4** | **12.5** | **13.4** | **13.65** | **10.7** | **10.9** | **11.5** |

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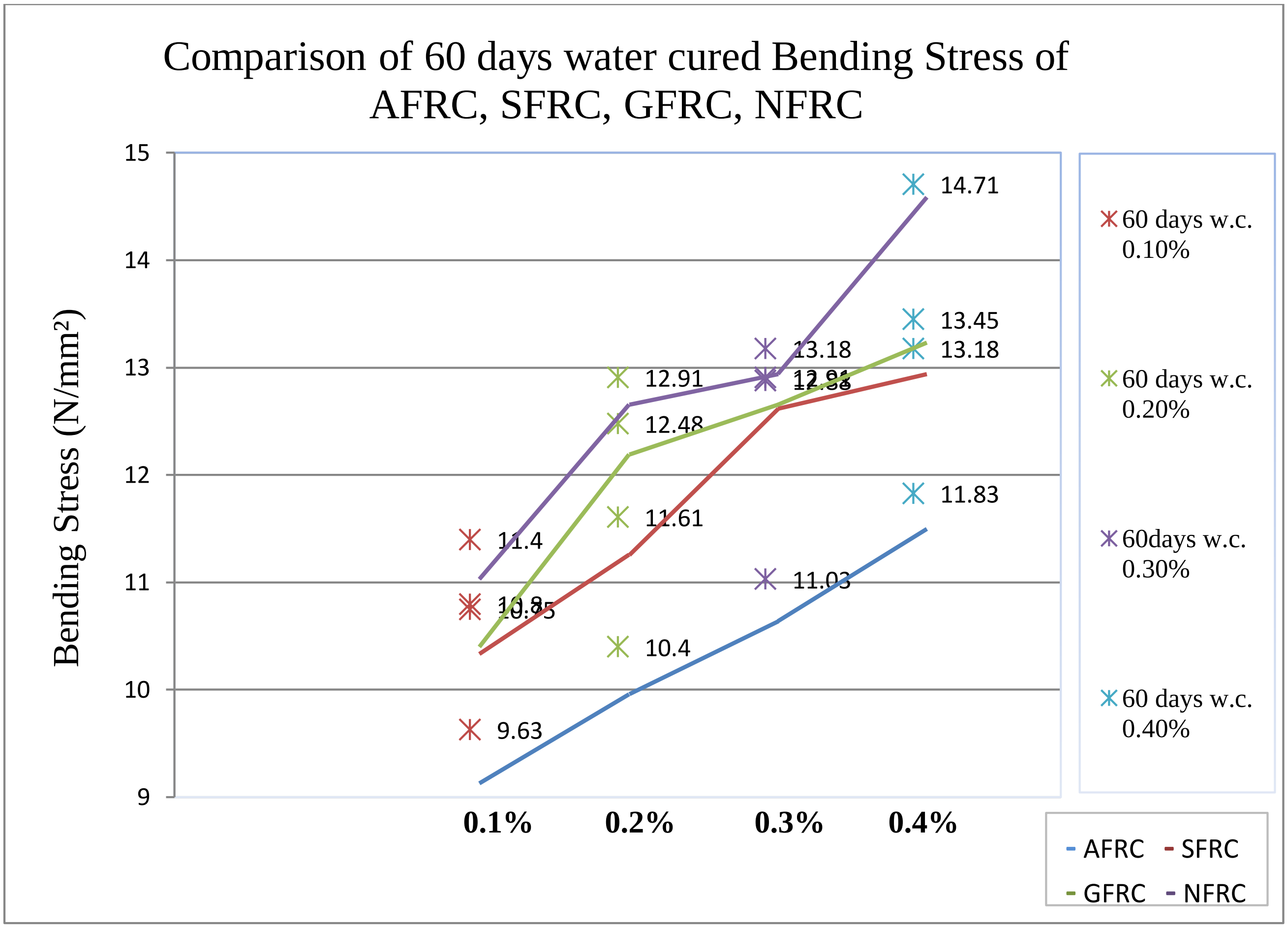
| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **12.91** | | | **12.88** | | | **13.18** | | | **11.03** | | |
| **0.40%** | **13.1** | **13.5** | **13.75** | **12.5** | **13.4** | **13.65** | **14.25** | **14.8** | **15.1** | **11.25** | **12** | **12.4** |
| | **13.45** | | | **13.18** | | | **14.71** | | | **11.83** | | |

***Table no.1: Bending Stress (N/mm$^2$) after 60 days cured in plain water***




To estimate the bending stress of FRC beams, which were prepared. For the FRC beam samples pounded in NaCl & $MgSO_4$ mix water for 60 days, flexural test has given following results-

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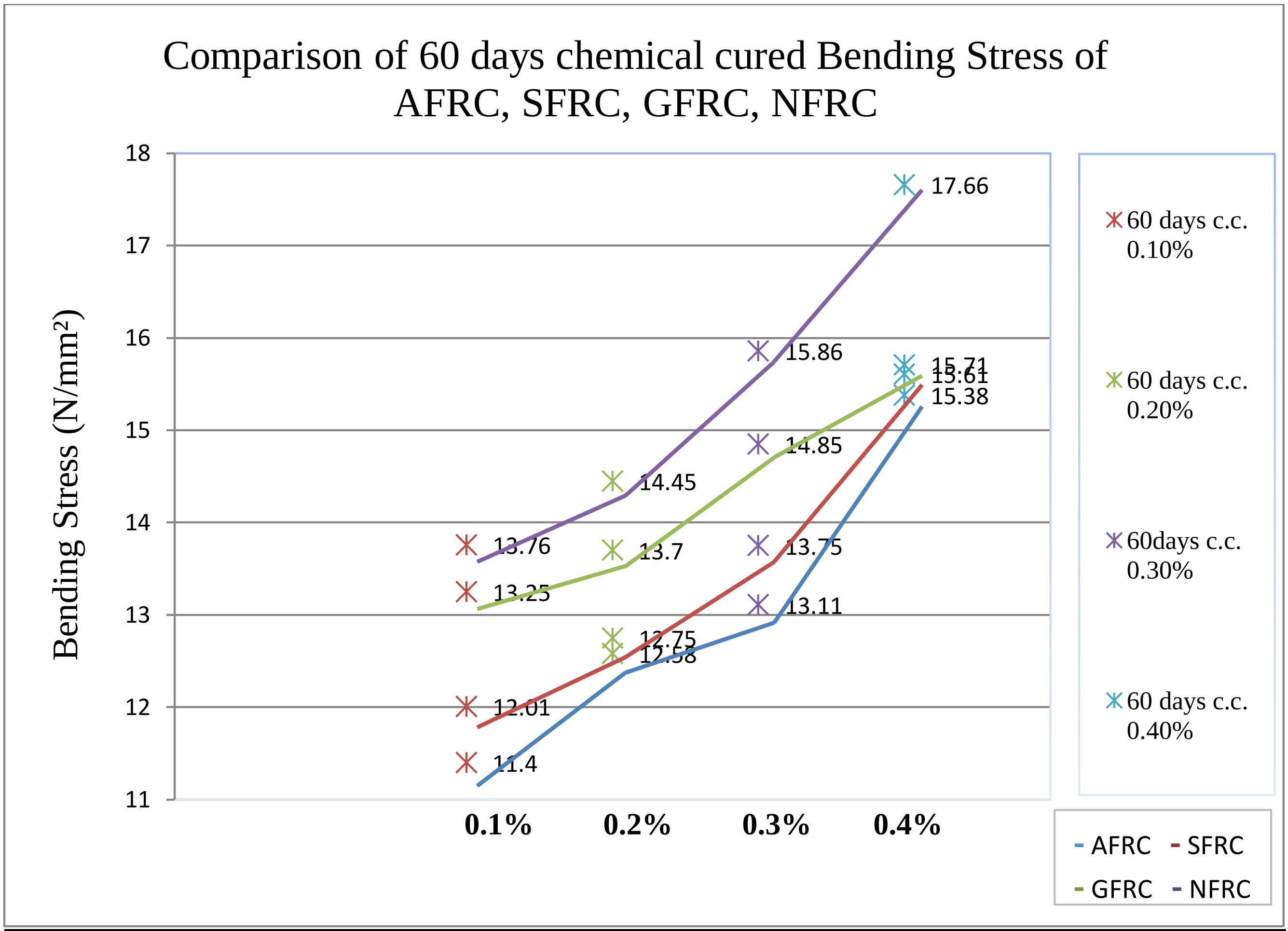
| | GFRC | | | SFRC | | | NFRC | | | AFRC | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fibre content % | Bending Stress (N/mm$^2$) | | | Bending Stress (N/mm$^2$) | | | Bending Stress (N/mm$^2$) | | | Bending Stress (N/mm$^2$) | | |
| 0.10% | 12.5 | 13.5 | 13.75 | 10.75 | 12.5 | 12.8 | 13 | 14 | 14.3 | 11.5 | 11.25 | 11.45 |
| | 13.25 | | | 12.01 | | | 13.76 | | | 11.4 | | |
| 0.20% | 13.4 | 13.75 | 13.95 | 12 | 13 | 13.25 | 13.75 | 14.5 | 15.1 | 12 | 12.75 | 13 |
| | 13.7 | | | 12.75 | | | 14.45 | | | 12.58 | | |
| 0.30% | 14.25 | 15 | 15.30 | 13.25 | 14 | 14.3 | 15.5 | 15.9 | 16.2 | 13 | 13.1 | 13.25 |
| | 14.85 | | | 13.75 | | | 15.86 | | | 13.11 | | |
| 0.40% | 14.75 | 15.5 | 15.9 | 14.5 | 16.25 | 16.4 | 17 | 17.8 | 18.2 | 14.75 | 16 | 16.1 |
| | 15.38 | | | 15.71 | | | 17.66 | | | 15.61 | | |

*Table no.2: Bending Stress (N/mm$^2$) after 60 days cured in chloride & sulphate mixed water*




## CONCLUSION

The bending stress is largely determined by the fibre orientation which depends on the mixing method. FRC controls cracking and deformation under impact load much better than plain concrete. About 15 MPa bending stress found at 0.40% fibre concentration when beams were cured in plain water & about 18 MPa bending stress found at 0.40% fibre concentration when beam samples were cured in NaCl & $MgSO_4$ mix water. As compare with other fibres such as GFRC, AFRC & SFRC, NFRC had maximum bending stress which is about 14MPa, 15MPa, 16MPa & 18MPa at fibre concentration of 0.10%, 0.20%, 0.30% & 0.40% respectively.

- As compared NFRC with GFRC, NFRC has higher bending stress found, though it is cured in plain water as well as in chloride & sulphate mix water. About 14MPa, 15MPa, 16MPa & 18MPa bending stress found for NFRC whereas GFRC has about 13MPa, 14MPa, 15MPa & 16 MPa bending stress at 0.10%, 0.20%, 0.30% & 0.40% fibre concentration respectively.
- As compared NFRC with SFRC, NFRC has higher bending stress found, though it is cured in plain water as well as in chloride & sulphate mix water. About 14MPa, 15MPa, 16MPa & 18MPa bending stress found for NFRC whereas SFRC has about 13MPa, 13MPa, 14MPa & 16 MPa bending stress at 0.10%, 0.20%, 0.30% & 0.40% fibre concentration respectively.
- As compared NFRC with AFRC, NFRC has higher bending stress found, though it is cured in plain water as well as in chloride & sulphate mix water. About 14MPa, 15MPa, 16MPa & 18MPa bending stress found for NFRC whereas AFRC has about 11MPa, 13MPa, 14MPa & 16 MPa bending stress at 0.10%, 0.20%, 0.30% & 0.40% fibre concentration respectively.

In spite of several existing solutions to overcome the shortcomings of **Natural Fibre**, the major concern till date is the Durability issue of Natural Fibre based composites and therefore, a great deal of research efforts is necessary for successful implementation of Natural Fibre in structural applications.

## REFERENCES

[1] Fibre Reinforced Concrete- N. Banthia - Nemkumar Banthia is a Professor and Distinguished University Scholar at the University of British Columbia, Vancouver, Canada. A fellow of the ACI, the Canadian Soc. of Civil Engg., Indian Concrete Institute and the Canadian Academy of Engineering, his awards include the Wason Medal of the ACI and the Solutions through Research Award of the Innovation Council of British Columbia.

[2] Faisal Fouad Wafa - Associate Professor, Civil Engineering Department, Faculty of Engineering, King Abdulaziz University, Jeddah, Saudi Arabia, JKAU: Eng. Sci., Vol. 2, pp. 49-6~1990.

[3] P. N. Balaguru and S. P. Shah, “Fibre Reinforced Cement Composites", McGraw-Hill Inc; 1992.

[4] S P Shah, V K Rangan, “Effect of Fibre Addition on Concrete Strength “, Indian Concrete Journal, Volume 5, Issue 2-6 Pp. 13-21, 1994.

[5] Experimental Study on Behavior of Steel and Glass Fibre Reinforced Concrete Composites -Kavita S Kene, Vikrant S Vairagade and Satish Sathawane, Bonfring International Journal of Industrial Engineering and Management Science, Vol. 2, No. 4, December 2012.

[6] V. Vairagade and K. Kene, “Experimental Investigation on Hybrid Fibre Reinforced concrete”, International Journal of Engineering Research and Applications, Volume 2, Issue 3, Pp. 1037-1041, 2012.

[7] Synthetic fibres - By Anne Laning, Publication #C920525 Copyright © 2013, The Aberdeen Group.

[8] Tensile behaviour of glass fibre reinforced concrete - J.A.O.Barros School of Engineering, University of Minho,Guimarães, Portugal, J.A.Figueiras Civil Eng. Dept., Faculty of Engineering, University of Porto, 4099 Porto, Portugal. C.V.D.Veen Faculty of Engineering, Delft University of Technology, Netherlands.

[9] The Use of Glass Fibre–Reinforced Concrete As A Structural Material - J.P.J.G. Ferreira and F.A.B. Branco.

[10] Synthetic Fibre Reinforcement for Concrete – **by** D. Ludirdja, **J.F.** Young, USACERL Technical RNepoovretm FbMer- 9139/0922, November 1992.

[11] Glass Fibre Reinforced Concrete Use in Construction - Eng. Pshtiwan N. Shakor*, Prof. S. S. Pimplikar**, *M.E. Civil (MIT) College, Sulaimaniyah International Airport,Iraq. **Head and Professor of Civil Eng. Dept., MIT College, Pune, International Journal of Technology And Engineering System (IJTES): Jan – March 2011- Vol.2.No.2.

[12] Natural Fibre Composites for Structural Applications - Shama Parveen*, Sohel Rana, Raul Fangueiro, * Fibrous Materials Research Group (FMRG), School of Engineering, University of Minho, Campus de Azurém, Guimaraes, Portugal, Mechanics of Nano, Micro and Macro Composite Structures, Politecnico di Torino, 18-20 June 2012, A. J. M. Ferreira, E. Carrera (Editors

[13] Suitability of Concrete Reinforced with Synthetic Fiber for the Construction of Pavements - Rakesh Kumar, Pankaj Goel and Renu Mathur, Rigid Pavements Division, Central Road Research Institute, Delhi-Mathura Road, New Delhi - 110025, India.