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Experimental Investigation on Flexural Behaviour of SFRC

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ABSTRACT

Steel fibre-reinforced concrete (SFRC) is used increasingly now a days with enormous application. The mixing of steel fibre (SF)to conventional reinforced concrete (RC) improves the cracking strength. It will restrict the growth of cracks and reduce the tensile strain in steel reinforcement bars and smaller crack width. It has excellent tensile, flexural strength, fatigue resistance and ductility.

This work studies the behavior of SFRC structural elements. It is to investigate the effects volume of fibre (VF) on the compressive, split tensile, and flexural behaviors of SFRC, and to compare modes of failure. The properties of fresh concrete and the strength of hardened concrete and flexural behaviour of SFRC beams & slabs under two-point loading were conducted. Cubes, cylinders and prisms were cast and tested for compressive, split tensile and flexural strength after a curing period of 28 days. Failure loads v/s cracking patterns of beams and slabs with varying percentage of SF (NF 0percent, 0.5percent, 1percent and 1.5percent) in concrete of M-20 & M-30 grade were studied.

Beam of size 150 mm x 150 mm x 700 mm and slabs of size 765 mm x 380 mm x 50 mm of different were casted and tested under two-point flexural loading.

The study concludes that, with 3 different fraction of VF, for both strength and economical aspects, 1.0 percent was showed as the best fibre volume. The load carrying capacity of SFRC beams and slabs with 1.0 percentVF is increased by 1.25percent with respect to non fibrous RC beams.

Keywords: Steel Fibre-Reinforced Concrete (SFRC), Steel Fibre.

I INTRODUCTION

1.1 GENERAL

Steel fibre-reinforced concrete (SFRC) is used increasingly now a days with enormous application. The mixing of SFto conventional RC improves the cracking strength. It will restrict the growth of cracks and reduce the tensile strain in steel reinforcement bars and resulting in smaller crack width. SFRC has the excellent tensile strength, flexural strength, fatigue resistance and ductility.

1.2 STEEL FIBRE

Steel fibre (SF) is cut from MS wire.The dia in the range of 0.15mm to 1.0mm, manufactured by M/s Stewols& Co and M/s Handy product.

II LITERATURE REVIEW

The fibres has been used since3500 years long, when sun-baked bricks reinforced with straw were used to build AqarQuf near Baghdad [1]. In addition, horsehair was used to reinforce masonry mortar and plaster [2].1960s in US, the first major investigation was made to evaluate the potential of SFas a replacement for steel reinforcing rods in concrete [3]. Experiments using plastic fibres in concrete with and without steel reinforcement were also conducted [4].

In now a day, SFRC isrecognized as a finer reinforcement which can reduces brittleness and increases the load carrying capacity of concrete members [5].

Romualdi and Batson [3] gave improvement in concrete propertiesthrough the use of randomly distributed SF. The effect of SF is on energy absorption capacity i.e. toughness and prevention of crack propagation in concrete. SFdo not have considerably influence in flexural characteristics of concrete prior to cracking and improve resistance of crack development [14,6,7]. In literatures, previous researchers [8, 9,10,11,12,13] have noted that the most suitable amount of SF is 1.0 percent to 2.5 percent of total concrete volume. Dosage below 1.0 percent does not have too much influence than 2.5 percent is ineffective due to workability and the physical difficulties in providing homogeneous distribution which cause drop in compressive strength.

Oh et al., [15] showed, the flexural strength of SFRC has been increased about 55percent with the addition of 2percent by volume of fibres.

Johnston [16, 17] has found that the compressive strength of SFRC is increased about with the addition of 1.2percent by volume of SF. Research conducted by Johnston [18] showed that the compressive strength of SFRC has been increased from 0 to 15percent with the addition of up to 1.5percent of SF by volume.

Swami and Saad [19], had done study on deformation and ultimate strength of flexural in the RC beams under 4 point loading with the usage of SF, test consists of 15 beams (130mm x 203mm x 2500mm) with same steel reinforcement (2Y - 10 @ top bar and 2Y - 12 @ bottom bar) and variables of fibres VF (0percent, 0.5percent and 1.0percent).

Tan et al [20] conducted some experiment on the shear behavior of SFRC. 6 simply supported beams were tested under 2 point loading with hooked SFof 30 mm long and 0.5mm diameter, as the fibre VF increased every 0.25percent from 0percent to 1.0percent. Vandewalle [21], had done a similar crack behavior investigation, which based on combination of five full scale RC beams (350mm x200mm x3600mm) with SF(VF of 0.38percent and 0.56percent).

Mindess et al. (2003) [18] reported that 60% of fibre applications are for concrete slabs-on-ground, for which they have been used as secondary reinforcement. Ali R. Khaloo [10] et.al, investigated on influence of length and volumetric percentage of steel fibres on concrete slabs with various concrete strengths by testing 28 small SFRC slabs under flexure. The result shows longer fibres and higher fibre content.

III EXPERIMENTAL PROGRAMME

3.1 EXPERIMENTALPROGRAMME AND OBJECTIVE

To study the behaviour of NF and SFRC of M-20 & M-30 grades and to check different properties of fresh concrete, and the mechanical properties of hardened concrete i.e., cube compressive strength, split tensile strength and flexural strength.

The Study includes casting and testing of 72 cubes, 24 cylinders, 24 prisms, 16 RC Beams and 16 RC Slabs. The cubes are tested for compression at 7, 14 and 28 days of curing. The cylinders and prism are tested for split tensile and flexural strength at 28 days.

SFRC beams and slabs are tested under 2 point loading at 28 days.72 cubes, 18 cubes of NF concrete, 18 cubes of 0.50percent VF of SF(Vf - 0.5percent), 18 cubes of 1.0percent VF of fibres(Vf - 1.0percent) and similarly 18 cubes for 1.5percent VF of SF (Vf - 1.5percent) were casted.

The cylinders, prism are cast in 4 sets, the 1 set consists of 06 NF concrete cylinders for M-20 &M-30 grades of concrete (3 each). 2 set consists of 06, 0.50percent VF of SF(Vf- 0.50percent), 3 set consists of 06, 1.0 percent VF of SF(Vf- 1.0 percent), similarly 4 set consists of 06, 1.5percent VF of SF (Vf– 1.0 percent).

The RC Beams and Slabs are cast in 4 sets; the 1 set consists of 04 NF concrete beams for M-20 &M-30 of concrete (2 each). 2 set consists of 04 RC beams 0.5percent VF of SF(Vf- 0.5percent), 3 set consists of 04 RC beams, 1.0percent VF of SF (Vf -1.0percent), 4 set consists of 4 RC beams, 1.5percent VF of SF.

3.3 MATERIALS:

Cement, fine aggregate, coarse aggregate, water, steel fibre, superplasticizer was used.

3.2.1 CEMENT: Ordinary Portland cement (OPC-53 grade) was used.

3.3.2 FINE AGGREGATE: The locally available sand was used.

3.2.3 COURSE AGGREGATE: The locally available crushed basalt stone aggregate of 12 mm down size was used.

3.2.4 WATER: Potable tap water is used.

3.2.5 STEEL FIBERS: A varying VF i.e., 0.50percent, 1.0percent& 1.5percent of fibreswas used. SFare used of dia 0.45 mm and length 36 mm (aspect ratio = 80).

3.2.6 SUPERPLASTICIZERS: SP-430, was used

3.3 MIX DESIGN: The Mix design is done forM-20 and M-30 grades of concrete.

M-20 : 1 :1.4 : 3.09

M-30 : 1 :1 : 2.2

3.4METHOD OF MIXING: The mixing is done same as for conventional concrete. However, fibres have been added along with coarse and fine aggregate.

(i) First add coarse aggregate + fine aggregate + cement. (ii) Thoroughly mix the above for 10-30 seconds, (iii) Add Water (iv) AddSF. (v) Final mixing

3.5 CASTING AND CURING

Typical SFRC mix done manually

3.6 TESTS ON FRESH CONCRETE

3.6.1 SLUMP CONE TEST AND COMPACTION FACTOR TEST

The slump test is prescribed by IS456 (2000), and BS 1881 Part 102: 1983.

The compacting factor test is described in BS 1881: Part 103:1993 and in ACI 211.3-75 (Revised 1987) (Reapproved 1992)

3.7 TESTS ON HARDENED CONCRETE

3.7.1 COMPRESSIVE STRENGTH TEST, SPLIT TENSILE STRENGTH TEST AND FLEXURAL STRENGTH TEST

The compressive strengths iscalculated byCompressive strength, f_c□ P/A N/mm^2

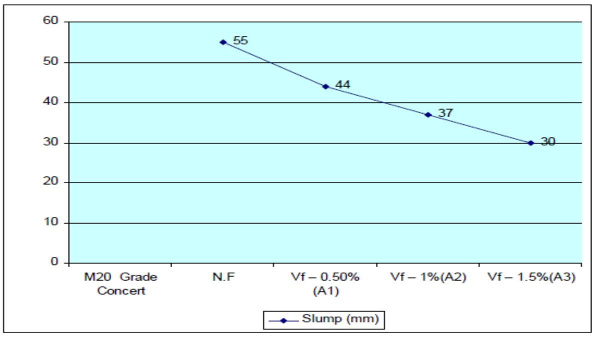
The Tensile strength is calculated by Tensile strength, $f_t = 2P/\pi DL$ N/mm^2

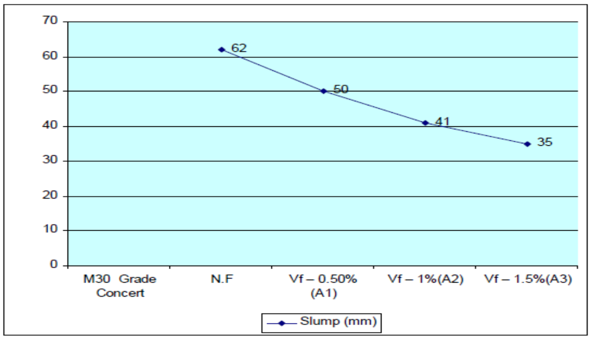
The flexural strength is calculated by Flexural strength, $f_b = (PxL)/(bxd^2)$ N/mm^2

IV RESULT

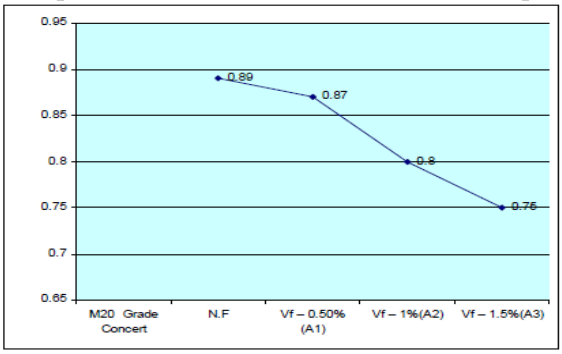
4.1 FRESH CONCRETE

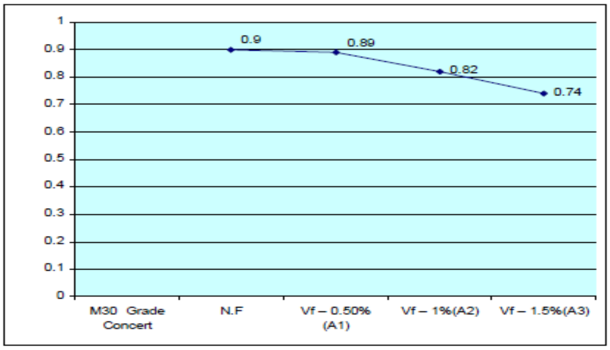
4.1.1 SLUMP CONE TEST AND COMPACTION FACTOR TEST: Slump cone test result shown as below for M-20 &M-30 grade.





Compaction factor result is shown in Graph.4.3, 4.4 for M-20 &M-30 grade.





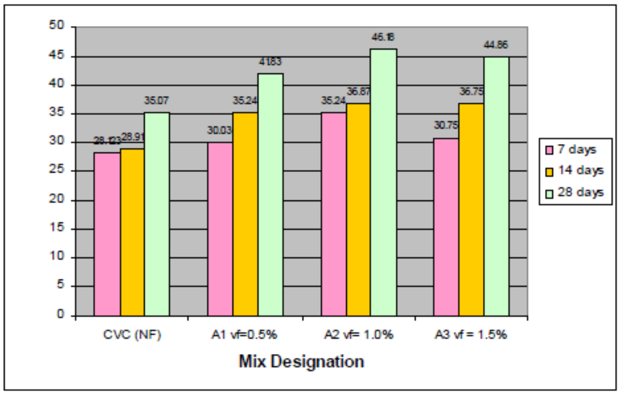
Graph 4.3: Compaction factor test for various Mixes of M_{20} grade

Graph 4.4: Compaction factor test for various Mixes of M_{30} grade

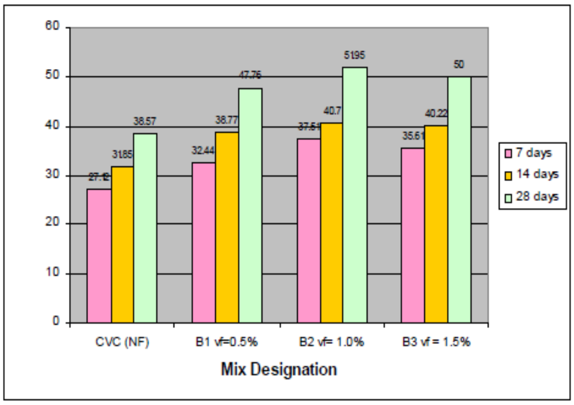
4.2 HARDENED CONCRETE

4.2.1 COMPRESSIVE STRENGTH TEST

The Cube compressive strength(IS: 516 – 1959) for M-20 &M-30 grade are as shown in graph 4.5 & 4.6 at 7, 14 and 28 days.



Graph 4.5: Comparison of Compressive Strength [Mix CVC (NF) A1, A2, A3, equivalent to M_{20} grade]



Graph 4.6: Comparison of Compressive Strength [Mix CVC (NF), B1, B2, B3, equivalent to M_{30} grade]

4.2.2 SPLIT TENSILE STRENGTH TEST

The split tensile strength(IS: 5816 – 1970)ofM-20 &M-30 grades at 28 days arecompared as shown in graph 4.7 and 4.8

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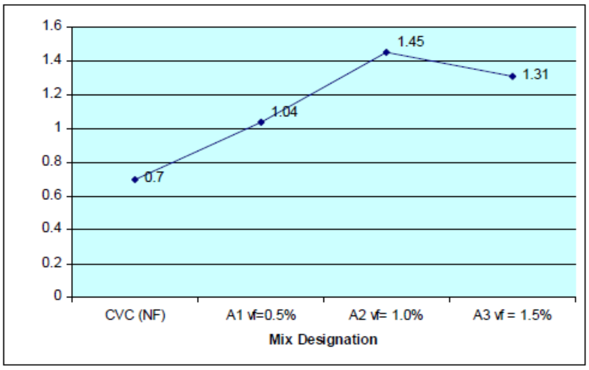
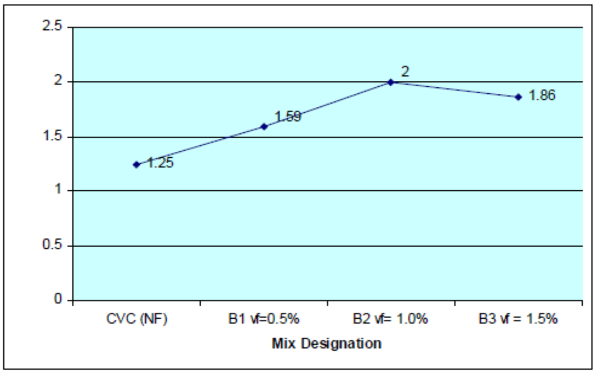


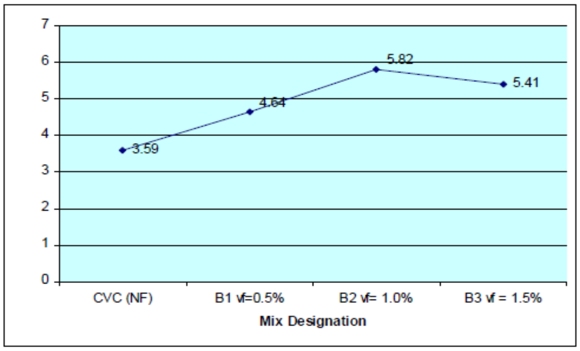
Graph 4.7: Split Tensile Strength for various Mixes of M_{20} Grade at 28 days



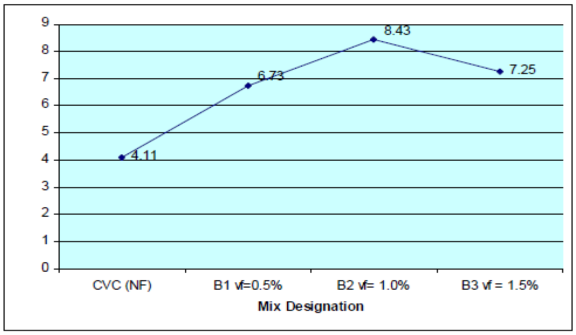
Graph 4.8: Split Tensile Strength for various Mixes of M_{30} Grade at 28 days

4.2.3 FLEXURAL STRENGTH TEST

Theflexural strength(IS: 516-1959) of M-20 &M-30 of grades at 28 days iscompared as shown in graph 4.9 and 4.10.



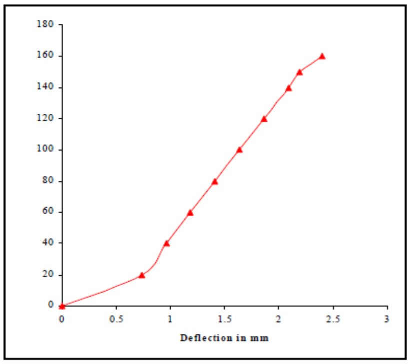
Graph 4.9: Flexural Strength for various Mixes of M_{20} Grade at 28 days



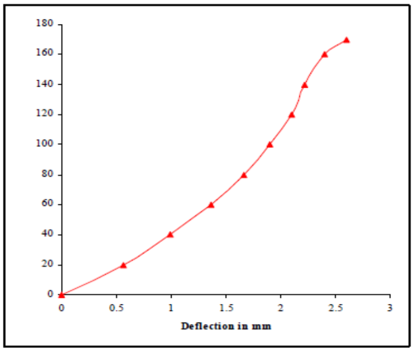
Graph 4.10: Flexural Strength for various Mixes of M_{30} Grade at 28 days

4. 3 RCBEAM ANDRC SLAB(IS: 516-1959)

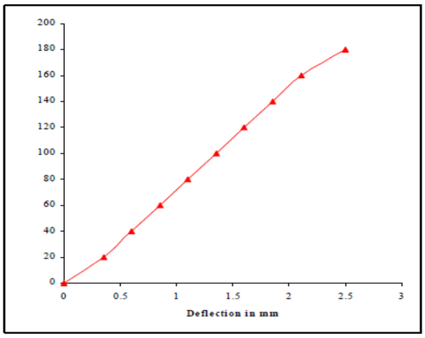
The dimension of beamis 700 mm x 150 mm x 150 mm. It is reinforced with 10mm dia bars @ bottom and 8mm dia bars @ top with 6mm dia bar stirrups. Load V/s Deflection curves for RC beams of mix CVC NF and SFRC for M-20 and M-30 grade as shown in graphs 4.11 to 4.18.



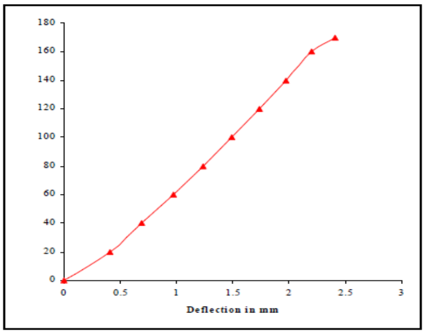
Graph 4.11: Loads V/s Deflection curves for RC Beams of Mix CVC NF, for M_{20} Grade



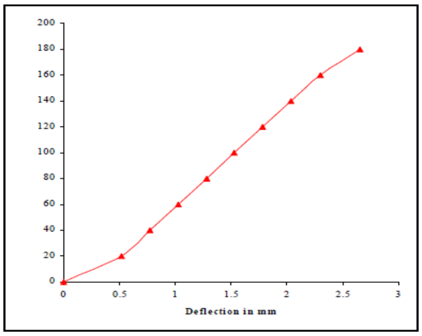
Graph 4.12: Loads V/s Deflection curves for SFRC beams of Mix 0.5% for M_{20} Grade



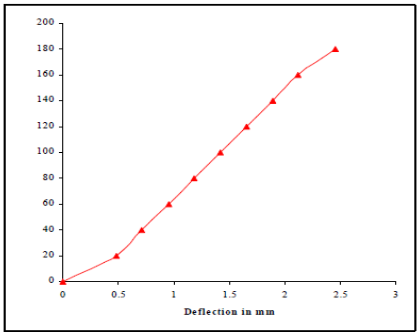
Graph 4.13: Loads V/s Deflection curves for SFRC beams of Mix 1.0% for M_{20} Grade



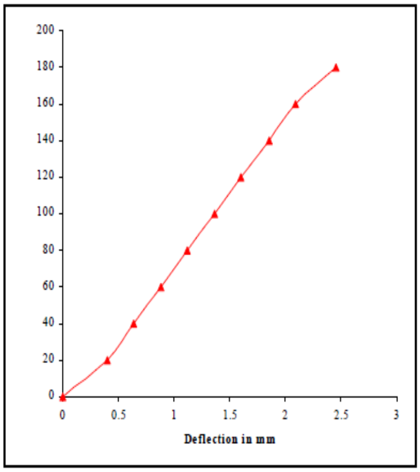
Graph 4.14: Loads V/s Deflection curves for SFRC beams of Mix 1.5% for M_{20} Grade



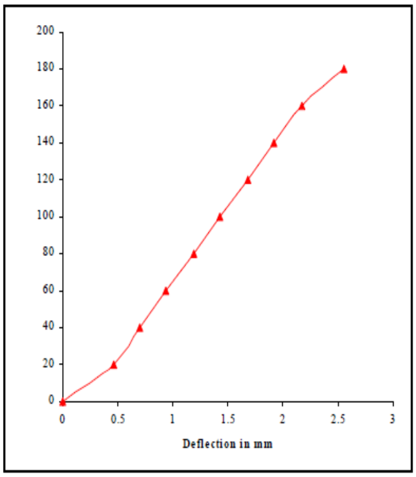
Graph 4.15: Loads V/s Deflection curves for RC Beams of Mix CVC NF, for M_{30} Grade



Graph 4.16: Loads V/s Deflection curves for SFRC beams of Mix 0.5% for M_{30} Grade

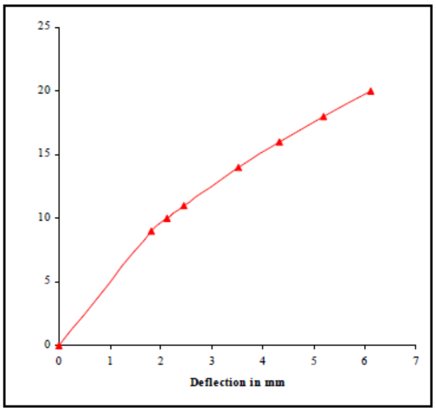


Graph 4.17: Loads V/s Deflection curves for SFRC beams of Mix 1.0% for M_{30} Grade

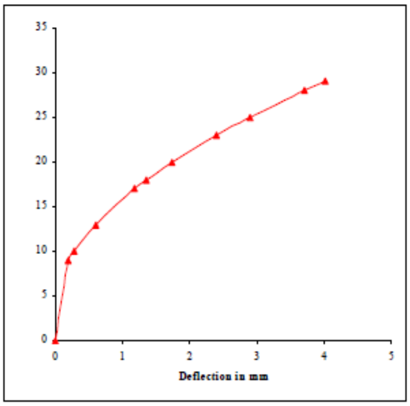


Graph 4.18: Loads V/s Deflection curves for SFRC beams of Mix 1.5% for M_{30} Grade

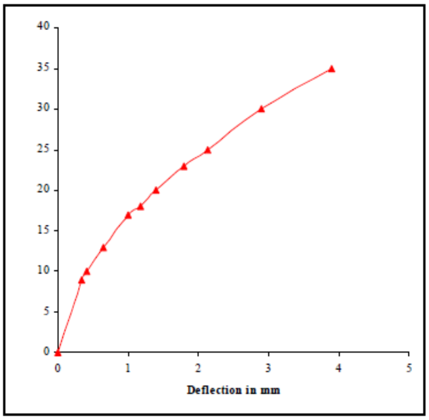
In RC slab,in smaller direction 8mm dia bars are used and in longer direction 6mm dia bars are used.Load v/s deflection curves for RC slab of Mix CVC NF and SFRC for M-20 and M-30 grade shown in graphs 4.19 to 4.26.



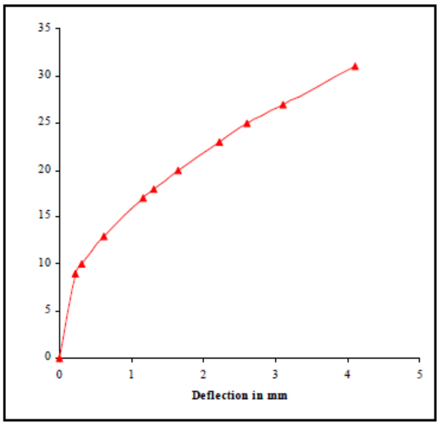
Graph 4.19: Loads V/s Deflection curves for RC slabs of Mix CVC NF for M_{20}



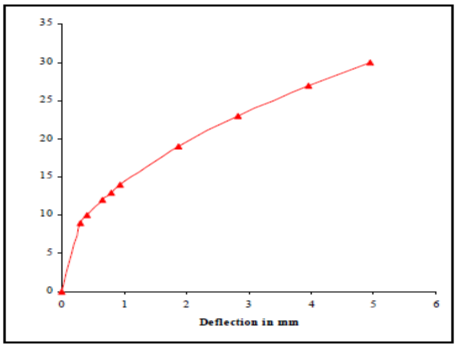
Graph 4.20: Loads V/s Deflection curves for SFRC slabs of Mix 0.5% for M_{20}



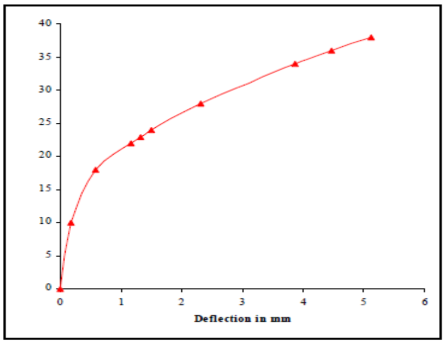
Graph 4.21: Loads V/s Deflection curves for SFRC slabs of Mix 1.0% for M_{20}



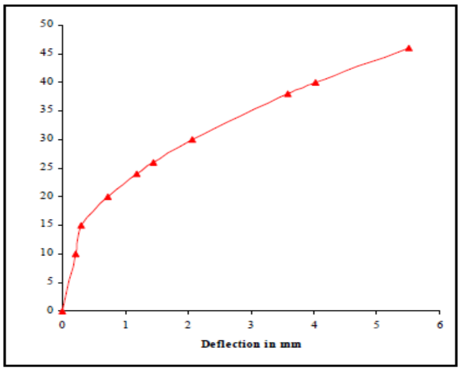
Graph 4.22: Loads V/s Deflection curves for SFRC slabs of Mix 1.5% for M_{20}



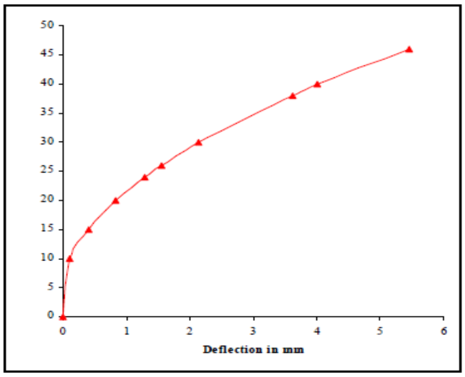
Graph 4.23: Loads V/s Deflection curves for RC slabs of Mix CVC NF for M_{30}



Graph 4.24: Loads V/s Deflection curves for SFRC slabs of Mix 0.5% for M_{30}



Graph 4.25: Loads V/s Deflection curves for SFRC slabs of Mix 1.0% for M_{30}



Graph 4.26: Loads V/s Deflection curves for SFRC slabs of Mix 1.5% for M_{30}

V CONCLUSIONS

1. The maximum compressive strength, Split tensile strength and flexural strength for 28days attained were 46.18 N/mm^2& 51.95 N/mm^2, 1.45 N/mm^2& 1.9 N/mm^2, 5.82 N/mm^2& 8.43 N/mm^2 with 1.0percent VF of fibres for M-20 &M-30 grade of concrete respectively.

2. The compressive strength, Split tensile strength and flexural strength had been increased for fibre content up to 1.0percent.

3. Compare with 3percentage of fibrei.e., 0.5, 1.0 and 1.5, for strength and economicalaspects, 1.0percent was showed as the best VF.

4. The load carrying capacity of RC beams with 1.0percent VF of fibres for M-20 &M-30 grade of concrete is higher and increased by 1.25percent than that of RC CVC beams (NF) and slabs.

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