STUDIES ON SUITABILITY OF FIBER REINFORCED HIGH VOLUME FLY ASH CONCRETE FOR RIGID PAVEMENTS

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ABSTRACT: ***This paper deals with an experimental study on the use of high volume fly ashin concrete for rigid pavements. High volume fly ash concrete (HVFAC) has very low water content and generally, more than 50 percent cement is replaced by fly ash. Because of the low water content, a high range water reducer or superplasticizer is used to achieve desired workability. Compared to conventional concrete, HVFAC has lower early compressive strength but very good later age strength, which continues to increase over several months. HVFAC has also performed better in terms of its elastic modulus, flexural, tensile and abrasion strengths. The production and consumption of cement, as an essential ingredient of concrete, is expected to increase substantially in the coming years in India as a result of increasing construction arising from India's rapid infrastructure development. This will result in significantly higher CO, emissions, nationally if corrective steps are not taken. The use of the HVFAC technology can allow large volumes of fly ash to replace Portland cement in various concrete applications, thereby providing the multiple benefits of reduced CO2 emissions, improved cost benefit ratios for infrastructure development, and reduced environmental hazards related to the disposal of fly ash in the landfills.***

The improvement of HVFAC development will help in reduction in the growth of greenhouse gas emissions from cement and concrete production, more sustainable use of natural resources and increased utilization of fly ash in the cement and concrete industry. HVFAC was first developed for mass concrete applications where low heat generation and adequate strength were required. Subsequent work has demonstrated that this type of concrete, given its excellent mechanical and durability properties, can also be used for structural applications. The main objective of this proposed research work is to develop the fiber reinforced high volume fly ash concrete (FRHVFAC) as a material for construction of rigid pavements. To achieve the above objective the following experimental works are planned. To find out the strength properties of fiber reinforced high volume fly ash concrete such as compressive strength, tensile strength, flexural strength, and impact strength required for rigid pavements. To find out the resistance of fiber reinforced high volume fly ash concrete to acidic attack. To find out the resistance of fiber reinforced high volume fly ash concrete to chloride attack. To study the behaviour of fiber reinforced high volume fly ash concrete under temperature variations.

The strength properties of FRHVFAC such as compressive strength, tensile strength, flexural strength and impact strength have shown an increasing trend up to 1.4% addition of steel fibers. FRHVFAC has shown better resistance to acidic attack by allowing less acid to penetrate. Substantial improvements are found in compressive strength, tensile strength, flexural strength and impact strength, when 1.4% steel fibers are added to high volume fly ash concrete and when subjected to acidic attack. The strength properties of FRHVFAC such as compressive strength, tensile strength, flexural strength and impact strength, have shown an increasing trend up to 1.4% addition of steel fibers, when subjected to sulphate attack of potasium sulphate solution of 15% concentration. More than 1.4% addition of steel fibers results in lowering the strength values. The thermal conductivity of FRHVFAC shows a decreasing trend with increase in fiber content up to 1.6%. More than 1.4% addition of fibers result in the increased values of thermal conductivity. A similar observation is made with coefficient of linear expansion where the co efficient of linier expansion of FRHVFAC shows a decreasing trend with increase in the fiber content up to 1.6%.

Key Words: HVFAC, FRHVFAC, Rigid Pavements, fly ash.

I. INTRODUCTION

Fly ash is one of the by-products produced from the process of coal burning. Electricity generation using coal as the energy source is the main industry, which produces fly ash as its major solid waste. There are still other types of solid wastes produced from the coal generating plants like bottom ash and gypsum but their volumes are generally far less than that of the fly ash. There are difficulties around the world to achieve effective utilization of fly ash or even toget rid of it. Majority of the fly ash is dumped or used in low-valued methods such as using asa land-fill material, soil improvement, road base, land reclamation, raw material for producing cement etc. The most effective use of fly ash at present, by considering both volume and value, isin the area of concrete. The use of fly ash as a cement substituting material is believed to be beneficial by environmental and economic aspect.

The current electricity generation (as on March 31, 2004) in India is about 1,12,058 MW, 65-70% of which is thermal (mostly coal based). According to an estimate 100,000 MW capacity or more would be required in the next 10 years due to continually increasing demand for electricity. In India fly ash generation is around 110 million tonnes / year and is set to continue at a high rate into the foreseeable future. Presently majority of the coal ash generated is being handled in wet form and disposed of in ash ponds, which are harmful for the environment and moreover ash remains unutilized for gainful applications. India has sufficient coal reserves. In India almost 65-70% of electricity production is dependent on coal which produces a huge quantity of fly ash as residue which is allegedly a waste product in thermal power stations.

Fly ash has a vast potential for use in high volume fly ash concrete (HVFAC) especially due to its physio-chemical properties. A good amount of research has been done in India and abroad on HVFAC strength and other requisite parameters. Presently in India, most of the ready- mixed concrete for private industry is using fly ash between 20 to 30 % of the cementitious material in it, while many government departments still have reservations towards its use. Batching plants on large construction sites are comfortable with fly ash up to about 25 — 30%. Much of the concrete mixed onsite with Tilting drum mixers does not use fly ash as a separate additive but blended cement use is common. As regards cement, nearly 60 to 70% of it being manufactured and sold is blended cement with 22 to 32 % of fly ash.

High volume fly ash concrete (HVFAC) has very low water content and generally, more than 40 percent cement is replaced by fly ash. Because of the low water content, a high range water reducer or superplasticizer is used to achieve desired workability. In situations where high early strength and high slump is not required, the use of superplasticizer may not be necessary. Compared to conventional concrete, HVFAC has lower early compressive strength but very good later age strength, which continues to increase over several months. HVFAC has also performed better in terms of its elastic modulus, flexural, tensile and abrasion strengths.

It is well known that concrete is very good in resisting compressive forces, but it is found to be weak against tensile forces. It has the qualities of flexibility and ability to redistribute stresses, but it possesses a low specific modulus, a limited ductility, and a very little resistance to cracking. The addition of fly ash to concrete further improves its compressive strength but contributes less to improve its other properties like tensile strength, ductility, resistance to cracking...etc. The potentialities of fly ash concrete can be exploited by imparting tensile resistance property to it. Investigations carried out by various researchers has proved that the introduction of discrete, uniformly dispersed, randomly oriented steel fibers to plain concrete not only improves its resistance against tensile forces, but also imparts greater ductility and delays the onset of first flexural crack. In fly ash concrete composites also, the addition of such fibers can improve its resistance against tensile stresses, delay the onset of flexural crack and improve ductility. Thus, the addition of two materials; namely fibers and high-volume fly ash in concrete results in a new composite called Fiber Reinforced High Volume Fly Ash Concrete, which not only shows better resistance to compressive forces but also exhibits substantial resistance to tensile forces.

Objectives of research work

The main objective of this proposed research work is to develop the fiber reinforced high volume fly ash concrete (FRHVFAC) as a material for construction of rigid pavements. To achieve the above objective the following experimental works are planned.

• To find out the strength properties of fiber reinforced high volume fly ash concrete such as compressive strength, tensile strength, flexural strength and impact strength required for rigid pavements.

• To find out the resistance of fiber reinforced high volume fly ash concrete to acidic attack.

• To find out the resistance of fiber reinforced high volume fly ash concrete to sulphate attack.

• To find out the resistance of fiber reinforced high volume fly ash concrete to chloride attack.

• To study the behaviour of fiber reinforced high volume fly ash concrete under temperature variations.

• To study the behaviour of fiber reinforced high volume fly ash concrete un decentral loading, edge loading and comer loading condition.

II. MATERIALS & METHOD

In this experimental program, the primary stage includes the preliminary research on selecting the raw materials.

Cement

In the present research work ordinary Portland cement of 43 grade UltraTech cement is used. The tests on cement are conducted in accordance with Indian standards confirming to IS: 8112 - 1989.

Fly ash

The fly ash used in the present study is taken from Raichur Thermal Power Station, Shakthinagar, Raichur, Karnataka.

Fine aggregate

The fine aggregates used in this experimental program is procured locally from Tungabhadra river bed near Harihar. The test on sand is conducted according to IS:2386 — 1963 and IS:383-1970.

Coarse aggregate

Locally available crushed granite coarse aggregates having the maximum size of 20 mm are used in the present work. The aggregates are tested as per Indian Standard Specifications IS: 2386-1963.

Super plasticizer

Conplast- SP430, a concrete superplasticizer based on Sulphonated Naphthalene Polymer is used as a water-reducing admixture and to improve the workability of fly ash concrete. Conplast SP430 has been specially formulated to give high water reductions up to 25% without loss of workability or to produce high quality concrete of reduced permeability. Conplast SP430 is non-toxic. CONPLAST SP430 is marketed byWs Fosroc Chemicals, Bangaluru

Steel fibers

Crimped steel fibers manufactured by Mls Stewols India (P) Ltd., Nagapur, are used in the present study.

Water

Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. Since it helps to form the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully. Potable water is generally considered satisfactory. In the present investigation, tap water is used for both mixing and curing purposes.

Mix design

The Indian codes are allowing up to 35% usage of fly ash in concrete. Hence in this research to design the HVFAC the guidelines of CANMET is used. The proportioning of HVFAC by guidelines of CANMET has used the absolute volume method, which is the most common procedure of mix design.

III. EXPERIMENTAL PROGRAM

Test for compressive strength (IS: 516 - 1959)

Concrete cubes of size l50mm x l50mm x l50mm are used to prepare the specimens for determination of compressive strength of FRHVFAC. All specimens are prepared in accordance with Indian Standard Specifications IS: 516 - 1959. All themoulds were cleaned and oiled properly. These are securely tightened to correct dimensions before casting.

Test for split tensile strength(I S:5816 — 1999)

Concrete cylindrical specimen of diameter l 50mm and height 300mm are cast for split tensile strength of FRHVFAC. All specimens are prepared in accordance with Indian Standard Specifications IS: 5816 -1999. All the moulds are cleaned and oiled properly. These are securely tightened to correct dimensions before casting. Care is taken to see that there are no gaps left for leakage of slurry. After 24 hours of casting, the specimens are stripped and kept for curing. The specimens are removed from the tank and tested for split tensile strength, using compressive testing machine of capacity 2000 kN. The test is carried out by placing the specimen horizontally between the loading surfaces of the compression testing machine and load is applied until the failure.

Test for flex ural strength (IS:516 — 1959)

Concrete beam specimen of dimension l00mm x 100 mm x 500 mm are cast for flexural strength of FRHVFAC. All specimens are prepared in accordance with Indian standard specifications, IS: 516 -1959. All the moulds are cleaned and oiled properly. These are securely tightened to correct dimensions before casting. Care is taken to see that there are no gaps left for leakage of slurry. After 24 hours of casting, the specimens are stripped and kept for curing. The specimens are removed from the curing tank after required period for flexural testing. The test is conducted on universal testing machine of 600kN capacity. Test specimens are stored in water at a temperature of 24° to 30°C for 48 hours before testing and tested immediately on removal from the water whilst they are still in a wet condition. The specimen is placed in the machine in such a manner that the load is applied to the uppermost surface as casted in the mould, along two lines spaced 133 mm apart. The axis of the specimen is carefully aligned with the axis of the loading device. The load on the specimen is gradually loaded till failure at the rate of l800N/min. Two point loading is adopted while testing the specimens.

Test for acidic attaek

The specimens are cured in water for 7, 28 and 90 days and then the specimens are subjected to acidic attack for 90 days. They are immersed in Sulphuric acid solution of pH 2.5 for 90 days. Before immersion the specimens are weighed accurately. The pH of solution is regularly checked and is maintained constant throughout the experimentation. After 90 days of acidic attack, the specimens are removed from the acidic media, washed in running water and weighed accurately to find loss of weight. Then they are tested for their respective strengths.

Test for sulph ate attack

The specimens are cured in water for 7, 28 and 90 days and then the specimens are subjected to sulphate attack for 90 days. They are immersed in Potassium sulphate solution of 15% concentration for 90 days. Before immersion the specimens are weighed accurately. The concentration of solution is regularly checked and is maintained constant throughout the experimentation. After 90 days of sulphate attack, the specimens are removed from the Potassium sulphate solution, washed in running water and weighed accurately to find loss of weight. Then they are tested for their respective strengths.

Test for chloride attack

The specimens are cured in water for 7, 28 and 90 days and then the specimens are subjected to chloride attack for 90 days. They are immersed in sodium chloride solution of 15% concentration for 90 days for chloride attack study. Before immersion the specimens are weighed accurately. The concentration of solution was regularly checked and is maintained constant throughout the experimentation. Afler 90 days of chloride attack, the specimens were removed from the sodium chloride solution, washed in running water and weighed accurately to find loss of weight. Then they are tested for their respective strengths.

Test for thermal properties.

The thermal properties like thermal conductivity and coefficient of linear expansion of FRHVFAC are studied for variation of fiber content. The guarded hotplate method was adopted for thermal conductivity measurement. The specimen size of 150 mm in diameter and 64 mm thickness is used for this purpose. A controlled hot plate is placed in between two specimens and conductivity is measured by measuring the temperature at both side of the specimen. The coefficient of linear expansion of concrete is defined as the rate of change of linear dimension per degree rise of temperature. The coefficient of linear expansion of concrete is determined by measuring the expansions of specimens by using temperature- controlled oven. The temperatures were measured by taking out the thermocouples from the specified points and by using digital temperature indicator.

IV. RESULTS AND DISCUSSION

The results obtained in this research work were presented here M40 concrete mix is designed in accordance with the guidelines of CANMET handbook with 50% replacement of cement by fly ash. The mix proportion arrived is 1:1.17:2.54 (BC: FA: CA) with water binder ratio of 0.3 and superplasticizer dosage of 1.1% by weight of binder content (cement + fly ash). Fibers are added at varying percentages of 0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6 and 1.8 % by volume fraction. The specimens are cast for compressive strength, split tensile strength, flexural strength and impact strength testsThe test results are shown in graphs for analysis.

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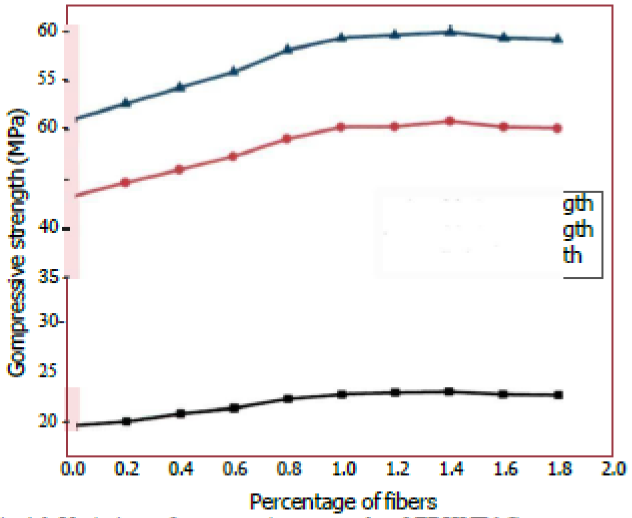

Fig 1 Variation of compressive strength of FRHVFAC

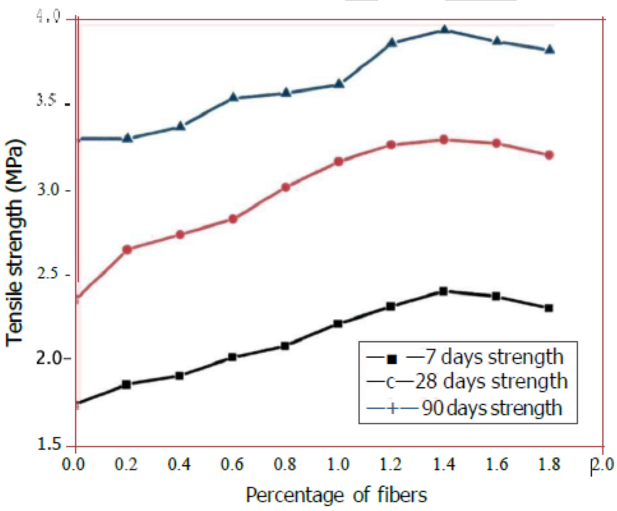

Fig 2. Variation of tensile strength of FRHVFAC

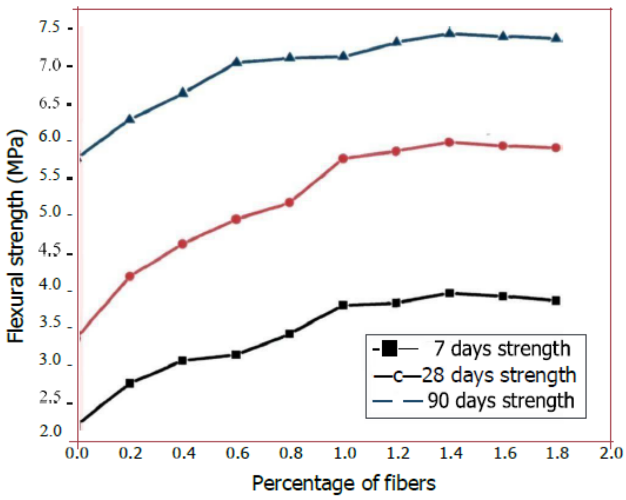

Fig 3 Variation of flexural strength of FRHVFAC

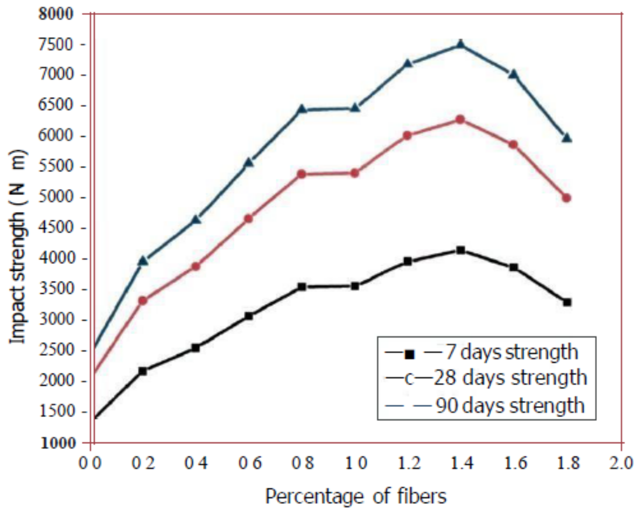

Fig 4. Variation of impact strength of FRHVFAC

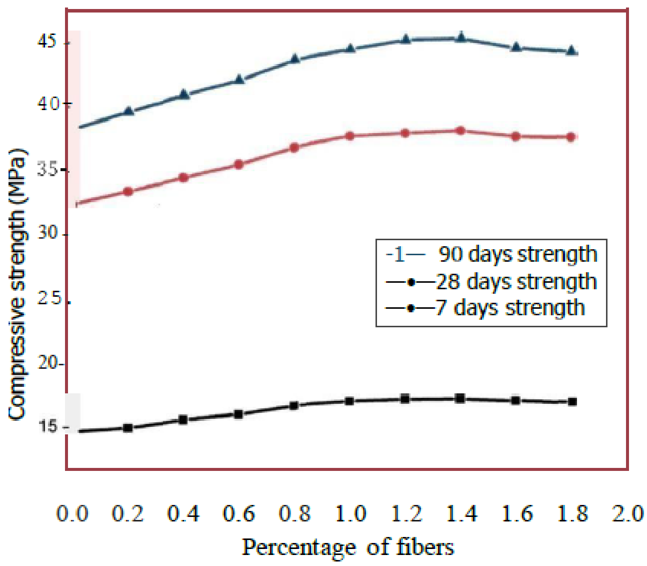

Fig 5. Variation of compressive strength of FRHVFAC when subjected to acidic attack

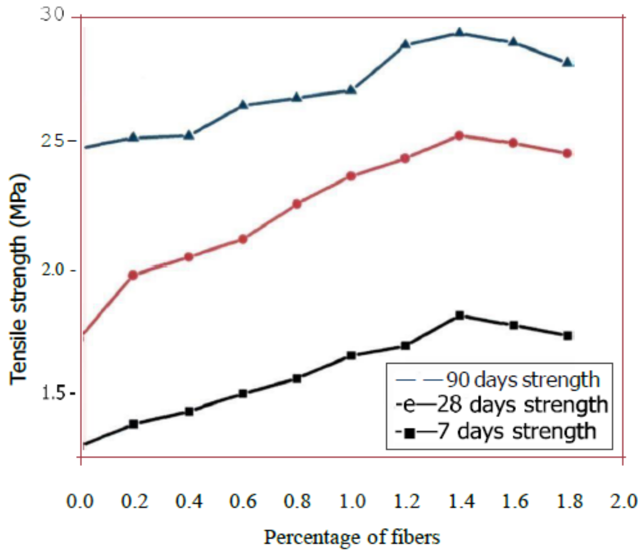

Fig. 6. Variation of tensile strength of FRHVFAC when subjected to acidic attack

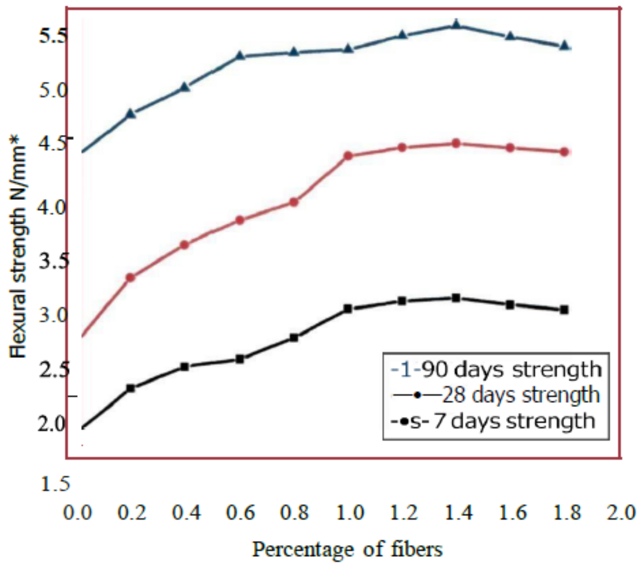

Fig 7 Variation of flexural strength in FRHVFAC subjected to acidic attack.

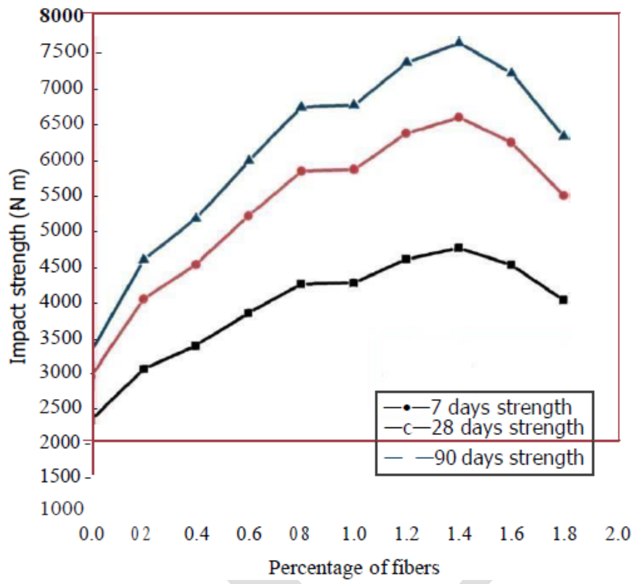

Fig 8.Variation of impact strength in FRHVFAC subjected to acidic attack.

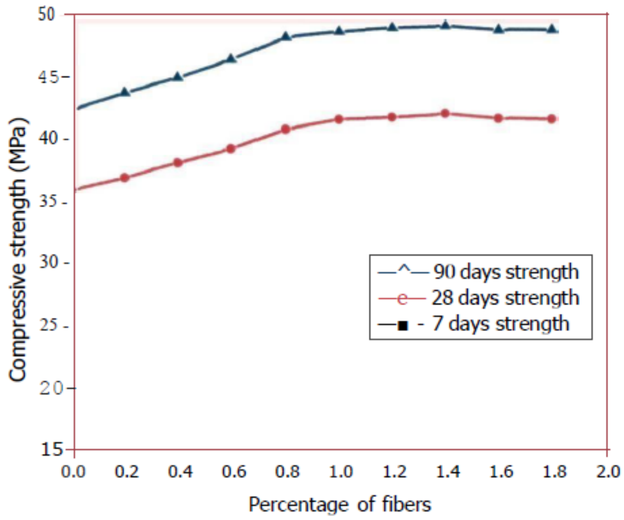

Fig.9 - Variation of compressive strength in FRHVFAC subjected to sulphate attack.

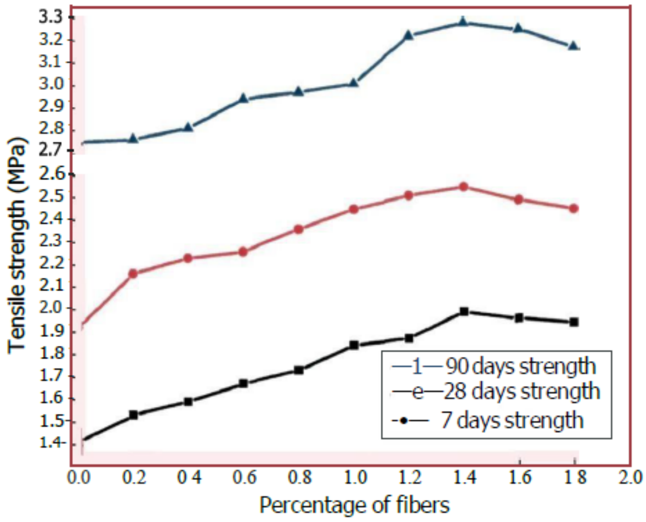

Fig. 9 Variation of tensile strength in FRHVFAC subjected to sulphate attack.

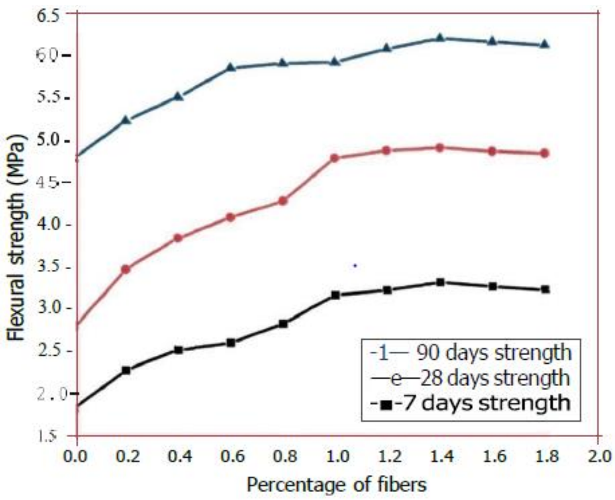

Fig. 10 Variation of flexural strength in FRHVFAC subjected to sulphate attack.

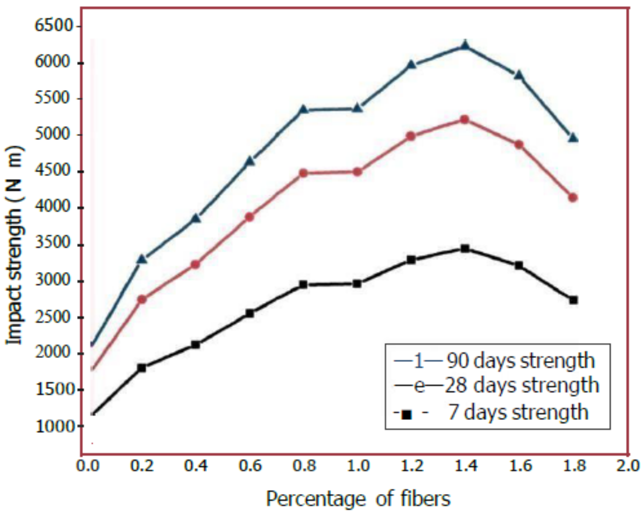

Fig 11.Variation of impact strength in FRHVFAC subjected to sulphate attack

V. CONCLUSIONS

Following are the few salient conclusions that can be drawn based on the experimental study conducted on suitability of fiber reinforced high volume fly ash concrete for rigid pavements.

1. The strength properties of FRHVFAC such as compressive strength, tensile strength, flexural strength and impact strength have shown an increasing trend up to 1.4% addition of steel fibers. Thereafter the strength properties show a decreasing trend. This is true for 7 days, 28 days and 90 days strength. Thus the use of steel fibers in high volume fly ash concrete can modify the strength properties. Therefore high volume fly ash concrete can be recommended in the construction of rigid pavements.

2. FRHVFAC has shown better resistance to acidic attack by allowing less acid to penetrate. Substantial improvements are found in compressive strength, tensile strength, flexural strength and impact strength, when 1.4% steel fibers are added to high volume fly ash concrete and when subjected to acidic attack. Therefore FRHVFAC can be recommended in the construction of rigid pavement where acid attack possibilities exists.

3. The strength properties of FRHVFAC such as compressive strength, tensile strength, flexural strength and impact strength, have shown an increasing trend up to 1.4% addition of steel fibers, when subjected to sulphate attack of potasium sulphate solution of 15% concentration. More than 1.4% addition of steel fibers results in lowering the strength values. Thus substantial improvements are found in compressive strength, tensile strength, flexural strength and impact strength, when 1.4% steel fibers are added to high volume fly ash concrete and when subjected to sulphate attack. Therefore FRHVFAC can be recommended in the construction of rigid pavement in soils affected by sulphates.

4. Remarkable improvement are also found in compressive strength, tensile

strength, flexural strength and impact strength when l.4% steel fibers are added to high volume fly ash concrete and when subjected to chloride attack. The strength characteristics have shown a decreasing trend after 1.4% addition of steel fibers in high volume fly ash concrete with chloride attack. Thus there is a clear indication that the use of steel fiber in high volume fly ash concrete can modify the properties and allow less chloride ions to penetrate. Therefore, FRHVFAC can be recommended in the construction of rigid pavements where chloride attack possibilities exists.
5. The thermal conductivity of FRHVFAC shows a decreasing trend with increase in fiber content up to 1.6%. More than 1.4% addition of fibers result in the increased values of thermal conductivity. A similar observation is

made with coefficient of linear expansion where the co efficient of linier expansion of FRHVFAC shows a decreasing trend with increase in the fiber content up to 1.6%.

6. The tests on destructive loading on FRHVFAC rigid pavements reveal the fact that their load carrying capacity is more as compared to high volume fly ash concrete rigid pavements. The corresponding strain values are also less in FRHVFAC pavements. Also it is observed that the number of cracks, width of cracks and length of cracks are much smaller in FRHVFAC pavements as compared to high volume fly ash concrete pavements.

7. Thus the study reveals the fact that the addition of steel fibers to high volume fly ash concrete can enhance the properties of concrete and make it suitable for the construction of rigid pavements.

VI. REFERENCES

1. ASTM C 593-95(2000), "Standard specffiCation for fiy ash and other pozzolans for use with lime, " Annual Book of ASTM Standards Vol .04.01, p. 1, 95, 2000.

2. Geoffrey Boffey and Elizabeth Hirst. "The use of pozzolans in lime mortar.Journal of architectural conservation", Vol. S No. 3. 1999, p. 36.

3. Pat Gibbons, "Pozzolans for lime mortars", The building conservation directory, online at www.buildingconservation.com, 1997,

4. CIDA, NRCAN, CII, "High volume fly ash concrete technology fly ash status summary report in India", CII , New Delhi, 2005

5. ASTM C 618-1993, "Standard specification for coal fiy ash and raw or calcined natural pozzolan for use as a mineral admixture in concrete ", Annual book of ASTM standards, www.astm.org, 1993.

6. Gabriel Varga, "The structure of kaolinite and metakaolin ", Epitoanyag 59, evf.2007, 1.szam.6-9, 2007

7. CII, CANMET and NRcan, "High volume fiy ash concrete technology hand book"
CII, New Delhi — March 2005

8. Malhotra V. M. and Mehta P. K., "High-performance high-volume fiy ash concrete: materials, mixture proportioning, properties, construction practice, and case histories", Marquardt Printing Ltd., Ottawa, Canada, August 2002

9. ACI Committee 544, "State-of-the-art report on fiber reinforced concrete ", ACI 544 1.R-96 (2002)

10. Bentur A. and Mindess S., "Fibre reinforced cementitious composites ", Elsevier, London, 1990.

11. Hannant D. I., "Fibre, cements and fibre concretes ", John Wiley & Sons, Ltd., Chichester, United Kingdom, 1987.

12. Balaguru P. N. and Shah S.P., "Fiber-reinforced cement composites ", McGraw- Hill, 1992.

13. Romualdi J. P., and Batson G. B., "Mechanics of crack arrest in concrete ", Journal of engineering mechanics division, ASCE, Vol. 89, No. EM3, pp 147-168,1963.

14. Romuldi J. P, "Two-phase concrete and steel material", U. S. Patent Office 3 429 094 , 1969.
178

15. Tatnll P.C. and Kuitenbrouwer L., "Steel fiber reinforced concrete in industrial
fioors ", Concrete International, p.43-47, December 1992.

16. Ersoy H. Y., "Composite materials ", Literature publishing house, Istanbul, 2001.

17. Faw T. F. and Paramasivam P. "Thin steel fiber cement mortar overlay for concrete pavement", Cement and Concrete Composites 12(1990), Elsevier Science Publisher Ltd, England, pp 175-184, 1990.

18. Ramakrishnan V., Balaguru P., Kostaneski L. and Johnston D., "Field performance of fiber reinforced concFete highway pavements. ", Proceeding of the first materials engineering congress on serviceability and durability of construction materials, Denver, Vol. 2, pp 903-912, 1990.

19. Tarun R. Naik, Shiw S. Singh and Mohammad M. Hossain , "Abrasion resistance of concrete as infiuenced by inclusion of fiy ash", Cement and Concrete Research, Vol. 24, pp 303-312, 1993.

20. Tarun R. Naik Shiw S. Singh and Mohammad M. Hossain, "Permeability of concrete containing large amounts of fiy ash" Cement and Concrete Research, Vol. 24, pp 913-922, 1994.

21. McCarthy M. J. and Dhir R. K., "towards maximizing the use of fly ash as a binder", Fueal 78 (1999), Elsevier Science Ltd., pp 121-132, 1998.

22. Siddique and Karanbir Singh., "Effect of san fiber on the impact strength of high fly ash concrete ", NBM & CW, pp13-20, 1999.

23. Cengiz Duran Atis., "Abrasion resistance of high volume fiy ash concrete ", Teknik Dergi, Vol. 11, No 4, pp 2217-2230, 2000.

24. Jiang L. H. and Malothra V. M., "Reduction in water demand of non-air- entrained concrete incorporating large volumes of fiy ash", Cement and Concrete Reasearch, Elsevier science Ltd., pp 1785-1789, 2000.

25. Seshagiri Rao M. V., Janardhana M. and Swaroopa Rani M., "Strength characteristics of high volume fiy ash concrete ", International Conference on Civil Engineering-2001, Bangalore, Interline publishing, 2001.

26. Kejin Wang, Surendra P. Shah and Pariya Phuaksuk , "Plastic shrinkage cracking in concrete materials - infiuence

of fiy ash and fibers ", ACI Material Journal, Vol. 98, No 6, pp 458-464, 2001.

27. Cengiz Duran Atis, "Heat evolution of high-volume fiy ash concrete ", Cement and Concrete Research, Pergmon, Elsevier science Ltd., pp 751-756, 2002.

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