Macro-synthetic fibre for segmental linings and other precast concrete elements

During the past few years, macro-synthetic fibre reinforcement has become the fibre of choice for many sprayed concrete applications including mining and civil road tunnels. Today the use of macro-synthetic fibre to reinforce ready-mixed and precast concrete is one of the fastest-growing sectors of the concrete admixture market.

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This rapid growth is due to a number of factors that include: the ability of modern macro-synthetic fibres to match the performance of steel fibres and welded fabric in many applications; the need in certain applications to find alternatives to steel due to the nature of the work, for example a marine environment that presents a particular concern of steel reinforcement corrosion; and the rising costs and lack of availability of welded fabric and steel fibres, which is driving constructors to look elsewhere for their reinforcement needs.

The recent publication of The Concrete Society’s TR65[1] highlights a range of uses for macro synthetics including some information on testing procedures. This documentation has been able to aid prospective users in the application of the product.

From 1 June 2008, polymer-synthetic fibres for structural or non-structural use in concrete, mortar or grout applications must comply with EN 14889-2[2] in most European countries. Conformity needs to demonstrate to end users that the fibres have been manufactured to the performance criteria listed on the certification. This does not necessarily mean that performance criteria for a particular application have been met, so suitability for a particular application should still be assessed by undertaking specific testing if necessary.

The following examples illustrate the use of macro-synthetics for two different precast applications.

Tunnel linings
Concrete tunnel linings can either be precast segmental linings or poured in-situ and can be unreinforced or reinforced with bar and/or steel fibres dependent on the tunnel’s geological conditions. Steel fibres have been in use for over 25 years as they can offer more efficient production and higher durability. The performance characteristics of some macro-synthetic fibres now make it possible to use this type of reinforcement as a replacement for steel fibre in these applications.

One of the first tunnel projects to incorporate a macro-fibre-only reinforcement solution in Europe is a 5.6m-diameter drive with an in-situ concrete lining in northern Spain. The end use of this 7km tunnel boring machine (TBM) drive is a water transfer tunnel providing much needed irrigation to the region. Due to durability issues associated with water and steel reinforcement it was decided to use a macro-synthetic fibre to reinforce the primary lining support, the precast invert segment and the final in-situ lining to eliminate the risk of corrosion and...
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Mean even further this reinforcement has found many applications over the last few years. The development of new fibres will mean even further opportunities for this reinforcement in the future.

Concrete electrical cabinet

Changing legislation and standards always present manufacturers with challenges that require innovation. Recent legislation in some European countries has required a reduction or total elimination of steel reinforcement in order to reduce conductivity from the interior of the cabinet to the exterior as a safety precaution. Although the impetus for change was legislation, the manufacturer has also gained significant time savings in the manufacturing process, and consequently reduced costs. Previously a steel cage was constructed using deformed bar. This had to be placed within the mould, ensuring that adequate cover was obtained to the cage. Once in position the self-compacting concrete could be poured.

Now the steel cage has been completely eliminated from the cycle, allowing a fast turnaround of the use of the moulds once the element has been removed. As there is no tying of steel this saves time, reduces labour and frees up space where the cage would have been stored. The reinforcement cage was replaced with 6kg/m$^3$ macro-synthetic fibre 48mm in length.

Prior to replacing the steel cage with fibre, a number of tests were carried out to ensure the required performances were met. Testing included compressive strength tests, the Brazilian tensile strength test and full cabinet fabrication trials to access the fibre’s performance.

Other advantages that the macro-synthetic fibre offers include:

- easy-to-handle, automatically dosed fibre reinforcement
- corrosion-free reinforcement
- long-term durability in constructions such as water and sewerage tunnels
- reduced spalling of concrete at high temperatures
- elimination of puncture injuries both in segment manufacture and ring installation.

Concluding remarks

The use of macro-synthetic fibre as an alternative to steel reinforcement has found many applications over the last few years. The development of new fibres will mean even further opportunities for this reinforcement in the future.

References:


Further information:


The tunnel lining, 300mm in thickness, is poured in-situ using a movable circular formwork and self-compacting concrete leaving a finished diameter of 4.8m.

Further developments in this type of application have allowed the use of macro-synthetic fibre in some of the largest tunnel segmental linings. For example, a segmental ring of 9.1m internal diameter with a thickness of 320mm and a tunnel length of 1.3km has replaced the specified 25kg/m$^3$ of hooked-end steel fibre with 5kg/m$^3$ macro-synthetic fibre-48mm.

The performance requirement for the fibre reinforcement in a 60MPa concrete was a residual strength of 2.9MPa at 3mm as tested to the Standard NBN B 15-238, 239. Some 5kg/m$^3$ of macro-synthetic fibre 48mm was able to meet this requirement. Testing showed that the macro-synthetic fibre was much more consistent in achieving this performance criterion than the steel fibre. Research suggests that steel fibre performance may be adversely affected by the brittle nature of high-strength concrete (over 50MPa) particularly at later ages which is not the case for macro-synthetic fibre.

The fibre reinforcement is used in combination with the reinforcement cage, in this case in order to add abrasion resistance to the lining and eliminate any spalling that may occur to the segments due to high jacking loads from the TBM’s jacks.
Barchip Shogun 48mm

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