Twintec Advisory Paper 2: Steel Fibre Reinforced Concrete (SFRC)

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Concrete is the material of choice for industrial storage facilities around the world. However, concrete is a brittle material in tension; to overcome this, concrete needs to be reinforced with another material, usually steel in the form of bar, fabric or fibres. These methods of reinforcement affect the post-cracking behaviour of concrete. In order to provide the material with a safe bearing capacity, a minimum quantity of reinforcement (bar or fibres) is required to guarantee the post-cracking ductility.

Reinforcement is not only required for improving the bearing capacity of the concrete slab, but also to control cracks induced by shrinkage. In a traditional slab design using light reinforcement, the development of micro cracks due to drying shrinkage cannot be controlled. As a result, the micro cracks join together and unrestrained shrinkage cracks develop. These can widen to the point that aggregate interlock is lost and load transfer from one side of the crack to the other cannot take place. To prevent random cracks from forming, a typical floor slab will be designed to crack at prescribed positions (formed or sawn induced joints), usually at centres of between 4 - 6m, these can be regarded as 'planned cracks'.

High dosage of steel fibres evenly distributed into fresh concrete will control and re-distribute the stresses that occur during the shrinkage of concrete. They bridge cracks that appear in concrete thereby providing a degree of post-cracking load transfer and also help to prevent micro-cracks from developing into macro-cracks. With fibre dosage rates of between 30 and 50kg/m^3, SFRC typically shows partial ductile behaviour.

However, the level of ductility (usually expressed as the 'Re3' value) is influenced by the fibre type and quality, dosage and concrete quality. The majority of joint-free floors worldwide use undulated cold-drawn steel fibres with an aspect ratio greater than 50 (length/diameter). The tensile strength of the wire ranges from 1,000 to 1,500 MPa depending on the fibre type. These have proved particularly effective in floor construction, performing especially well in suspended ground floor slabs.

Design

For both slabs on grade and on piles, designers and fibre manufacturers have developed proprietary design methods which take into account the ability of the composite material to redistribute stresses. The design methodology for the fibre-only systems combines the yield line theory (e.g. Johansson, Meyerhof) together with other well established elastic design theories in order to control the serviceability states. These are well established design methodologies with a track record of many millions of square metres.

In accordance with current established standards, partial safety factors (SF) are applied on both material and loading. Thus, a material safety factor of 1.5 affects the characteristic strength of SFRC, while load factors vary with the type of loading and application (static, dynamic, structural, etc.). Global safety factors usually range from 1.8 (slab on grade) to 2.25 (suspended slab on piles).

SFRC offers the following benefits to a designer:

- 3-D distribution of reinforcement making it suitable for reinforcing concrete in bending, shear and shrinkage restraint.
- No un-reinforced concrete; optimal concrete consumption can be obtained.
- Uniform fibre distribution, showing similar flexural resistance in both hogging and sagging situations.
- Geometrical design; the design parameter is the thickness of concrete at a constant reinforcing rate in place of reinforcing steel rate for given thickness.

Effects of using SFRC:

- **Flexural Toughness**: Tests on beams and slabs show that SFRC is able to sustain considerable loads even when subjected to very large deflections.
- **Shear**: High dosage of fibres can increase the shear capacity by 50%.
- **Impact and Fatigue**: SFRC is known to be considerably better than plain or lightly reinforced concrete under dynamic and cyclic loading.
- **Shrinkage**: Shrinkage can decrease by 10-15% when high dosages of steel fibres are incorporated. However, the main effect of the fibres will be to release the shrinkage-induced tensile stresses.

Programme

The use of SFRC eliminates or dramatically reduces the amount of rebar required and hence leads to programme savings related to fixing of steel. These savings become significant on slabs that require high levels of reinforcement such as suspended ground floor slabs or heavily loaded slabs.

An example is shown below comparing a traditionally reinforced concrete slab versus a SFRC suspended ground floor slab. As can be seen on this particular project, a saving of 366%.

Project	Area (m^2)	Design	Flatness	Prep. Days	Prod. Days	Total Time On Site
X	10,000	Custom Mesh @ 25kg/m^2	FM2	48	7	11 weeks
Y	10,000	45kg/m^3 AFT + 1/60 WDWF	Cat 1	6	6	3 weeks

Conclusion

A SFRC jointless slab is designed to eliminate the need for sawn induced contraction joints in ground bearing floor slabs. The design is a well proven method with a thirty year track record. Eliminating the sawn joints has a significant benefit to the end user in terms of increased flexibility of use, improved toughness and durability and reduced maintenance costs for both floor slab and MHE.

A SFRC can also be used on piled slabs, leading to easier construction, reduction of formed joints and increased productivity.

However, once building owners, consulting engineers, architects and general contractors have decided to opt for a SFRC jointless slab, they must take precautions in choosing the right specialist contractor for the job by carefully reviewing the following items:

- The contractor's track record in SFRC jointless floors (there is no substitute for experience).
- Visit SFRC reference floors and ask the opinion of their users.
- Check the site quality control procedures proposed by the specialist contractor.
- Check the CV's of managers and workers, particularly their expertise with SFRC.
- Ensure early co-ordination takes place with the contractor to optimise the detailed design and particularly adjoining interfaces.
- Limit the number of split responsibilities within the contract.

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