Improving concrete performance in fires

Figure 1: ADFIL's extrusion process – chemical extrusion of fibres.

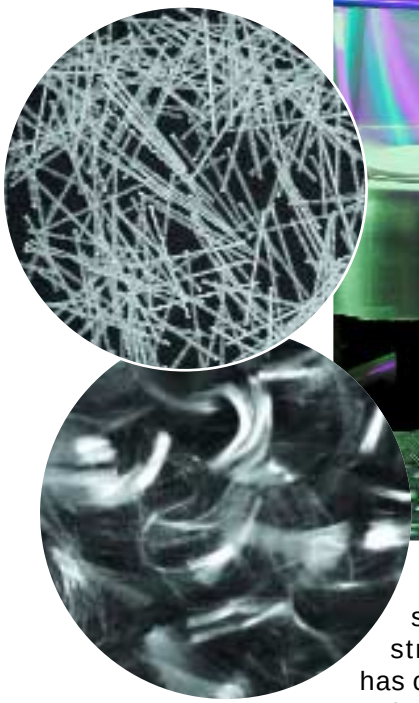

Figure 2 above: Close-ups of polypropylene fibres.

The danger that the explosive spalling of concrete poses to structural integrity and human life has come to the fore following a number of high-profile disasters such as the tunnel fires at Kitzsteinhorn in Austria, Mont Blanc in France and the Channel Tunnel. When intense heat creates trapped water vapour within high-density concrete, the resulting build-up of pressure generates cracks. The progressive loss of surface leads to the partial collapse of the concrete lining through explosion, known as spalling.

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With the Dutch Rijkswaterstaat (RWS) hydrocarbon temperature/time curve showing that the confined space inside a tunnel generates temperatures up to 1100°C (2000°F) during the first five minutes of a fire and research from Dr Gabriel Khoury of Imperial College, London finding that spalling occurs in the first 20–30 minutes of a fire, it is a critical issue for the concrete specifier[1].

Yorkshire-based Anglo-Danish Fibre Industries Ltd (ADFIL) promotes the use of polypropylene fibres in construction projects both above- and below-ground, and has played a central role in increasing awareness of the performance benefits of such materials to increase the permeability of heated concrete and prevent explosive spalling.

Although a host of fibres with a minimum diameter of 32 microns are available to the industry, a patented innovative extrusion process using a special blend of chemicals allows polypropylene beads to be stretched to diameters within the range 5–30 microns (see Figure 1). The resulting IGNIS fibre has been specially developed to melt in the concrete at just 160°C (320°F) (see Figure 2).

(Photos: ADFIL)

Figure 3: The Eureka project is looking at how fibres can be used in vertical structures.

Additional research from Gabriel Khoury[1] found that the greater the quantity of individual fibres present in the concrete, the higher the number of channels and voids that will be created during the fire. The fine quality of IGNIS provides three times the number of fibres per 1kg dosage than other commercially available polypropylene fibres, thus creating a greater number of capillaries for the vapour to escape through, giving better performance in a fire.

Tests on the fibres have found that the additives used in the extrusion process ensure that the fibre does not degrade and will provide effective protection for the life of the concrete.

The use of polypropylene fibres has developed rapidly in European tunnelling. Continuing research and testing programmes are under way to further develop the level of fire protection afforded to treated concrete.

ADFIL is one of 17 companies to be awarded a grant from the Department of Trade and Industry (DTI) through the Eureka initiative, a government-funded scheme that promotes collaborative research in advanced technology across Europe, to develop IGNIS for use in vertical structures (see Figure 3).

One of the project's aims is to develop a software package that will enable civil engineers to design fire-resistant concrete for use in bridges, tunnels and high-rise buildings. The research will also establish the exact fibre dosage necessary to allow concrete in tunnels to resist explosive spalling during various fire curves (i.e. RWS and ISO).

Ultimately, the findings will improve efficiencies in construction, allowing lower volumes of fibres to be used without compromising the effectiveness of the passive fire protection system. The global market for concrete mixes using polypropylene may well expand rapidly as a result. ■

Reference:

1. KHOURY G. Effect of fire on concrete and concrete structures. *Progress in Structural Engineering and Materials,* Vol.2, issue 4, 2000, pp 429–444.