

A photograph of a road tunnel interior. The tunnel walls are made of concrete with visible reinforcement. Two large circular fans are mounted on the ceiling. A car is driving through the tunnel, blurred to indicate motion. The lighting is warm and focused on the road ahead.

Structural fire protection with PP-fibre modified concrete in German road tunnels

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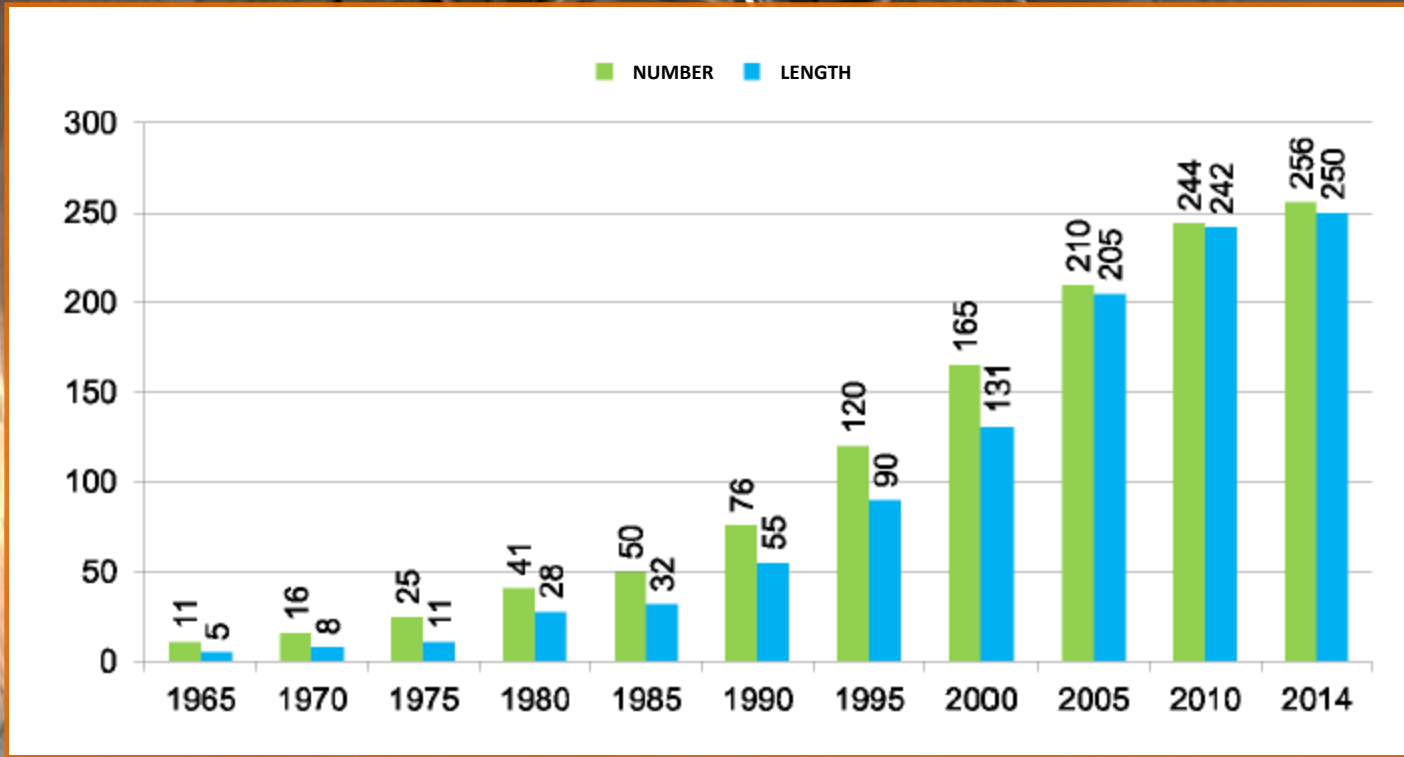
Rome, 6/18/2015

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Tunnels in the trunk road system



Outline

- Damages at tunnel linings in case of fire
- Mode of action of PP-fibres in concrete
- Research projects at BAST
- Pilot projects
 - Tunnel Bautzen
 - Bühl tunnel
- Transfer into the regulations

Damages at tunnel linings in case of fire



Damages at tunnel linings in case of fire

Damages

Mode of action

Research projects

Pilot projects

Transfer into Regulations

Tunnel linings are exposed to fire

Water passes from liquid to a gaseous state

Water vapour pressure leads to explosive concrete spalling

Bearing reinforcement is getting exposed

Loss of load bearing capacity

(at worst) Collapse

Mode of action

Damages

Mode of action

Research projects

Pilot projects

Transfer into Regulations

Fire impact at tunnel linings

Melting of PP-Fibres

consistently networked pore system

Water vapor pressure release

Impact: Reduction of explosive concrete spalling

Research projects at BASt

Damages

Mode of action

Research projects

Pilot projects

Transfer into Regulations

- Research goal: verify and validate the influence of PP-fibres in the concrete on the fire and spalling behaviour according to the regulations for Federal German road tunnels
 - Fundamental study done by BASt (2008)
 - External research project done by MFPA Leipzig
 - Completed in 2010

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Fire tests on large scaled specimens

Damages

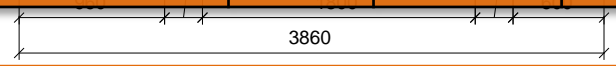
Mode of action

Research projects

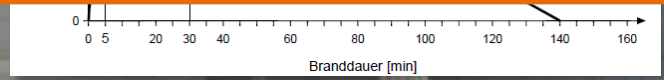
Pilot projects

Transfer into Regulations

Specimen		OB 1	OB 2
PP-fibre content	[kg/m ³]	--	2,0
Horizontal loading		yes	yes
Mass loss	[% by wt]	11,00	4,66
Maximum value of the concrete spalling depth	[mm]	-156	-66
Average value of concrete spalling depth	[mm]	-61	-29



Result: efficacy of PP-fibres with a diameter of 6 mm and a dosage of 2 kg/m³ concrete was demonstrated



Concrete technology feasibility study

Damages

Mode of action

Research projects

Pilot projects

Transfer into Regulations

- Alteration of the concrete properties by the addition of PP-fibres
 - Increase of the water demand
 - Increase of the air content
 - Change of the rheological properties (viscosity / flowability)
 - Danger of bleeding

Pilot project Tunnel Bautzen

Damages

Mode of action

Research projects

Pilot projects

Transfer into Regulations



Source:SGHG



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Pilot project Tunnel Bautzen

Damages

Mode of action

Research projects

Pilot projects

Transfer into Regulations

- length: 200 m
- Cross section: rectangular frame with a clear width of 9.50 m
- Build with cut-and-cover technique
- Tunnel shell build from Sept.2011 till Mar.2013
- Dosage and geometry of the PP-fibres according to the experiences from the research project
- Target value of the consistency according to EN 12350-5 was 480 +- 20 mm (F3)
- To secure the workability, compactability and pumpability of the concrete sample concretings were conducted

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Concreting of sample walls

Damages

Mode of action

Research projects

Pilot projects

Transfer into Regulations

- Sample walls:
 - dimensions: 3.5 m x 3.0 m x 0.8 m
 - actual reinforcement
 - bodies corresponding to the future operational technology
- ready-mixed concrete from the manufacturer which delivered the tunnel construction site
- the concrete was pumped in the formwork and compacted with internal vibrators
- Cores were taken to identify the recovery rate at wash-out tests



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Pilot project Bühltunnel

Damages

Mode of action

Research projects

Pilot projects

Transfer into Regulations



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Pilot project Böhltunnel

Damages

Mode of action

Research projects

Pilot projects

Transfer into Regulations

- length: 525 m
- Cross section: RQ 10,5 t (tunnel diameter 9.5 m)
- Tunnel shell build from Jun.2013 till Dec.2014
- Target value of the consistency was 580 +/- 20 mm
- Deviation from geometry and dosage of the PP-fibres:
 - 1.4 kg/m³ PP-fibres with a diameter of 0.0154 mm and a length of 6 mm
 - To ensure the equivalence of the structural fire protection fire tests on loaded medium scaled specimens were conducted

Transfer into Regulations

Damages

Mode of action

Research projects

Pilot projects

Transfer into Regulations

- **NEW: Annex to the Additional Technical Contract Conditions (ZTV-ING)**
 - Since March 2015
 - To safeguard the requirements for the application of a PP-fibre modified concrete in the german regulations

ZTV-ING - Teil 5 Tunnelbau - Abschnitt 1 Ges

Anhang B
Verwendung von PP-Faserbeton für den baulichen Brandschutz im Tunnelbau
B 1 Allgemeines

Die Beton wird unter Verwendung von...
 B 1.2 Begriffsbestimmungen
 PP-Faser
 Mikro-PP-Faser
 B 2 Verwendung von PP-Fasern im Beton
 B 3
 (1) Z
 zes s
 und
 det w
 (2) B

Anhang B
Verwendung von PP-Faserbeton für den baulichen Brandschutz im Tunnelbau
B 1 Allgemeines

B 3
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Practicality test of the designed concrete

Damages

Mode of action

Research projects

Pilot projects

Transfer into Regulations

- Large scaled sample walls
 - Provided with actual reinforcement
 - Minimum dimensions: 4.5 m x 3.0 m x 0.35 m
- Concrete has to be made and delivered by ready-mixed concrete manufacturer that in further course delivers the tunnel construction site
- Concrete has to be pumped in the formwork
- Compacting with actual technique subsequently used



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Bleeding

Damages

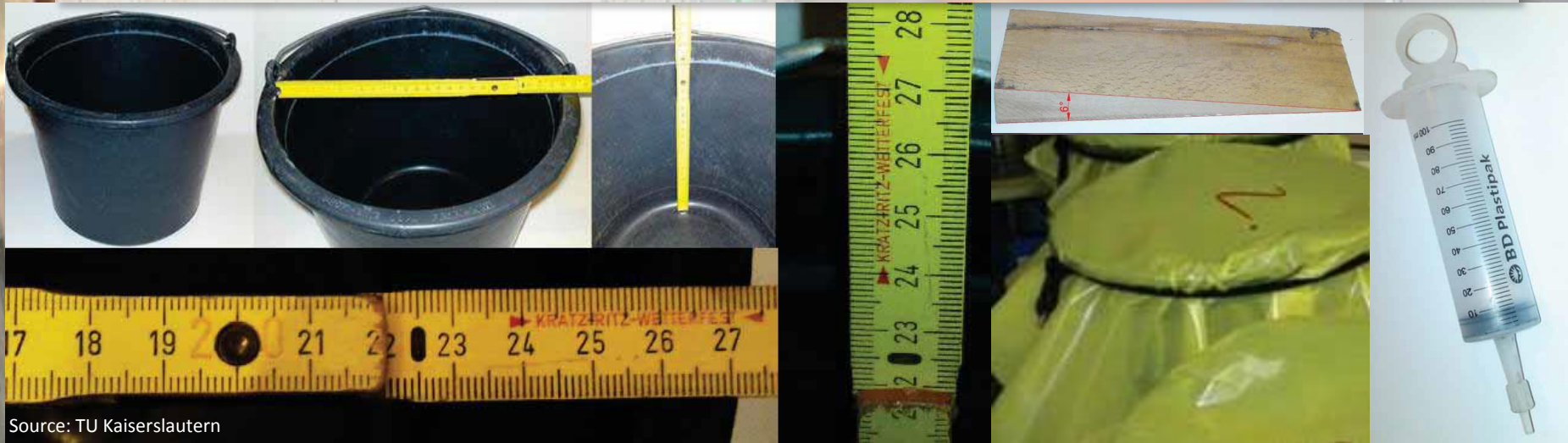
Mode of action

Research projects

Pilot projects

Transfer into Regulations

- Evaluation of bleeding tendency
 - With „Eimerverfahren“ (bucket method)
 - Acc. to DBV (German Institute for Concrete) data sheet „Specific testing of fresh concrete“



Source: TU Kaiserslautern

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Recovery rate of PP-fibres

Damages

Mode of action

Research projects

Pilot projects

Transfer into Regulations

- Verification of the actual PP-fibre content in the fresh concrete with wash-out tests
 - Acc. to ÖBV Guideline „Erhöhter Brandschutz mit Beton für unterirdische Verkehrsbauwerke“
 - Stricter limit values (single value: 90%; mean value: 95%)
 - PP-fibre content has to be stated in fixed intervals
 - ready-mixed concrete manufacturer : every 200 m³ of concrete or twice per production week
 - Construction site: every 300 m³ of concrete or every third day of concreting



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Recovery rate of PP-fibres

Damages

Mode of action

Research projects

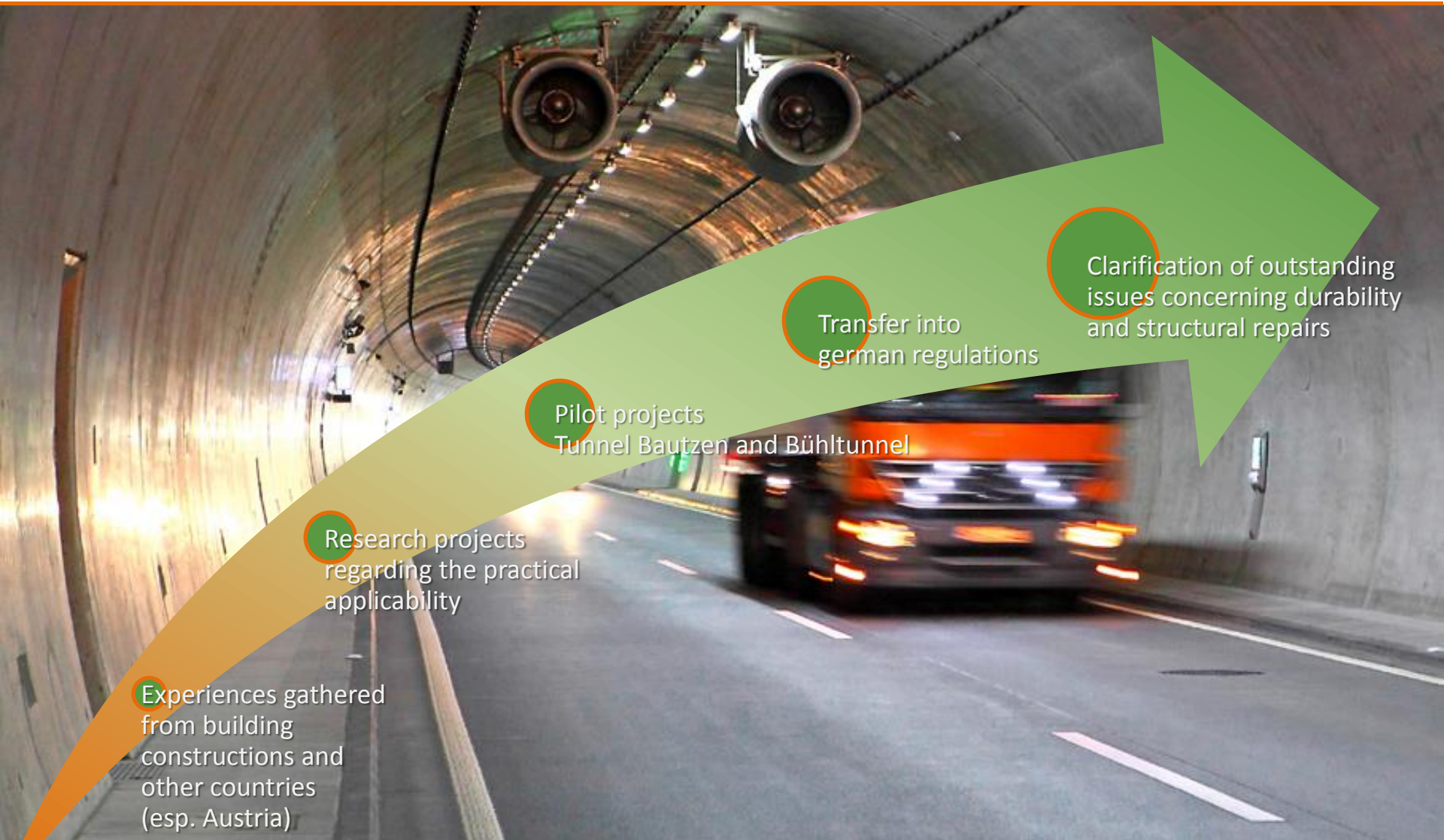
Pilot projects

Transfer into Regulations

- Verification of the actual PP-fibre content in the hardened concrete
 - Acc. to ÖBV Guideline „Erhöhter Brandschutz mit Beton für unterirdische Verkehrsbauwerke“
 - Test is only applied when proof of conformity fails



Chronology



Experiences gathered from building constructions and other countries (esp. Austria)

Research projects regarding the practical applicability

Pilot projects
Tunnel Bautzen and Bühlertunnel

Transfer into
german regulations

Clarification of outstanding issues concerning durability and structural repairs

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Thank you for your kind attention!



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