CONCRETE
SikaFiber® TECHNOLOGY

BUILDING TRUST

FIBRE REINFORCEMENT

Fibres are an ideal ingredient for improving the performance of concrete and mortar. They increase energy absorption and fire resistance, whilst reducing shrinkage crack, fracture formation and crack widths. By adding fibres to the mix during production, concrete becomes more durable and resistant. When used in construction projects, it ultimately requires a lot less reinforcing steel than conventionally-reinforced concrete. For centuries, fibre reinforcement has been a major part of construction, and as materials and processes have evolved, so too has fibre technology. Concrete applications with fibres have expanded considerably in recent times, and are now fully-established in the market – with new materials now capable of replacing traditional fibres, like steel and glass. SikaFiber® Technology is well and truly at the forefront of these developments.

FIBRES IMPROVE YOUR CONCRETE AND YOUR STRUCTURE

CRACKING AND FRACTURING BEHAVIOUR IS GREATLY IMPROVED thanks to fibre-reinforced concrete. During the concrete's hardening process, embedded fibres in the cement matrix inhibit the emergence of cracks through their tensile strength and extensibility. Where the strain is greater, they prevent larger cracks by causing them to dissipate into a number of smaller, finer and generally harmless ones.

THE STRENGTH OF FIBRES

Cracks can occur at different times during the life of concrete. In the beginning during the hardening process, the main concern is early-age shrinkage cracking. With older, hardened concrete, stress cracks can occur from loading.

If cracking in the concrete does occur, then the elastic (E) modulus of the fibres is crucial, because it defines the resistance of the fibres against deformation.

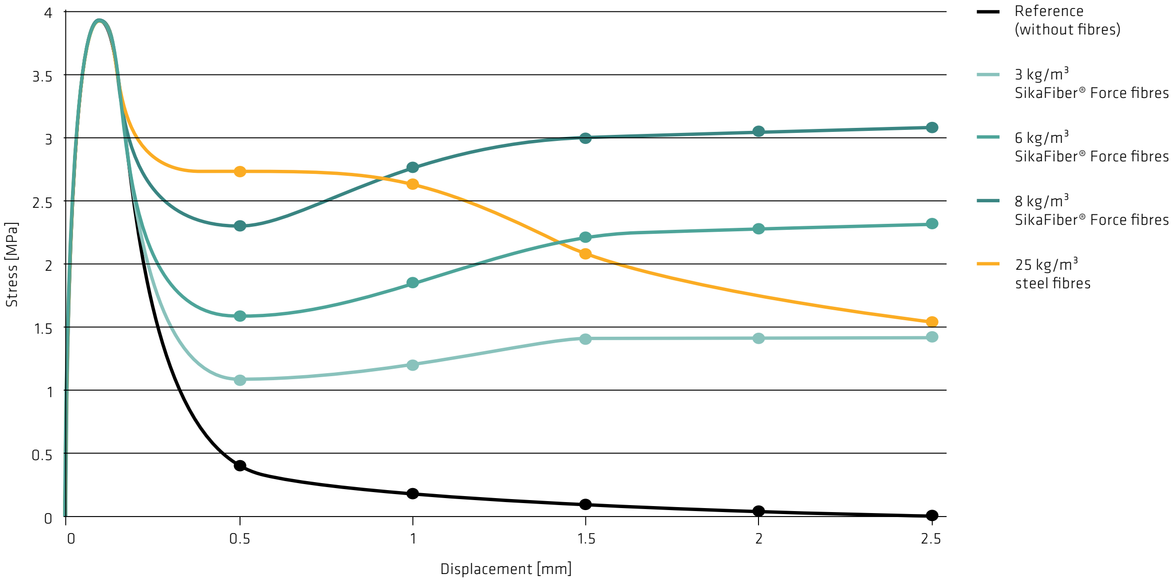
The graph below illustrates how different fibres work under stress:

- **Steel fibres** exhibit a higher E-modulus and stress capacity after the concrete's first crack. Due to the shorter steel fibre length (35 mm), this stress level decreases with increasing displacement.
- **Polypropylene fibres** exhibit a load drop after the first crack (peak load), but with increasing displacement. The fibres then take over the loads and the stress capacity of the unit actually increases significantly.

THE BENEFITS OF FIBRE REINFORCEMENT

- Less cracking due to early-age shrinkage
- Better cohesion in the fresh concrete
- Higher flexural and shear strengths
- Improved load capacity and ductility
- Increased abrasion resistance
- Increased fire resistance
- Potential to reduce CO_2

EN 14651 RESIDUAL STRENGTH TEST



TYPICAL APPLICATIONS FOR FIBRE-REINFORCED CONCRETE

FIBRES ARE THE IDEAL COMPONENT for enhancing and improving concrete and mortar, because they are easy to work with and bond well with the mix, whatever the application. They can increase impact resistance and reduce cracking damage in roads, bridge decks, floor screeds and precast concrete units. Plus, fibres can improve the ductility of sprayed concrete linings and increase the fire resistance of tunnel linings. Here are some examples of typical applications:

SPRAYED CONCRETE

The addition of fibres increases the ductility of sprayed concrete. If the sprayed concrete lining of an excavated tunnel support is cracked due to high flexural stresses, the fibres can accommodate tensile forces and act as an excellent yielding support. Fibres also increase the mechanical capacity of the lining, meaning extra reinforcement can then be reduced, or even omitted completely. This would ultimately result in tunnel excavation supports that are both quicker to install and more cost-effective.

FIRE PROTECTION

Synthetic micro-fibres make concrete a lot more fire-resistant, which is particularly important in structures like traffic tunnels. If a fire were to break out, the synthetic fibres melt within the concrete and create a capillary system through which water vapour pressure can be relieved. Concrete spalling is either reduced significantly or prevented completely, so the amount of repair work required is reduced too. All this results in a structure that is safer, more stable and more durable.

SLABS / RUNWAYS / ROADS

Using fibres in concrete floor slabs and runways helps to stabilise the concrete mix and greatly reduces early-age shrinkage cracks. Fibres also result in better flexural behaviour, greater impact resistance and greater durability. This means the amount of extra reinforcement needed can be reduced and the joint spacing increased. Fibres also help to prevent the joints and other perimeter edges from shearing.

FLOOR SCREEDS

Fibres are used in many types of floor screeds to improve the workability, impact resistance and fracture toughness of the fresh mortar. They also improve the quality and durability of the hardened screed by controlled crack distribution and shrinkage reduction. If any cracks form during the initial hardening phase, they are split into a number of small, fine cracks instead of single larger cracks, which means the potential for damage is reduced considerably.

PRECAST CONCRETE

Using fibres in precast concrete units reduces the amount of extra steel reinforcement needed, which makes for lighter units that are quicker to produce and install. The consistent, even distribution of the fibres throughout the concrete cross-section also gives high-impact resistance throughout the unit. As a result, units can be installed securely and without any damage. With synthetic fibres there is no hidden risk of injury to workers during production or installation.

REFURBISHMENT

Repair mortars formulated and produced with fibres have greater durability with improved crack distribution, plus an increased working capacity due to their crack-bridging ability. Their improved internal cohesion also allows spray-applied layers of greater thicknesses to be applied, increasing the application rate and reducing the overall cost as a result.

HIGH STRENGTH CONCRETE (HSC) AND ULTRA HIGH PERFORMANCE CONCRETE (UHPC)

Particularly slender components usually require HSC or UHPC, as do projects where high structural and load-bearing stability is needed during extreme conditions like earthquakes. Thin, short fibres that have a high E-modulus can be used in these cases. This means extra untensioned reinforcement can either be reduced, or be combined with the fibre reinforcement to greatly increase energy absorption capabilities.

FIBRE TYPES

DIFFERENT FIBRE TYPES ARE USED TO DELIVER DIFFERENT PERFORMANCE REQUIREMENTS.
Short, thin synthetic fibres are used for fire protection and crack reduction, whilst long synthetic or steel fibres generally come into play to increase energy absorption. One size doesn't always fit all, and special requirements demand special fibre materials and shapes – Ultra High Performance Concrete (UHPC) requires short fibres with a high E-modulus, for example. Sika provides solutions for all these eventualities, as well as other special types and blends of fibres.

STEEL FIBRES

Steel fibres are characterised by high E-modulus (200 GPa) and high tensile strength (2500 MPa). They prevent creep of the concrete but don't counteract early-age shrinkage. If any corrosion occurs, it won't cause spalling of the concrete – just a change of colour on the concrete surface. Protruding steel fibres can pose a risk of injury or damage to waterproofing membranes.

SYNTHETIC MACRO-FIBRES

Synthetic macro-fibres have a lower E-modulus than steel fibres (5 – 15 GPa). Unlike steel fibres, synthetic macro-fibres can't take extremely high loads, but they're hugely effective in the early phases of hardening to prevent and / or reduce the size of cracks developing in the concrete. They're also corrosion-resistant and give the concrete greater ductility.

SYNTHETIC MICRO-FIBRES

Synthetic micro-fibres have an even lower E-modulus (3 – 5 GPa) than synthetic macro-fibres. They're mainly used to reduce early-age shrinkage cracking and to improve fire resistance, thanks to their low melting point (160°C). Like macro-fibres, they're also corrosion-resistant.

BEST USE OF THE DIFFERENT TYPES OF FIBRES

State of concrete or mortar	Effect / property improvement	Recommended fibre type
Fresh	Improved rheology	Micro-PP fibres
Up to about 12 hours old	Reduction of early-age shrinkage cracking	Micro-PP fibres
1–2 days	Reduction of cracks induced by restraint or temperature	Micro and Macro-PP fibres
28 days' hardening or more	Transmission of external forces	Macro-PP and Steel fibres
28 days' hardening or more	Improvement of fire resistance	Micro-PP fibres

SikaFiber® Force Macro Fibre AND SikaFiber® PPM Micro Fibre

SIKA PROVIDE A RANGE OF HIGH PERFORMANCE MACRO AND MICRO FIBRES FOR USE IN CONCRETE

SikaFiber® Force fibres are macro synthetic fibres which are specially extruded, embossed and cut to specific lengths to suit a wide range of concreting applications. They can be used in ready-mixed concrete, precast and sprayed concrete applications both above and below the ground, such as:

- Internal floor slabs
- External hardstandings and pavements
- Precast concrete elements
- Agricultural areas
- Marine/coastal defence concrete
- Shotcreting applications.

The extruded, embossed profile of the fibres improves the bond within the concrete, reducing pull-out and enhancing the concrete's performance. The fibres have been designed to replace traditional steel reinforcement and provide a number of benefits including:

- Easier and safer to handle compared to steel
- Reduce construction time
- Ready-mixed concrete trucks can discharge at the 'live' edge of the concrete
- Cannot be misplaced
- No need to cut, fix or place steel mesh
- Reduce wear on concrete pumps
- Reduce carbon footprint
- Fibres do not rust or corrode
- Provide a 3-dimensional reinforcement system.

SikaFiber® PPM is a polypropylene monofilament micro-fibre. The fibres are coated with surfactant to improve dispersion. They are extremely fine and therefore hardly visible within the hardened surface of the end cementitious product. Typically these micro-fibres are used for:

- Internal floor slabs
- Concrete buildings
- Repair materials
- External hardstandings
- Pattern imprinted concrete
- Bridges
- Precast concrete
- Extruded concrete
- Agricultural areas
- Piling concrete
- Shotcrete/Gunite
- Water retaining structures.

Micro-fibres are specially designed to provide the following benefits:

- Reduce plastic shrinkage cracks, plastic settlement and bleeding
- Offer an alternative to crack control mesh with the appropriate design
- Reduce water and chemical permeability
- Increase abrasion resistance and impact resistance.

IMPROVED CONCRETE PERFORMANCE WITH FIBRES

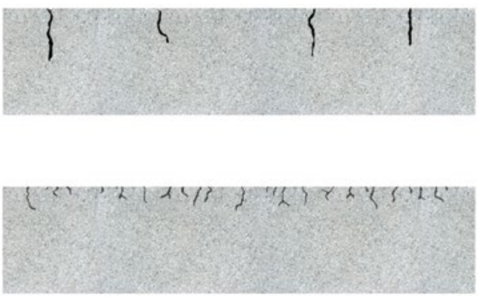
SPECIFIC CONCRETE CHARACTERISTICS ARE OBTAINED BY USING DIFFERENT FIBRE TYPES, or mixtures of different fibres, depending on what the performance requirements are. Longer high E-modulus fibres are used to achieve high energy absorption, whilst longer low E-modulus fibres are used for increased ductility and crack reduction.

With smaller fibres, those with a low E-modulus also improve the reduction of cracking, whilst those with a low melting point provide increased fire resistance. As such, different combinations and quantities of these fibres can be used across a wide range of applications and project requirements. Here are some of the most commonly sought-after requirements in more detail:

STRUCTURAL BEHAVIOUR

Concrete is generally strong in compression but weak in tension. If concrete fractures because of high bending stress and no extra reinforcement has been used, the system collapses without warning. As with conventional steel reinforcement, high forces can be transferred and distributed within the concrete using suitable fibres.

Crack-bridging fibres not only improve post-cracking behaviour but also help to keep bigger cracks from spreading. The fibres that cross the crack and are anchored in the matrix on both sides, effectively “sew” its two sides together and prevent it from widening. As a result, fibre-reinforced concrete has increased ductility and is capable of absorbing higher energy in the area, under load versus deflection.



CRACK DISTRIBUTION

When cement-based binders start to harden, shrinking stresses can often lead to the concrete cracking, which can be seen visually as damage. By adding fibres to the mix, these stresses are split and distributed. Bigger cracks are not able to form because the shrinkage volume is compensated for by the formation of smaller cracks instead, which will not significantly reduce the concrete’s strength.

The surface aspect is improved and the concrete is able to essentially heal itself. As such, the concrete is a lot more durable with the addition of fibres.

FIRE PROTECTION

Traditional concrete can be problematic when exposed to fire, because the sharp rise in temperature makes the concrete's physically and chemically-bound water evaporate very quickly.

When the water turns to vapour, its volume increases a thousand-fold. The denser the matrix and higher the moisture content of the concrete, the higher the developing vapour pressure will become. If this pressure is not relieved quickly enough, explosive concrete spalling can happen after only a few minutes. Any extra reinforcement is then exposed to damage from the fire, leading to extensive and deep-reaching damage to the overall structure.

By adding polypropylene fibres to the concrete, the risk of explosive spalling in a fire is reduced considerably, if not completely. These fibres have a relatively low melting point of 160°C, which means they will progressively melt and create a capillary system through which the evaporating water can escape, without any significant destructive pressure build-up.

MECHANICAL RESISTANCE

The impact and shock resistance, notched bar impact strength and edge strength can all be increased significantly with synthetic fibres and most steel fibres.

Impact strength can be improved by adding steel or polypropylene fibres in quantities of only 0.1% by volume. This strength improves considerably when a higher quantity of fibres is used, and adding a combination of fibres with a high and low E-modulus and high elongation at break has proved beneficial too.

HOW TO USE AND HANDLE FIBRES

FOR THE CONCRETE TO PERFORM AT ITS VERY BEST, and to achieve the characteristics that are needed from it, a number of key factors have to be considered when using fibres in the initial concrete design. These include:

- Selecting the right fibre type or combination in terms of size and material (this is particularly critical)
- Determining how the concrete mix design is adapted
- The fibre dosing system and timing
- How the overall mixing procedure will work.

An appropriate concrete placing and finishing method must also be used, either in the precast factory or on-site.

FIBRE DOSING QUANTITIES

Objective – reason for use	Fibre type	Quantity per m³
High loading capacity	Synthetic macro-fibre Steel macro-fibre	4 – 8 kg 20 – 40 kg
Extremely high loading capacity	Steel micro-fibre	50 – 100 kg
Reduced early-age shrinkage cracks (plastic shrinkage)	Synthetic micro-fibre	0.5 – 1 kg
Increased fire resistance	Synthetic micro-fibre	2 – 3 kg
Increased impact strength	Synthetic micro-fibre	0.5 – 1 kg

MIX DESIGN

A well-balanced mix design is the key factor for an optimum fibre performance. Fibres add surface area to the concrete, so the mix design must be adjusted to ensure adequate workability and optimum bond with the cement matrix. This involves:

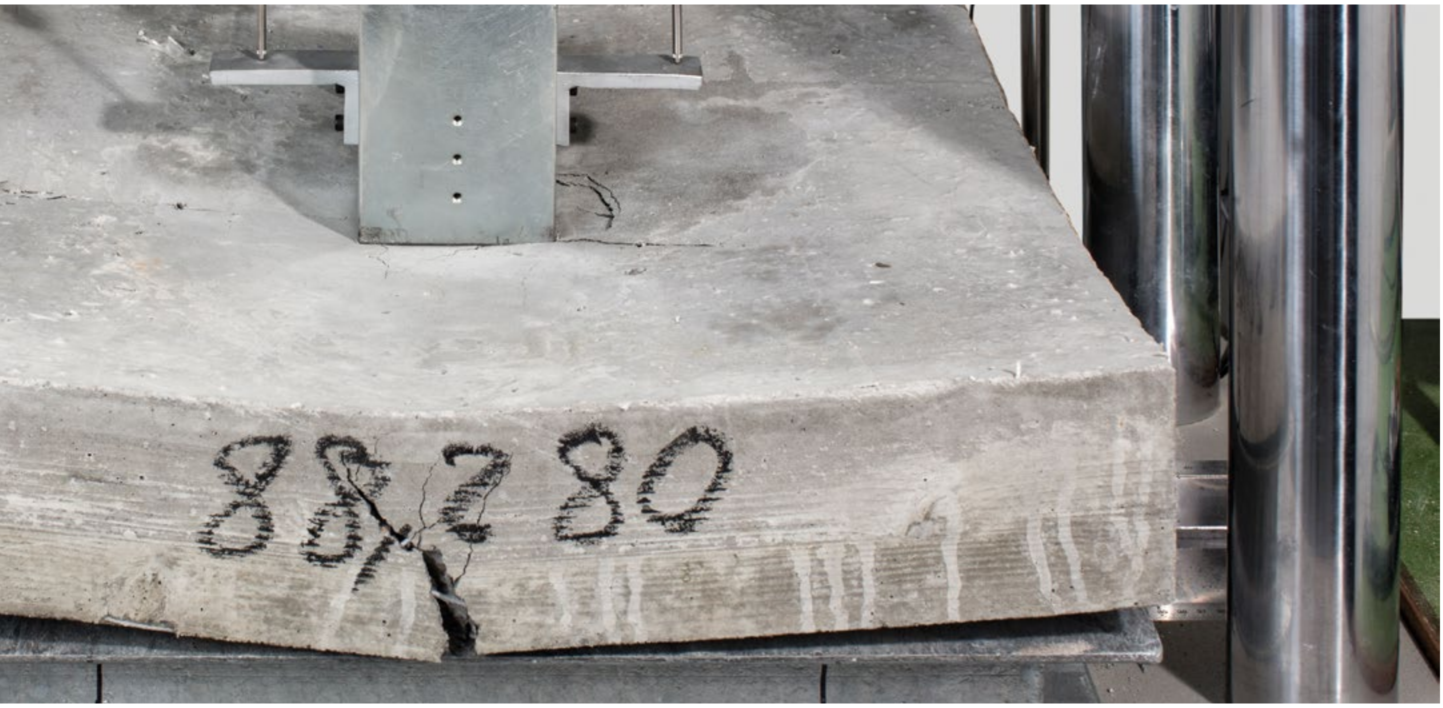
- The correct choice of binder and water content
- The correct aggregate grading curve
- Optimum fibre quantity
- Considering any other additives and admixtures.

A well-developed mix design positively influences all steps of fibre-reinforced concrete production, placing and performance.

Production
- No fibre balling
- Good fibre distribution
- Low mixer resistance
- Shorter mixing time.

Performance
- Good fibre-cement bonding
- Low water-cement ratio.

Placing / pouring
- Easy hopper grille passing
- Good pumpability
- Low pump pressure
- Good sprayability
- Less rebound.



DOSING METHOD

The fibre dosing and mixing method has a great influence on their optimum distribution in the concrete. Macro-fibres are normally formed into bundles, which can only disperse during the wet-mixing process to ensure they are distributed evenly. Water-soluble bags are used for dosing smaller quantities of fibres to prevent balling.

DELIVERY / PLACING

The concrete placing system can influence the fibre distribution and content, as well as their alignment in the matrix. Some fibre types cause far greater machine wear, whilst others generate pumping problems at high dosages. Because of this, the delivery and placing process should always be taken into consideration when selecting and evaluating fibre types.

FIBRE TYPE

The exact fibre type needed is usually defined quite clearly by the requirements of the concrete. As such, macro- or micro-fibres are specified according to their material type, geometry and shape. The performance is also affected by the concrete production process, its surface treatment and finishing etc, which must also be specified.

MIXING PROCESS

An unsuitable or inadequate mixing process can result in uneven and inconsistent distribution of the fibres in the concrete, or damage to the fibres themselves. The quantity to be added, and the mixing time, must therefore also be specified and followed.

CONCRETE PRODUCTION MADE SIMPLER WITH FIBRES

USING FIBRES IN CONCRETE CAN SIMPLIFY THE PRODUCTION PROCESS, in both precasting and on-site workflows. That is because the need for extra steel reinforcement can be reduced at many points, or even eliminated completely, which helps to speed up a project and make it more cost-effective. Because synthetic fibres increase fire resistance, there is no need to over-design concrete cross-sections, or post-apply fire protection systems – making the construction process even simpler.

TUNNELLING AND MINING

By using fibre-reinforced sprayed concrete, conventional reinforcement can be dispensed with, given moderate rock pressures. The time-consuming steel fixing operations which interrupt the workflow are then eliminated. Without this extra reinforcement, the sprayed concrete can be applied without 'spray shadows' and rebound is reduced. The result is an optimised application process and improved structural quality of the tunnel / mine.

DECK CONSTRUCTION

In addition to reducing steel reinforcement, the use of fibres can significantly increase the joint spacings. Also, because a blinding layer can be partially omitted, the layer thicknesses of the slabs can also be reduced. Optimum distribution of the fibres right into the corners also provides increased edge protection. All of these factors make the installation and construction of decks far more efficient.

UTILITY BASEMENTS

In the event of a fire, synthetic micro-fibres that have been added to the concrete significantly reduce spalling, or even prevent it altogether. Because of this, the design of structural concrete elements can be simplified and additional fire protection treatment is not needed. Fire protection using fibres can help save time and maximise the basement's available space.


Sika

STANDARDS AND TESTING

THE PERFORMANCE AND CHARACTERISTICS OF FIBRE-REINFORCED CONCRETE NEED TO BE TESTED with methods tailored to suit the specific end application, to make sure it can be used safely in future specifications. These test methods are now fully-standardised internationally through the European Standards (EN), as well as the American Society for Testing and Materials (ASTM).

FIBRE-REINFORCED CONCRETE AND MORTAR – STANDARDS AND TESTING

Test method	Standard	Description
Energy absorption	ASTM C1550	Round panel test
	EN 14488-5	Square panel test
Residual strength	EN 14651	Beam test
Fire resistance	RWS	Max. 1,350°C, 2 hours
	ISO 834	Starts at low temp, but continuously increasing
	HC modified	Max. 1,200°C, 4 hours
Shrinkage cracking	ASTM C 1581-04	Test method for determining restrained shrinkage
Impact resistance	Various local standards	Impact energy tests

Round panel test: ASTM C1550

Square panel test: EN 14488-5

Beam test: EN 14651

CASE STUDIES

SUCCESSFUL CONSTRUCTION PROJECTS ALL AROUND THE WORLD HAVE BENEFITTED from fibre-reinforced concretes and mortars, as well as from Sika's technical expertise and extensive practical experience. The advantages of fibres can be seen most clearly in tunnelling and mining projects, as well as in precast construction, flooring and any project that requires excellent fire resistance. Here are just a few examples:

OAKFIELD RECYCLING CENTRE, UK

Oakfield recycling centre in Hucknall needed a concrete slab that could withstand the impact of heavy machinery to replace their existing steel mesh system. The use of SikaFiber® Force synthetic macro-fibers delivered the strength required while also eliminating the risk of corrosion and other issues associated with traditional steel reinforcement.

The addition of synthetic micro-fibres provided greater impact and abrasion resistance, extending the durability of the concrete slab and ultimately the working life of the facility.

OIL TERMINAL, GERMANY

SikaFiber® Force synthetic macro-fibres were used together with the German 'white-topping' method for repairing the slabs in an oil harbour in Stuttgart. The fibres were used to improve the fatigue behaviour of the new concrete topping.

CALDEARENAS ROAD TUNNEL, SPAIN

SikaFiber® Force synthetic macro-fibres were added to the sprayed concrete to increase the ductility of the concrete lining. This kind of fibre-reinforced concrete produces a more efficient and cost-effective excavation support.

SUBWAY TUNNEL SEGMENTS, USA

In the San Francisco Central Subway Project, SikaFiber® synthetic micro-fibres were used to prevent explosive spalling of concrete in the event of fire in the tunnel. The fibres were used at a dosage of 1.2 kg/m³ of concrete.

SIKA FULL RANGE SOLUTIONS FOR CONSTRUCTION:


LIQUID APPLIED ROOFING


SINGLE PLY ROOFING


CONCRETE


CONCRETE REPAIR


STRUCTURAL STRENGTHENING


WATERPROOFING


JOINT SEALING


FAÇADE STRUCTURAL ADHESIVES


FLOORING


INDUSTRY


DISTRIBUTION

BUILDING TRUST

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WHO WE ARE

Sika Limited and Sika Ireland Limited are part of the global Sika Group, specialising in the manufacture and supply of chemical based products. Sika have a leading position in the development and production of systems and products for bonding, sealing, damping, reinforcing, and protecting in the building sector and the motor vehicle industry. Sika has subsidiaries in 100 countries around the world and manufactures in over 200 factories. With more than 18,000 employees Sika generates annual sales of CHF 6.25 billion (£4.76bn). We are also committed to providing quality, service, safety and environmental care.

In the UK and Ireland, we provide market-leading solutions for concrete, waterproofing, roofing, flooring, refurbishment, sealing & bonding, and industry, and have manufacturing sites in Welwyn Garden City, Preston, Leeds and Dublin with more than 865 employees and a turnover of more than £240 million.

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ISO 9001 Quality Management — FM 12504

ISO 14001 Environmental Management — EMS 45308

OHSAS 18001 Occupational Health & Safety Management — OHS 585274

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