

FIRE PERFORMANCE OF SECONDARY TUNNELS LINING WITH DIFFERENT FIBER COMBINATIONS

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1

FOCUS OF RESEARCH PLAN

- ▶ This research plan has been designed in order to increase security in the tunnels in case of fire and to find effective and optimal solutions for fire protection of tunnel lining.
- ▶ The focus of this research plan is to find solutions for **reducing the explosive spalling** of concrete which in case of fire:
 - ▶ directly endangers human lives,
 - ▶ interferes with firefighters while rescuing people,
 - ▶ causing significant material damage,
 - ▶ lengthy shutdowns for repairs = enormous economic losses

2

TUNNEL FIRE – SPALLING DAMAGE



MONT BLANC TUNNEL FIRE (1999)

PIECE OF SPALLED CONCRETE

- ▶ Major tunnel fires to date have shown that damage to the load-bearing reinforced concrete structure occurs primarily through spalling of the concrete in the direct vicinity of the fire, and in the first 5 to 10 minutes after the fully-developed fire breaks out.

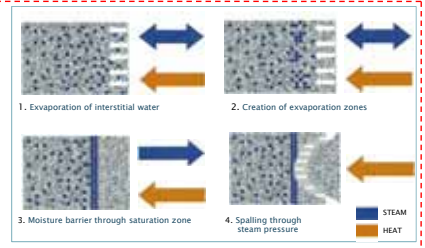
3

SPALLING MECHANISM

▶ THERMO-HYDRAULIC PROCESSES

lead to the build-up of high steam pressure in the pores of the concrete

- 1.) Steam finds its way into the concrete
- 2,3.) Steam condenses in the cooler area, raises the local water content to saturation point and thus causes an extreme reduction in vapour permeability
- 4.) High steam pressure exceeded concrete tensile strength = spontaneous spalling



▶ THERMO-MECHANICAL PROCESSES

lead to stresses in the concrete attributable to the non-linear temperature distribution in the concrete cross-section and the different thermal properties of the materials present in the concrete.

4

HOW PP FIBERS INHIBIT EXPLOSIVE SPALLING

- ▶ Previous studies that have been conducted mainly on reinforced concrete with polypropylene fibers have produced good results in terms of resistance of such concrete to fire action.
- ▶ PP microfibers melt at approximately 165°C and create randomly oriented channels inside of concrete. These channels are also connected with the microcracks created by thermal effects such as aggregate expansion.
- ▶ That network of channels and microcracks releases steam pressure and inhibits concrete spalling.



NETWORK OF FIBER CHANNELS AND CONCRETE MICROCRACKS

5

MICROFIBERS

- ▶ The plan is to explore that area in more detail in terms of fire resistance regarding the tunnel lining made of reinforced concrete with different combinations of microfibers with an emphasis on the use of recycled microfibers.
- ▶ In addition to fire resistance research in this study we will be exploring the economic component of each tested combination and the possibility of simple preparation and installation of such concrete.

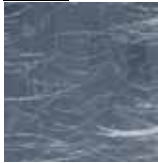
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POLYPROPYLENE MICROFIBERS // // // // // POLYETHYLENE MICROFIBERS

COMBINATION 1

- As a basic reference sample type we will examine concrete reinforced with polypropylene (PP) fiber (22mm long with 32µm diameter , 1.0 kg/m³).

PP fibers



COMBINATION 2

- RPET fibres = Recycled Polyethylene terephthalate, recycled fibres from PET bottles (3.8 kg/m³).

RPET fibers



HYBRID FIBERS (H)

The other five types of samples will be reinforced with a combination of two or three types of fibers – hybrid fibers (H).

- Hybrid fiber combination **H1** is a combination of PP and steel microfiber.
- H2** is a combination of RPET and steel fibers
- H3** is a combination of three fibers from recycled car tires
- Fiber combination **H4** contains combination of recycled carpet waste fibers and steel fibers
- H5** combination contains glass (GF) and polypropylene (PP) fibers.

HYBRID FIBERS (H1 and H2)

COMBINATION H1 and H2



- Hybrid fiber combination **H1** is a combination of PP and steel microfibers 30 kg/m³ of steel fibres and 1.0 kg/m³ of polypropylene (PP) fibers
- H2** is a combination of RPET and steel fibers. 25 kg/m³ of steel fibres 3.8 kg/m³ of polypropylene (PP) fibers

With using hybrid fibers as concrete reinforcement we expect to achieve two effects. One fibre type **relieves the steam pressure**, another **increases concrete tensile strength**.

HYBRID FIBERS (H3)

COMBINATION H3

- H3** is a combination of three fibers **from recycled car tires**.
- first one is composed of **recycled textile fibers** obtained during mechanical recycling of waste tyres (irregular shape and dimension–2.2kg/m³)
- second one is composed from **recycled rubber** which were the main component of tires (18.9kg/m³)
- third is composed from **recycled tire steel fibers** which were the radial steel reinforcement of tires. (30kg/m³)



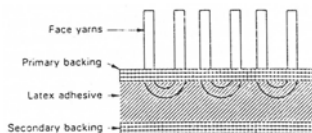
HYBRID FIBERS COMBINATIONS H4 AND H5

H4.COMBINATION (recycled carpet waste fibers and steel fibers)

Recycled carpet waste fibers

The backing layers consist typically of two sheets of polypropylene mesh. The face yarn is most commonly made of either nylon or polypropylene.

Combination **H4** contains 9,5kg/m³ recycled wasted carpet polypropylene fibres, 0,9kg/m³ wasted carpet nylon fibres and 25kg/m³, steel fibres.



H5 COMBINATTION

Glass fibers (GF)-20kg/m³ and polypropylene fibers (PP)-1kg/m³



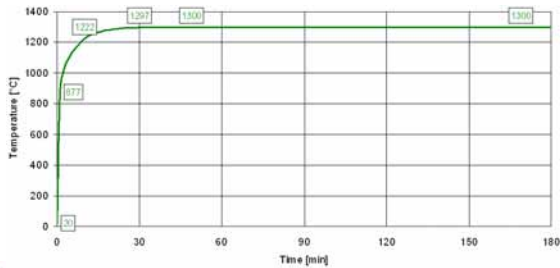
SAMPLES

- After testing mechanical characteristic on standard sample size, fire testing will be cconducted at stamples that provoke explosive spalling:

- Dimensions:** samples with large surface dimensions and medium thickness 1700mm x 1200mm x250mm (explosive spalling is unlikely to occur in very thin sections, because moisture tends to escape more readily, also explosions are less likely in thick members greater than 300mm. Explosive spalling is, therefore, most likely to occur in 'medium' size sections.)
- Moisture content** of stamples will be about 5% by weight
Spalling can occur if the moisture content of concrete is more than 2% by weight.

FIRE SAMPLE TESTING

- Fire testing will be conducted with modified Hydro Carbon fire curve with a peak temperature of 1,300 °C, instead of the 1100°C, standard HC curve.



CONCLUSION?

There is no conclusion because we do not have the test results, we just have assumption that we want to verify. The assumption is:

Some of the presented combination of fibers ensures safe behavior of concrete in the tunnel fire, is cost-effective and sustainable, so it can be used in practice.

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