

# Steel fibres for steel decks



Figure 1: Colmore Plaza, Birmingham.

**Some members of The Concrete Society might have been surprised that the Steel Construction Institute helped with Technical Report No. 63: Guidance for the design of steel-fibre-reinforced concrete<sup>(1)</sup>. Of course, despite the contrary claims of steel producers, there is often a substantial quantity of concrete that goes into a steel-framed building, either precast or in-situ. One major building element that comprises quite a volume of concrete (along with steel floor beams) is the flooring. It was the use of SFRC on steel decks that led to the involvement of the SCI.**

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Steel-fibre-reinforced concrete (SFRC) is of itself a composite material but here, concrete on permanent steel shuttering is referred to as ‘composite construction’.

Well-informed engineers will, of course, be aware of the possibility of using fibre reinforcement to replace fabric in composite construction. This article explains the reasoning behind such a substitution and goes on to illustrate a number of advances in the field.

## Fabric replacement

Designers (at least in theory) use BS 5950 Part 4<sup>(2)</sup> to calculate and specify the material required for a particular loading and span configuration of steel deck. In practice, like most of us, individuals use software, either ‘freestanding’ or a program provided by a decking supplier, for example Kingspan’s ‘Toolkit’.

What is often not clear, when using these tools, is that the reinforced concrete slab is generally designed as simply supported in accordance with clause 6.1.1a. Even so, the designer must provide top reinforcement, generally

fabric, with the area given by:

*0.1% of the gross cross sectional area of the concrete at the support*

as set out in clause 6.8.

This 0.1%  $A_c$  is often referred to as ‘anti-crack’ steel whereas, as should be obvious, due to the different strain characteristics, the concrete will fail (crack) long before the steel becomes significantly loaded, as in all reinforced concrete flexural design.

Steel fibres have been used to replace secondary reinforcing steel for some years, so it was natural that fibre manufacturers such as Bekaert should look to replace this 0.1%  $A_c$  with fibres.

## Fire

Clause 6.8 goes on to mention fire resistance, a fairly major consideration in most buildings. Therefore, with the help of the Steel Construction Institute, Bekaert and others have invested in fire testing in accordance with BS 476:Part 21:1987 clause 7<sup>(3)</sup>.

These are full-scale destructive tests, requiring the construction of a floor panel across three beams. The panel is lowered onto the top of a furnace, the beams are fire protected and insulation is liberally applied to the edges of the panel. The floor thus provides the roof to the furnace. The testers attach an array of thermocouples and apply the required load. The gas burners are then ignited and the furnace temperature rises at a carefully regulated rate following a defined temperature/time curve, until failure.

Arising from these tests, using a fire engineering model, the SCI produced the load span tables seen in the Kingspan literature, with values for 60- and 90-minute fire ratings.

## Longitudinal shear

Most times, designers will look to design their steel frame supporting the deck using the composite section. One of the criteria to be checked is longitudinal shear.

The ductile behaviour of steel-fibre-reinforced sections has been explored by the Brite EuRAM Project BRPR-CT98-0813<sup>(4)</sup> wherein the Universidad de Catalunya concluded that the presence of steel fibres:

*did lead to a significant increase in the ductility under shear failure and to a slight increase in shear strength.*

A series of Hofbeck tests on a variety of fibre reinforcement has led to a body of encouraging results. As TR 63 records, referring to push-off testing of shear studs:

*Generally the capacity of the studs is better than conventionally-reinforced specimens.*

Of course, one of the benefits of fibre reinforcement is its homogeneous nature. If you choose fabric, BS 5950:Part 3.1:1990<sup>(5)</sup> requires the reinforcement to be 15mm below the top of the shear stud (additionally, and for the same structural purpose, the bridge code, BS 5400:Part 5:2005<sup>(6)</sup> requires these bars no more than 50mm above the flange). It is difficult to meet these stipulations and, at the same time, have the fabric high enough in the slab to restrict cracking.



Figure 2: Gartloch Village.

All that assumes, of course, that the fabric is correctly positioned on-site. If designers were to witness the flimsiness of an A142 fabric and see how it sags as people tread on it when concrete is placed, then one would expect to see SFRC specified more often.

However wonderful fibres are, there are areas where you will need conventional reinforcement. Around the edges of the floorslab, at stairwells and liftshaft penetrations, U-bars should be detailed around the shear studs on the edge beams.

#### Recent developments

Further research and more experience of this application are leading to greater flexibility in the use of steel fibre reinforcement.

Bekaert and Kingspan have this year fire tested a new lower dosage of a higher-performance fibre, Dramix RC 80/60 BN at only 20kg/m<sup>3</sup>. Shear testing has already demonstrated excellent performance and, of course, the lower dosage makes life easier for the concrete producer and the client's budget.

Reviewing practice elsewhere in Europe where self-compacting concretes (SCC) dosed with 40kg/m<sup>3</sup> of Dramix fibres are in use at precast producers, it is clearly possible to produce a fibre-reinforced SCC capable of being pumped onto steel deck. This has been demonstrated on a site in South Yorkshire and combines the benefits of both self-compacting material with those of using steel fibres.

Handling fabric several storeys up costs crane time, increases the risks of working at height and can be difficult to schedule on a congested inner-city site. So it was easy to see why the contractor on the Colmore Plaza site in Birmingham city centre chose SFRC. At 14 storeys, this is the tallest building using SFRC floors in the UK (so far as we know). This project was poured entirely at night without irking any office workers. As can be seen from Figure 1, access and site storage were tight too.

The contractor had a rather different aim at a project in Gartloch; it is difficult to get fabric onto a floor when you only have window and door openings for access, as illustrated in Figure 2.

#### Future work

A variety of discussions between fibre and decking suppliers continue, in order to have a well-engineered consensus on dealing with other clauses of the British Standard.

The implementation of Eurocode 4 is underway and, no doubt, engineers will be looking for ways to better understand how the code works and how it can be integrated into their working practice.

Both of these activities will be supported by research, where necessary, to ensure safe and economical buildings using fibre-reinforced composite floors. ■

#### References:

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5. BRITISH STANDARDS INSTITUTION, BS 5950-3: *Structural use of steelwork in building. Design in composite construction. Code of practice for design of simple and continuous composite beams*. BSI, 1990.
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