Sikacrete® F
Fire Protection Mortar
Fire - The Effects on Concrete and Steel

The transportation of goods on road and rail networks is subject to many risks. One of the greatest hazards is a fire in a tunnel and the likelihood of these increases, the more the volume of traffic multiplies on both our roads and railways.

A tunnel fire is an extreme situation for motorists and passengers, the rescue services, plus the rolling stock or vehicles and the tunnel structure itself. In the event of a fire in a tunnel the temperatures rapidly become very high because the heat inside cannot easily escape, therefore the fire spreads extremely quickly and so can soon ignite other carriages or vehicles, plus their goods and other contents. Dependent on the type and number of burning vehicles and their loads, temperatures of over 1000°C can easily develop in the tunnel and this can last for several hours.

The extreme heat, smoke and other fumes generated can greatly hinder or even prevent people’s evacuation, early vehicle removal and extinguishing of the fire.

Unprotected mass concrete and reinforced concrete tunnel walls are quickly and completely destroyed when exposed to temperatures of over 400°C. In a tunnel fire this means that such an event usually results in the collapse of the tunnel soffit, or even the total collapse of tunnels through unstable geological situations.

In addition to the obvious initial human and economic losses, severe fire damage to a tunnel structure can also cause serious long term disruption to the traffic flow, together with substantial additional costs to businesses and individuals, since the necessary remedial and rebuilding works will frequently last for several months.
In mass concrete and reinforced concrete exposed to a fire, as the temperature rises the liquid capillary water (free water) and ‘physically bound water’ (in gel pores and interstitial layers), changes to water vapour and then steam above 100°C. As the temperature continues to increase, so does the water vapour pressure in the concrete: at the beginning the steam readily escapes on all sides, through the capillary pores and cracks in the concrete and without problems.

However as vapour continues to form at an increasing rate and steam escapes through the surface facing the flames, the available spaces for continued vapour expansion inside the pores and capillaries of the concrete are filled after only a relatively short time.

A vapour ‘saturation zone’ is then created into which additional vapour can no longer enter, therefore as the temperature continues to rise, the vapour pressure in the saturation zone also keeps increasing.

As soon as this pressure is higher than the internal tensile strength of the concrete matrix, the concrete fractures and spalls. Then a new saturation zone is rapidly created behind the newly exposed concrete surface and this destructive scaling process continues. As a result concrete is continuously eroded during a fire and its strength and structure can be completely destroyed.

New concrete structures can be built with integral protection from fire, e.g. by the addition of Sika polypropylene fibres to the concrete mix design. In a fire these fibres melt and make additional spaces for the vapour to form and expand, greatly reducing the rate of increase and level of vapour pressure.

Unfortunately the embedded reinforcing steel is still exposed to high heat transfer temperatures inside the concrete and steel loses its static and dynamic load bearing properties when this heat becomes too great.

Steel reinforcement in fire-resistant concrete should generally never be exposed to temperatures exceeding 250°C, because at this temperature its strength is already reduced by around 20%.
Therefore these are tested in accordance with established International Standards at accredited fire testing institutes and laboratories. The fire exposure levels to which a fire protection system should be tested depends mainly on the volume and type of traffic, plus the proportion of heavy goods vehicles or containers that are anticipated.

Performance Requirements
Passive fire protection systems should meet the following requirements:
- Concrete temperatures during the fire exposure < 380°C
- Steel reinforcement temperatures during the fire exposure < 250°C
- No spalling during the fire exposure
- No delamination of the fire protection material after the fire exposure test

Fire Rating Curves
Four fire exposure rating curves are currently used:
- ISO 834
- Dutch Rating Curve RWS (Rijkswaterstaat)
- Increased hydrocarbon curve HCinc
- German regulation ZTV-Tunnel

These fire exposure rating curves all simulate the temperature profile of a tunnel fire. The example of the Dutch RWS curve defines the maximum exposure which can be expected in the worst case scenario: This is defined as a fire of a road tanker truck with a load capacity of 50m³ that is 90% full of liquid hydrocarbon fuel (petrol).
The requirements for a fire protection system, especially in a tunnel, are many and diverse. Technical challenges such as fire resistance, system application details and long term durability must all be overcome and a high cost: performance benefit must be obtained. The interests of all of the parties involved: authorities (standards), designers, contractors & owners, must define the requirements for fire protection products that are intended for use on specific road and rail structures.

Requirements

Standards:
Several different fire scenarios are described in International Standards. The European Hydrocarbon Fire Curve increased (HCinc) can be used as an ‘umbrella’ for all of International Standard fire loads. The HCinc defines a worst case scenario in a road tunnel, where several vehicles are burning simultaneously and the prevailing temperature is 1300°C, over a period of 4 hours. The fire protection mortar should protect the concrete below it, with the concrete temperature during or after the 4 hours, not being above 380°C and the reinforcement temperature should not be above 250°C. Additional toxic gases should also not be generated by the fire protection mortar itself. The layer thickness required is not defined in this standard.

Contractor:
Contractors need a fire protection product which can be applied within the limited time stipulated by the designer. The projects requirements must be achievable with relatively low volumes of material (thin layers), and the application must be quick and easy. This means that the system must not be too complicated, so that specialist expertise and equipment are not required.

Designer:
Designers need a system which can be applied in the shortest possible time to keep the refurbishment period to a minimum. The products should ideally also be simple enough not to require specialist expertise and they should normally need no additional products (coatings, anchors etc). The systems must not need to be applied in very thick layers, because as a general rule structural opening dimensions must not be narrowed and reduced by the refurbishment and fire protection works.

Owner:
The owner needs a fire protection system which allows minimal tunnel and lane or track closure times for its application during the structures refurbishment; in order to keep the traffic moving and to keep all routes open for as long as possible. The fire protection system must also have long term durability so that any future maintenance requirements are reduced and of course, the system must perform reliably in a fire.
**Sikacrete®-213F** effectively protects concrete from the effects of extreme heat in the event of a fire. The structures only need a thin layer of **Sikacrete®-213F** to allow them to survive extensive fire stress and remain undamaged.

**Sikacrete®-213F** is a hydraulically bound, fire protection mortar system with Vermiculite as its insulating filler component. Vermiculite is a multilayer-lattice silicate material (mica type), which expands at high temperatures. At temperatures between 700°C and 1000°C the special Vermiculite, in the form of thin mica discs, expands by up to twenty times its original size, as water naturally bound within it escapes.

**Sikacrete®-213F** has clearly demonstrated in many different national and international fire tests that it is a fire protection mortar with outstanding properties.

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The **Sikacrete®-213F** material consumption is also well below the normal consumption of dry-sprayed fire protection mortars, this is due to the special lightweight Vermiculite fillers and its application by the wet spray process. **Sikacrete®-213F** is applied at 6 kg/m² for every 10 mm layer thickness.

Tests to International Standards show the outstanding fire protection behaviour of **Sikacrete®-213F**.

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**Characteristics**

**Excellent Performance**
- Fulfills International Standards
- Extremely low material consumption
- Thin-layer system

**High Workability**
- 1 component system
- Fast and easy to apply
- Good surface finishing
In tunnels the additional fire protection product performance requirements are becoming increasingly strict. Whilst it used to be enough to protect the tunnel structure from fire, higher durability of this fire protection layer is now demanded. The fire protection mortars are under great stress from changes in temperature e.g. freezing in winter, and increased traffic loadings e.g. air pressure / suction forces.

Sikacrete®-223F withstands all of these challenges, normally without requiring additional reinforcement mesh or protective coatings, which also makes it much quicker to apply than traditional fire protection mortar systems.

**Sikacrete®-223F** is a thin layer fire protection mortar system with high durability

**Characteristics**

**High Performance**
- Fulfils International Standards
- Low material consumption
- Thin-layer system

**High Workability**
- 1 component system
- Fast and easy to apply
- Good finishing

**High Durability**
- High strength
- Frost, freeze/thaw and de-icing salt resistant
- Machine cleanable

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**Sikacrete®-223F** is a fire protection system suitable for many applications, including those with higher mechanical requirements. Due to its special properties, **Sikacrete®-223F** provides a high level of fire protection and extended durability. **Sikacrete®-223F** is frost, freeze/thaw and abrasion resistant.
Sikacrete® F fire protection mortar systems are very easy to use and can therefore be applied very quickly without additional specialist expertise. The products do not differ in their method of installation from conventional concrete surface repair mortars and they are applied by the same wet spray equipment and techniques.

Application

Sikacrete® F system was especially developed to be applied using traditional wet spray mortar machines.

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<td>Very thin layer system</td>
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<td>Frost, freeze/thaw and de-icing salt resistance</td>
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Typical Areas of Use

Sikacrete® F fire protection mortar is ideally suited to be used on:
- Mass concrete structures
- Reinforced concrete structures
- Tunnels and other road / rail network structures
The different types of applications, exposures and heat stresses on different structures and projects can demand special project specifications and adaptations to be produced. **Sikacrete® F** systems can easily be adjusted to all of the different conditions required, because where necessary they can be combined with additional reinforcement and surface protection products or systems to provide special solutions.

**Different applications**

**System 1 (most normal situations)**
If no additional stresses are expected, a single layer of **Sikacrete® F** without any additional reinforcement or surface coating is generally sufficient.

**System 2 (soffit requirements)**
If a soffit requires fire protection, then the use of additional wire mesh reinforcement is normally recommended.

**System 3 (additional requirements)**
If additional heavy exposure or stresses can occur, such as:
- Vibration (i.e. from traffic)
- Air pressure/suction force on the surface (i.e. in a rail tunnel)
- Frost and/or de-icing salt exposure, then an additional combination of wire mesh reinforcement and suitable surface protection can be applied.

**Alternative surface finishes**

- Rough sprayed
- Trowelled finish
- Trowelled and protected with **Sikagard®- Wallcoat T**
Adler tunnel, Switzerland

Project Description
The Adler railway tunnel lies between Liestal and Muttenz near Basle in Switzerland; it is 5.3 km long and the original construction took 5 years with completion and opening in 2000. The tunnel was part of ‘Bahn 2000’ (a major extension and renewal project for much of the Swiss rail network). However, only 10 years after completion, cracks in the arch occurred at about 40 meters due to excessive swelling of Gypsum Keuper in the surrounding geology, so substantial repair works were urgently required. The forces exerted had actually lifted the tunnel invert by up to 70 mm over a 40 meters section. To permanently solve this problem, additional concrete beams were installed as abutments along the lifted section and these were firmly anchored with rock bolts, to transfer any future forces directly into the bedrock of the mountain.

Project Requirements
To protect the reinforced concrete beams and rock bolt head plates in case of fire, a passive fire protection system also had to be installed. The fire protection requirement was the fire load scenario in International Standard ISO 834 - ‘Fire curve for an exposure time of 60 minutes’. The inner lining and abutments structures were also specified to not exceed a temperature of 200°C, with a maximum temperature of 120°C allowable for the steel bolt head plates after the same time period. These head plate recesses also had to be easily accessible at all times in operational service, so that the bolts can easily be monitored and retightened as required.

Due to the limited structural dimensions, the fire protection system layer thickness was also ideally to be limited to a maximum of 3 cm, plus in operation the fire protection layer had to withstand loadings of 4.0 kN/m² from the air pressure / wind suction created by the rail traffic. Additionally a single track rail operation had to be maintained continuously during the fire protection works.

Sika Solution
Sikacrete®-213F was selected as the fire protection system in the repaired tunnel section as it could meet all of the requirements at a layer thickness of just 3 cm. To ensure optimum adhesion to the substrate, the concrete surfaces were initially prepared by high pressure water jetting. Wire mesh was also fixed onto the concrete to reinforce the fire protection system, where it is exposed to the suction pressure stress from the trains. Removable fire protection panels were produced and installed in the bolt head recesses to make monitoring and re-tightening as easy as possible. As single-track rail operations were continuing the Sikacrete®-213F fire protection mortar was spray applied in stages, first the apex, then the abutment structure and around the removable fire protection panels. The traffic was then switched to the other track and the fire protection was installed on the other side. A total area of more than 750 m² was protected with the Sikacrete®-213F system.

Sika Products
Fire Protection Mortar  Sikacrete®-213F

References
Adler tunnel, Switzerland
"Wien Mitte" Railway Station, Vienna Austria

Project Description
The Wien Mitte railway station is located between the centre of Vienna (Innenstadt) and the busy Landstrasse precinct and handles 30'000 rail and underground passengers every day. Wien Mitte is therefore the busiest Station in Vienna and Austria with several main line rail tracks and two underground lines (the U3 and U4) all come together and intersect.

This project involved major reconstruction of the entire station, with an overall investment of EUR 400 million. The station building was expanded to create a new shopping centre and office complex, with the work beginning in July 2007, completion was in mid-2010.

Below ground the platforms were renovated and lengthened with new escalators installed including from the main entrance directly to the platforms. After all of this structural work and to improve safety in fire, the reinforced concrete surface had to be refurbished and then protected in the event of a future fire.

Project Requirements
The old asbestos fire protection system had to be replaced with a new fire protection system, once the concrete behind it was repaired. The new fire protection layer was required to protect the concrete, even in the event of a major train fire. During the renovation works the station also had to remain open and the passengers had to be protected against asbestos dust from the removal of the old system.

Sika Solution
Low-pressure chambers were established for the refurbishment so that the works could be done without asbestos pollution in the passenger-areas. After blastcleaning the exposed deteriorated concrete surface, any exposed steel reinforcement was protected by application of SikaMonoTop\textsuperscript{®}-610 and the concrete damage was replaced and repaired with SikaTop\textsuperscript{®}-122 SP.

For the fire protection, a layer thickness of 25 mm Sikacrete\textsuperscript{®}-213F was determined to be sufficient to meet the required standards. A total of more than 2200 m\textsuperscript{2} of the Sikacrete\textsuperscript{®}-213F were applied by low pressure wet spray techniques.

Sika Products

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<th>Steel Reinforcement Protection</th>
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<td>SikaMonoTop\textsuperscript{®}-610</td>
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<td>Sikacrete\textsuperscript{®}-213F</td>
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Sika – a Global Player in Specialty Chemicals for Construction and Industry

Sika is a leading Swiss company, globally active in specialty chemicals. Our local presence worldwide links us directly with customers and ensures the success of Sika and its partners. Every day highly motivated people strive to provide the best customer service.

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