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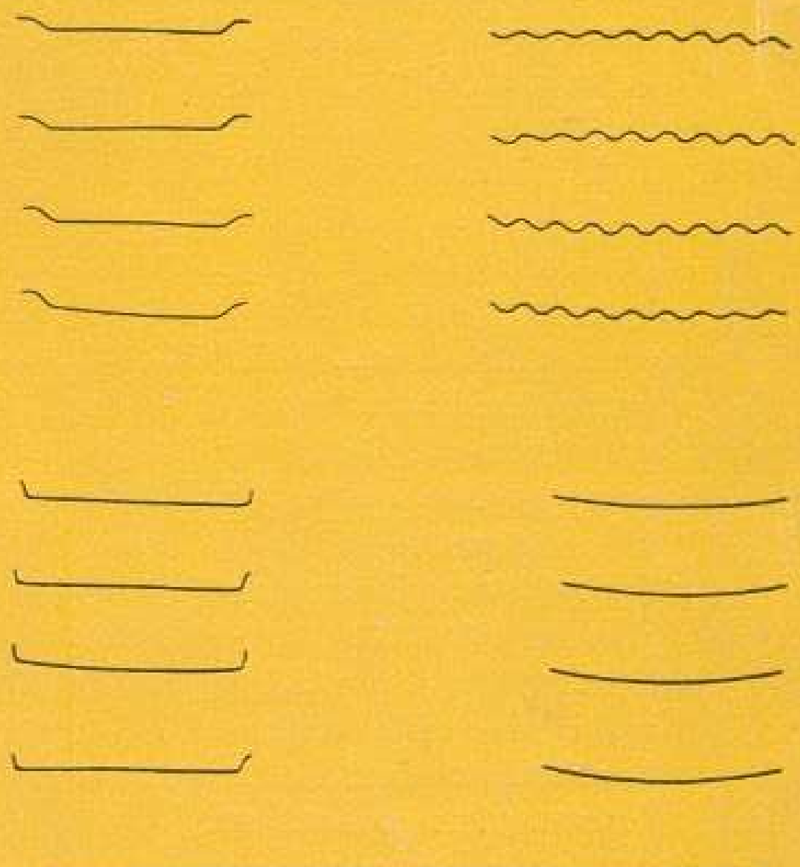
CRI TECHNOLOGY DIGEST



CEMENT RESEARCH INSTITUTE OF INDIA

STEEL FIBRE REINFORCED CONCRETE (SFRC) —CRI EXPERTISE

STEEL FIBRE REINFORCED CONCRETE (SFRC) CRI EXPERTISE

Conventional concrete, a cement based matrix, when subjected to tensile stress system or impact loading is observed to exhibit brittle type of failure. It is now well established that the tensile strength, toughness and ductility may be significantly improved by the introduction of fibres in the concrete mix. There has been a growing interest in adopting this technology of fibre reinforced concrete in construction industry.

Steel fibre reinforced concrete (SFRC) is a composite material which essentially consists of conventional concrete or mortar reinforced by random dispersal of short, fine steel fibres of specific geometry. These fibres act as crack-arrestors, restrict the development of cracks and thus transform an inherently brittle material, with its low tensile strength and impact resistance, into a strong composite with superior crack resistance, improved ductility and distinctive post-cracking behaviour prior to failure.

Different types of fibres have been tried to reinforce concrete, such as that of steel, carbon, asbestos, vegetable, polypropylene and glass. In general, all these types of fibres can be classified into two basic categories : those having a higher elastic modulus than the cement matrix (called 'hard' intrusion) and those with lower modulus (called 'soft' intrusion). The properties of the fibre reinforced concrete are very much affected by the type of fibre. Low modulus fibres, like polypropylene and vegetable fibres improve the impact resistance of concrete considerably, but these do not contribute much towards flexural strength. On the other hand high modulus fibres like carbon, glass and steel fibres improve both the flexural and impact resistance simultaneously. Considering the importance of concrete in construction and in view of its weakness in tension against impact, it is appropriate to state that of all the fibres, steel fibres are probably the best suited for structural applications.

MERITS AND APPLICATIONS OF SFRC

It is now established that SFRC possesses improved characteristics of crack resistance and ductility, impact resistance, shatter/spalling resistance, abrasion resistance, flexural strength and fatigue resistance. It also has the capability to support substantial loads after cracking.

Owing to the advantages SFRC offers, it is coming to the fore-front in such major areas of special applications as shown in Table 1. This technology digest briefly discusses the R&D work done by CRI on SFRC and its application in various situations.

DEVELOPMENTAL WORK BY CRI

Keeping in view the extensive work already carried out on other types of fibres, CRI concentrated the R&D investigations on the use of steel fibres only. It was realized that one of the major difficulties in using steel fibre reinforced concrete was the non-availability of steel fibres in the country. In view of this, CRI developed and fabricated a fibre forming machine (Fig 1) which can automatically

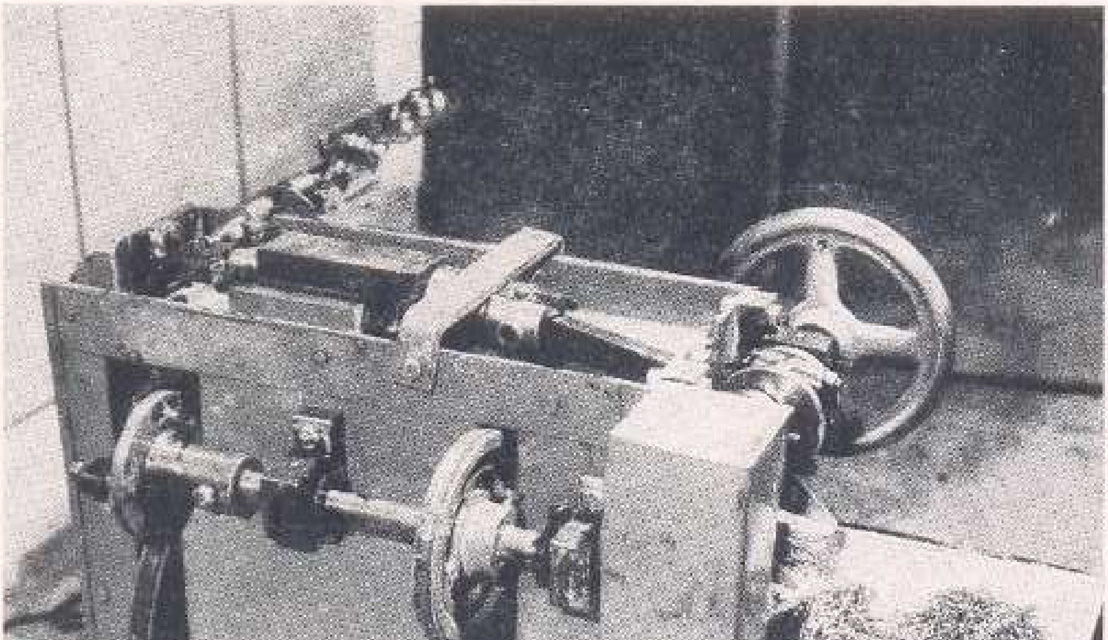


Fig 1 Fibre Forming Machine

produce steel fibres of various shapes, sizes and aspect ratio's. The machine can handle wires in the diameter range of 0·3 to 1·0 mm. Typical shapes of fibres that can be produced by the CRI fibre forming machine are shown in Fig 2. Another pre-requisite for using steel

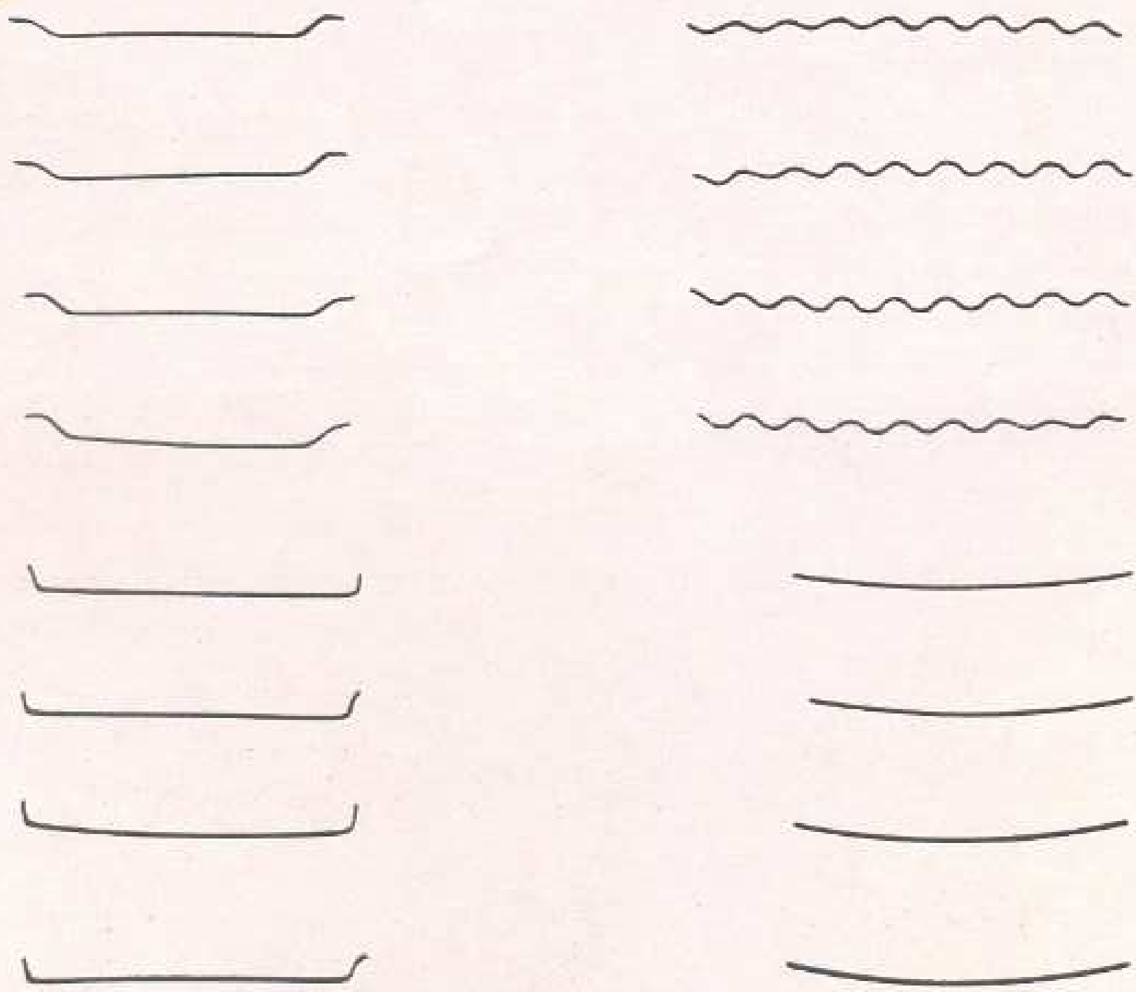


Fig 2 Typical Shapes of Fibres

Table 1

AREAS OF APPLICATION OF SFRC

In-situ Placement	*Precast Products*	*Composite Construction*
1. Hydraulic Structures 2. Defence Installations 3. Tunnel Linings 4 Overlays for Airport Pavement 5. Industrial Floors 6. Overlays/Wearing Coat for Bridge Decks 7. Overlays for Highway Pavements 8. Repair Work	1. Manhole Covers 2. Concrete Pipes 3. Building Components	1. Temporary form work — finally becoming integral part of the structural element 2. FRC skin for protecting concrete in marine environment in : i) Bridge girders ii) Pile foundations 3. Building components

fibres in concrete mix was denesting and uniform feeding the individual steel fibres into the concrete mixer. This was accomplished by developing a fibre dispenser (called 'Denester'). This denester (Fig 3) dispenses the fibres into the concrete mix at a predetermined feed rate. As a part of this study, the effect of size, shape, aspect ratio and volume fraction of the fibres on the workability of concrete in the fresh state and the flexural strength in the hardened state were investigated. Four commercially viable shapes of fibre (Fig 2) were used in this study. The aspect ratio of the fibres considered ranged between 50 and 100; the volume fraction of fibres in concrete varied between 1·0 and 3·0 percent. Other physical properties of SFRC investigated included first crack flexural strength, ultimate compressive strength, impact strength, and behaviour under cyclic loading. Significant improvements obtained in SFRC vis-a-vis conventional concrete are given in Table 2.

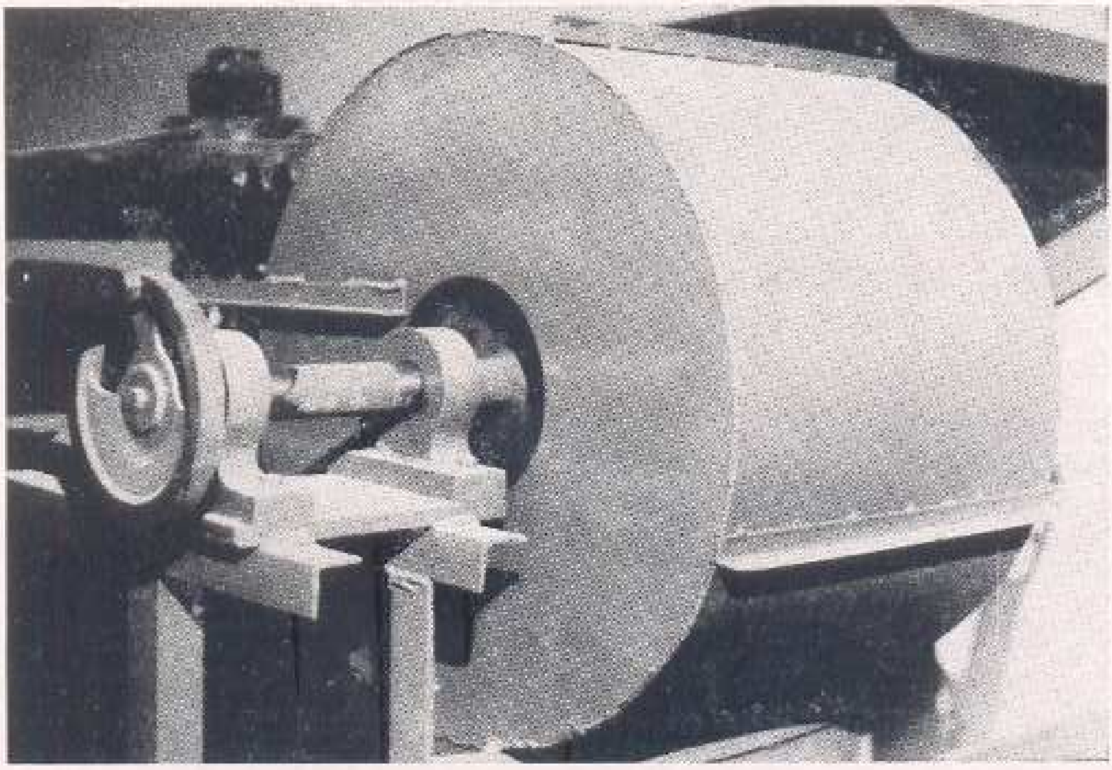


Fig 3 Steel Fibre Dispenser

Limited durability tests indicate that uncracked specimens when exposed to aggressive agencies have retained their strength and load deformation characteristics.

SFRC as composite material has potential for its use in protecting concrete structures in aggressive environment. The important properties of SFRC-skin, eg, increased ductility and cracking resistance could be employed for effective utilization of this material in composite constructions. It can be used as an integral part of structural member in the tension zone to improve the service performance of such members for fulfilling the condition of serviceability limit state.

Table 2

IMPROVEMENTS OBTAINED IN SFRC

Property	*Improvement Over Plain Concrete*
First crack flexural strength	150%
Ultimate compressive strength	125%
Impact resistance	650%
Flexural fatigue endurance	225%

Although SFRC appears costlier, when directly compared with conventional concrete, but when the intrinsic improved properties of the material are taken advantage of in the design, substantial benefits will result, like reduction in section, improved and longer service, less downtime for repairs. When all these direct and indirect benefits are taken into consideration and a cost-benefit analysis made, it is expected that SFRC would very favourably compare with conventional concrete.

TYPICAL MIX PROPORTIONS

SFRC mix differs from conventional concrete in having higher cement content, a lower size coarse aggregate and lesser coarse aggregate content. SFRC mix proportions in practical applications varies within the following ranges :

Cement content	:	300-500 kg/m^3
Water-cement ratio	:	0·45 to 0·60
Percentage of sand to total aggregate	:	50-100 percent by weight
Nominal size of coarse aggregate	:	20 to 10 mm
Fibre content	:	1·0 to 2·5 percent by volume of concrete
Fibre aspect ratio	:	50 to 100

FIELD TRIALS

In order to establish the practical feasibility of field application of fibre reinforced concrete and also to establish its performance, CRI in collaboration with the International Airports Authority of India, has laid three pavement slabs in a jet bay at Delhi Airport (Fig 4). This also provided an opportunity to tackle field problems relating to handling and dispensing of fibres into the concrete mix; and also the mixing, handling, placing and compaction of SFRC in Indian conditions where the concreting operations are essentially labour intensive.

Fig 4 Pavement Slabs in a Jet Bay at Delhi Airport

Out of these three slabs, one slab was of conventional concrete with a design thickness of 400 mm laid over 150 mm water bound macadam (WBM). The second was laid with full depth SFRC of 300 mm thickness and a third slab of similar thickness was laid with SFRC at top and bottom edges of the slab. Although the theoretical calculations indicated that the pavement thickness can be reduced upto 40%, the actual reduction provided was only to the extent of 25% mainly to ensure common subgrade pressure conditions. The performance of these slabs which are subjected to full parking load of jumbo aircrafts has been good.

CRI EXPERTISE

CRI has now become pioneer in the field of SFRC technology in this country and has acquired the capability of dealing with SFRC in field conditions on large scale concrete constructions. CRI is also now considering the use of SFRC in wearing coat of bridges and in defence installations.

Prepared by : Dr N Raghavendra and Shri Rattan Lal

Edited by : Shri S S Kalra

For further enquiries write to :

CEMENT RESEARCH INSTITUTE OF INDIA

M-10 South Extension II Ring Road

NEW DELHI 110049

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