Precast Elements Made of UHPC
– From Research to Application –

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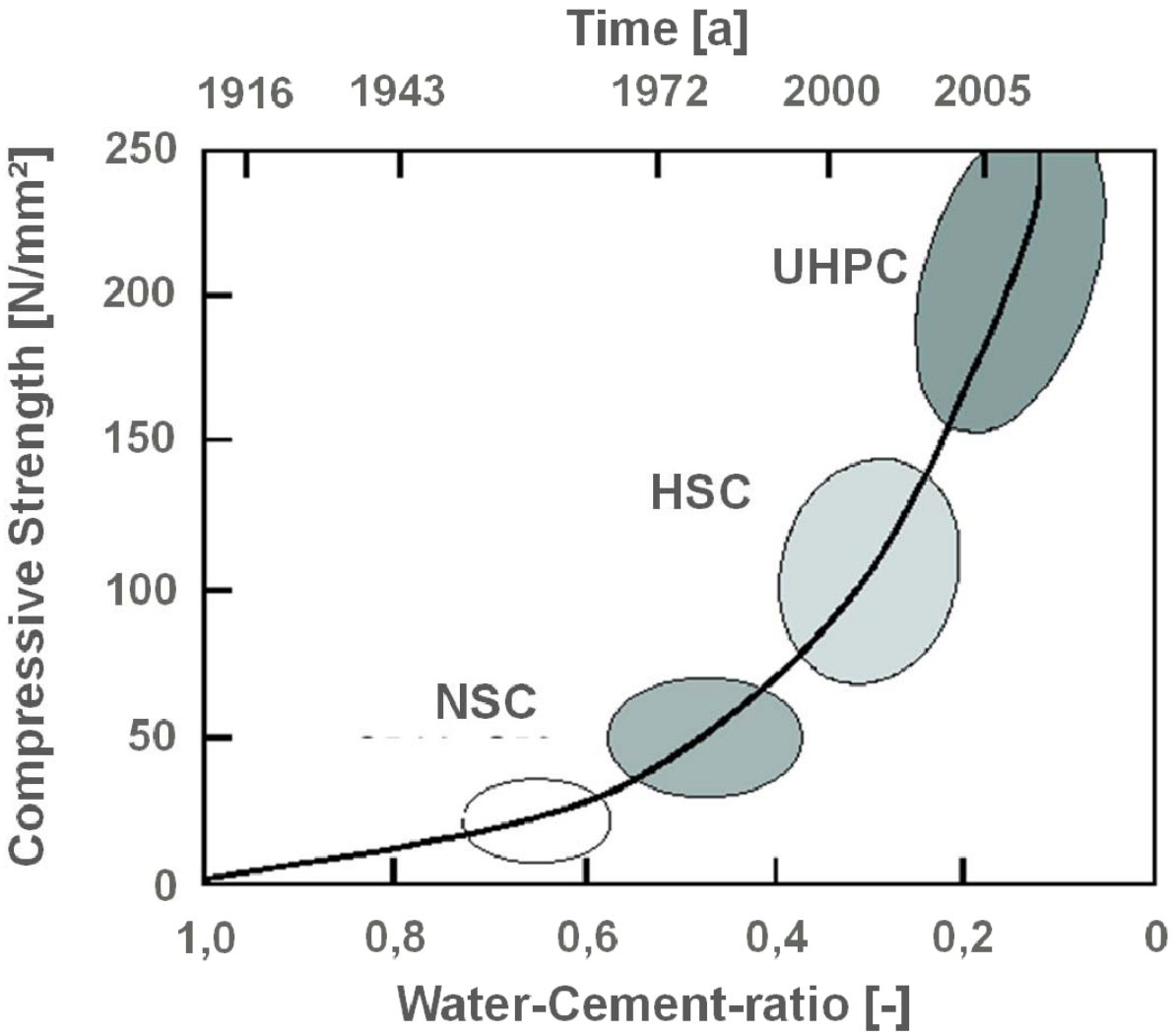
Development of Concrete Compressive Strength



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Ultra High Performance Concrete (UHPC)

A High-Tech Concrete

- Very densed Microstructure
- High workability
- High compressive strength (150-230MPa)
- High durability
- ……..

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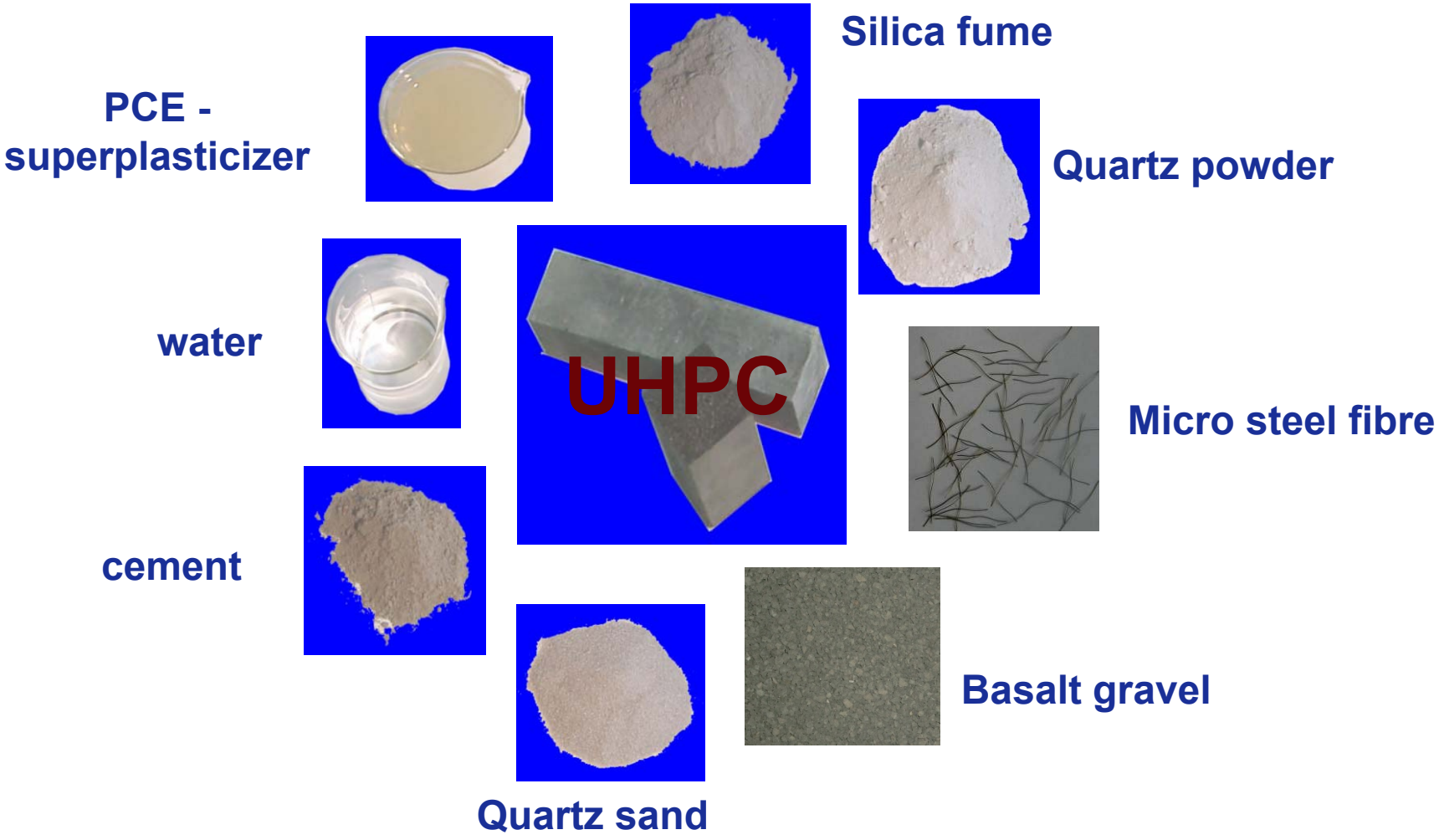
Composition of UHPC



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Properties of Fresh UHPC

Flow ability of UHPC

- Composition of raw materials
- Mixing procedure
- Content and type of superplasticizer

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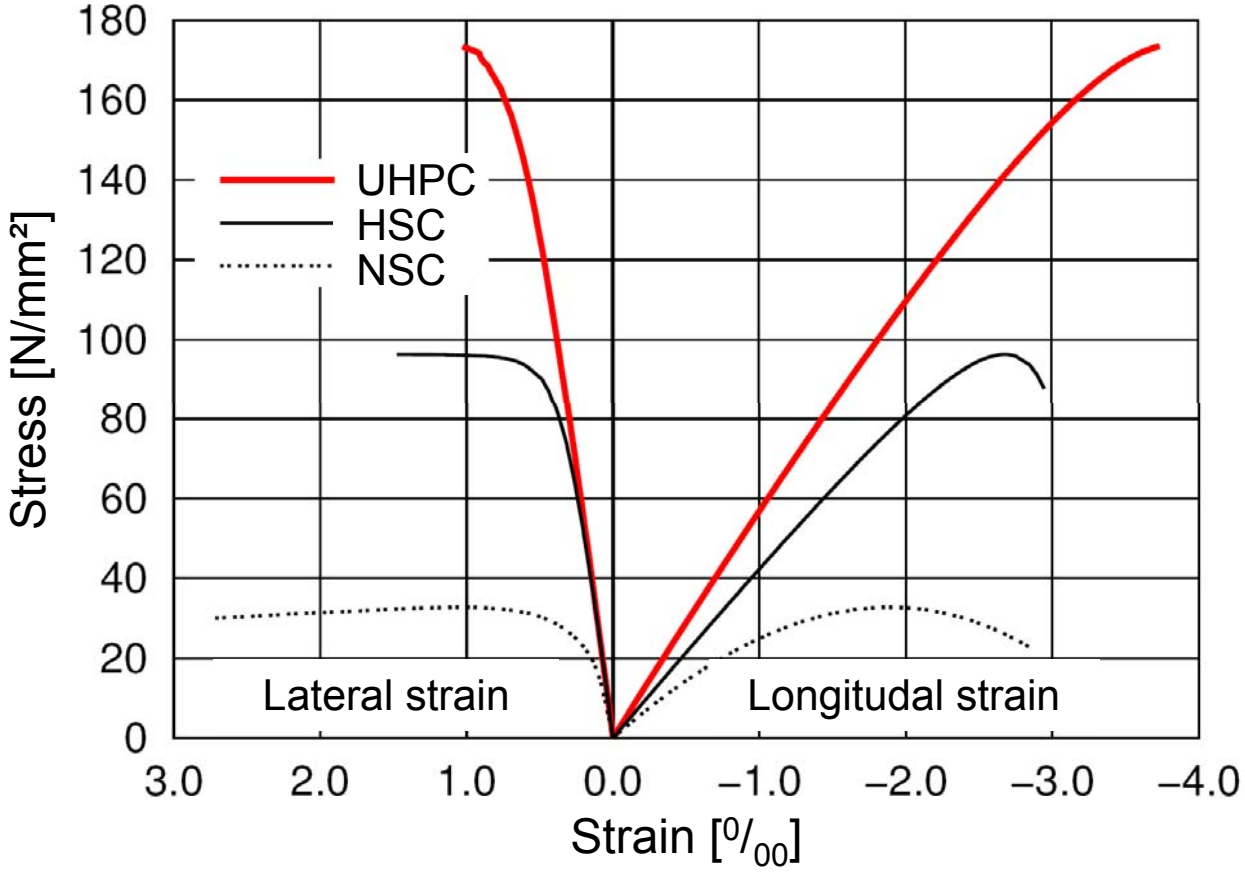
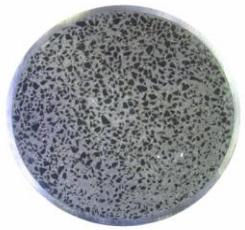
Properties of UHPC in Uniaxial Compression





UHPC
172 N/mm²

HSC
96 N/mm²

NSC
36 N/mm²

- **High compressive strength (f_c > 150 N/mm²)**
- **High E-Modulus (E_c > 45000 N/mm²)**
- **Linear relationship up to 70 - 80% of the peak**

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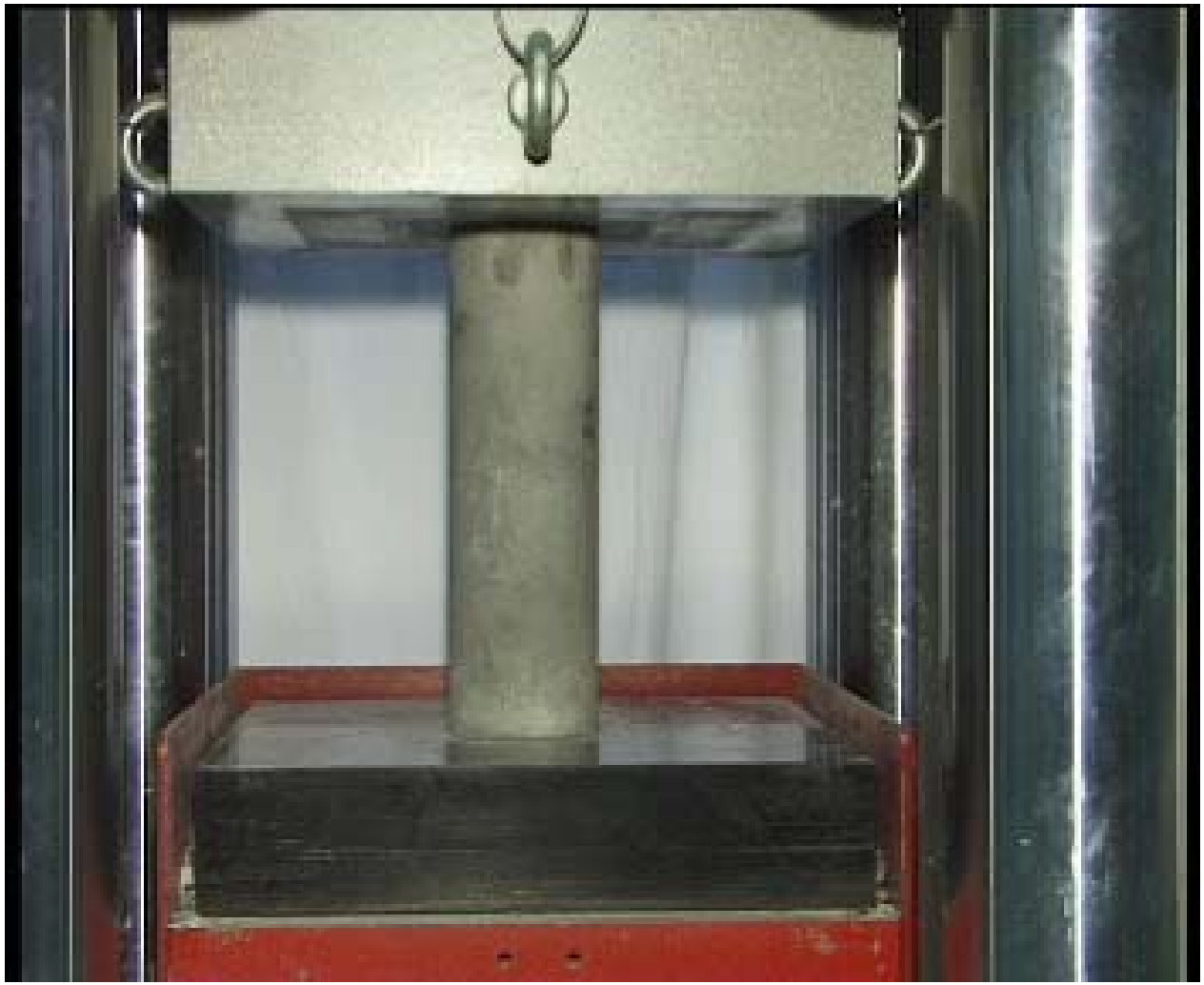
Hardened UHPC in Uniaxial Compression



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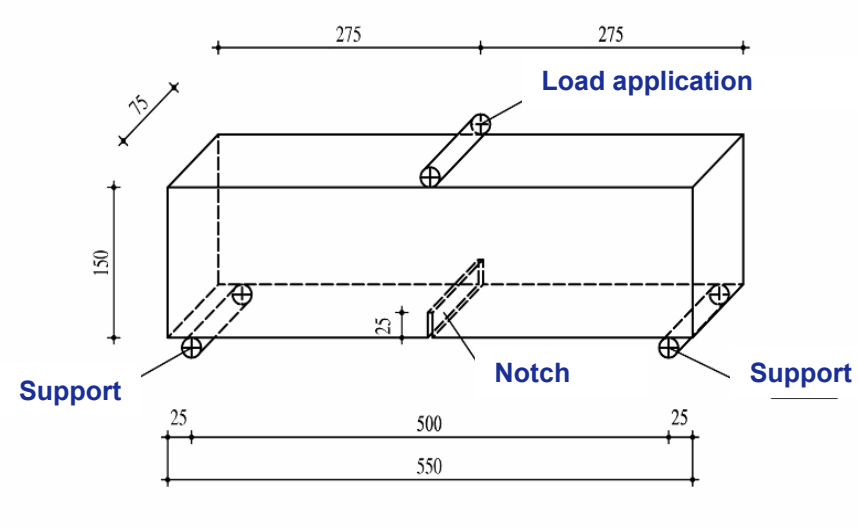
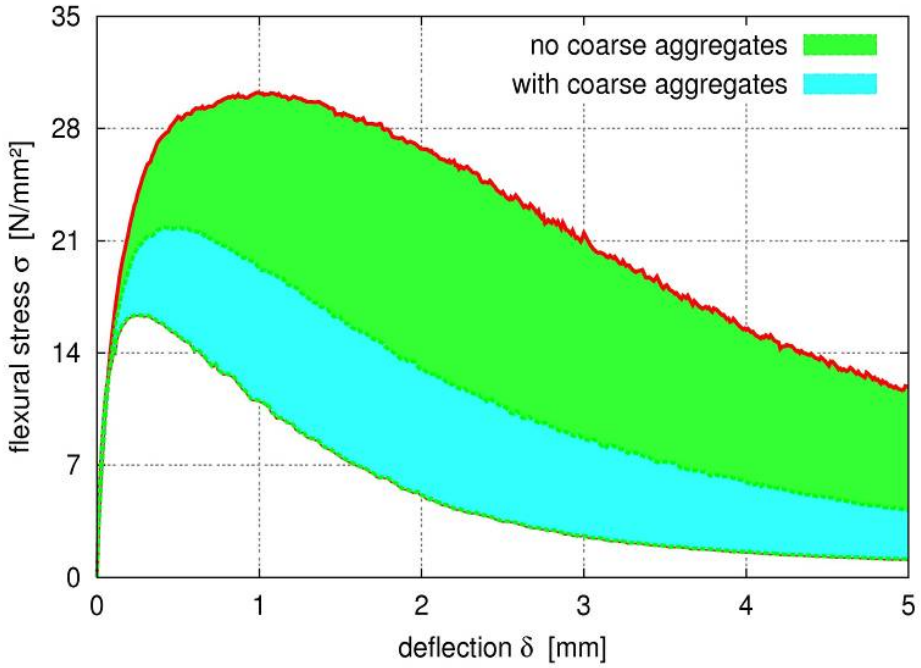
Properties of UHPC subjected to Tension

RILEM TC 162-TDF
3-point-bending-test





- **Fairy ductile behavior in post-peak range**
- **High flexural tensile strength**
- **Possible strain hardening due to multiple cracking**

⇒ The properties can be optimized though varying fibre geometry & contents!

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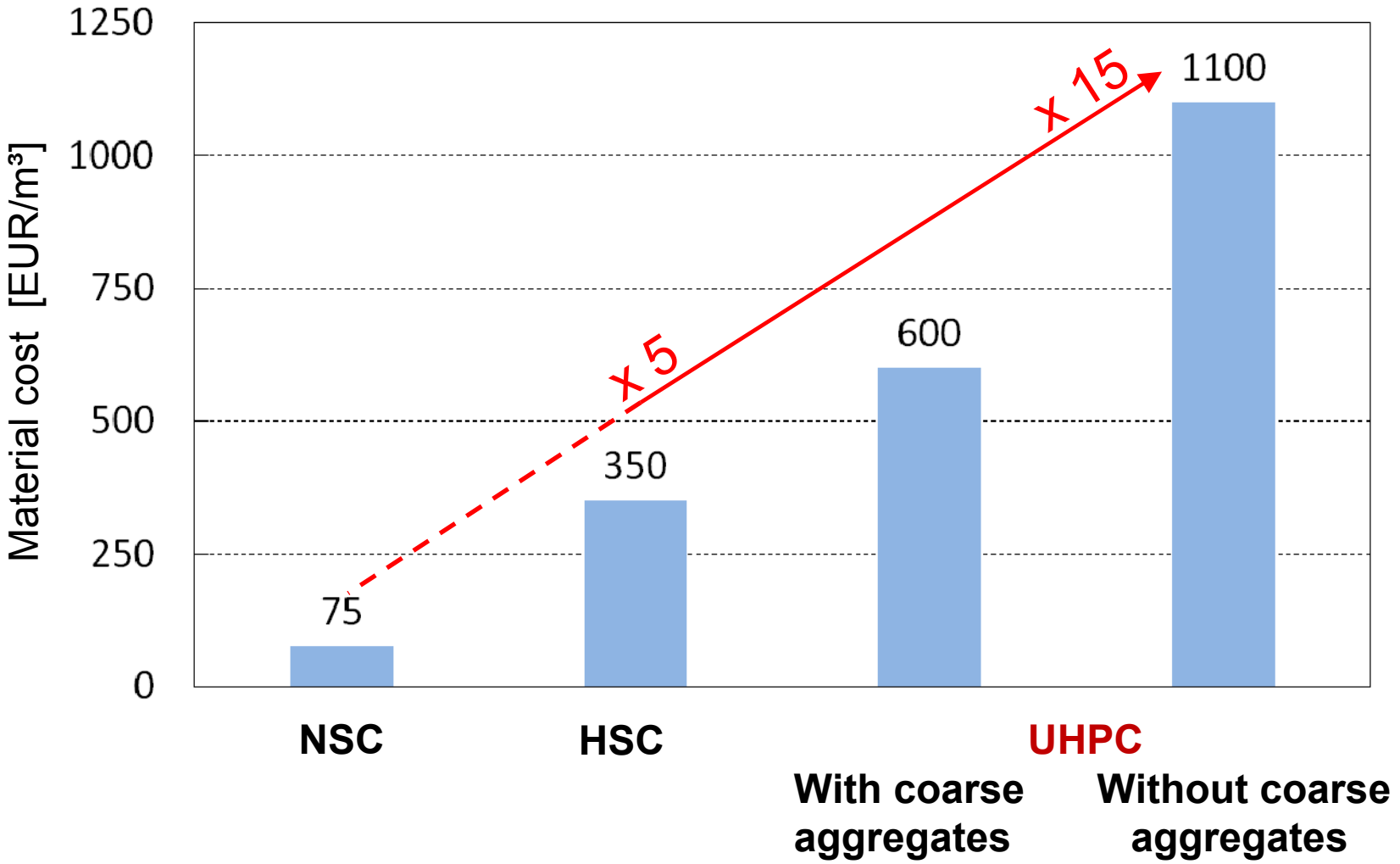
A Comparison of the Material Costs



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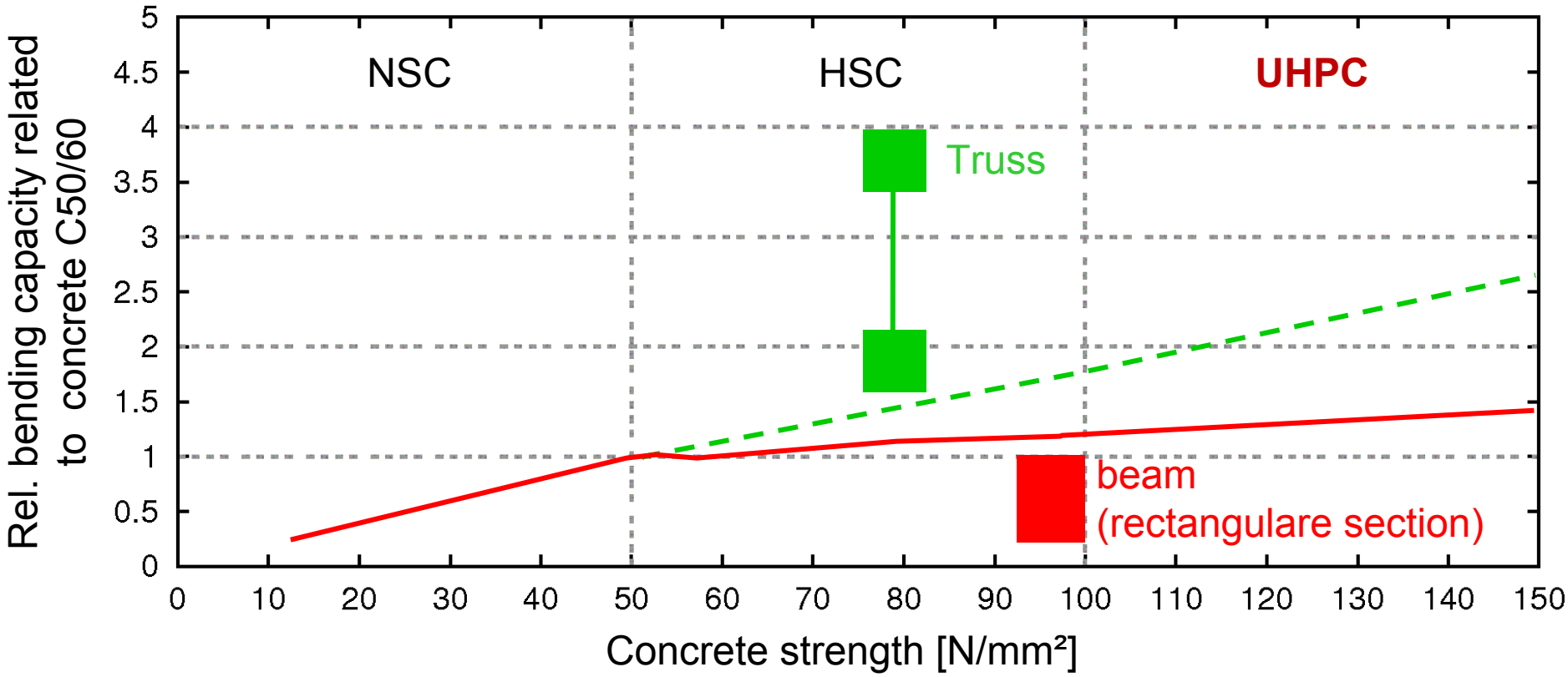
Comparison of Bending Capacity of NSC and HSC



⇒ In conventional concrete structures, the advantages

of UHPC can not be fully used!!!

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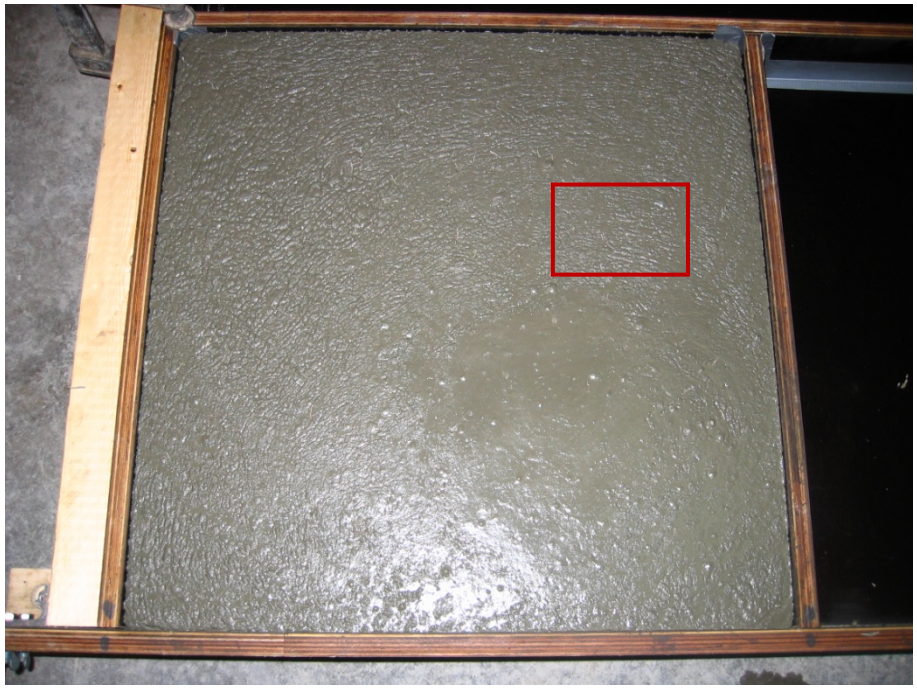
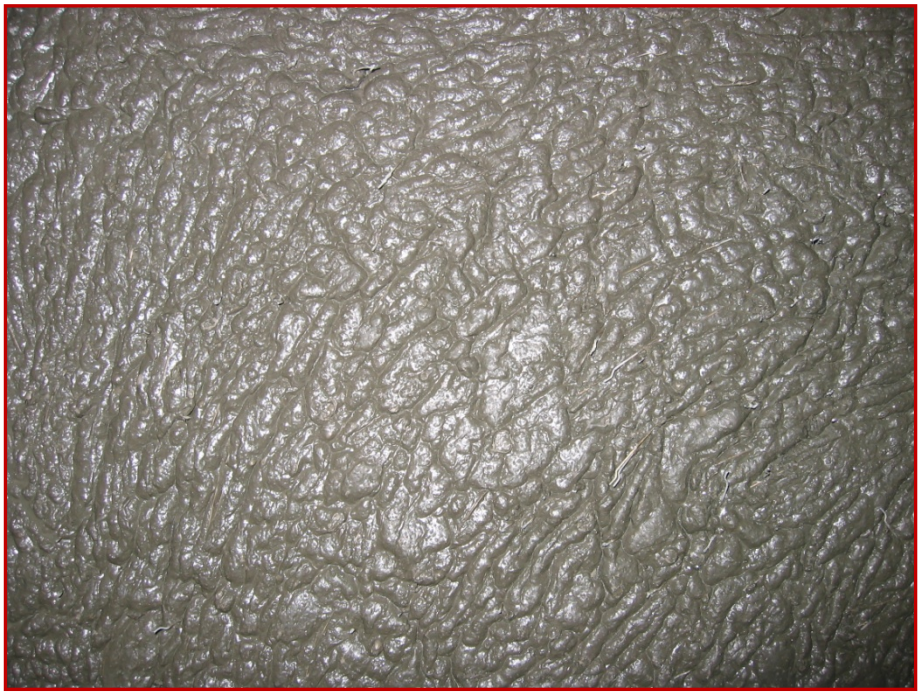
Properties of Fresh UHPC

„Elephant skin“ on the casting surface (about 15 minutes after mixing)





⇒ **The using UHPC in precast elements is recommended!**

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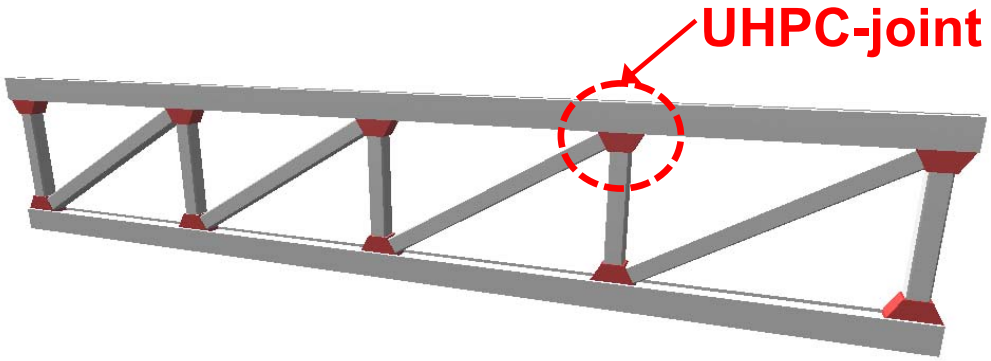
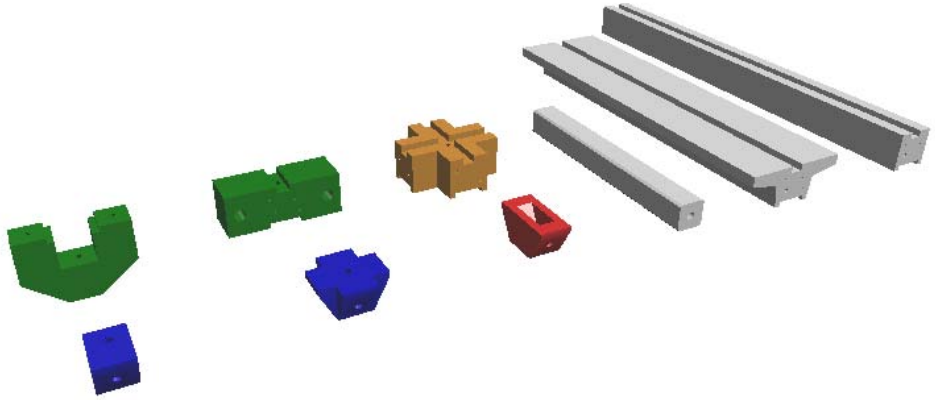
Modular Truss System made of UHPC

Side View



Elements



Advantages

- No monolithic joint
- Dependence of the truss only on the joint element
- Serges fabrication of the truss member
- Assembling in precast plant and on site possible
- Non-destructive disassembling and reutilization of the construction

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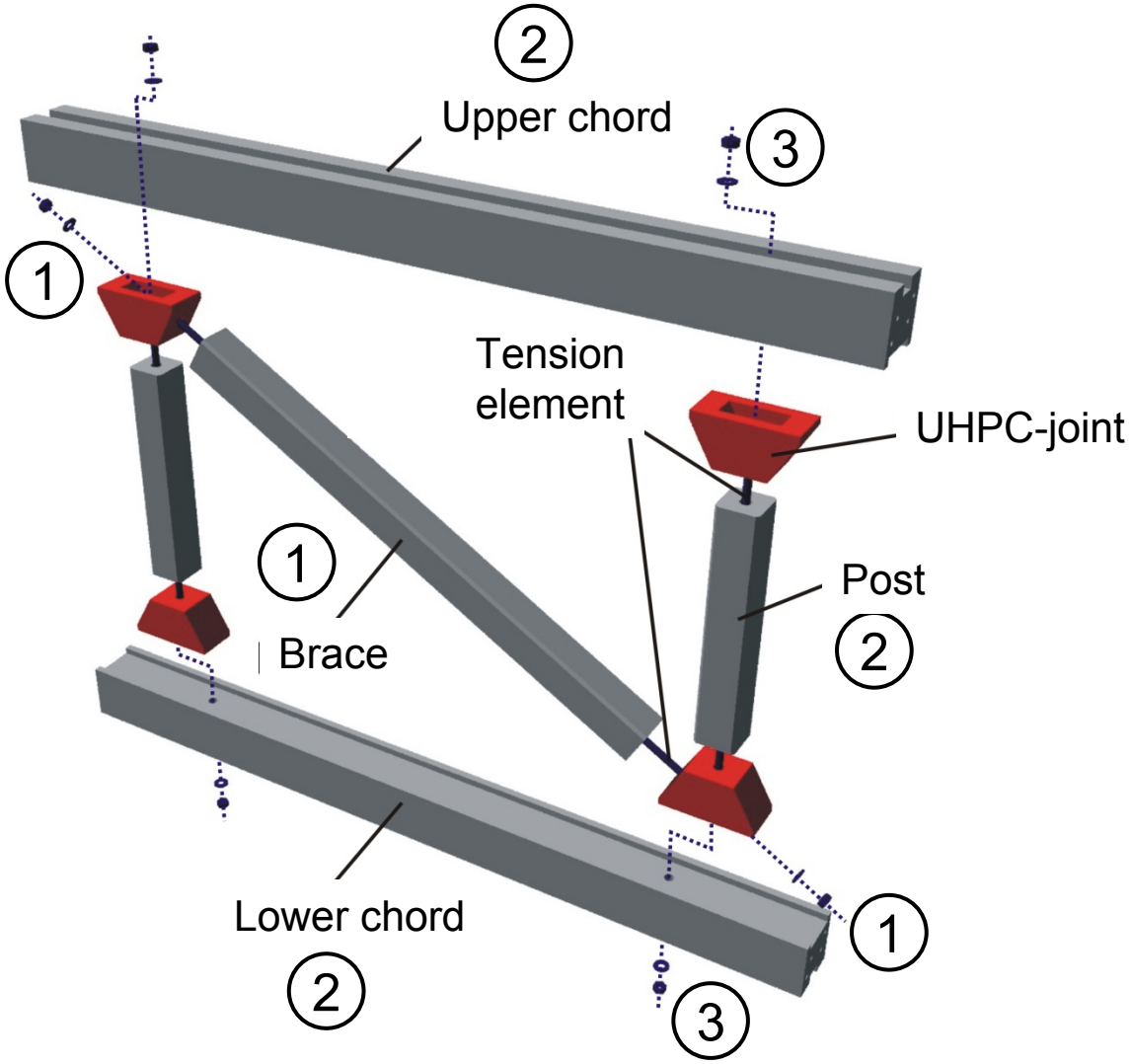
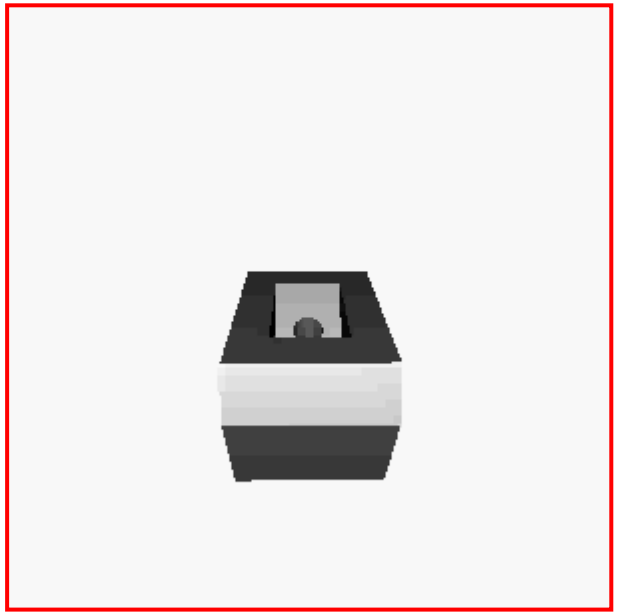
Modular Truss System made of UHPC

Elements





UHPC-joint

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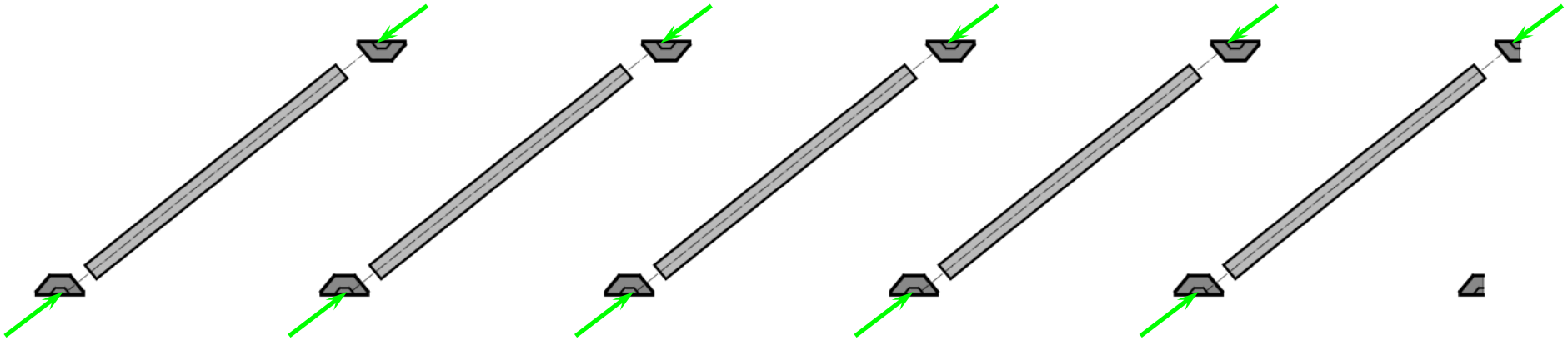
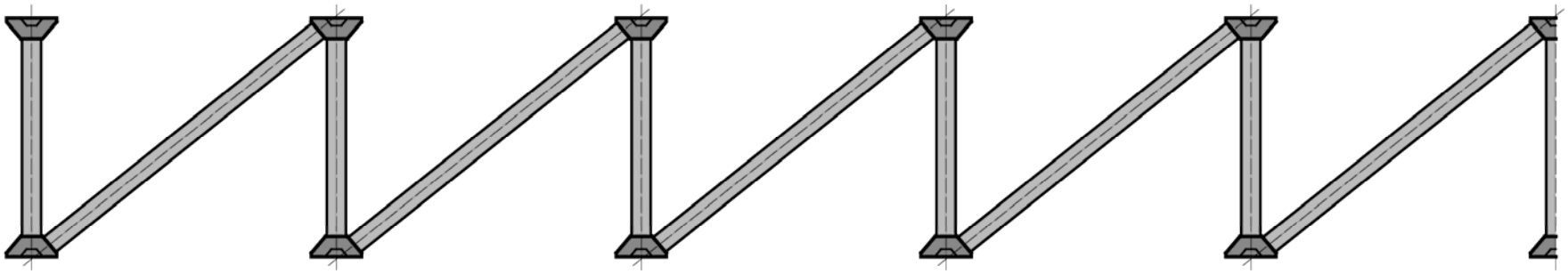
Assembling of the joints / posts



Assemling of the braces



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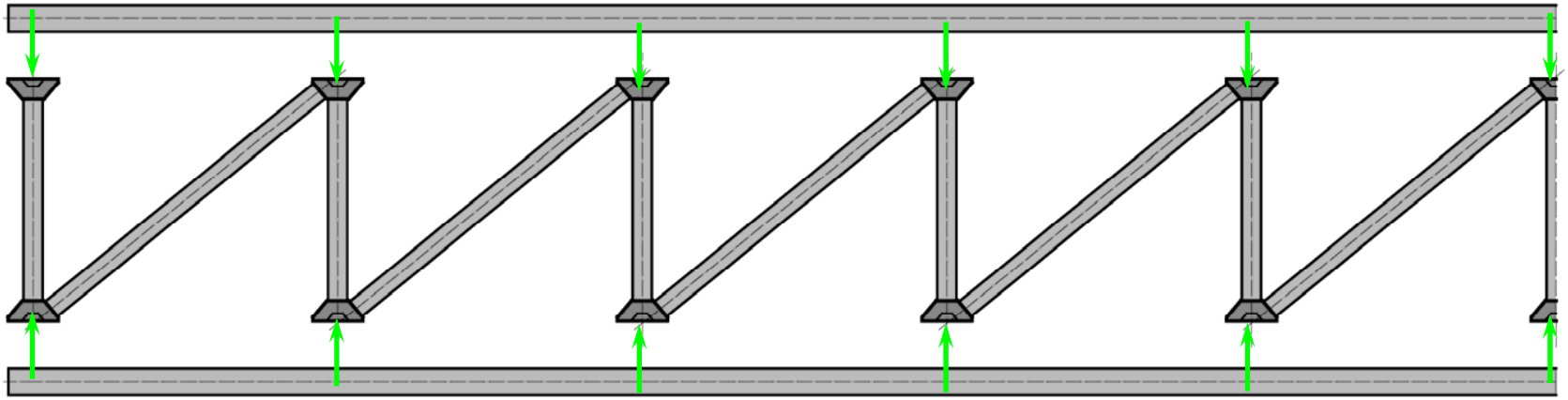
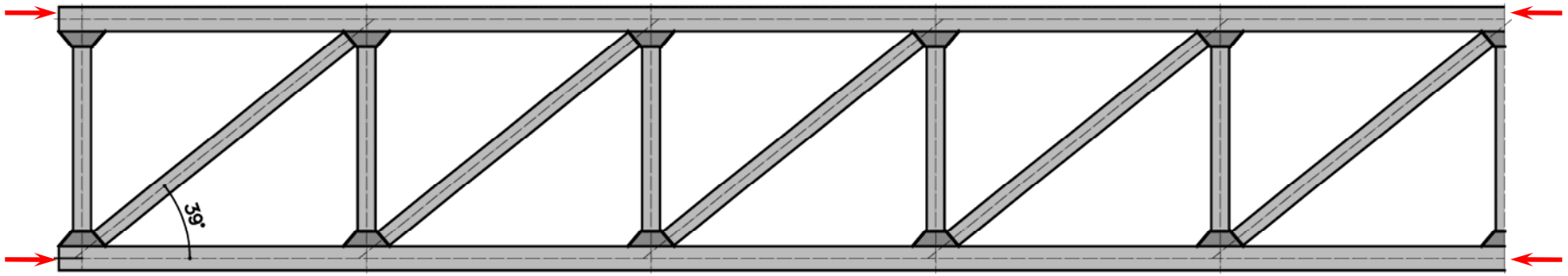
Modular Truss System made of UHPC

Montage of the joints / posts



Prestressing of the chords



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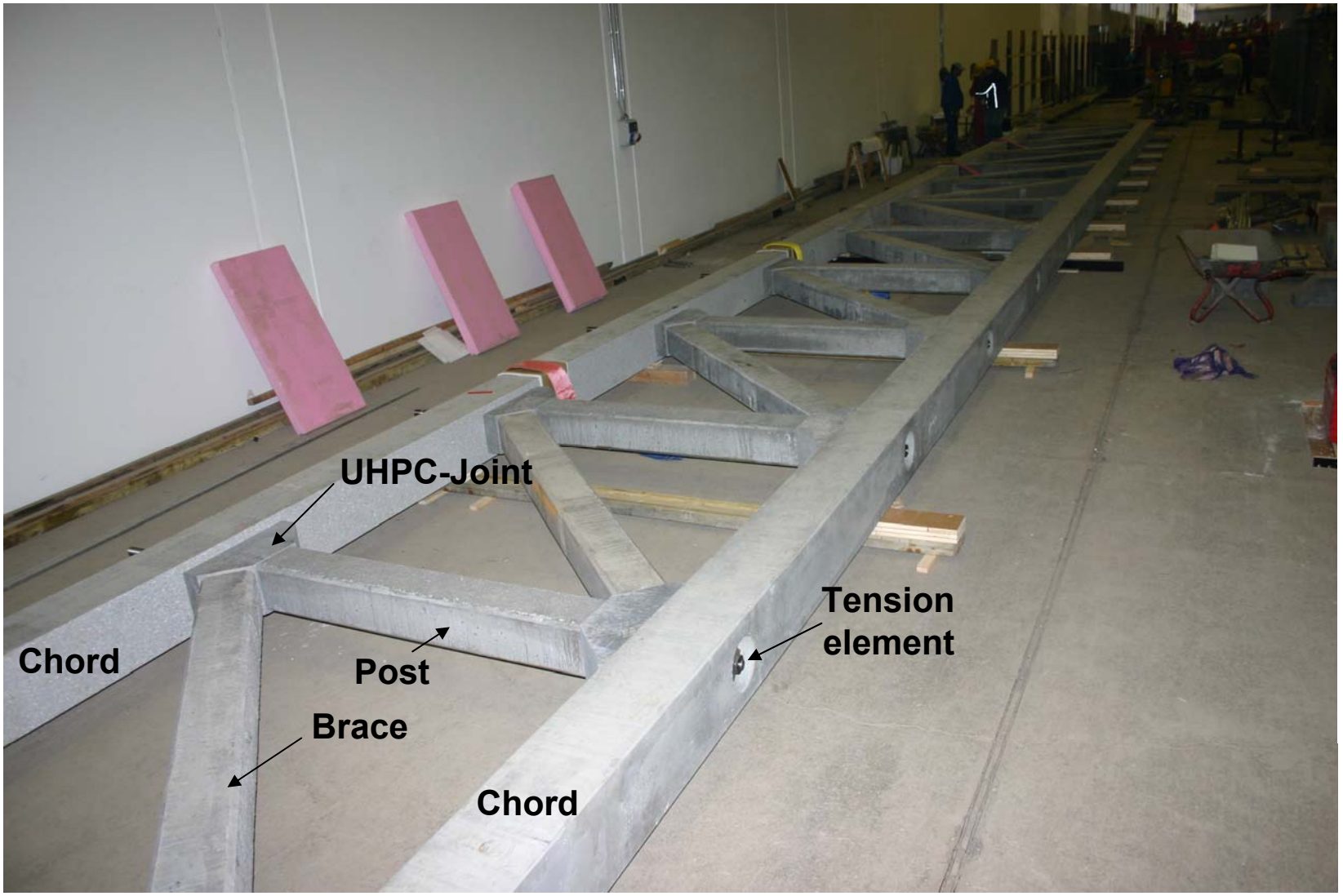

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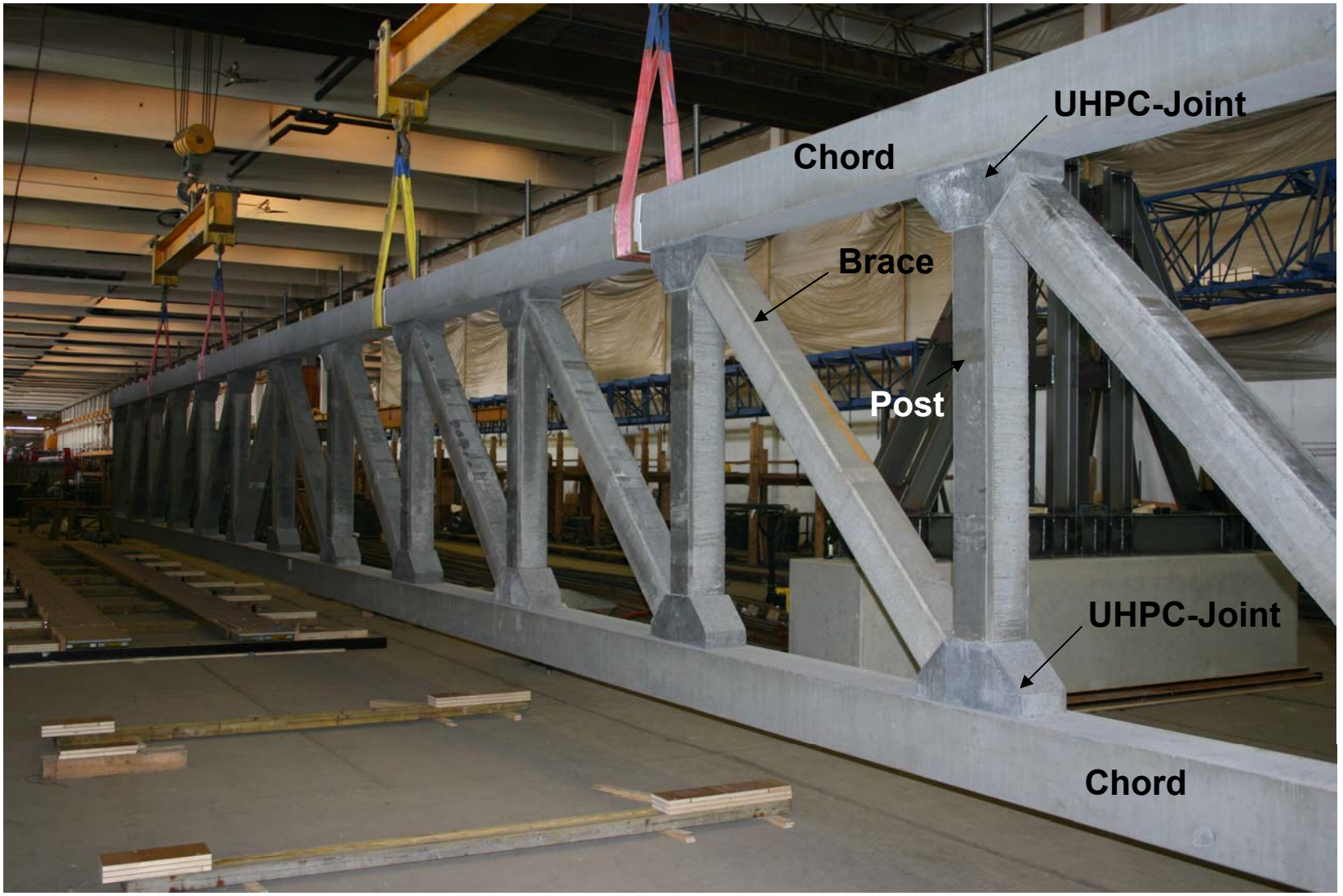

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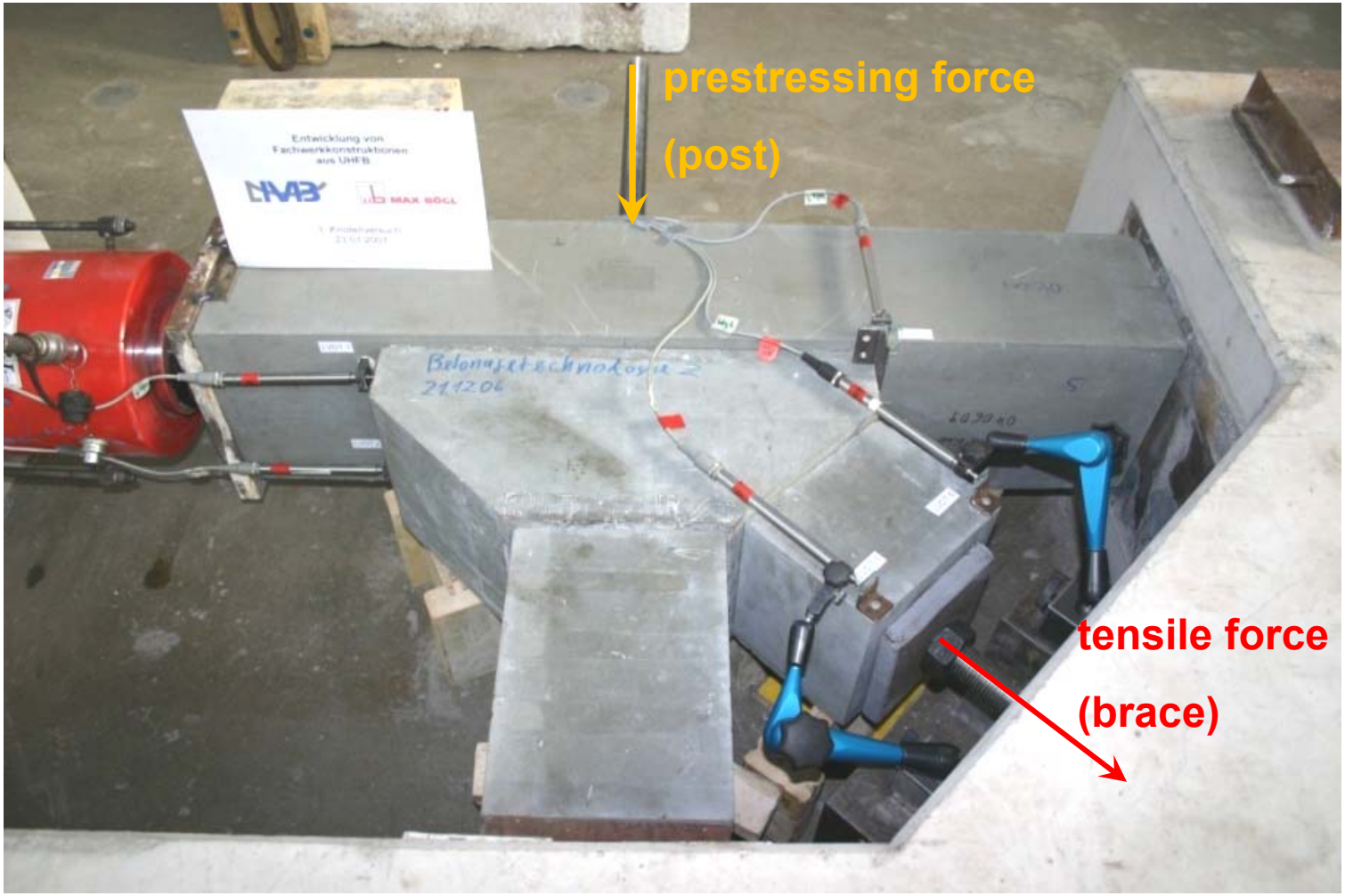
Modular Truss System made of UHPC

Test Set-up for UHPC-joint



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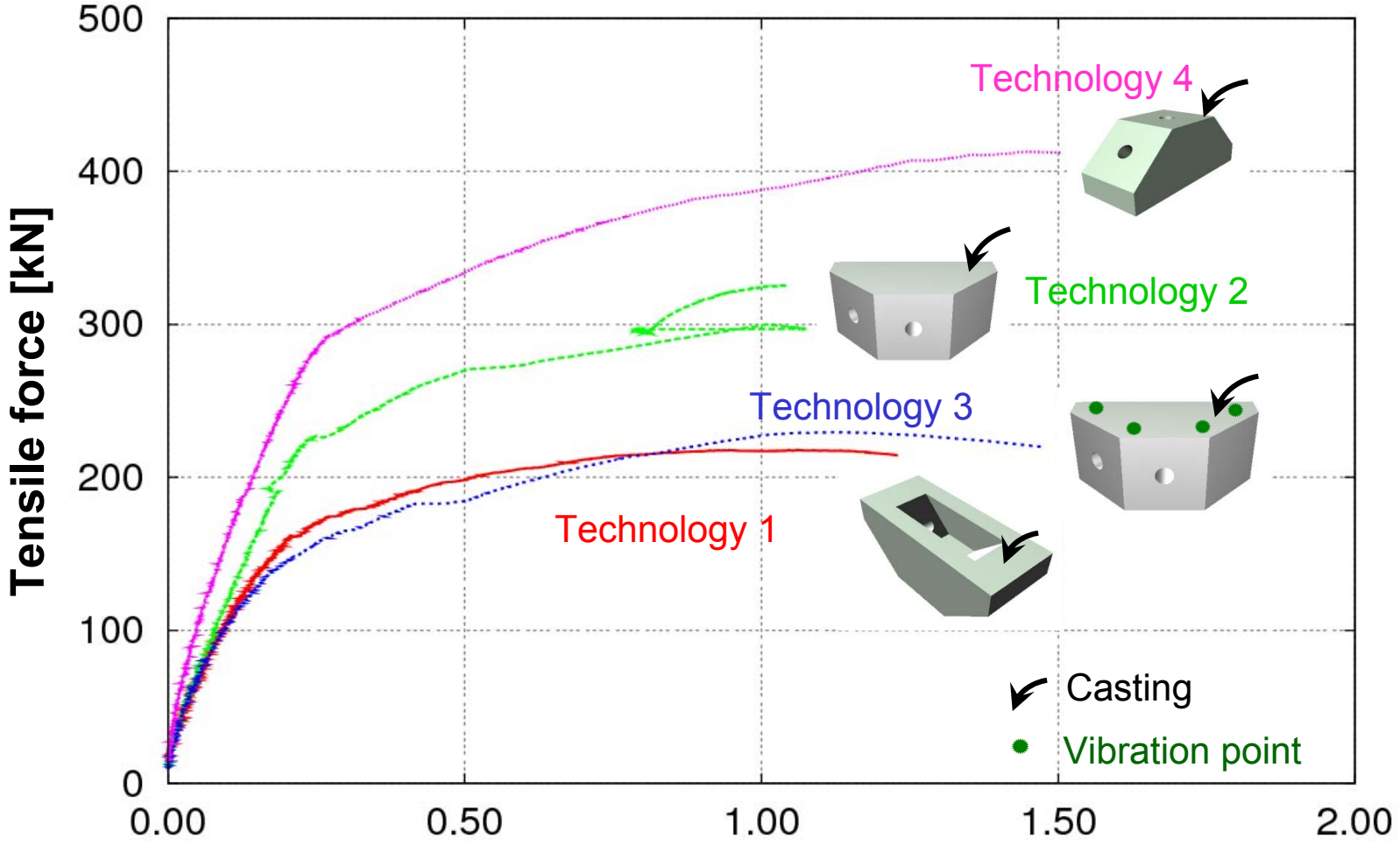
Modular Truss System made of UHPC

Influence of the Casting Technology



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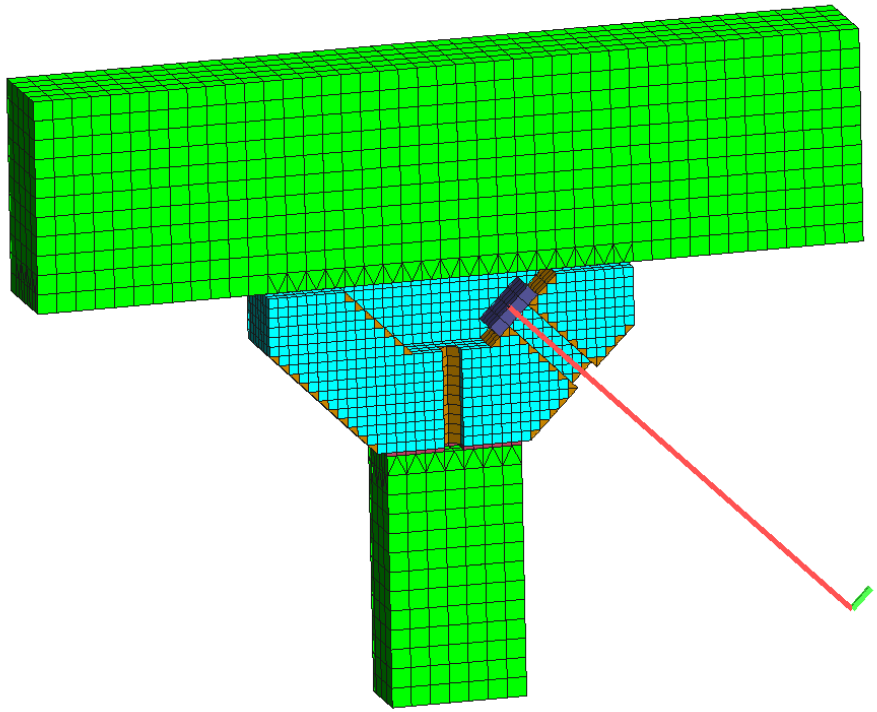
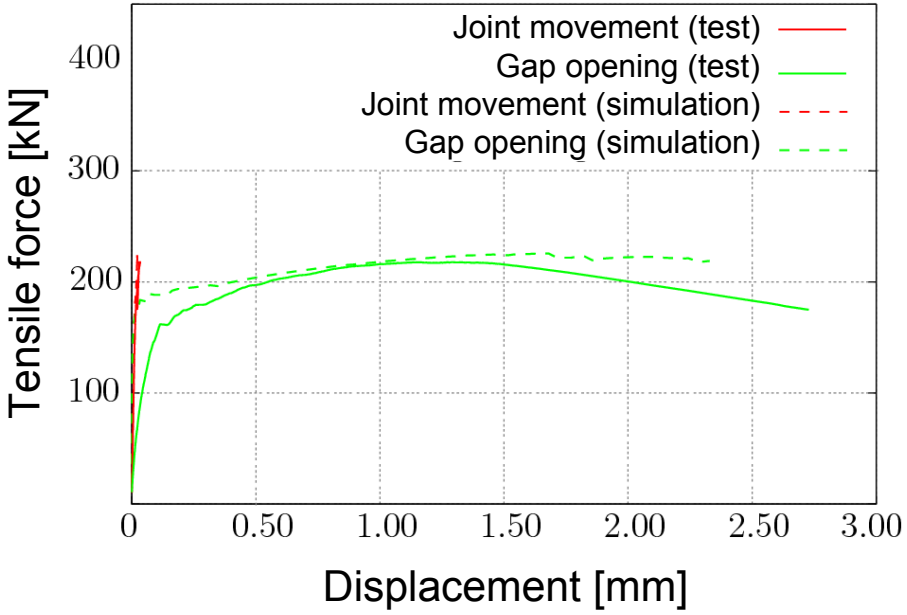
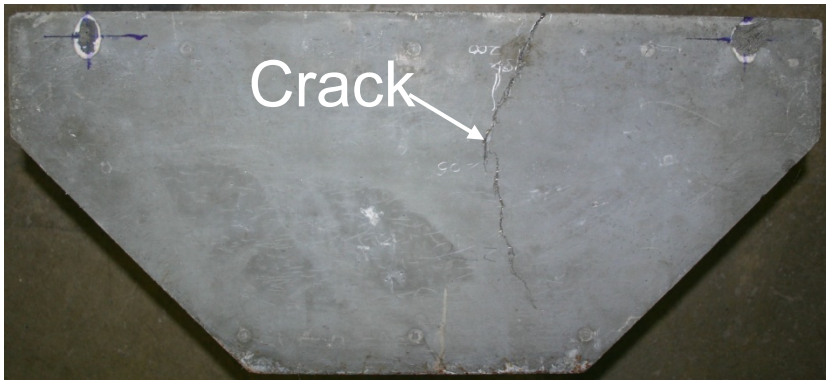
Modular Truss System made of UHPC

Numerical Simulations





- ATENA software package
- Fracture-plastic model for concrete
- Interface element



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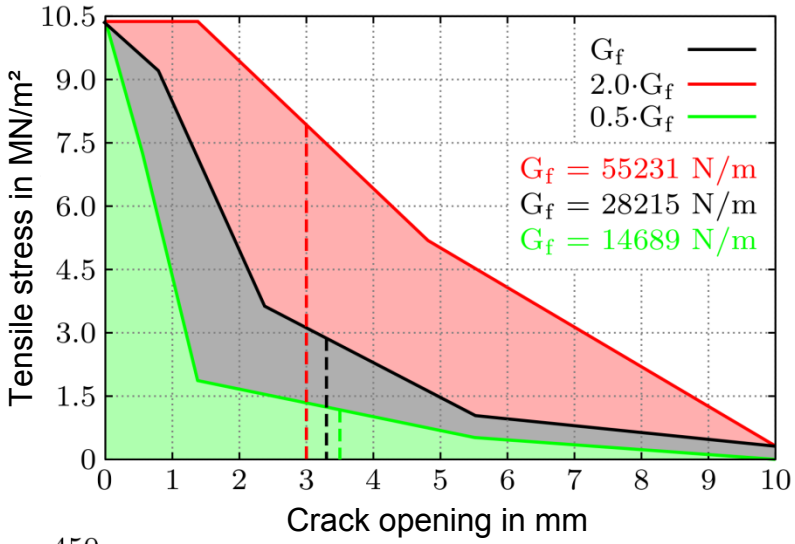

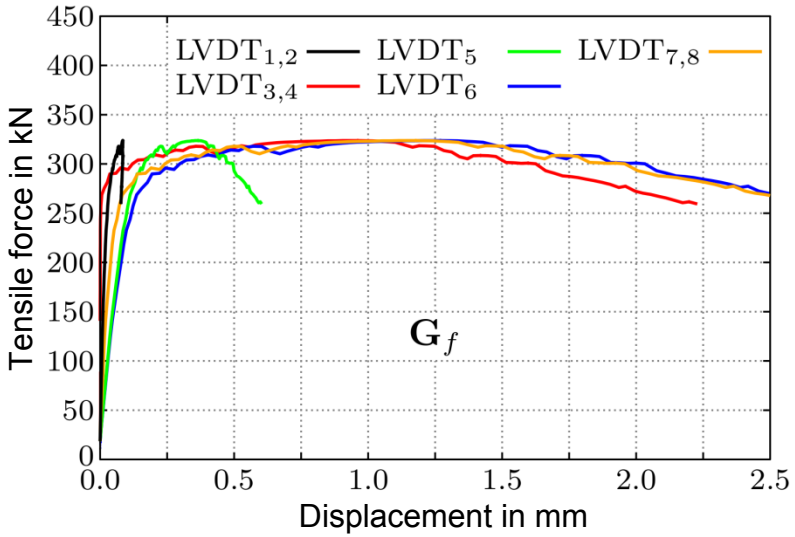

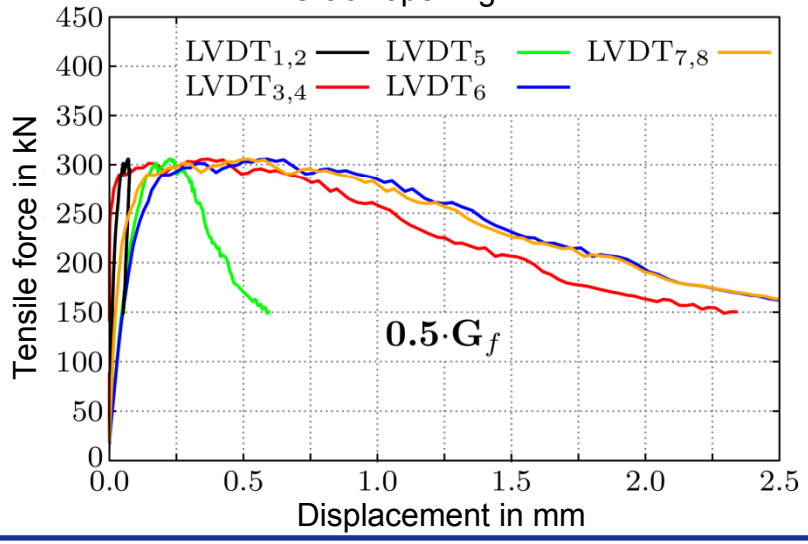

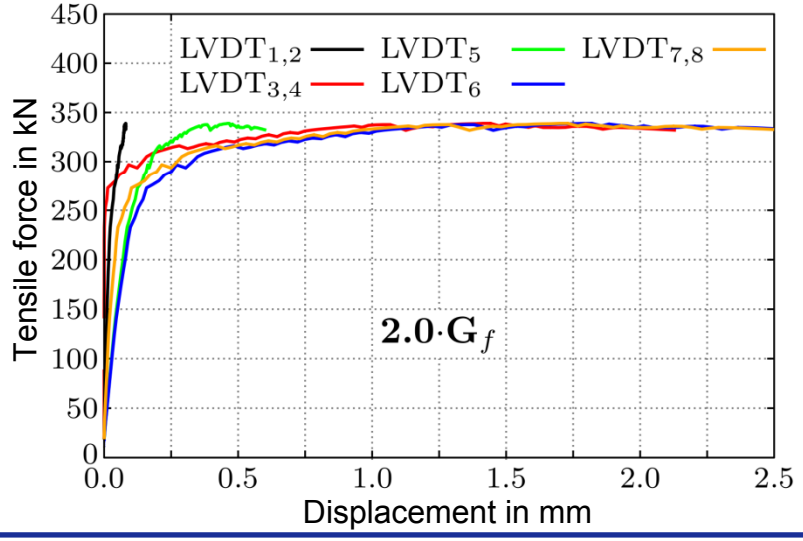

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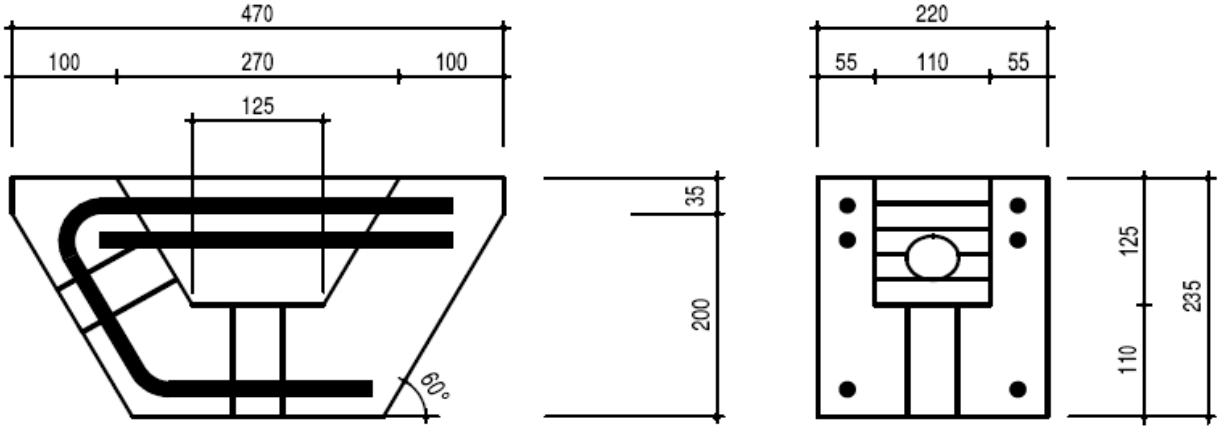

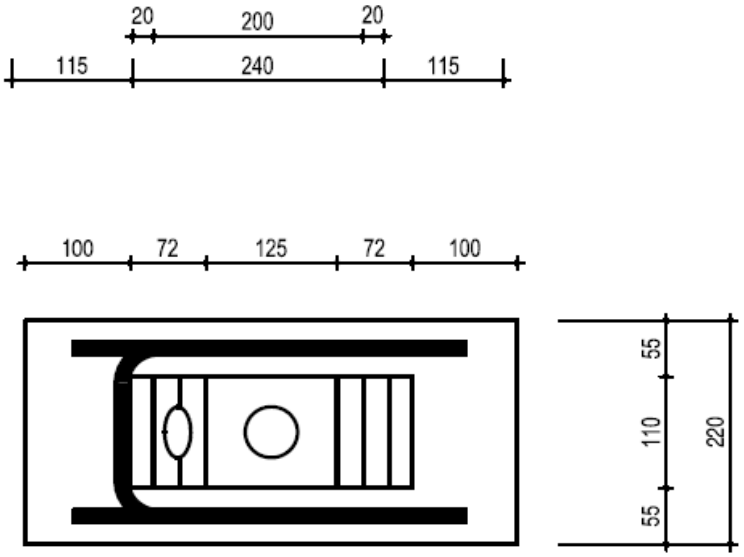

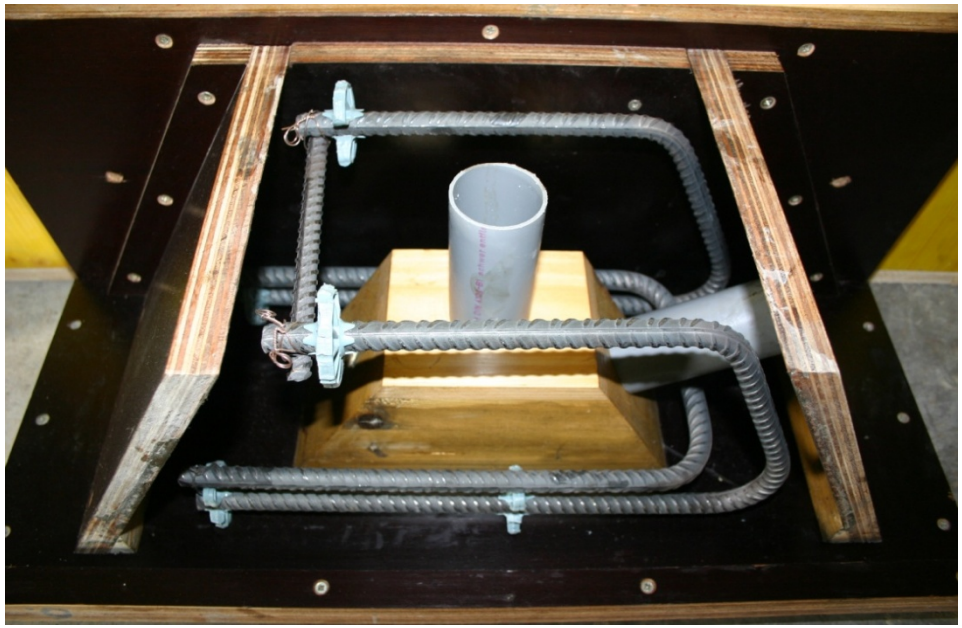

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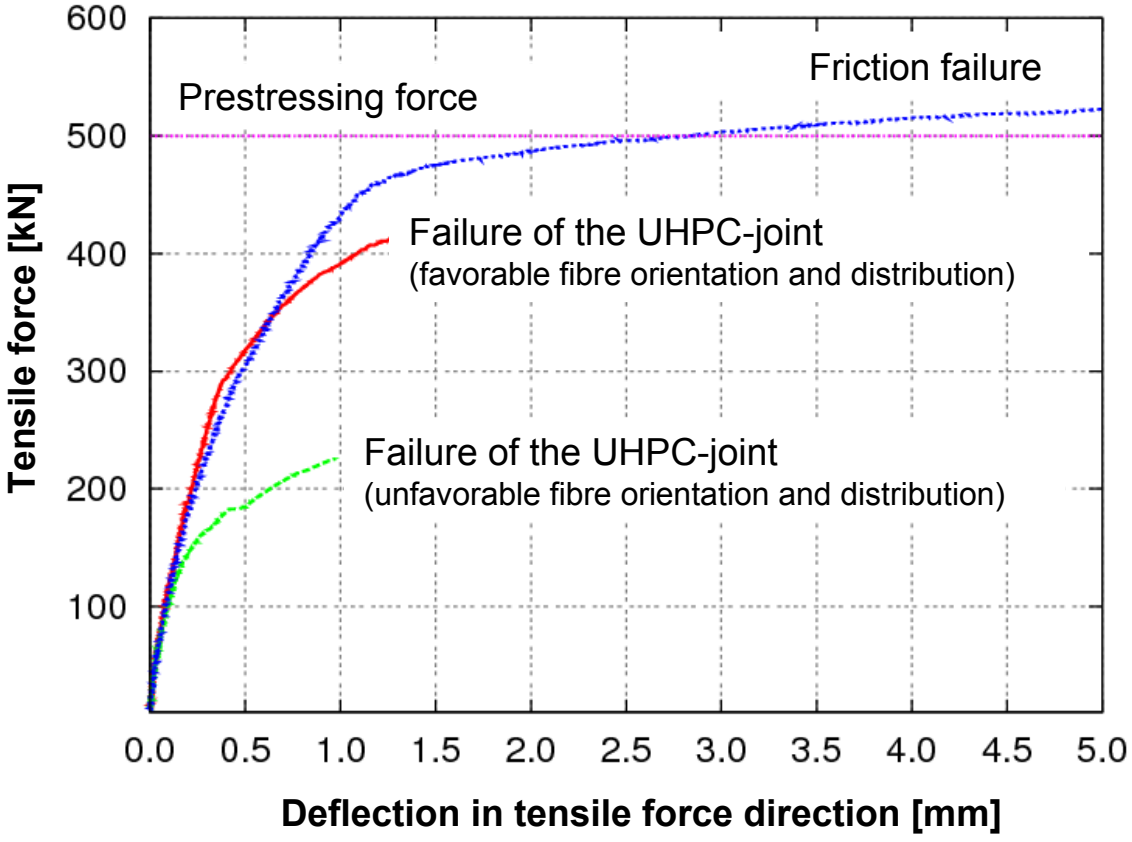
Modular Truss System made of UHPC

UHPC-joint with Brace Inclination of 45°



a) **without** reinforcement:

- Brittle failure of the UHPC-joint
- Load capacity is influenced by the fibre orientation and fibre distribution

b) **With** reinforcement:

- Ductile failure of the friction between UHPC-joint and chord ($\mu \approx 0.65$)
- Friction can be increased up to $\mu \approx 0.80$

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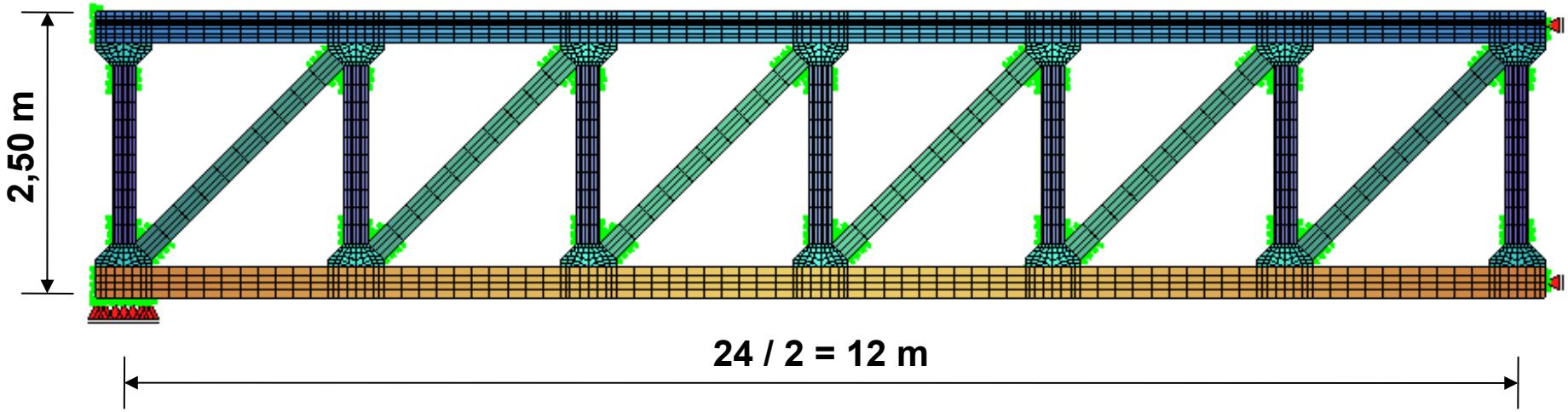
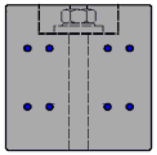
Modular Truss System made of UHPC

Influence of the Production Tolerance





Chord
b/h = 30/30 cm

Brace/ post
b/h = 30/30 cm

Prestressing force:	P = 950 kN (upper chord) P = 950 kN (lower chord)	P = 100 kN (brace) P = 660 kN (post)

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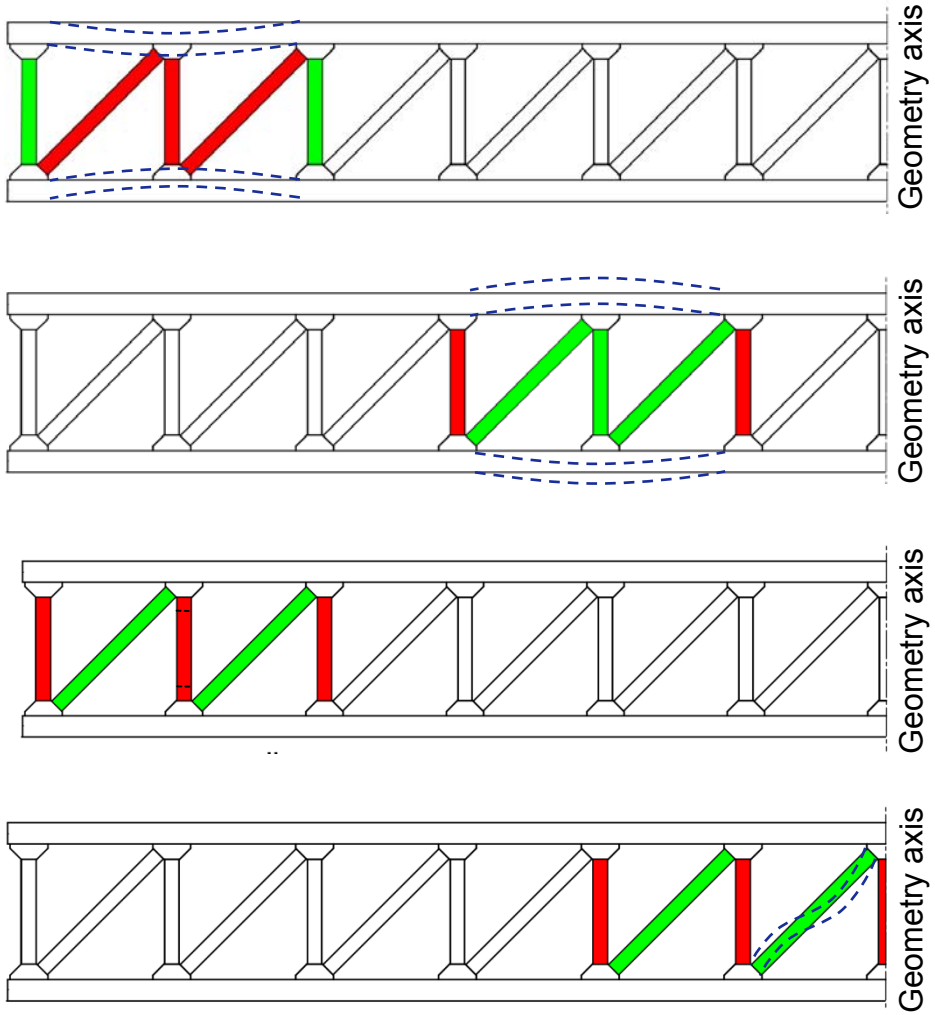
Modular Truss System made of UHPC

Influence of the Production Tolerance

- Upper chord
- Lower chord
- Post
- Brace



Short element

Long element

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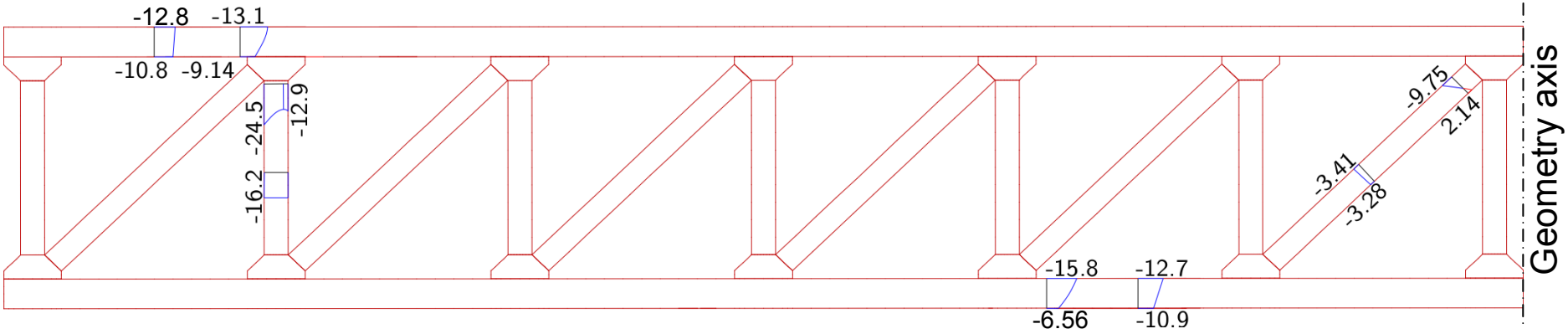
Modular Truss System made of UHPC

Influence of the Production Tolerance

Production tolerance ΔL = ± 0,50 mm



Tensile stress due to production tolerance

Upper chord	Lower chord	Brace	Post
+ 3,16 MN/m²	+ 3,20 MN/m²	+ 2,19 MN/m²	+ 2,10 MN/m²

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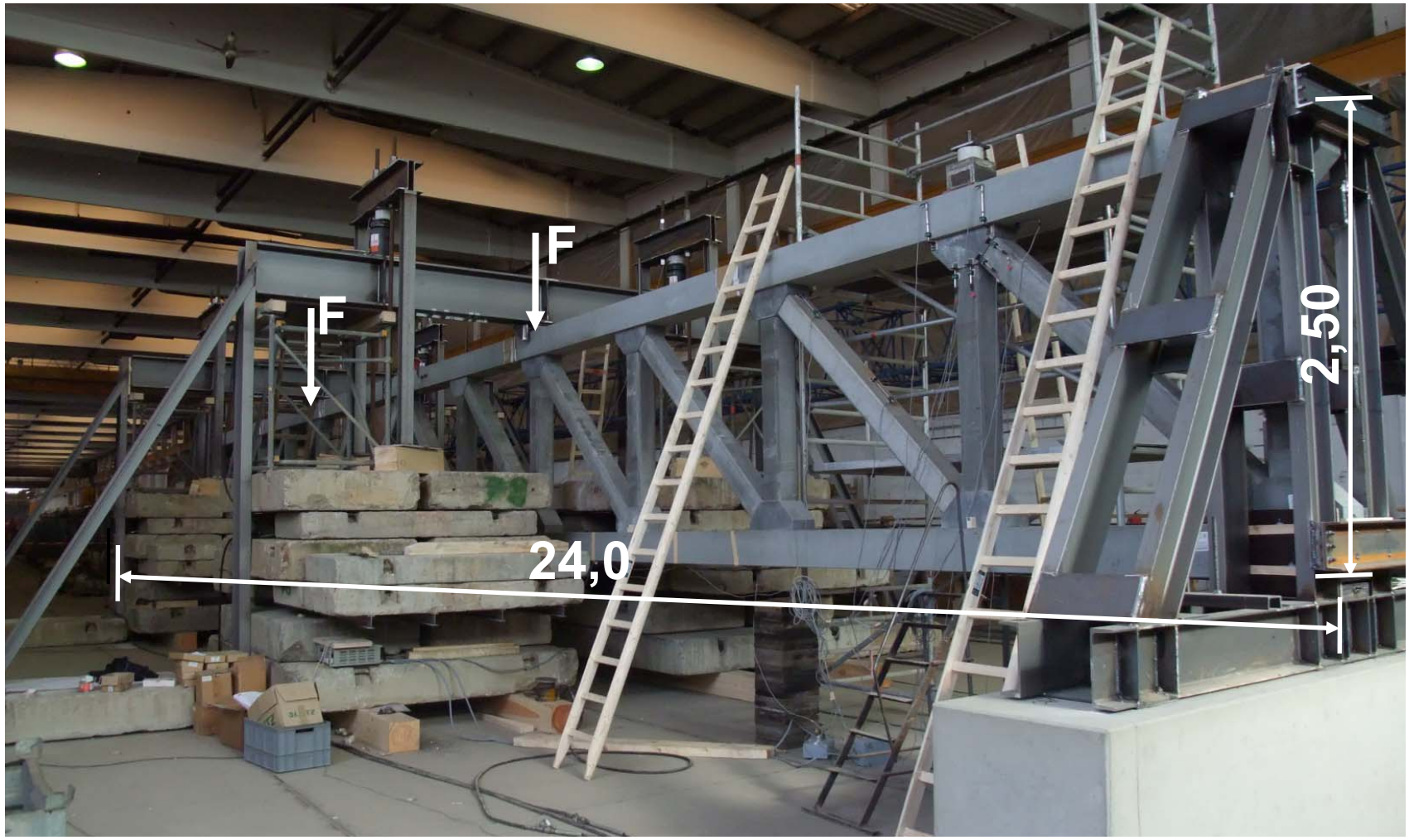
Modular Truss System made of UHPC

Test Set-up for full scale test



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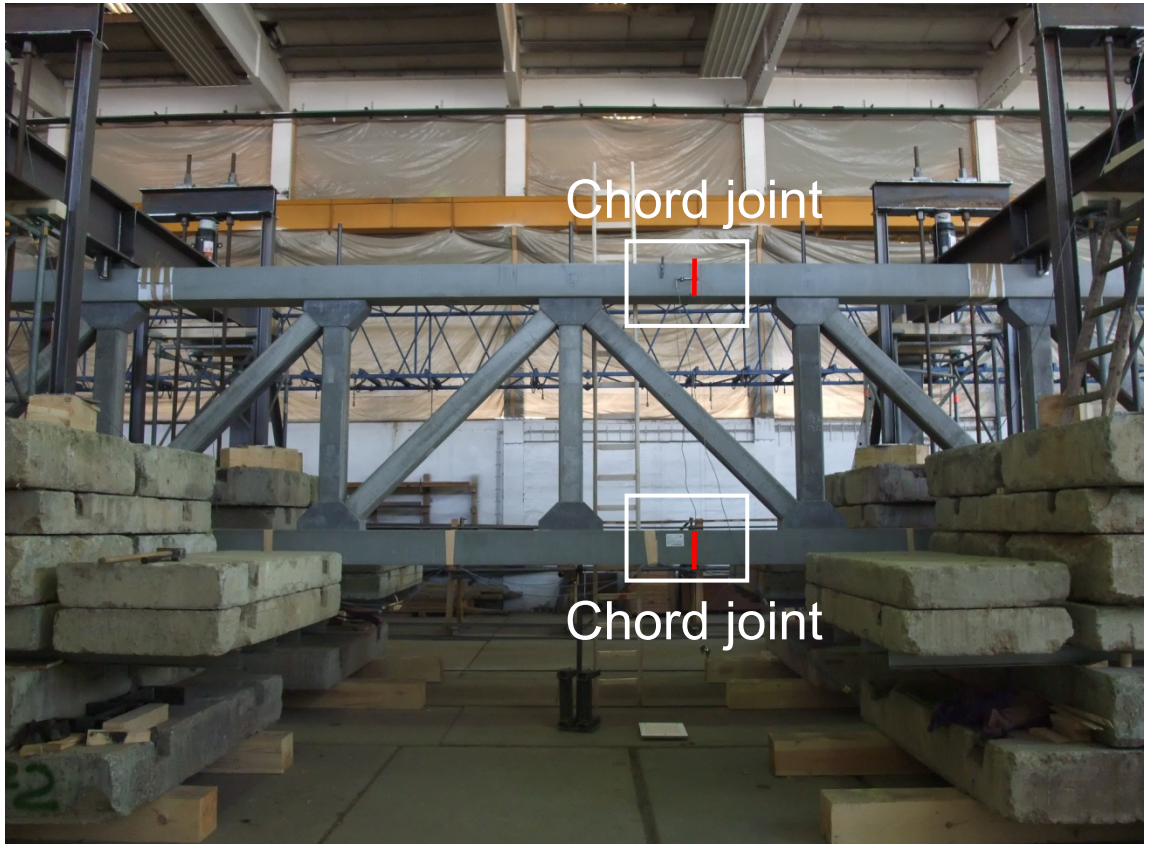

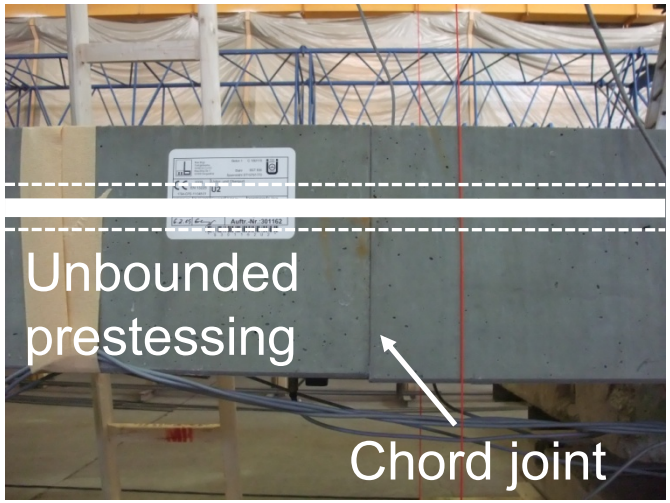

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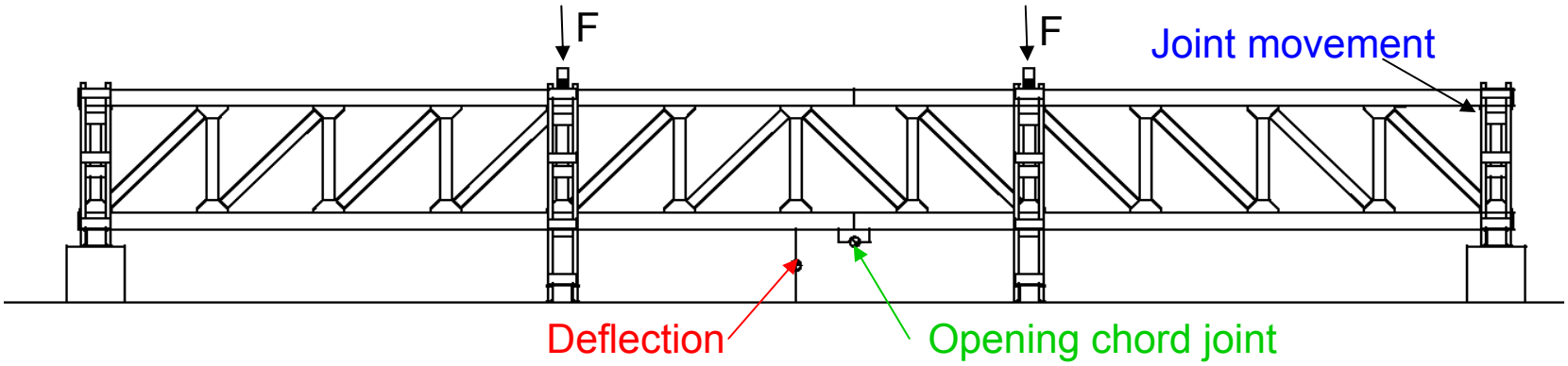

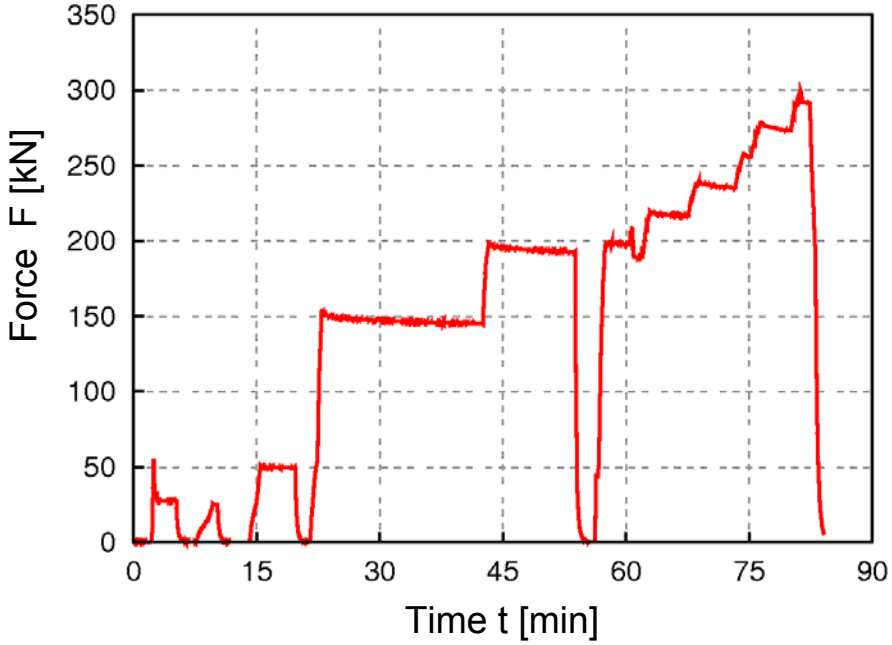

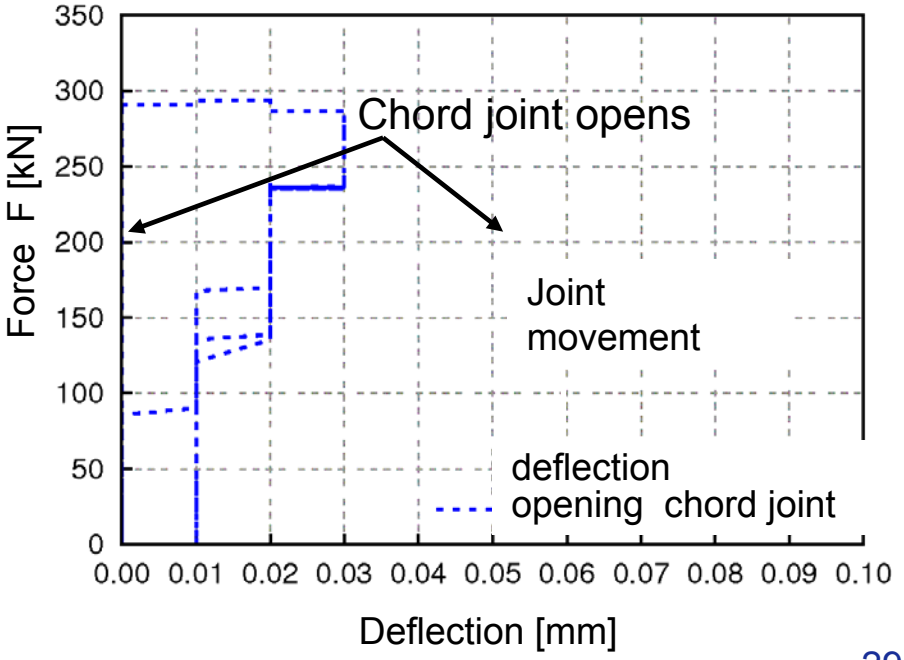

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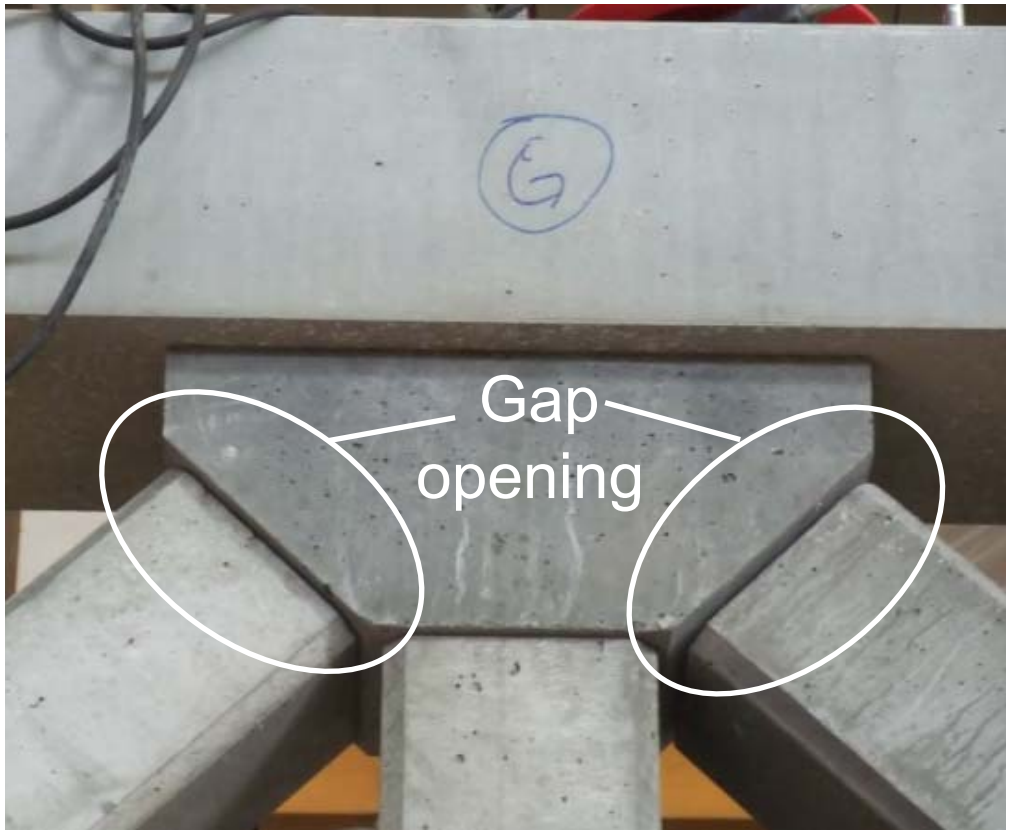
Modular Truss System made of UHPC

Failure of Truss System

lower chord

Upper chord



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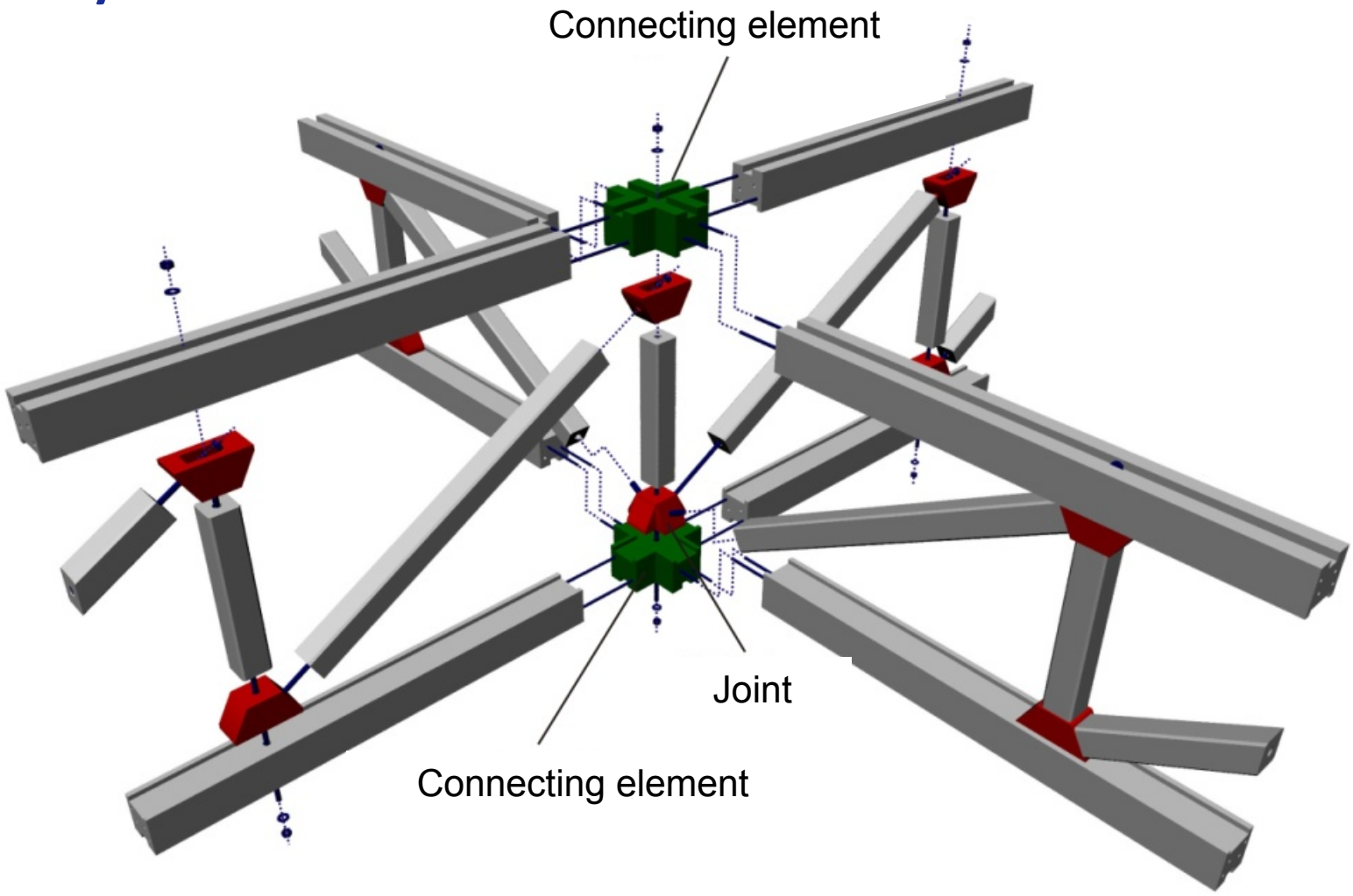
Modular Truss System made of UHPC

space System



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The Gärtnerplatz Bridge, Germany

A Hybrid UHPC-Steel Bridge

Ekkehard FEHLING, Professor; University of Kassel,Germany
Kai BUNJE, Civil Engineer, IBB Fehling+Jungmann, Kassel, Germany
Michael SCHMIDT, Walter SCHREIBER

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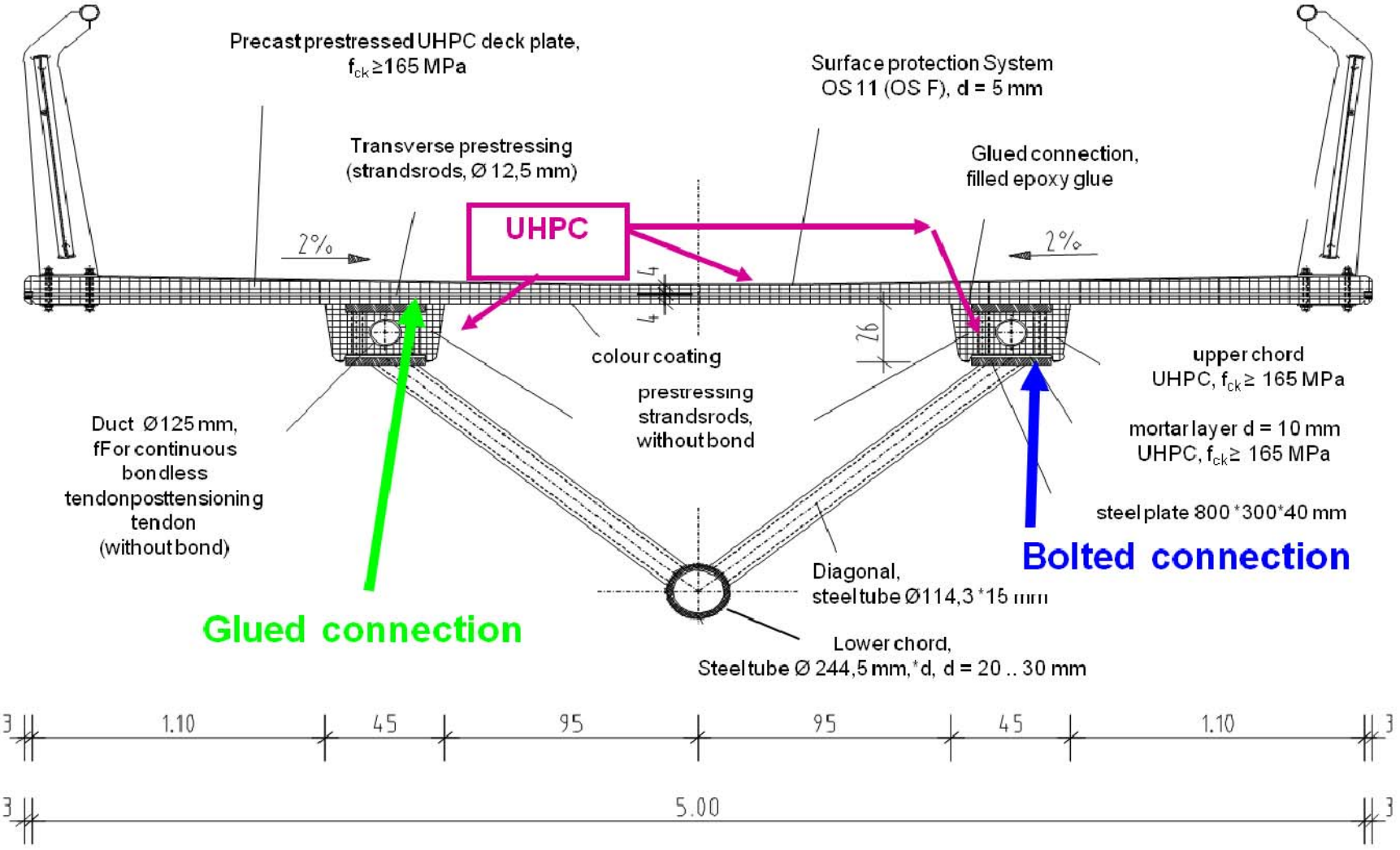
The Gärtnerplatz Bridge

Cross Section



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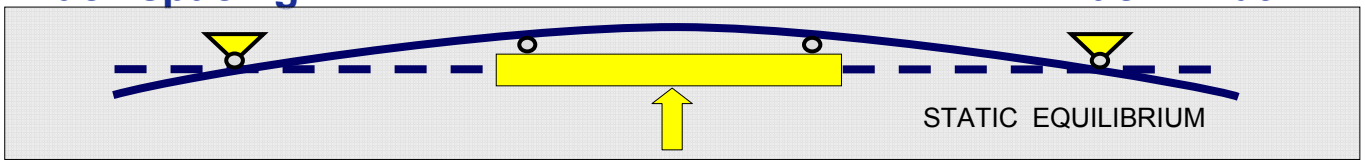
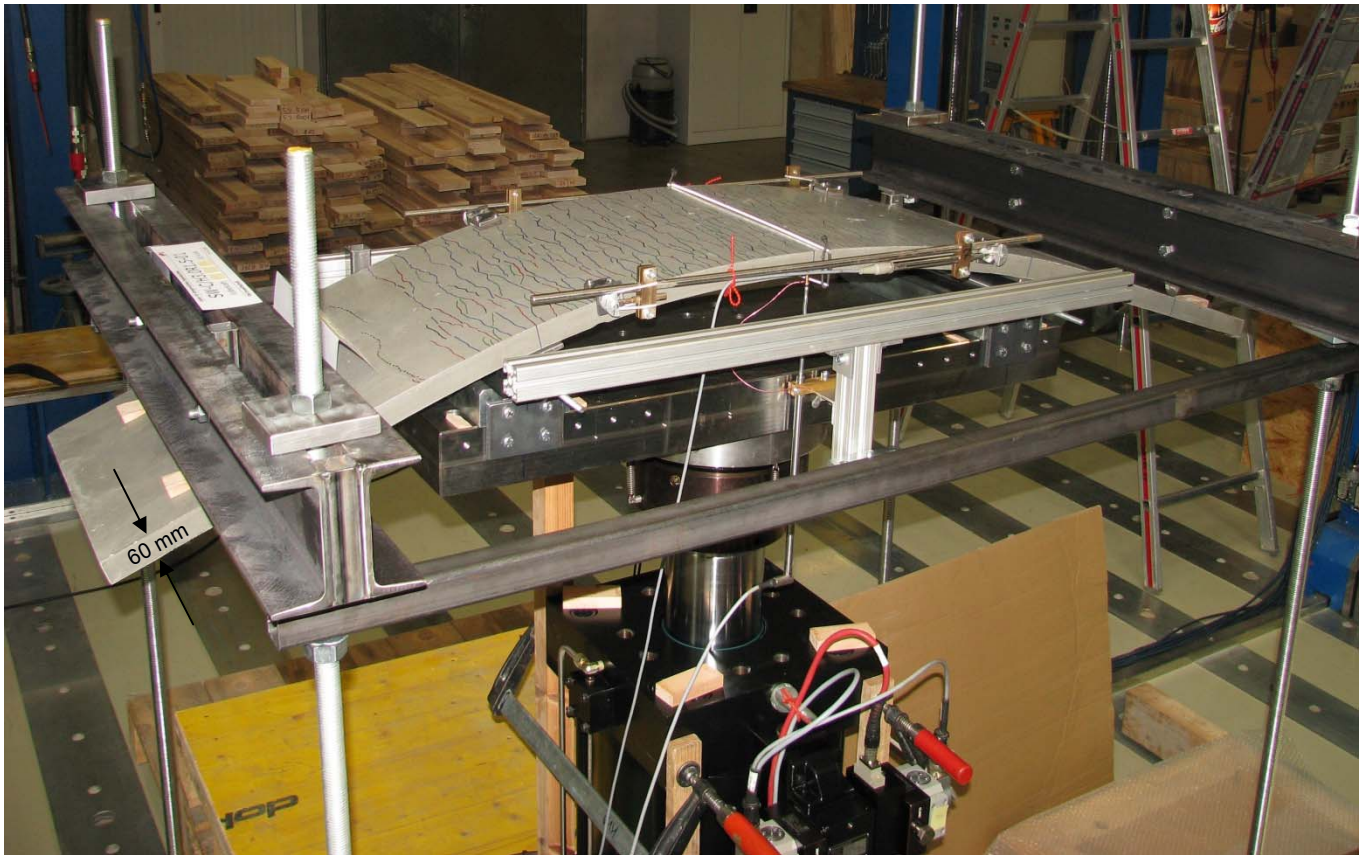
Bending Test

Crack spacing << **Crack width <<**





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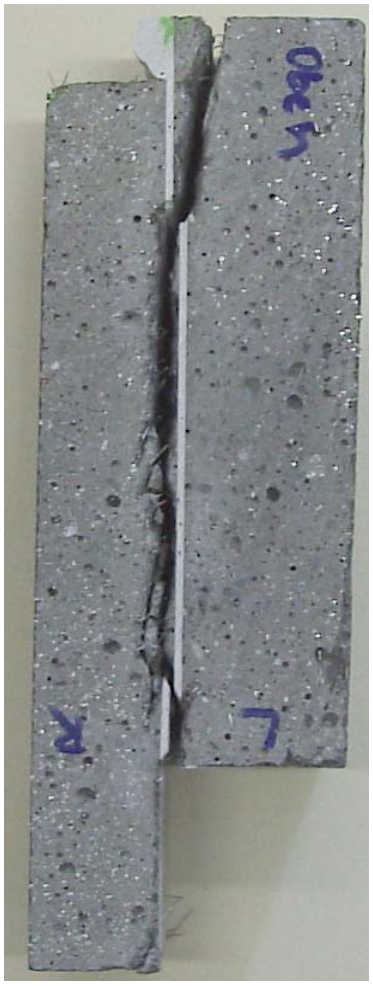
Shear / Tension Test



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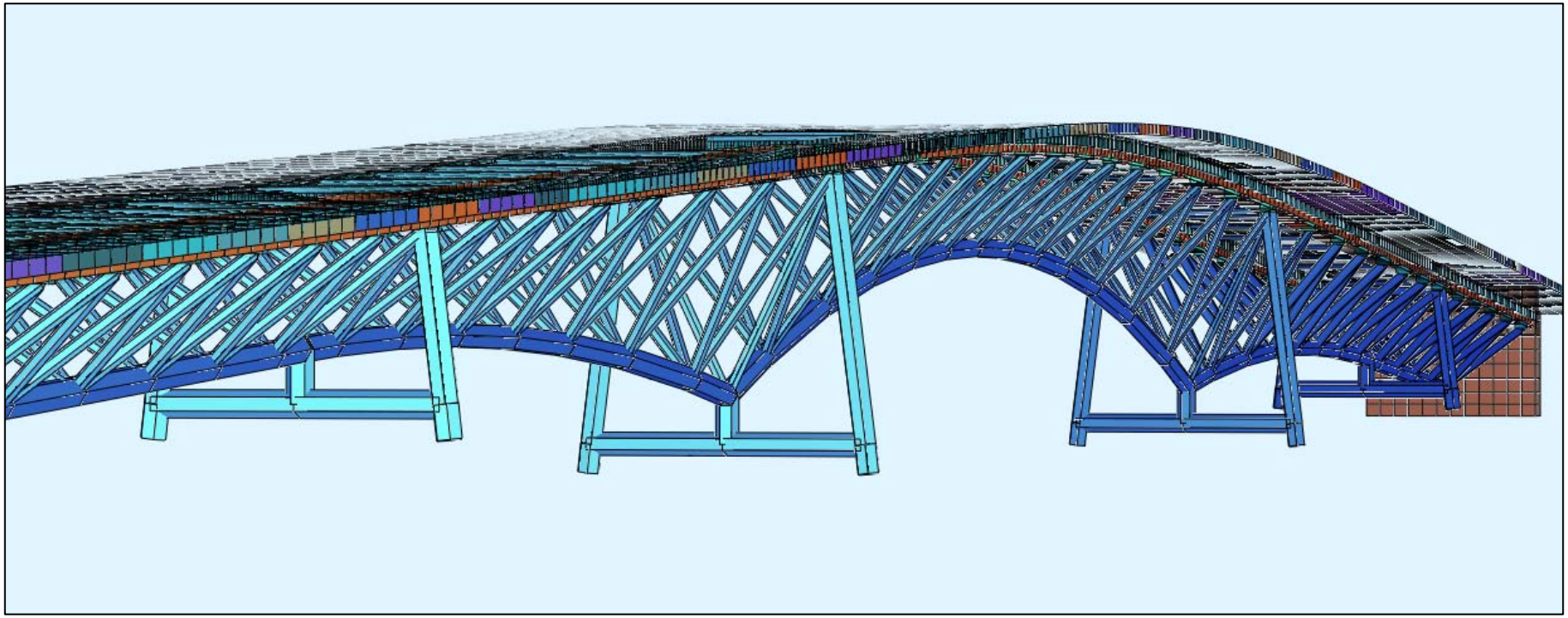
The Gärtnerplatz Bridge

Structural Analysis



- SOFiSTiK software package
- Detailed considerations of construction sequence
- Effects of force redistributions due to creep (and shrinkage)

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The Gärtnerplatz Bridge

Precast UHPC elements for Bridge Decks

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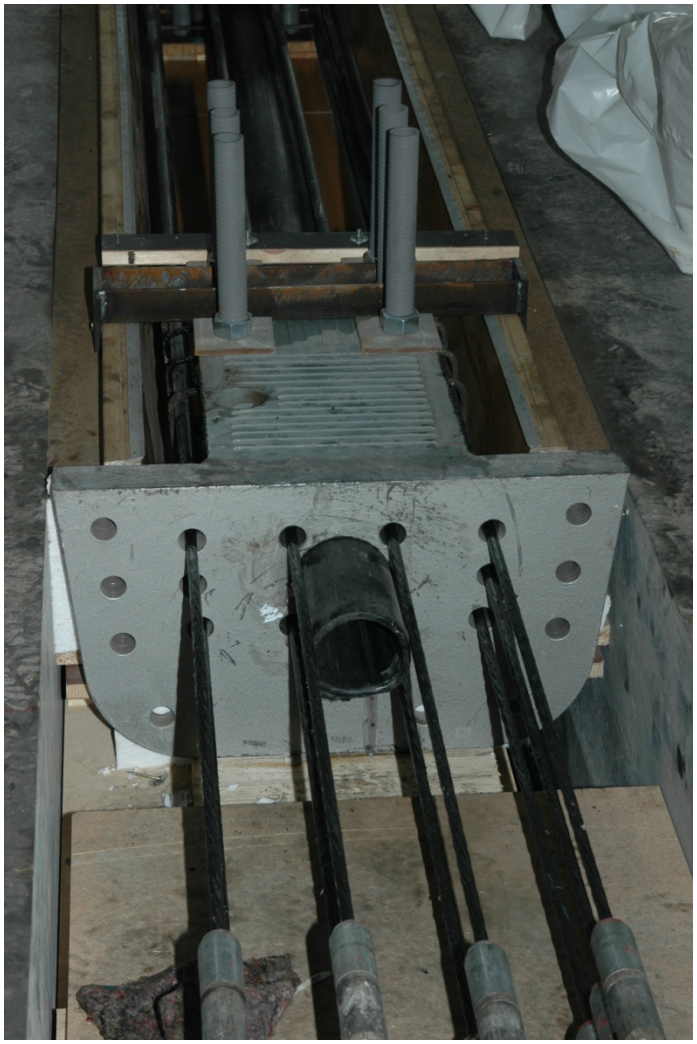
Precast UHPC Element for upper chords



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Connecting Steel Truss and upper chord

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Transpotation to site

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Connecting of superstructur to continous beam

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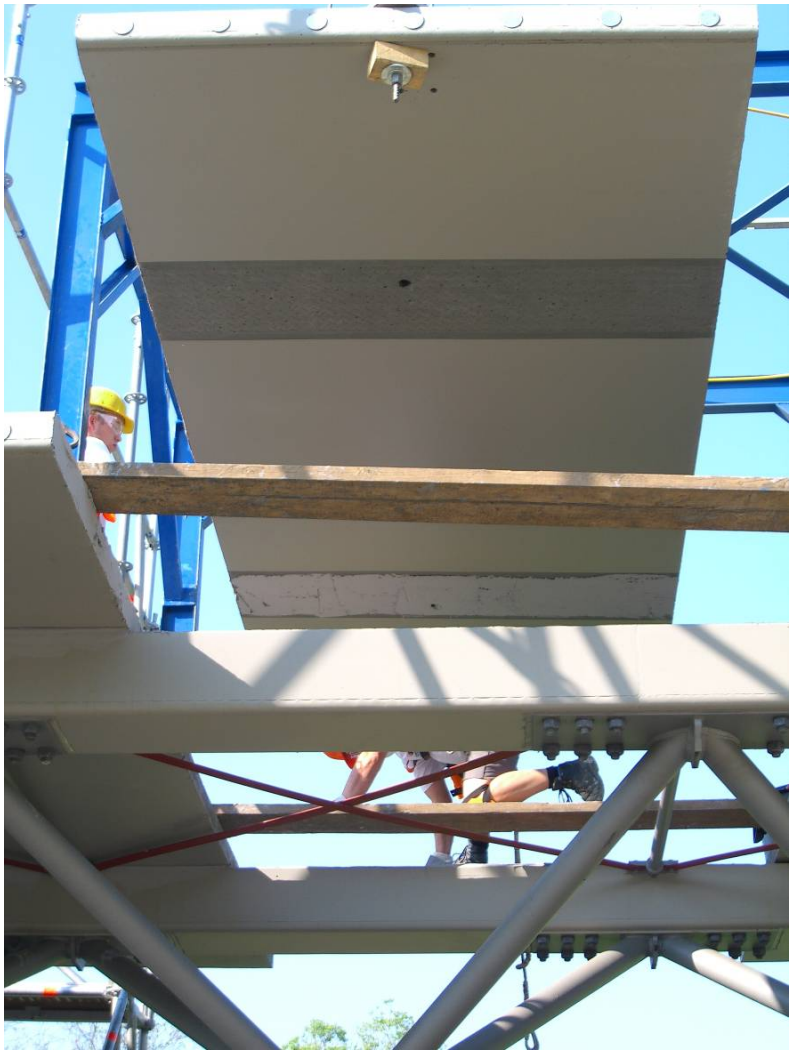
The Gärtnerplatz Bridge

Assembling of bridge decks



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The Gärtnerplatz Bridge

Assembling of bridge decks

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Assembling of handrails

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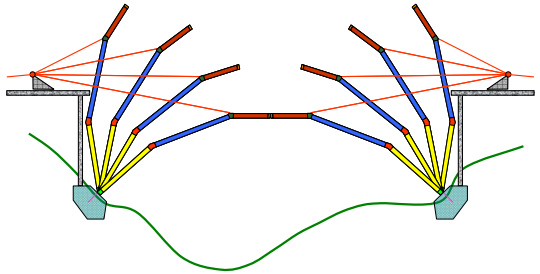
The “WILD Bridge“, Austria
UHPC for Precast Segmental Arch Structure

Swivel with Method of Arch Erection



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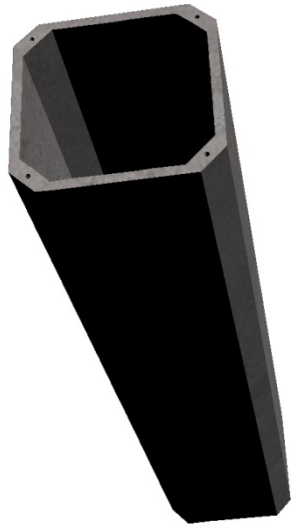
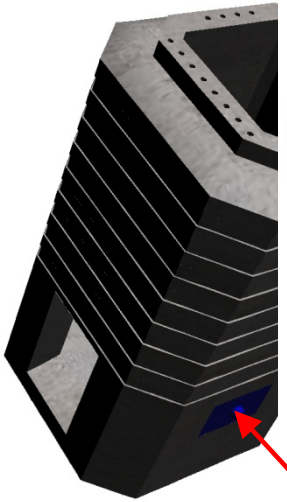
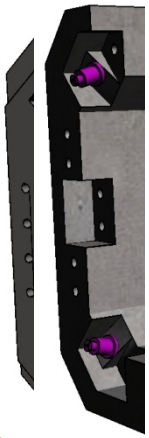
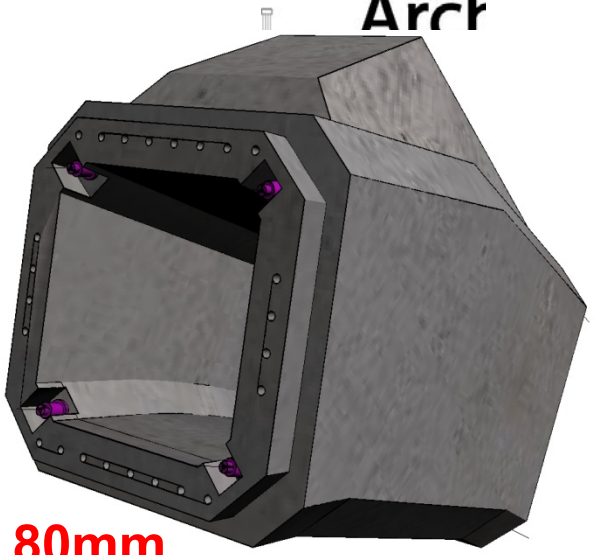
The “WILD Bridge“

Erection and Elements

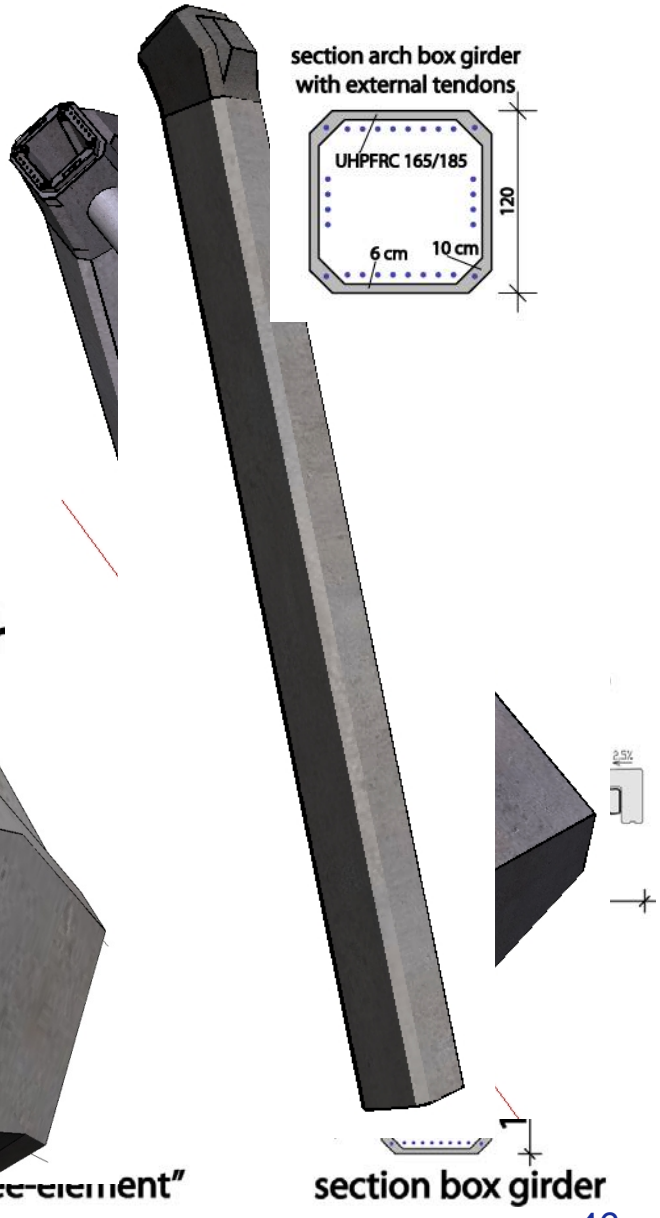








bolt 80mm



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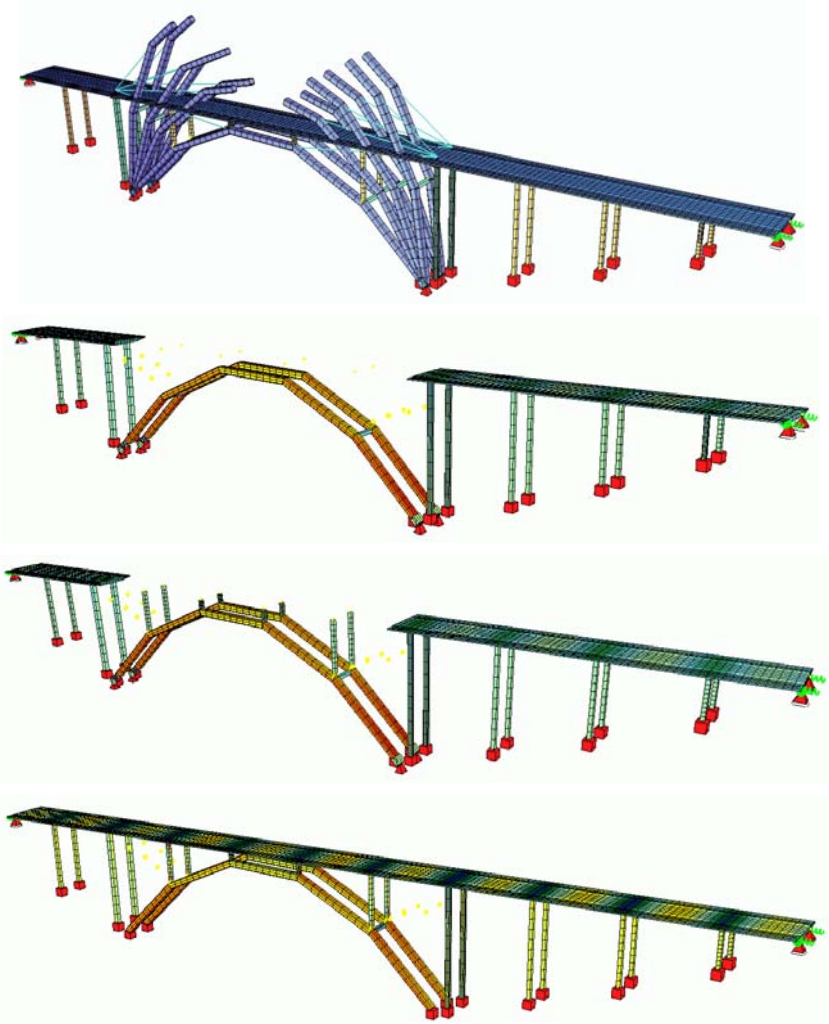
The “WILD Bridge“
Modelling, Analysis and Design



SLS/ULS Stress-strain relations for the design of cross-sections taken from German ”Sachstandsbericht”

SLS:

- Decompression in the arch and the segmental joints under characteristic loads in longitudinal direction adequate durability!!!!
- In transverse direction and in the „knee-elements“ the tension stresses should be lower then the matrix strength under the characteristic loads

ULS:

- Segments; stress-strain relation for tension and compression, segmental joints; only compression
- Gaping of the segmental joints is limited by one third of the height of the section
- Low shear force easily transferred in the remaining compression zone through friction
- Shear carrying capacity calculated according to German guideline „Stahlfaserbeton“

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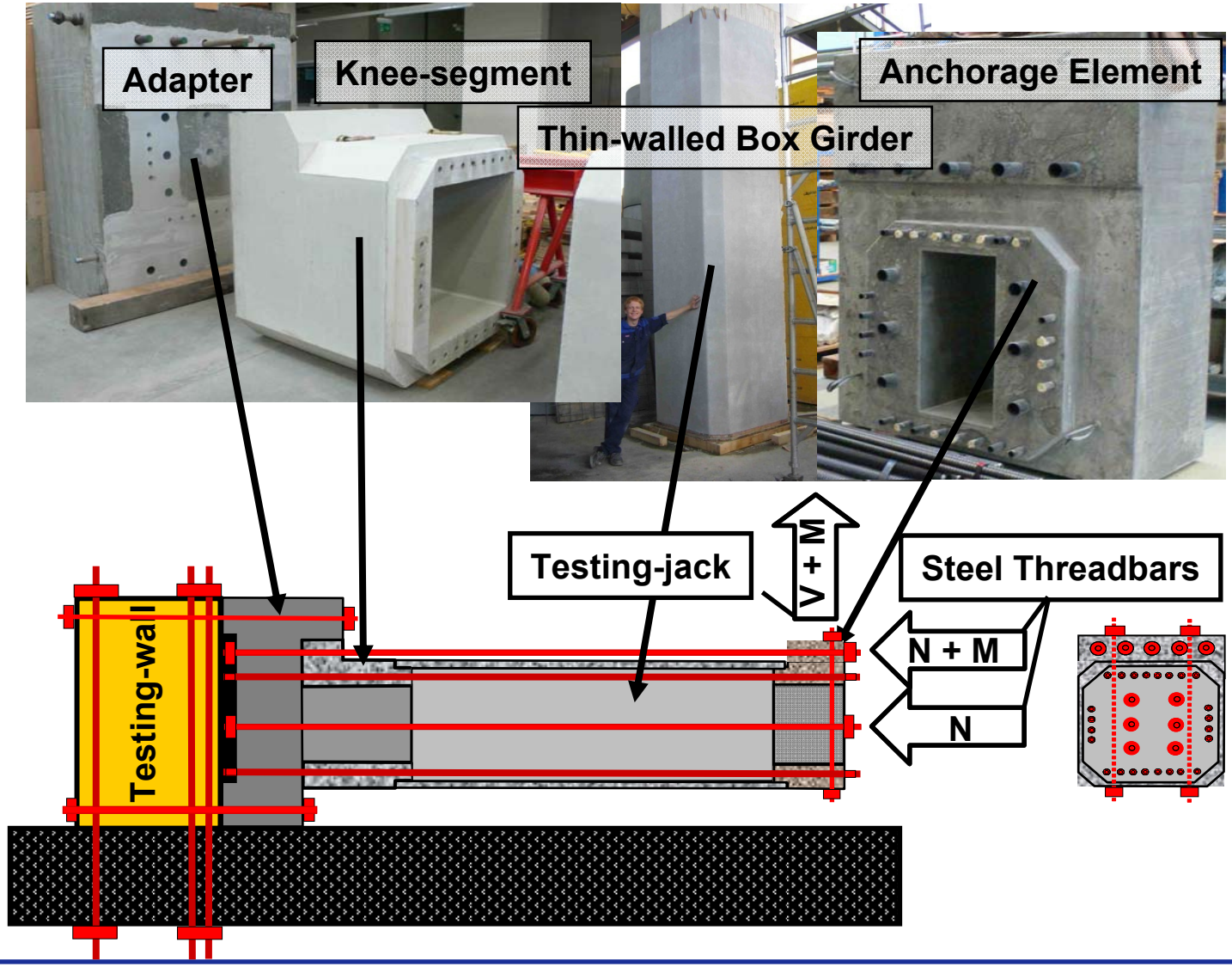
The “WILD Bridge“

1 : 1 Full Scale Test



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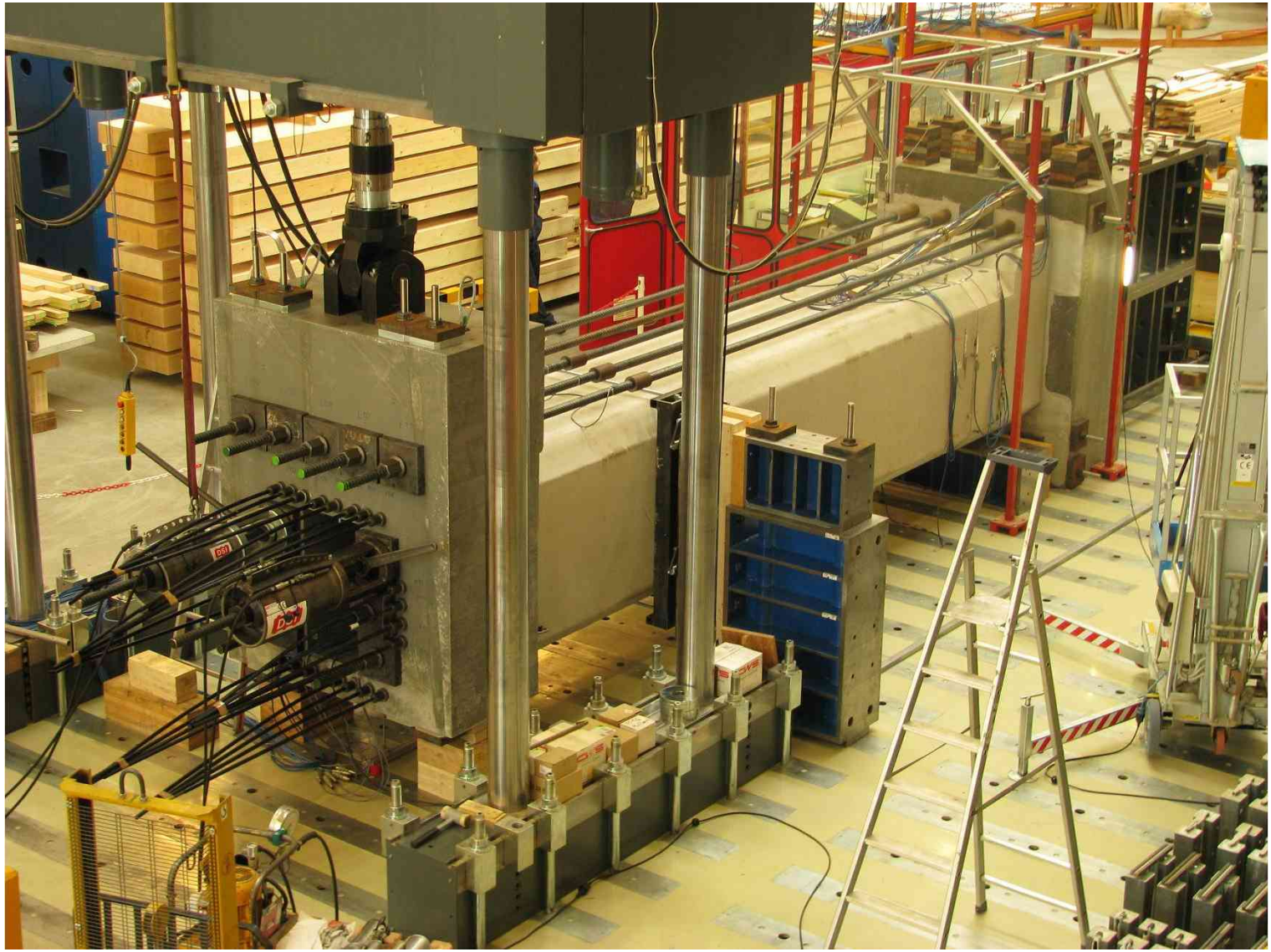

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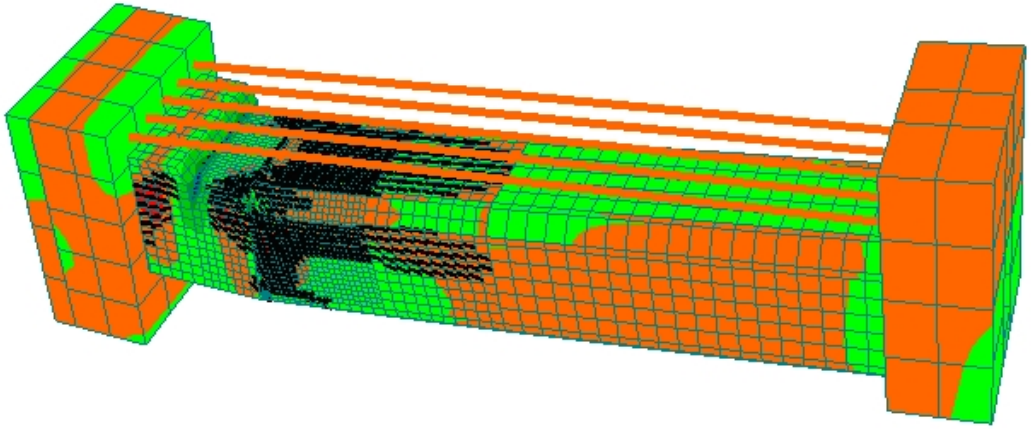

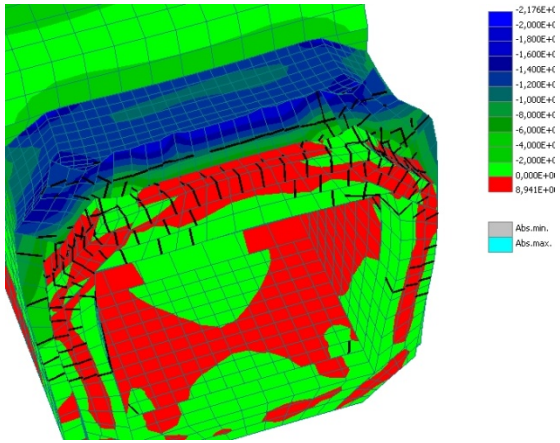

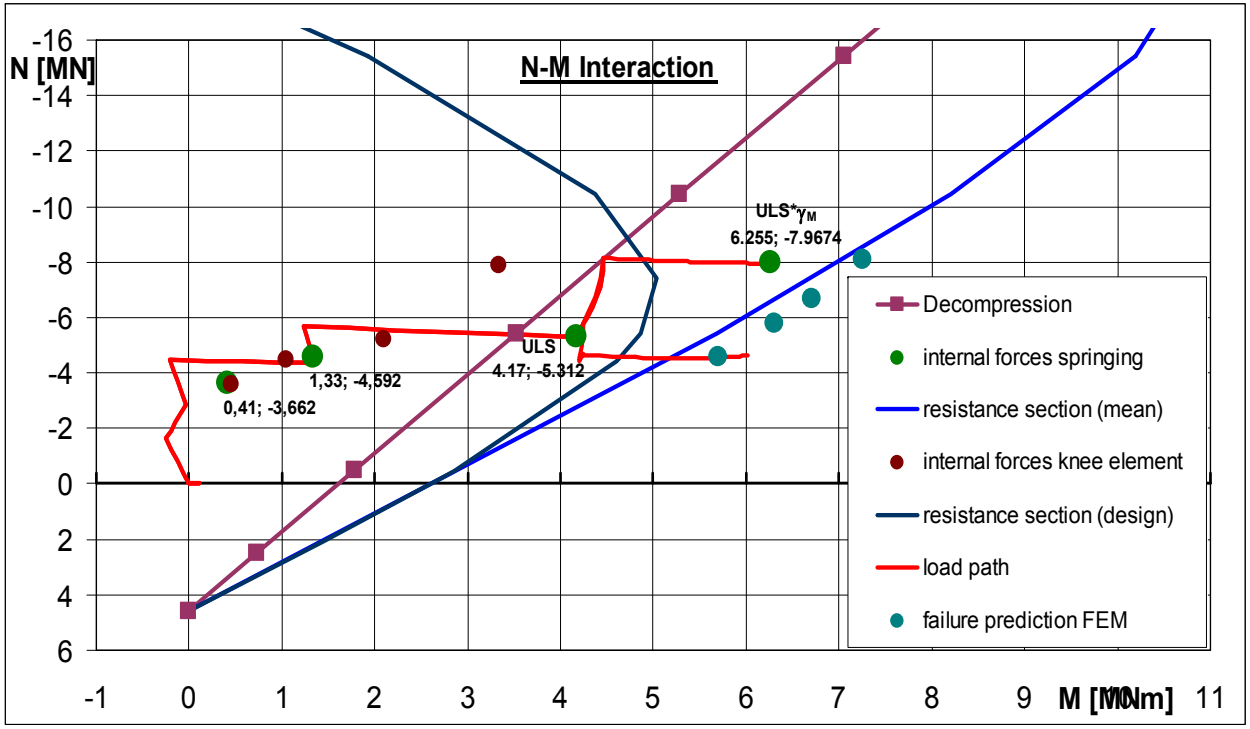

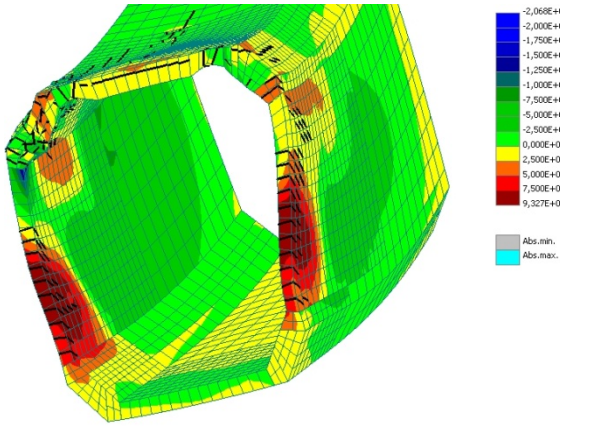

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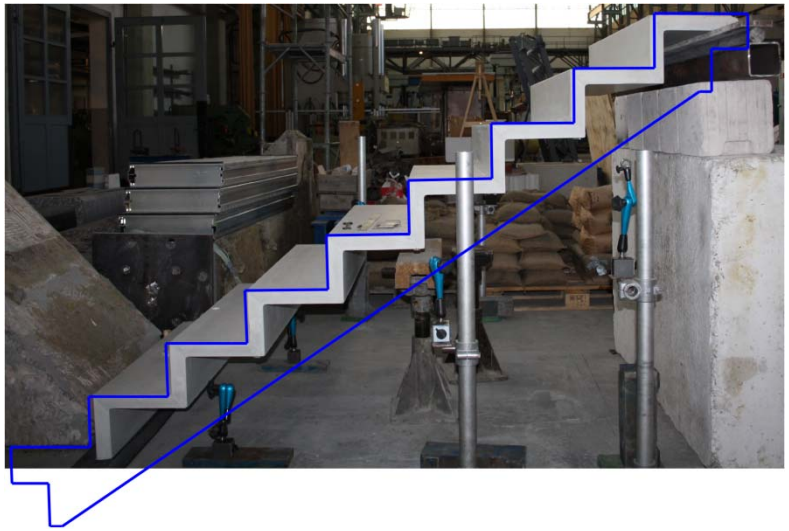
UHPC – Stair without Conventional Reinforcement

Comparison



	Conventional stair	UHPC-stair
Concrete volume	0,850 m^3	0,205 m^3
Mass	2.125 kg	515 kg

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Thanks for your
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