Research for Civil Security
Programme of the Federal Government of Germany

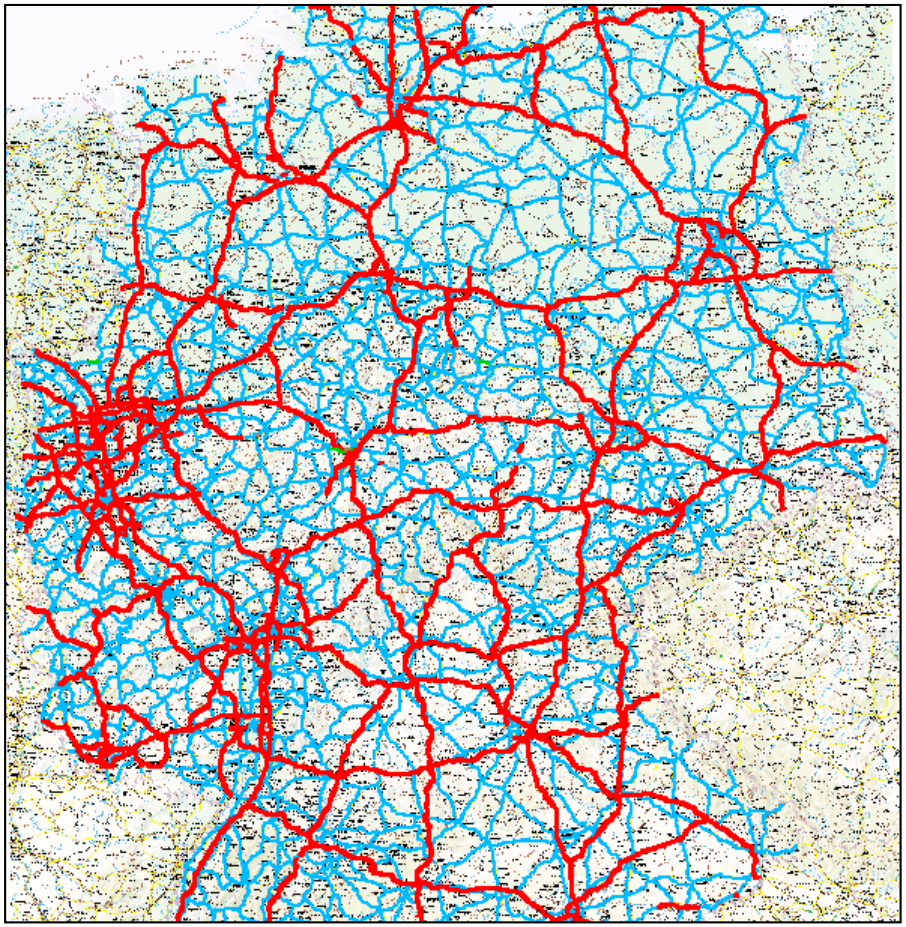
Tunnel safety & security - SKRIBT^{Plus}

ITA-COSUF Workshop
Berlin, 5th of June 2014

High density of traffic in Germany

The supply of
- 240 tunnels
- 39.000 bridges

Tunnels and bridges are important components of traffic infrastructure, but also liable to break down particularly.

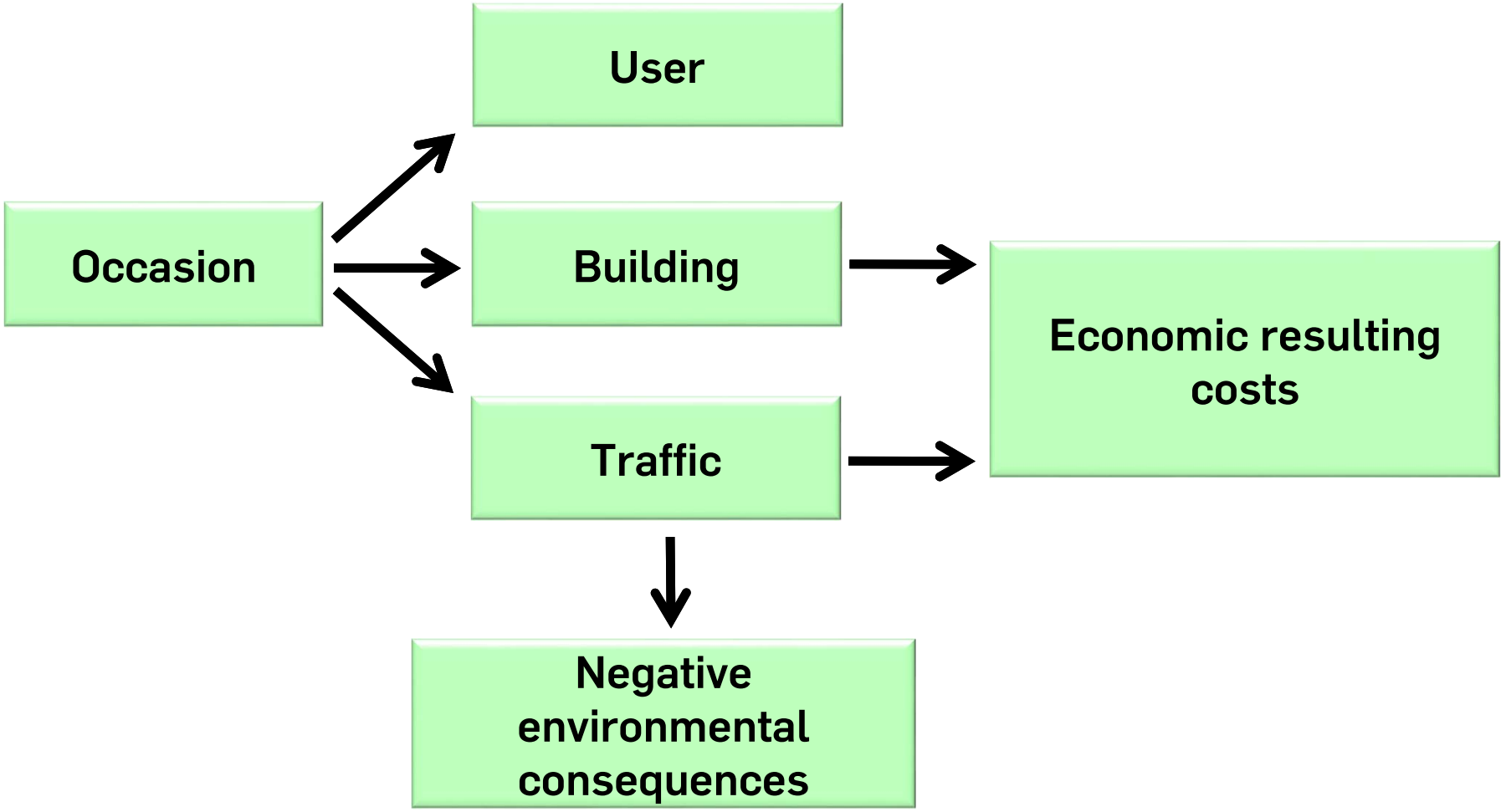


Holistic assessment

Terrorism / Criminality

Extreme natural phenomenom

Serious major accident

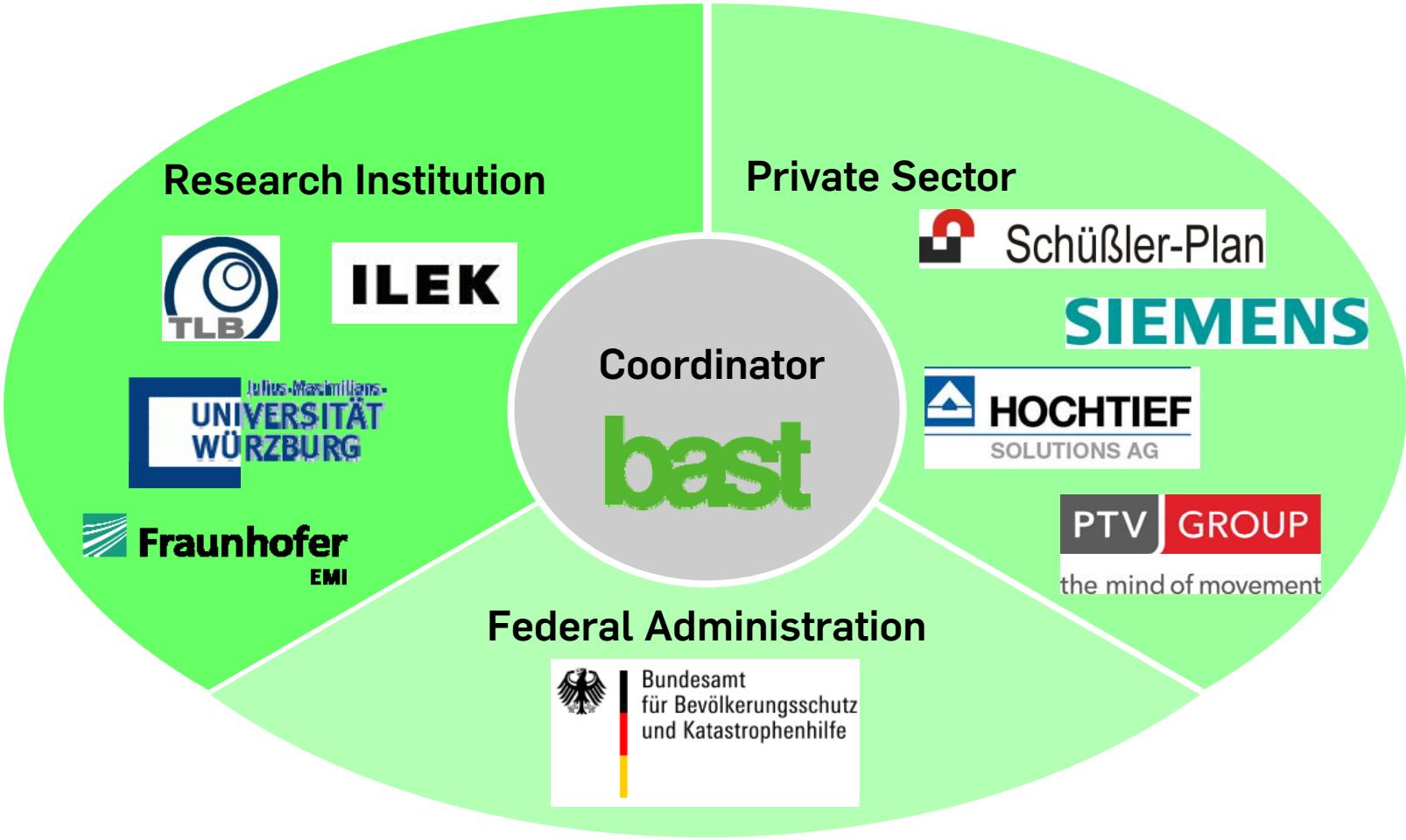

User
Occasion
Building
Economic resulting costs
Traffic
Negative environmental consequences

Protection of critical bridges and tunnels (SKRIBT^{Plus})

as part of the scenario-oriented security research

Supported by: Bundesministerium für Bildung und Forschung	Research programme for Civil Security of the Federal Government : „Protection of traffic infrastructure“ as part of the scenario-oriented security research	Project Management: VDI Technologiezentrum
Term 3 years: 01/2012 – 12/2014		Cooperative Project: interdisciplinary handling by several project partners

Project Partners



Some key developments (tunnel related):

- Quantitative risk assessment for tunnels under explosive and fire loads
- Probabilistic assessment model for spalling processes in tunnels
- Calibration of hydrocode simulations via scaled field tests
- Development of UHPC-based sprayed concrete mixtures for the structural upgrade of tunnels under explosive and fire loads

- Quantitative risk assessment for tunnels under explosive and fire loads

Object or scenario based approach for the structural assessment?

- Object based approach leads to a reliability analysis of the specific facility under possible hazards (good for bridges but of lesser appropriateness for tunnels)

- Scenario based approach defines a set of probable final states under the premise of a specific scenario

- Within SKRIBTPlus a scenario based approach was already taken and implemented for the assessment of the user risks
  - ➔ A scenario based approach was needed

SKRIBT^{Plus} approach

Initialereignis	Verzweigungen im Ereignisablauf													Endzustände
	Benzin / Diesel	Frei-setzung	Zündung	Ereignis ort	Zeit-raum	Verkehrs-zustand	Detektion erfolgreich	Sperr-einrichtung aktiviert	Lüftungs-system aktiviert	weitere Sicherheits-systeme vorhanden und aktiviert	Erhöhtes Ausmaß (Bus)	Grad der Beein-trächtigung des Bauwerks	Dauer der Beein-trächtigung	Verlagerung der Verkehrs-ströme	$P_{ei} = P_0 \prod P_i$
Brand	30 MW / 50 MW / 100 MW	spontan / kontinuierlich	sofort / verzögert	Mitte / Rand	Tag / Nacht	Frei / Stau	ja / nein	ja / nein	ja / nein	ja / nein	ja / nein	vollständig / teilweise / keine	Tage / Monate / Jahre	ja / nein	
Wahrscheinlich-keit P_0	Verzweigungswahrscheinlichkeiten Pi														Wahrscheinlichkeit P_{ei}

Procedure

- Synchronization of the structural analysis with the already existing user analysis
- Therefore adding structure related branches to the event trees (e.g. “spalling” for fire or “resonance frequency” for explosion)

SKRIBT^{Plus} approach

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	Benzin / Diesel	Frei-setzung	Zündung	Ereignis ort	Zeit-raum	Verkehrs-zustand	Detektion erfolgreich	Sperr-einrichtung aktiviert	Lüftungs-system aktiviert	weitere Sicherheits-systeme vorhanden und aktiviert	Erhöhtes Ausmaß (Bus)	Grad der Beein-trächtigung des Bauwerks	Dauer der Beein-trächtigung	Verlagerung der Verkehrs-ströme	$P_{ei} = P_0 \prod P_i$
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Wahrscheinlich-keit P_0	Verzweigungswahrscheinlichkeiten Pi														Wahrscheinlichkeit P_{ei}

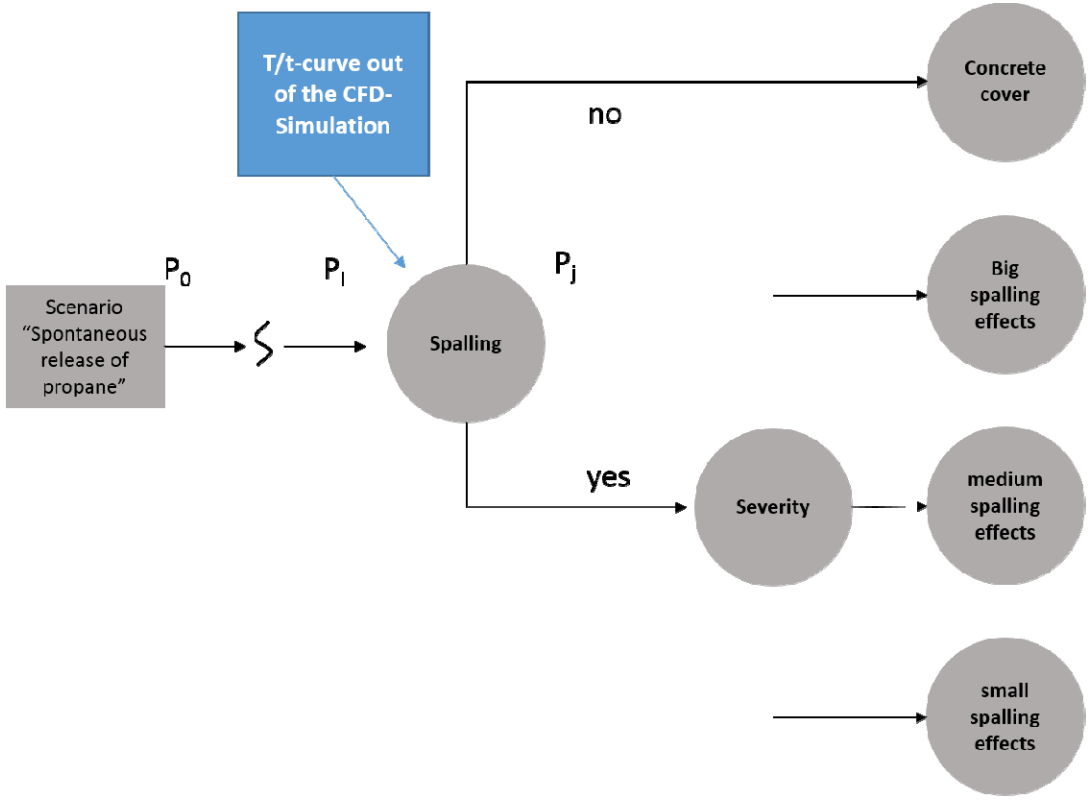
Result

- Probability of final state i under the premise of the specific scenario, including probabilities for cascading effects (flash over, fire after explosion)
- Presssure/time- or Temperature/time-curves as the result of the accompanying Hydrocode- or CFD-Simulations, and a predefined local damage which then will be applied to the structure

- Probabilistic assessment model for spalling processes in tunnels

SKRIBT^{Plus} approach

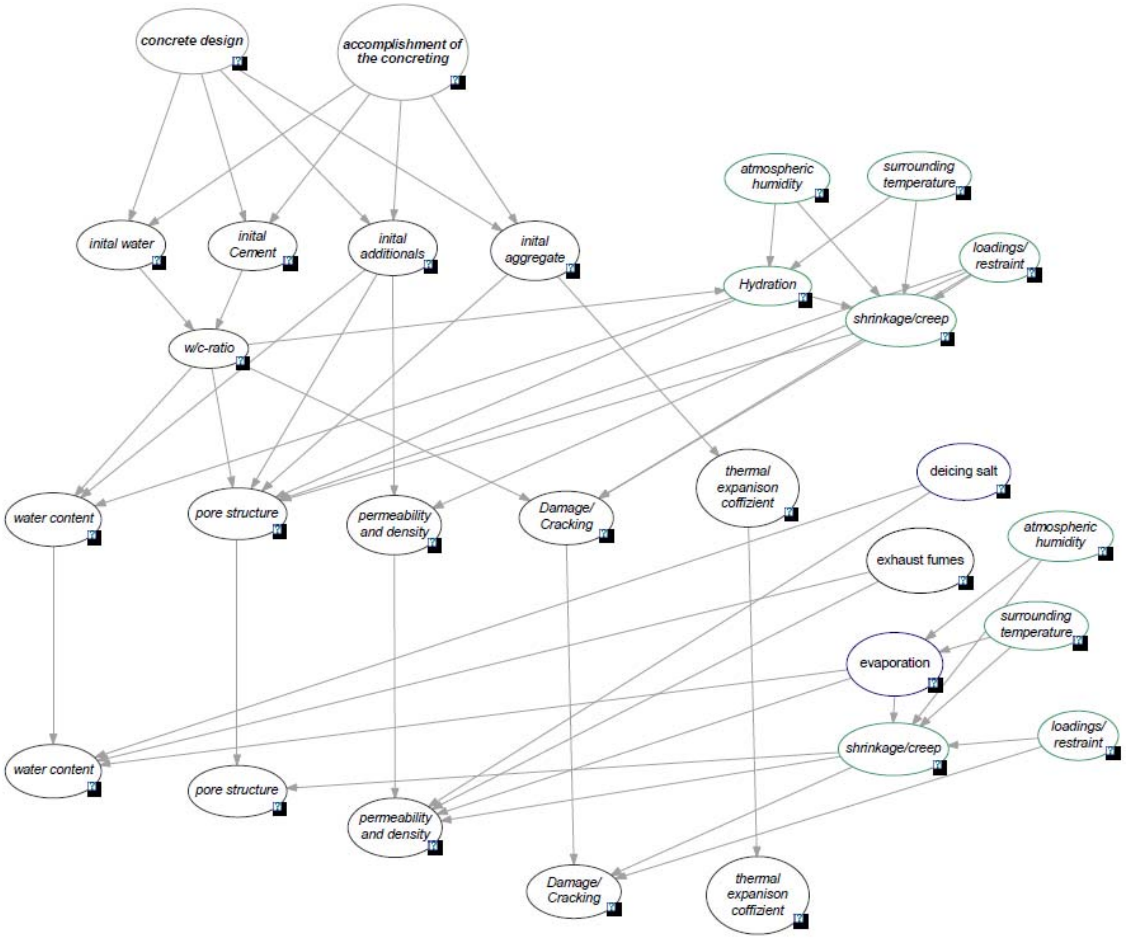
- CFD delivers probability and possibly a specific T/t-curve
- Input values for a probabilistic assessment of spalling phenomenons in case of fire loads
- 2D-vector (Probability of final state and severity of spalling)



Some general thoughts…

- Spalling of concrete under fire exposure is a stochastic process
- Even under identical circumstances (t_{Max}, Δt, etc.) identical mixtures will produce varying results (spalling width, spalling depth)
- A numerical simulation of spalling is (up to now) not possible when looking for reliable results
- In the course of SKRIBT^{Plus} an approach via BayesianNetworks was taken

Basic model


concrete design
accomplishment of the concreting
inital water
inital Cement
inital additionals
inital aggregate
atmospheric humidity
surrounding temperature
loadings/ restraint
Hydration
shrinkage/creep
w/c-ratio
water content
pore structure
permeability and density
Damage/ Cracking
thermal expanison coffizient
deicing salt
atmospheric humidity
exhaust fumes
surrounding temperature
evaporation
loadings/ restraint
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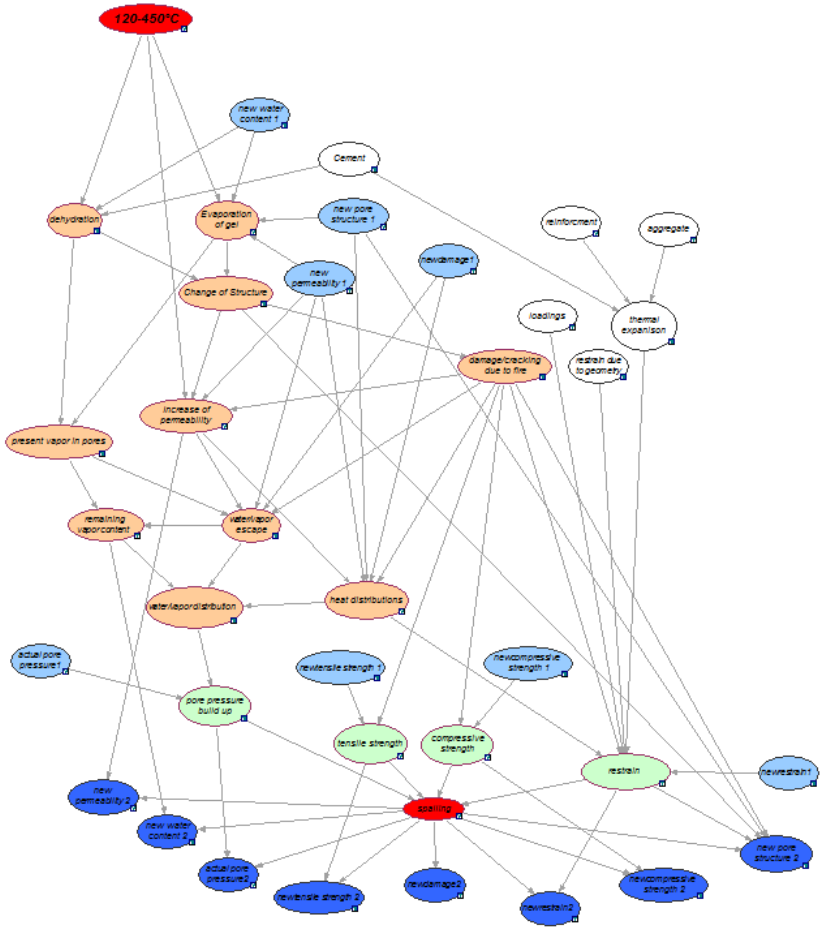
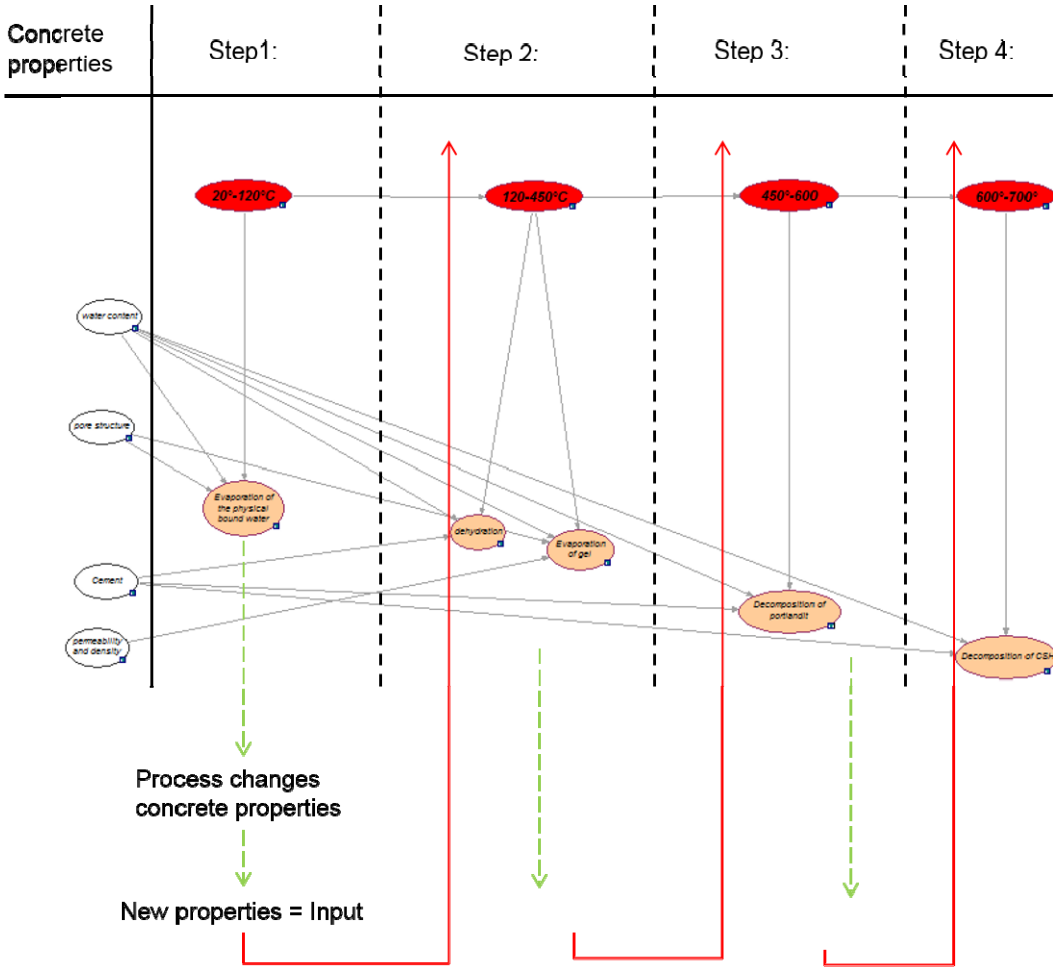
Development of t-related networks

(here exemplarily display of the network for the area from 120°C to 450°C)



Consecutive temperature-related calculation

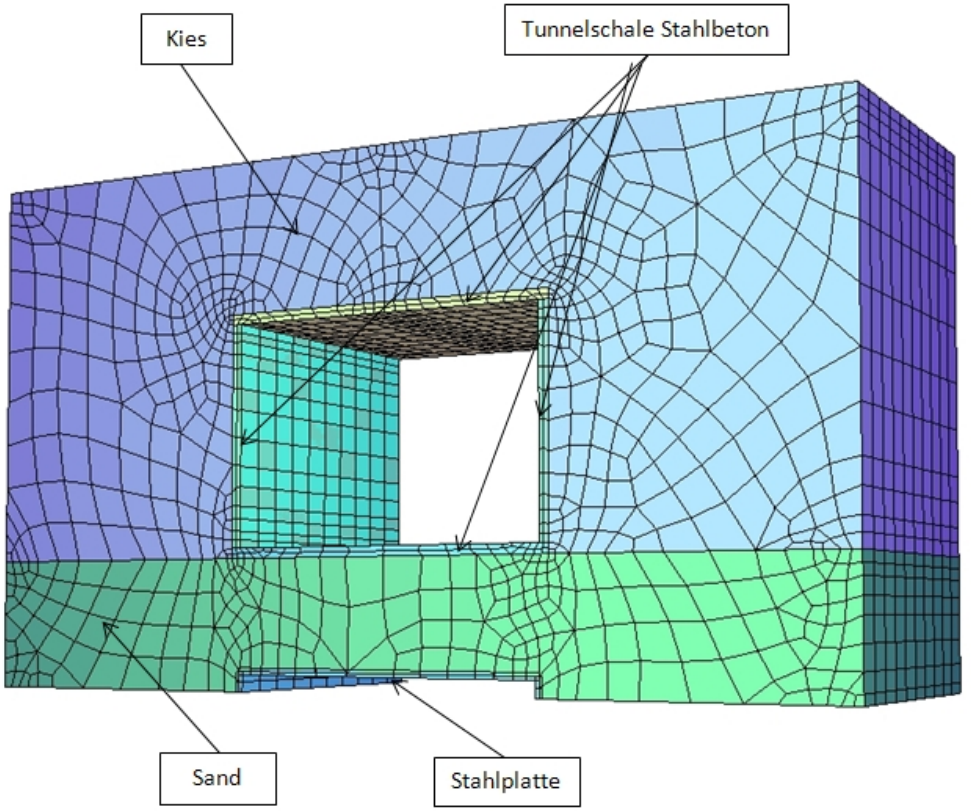


Calibration and validation

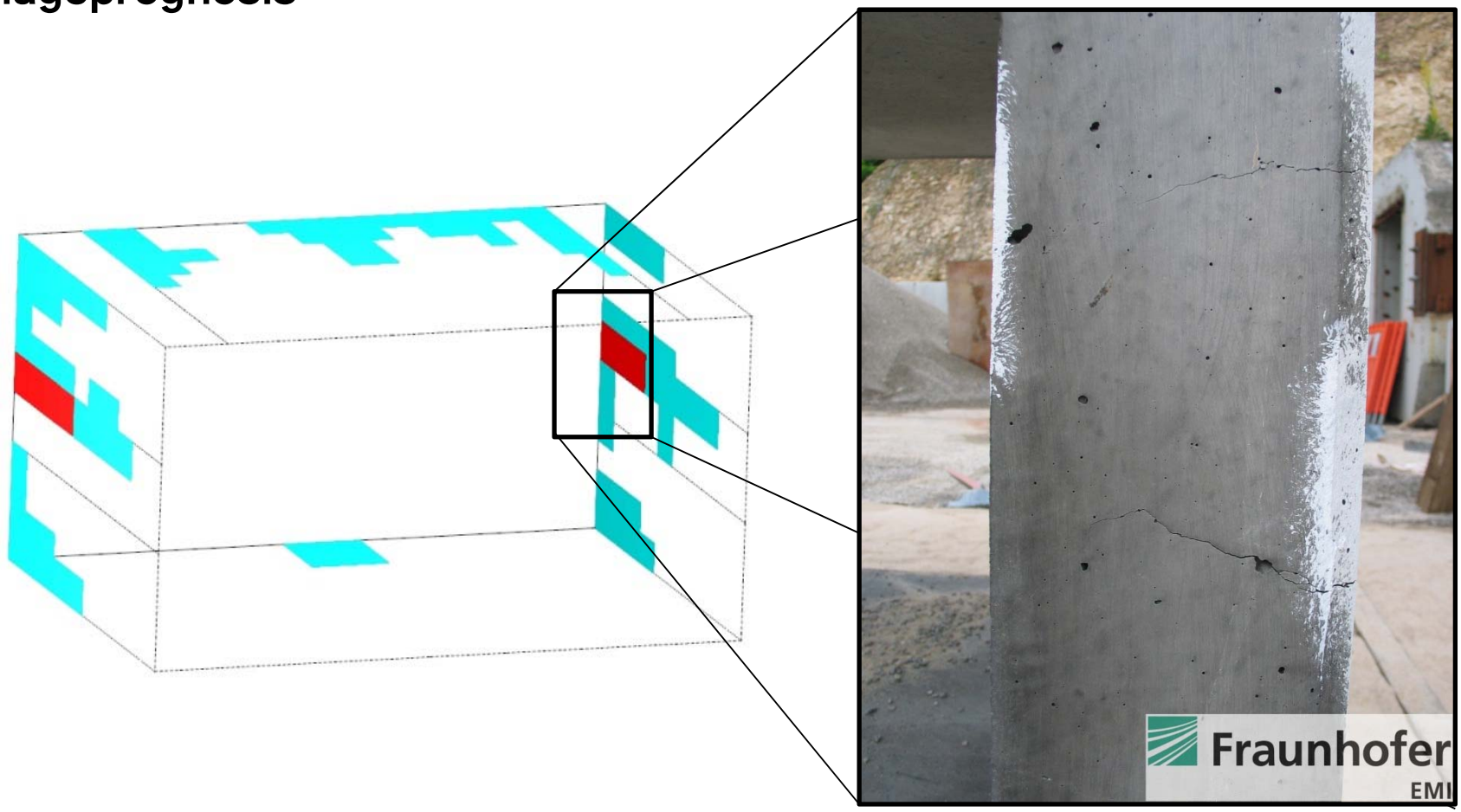
- Results from actual fire test were used for calibration of the model and the model showed a good affinity with these results
- Further work is surely needed, especially in terms of more precise calibration
- Currently no add-ons (PP-fibres etc.) are integrated

- Calibration of hydrocode simulations via scaled field tests

Field test and the corresponding numerical model

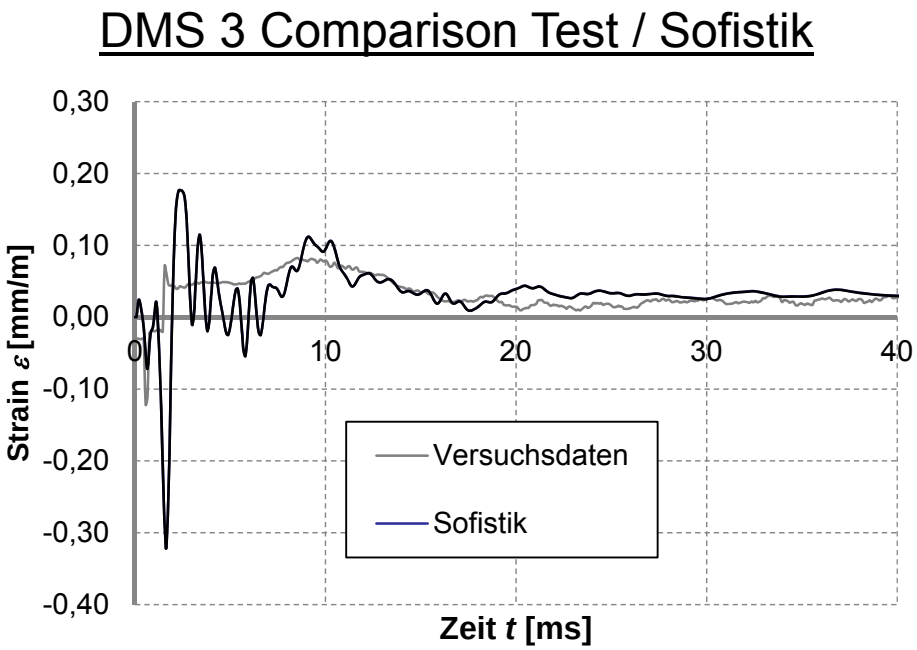


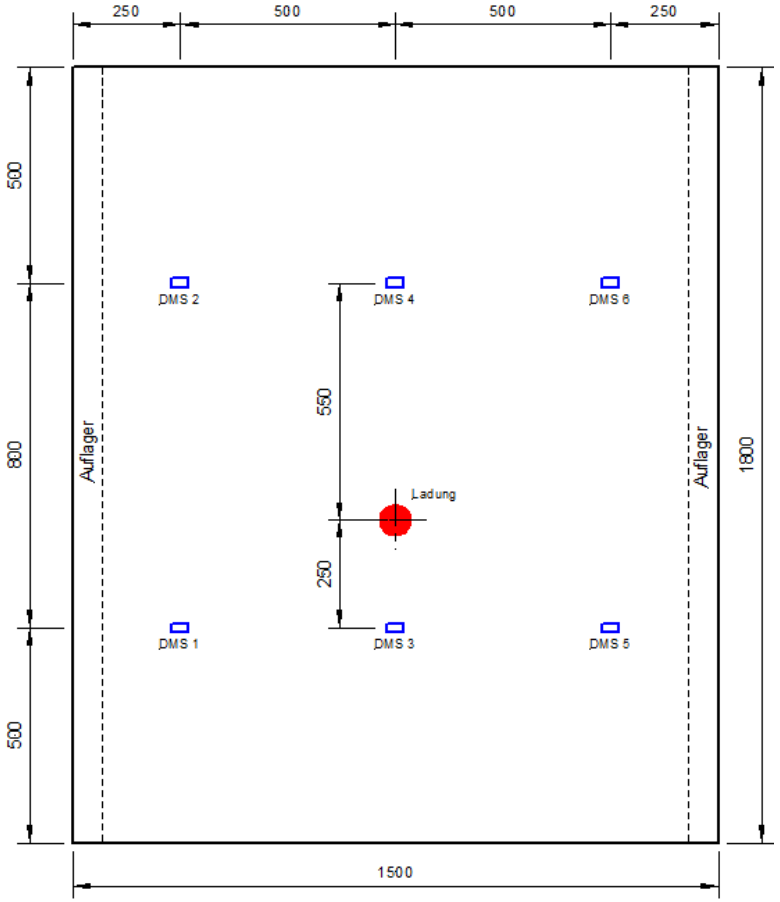
Damageprognosis



Simulation of the test

DMS





Cooperative Project SKRIBT^{Plus}

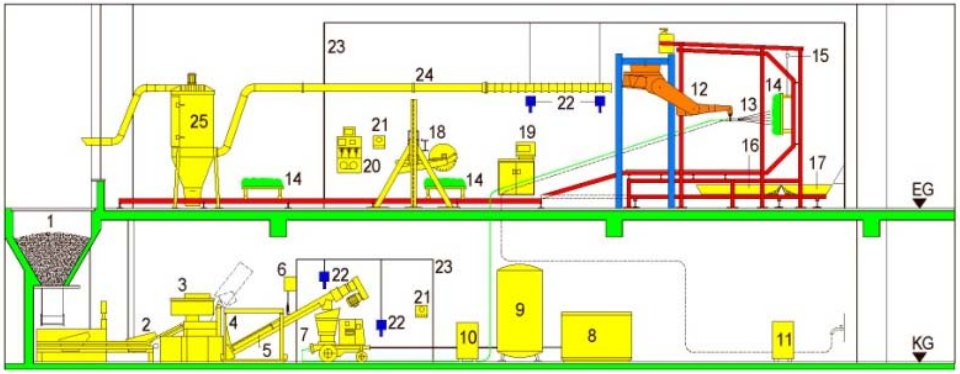
- Development of UHPC-based sprayed concrete mixtures for the structural upgrade of tunnels under explosive and fire loads

Task and outline

- Up to now just the possibility of pre-cast-elements with high resilience against fire as well as high speed dynamics
- E.g. SIFCON or DUCON
- Not applicable for refurbishment or upgrading, especially under more or less extreme conditions of underground facilities (complex geometries, arches and bows)
- Development of a sprayable recipe for a UHPC at TLB

Cooperative Project SKRIBT^{Plus}

Ongoing R&D-activities at TLB



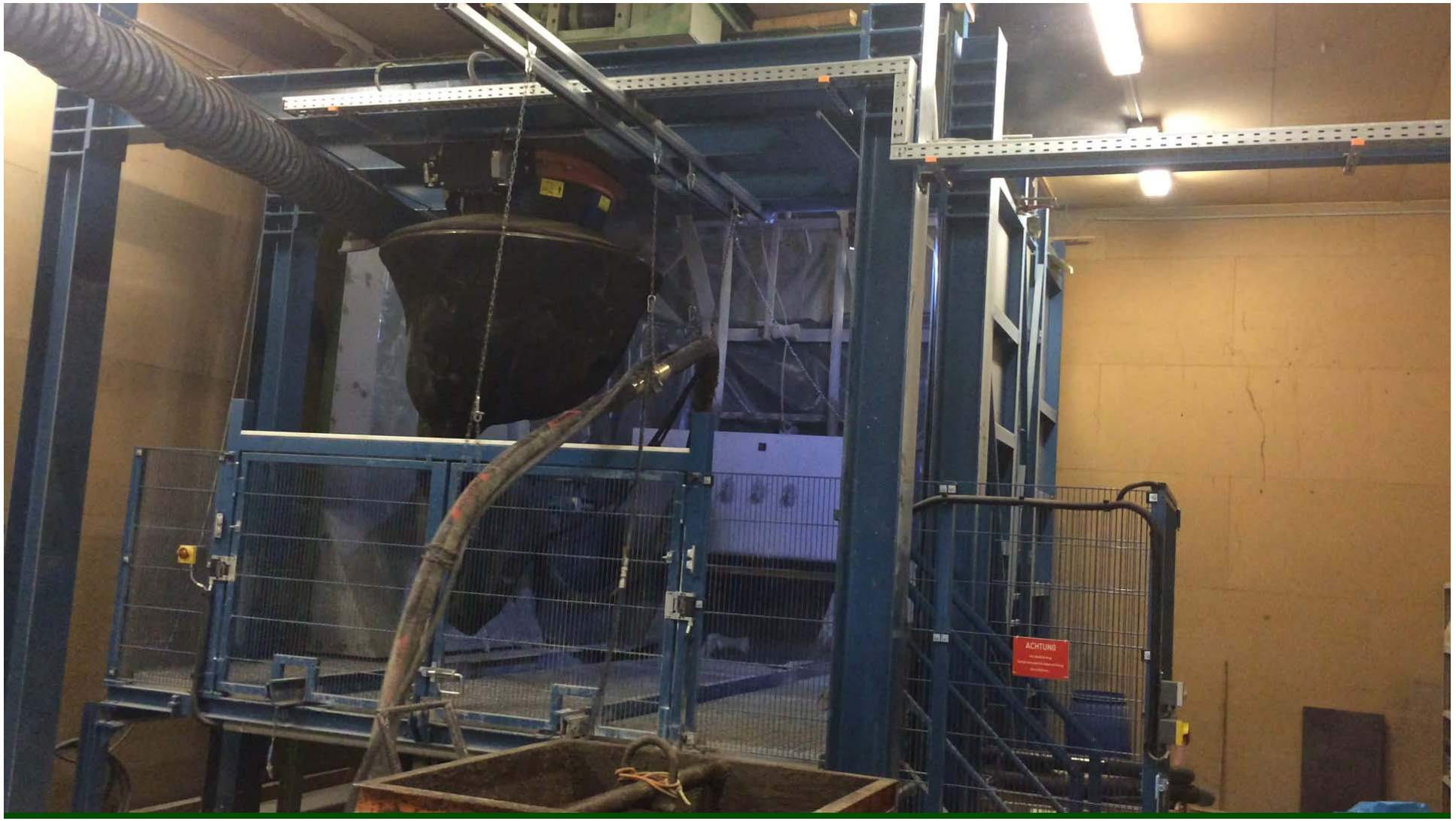
1 Depot Zuschlag, Zement
2 Dosierung Zuschlag, Zement
3 Zwangsmischer
4 Vorratssilo/Waage
5 Dosierschnecke
6 Dosierung Zusatzmittel
7 Spritzbetonmaschine
8 Kompressor
9 Druckluftkessel
10 Mess- und Regel (Luft)
11 Mess- und Regel (Wasser)
12 Spritzroboter
13 Spritzdüse
14 Verfahrbare Spritzpalette
15 Palettenwaage
16 Rückprallwaage
17 Wanne Differenzmenge
18 Bohr- und Sägestand
19 Steuereinheit Spritzroboter
20 Messwerterfassung
21 Gegensprechanlage
22 Staubmessgeräte
23 Staubdichte Umhausung
24 Be- und Entlüftung
25 Absaug- und Entstaubungs-anlage

Status

- Development of a “workable” mixture is finished
- Basic features are 140 kg/m^3 steel fibres (micro and makro fibres), 3 kg/m^3 PP-fibres and a sprayable UHPC with an estimated compression strength of 120 N/mm^2
- Mixture is workable for up to 3 hours
- Specimen for fire tests (spalling) and explosion test are prepared
- Within the next 2 months fire test and explosion test will be carried out

Impressions

Cooperative Project SKRIBT^{Plus}



Impressions