

Fire Testing of Concrete and Concrete Protection Systems for Tunnels in Sweden -An Overview

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Overview of presentation

1. SveBeFo project
2. Fire resistance tests of concrete elements for tunnel application
3. Compilation of tests
4. Illustrative example



SveBeFo project

- Objective to compile and publish experience gained in Sweden from fire protection of tunnel lining systems
- Three parts:
 1. Review requirements in codes and regulations
 2. Summarize tests and research activities
 3. Give examples of technical solutions used in recent tunnel construction projects
- Focused on Sweden, some information from other European countries.
- Conducted by Brandskyddslaget and SP.
- Resulted in acceptance to publish a large amount of tests previously covered by client confidentiality agreements.



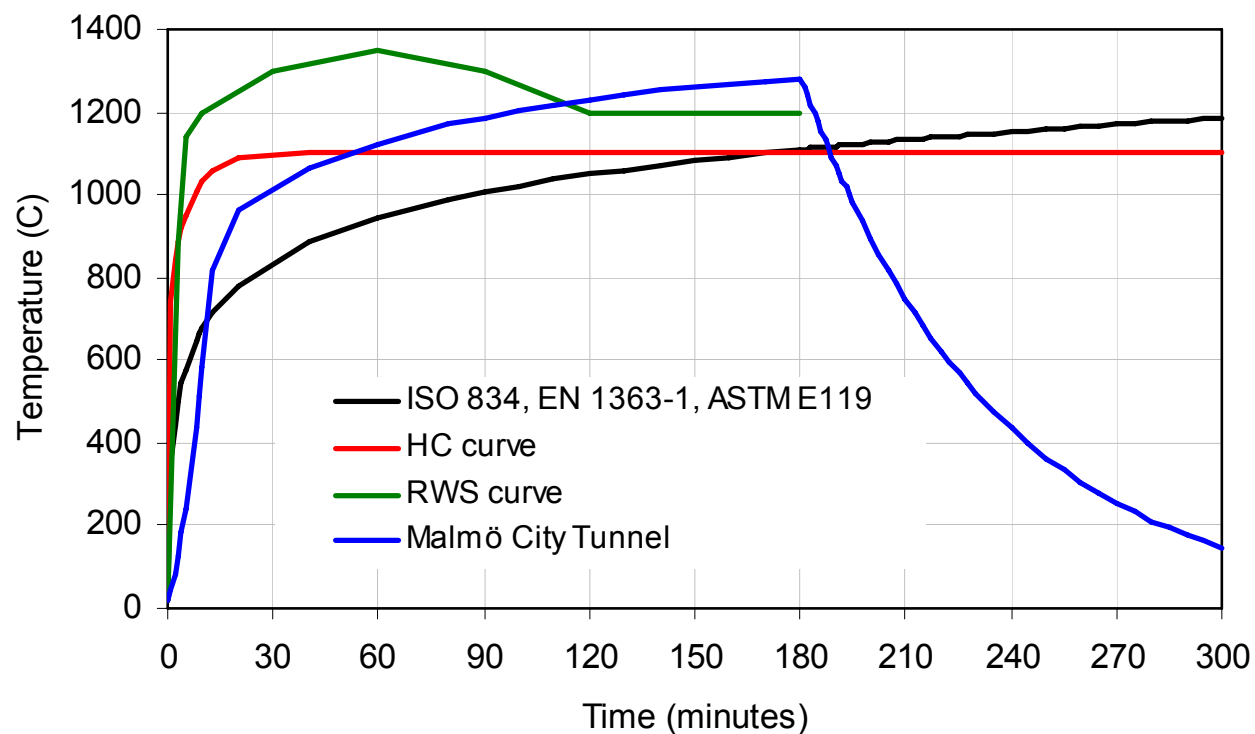
Fire resistance testing of tunnel lining systems

Test objects are mounted as ceiling or wall in a furnace



Fire resistance testing of tunnel lining systems

- Standards: ISO 834, EN 1363, ASTM E 119, SP Brand 119
- The temperature of the furnace follows a predefined temperature curve



Fire resistance testing of tunnel lining systems

Results as temperatures in the material, spalling depth, adhesion and others...



Test series compiled in SveBeFo report not previously published

Tests of concrete elements

- Hallandsås tunnel - large scale
- Malmö City Tunnel - small scale
- Malmö City Tunnel - large scale (2 test series)

Tests of spray-on concrete on concrete elements

- Hallandsås Tunnel - large scale

Tests of spray-on concrete on insulation on rock or concrete

- Citybanan, spray-on concreted on insulation/tightening materials - large scale
- Citybanan, spray-on concrete as protection of PE-insulation – small scale
- Citybanan, spray-on concrete as protection of PE-insulation – large scale

Tests of other insulation systems

- Calcium silicate boards (Promatect-T) on concrete elements– large scale
- Concrete like material (Maxit) – small scale



Illustrative example - Tests for the Malmö City tunnel

- EN 1363-1, using Malmö City Tunnel-curve for 300 minutes
- 8 concrete wall elements of size 1800 x 1200 x 400 mm³
- Compression load of 5.4 MPa using threaded bars
- Objective: investigate spalling tendencies and thermal insulation characteristics
- Concrete of 4 different formulas containing different amount of polypropylene fibres
- Conditioned during 2 month in water

Illustrative example - Tests for the Malmö City tunnel

Content	B1	B2	B3	B4
CEM I (kg/m ³)	368	377	379	380
Macadam 16-25 (kg/m ³)	588	615	612	613
Macadam 11-16	338	343	340	343
Macadam 4-8	218	223	223	223
Peramine HPA (kg/m ³)	1.12	0.67	0.72	0.70
Filler 0-2 (kg/m ³)	698	655	651	648
Peramine F (kg/m ³)	5.19	6.28	5.70	6.65
Silica slurry (kg/m ³)	25	30	30	30
PP-fibre 6 mm x 18 µm (kg/m ³)	0	0.75	1.0	1.5
Total water (kg/m ³)	144	142	143	145

Illustrative example - Tests for the Malmö City tunnel

- Temperatures at different depth from exposed surface
- Spalling depths

Test Object	Amount of PP-fibre (kg/m ³)	Spalling depth	
		Average (mm)	Maximum (mm)
B1-1	0	65	108
B1-2	0	57	102
B2-1	0.75	52	99
B2-2	0.75	50	108
B3-1	1.0	15	45
B3-2	1.0	24	83
B4-1	1.5	19	74
B4-2	1.5	12	44

Summary of general findings from the SveBeFo project (1)

- High risk of spalling in many concrete qualities, especially for dense concrete
- Small addition of PP-fibres reduces the spalling in all types of concrete
- In the majority of the large tunnel construction projects currently in progress in Sweden, PP-fibres will be added to concrete or spray-on concrete to some extent
- For spray-on products and boards, the anchorage systems must be accurately designed and tested



Summary of general findings from the SveBeFo project (2)

- Some protection systems are based on vaporization of bound water or other substances, but tested during a relatively short time period, e.g. 60 minutes. The duration of real tunnel fires might be longer.
- PP-fibres has a large influence on the concrete rheology
- When adding PP-fibres to spray-on concrete, it is important to accurately adjust the formula and have good control of all the ingredients. High risk to get a layered structure.



Thank You !!!



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