

## TensiNet at ABS 2022



### 17th Advanced Building Skins Conference & Expo - 20-21 October 2022, Bern, Switzerland

Members of the TensiNet Association gave interesting presentations during ABS 2022: presentations on **Architectural Membranes for High-performance Building Skins** (session A3), on the behaviour of membranes in the **session Life Safety and Fire Prevention in Façades** (session A4) as well as in the session **Building a Sustainable World** (A5). These presentations were attended and appreciated by a wide audience.

#### A3: Architectural Membranes for High-performance Building Skins

- Fabric façades from recycled PET bottles - Katja Bernert, Mehler Technologies GmbH
- Fluon ETFE film - Ben Runhaar, AGC Chemicals Europe
- Prediction of rain noise in large halls covered by structural skins - Monika Rychtarikova, KU Leuven
- Transparent ETFE cushion roof - Fridolin Mall, formTL
- Moveable structures as 5th skin - Christoph Paech, schlaich bergemann partner
- m<sup>3</sup> ETFE cloud | the way - Thomas Toepfer, se cover

#### A4: Life Safety and Fire Prevention in Façades

- Life safety and fire prevention in façades - Carl Maywald, Vector Foiltec
- How to get full fire safety for façades Allan Hurdle, Serge Ferrari

#### A5: Building a Sustainable World

- Membrane structures and embodied carbon reduction - Marijke Mollaert & Zehra Eryuruk, VUB. Carol Monticelli & Alessandra Zanelli, POLIMI
- Sustainability aspects in lightweight construction: How can education improve the state of the art of sustainable construction? - Sarah von Der Weth, IMS Bauhaus Archineer Institutes e.V.

# Fabric Façades from recycled PET bottles

**Katja Bernert**

Dipl.-Ing. Architect

Textile Architecture Expert



a company of  FREUDENBERG

[Katja.Bernert@freudenberg-pm.com](mailto:Katja.Bernert@freudenberg-pm.com)

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Sustainability ... a lip service?

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Je oller desto doller! The elder the better!



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3



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## Sustainable Textile Architecture?



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# Is recyclability enough?



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# Talking about Sustainability in Textile Architecture



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Recyclable?



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Eatable?



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# Gyro Gearloose mentality



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## Cleanability



**A maximum Fluor content in the coating, combined with good weldability is the key to a longlasting performance.**



## Longevity

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# Maintenance as a key to durability



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## Self cleaning is a legend!



Type III in Ashford, UK



Glass/PTFE project in France



There's plenty of rPET!



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Eco Check ✓



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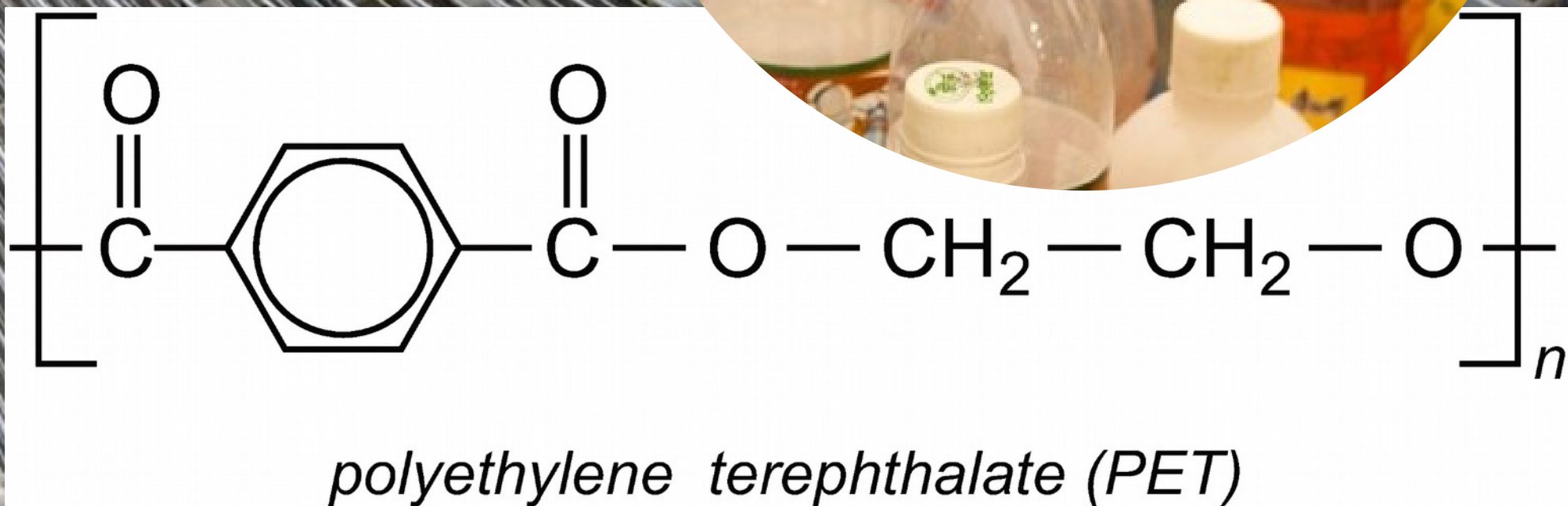


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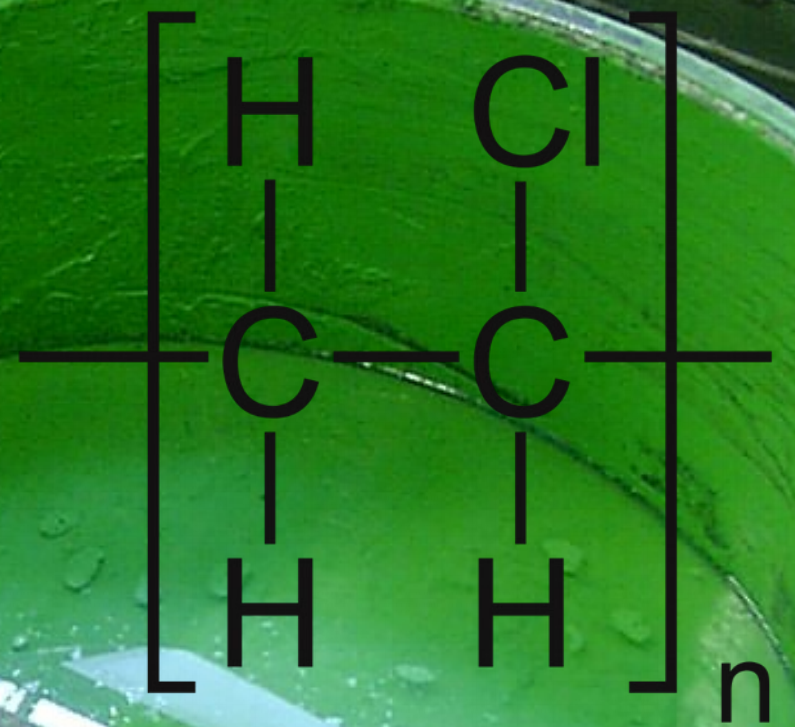




we weave old bottles

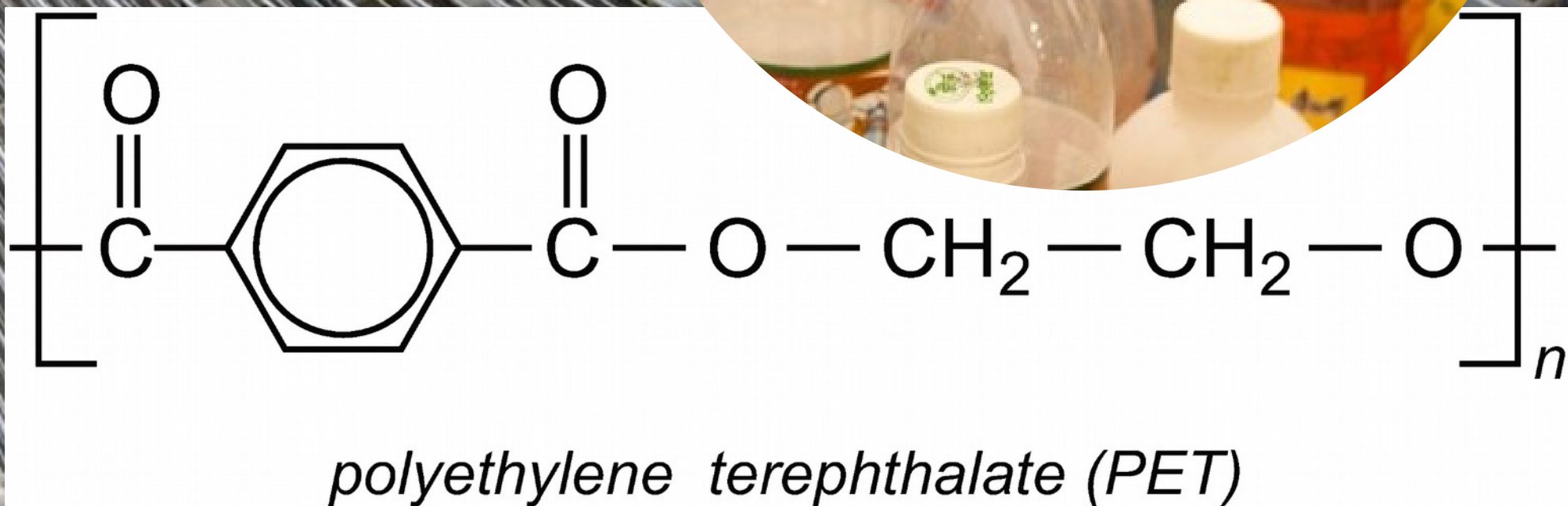


... we coat – e.g. in black!

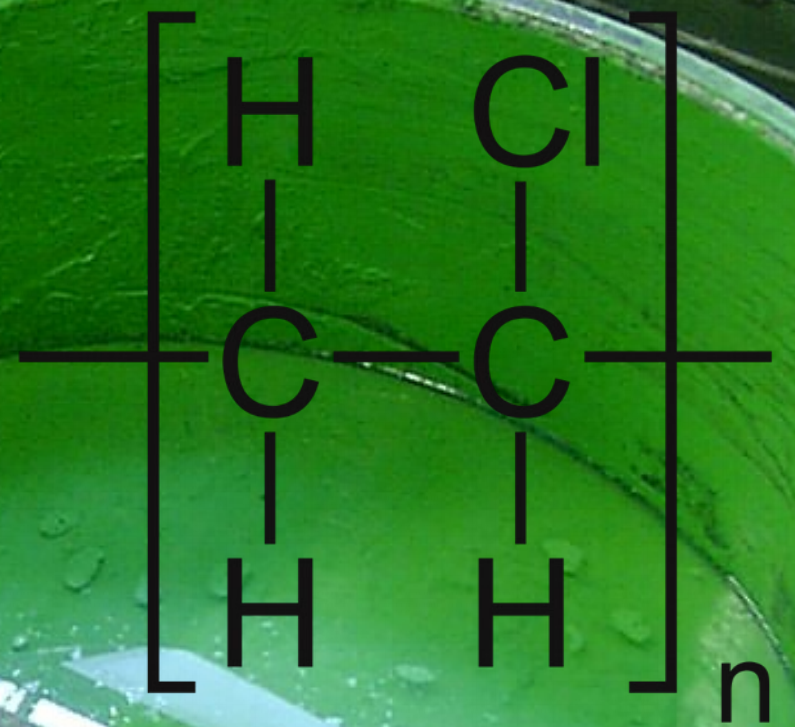




we weave old bottles



... we coat – e.g. in black!





## Recycling options for other than Textile Architecture Material

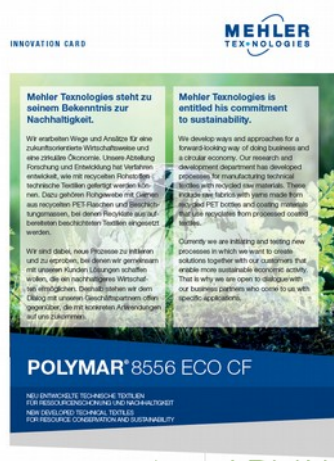
<b>VALMEX® 650 ECO F</b>	8212 5240
<b>Beschichtungsart</b> Coating	<b>PVC</b> PVC
<b>Brennverhalten</b> Burning behaviour	<b>BS 7837, California T 19</b> <b>D.M. 26.06.84 (UNI 9177): CL. 2,</b> <b>DIN 4102: B1, NFPA 701 Test 2,</b> <b>EN 13501-1: B-s2-d0, GOST: G1,</b> <b>ASTM E 84 Class A, CAN ULC S109,</b> <b>NFP 92507: M2 (certain colours)</b>
<b>Gesamtgewicht</b> Total weight	<b>650 g/m<sup>2</sup></b> DIN EN ISO 2286-2
<b>Reißkraft</b> Tensile strength	<b>2660 / 2660 N/50 mm</b> DIN EN ISO 1421/V1
<b>Weiterreißfestigkeit</b> Tear strength	<b>20 / 20 daN</b> DIN 53363
<b>Haftfestigkeit</b> Adhesion	<b>approx. 9,5 DaN/5 cm</b> PA 09.03 (intern)
<b>Trägermaterial</b> Base fabric	<b>100 % R-PET</b>

**VALMEX® 650 ECO F**  
Farbe: Weiß 907901

Das Material hat einen Anteil von 28 % recycelten Rohstoffen und setzt in Sachen Nachhaltigkeit im Bereich Zelte wichtige Trends. Das R-PET-Gewebe von VALMEX® 650 ECO F besteht zu 100 % aus recycelten PET-Flaschen, wobei seine Eigenschaften denen herkömmlicher Trägergewebe sehr nahekommen. 650 ECO F gehört zur VALMEX®-Produktlinie, die sich u.a. durch Witterungsbeständigkeit, UV-Beständigkeit und lange Lebensdauer auszeichnet.

**VALMEX® 650 ECO F**  
Colour: White 907901

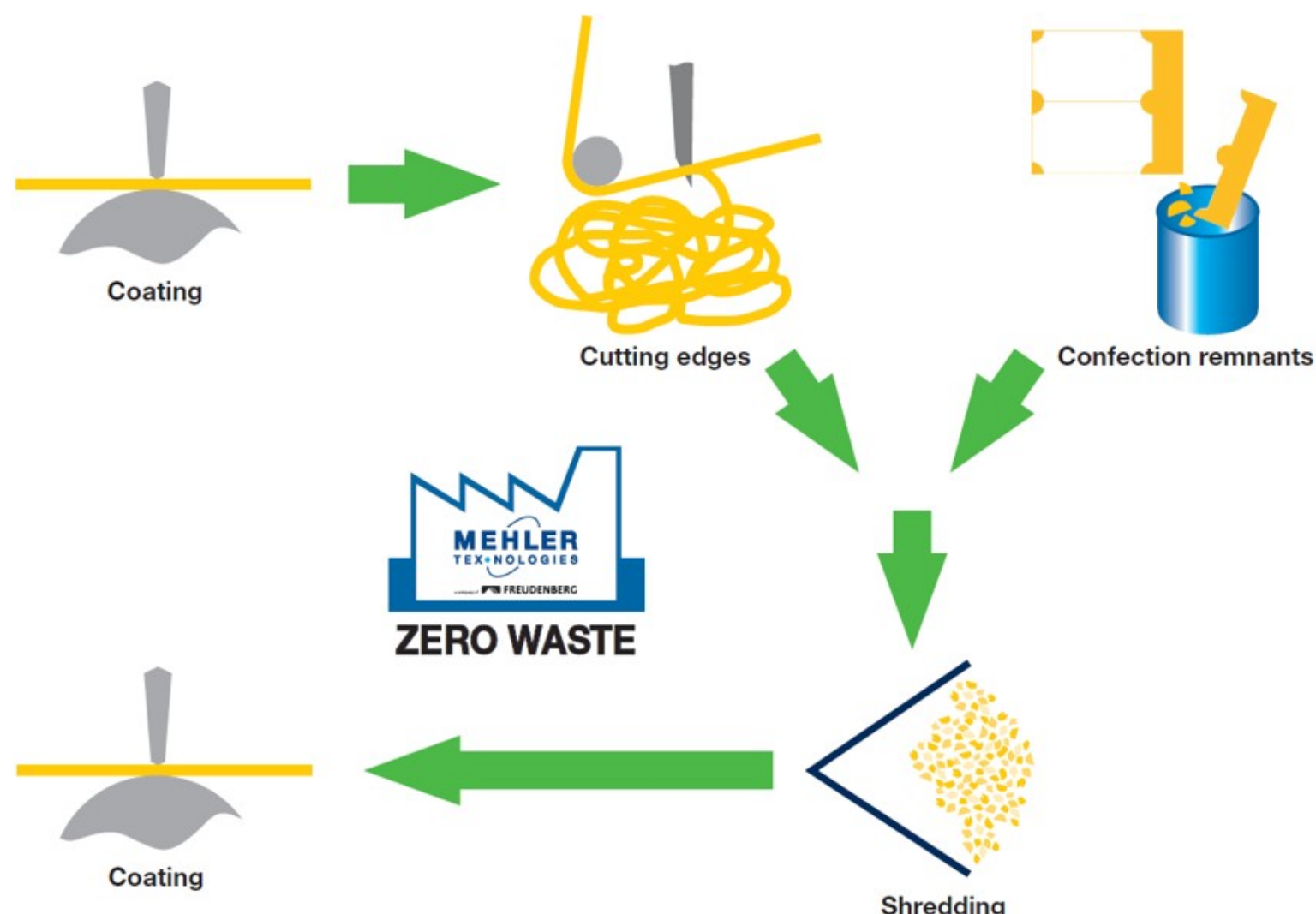
The material has a share of 28% recycled raw materials and sets important trends in terms of sustainability in the field of tents. The R-PET fabric of VALMEX® 650 ECO F consists of 100% recycled PET bottles, and its properties are very similar to those of conventional base fabric. 650 ECO F belongs to the VALMEX® product line, which is characterized by weather resistance, UV resistance and a long service life, among other things.



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## Innovation in Progress: Schematic Process



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# upcycled yarns: GRS certificate of our yarn supplier



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# technical data of all-new and up-cycled material in the same range

Technical datasheet No.: **2293.1**  
Product: VALMEX® TF 400 ECO F  
Article No.: 9638 5246

Type of coating and finish		
Type of coating	PVC	
Finish	Multi-composed PVDF-Jacquer system on both sides, antimicrobial, UV-protected	
Burning behaviour	DIN 4102: B1, BS 7837, EN 13501-1: B-s2-d0, California T 19, NFPA 701 Test 2, ASTM E 84 Class A, VKF Richtlinie: 5.2, CAN ULC S 109, AS 1530 part 2, AS 1530 part 3, NFP 92507: M1	
for Burning behaviour	always check validity of fire certificate, also check country-specific validity	
Total weight	420 g/m <sup>2</sup>	EN ISO 2286-2
Tensile strength warp/weft	3000/2250 N/50 mm	EN ISO 1421/V1
Tear strength warp/weft	250/250 N	DIN 53363
Adhesion	18 N/cm	PA 09.03 (intern)
Cold resistance	-20 °C	EN 1876-1
High Temperature	+70 °C	PA 07.04 (intern)
Light fastness	>6 Note, Value	EN ISO 105 B02
Base fabric		
Material	PES	DIN EN ISO 2076
Yarn count	3300 / 2200 dtex	DIN EN ISO 2060
for base fabric	low-wick	
Remarks	weldable without grinding and with common welding equipment, preliminary datasheet, .	

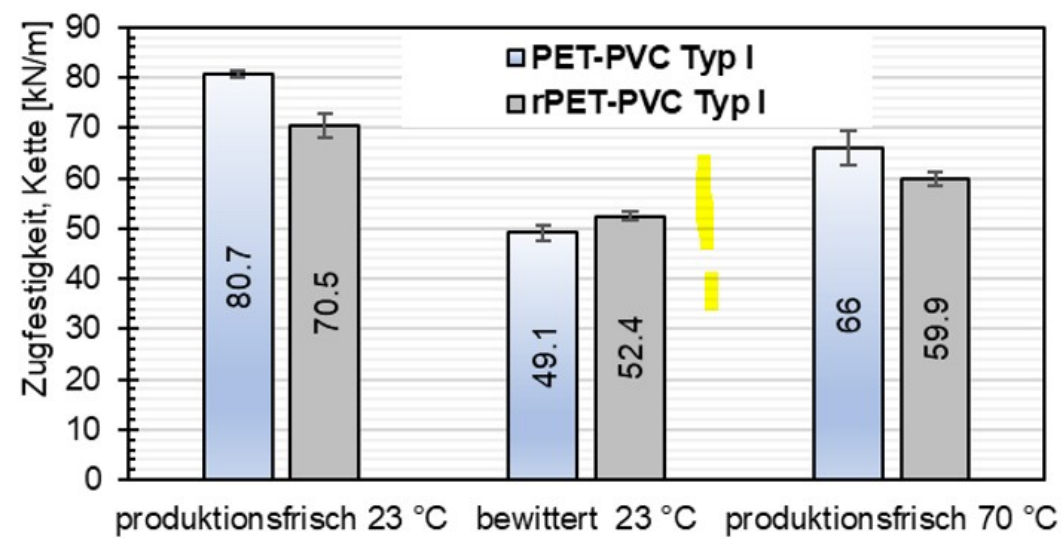
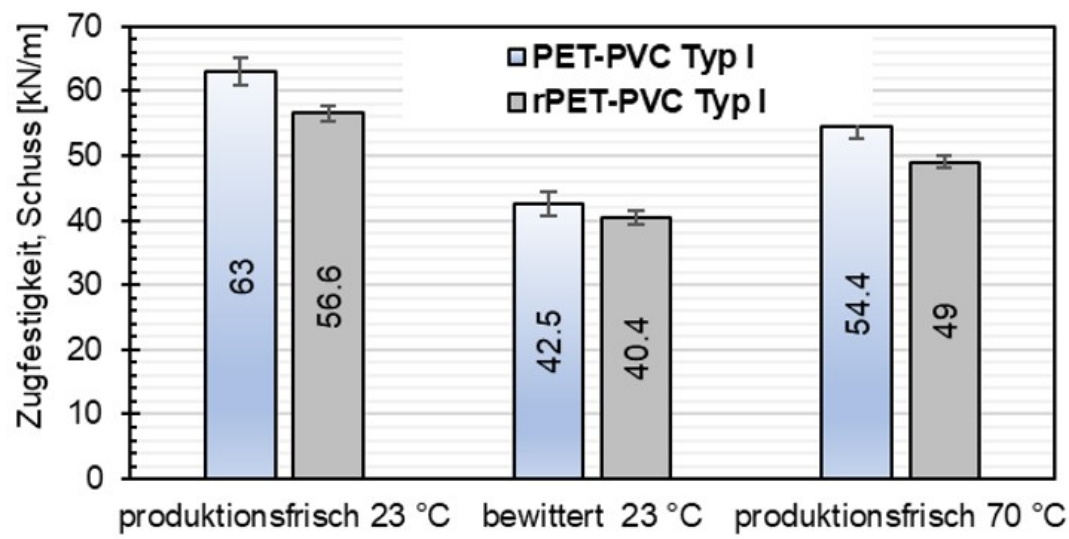
Technical datasheet No.: **1669.38**  
Product: VALMEX® TF400 F1  
Article No.: 7280 5246

Type of coating and finish		
Type of coating	PVC	
Finish	Multi-composed PVDF-Jacquer system on both sides, antimicrobial, UV-protected	
Burning behaviour	DIN 4102: B1, BS 7837, EN 13501-1: B-s2-d0, California T 19, NFPA 701 Test 2, ASTM E 84 Class A, VKF Richtlinie: 5.2, CAN ULC S 109, AS 1530 part 2, AS 1530 part 3, NFP 92507: M1	
for Burning behaviour	always check validity of fire certificate, also check country-specific validity	
Total weight	420 g/m <sup>2</sup>	EN ISO 2286-2
Tensile strength warp/weft	4000 / 3000 N/50 mm	EN ISO 1421/V1
Tear strength warp/weft	800 / 550 N	DIN 53363
Adhesion	20 N/cm	PA 09.03 (intern)
Cold resistance	-20 °C	EN 1876-1
High Temperature	+70 °C	PA 07.04 (intern)
Light fastness	>6 Note, Value	EN ISO 105 B02
Seam strength	1400 N/50 mm	EN ISO 1421/V1
Base fabric		
Material	PES	DIN EN ISO 2076
Yarn count	3300 / 2200 dtex	DIN EN ISO 2060
for base fabric	low-wick	
Remarks	weldable without grinding and with common welding equipment, .	
GRAB-Test (warp/weft)	- N	ASTM D-751 Procedure B, FTM 191 -5100





# Bottle past makes fabric less vulnerable

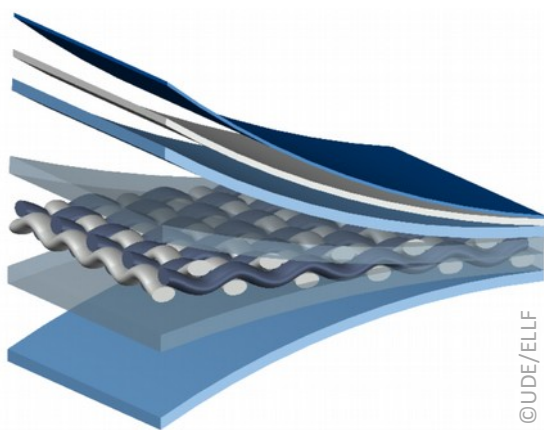


Results from tests at [www.uni-due.de/iml](http://www.uni-due.de/iml) rPET-paper Hastia Asadi | Katja Bernet | Jörg Uhlemann | Natalie Stranghörer



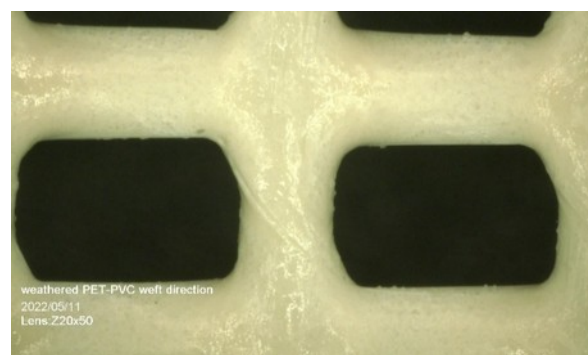
## Comparing all new PVC/PES-fabric with rPET-fabric

Aufbau PET-PVC-Gewebe



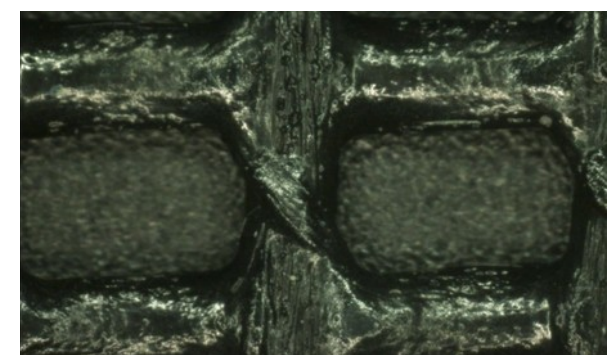
©UDE/ELLF

PET-PVC-Gewebe Typ I



©UDE/ELLF

rPET-PVC-Gewebe Typ I



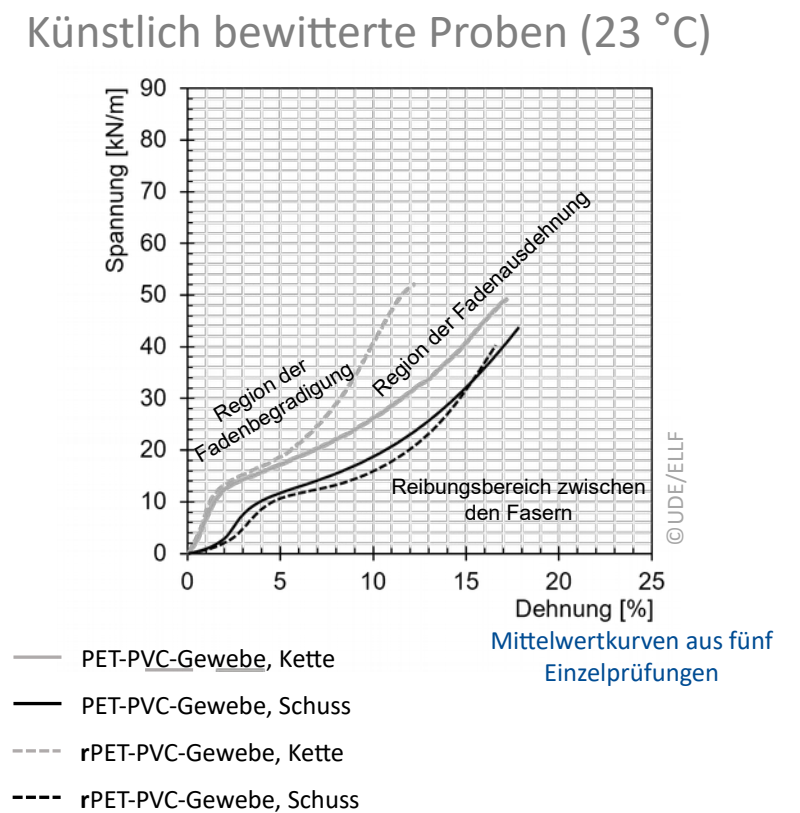
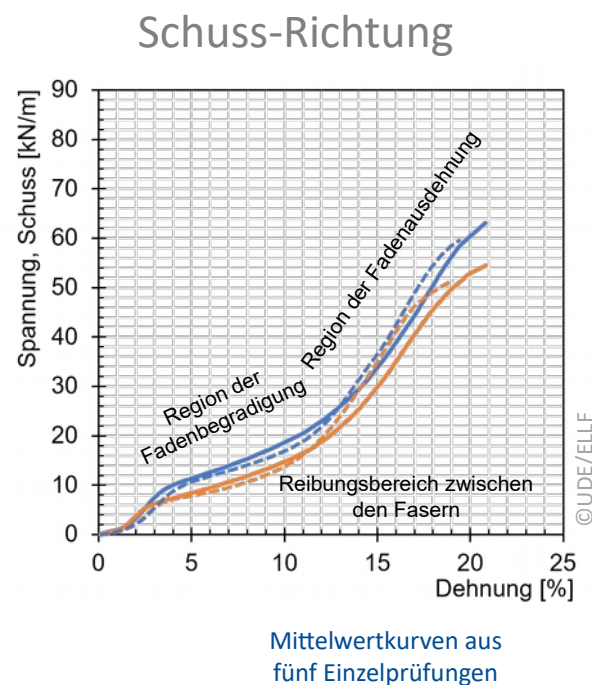
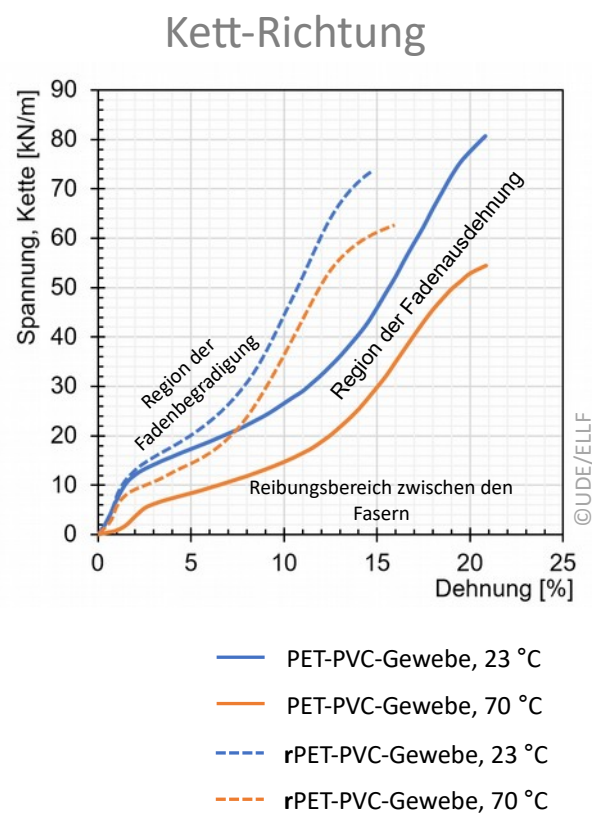
©UDE/ELLF

	PET-PVC-Gewebe	rPET-PVC-Gewebe
Gewicht	435,0 [g/m <sup>2</sup> ]	421,0 [g/m <sup>2</sup> ]
Dicke	0,87 [mm]	0,83 [mm]
Bindung	Leinwand	Leinwand
Fadendicht Kette/Schuss	identisch	identisch
Anzahl Garne Kette/Schuss	identisch	identisch

Results from tests at [www.uni-due.de/iml](http://www.uni-due.de/iml) rPET-paper Hastia Asadi | Katja Bernet | Jörg Uhlemann | Natalie Stranghörer



# Results of short term tensile strength tests (DIN EN ISO 1421)

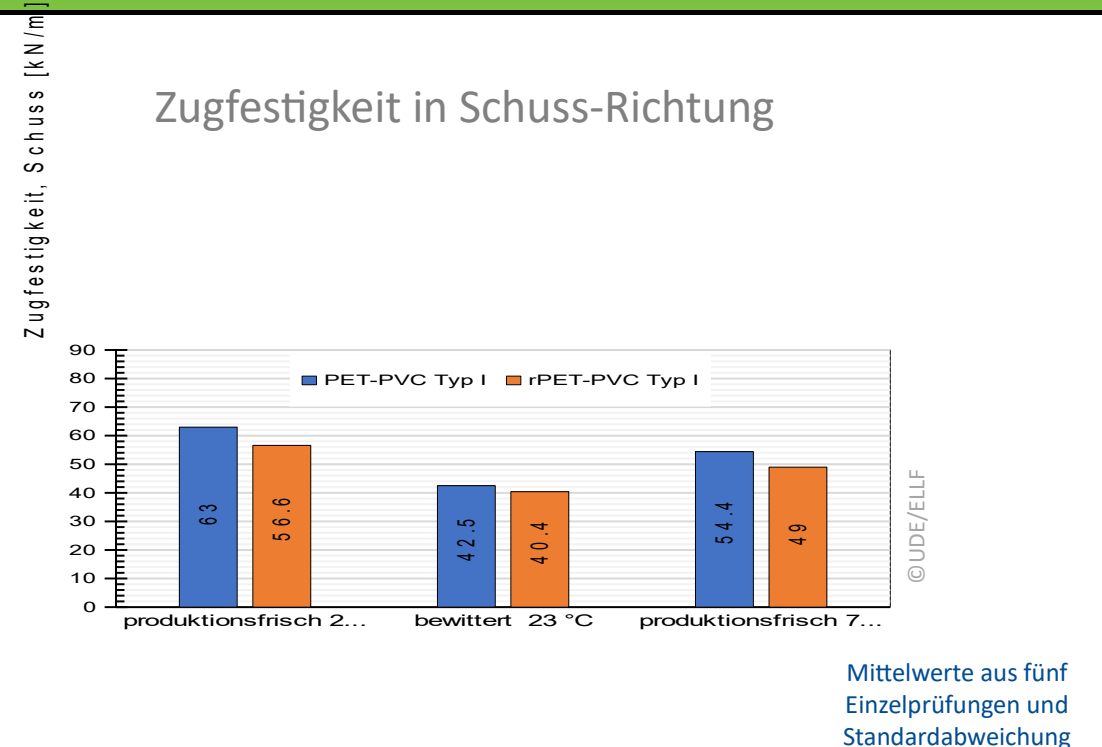
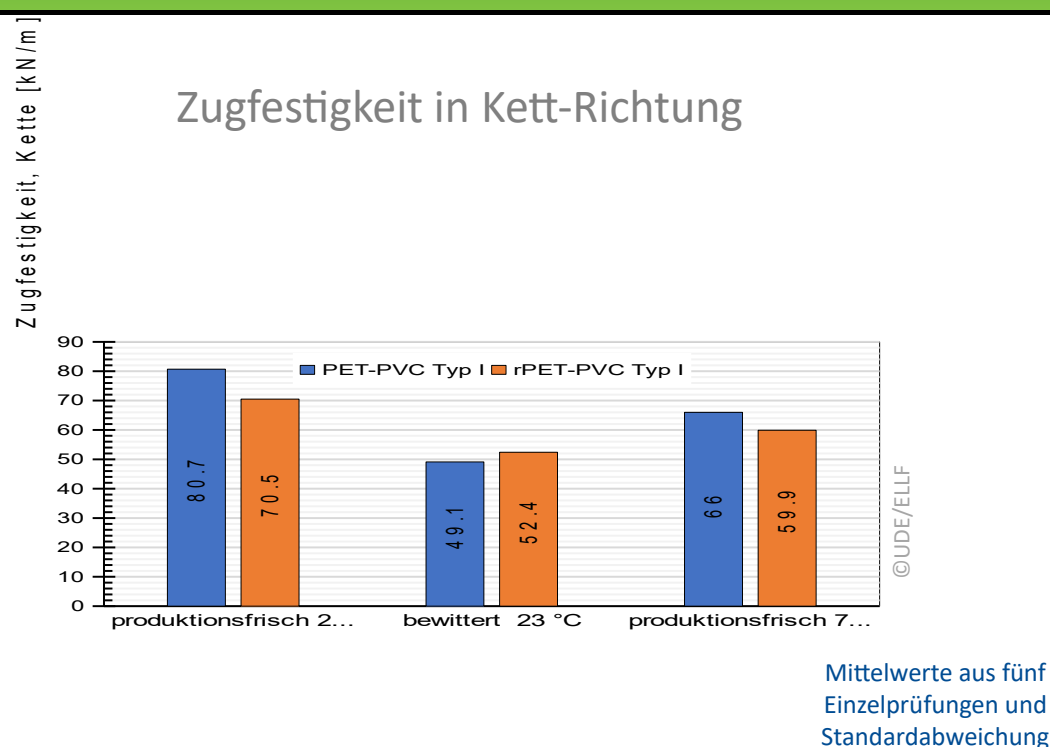


- Deutlich steiferes Verhalten des rPET-PVC-Gewebes vor allem in Kett-Richtung.
  - Geringere Sensitivität des rPET-PVC-Gewebes gegenüber erhöhter Temperatur.
  - Nach künstlicher Bewitterung: Materialverhalten überwiegend identisch, erhöhte Kett-Steifigkeit des rPET-PVC-Gewebes.
- ⇒ rPET-PVC-Gewebe Typ I besitzt höheren Widerstand gegen Witterungseinflüsse und hohe Temperaturen.

Results from tests at [www.uni-due.de/iml](http://www.uni-due.de/iml) rPET-paper Hastia Asadi | Katja Bernet | Jörg Uhlemann | Natalie Stranghörer



# Results of short term tensile strength tests (DIN EN ISO 1421)



Unterschied  $\Delta f_m$  der mittleren Zugfestigkeiten  $f_m$  zwischen rPET-PVC- und PET-PVC-Gewebe nach (Gl. 1)

	Kette	Schuss
Produktionsfrisch, 23 °C	-12,6 %	-10,2 %
Produktionsfrisch, 70 °C	-9,2 %	-9,9 %
Bewittert, 23 °C	6,7 %	-4,9 %

$$\Delta f_m = \frac{f_{m,rPET} - f_{m,PET}}{f_{m,PET}} \cdot 100 \quad (\text{Gl. 1})$$



vergleichsweise geringe Zugfestigkeit des rPET-PVC-Gewebes



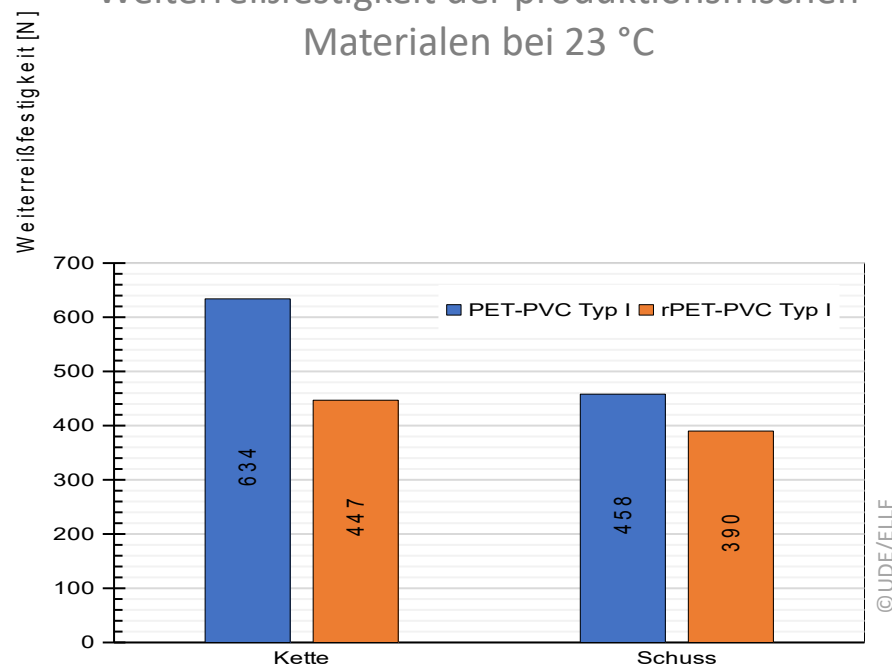
Zugfestigkeit beider Materialien im selben Festigkeitsbereich mit überlappenden Streuungsbereichen

Results from tests at [www.uni-due.de/iml](http://www.uni-due.de/iml) rPET-paper Hastia Asadi | Katja Bernet | Jörg Uhlemann | Natalie Stranghörer





Weiterreißfestigkeit der produktionsfrischen Materialien bei 23 °C



Mittelwerte aus fünf Einzelprüfungen und Standardabweichung

Unterschied  $\Delta f_{T,m}$  der mittleren Weiterreißfestigkeiten  $f_{T,m}$  zwischen rPET-PVC- und PET-PVC-Gewebe in Anlehnung an (Gl. 1)

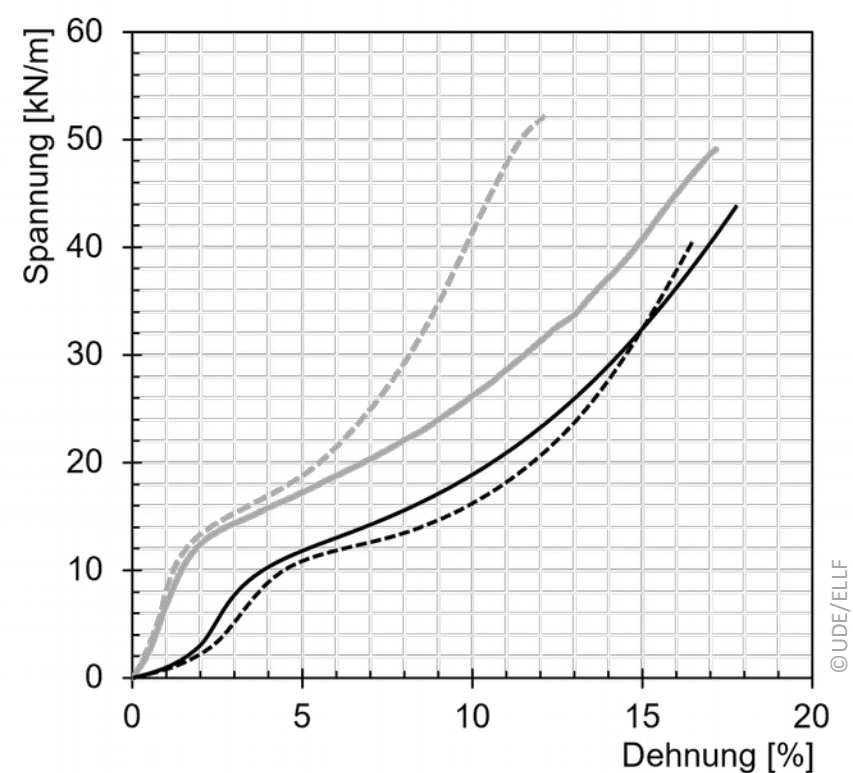
	Kette	Schuss
Produktionsfrisch, 23 °C	-29,5 %	-14,8 %

- Vergleichsweise geringe Weiterreißfestigkeiten des rPET-PVC-Gewebes, besonders in Kett-Richtung.
- ⇒ Untersuchungen an bewittertem Material stehen noch aus.

## In short:

- rPET-PVC-Gewebe weisen vergleichsweise geringere Zug- und Weiterreißfestigkeiten im produktionsfrischen Zustand auf als PET-PVC-Gewebe
- Untersuchungen bei erhöhten Temperaturen und von künstliche bewitterten Proben haben allerdings gezeigt, dass rPET-PVC-Gewebe eine höhere Resistenz gegen diese festigkeitsmindernden Einflüsse besitzt.
- Die Zugfestigkeit der bewitterten Proben beider Materialien sind nahezu identisch.
- Weiterreißprüfungen an bewitterten Proben stehen noch aus.

Künstlich bewitterte Proben (23 °C)



— PET-PVC-Gewebe, Kette  
 — PET-PVC-Gewebe, Schuss  
 - - - rPET-PVC-Gewebe, Kette  
 - - - rPET-PVC-Gewebe, Schuss

Mittelwertkurven aus fünf Einzelprüfungen



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27

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## Maintenance and inspection as a key to Durability!



### Ashford Designer Outlet Village Annual Inspection 2011



Inspection carried out by:	Dave Cackett
Report prepared by:	CHT Gariside
Date of Inspection:	July 2011

Architen Landrell Associates Ltd  
Station Road  
Cheslow  
Warminstershire  
NP16 5PF  
Tel: 01291 638200  
Fax: 01291 621991

Insurance and Warranty  
Ashford Fashion Outlet

**Maintenance**

the mechanical, as well as the physical condition of the structure the warranty holder shall be responsible for the maintenance of the structure in accordance with Appendix 3 to detect and they shall be further investigated and a record shall be made. A record of these general inspection deficiencies shall be recorded on an Inspection Report. The damage or deficiencies found and the remedial action Appendix 3 must be, made available to the client 14 days prior written notification. The warranty will provide



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# No CHOICES!



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# Teamwork!



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# The weaver takes R-PET



[Zurück zur Übersicht](#)

Teilen auf



Manufacturer and Client with a changed mind set

**The manufacturer dismisses the „has always been like that“ attitude!**



**The client pays the extra money ...**



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Paragraphs might help ..



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TensiNet's initiative: more EPD's in Tensile Architecture!



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# AMA's Initiative: AWArding Sustainability in Tensile Architecture

AMA Awards  
WINNER

Best Product 2021

AMA Awards  
WINNER

Best Project 2021

AMA Awards  
WINNER

Best Design 2021

AMA Awards  
WINNER

Best Idea 2021

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## Leaving our Comfort Zones ...



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Thank you for your attention!

courage



# Fluon ETFE FILM

## Agenda

- **AGC Chemicals**
- **ETFE Fluon Film**
- **Properties of ETFE Fluon Film**
- **Special grades:**
  - **UV-cut, Pigmented and Matted**
  - **New low haze developments**
  - **New printed grades**





**GLASS**  
Sales EUR 5.6 bn\*

42%

### Flat Glass

- Float flat glass
- Figured glass
- Polished wired glass
- Low-E glass
- Decorative glass
- Fabricated glass for architectural use

### Automotive Glass

- Tempered glass
- Laminated glass



**ELECTRONICS & CERAMICS**  
Sales EUR 3.0 bn\*

22%

### Display

- LCD glass substrates
- Speciality glass for display applications
- Cover glass for car-mounted displays
- Display related materials
- Glass for solar power systems
- Fabricated glass for industrial use

### Electronic Materials & Ceramics

- Semiconductor process materials
- Optoelectronics materials
- Lighting glass products
- Laboratory glass, etc.
- Ceramic products for logistics and financial services, etc.



**CHEMICALS**  
Sales EUR 4.9bn\*

36%

### Fluoro - & Speciality Chemicals

- Fluorinated Resins
- Water and oil repellents
- Gases and Solvents
- Pharmaceutical and agrochemical intermediates and active ingredients
- Iodine-related products

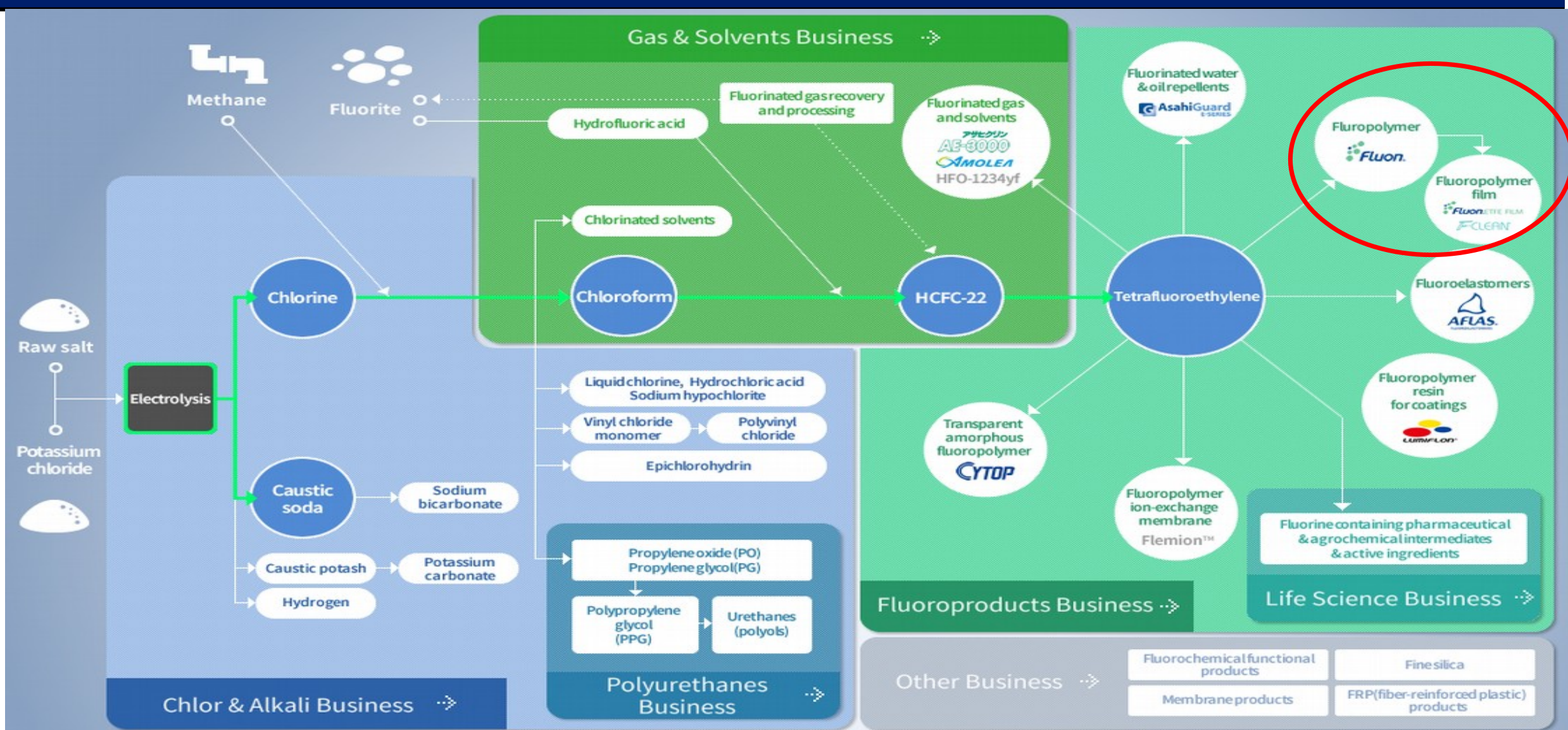
### Chlor-alkali & Urethanes

- Vinyl chloride
- Vinyl chloride monomer
- Caustic soda
- Urethane

\*As per Financial Year 2021

© AGC Inc. AGC Chemicals Europe

# AGC Chemicals



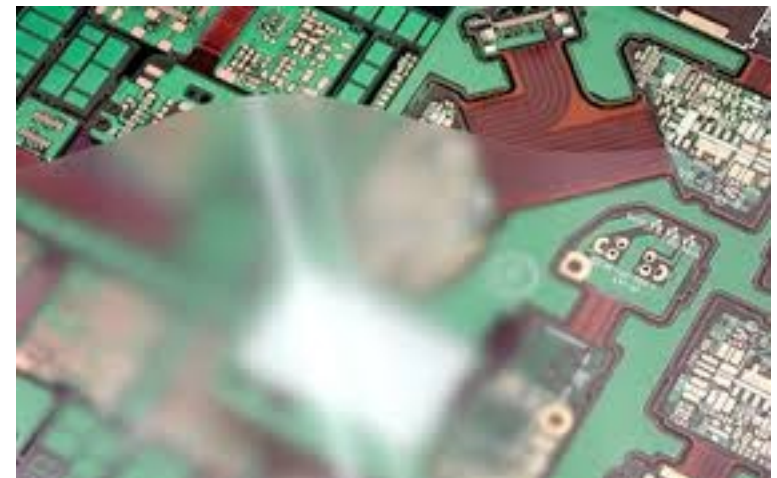


# ETFE FILM

5

## Various uses of ETFE Film

- **Electronics (semi-conductor)**



- **Green-houses**



• **Architectural**

6

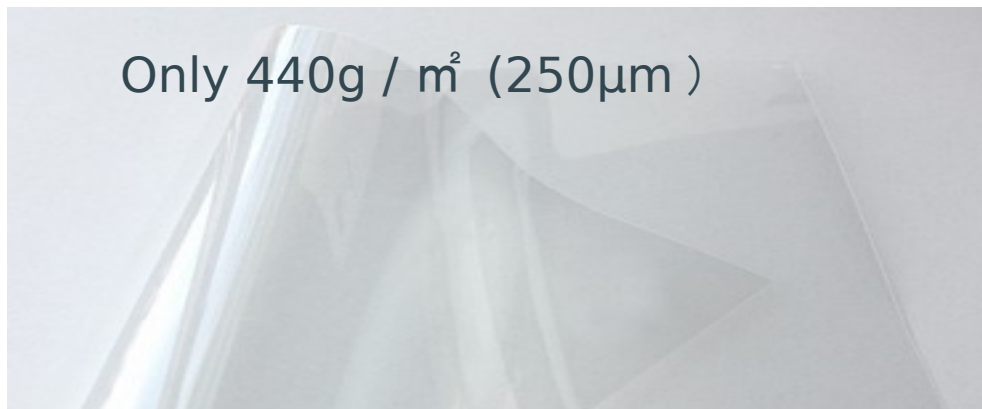
- **Light weight**
- **Transparency**
- **Durability**
- **Comfortable space**
- **Wide design solutions**
- **Recyclable**

7

## Properties of ETFE Film

- **Light weight**

Only 440g / m<sup>2</sup> (250μm )



- **Transparent**



8



- Durability**

Items	Ref: Initial ETFE	Exposed Film (27 years)	
		Before cleaning	After cleaning
Light Transmission(%)	94.0	91.4	93.8
Tensile Strength at Break(Mpa)	60.0	59.1	59.1

- Recyclable**

### ETFE Film Recycling Scheme



- Very strong**



- Design options**



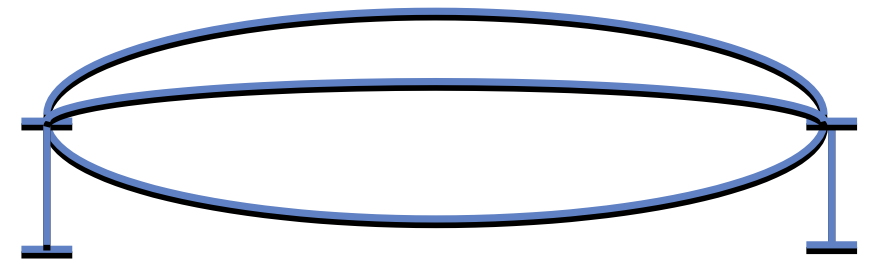


## Types of ETFE Film

11

## Typical design

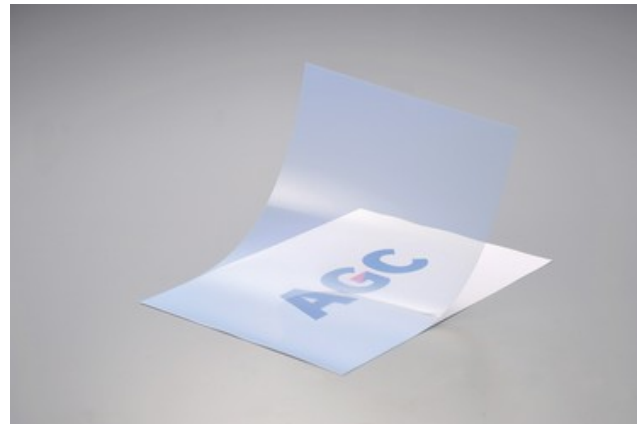
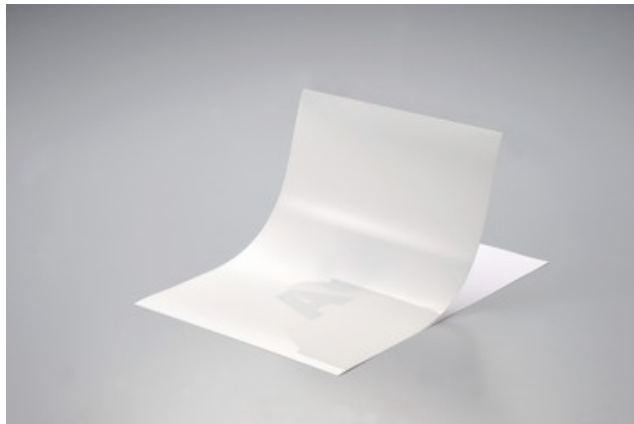
- **ETFE Film is mostly used in a cushion layout with 2, 3, 4 or even 5 layers of ETFE Film**
- **Our standard clear ETFE Film is used on bottom or in between layers**
- **A special grade film would typically be use for the outside film of a cushion**
- **Only Low Haze and UV-Cut film will be used as inner or bottom film layers**
- **Our standard Films we offer with a thicknesses of 100-500 micron**



12

# Special grades. (pigmented and diffused) **AGC** Our Dreams, Our Challenge

- **We currently offer two pigmented grades as list product.**
- **The white and transparent Blue**
- **Other colours are possible, but only for larger projects**
- **We also offer a matted or diffused Film, which offers the same transparency as normal film, but offers a sort of privacy.**
- **Used mainly for facades**

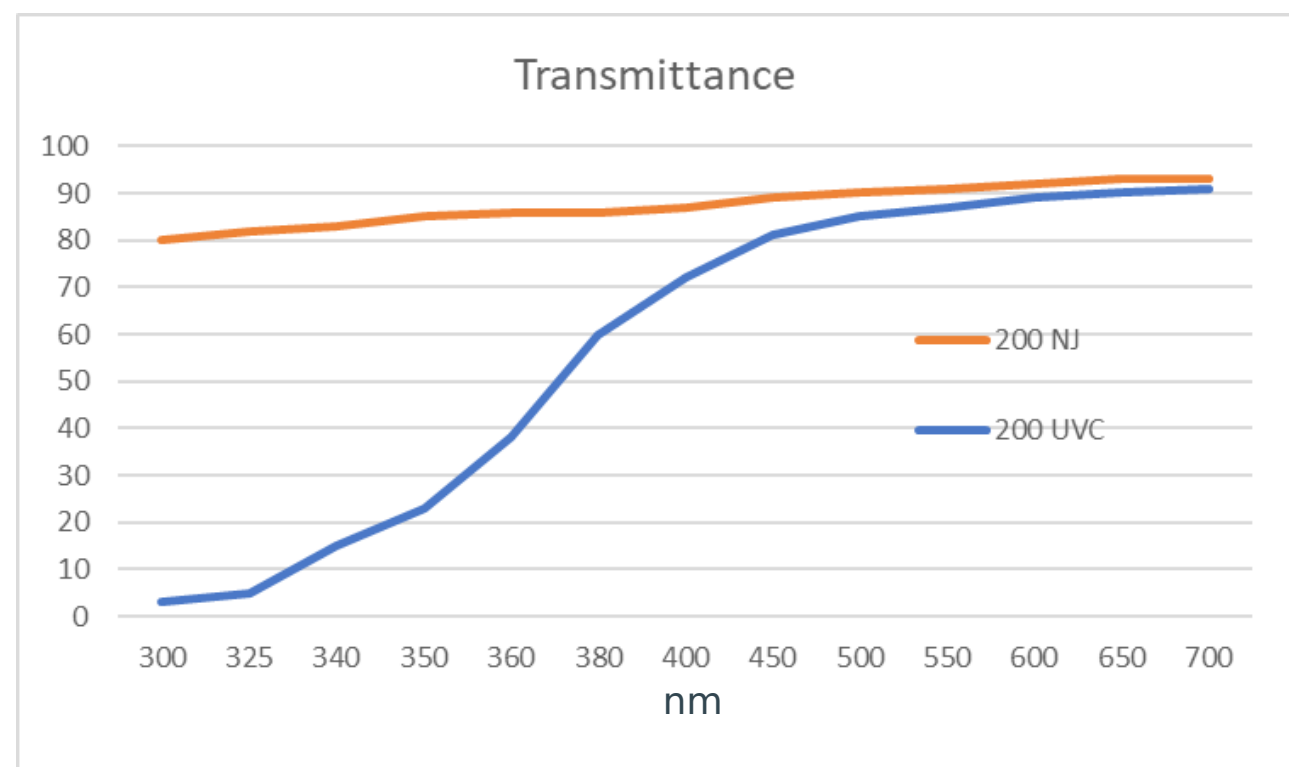


13

## Special grades. (UV Cut) **AGC** Your Dreams, Our Challenge

- **Another special grade we offer is the UV-Cut grade.**
- **The UV radiation is blocked to a certain extend and protects people underneath from harmful UV radiation**

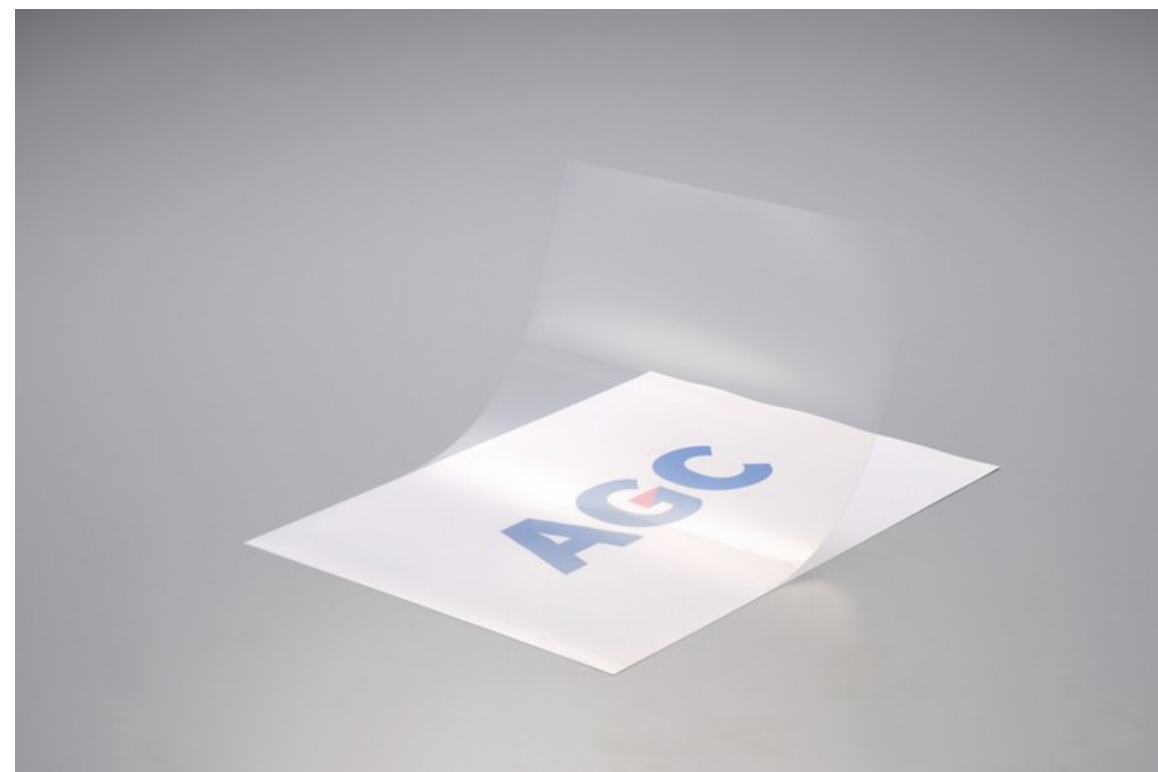
- **Today mostly used in ANZ region**
- **Available in different thicknesses**



14

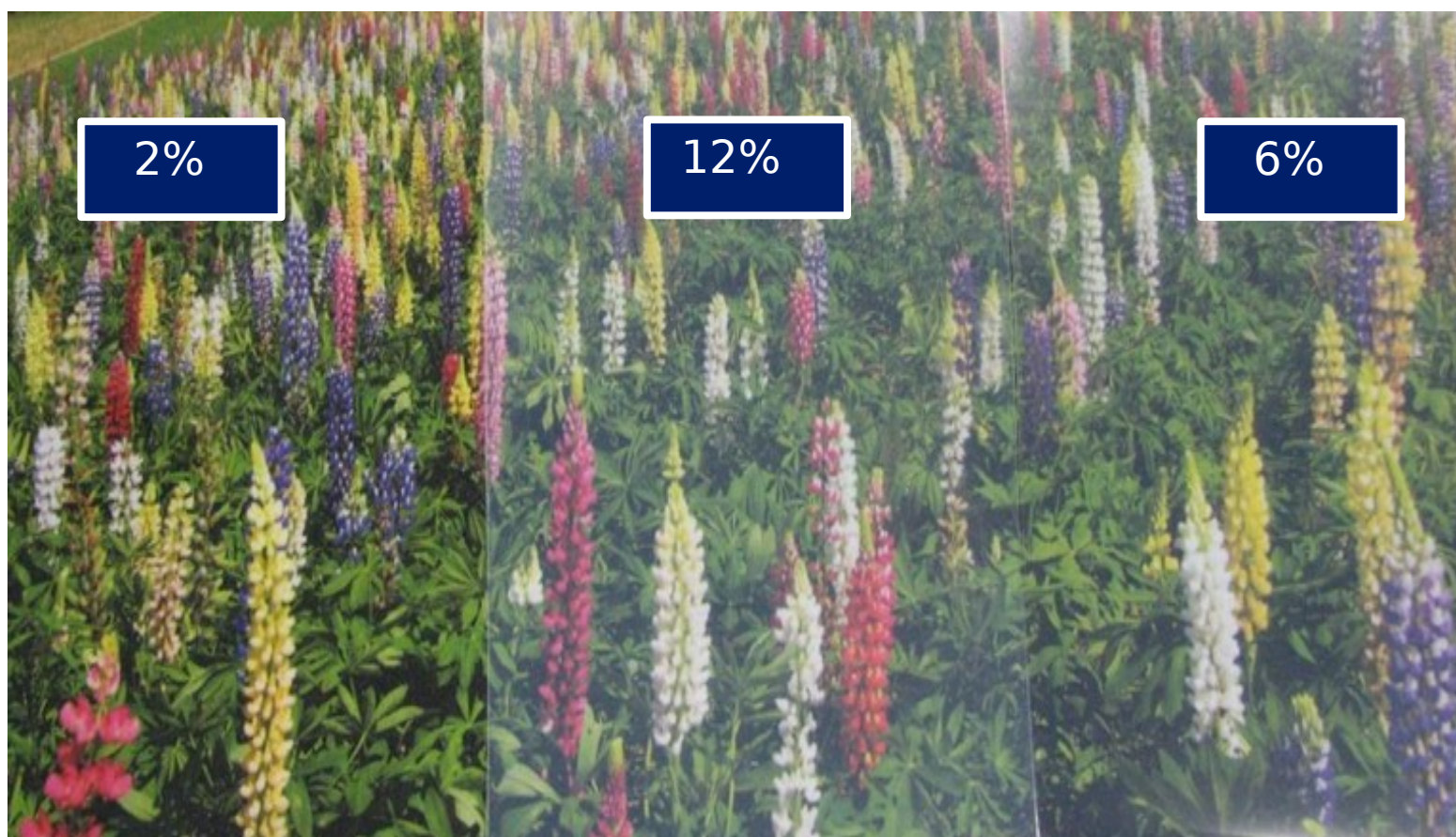
# Special grades (Low Haze)

- **Haze level depends on the thickness**
- **Multiple layer cushion systems create a milky appearance**
- **Not used often for facades**
- **Standard 250 micron has a haze level between 10-12%**



15

## Different clarity (haze level)



**250um thickness**

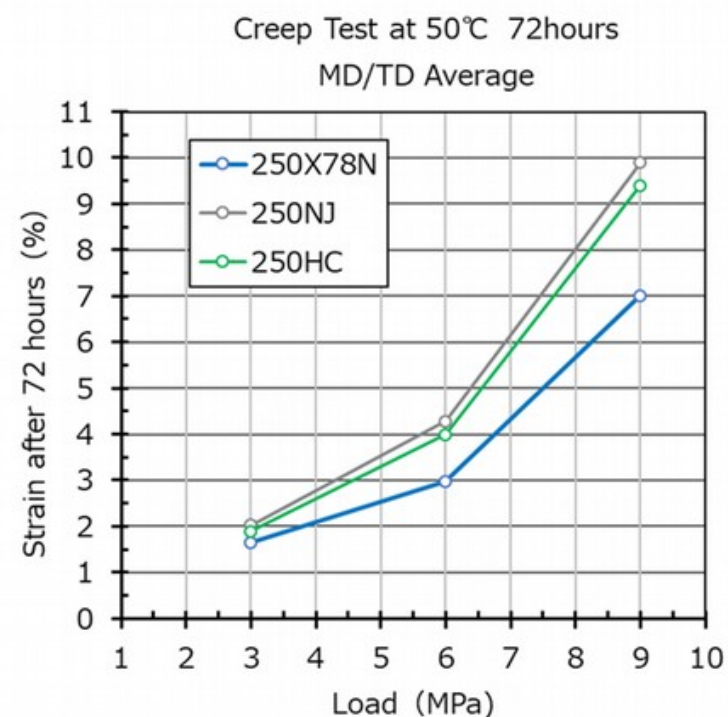
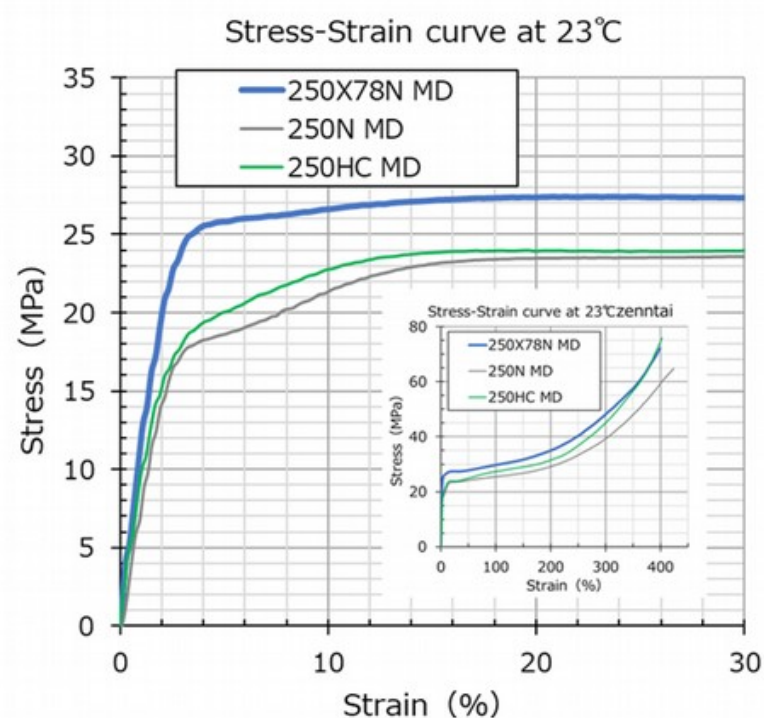
**6% commercialized in 2019**  
**2% to be commercialized in 2023**





## 2% Ultra Low Haze

- **First prototype show haze level below 2%**
- **Strength, also at high temperatures, is excellent**
- **Expect commercialization in 2023**



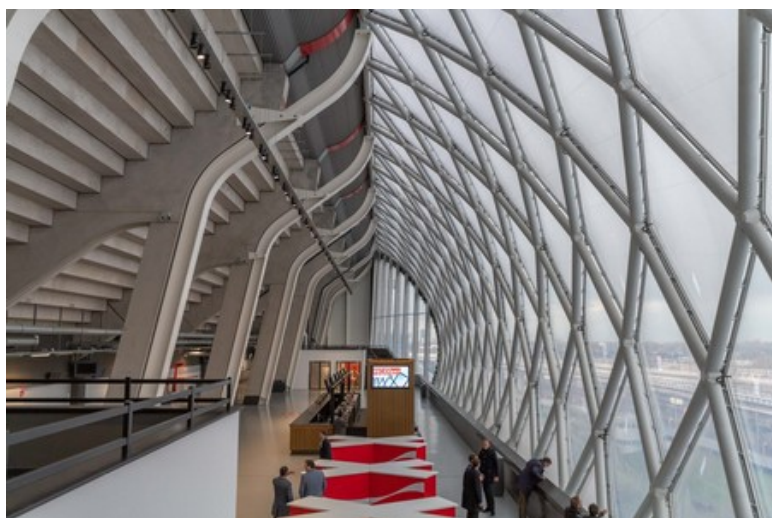
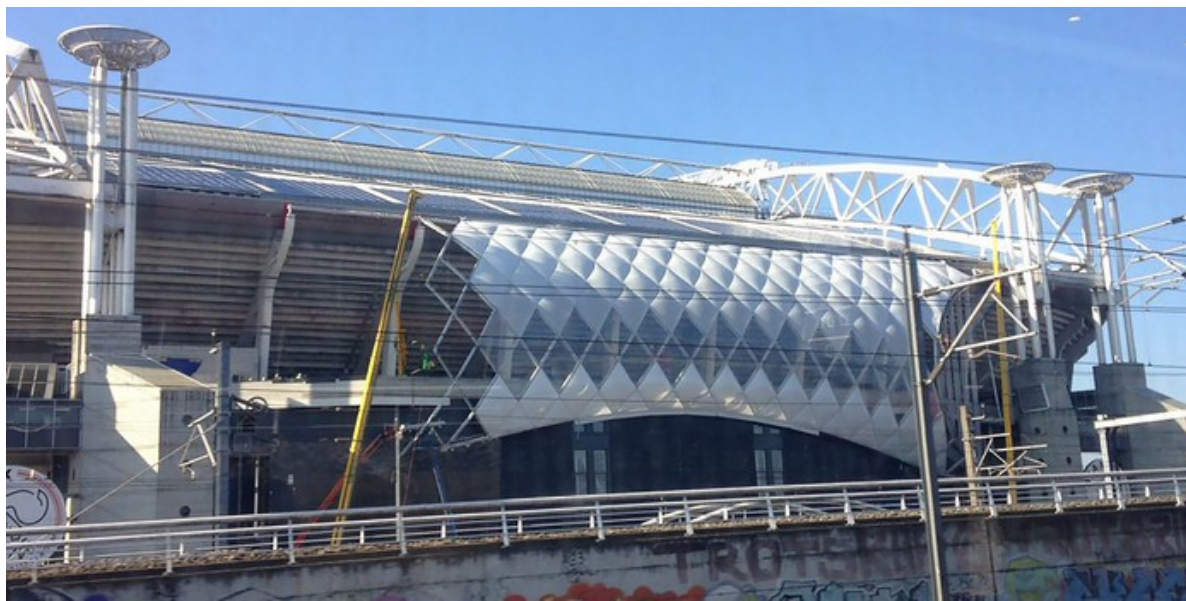


# Johan Cruijff Arena



**First project to use our 6% haze ETFE Film (250 micron)**

# Johan Cruijff Arena (Amsterdam)





- **The 2% haze is still a development product and not fully commercialized**
- **First trial fabrication and installation was done at the Caixa Forum project in Valencia**
- **Special handling during fabrication, transportation and installation is required to make sure the film is not damaged**



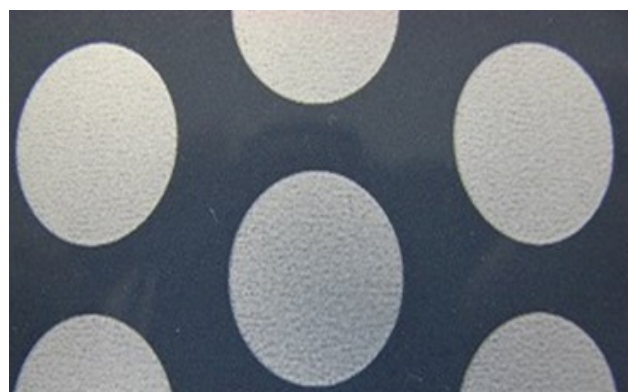
Caixa Forum, Valencia



21

## Special grades (printed film)

- **AGC offer in house printing on our ETFE Film.**
- **We have a range of designs which we offer as a standard**
- **New designs are possible if the volume is big enough (need to create new printing roll)**
- **Main function is temperature control. (designs cannot be detected from 5 meters high anymore)**
- **We use special inks (based on our own Fluorinated resin) and give warranty.**



22

- **We offer our standard reflective ink (P-type) and so called high reflective inks (H-type).**
- **We have now improved the durability of H type and can offer 10 years declining warranty on 1 layer applications as well. Previously we could only offer this in combination with a seal coating**
- **The new ink is called K-type.**
- **Latest R&D is around ETFE Film suitable for digital printing.**



Thank you

Ben Runhaar  
ben.runhaar@agc.com



# Prediction of rain noise in large halls covered by structural skins

Monika Rychtáriková<sup>1,2</sup>, Majid Lavasani<sup>1,2</sup> and Vojtech Chmelík<sup>2</sup>

<sup>1</sup>Faculty of Architecture, KU Leuven

<sup>2</sup>Faculty of Civil Engineering, STU Bratislava

[Monika.Rychtarikova@kuleuven.be](mailto:Monika.Rychtarikova@kuleuven.be)

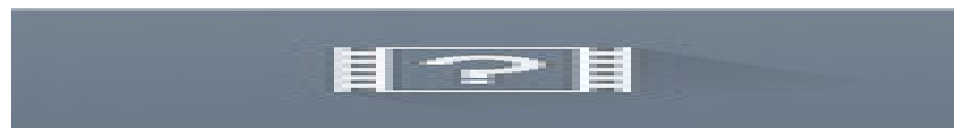


## One slide of theory

- Sound?
  - To have sound, **sound source** is needed
    - Vibrating object (frequency and amplitude)
    - Airflow that can bring molecules of air in vibration

- **Sound waves in air** (free field)

- Speed ca 340 m/s



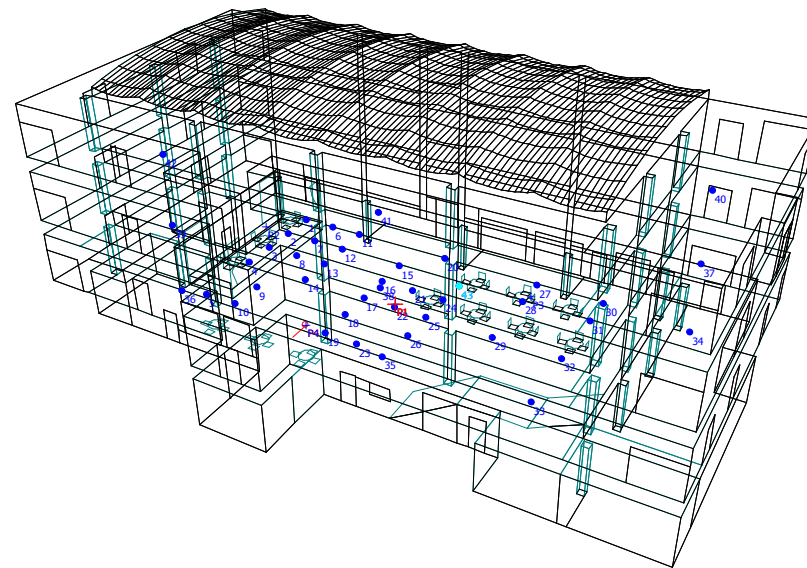
- **Sound reflections in rooms** (diffuse field)





# Building alias musical instrument

- Building as a musical instrument
  - Vibrating plates, whistling cavities



Odeon©1985-2009 Licensed to: KU Leuven Research & Development, Belgium Restricted version - research and teaching only!

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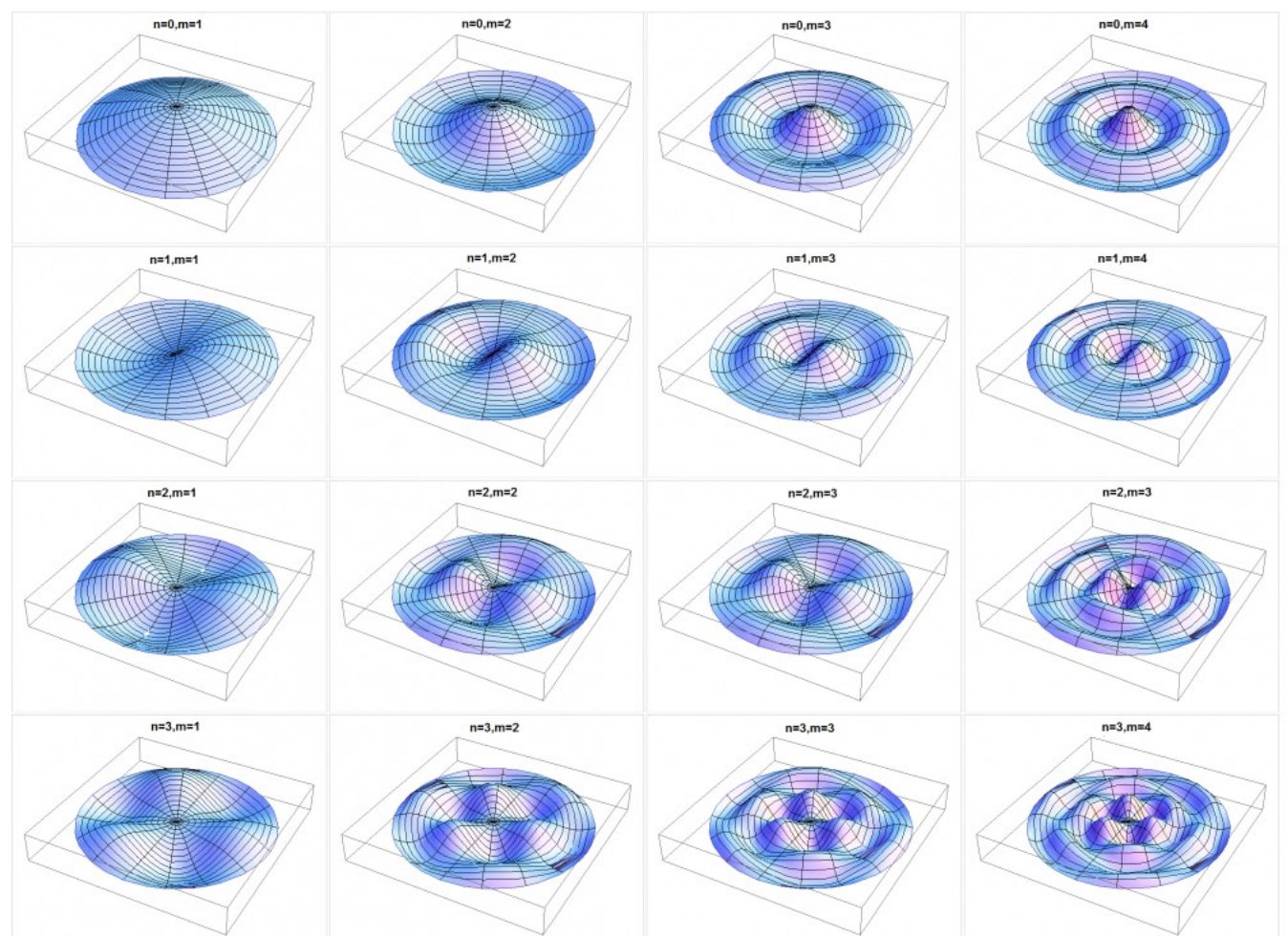
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Canton de Berne



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## Roof as a sound source

- Effect of thickness
- Effect of stiffness
- Effect of size
- Effect of edges
- ...



<http://www.bio-physics.at>

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# What is rain ?

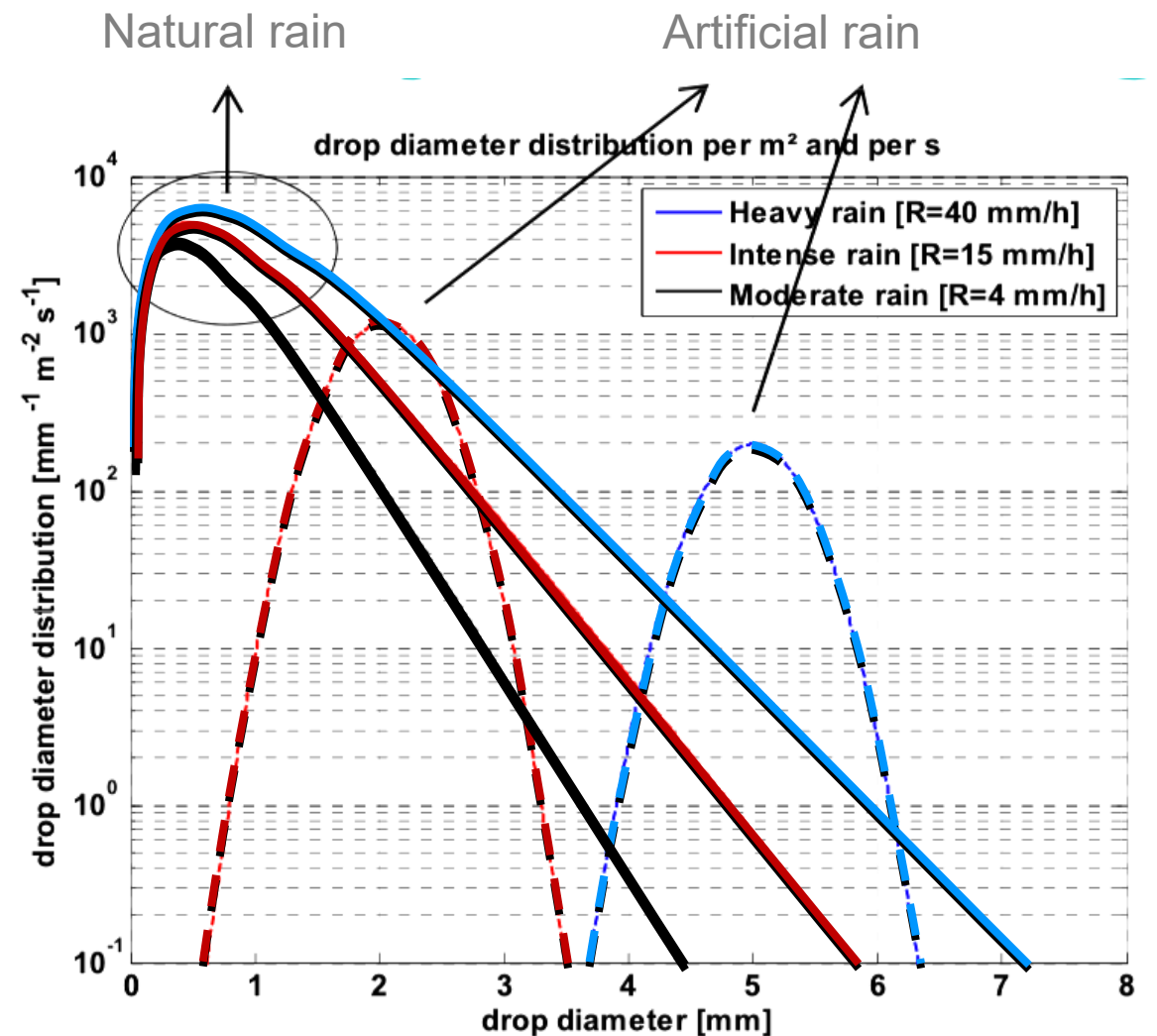
- ISO Standards 10140

- Intense Rain

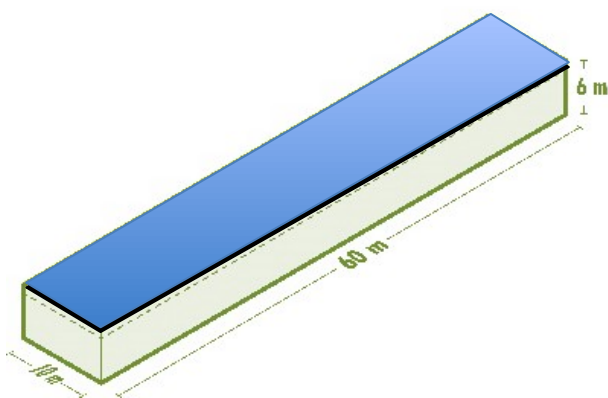
- Rainfall rate:  $15 \text{ mm}\cdot\text{h}^{-1}$
- Drop diameter: 2 mm
- Impact velocity:  $4 \text{ m}\cdot\text{s}^{-1}$

- Heavy Rain

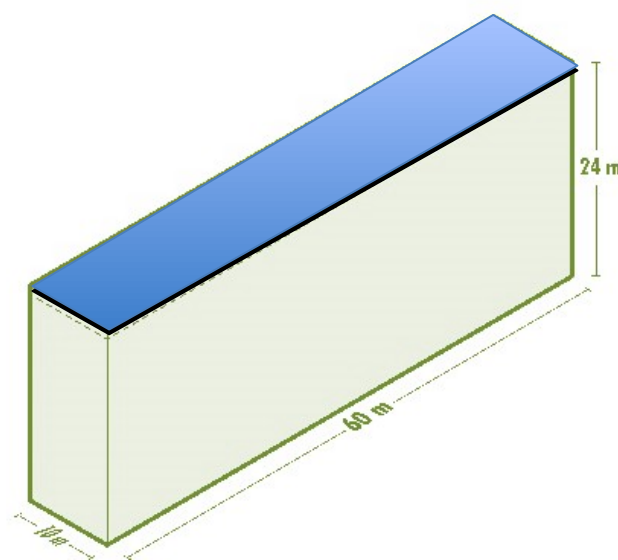
- Rainfall rate:  $40 \text{ mm}\cdot\text{h}^{-1}$
- Drop diameter: 5 mm
- Impact velocity:  $7 \text{ m}\cdot\text{s}^{-1}$



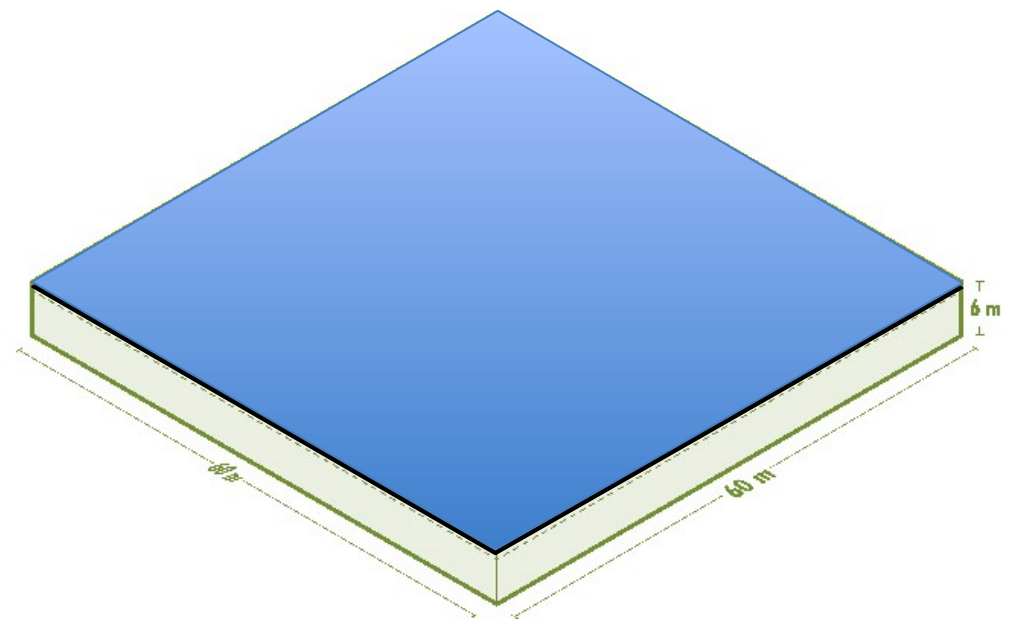
## Erster Blick – influence of shape



**Case 1**  
Length 60 m  
Width 10 m  
Height 6 m



**Case 2**  
Length 60 m  
Width 10 m  
Height 24 m

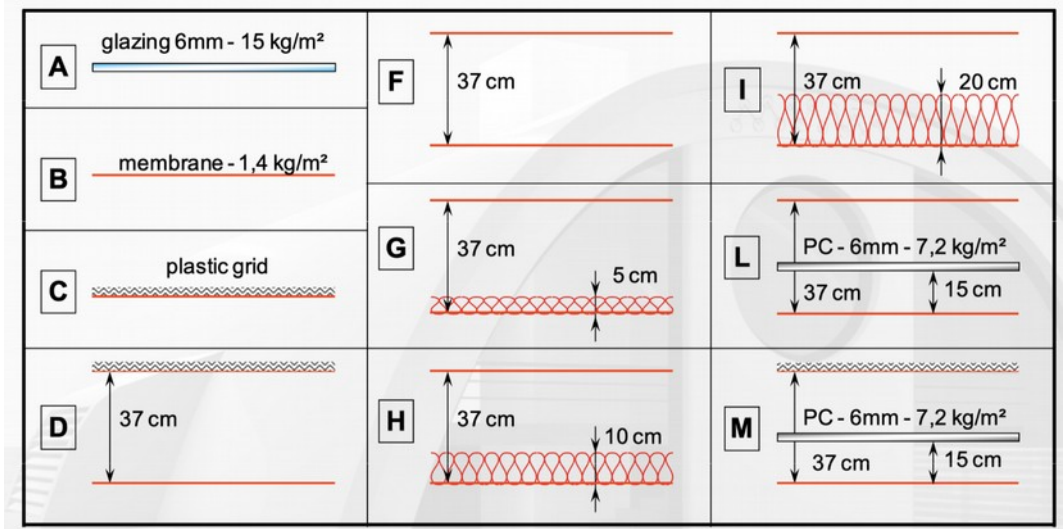
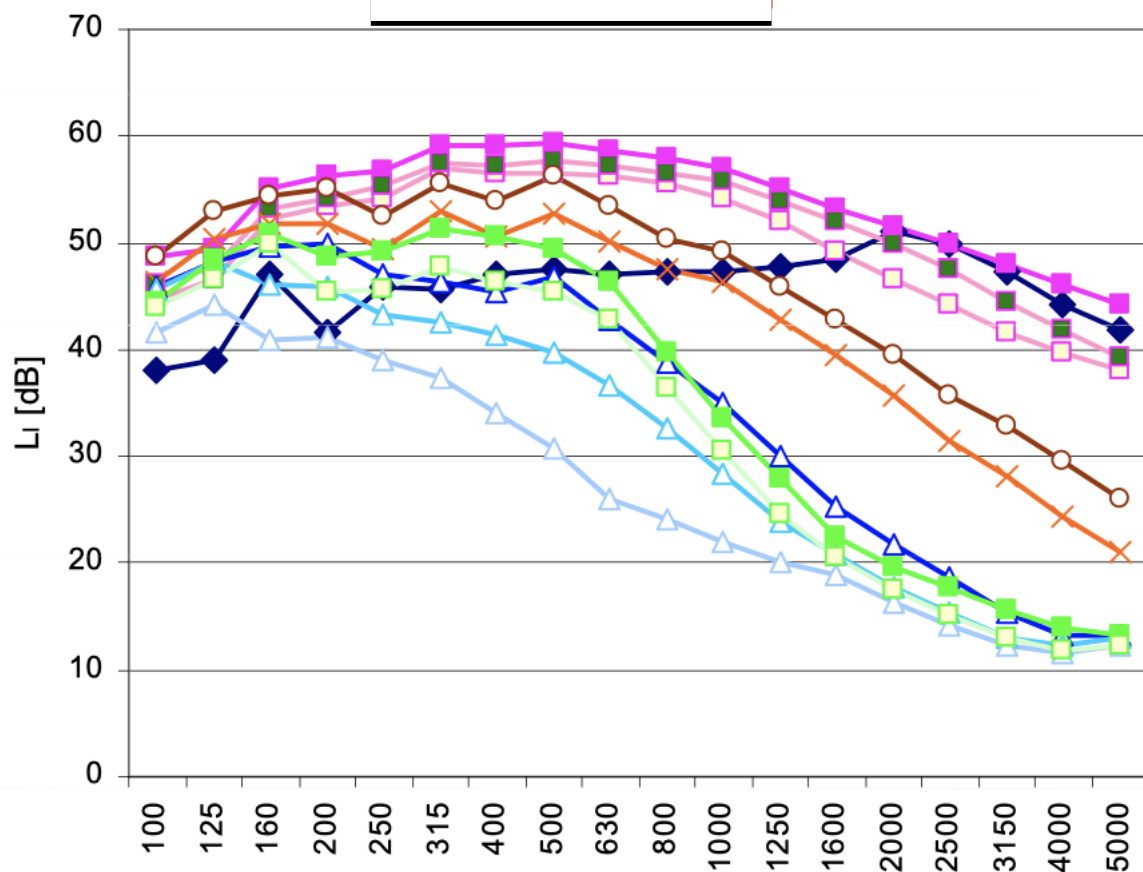


**Case 3**  
Length 60 m  
Width 60 m  
Height 6 m



# Rain noise - lightweight roof from literature

## Measured spectra



- ◆ A - Glazing 6mm - LIA = 58,9 dB
- ◆ B - Membrane 1,4 kg/m<sup>2</sup> - LIA = 65,6 dB
- C1 - Membrane 1,4 kg/m<sup>2</sup> + white mesh - LIA = 62,5 dB
- ◆ C3 - Membrane 1,4 kg/m<sup>2</sup> + darkgreen mesh - LIA = 64 dB
- F (2) - Double membrane - 37 cm cavity - LIA = 59,2 dB
- × D1 - Double membrane - 37 cm cavity + white mesh - LIA = 56,1 dB
- △ G - Double membrane - 37 cm cavity - 5 cm mineral wool - LIA = 49,5 dB
- △ H - Double membrane - 37 cm cavity - 10 cm mineral wool - LIA = 44,6 dB
- △ I - Double membrane - 37 cm cavity - 20 cm mineral wool - LIA = 38,6 dB
- ◆ L - Double membrane - 37 cm cavity - 6 mm PC sheet at 15 cm - LIA = 52,4 dB
- M - Double membrane - 37 cm cavity - PC sheet at 15 cm - white mesh - LIA = 48,8 dB

# Rain spectra - literature

## Measured spectra

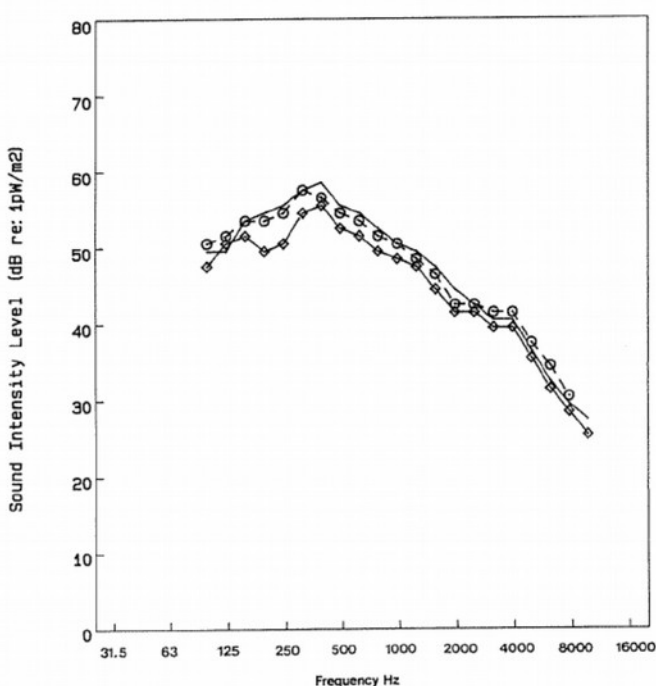
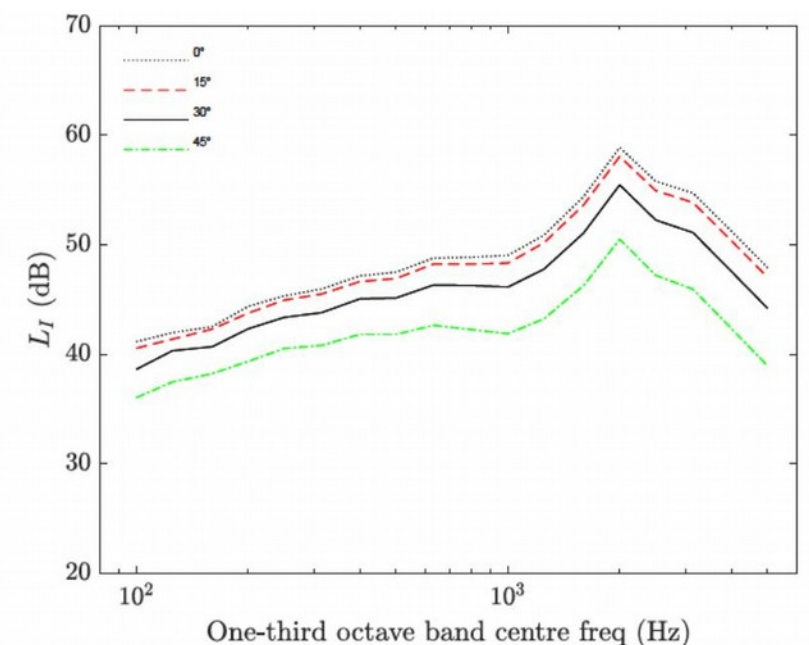
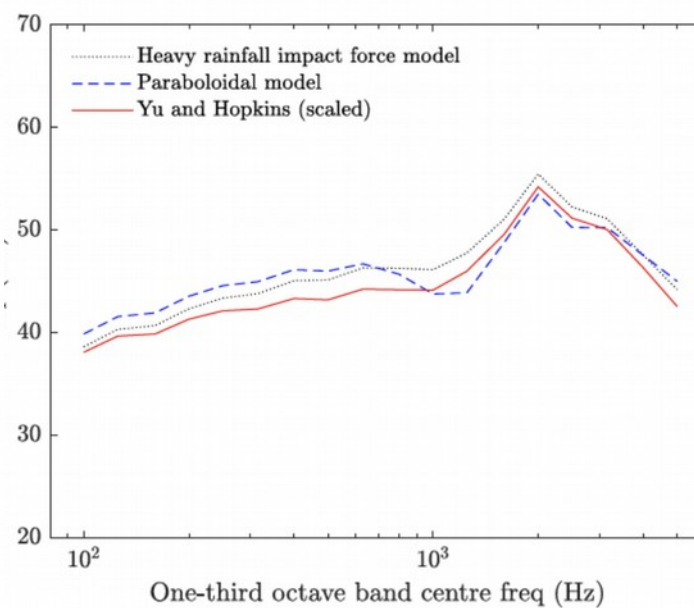


Fig. 6. Sound intensity radiated by roofs due to simulated rainfall of 80 mm/h. (—, System 1; -○- -○-, System 5; -◇- -◇-, System 6.)

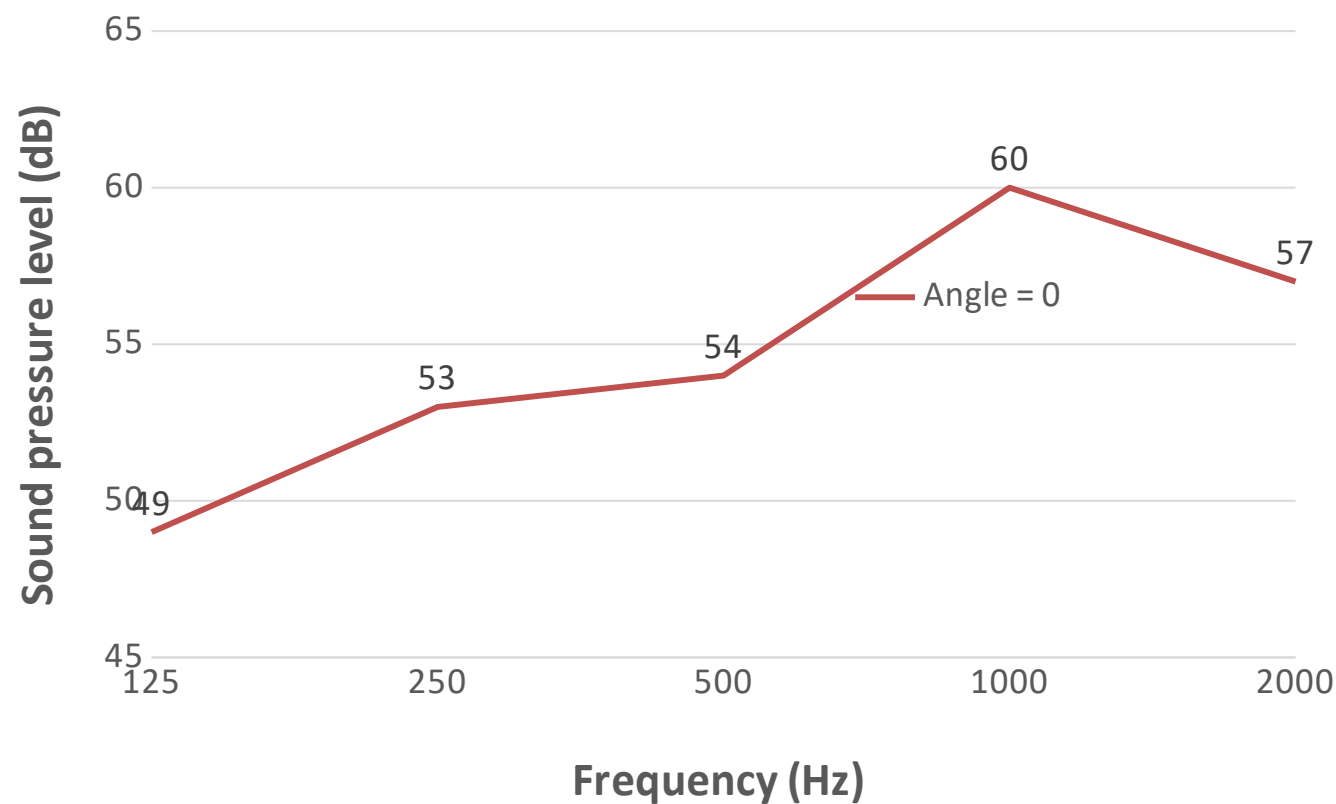


Predicted rain noise sound pressure level (dB) for rainfall on the standard reference specimen for heavy rain inclined at different angles (Schimid et al., 2020)



# Rain spectra - literature

- Predicted rain noise sound pressure level(dB) for rainfall on the standard reference specimen for a flat roof

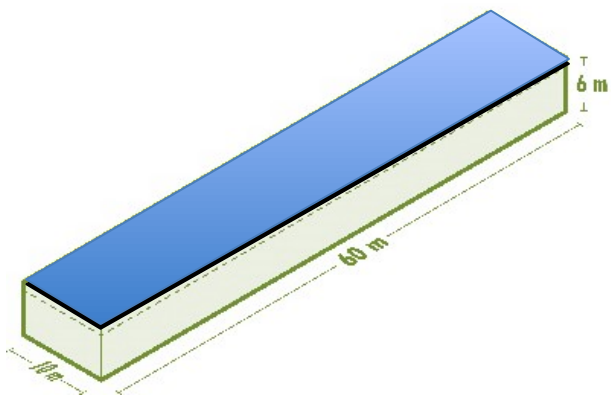


## Preliminary study

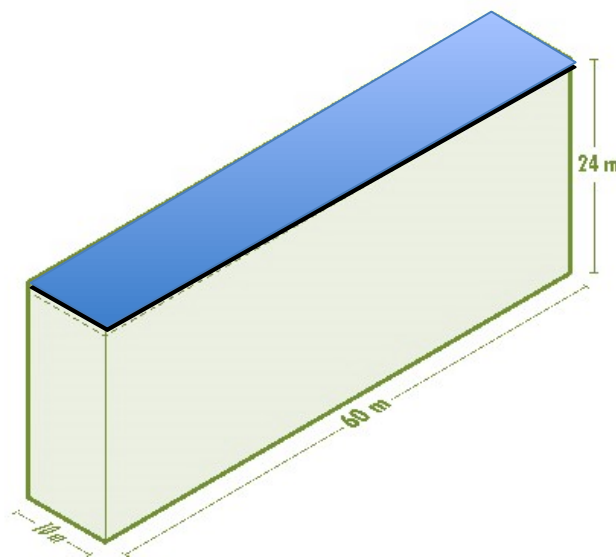
Majid Lavasani – Vojtech Chmelík – Monika Rychtarikova



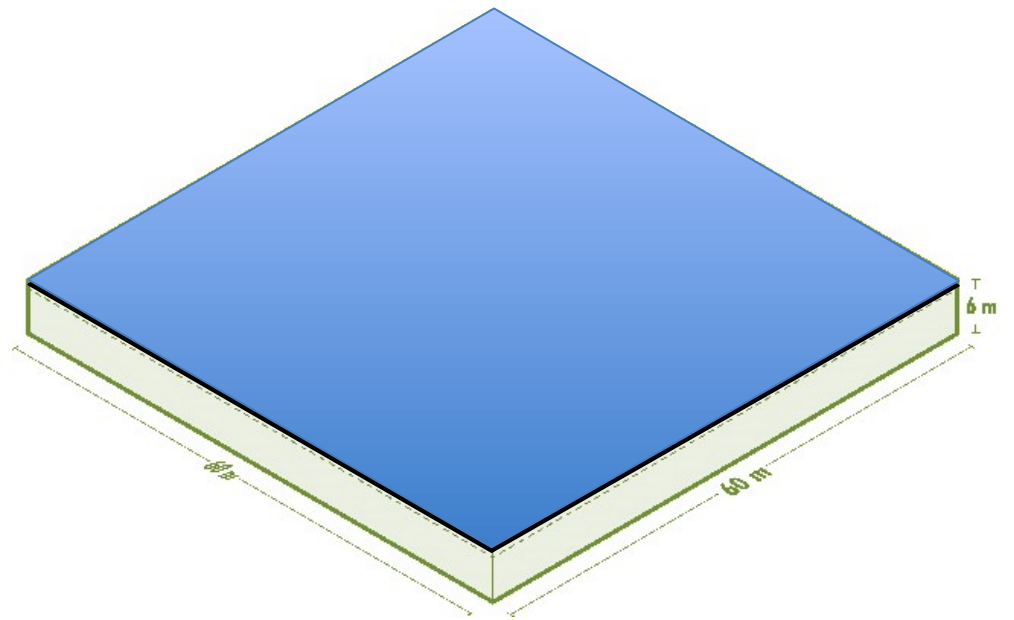
# Erster Blick – influence of shape



**Case 1**  
Length 60 m  
Width 10 m  
Height 6 m



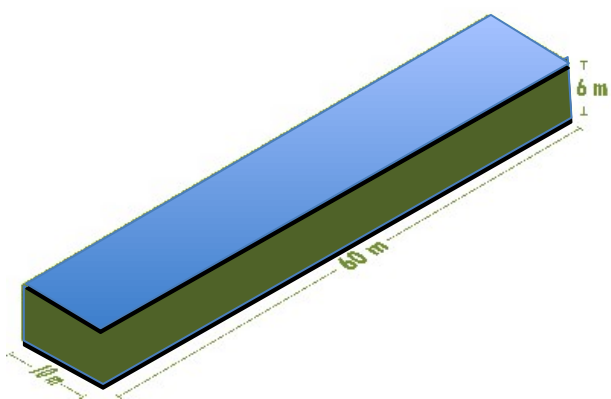
**Case 2**  
Length 60 m  
Width 10 m  
Height 24 m



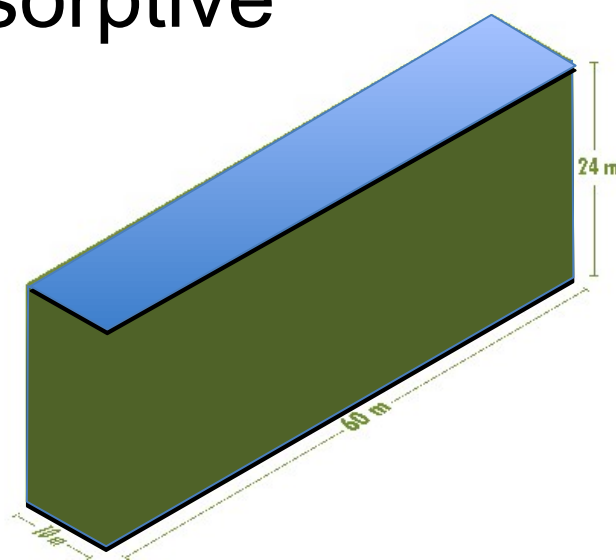
**Case 3**  
Length 60 m  
Width 60 m  
Height 6 m

# Erster Blick – influence of wall absorption

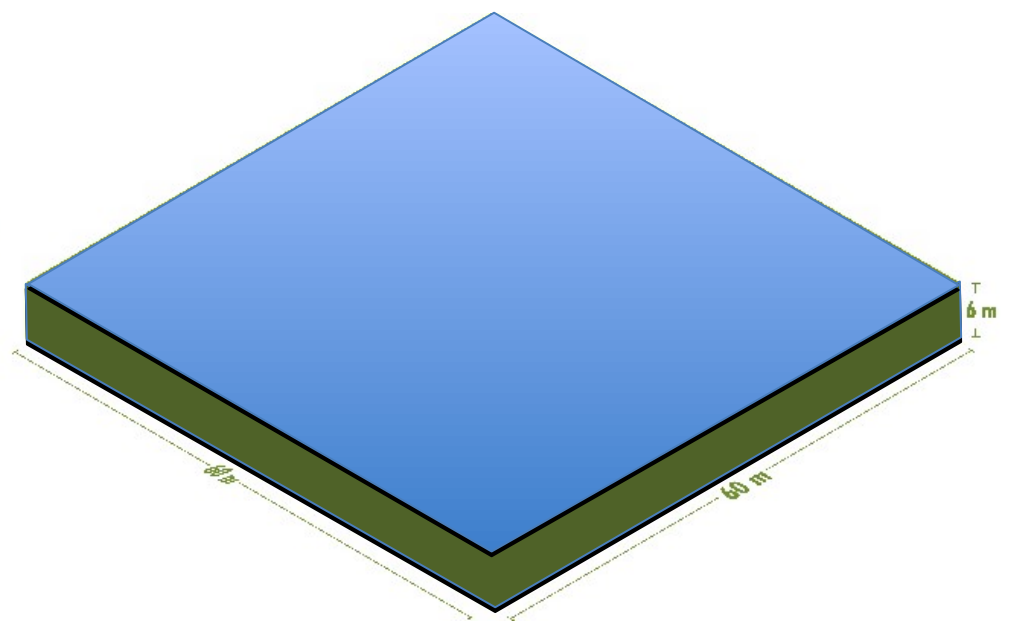
- Highly sound absorptive



**Case 1**  
Length 60 m  
Width 10 m  
Height 6 m



**Case 2**  
Length 60 m  
Width 10 m  
Height 24 m

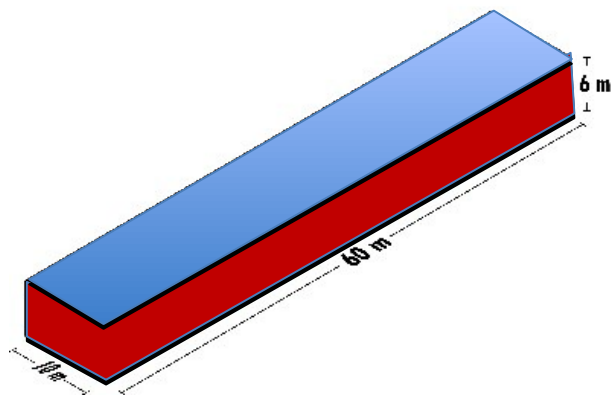


**Case 3**  
Length 60 m  
Width 60 m  
Height 6 m

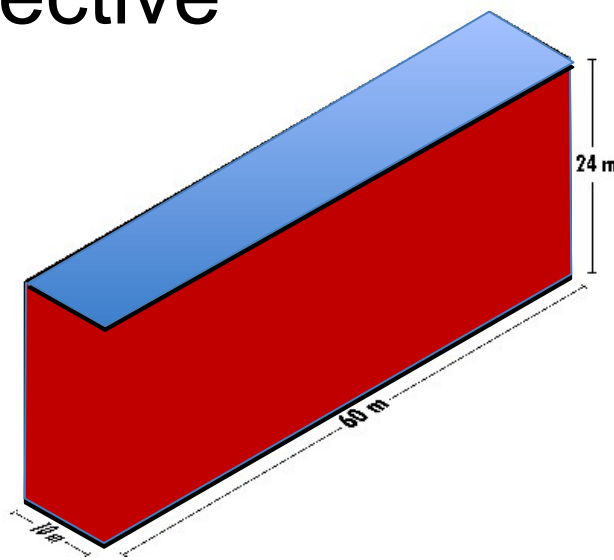


# Erster Blick – influence of wall absorption

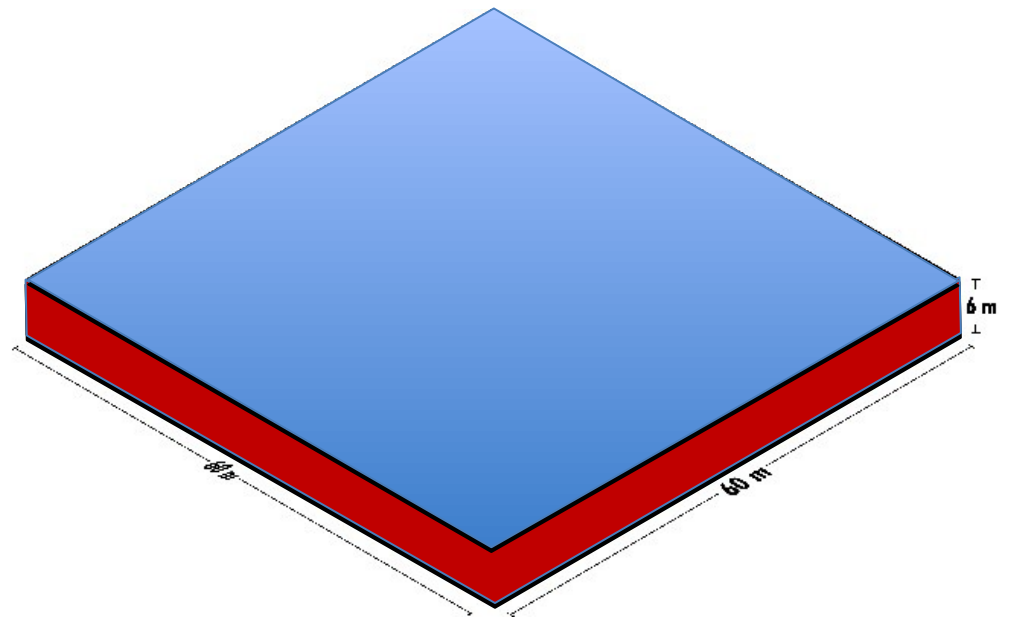
- Highly sound reflective



**Case 1**  
Length 60 m  
Width 10 m  
Height 6 m

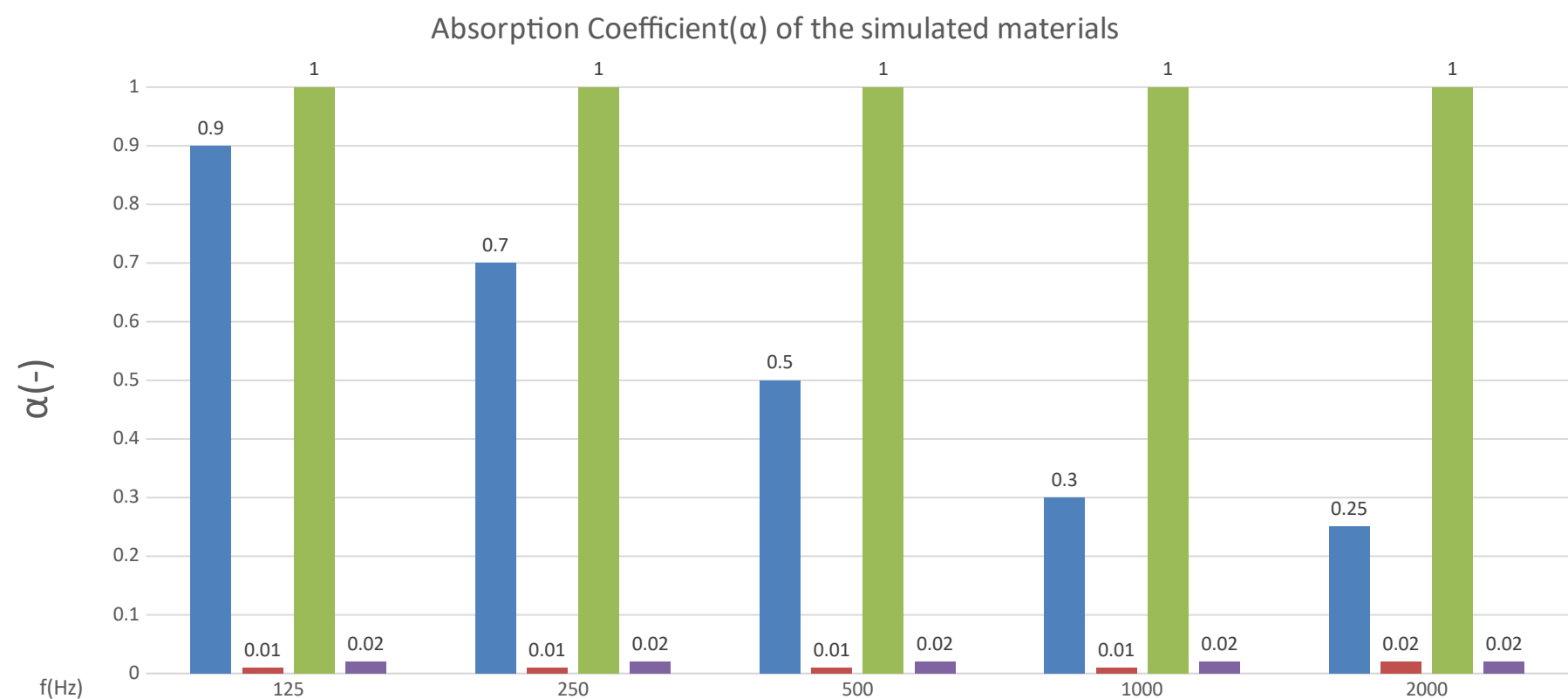


**Case 2**  
Length 60 m  
Width 10 m  
Height 24 m



**Case 3**  
Length 60 m  
Width 60 m  
Height 6 m

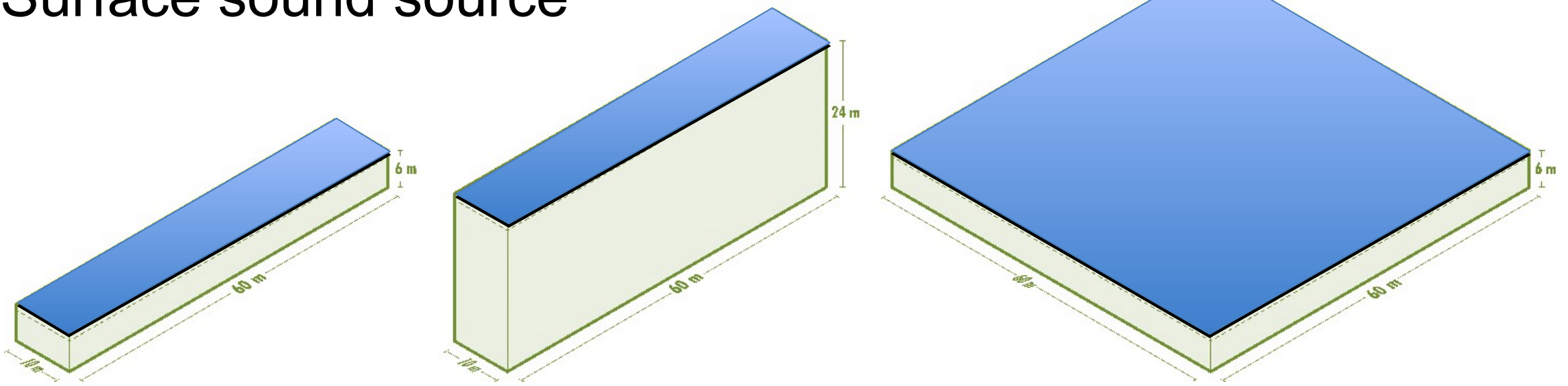
## Sound absorption of used materials





# Influence of sound source modeling

- Surface sound source



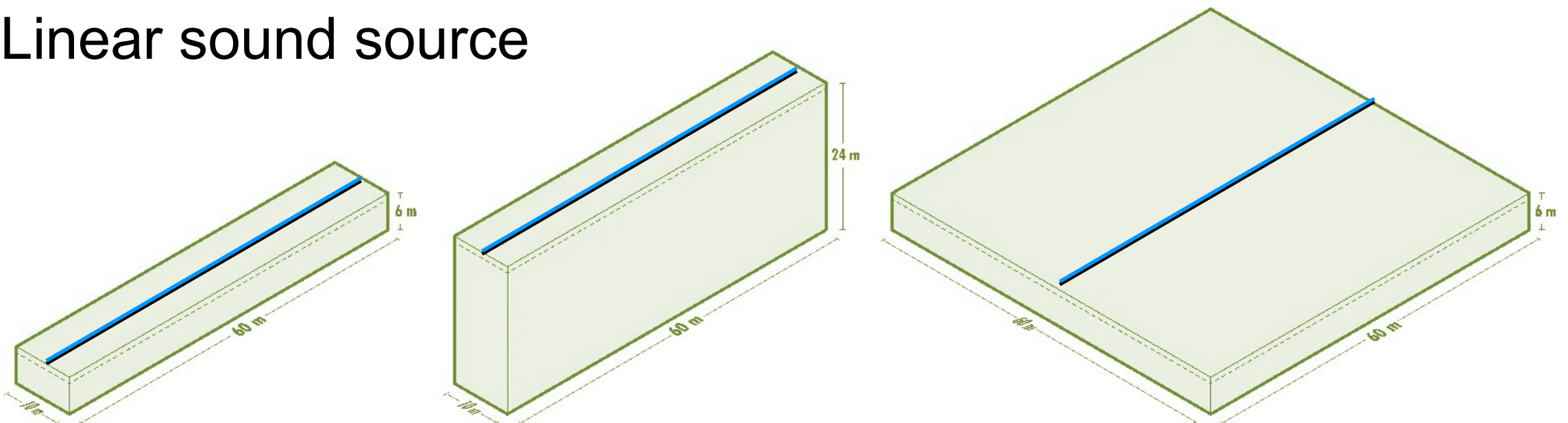
**Case 1**  
Length 60 m  
Width 10 m  
Height 6 m

**Case 2**  
Length 60 m  
Width 10 m  
Height 24 m

**Case 3**  
Length 60 m  
Width 60 m  
Height 6 m

# Influence of sound source modeling

- Linear sound source



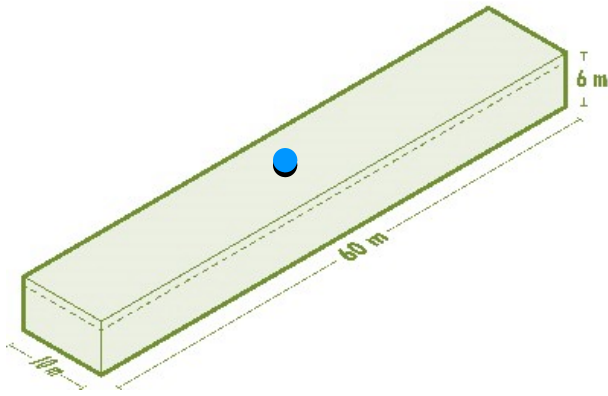
**Case 1**  
Length 60 m  
Width 10 m  
Height 6 m

**Case 2**  
Length 60 m  
Width 10 m  
Height 24 m

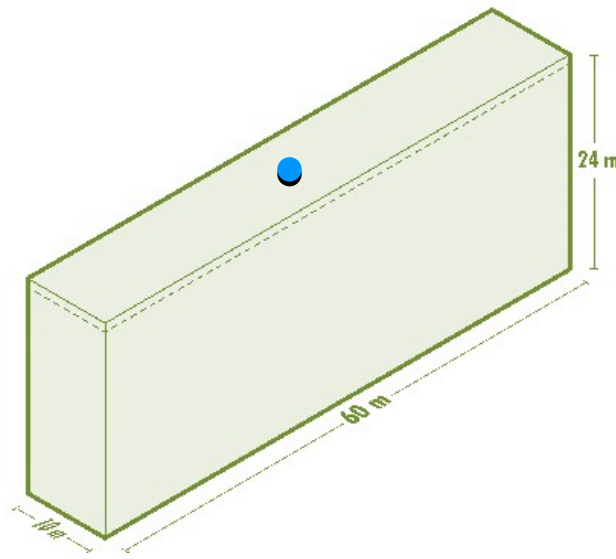
**Case 3**  
Length 60 m  
Width 60 m  
Height 6 m

# Influence of sound source modeling

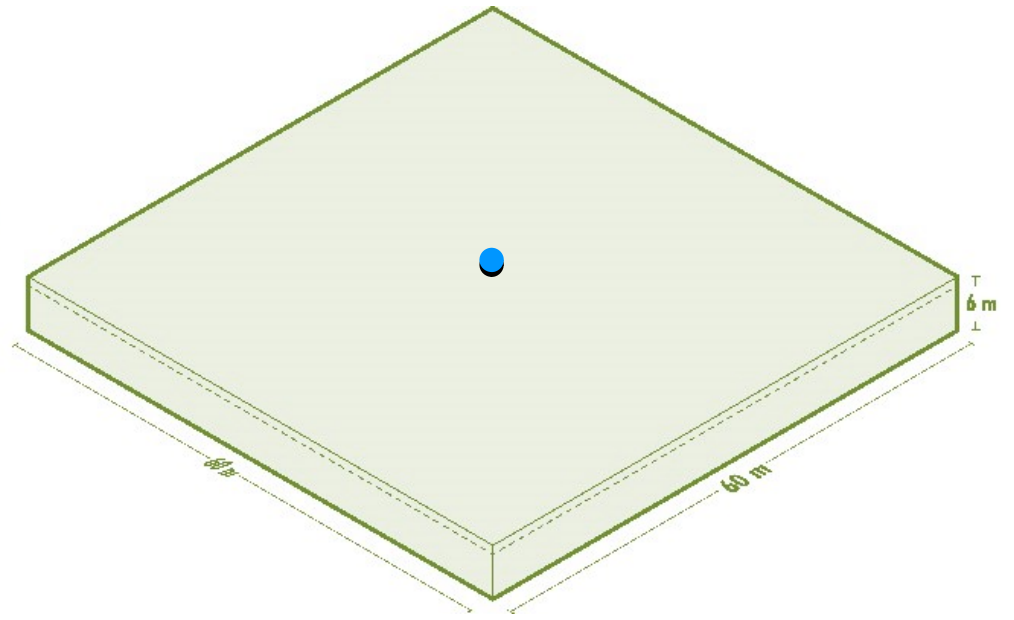
- Point source



**Case 1**  
Length 60 m  
Width 10 m  
Height 6 m

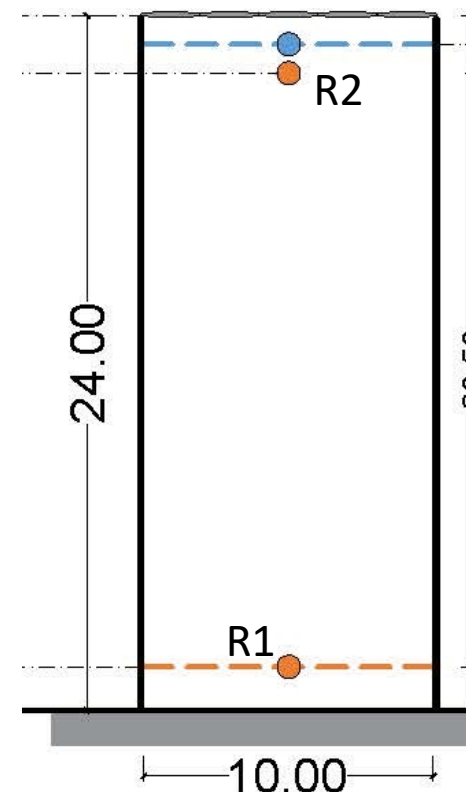
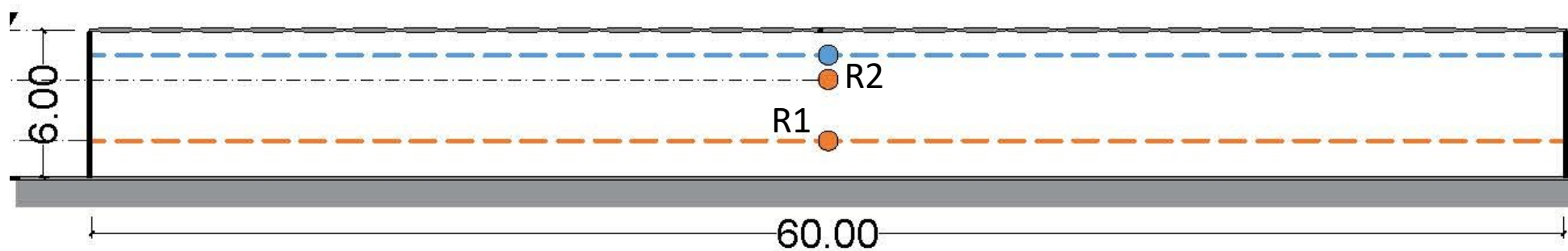
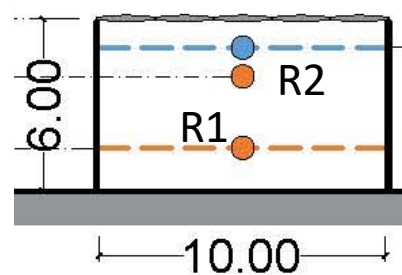


**Case 2**  
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Width 10 m  
Height 24 m



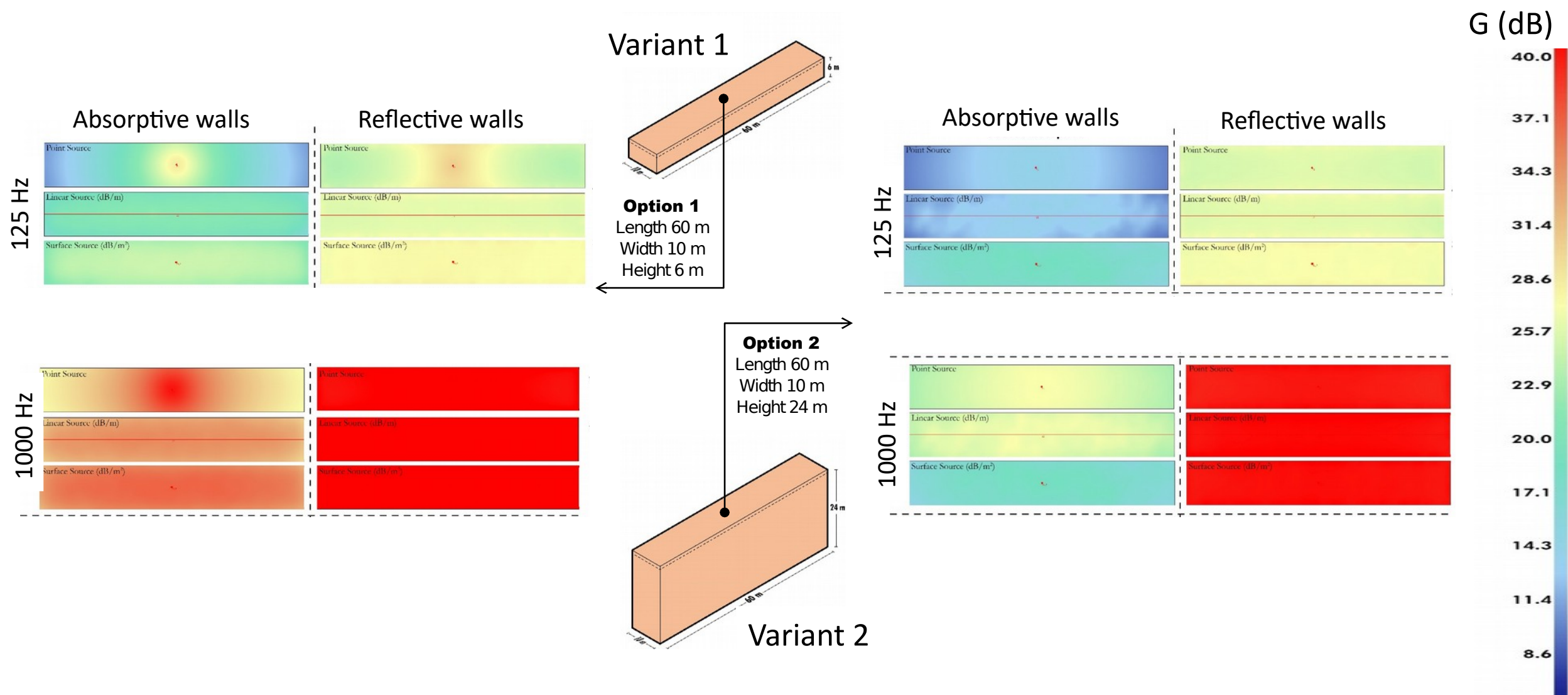
**Case 3**  
Length 60 m  
Width 60 m  
Height 6 m

# Influence of sound source modeling

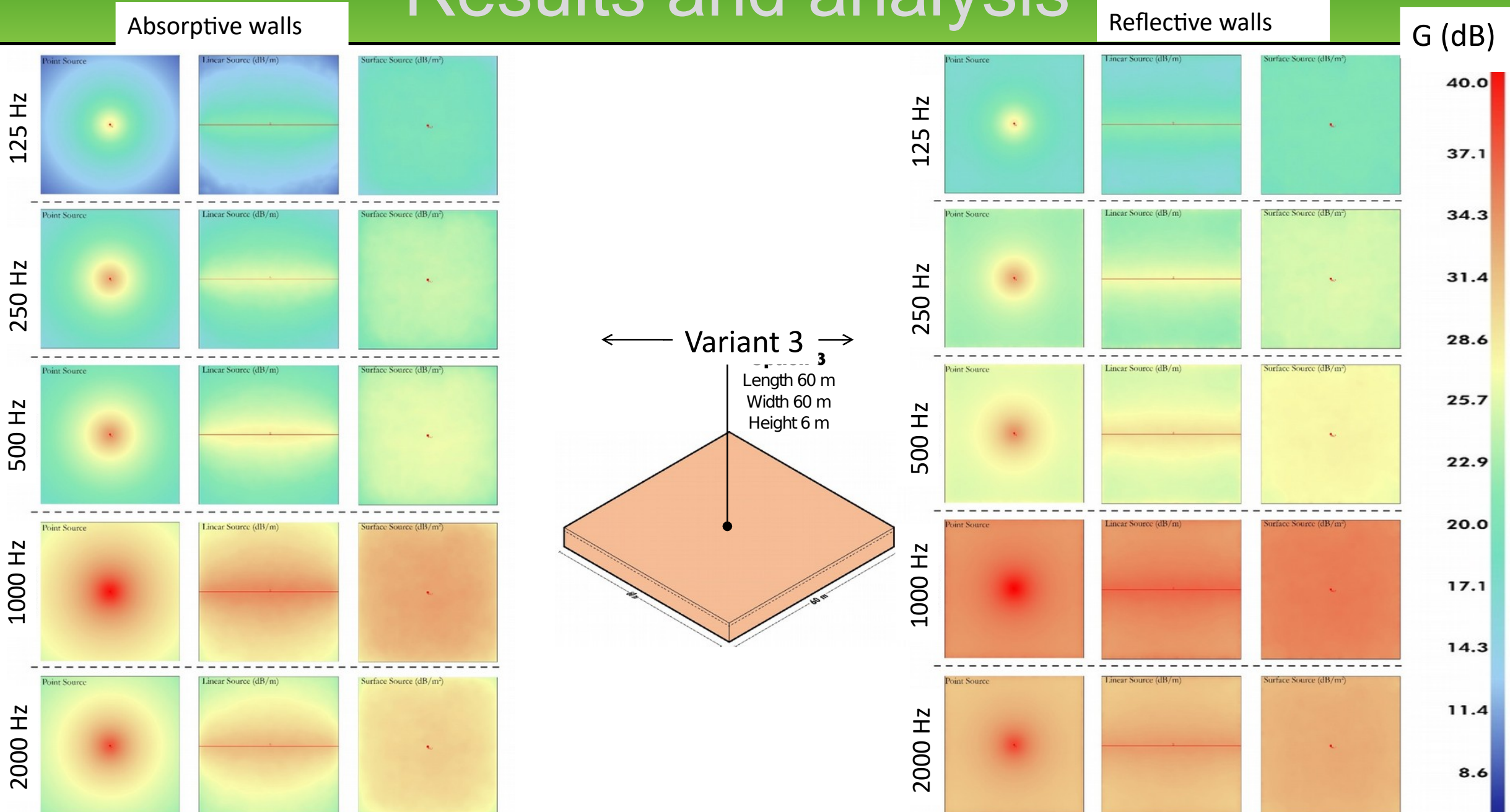




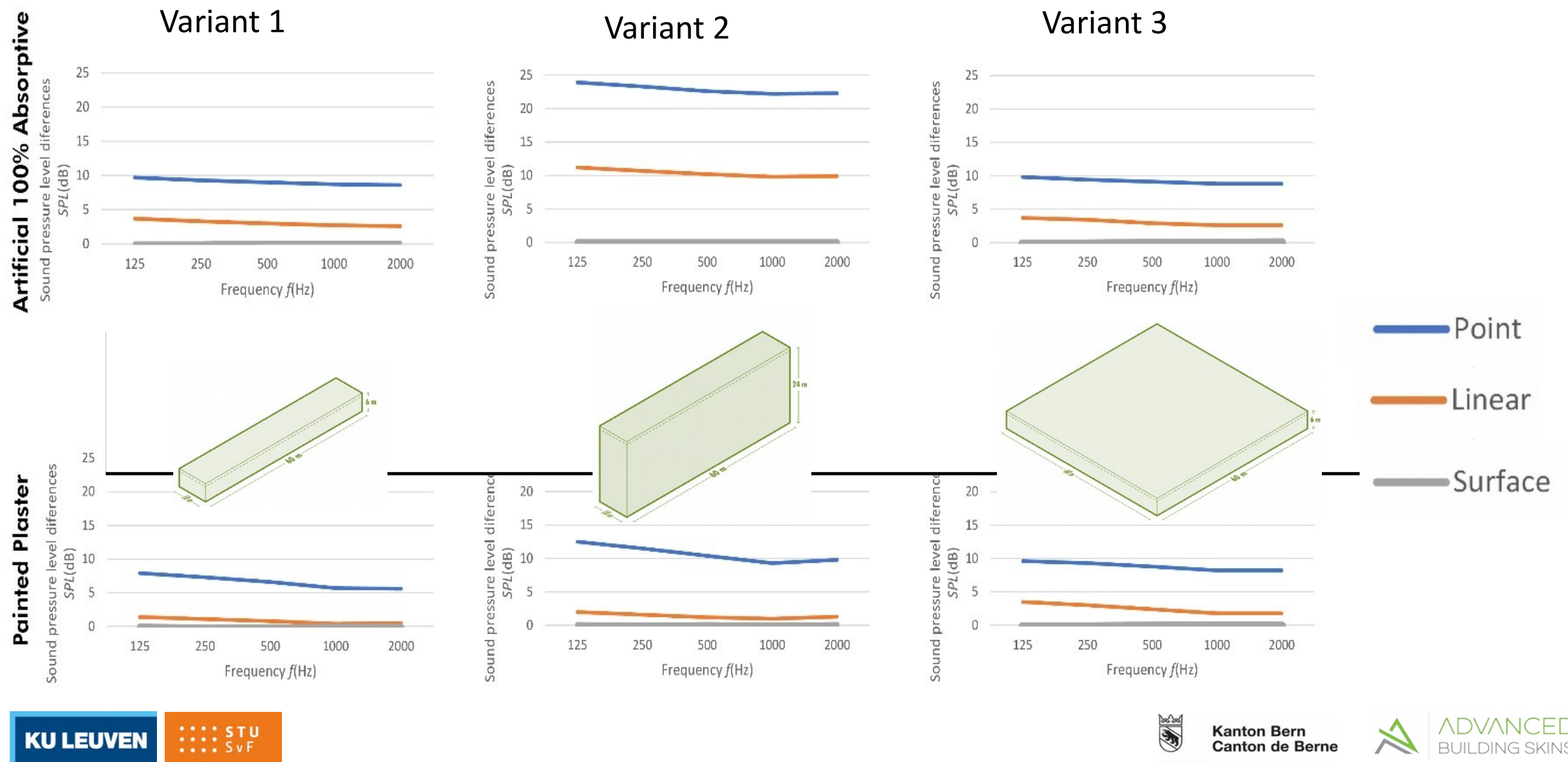
# Results and analysis



# Results and analysis



# Results and analysis



## Preliminary conclusions

- Rain noise attenuation in 3 simulated rooms is not very significant - roof acts as surface source
- Research focus - noise suppression at source level
  - Important/ complicating factors are:
    - thickness and tension of membrane
    - multiple layers (cushions)
    - Impact of edge effect
- Research on disturbance of rain noise/ psychoacoustic



# Transparent ETFE cushion roof

## Fridolin Mall

formTL

fridolin.mall@form-tl.de

formTL ingenieure für tragwerk und leichtbau gmbh

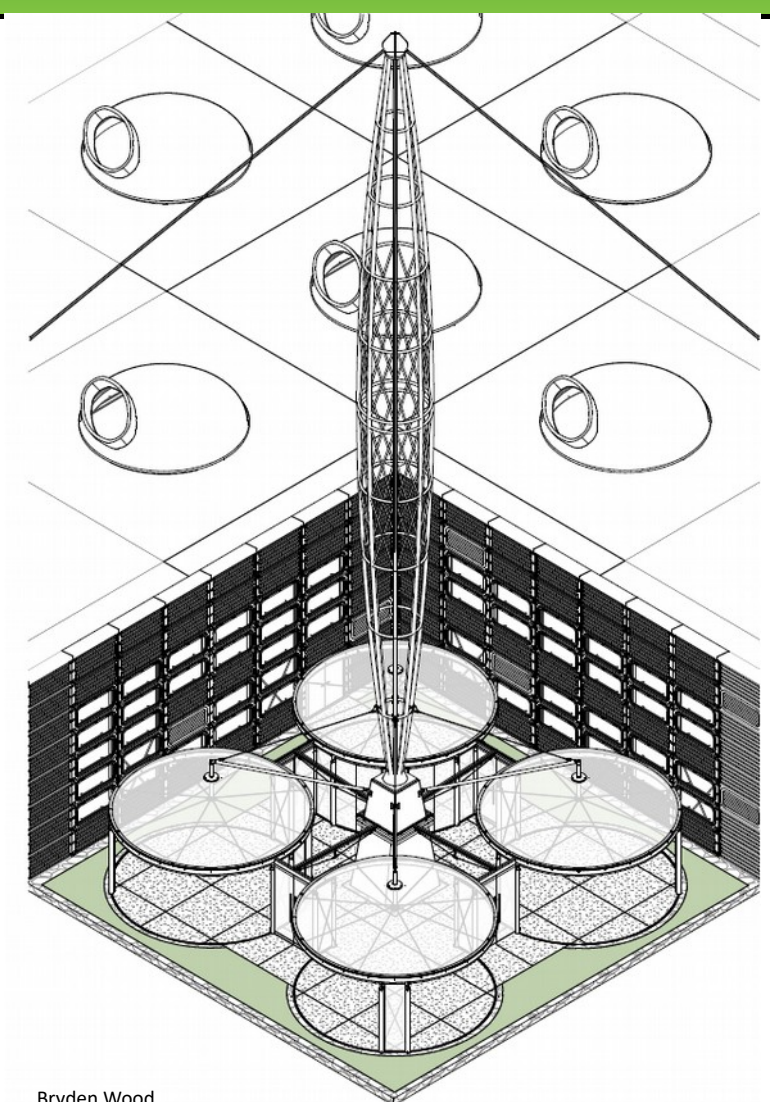
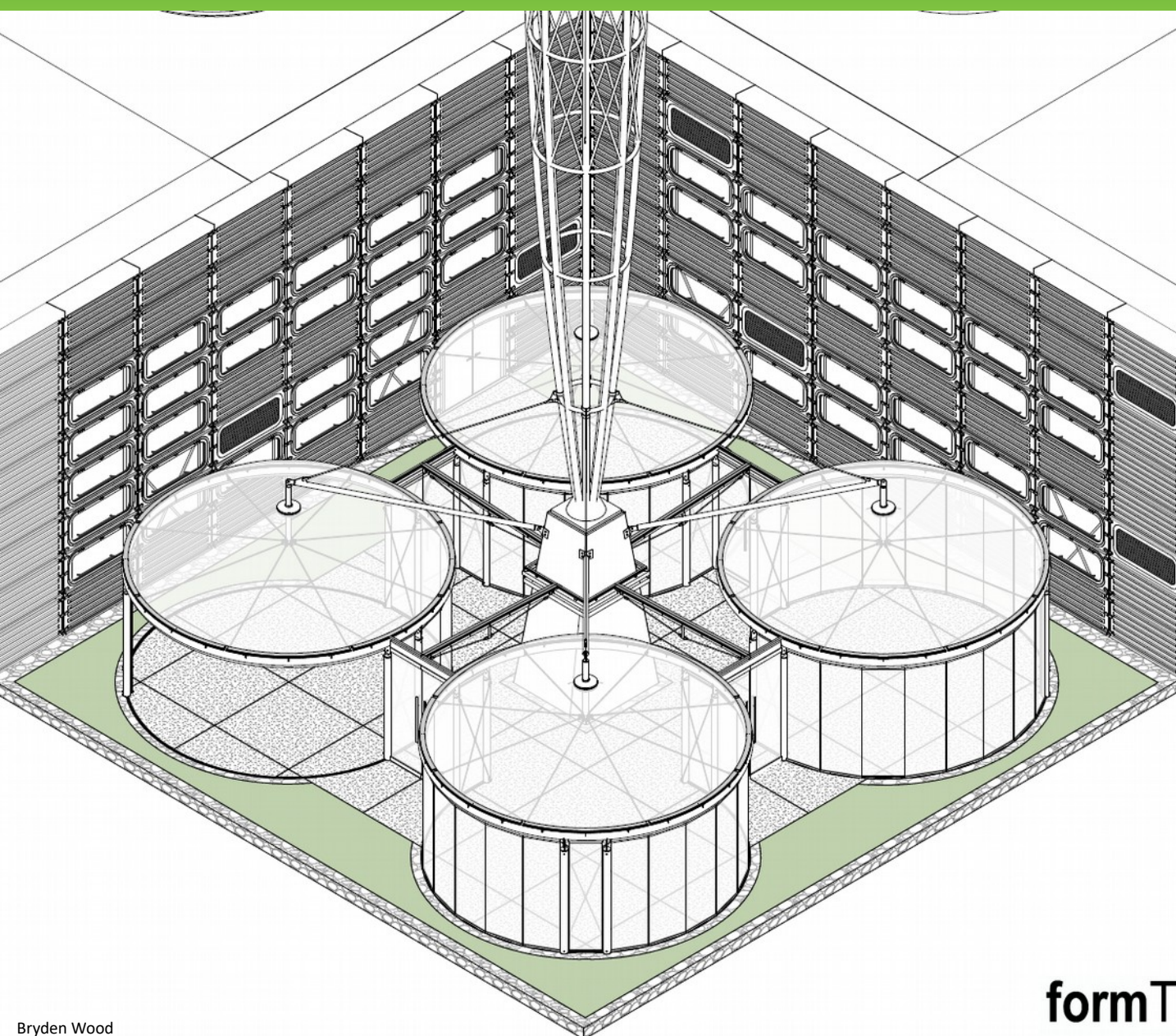


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Canton de Berne



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## introduction



Bryden Wood

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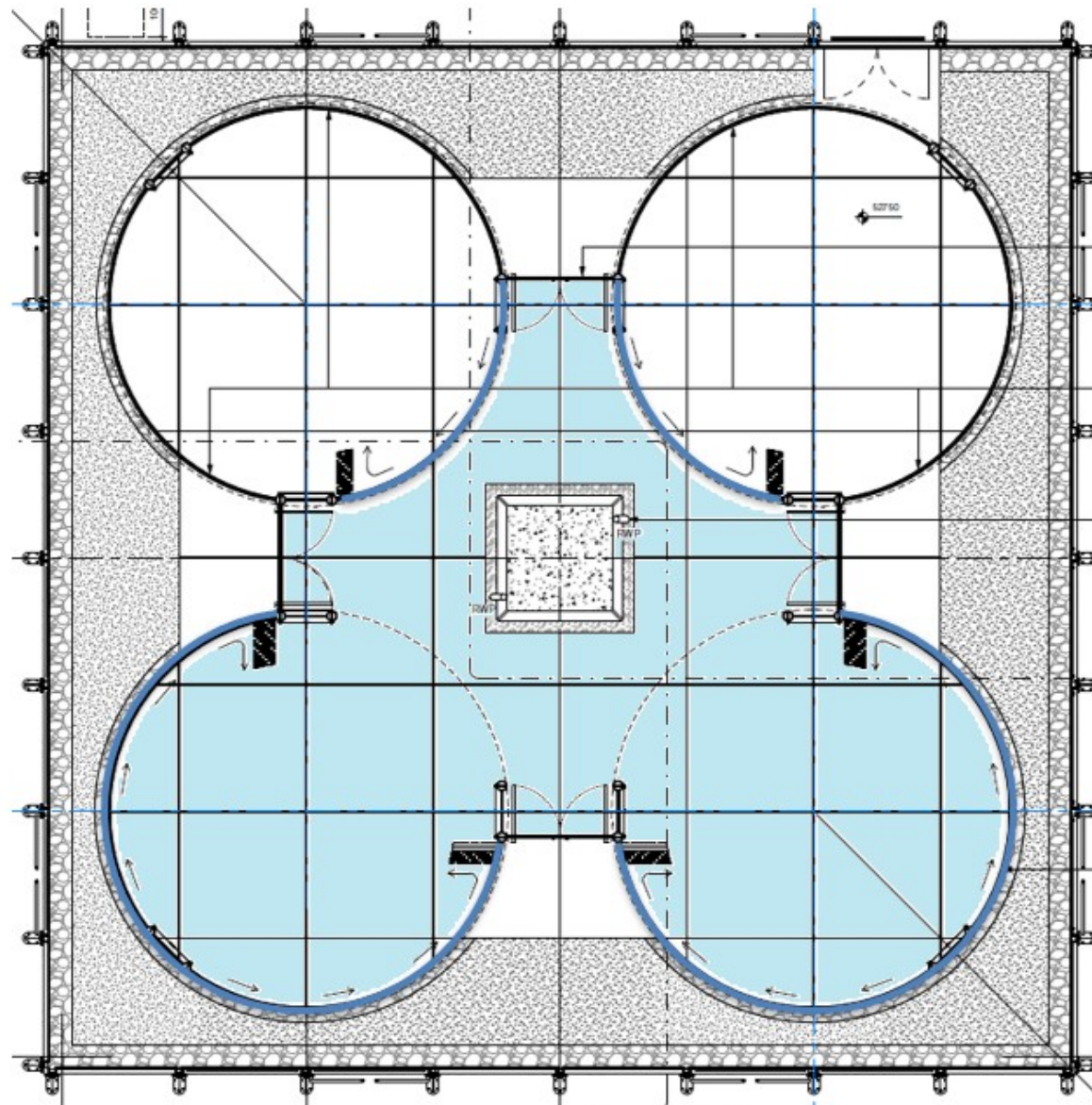
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# introduction



Bryden Wood

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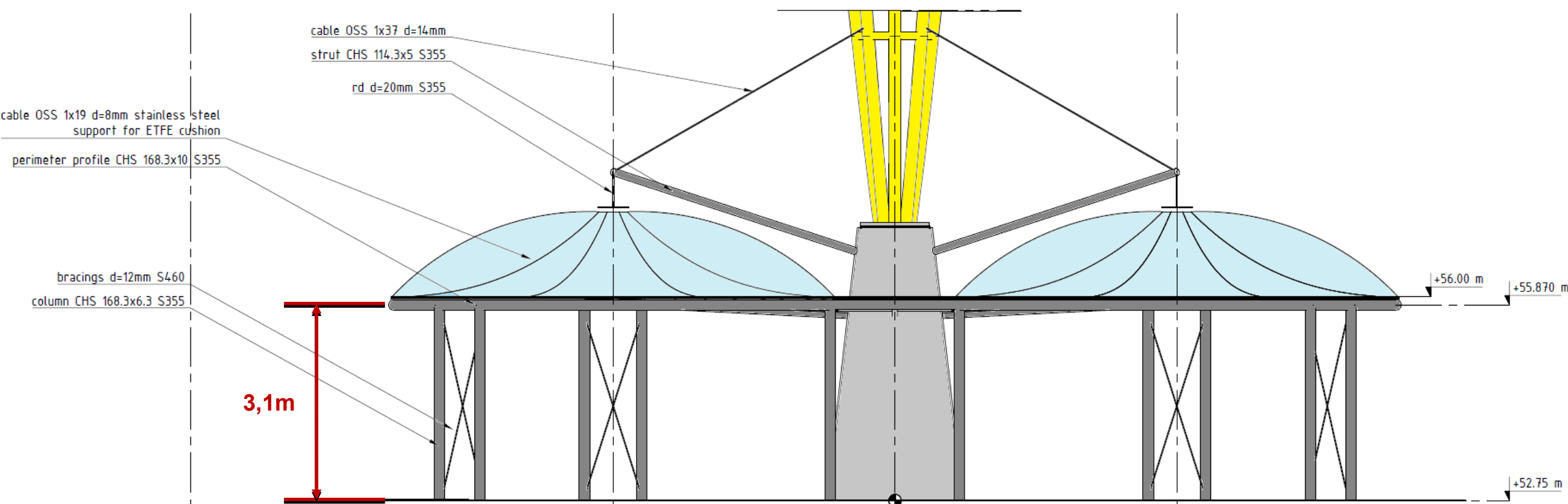


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# side view



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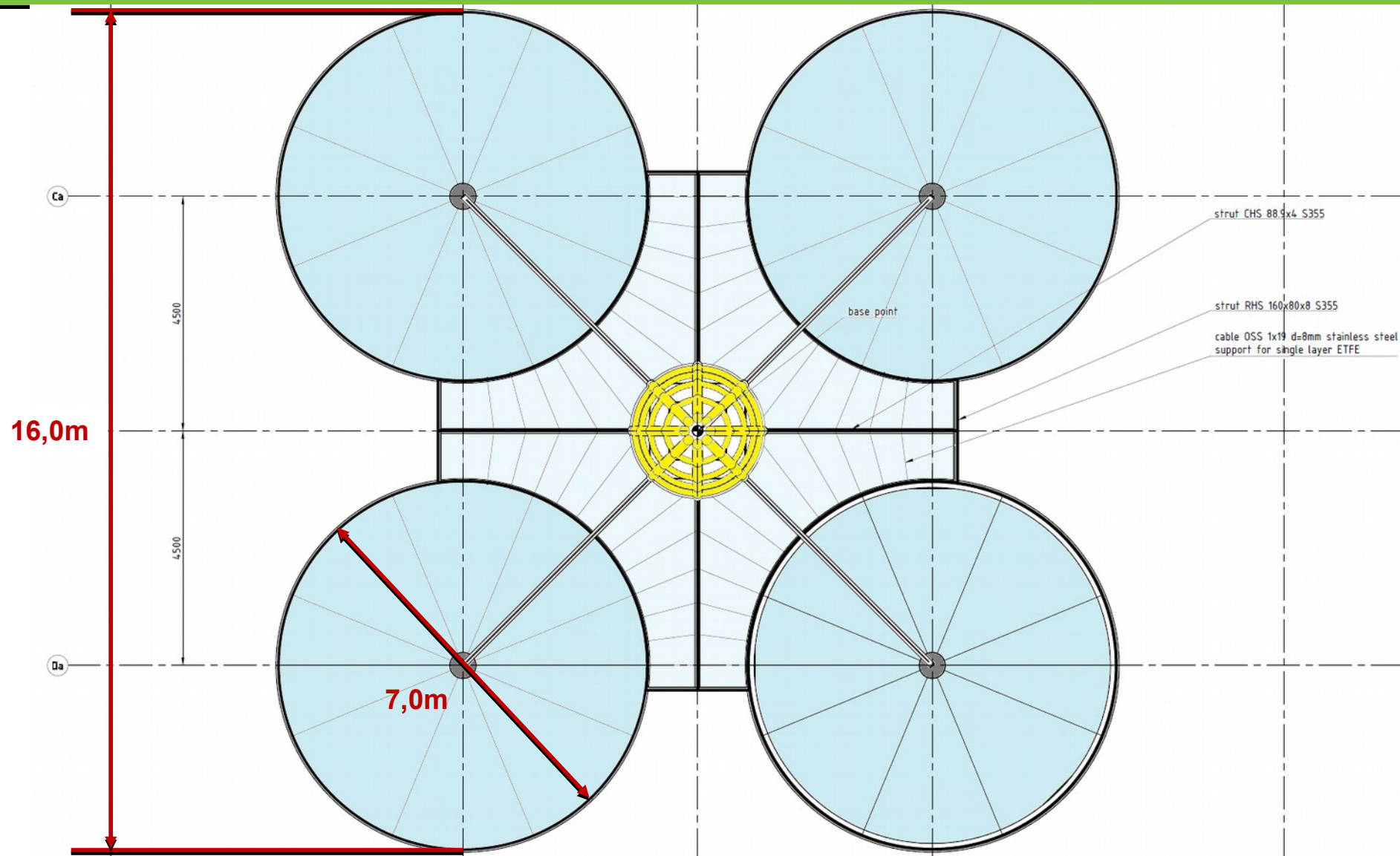
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# plan view



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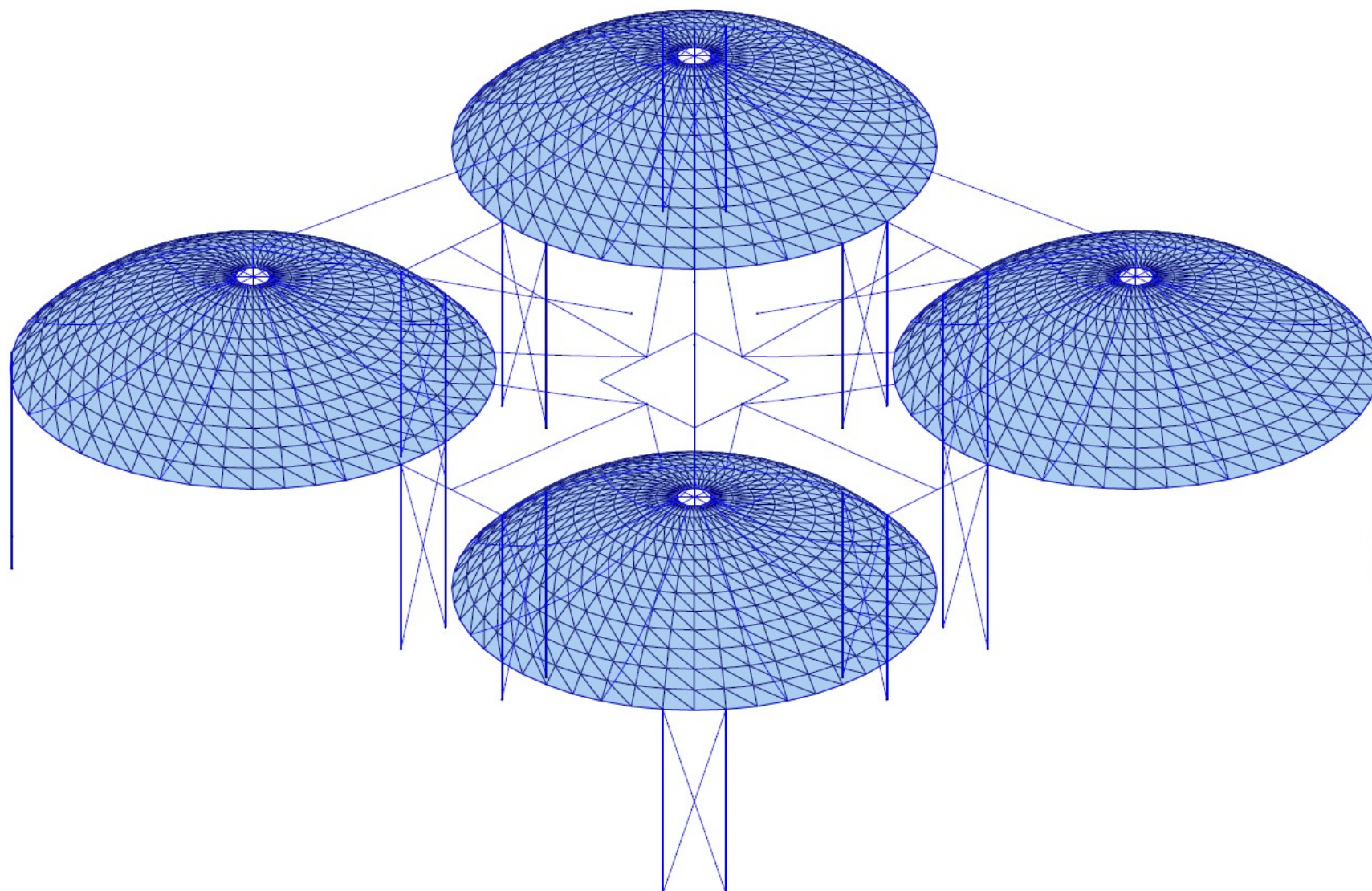


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# analysis model



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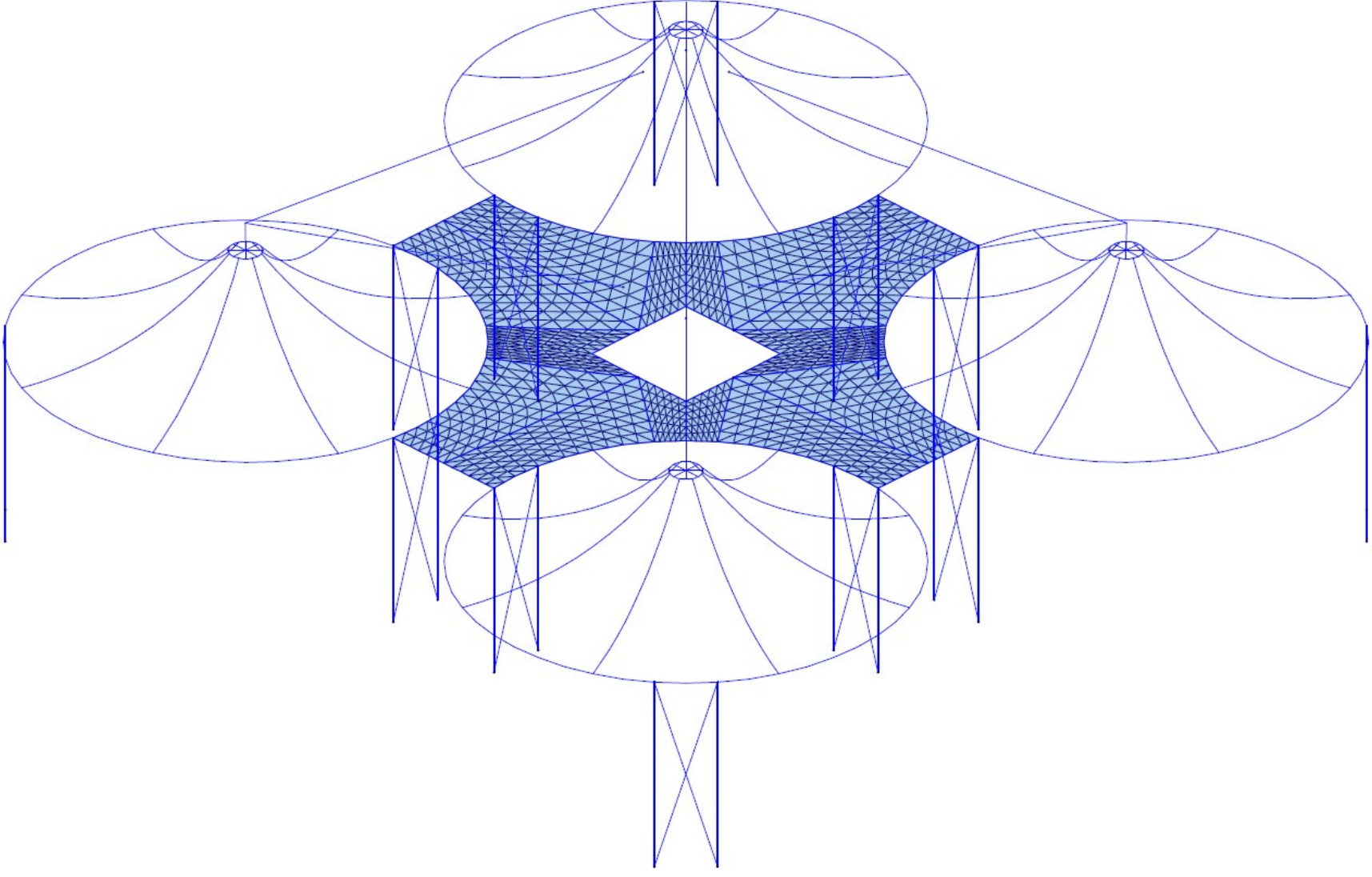
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# analysis model

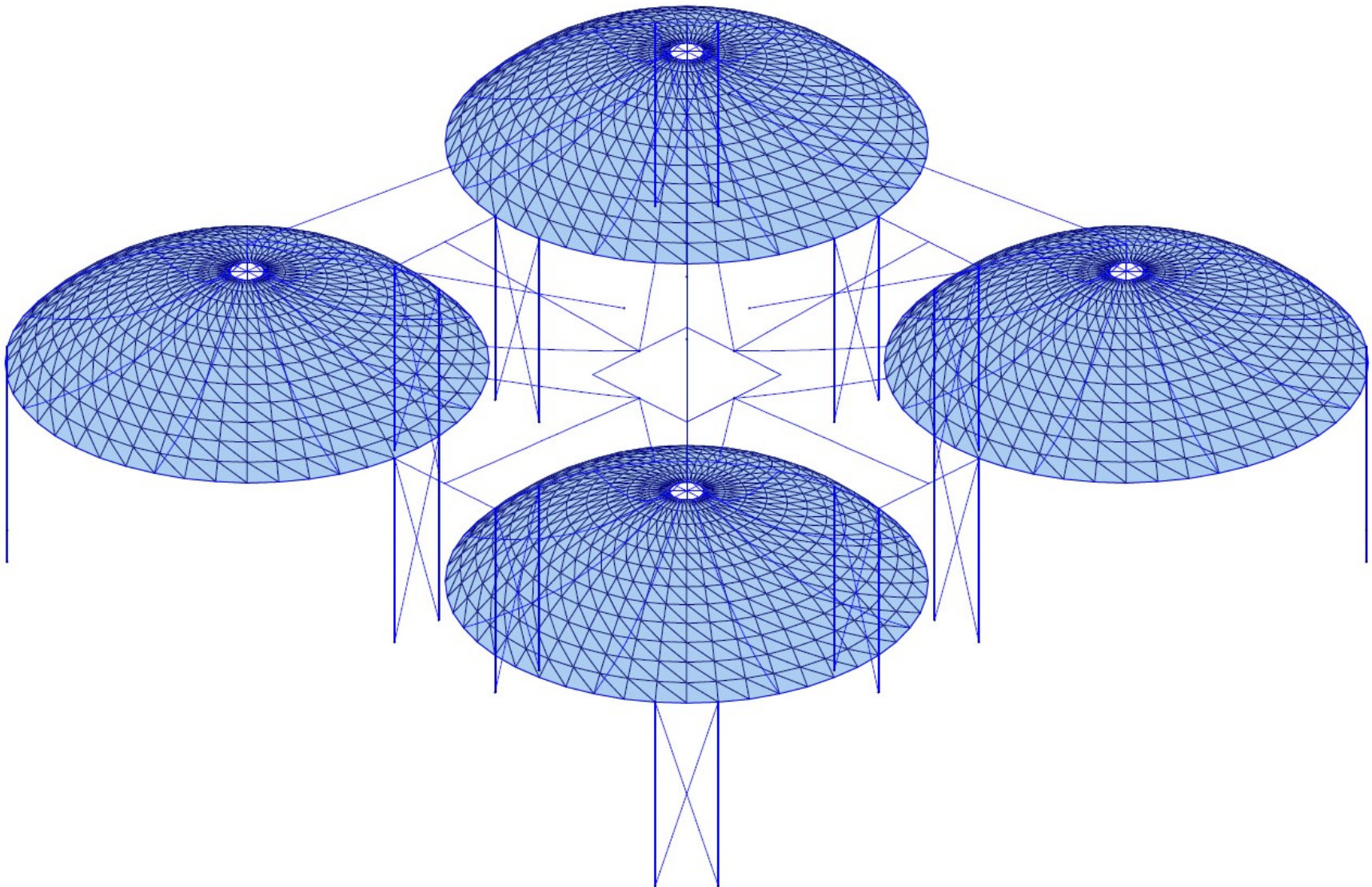


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# analysis model



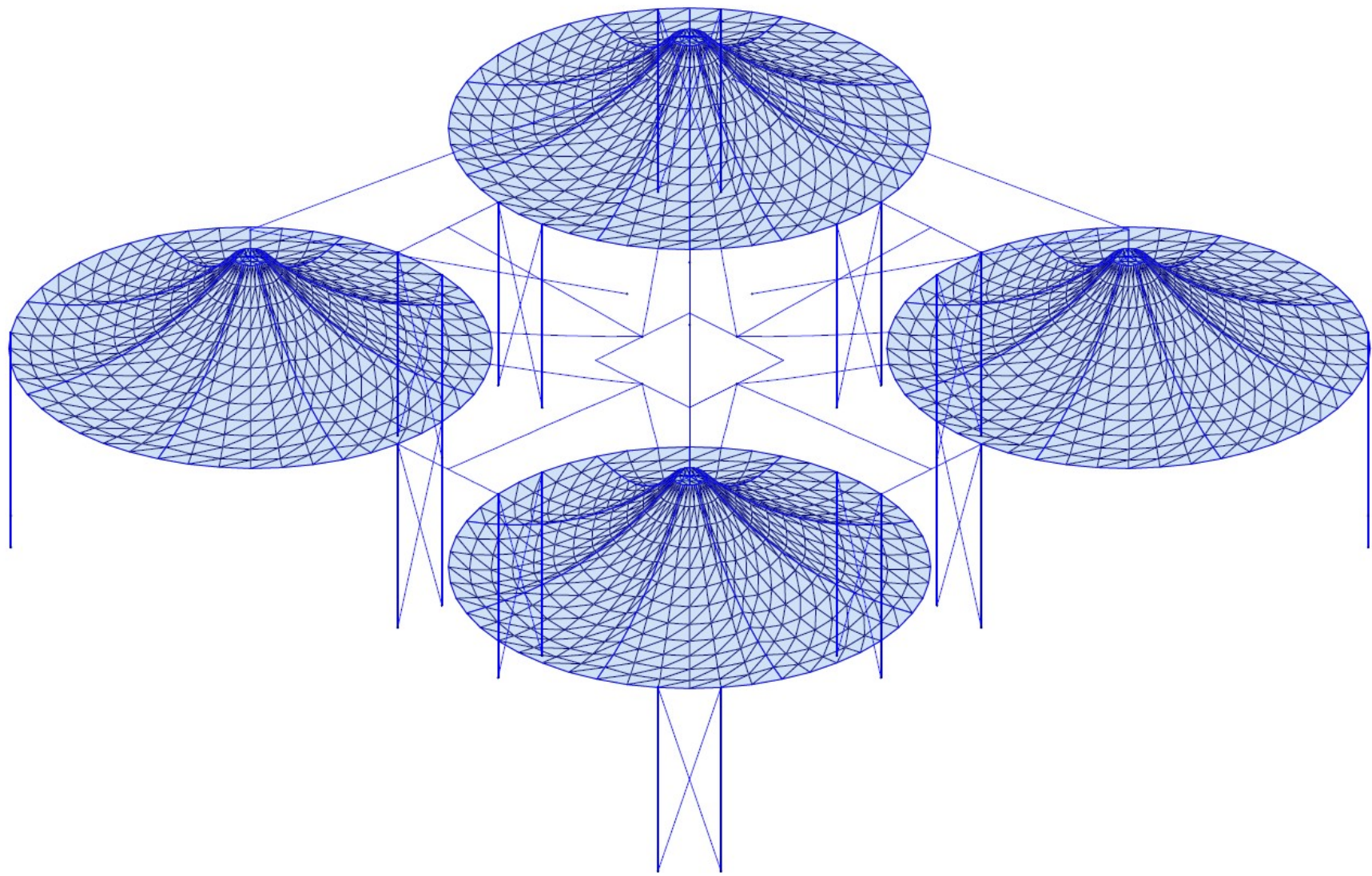
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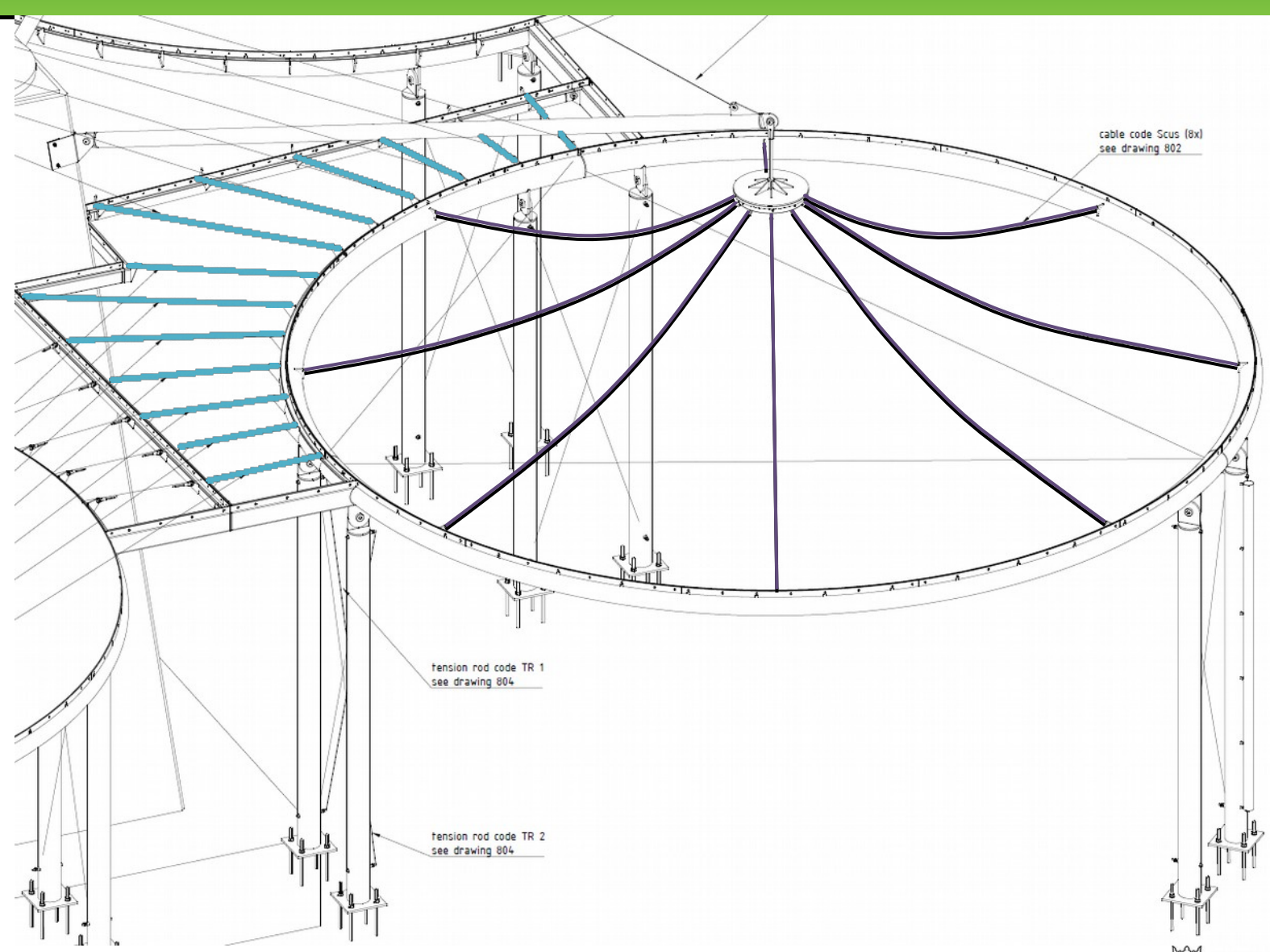
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# analysis model

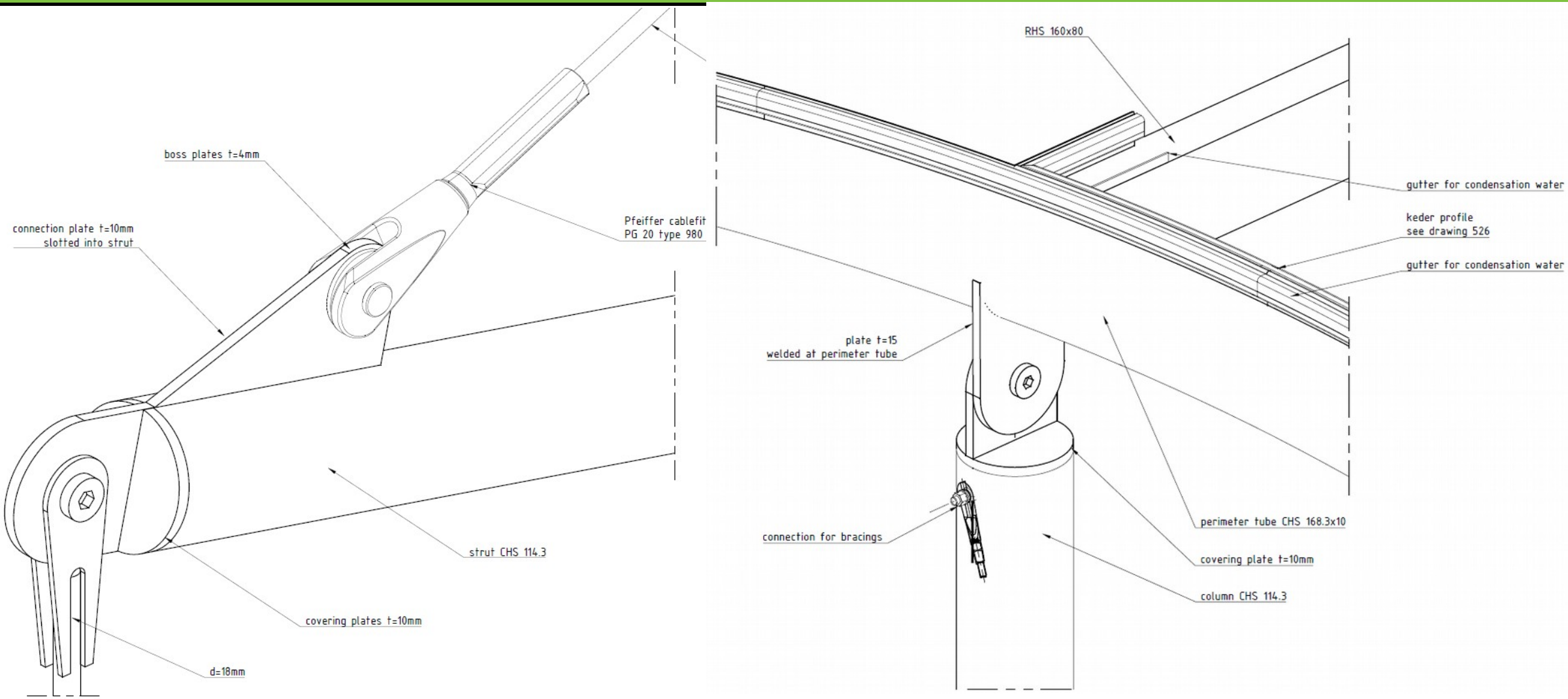


# overview cables

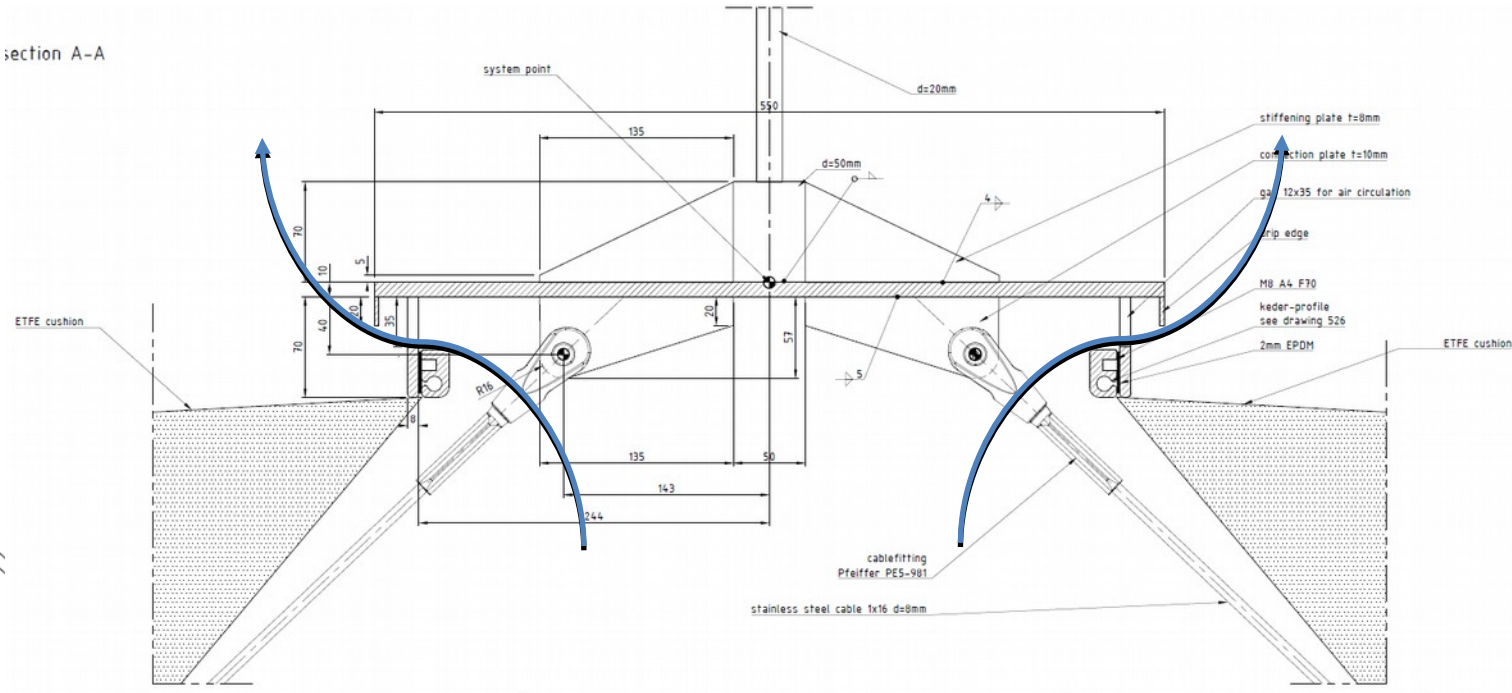
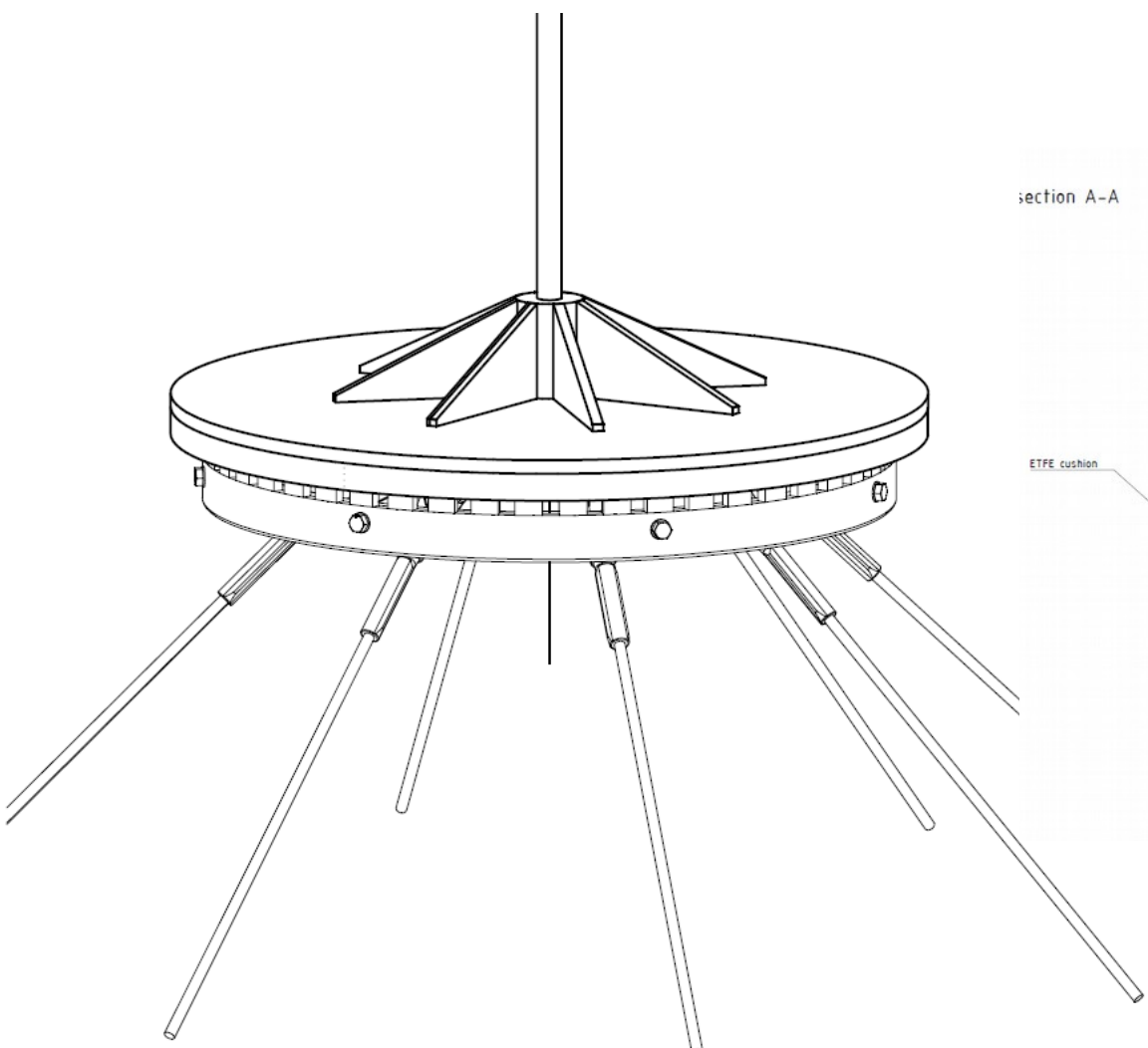




# details

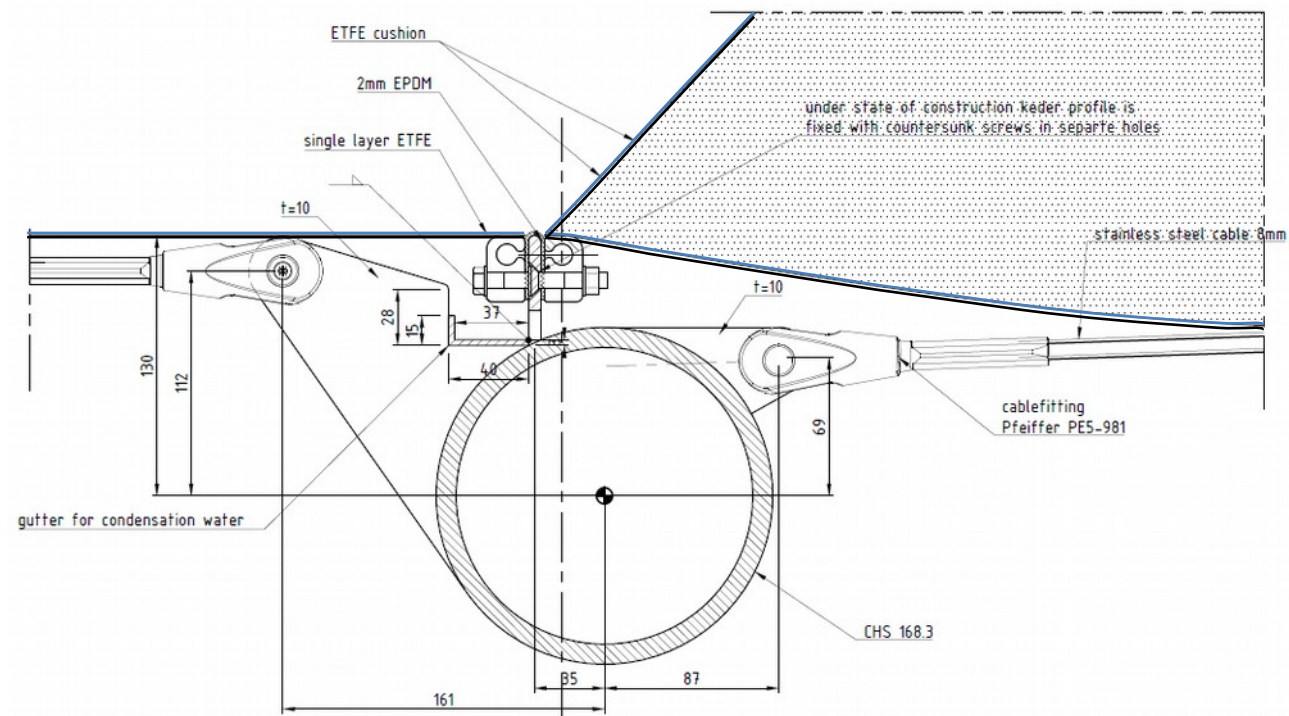
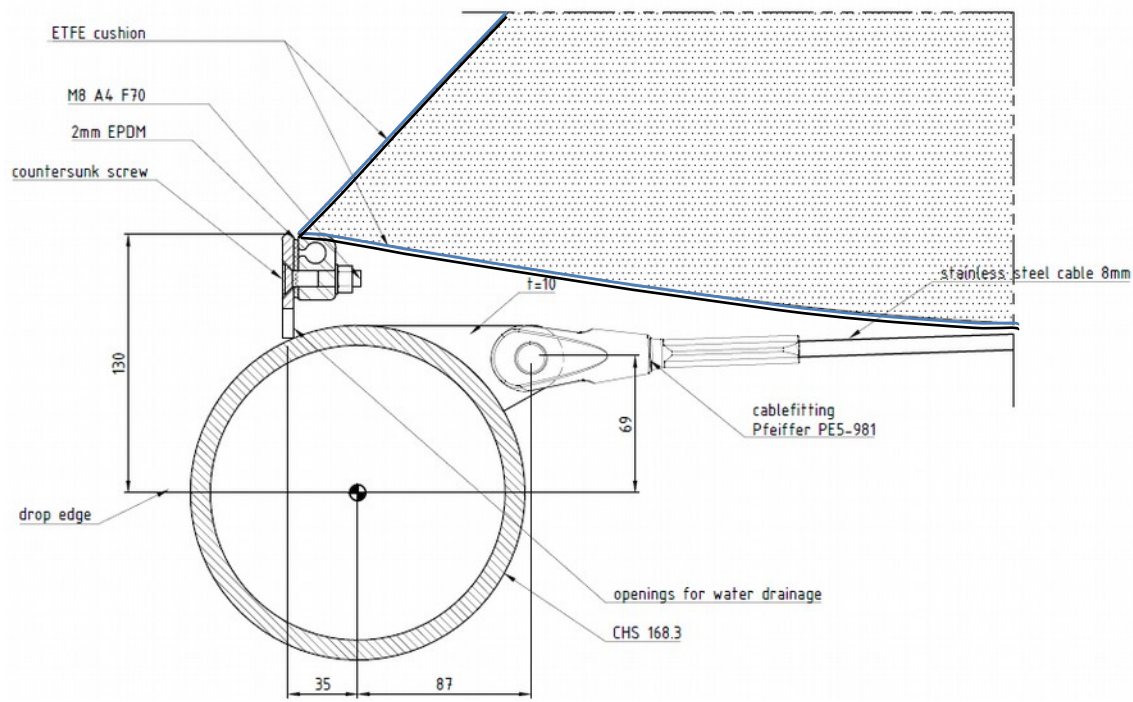


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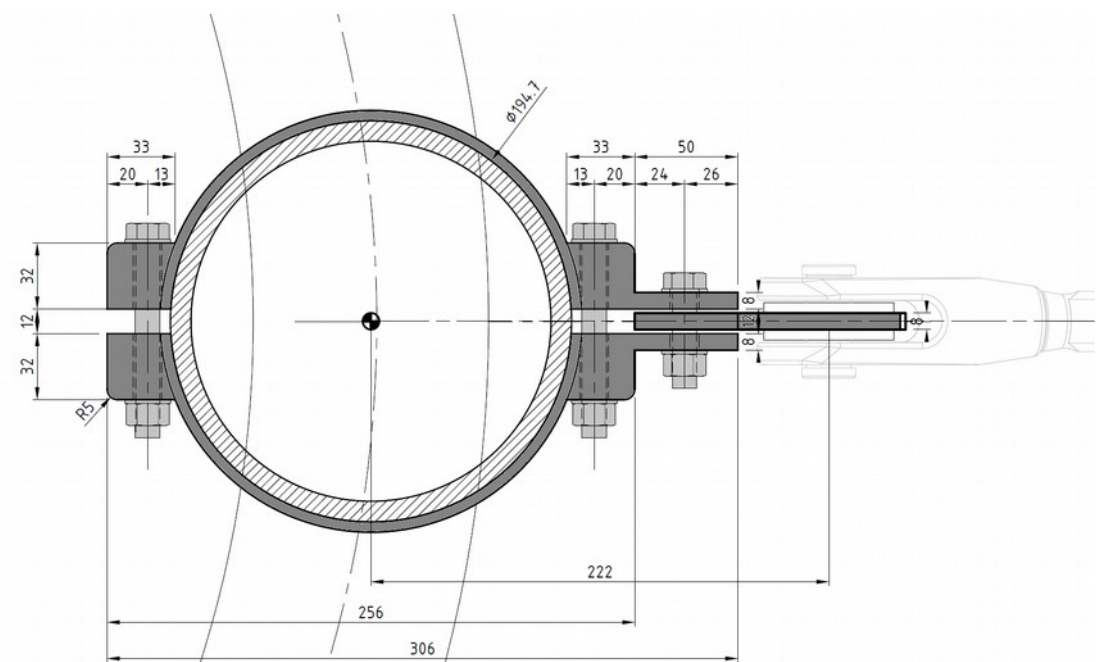
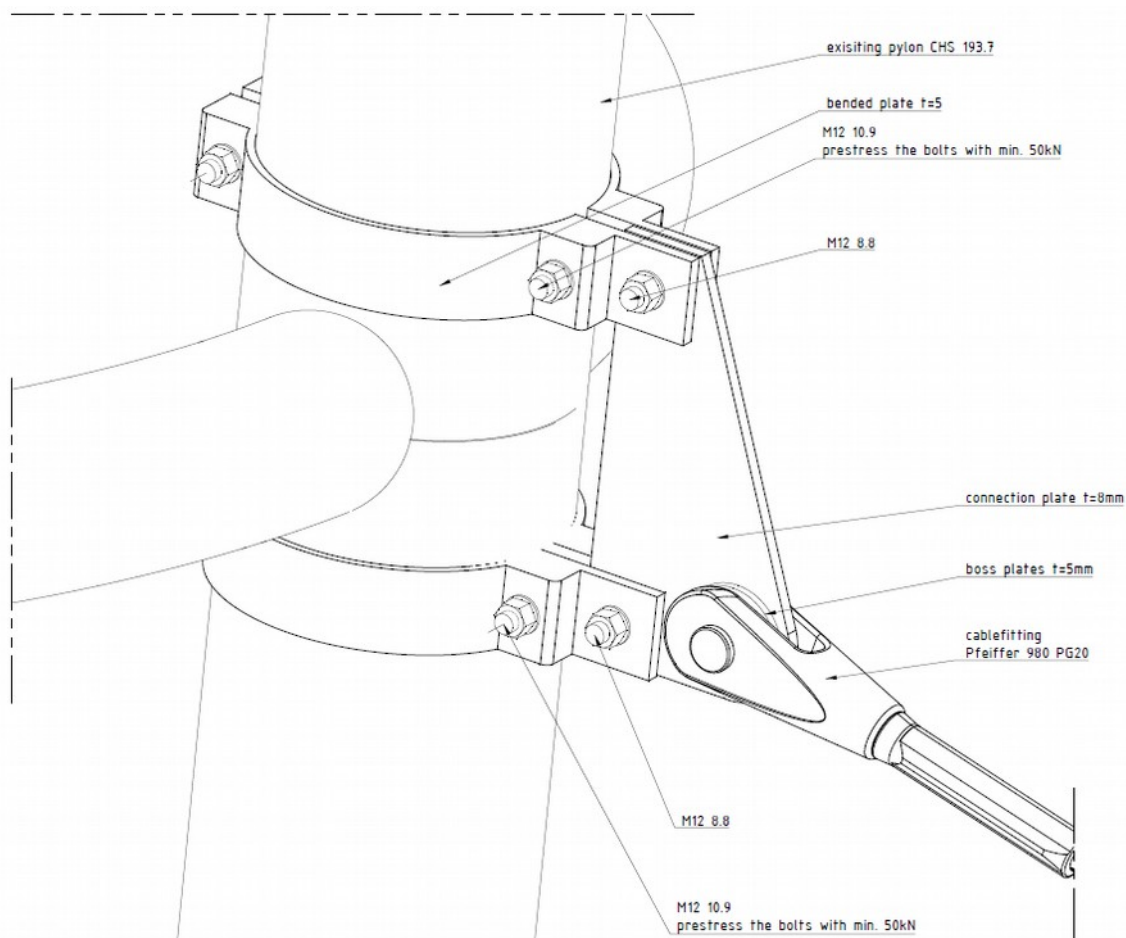




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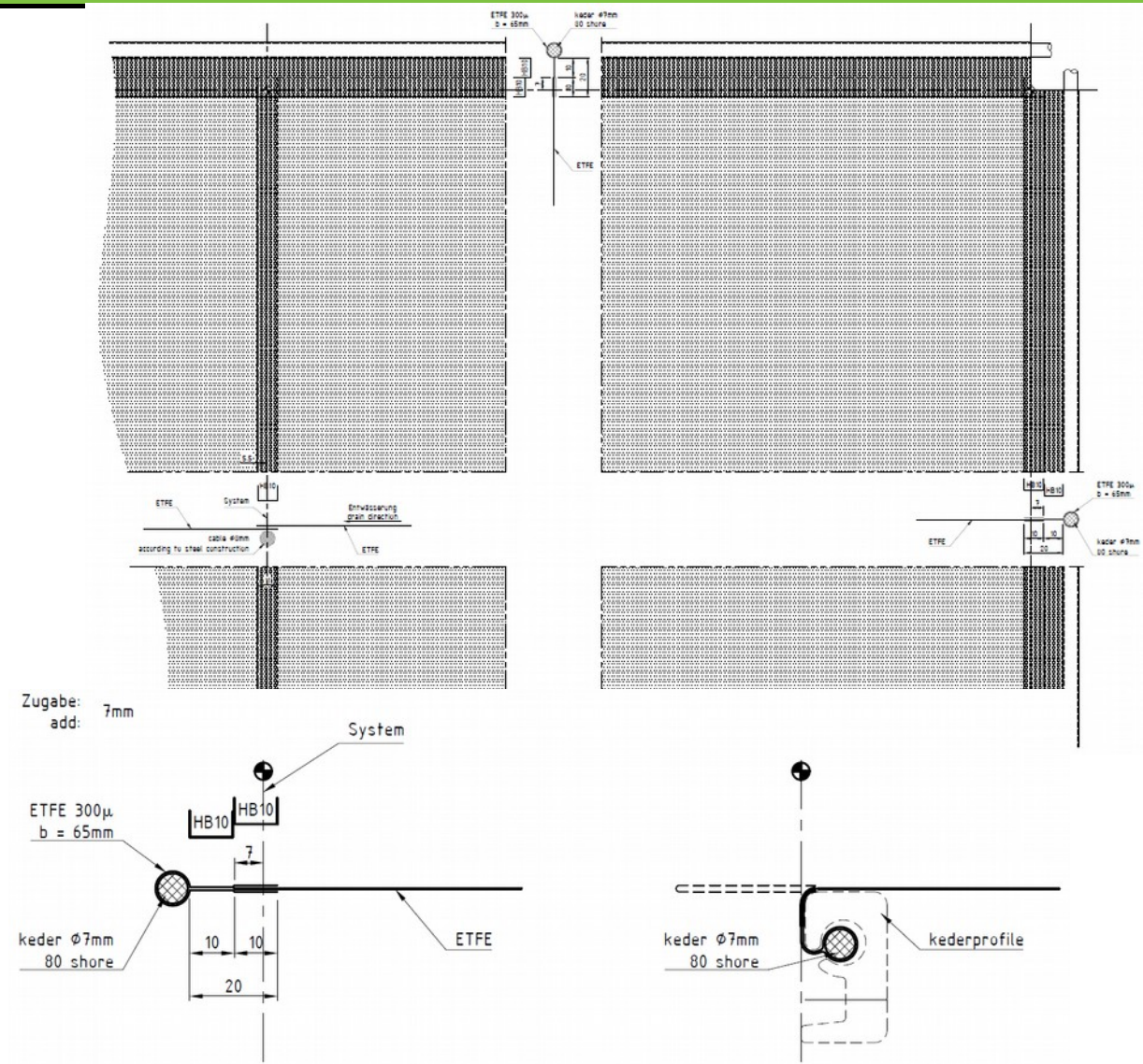
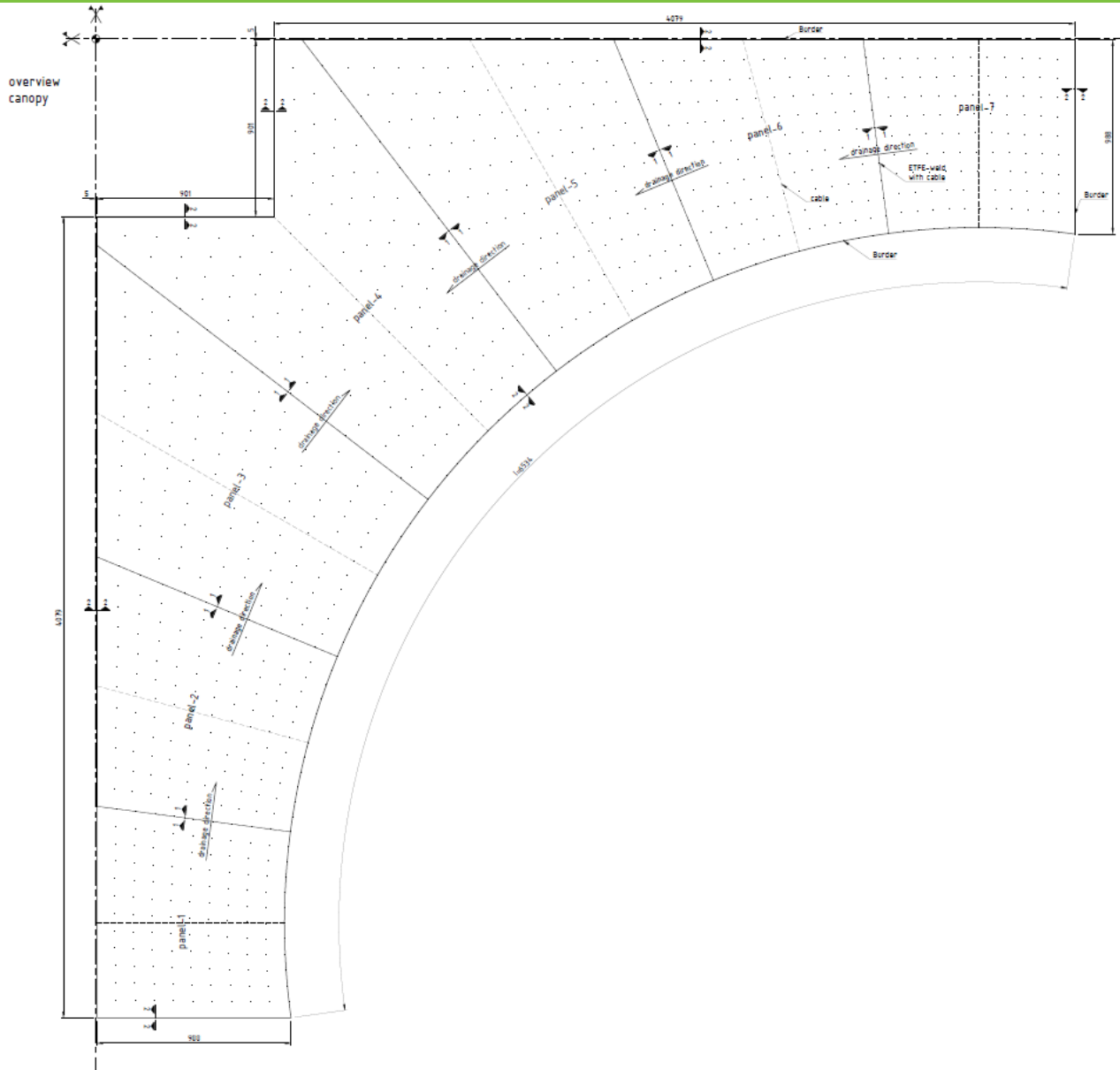


# details





# cutting pattern



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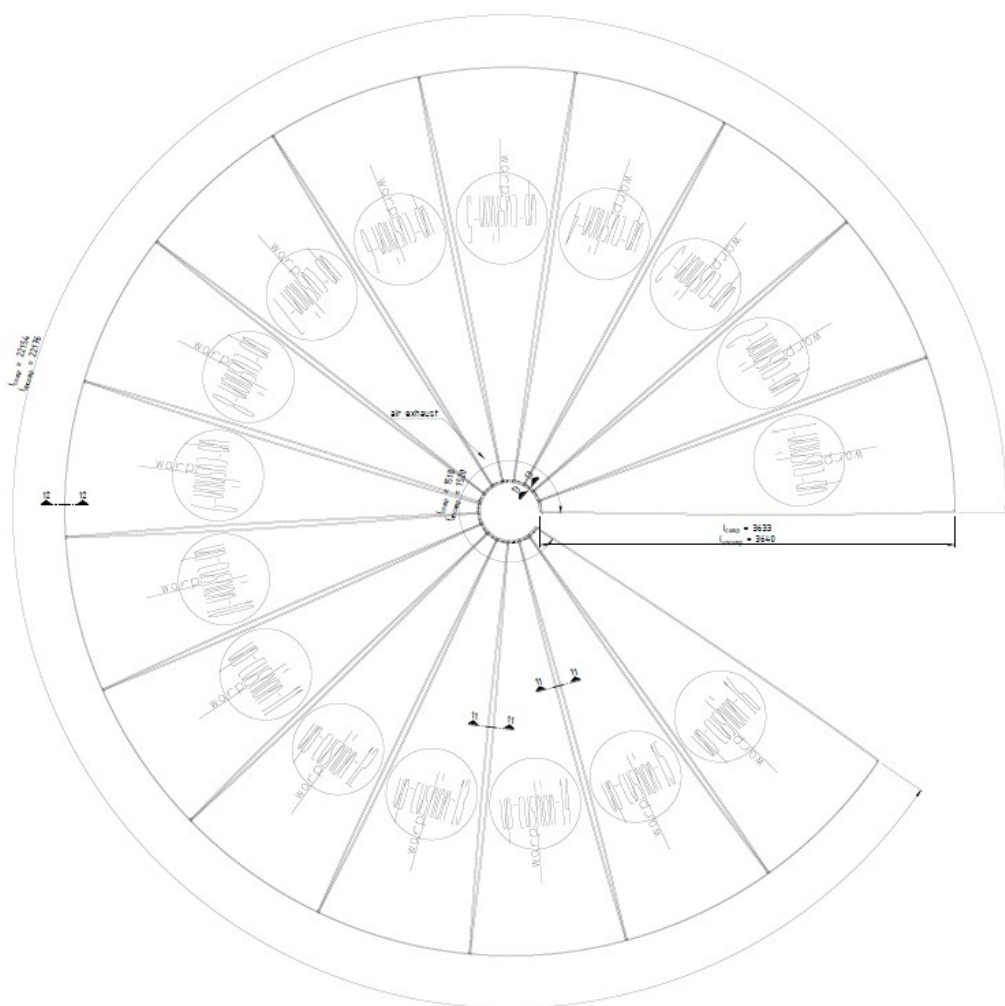
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Canton de Berne



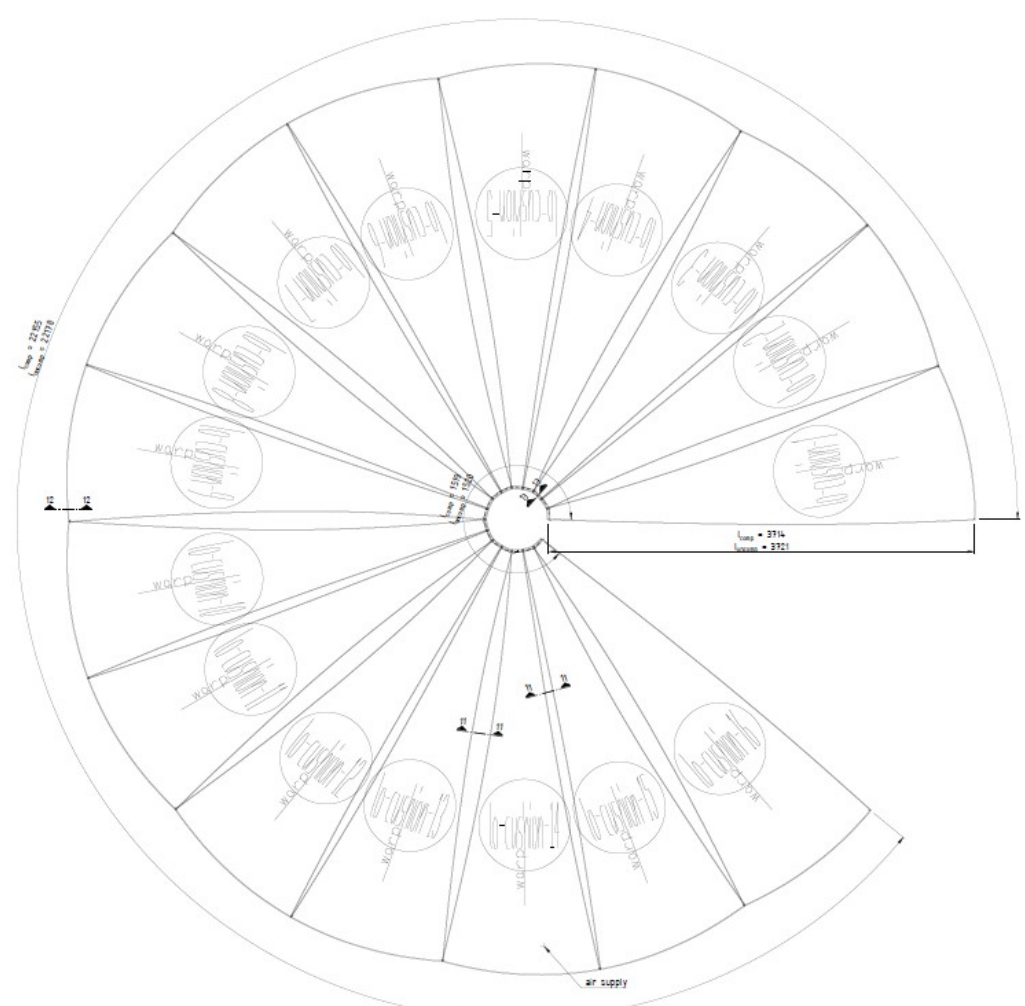
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# cutting pattern

cutting pattern  
cushion - upper



cutting pattern  
cushion - lower



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# installation



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kesselhaus | güttinger straße 37 | 78315 radolfzell | +49 7732 9464 0 | info@form-TL.de

**Thank you for your attention !**

Fridolin Mall

**formTL** ingenieure für tragwerk und leichtbau gmbh



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Canton de Berne



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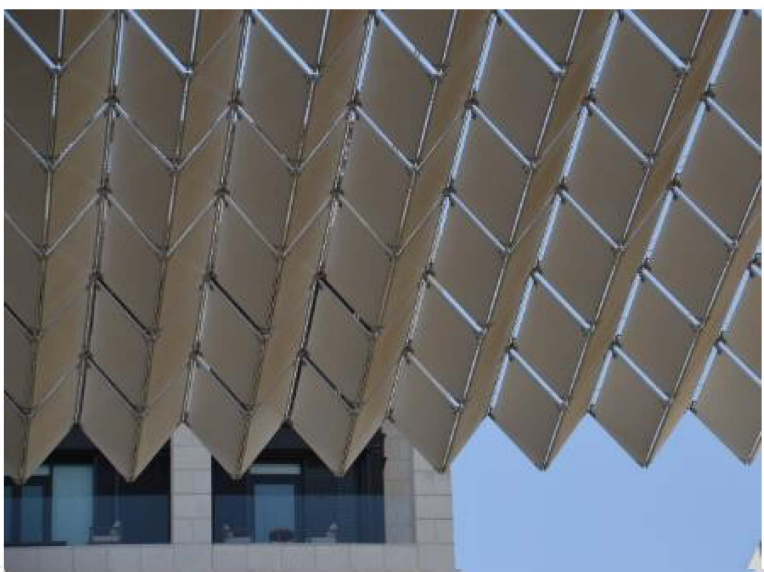
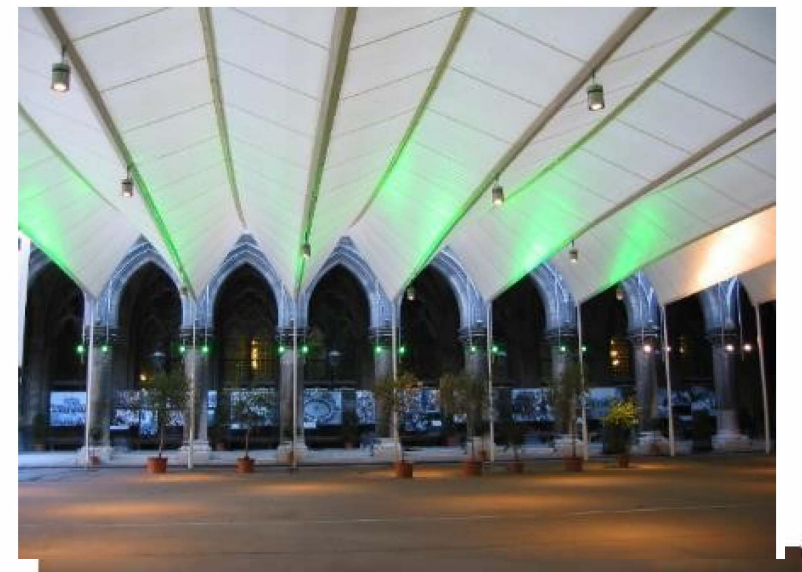
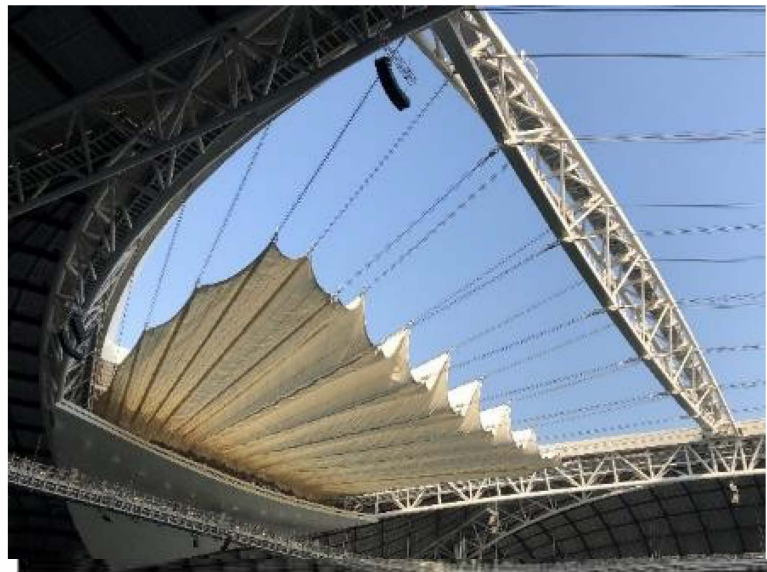
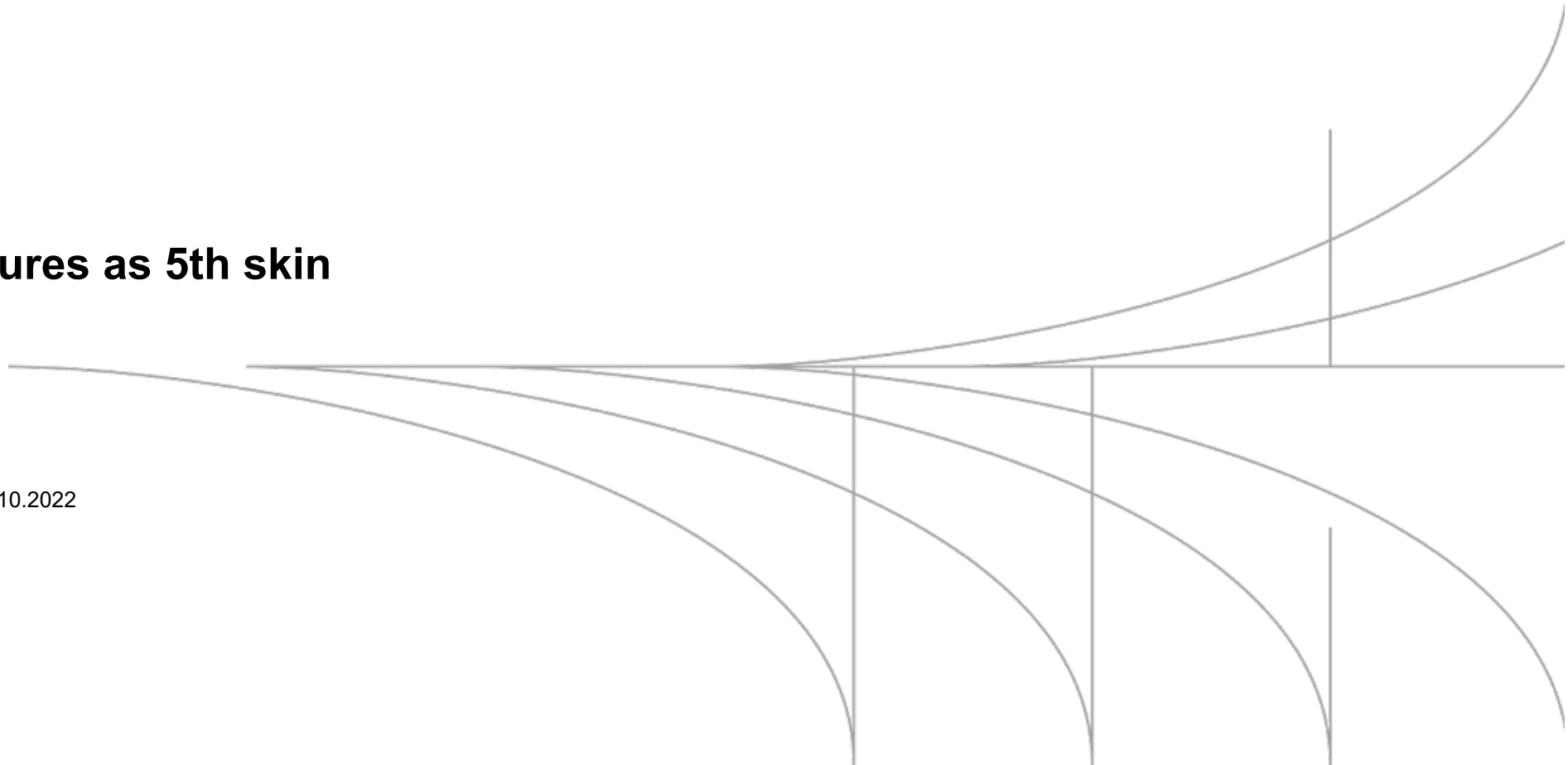


# sbp

schlaich  
bergemann partner

## moveable structures as 5th skin Christoph Paech

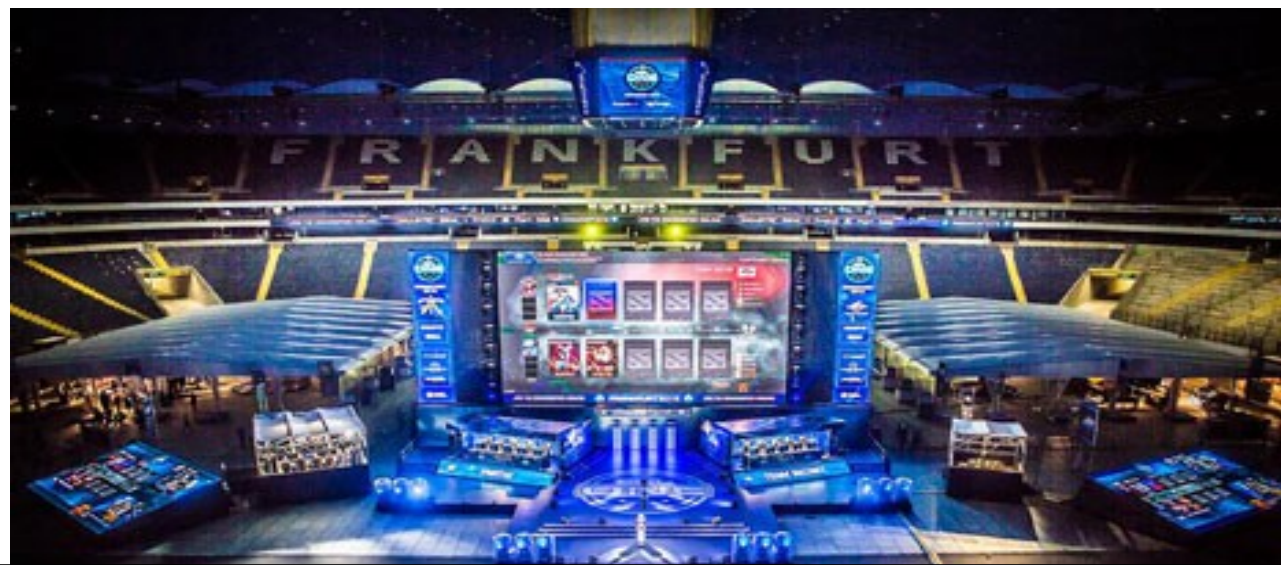
Advanced Building Skins, Bern 20.10.2022



# sbp

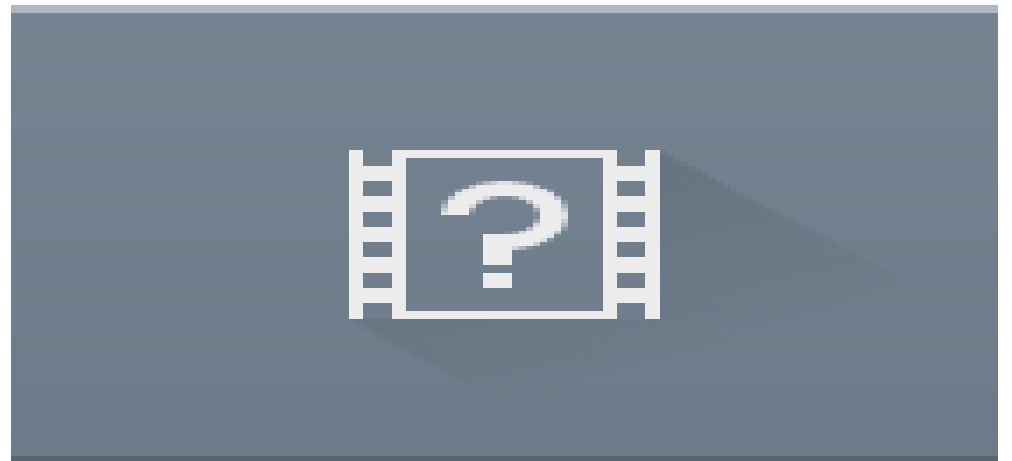
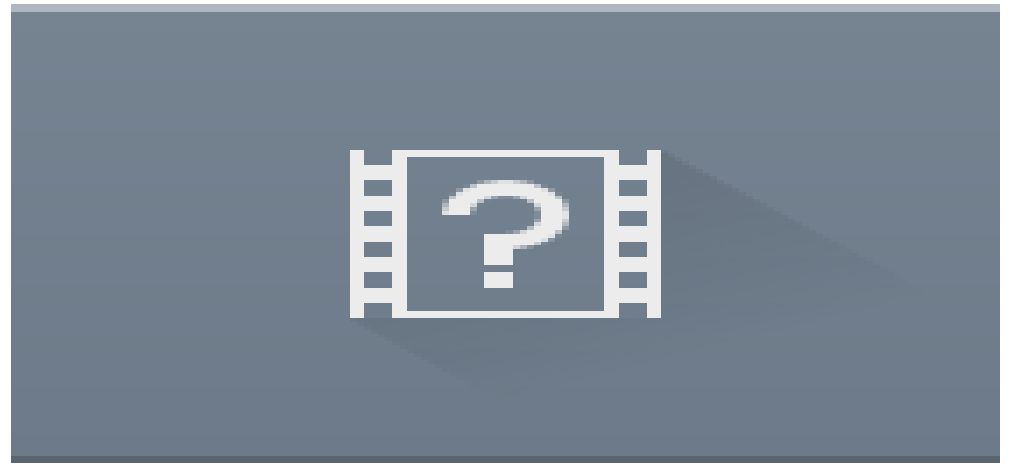
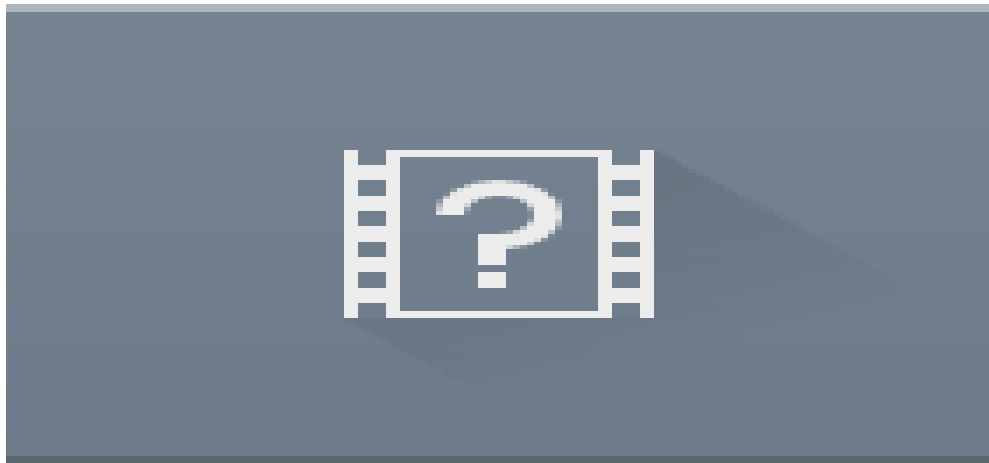
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**sbp**  
schleich  
bergemann partner

Multiuse for successful Venues

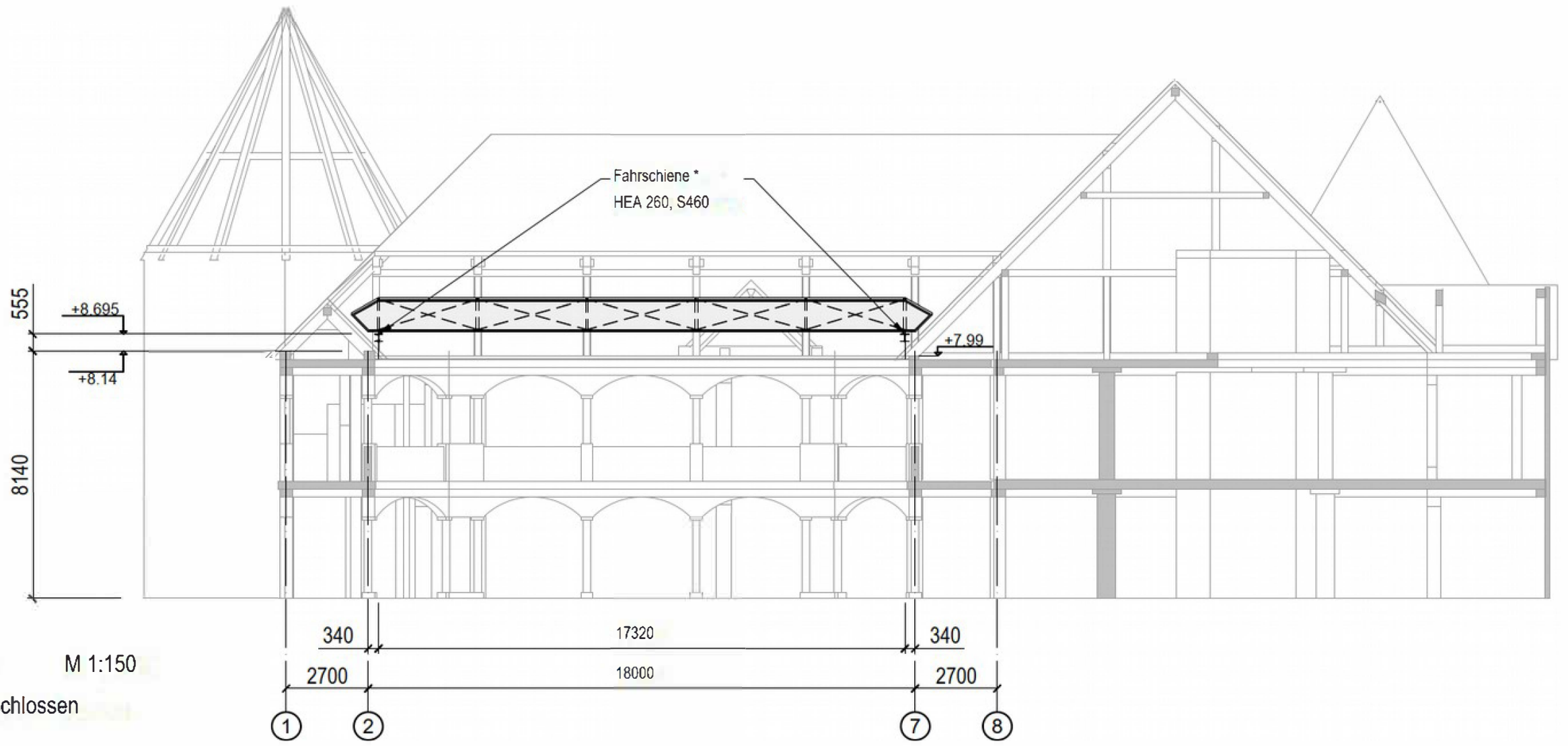


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bergemann partner







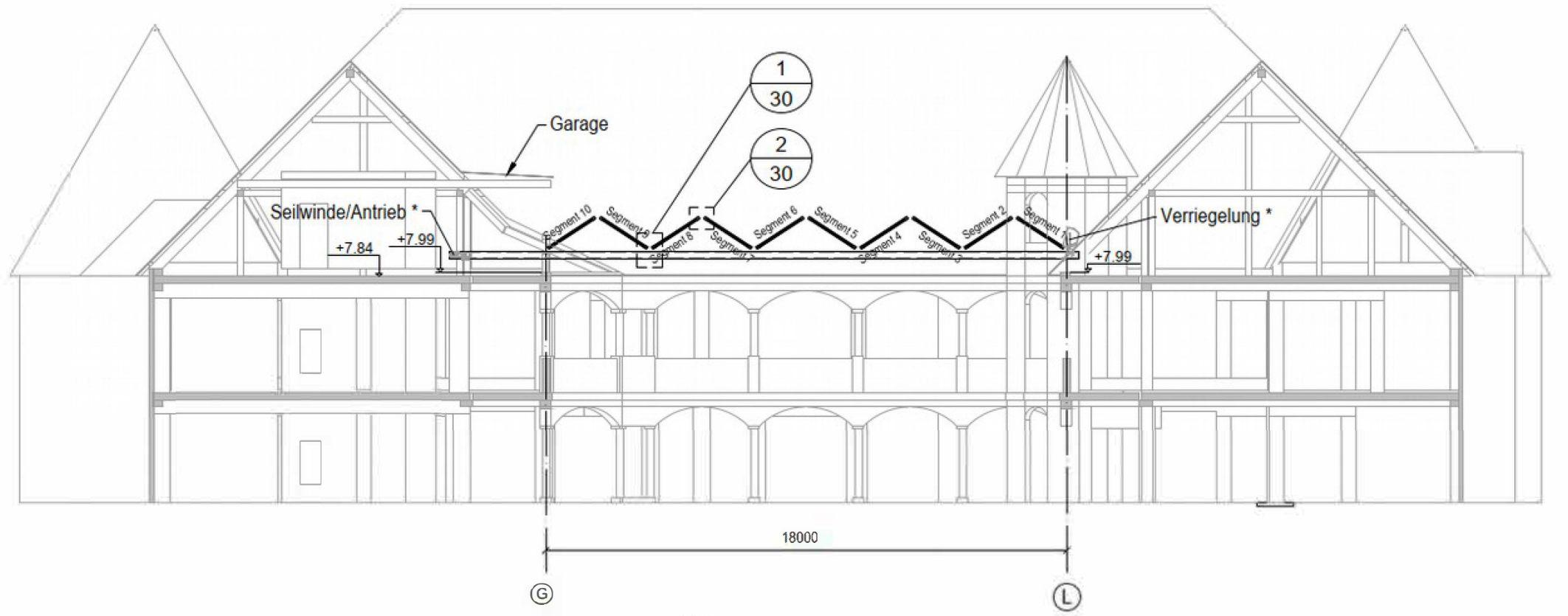


B - B M 1:150

Dach geschlossen

sbp

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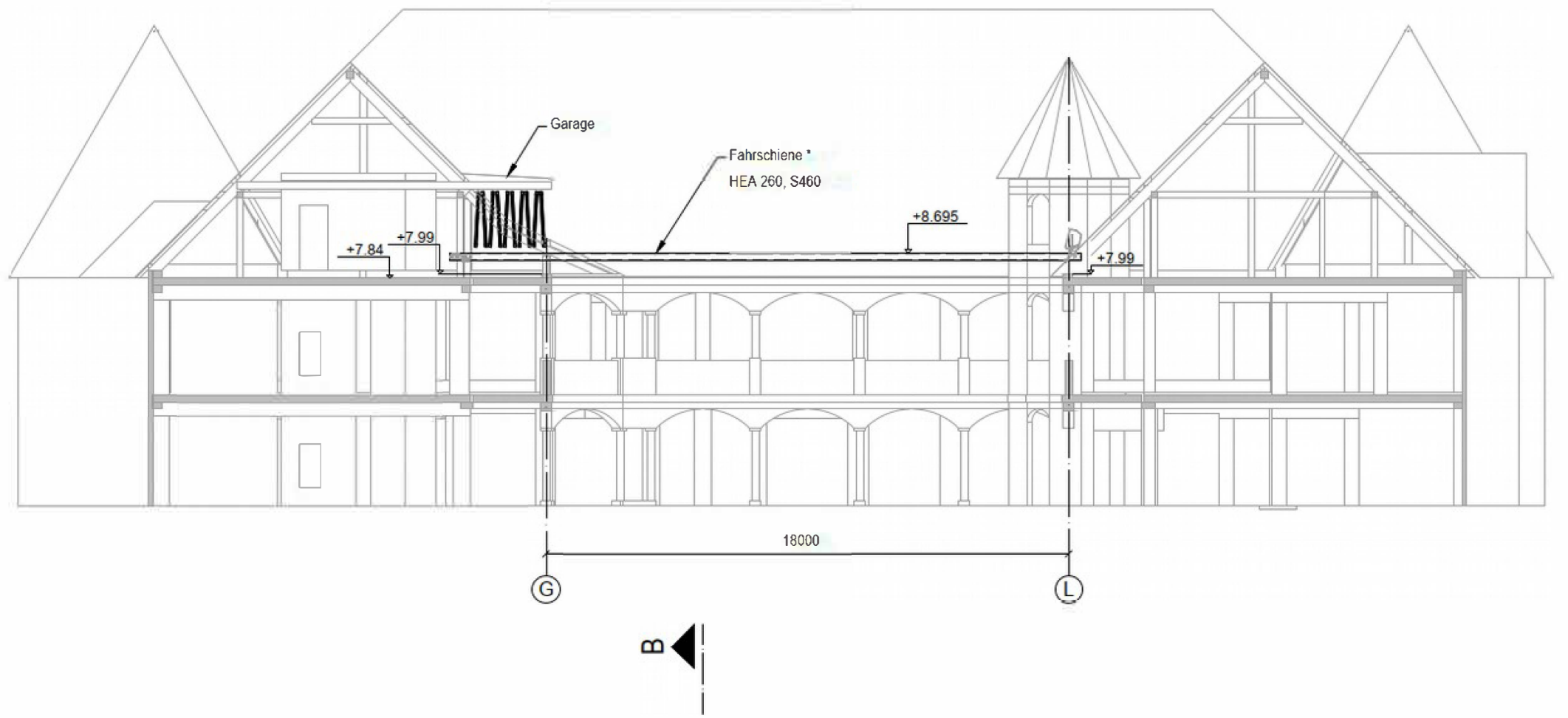
A - A M 1:150 Dach geschlossen



sbp

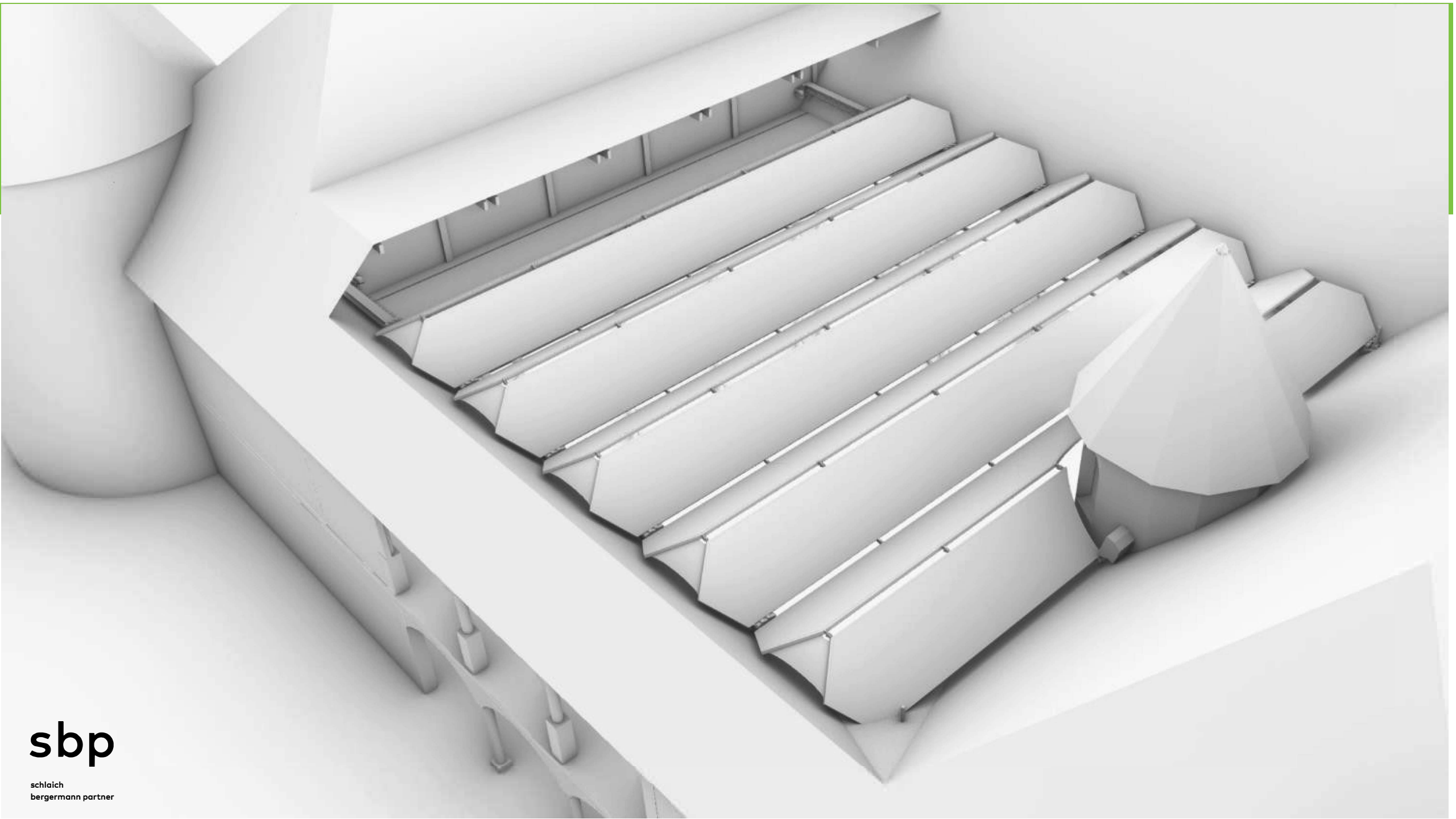
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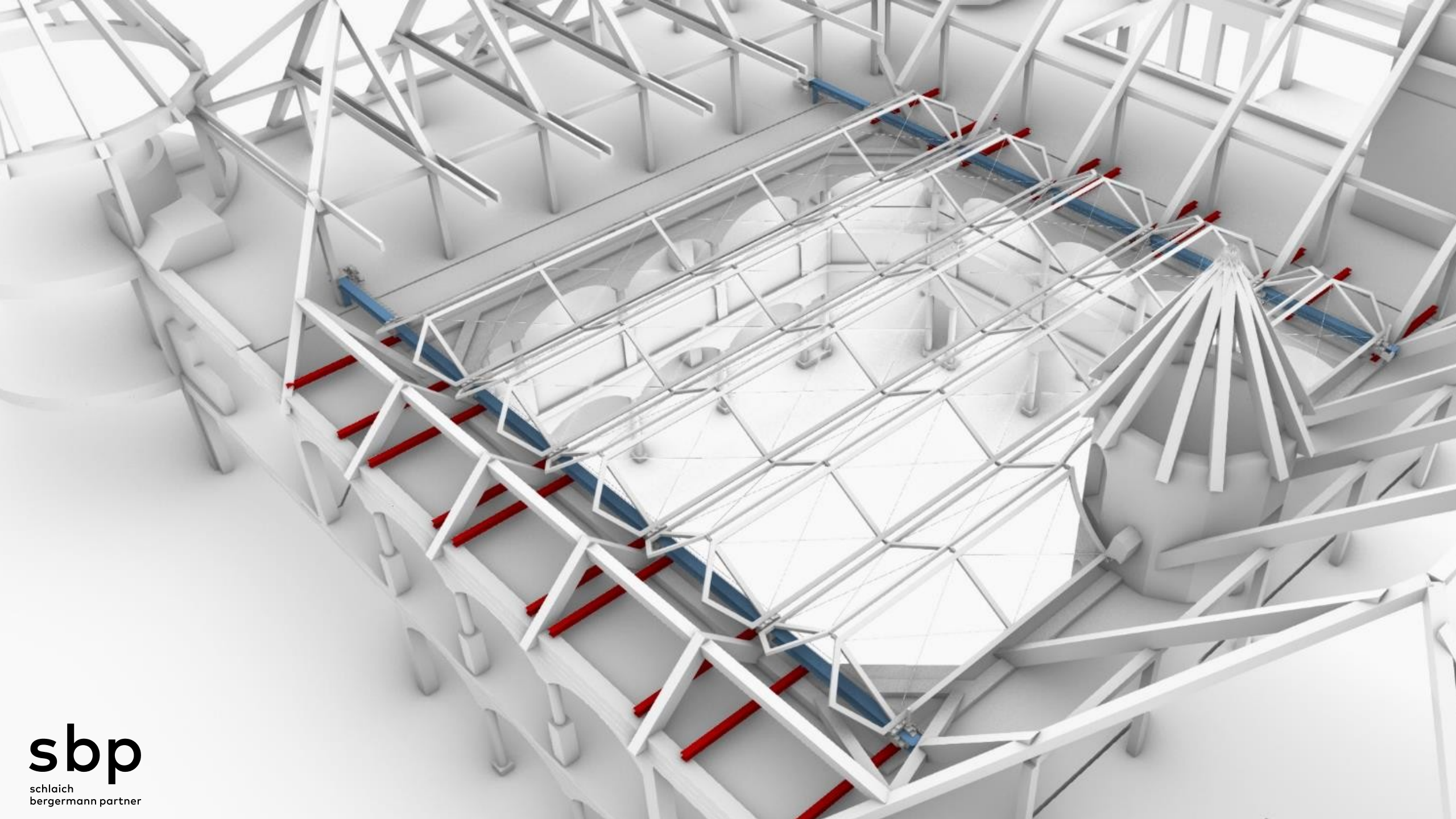
A - A M 1:150  
Dach geöffnet

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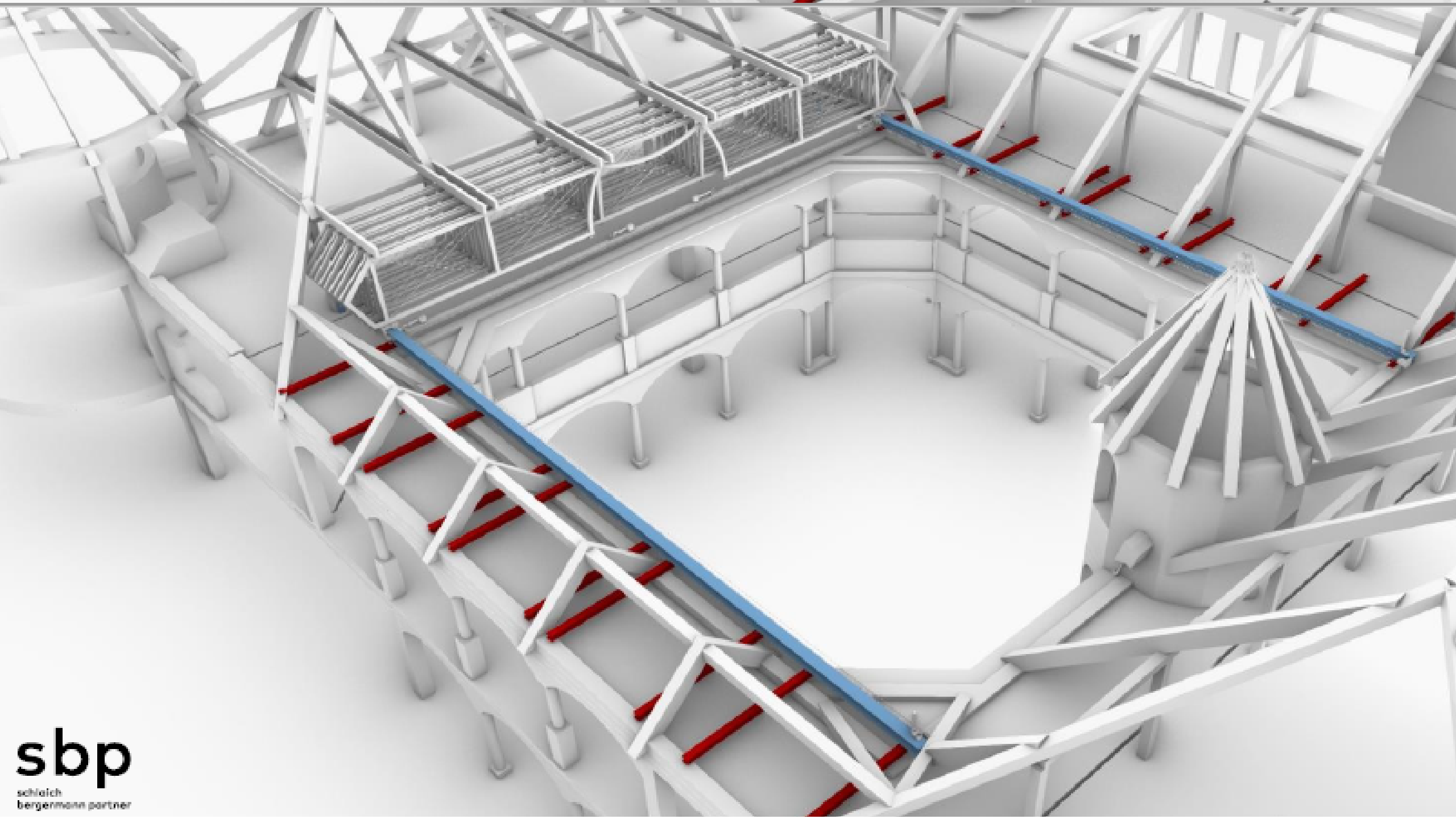


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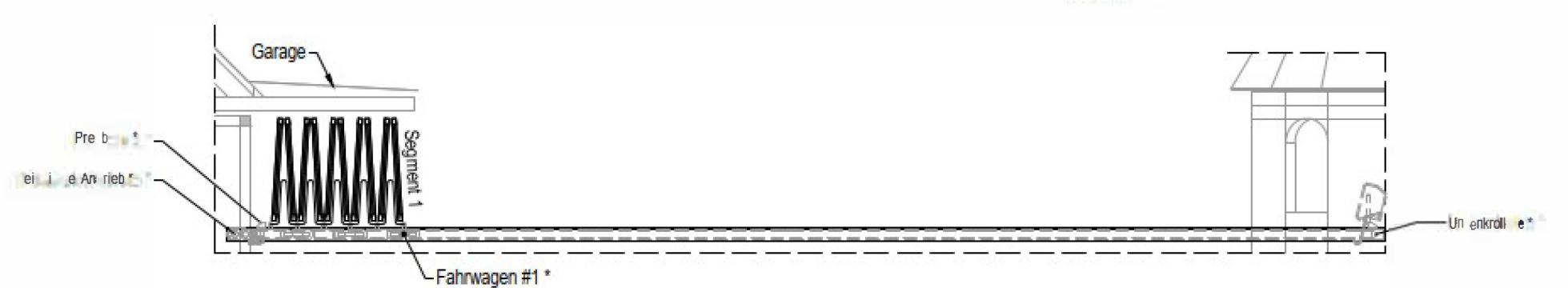
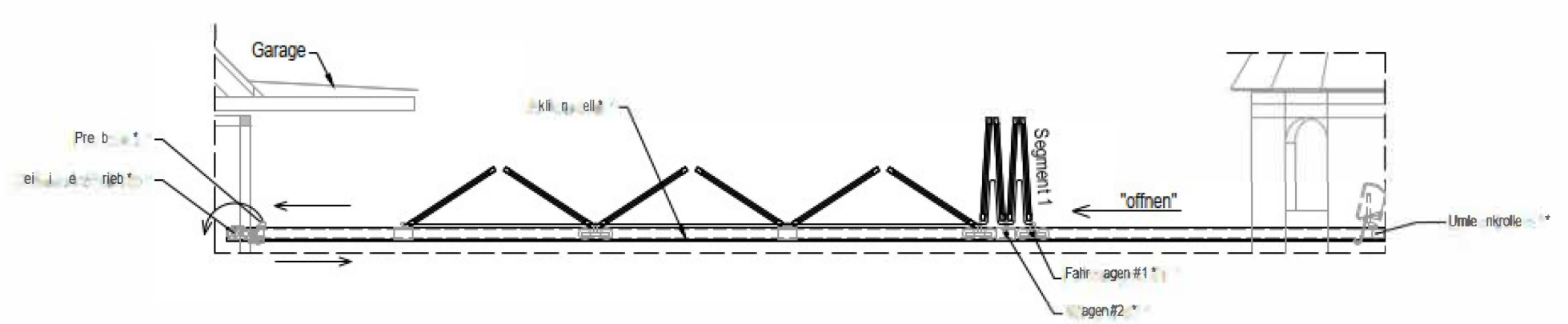
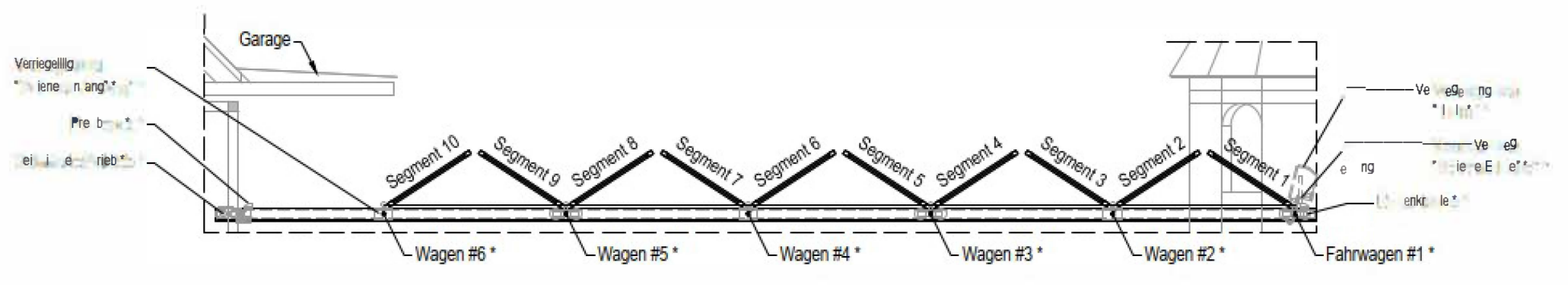
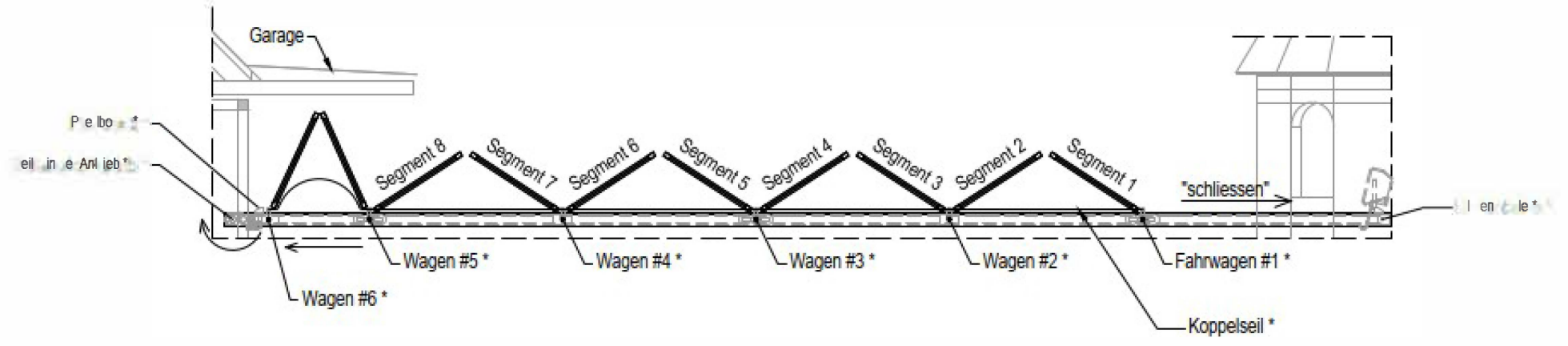
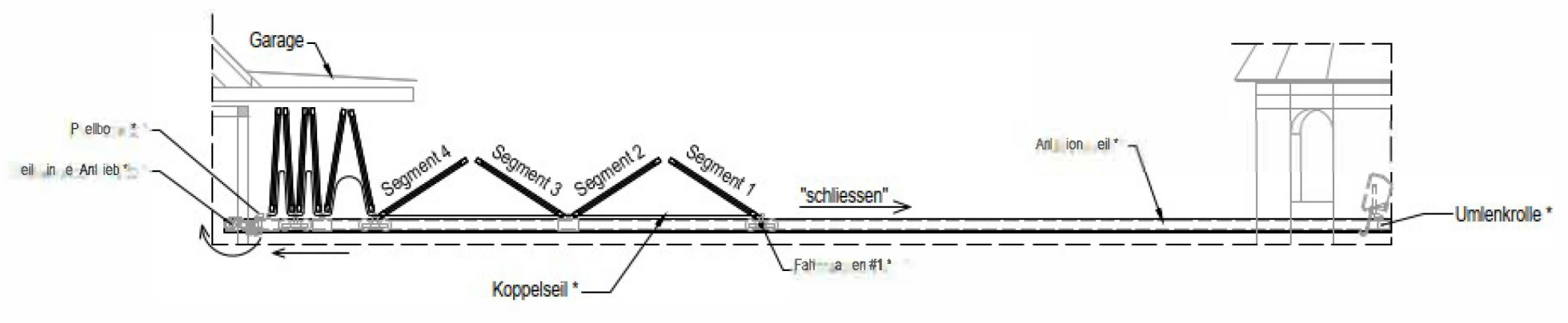
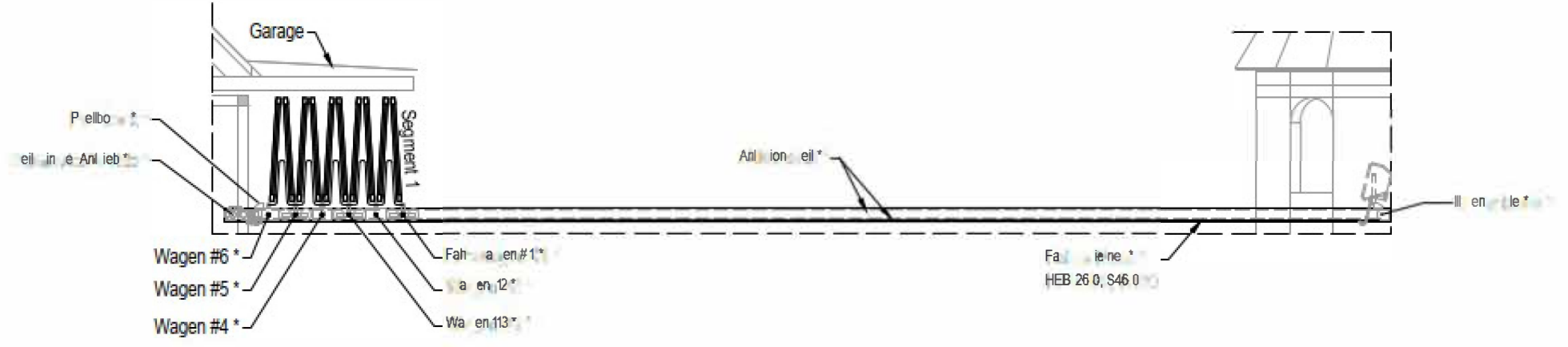


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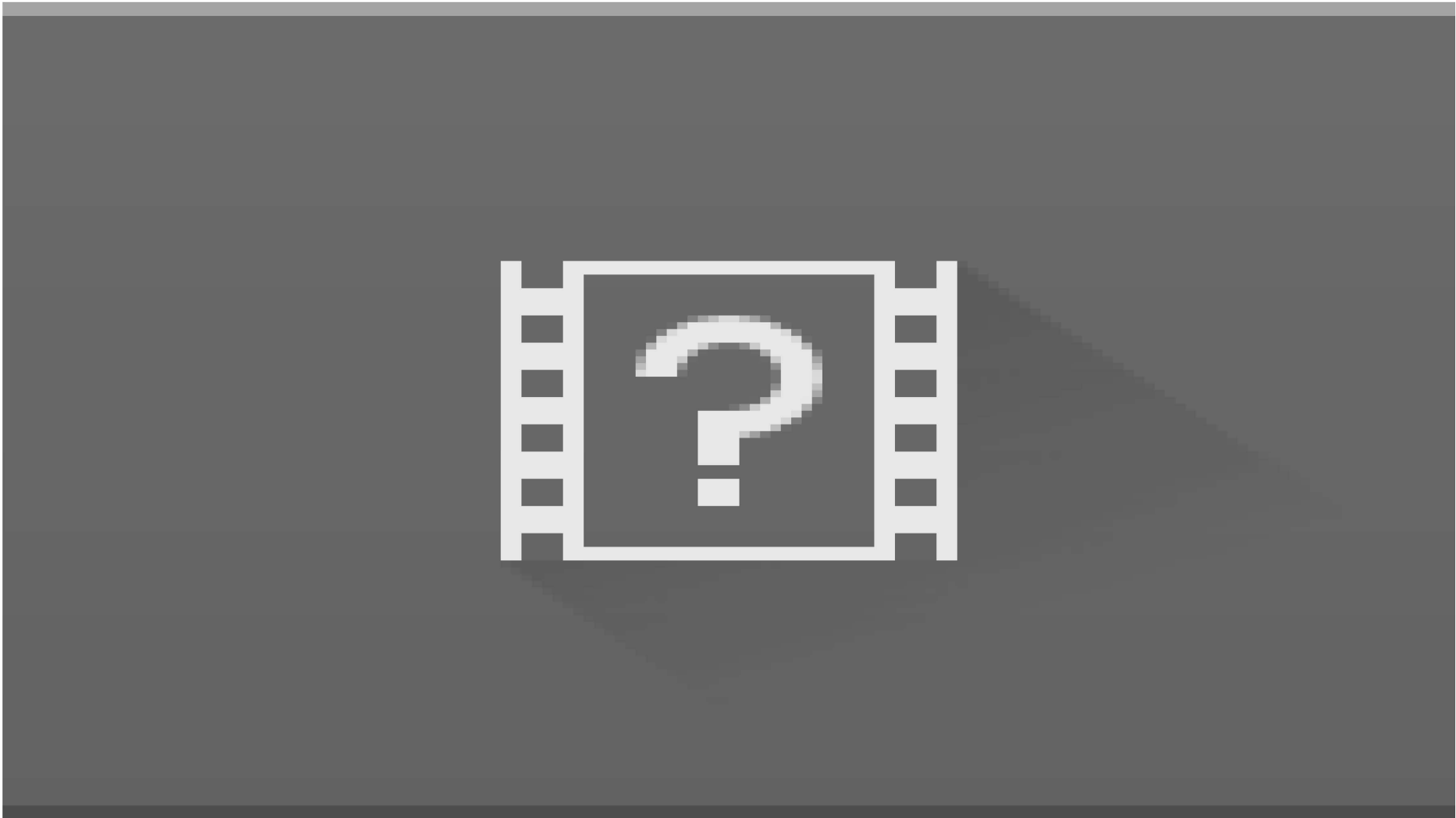
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bergemann partner

Client  *Concept Development & Design Retractable Roof:*

Architect **Tillner & Willinger** *Retractable Roof Contractor:*

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**PFEIFER**



# seele



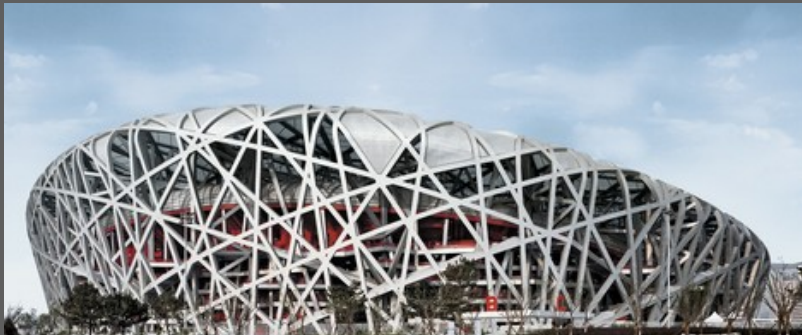
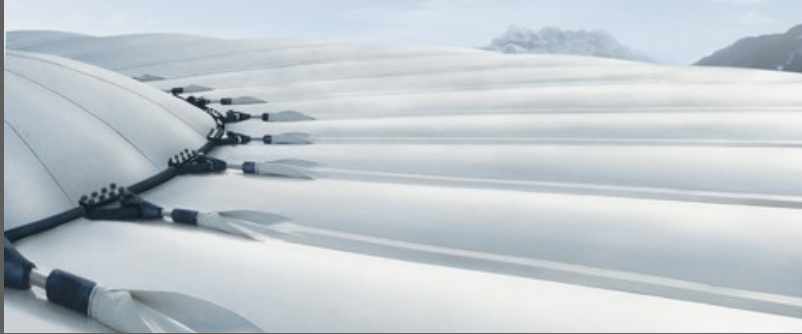
seele

20<sup>th</sup> Oktober 2022

## 1.000 m<sup>3</sup> ETFE Cloud | The Way

Thomas Toepfer, Sales Director | se cover, Germany





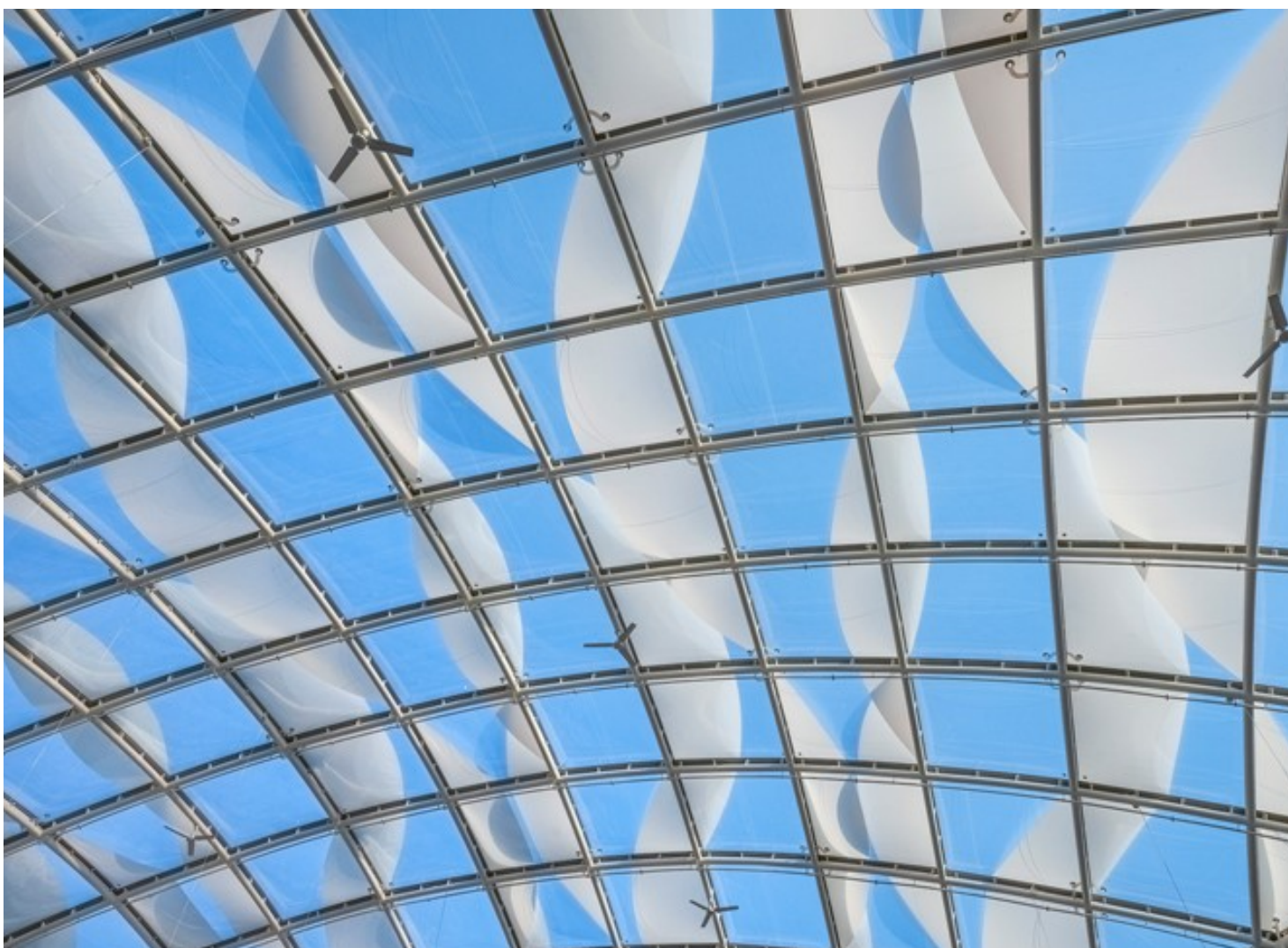
Auchan Pole Europe





Mont-Saint Martin, France (2016)

VDDT Architectes, F-Lille



**1,800sqm**

ETFE cushion  
façade 900sqm, roof 870sqm

**122**

Tripple-layer ETFE-cushions

**2**

Printed area to match the wave design





The inner and outer layers of the 3-layered ETFE air-filled cushions are partly printed with organic lines and zones.



The printing on the cushions ensures that sunlight is reflected, which prevents an excessive heat on the inside.

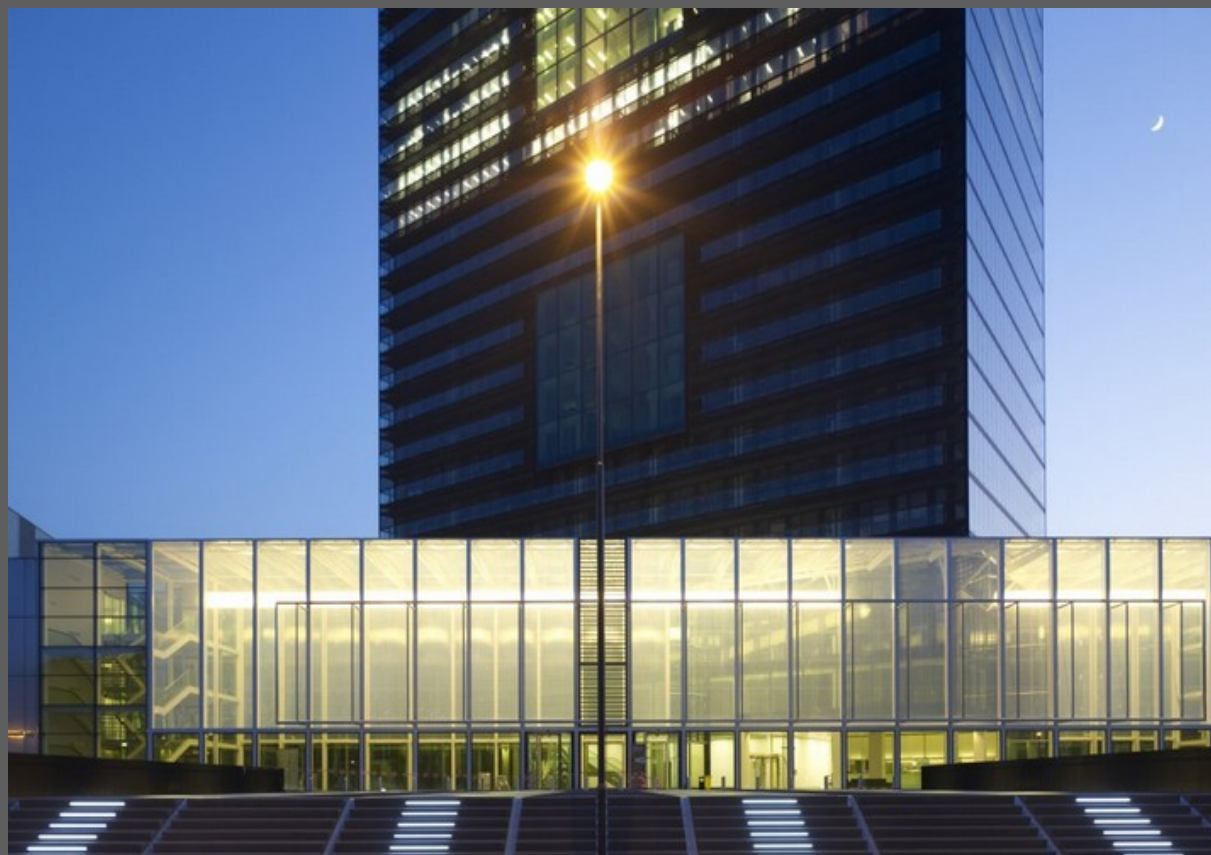


Foto from cepezed



Foto from cepezed





Utrecht, Netherland

New images after 20 years



A beautiful light-filled atrium as a connection between the buildings with a three-sided ETFE-solution.





Masoala  
Rainforest

© seele 12

## Masoala Rainforest

seele



Zoo Zürich, Switzerland

Gautschi & Storrer | Switzerland

© seele 13





**14,000 sqm**

ETFE cushion roof & facade

**System**

Four-layer ETFE cushion

**Dimension**

Cushion length up to 106m



Impression from the inside.

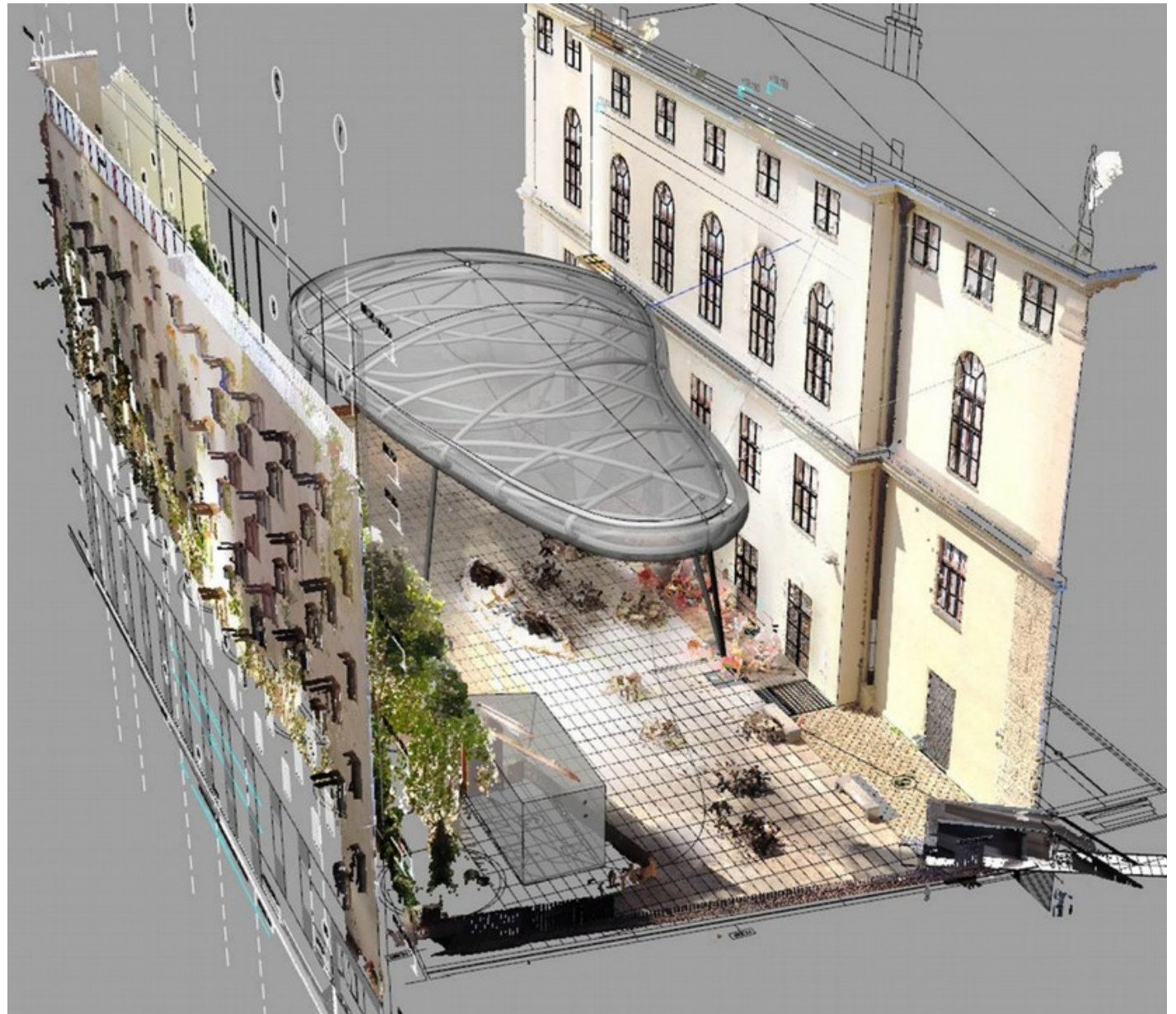




Brno The Cloud | First Vision



Brno The Cloud | First Vision





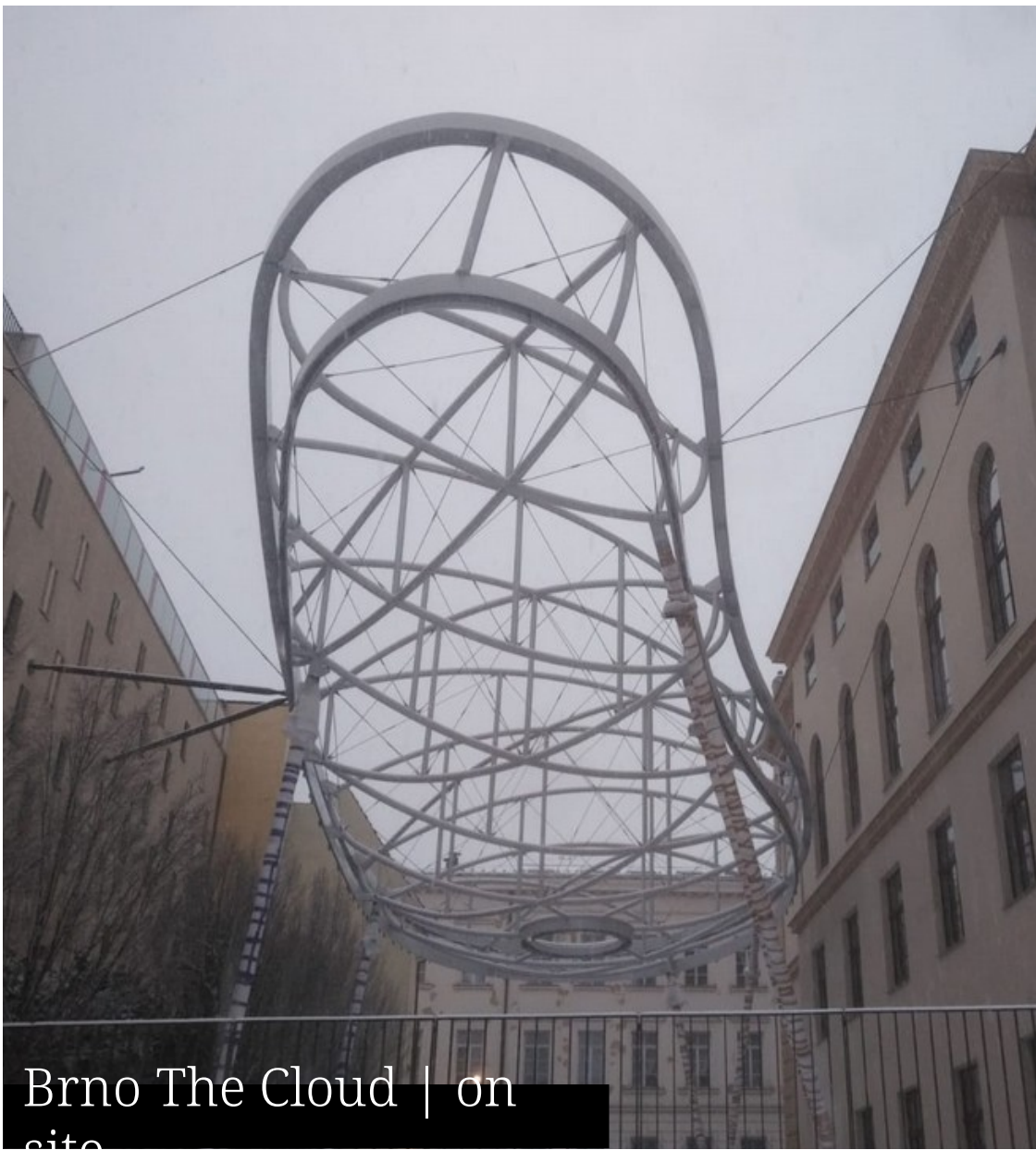


Brno The Cloud | First Steps



Brno The Cloud | Manufacturing





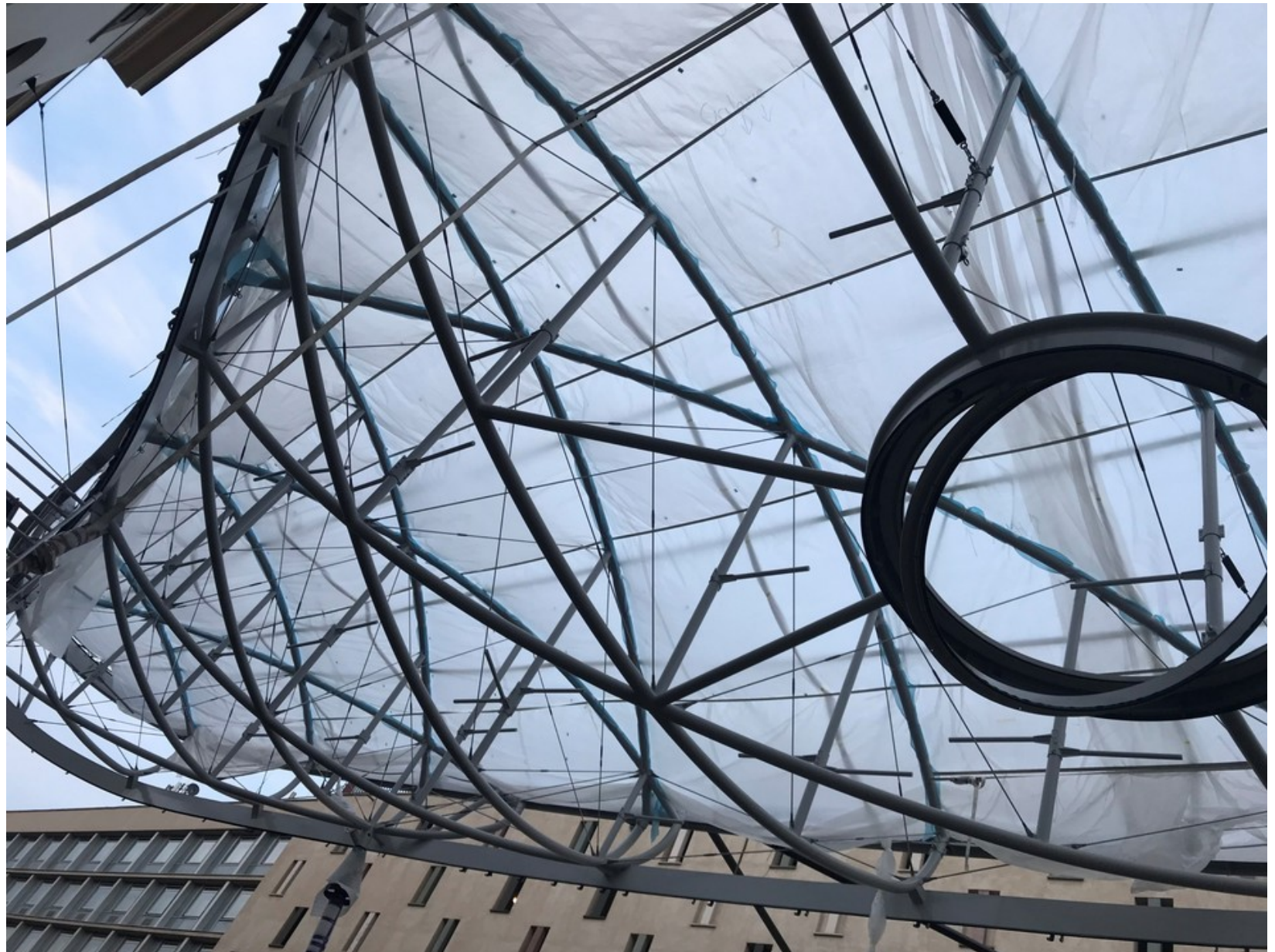
Brno The Cloud | on site



© seele 20



Brno The Cloud | Installation



© seele 21





Brno The Cloud | Installation



Brno The Cloud | Installation







Brno The Cloud | Final Version

# Brno The Cloud



Brno, Czech Republic

Atelier Štěpán s.ro, Vranov | C Z





**1.050 m<sup>3</sup>**

Air in one chamber

**3**

One-layer elements with inner- & border- & upperlayer covering the the steelstructure as one air chamber

**6**

Penetrations for the steel columns

**520 mm**

Supporting cables in chaos design



Inside view through the steel structure.

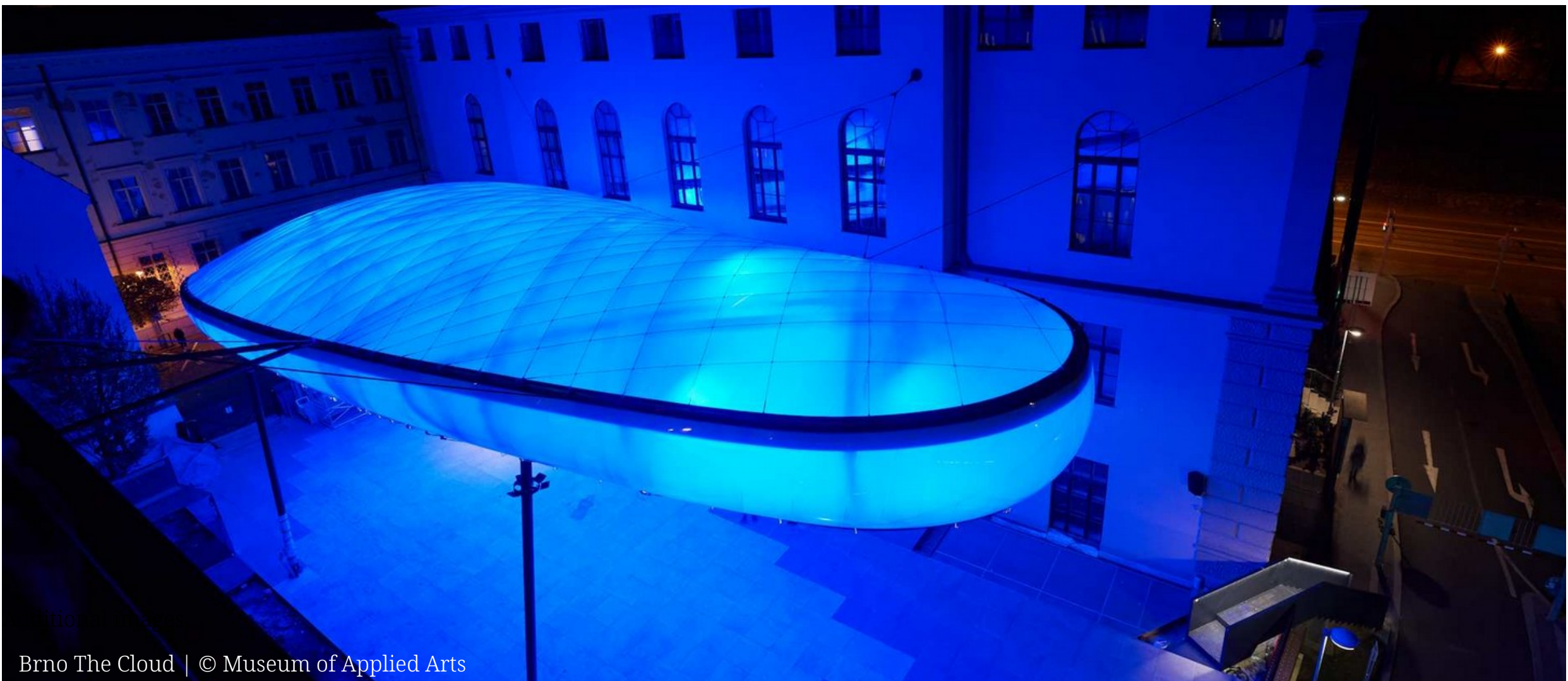


Inside view with the opening for maintenance and light control. (without air pressure)





Additional images





elees



# Life Safety and Fire Prevention in Façades

Dr. Carl Maywald



vector foiltec  
CREATE. SUCCESS.



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Canton de Berne



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## The Grenfell Tower

vector foiltec  
CREATE. SUCCESS.

Failure –  
typically the most effective mechanism for  
evoking rapid reform?!

1974 built in concrete

2016 energetically refurbished by curtain-wall facing  
with air space including new windows

....causing many to suggest the cladding was responsible.....

**flashover!!**

....as many as 600 high rise buildings in the UK feature similar  
cladding....

June 14, 2017

72 people died





# Standard Test Procedures

Europe	National	US / Canada	Maritime	ISO
EN 13501	DIN 4102	NFPA 701	IMO FTPC-5	ISO 1182
EN 11925	BS 476	ASTM D1929	IMO Res. MSC.61	ISO 1716
EN 13823	.....	ASTM E662	IMO Res.A.653	ISO 9705-1
EN 13238		ASTM D5207		ISO 13784-1
		ASTM E84 (UL 723)		
		ASTM E2768		
		ASTM E136-04		
		UL 94		
		ULC-S135-04		

Focus is set on 1. fire resistance 2. flammability of building products





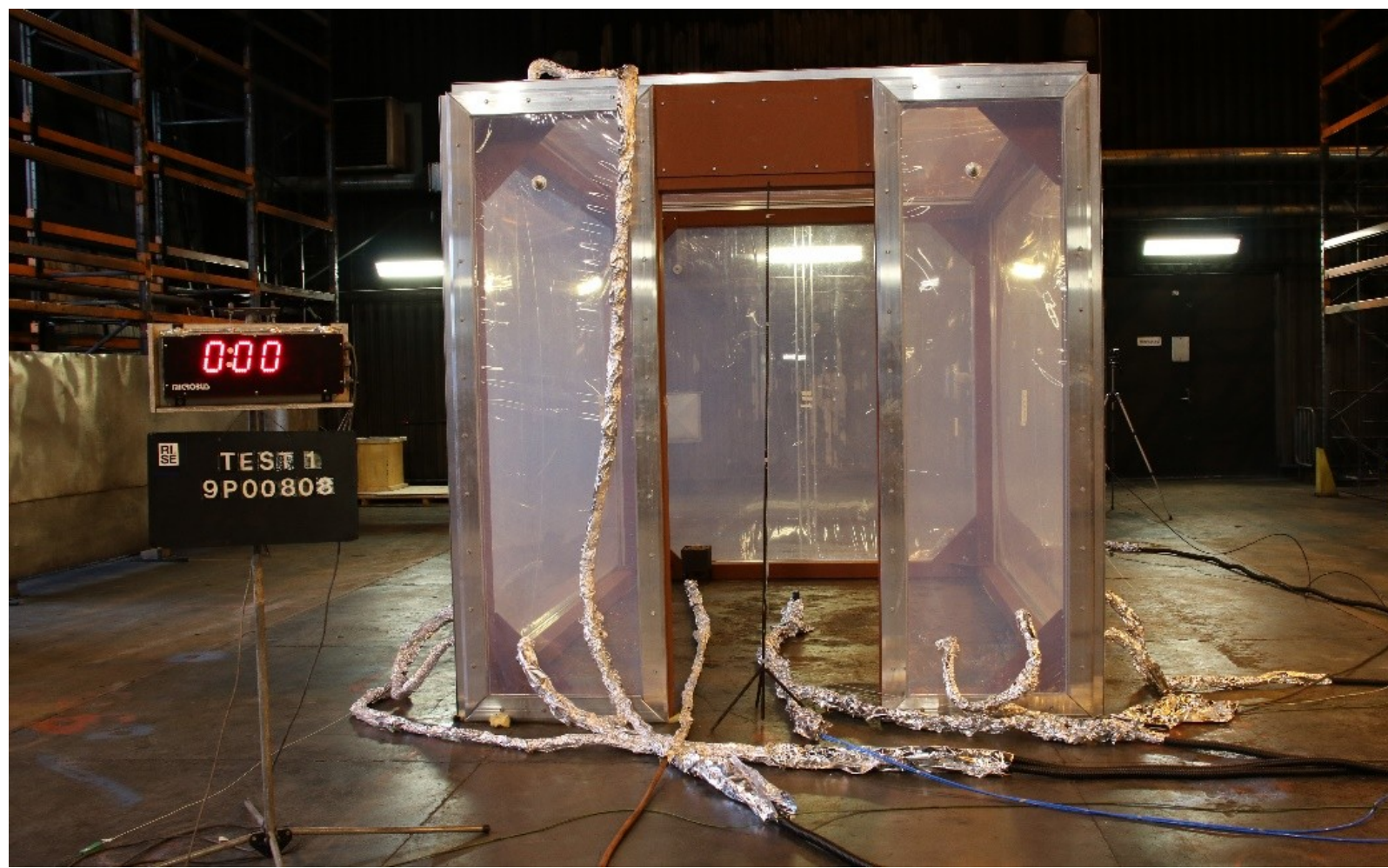


B767 after the fire - Dec. 12, 2016, 10:12 hrs

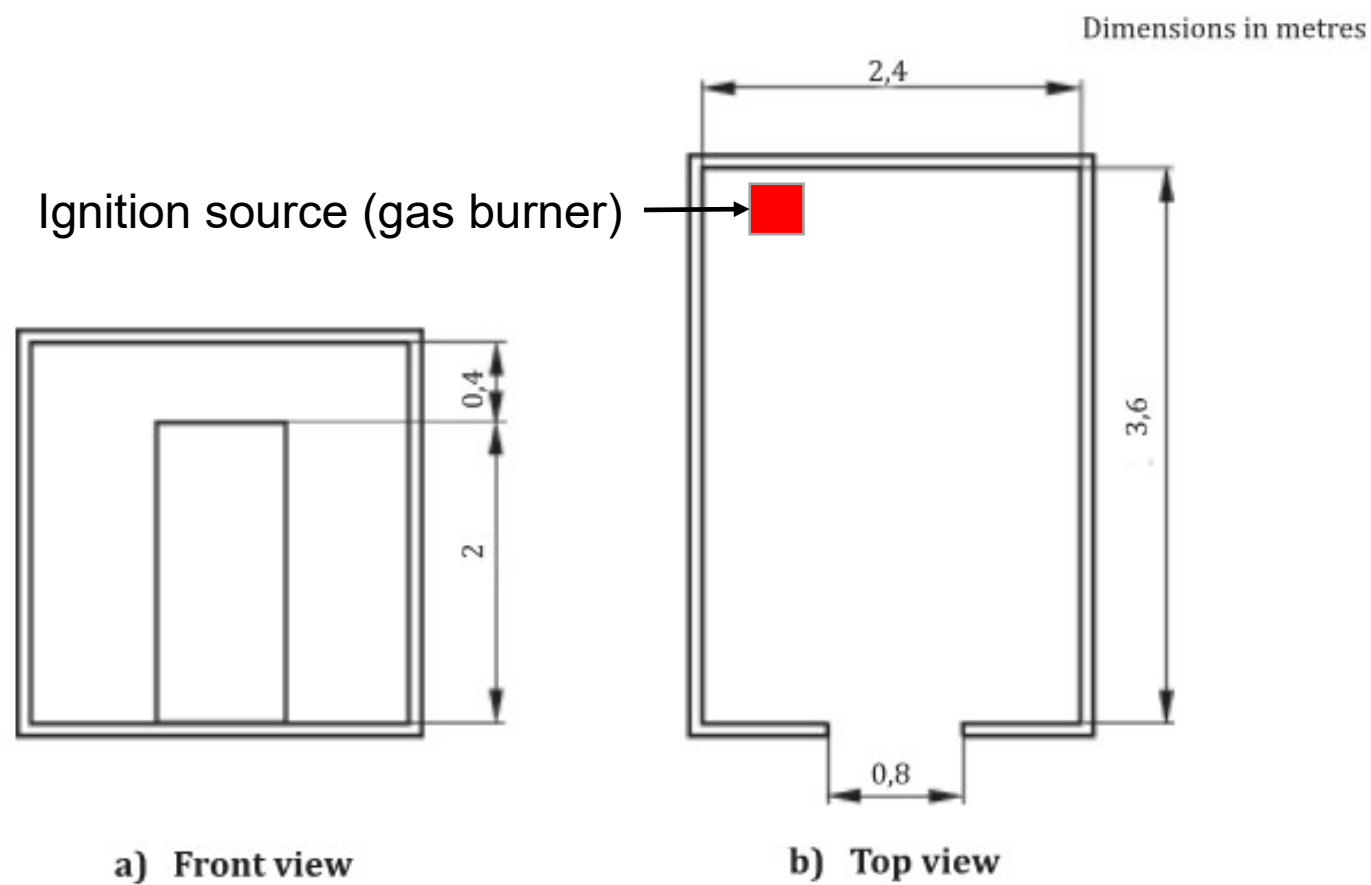
- ETFE roof opened at 200°C
- Heat & Smoke released to outside
- 200 people evacuated from the office building
- 0 people hurt
- Fire extinguished after 45 minutes
- Office Building cleared and reopened in the afternoon

## Fire Test of Texlon®-ETFE Cushions

- Small Room Fire Test according to **ISO 9705-1 & ISO 13784-1**
  1. 10 min @ fire of 100 kW
  2. 10 min @ fire of 300 kW
  3. 10 min cooling down
- Measurement of temperatures  
heat release rate (HRR)  
smoke release rate (SRR)
- Fire Research Department  
Research Institute of Sweden







## Tests with clear and printed Texlon®-ETFE cushions



Clear 3-layer ETFE foil cushion:  
250  $\mu\text{m}$  outer foil  
100  $\mu\text{m}$  middle foil  
250  $\mu\text{m}$  inner foil

Same standard cushion design with  
silver print pattern DH 9:92 dark  
on the inner side of the outer foil (side 2)

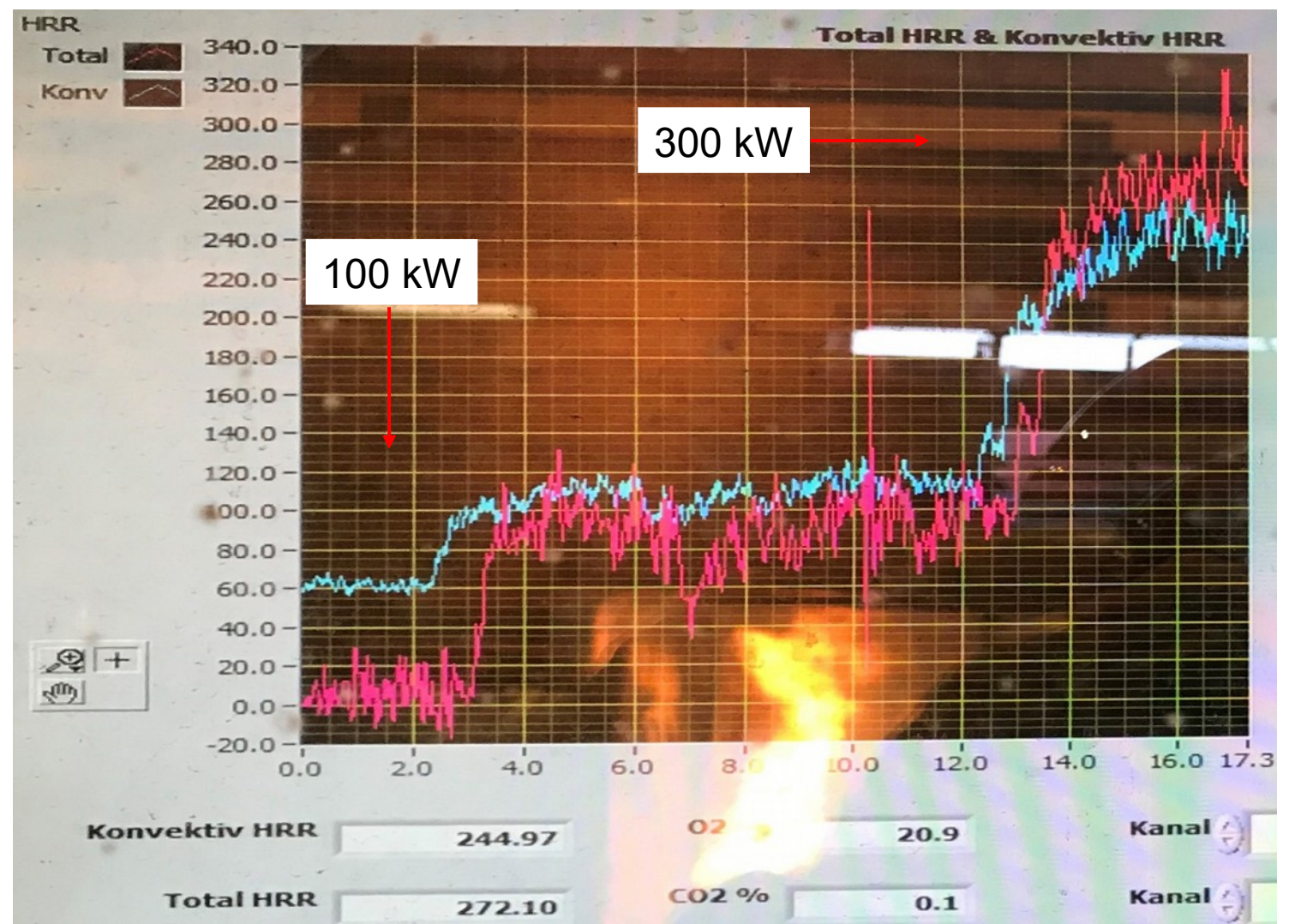




Heat release rate vs. Time → FIGRA

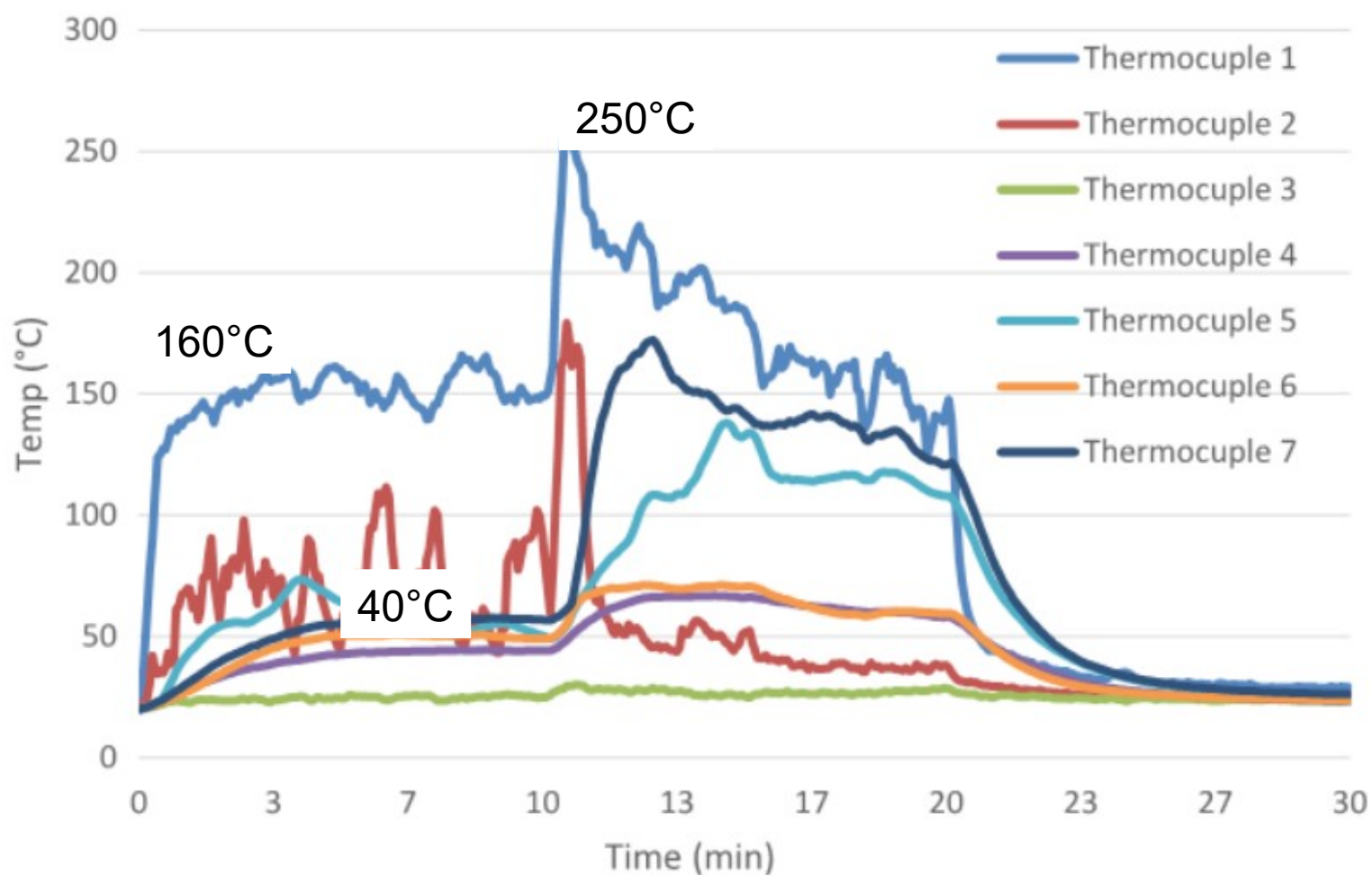
Heat release rate due to the ignition source only

No additional heat release contribution due to the ETFE foil





## Temperature profile door, walls and ceiling (ISO 9705-1)



### Inside Room

#### Thermocouple 1

Centre of doorway at 1,9 m

#### Thermocouple 2:

Centre of doorway at 1,5 m

#### Thermocouple 3

Centre of doorway at 1,0 m

### External Surface

#### Thermocouple 4:

Centre of right wall panel

#### Thermocouple 5:

Centre of rear wall panel

#### Thermocouple 6:

Centre of left wall panel

#### Thermocouple 7:

Centre of ceiling panel

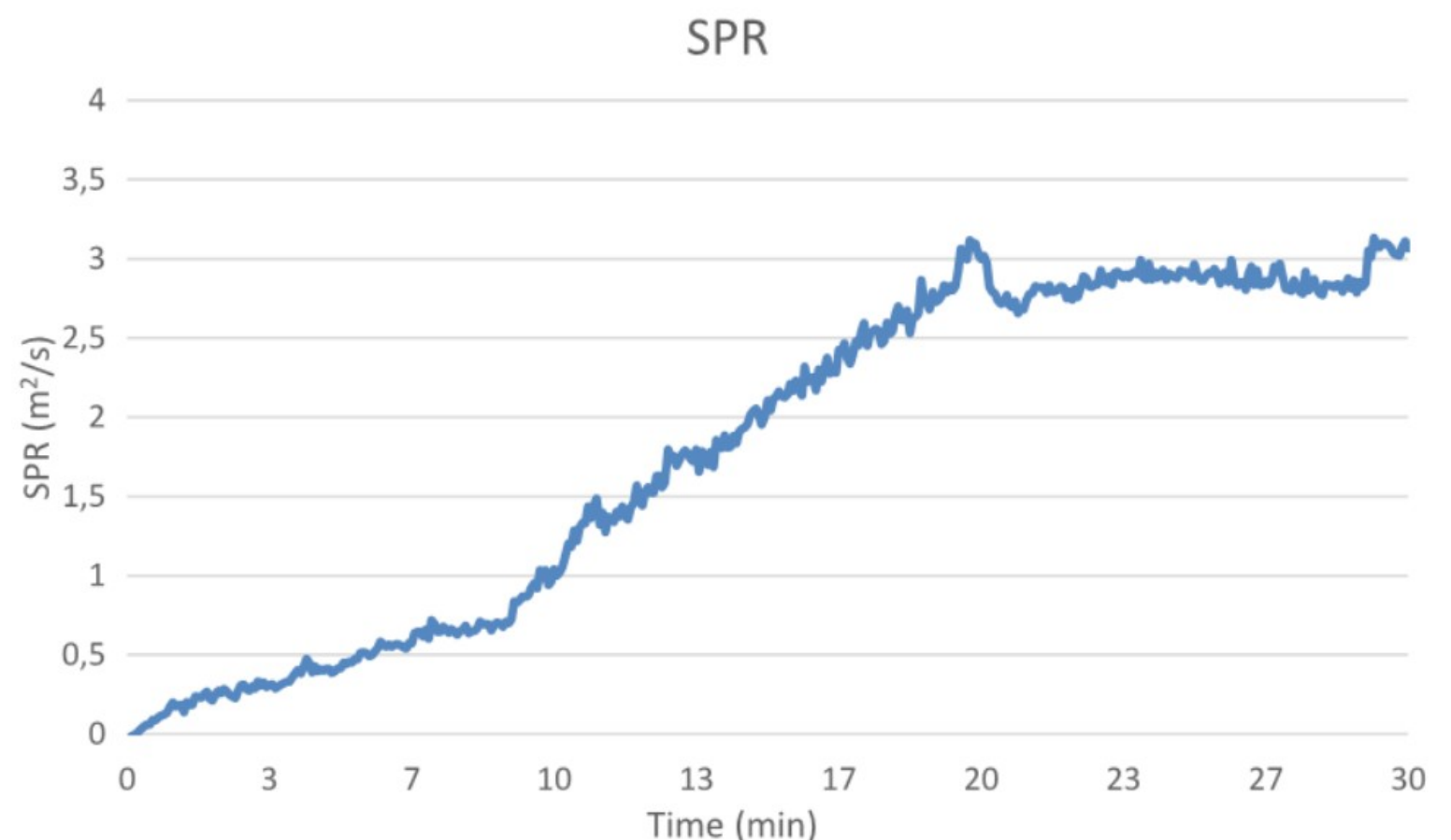
## Smoke Production Rate including Burner

Gas burner was switched off at 20:00.

Test was terminated at 30:00.

Lenses of the smoke measurement system were contaminated, causing the photometric signal not to return to the base level.

Thus, smoke production is not significant





## Printed foil with highest coverage of dye

- No additional damages visible in the foils
- Same heat release rate and temperatures like for clear foil



## Status of seals and foil under AI – extrusion profiles after test



Silicone seal still intact !



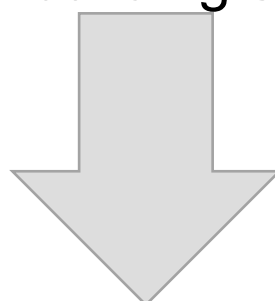
Foils and Keder not destroyed !



1. Small room fire test – reflects real fire scenarios
2. Aluminium profiles and Silikone gaskets not affected due to fire loads
3. ETFE melting and opening of the structure
4. Small local openings due to low heat conduction
5. Cushions that are not exposed to direct heat remain in good order
6. Off-take of smoke gases through the holes
7. Only small ETFE wire-like residues after melting
- 8. No flash-over**

## Conclusion

1. Fire safety requires evidence regarding performance of a **building system** exposed to fire.
2. The Small Room Test according to **ISO 13784-1** and calculation of SMOGRA and FIGRA according to **ISO 9705-1** allow for a good understanding of the reaction to fire of a **building system**
3. There are no criteria defined in **ISO 13784-1** nor in **ISO 9705-1** that allow for certification and/or classification of a building system
4. Criteria may be





## Criteria for a fire performance rating of building systems

1. Flash-over
2. FIGRA / HRR according to **ISO 9705-1**
3. SMOGRA according to **ISO 9705-1**
4. Temperature at thermocouple 1, 2, and 3 (door)
5. Temperature at thermocouple 4, 5, 6, and 7 (external surface)
6. Burning droplets

**To be defined by fire experts**

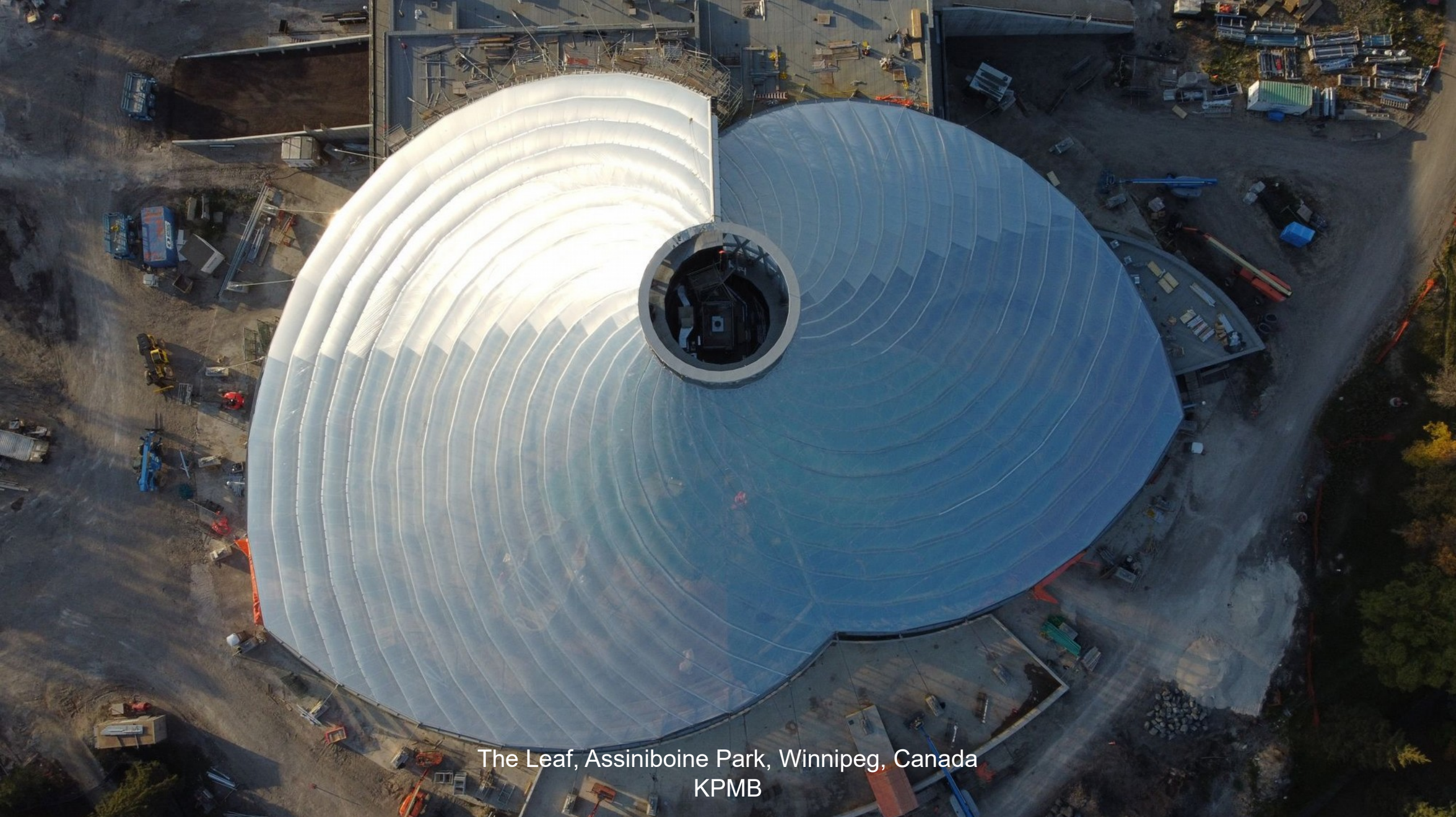
**ISO/TC 92 SC1    CEN/TC 127**



**Create New Worlds!**

The Leaf, Assiniboine Park, Winnipeg, Canada  
KPMB





The Leaf, Assiniboine Park, Winnipeg, Canada  
KPMB









# How to Get Full Fire Safety for Façades

A presentation on A2-s1,d0  
vertical wall membranes,  
breathable and water proof to  
W1

Today's presenter

Technical Consultant  
for Stamilol Safe One and  
for Fire and Smoke Control

**Allan Hurdle**

AKH Services Ltd





# Serge Ferrari Group – Project development



- Solar Protection
- Façade
- Tensile Architecture
- Furniture/Interior Design
- Acoustics

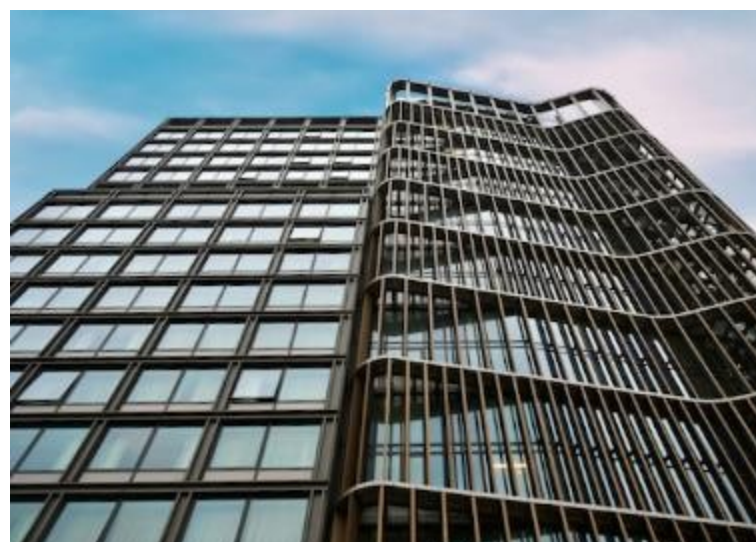


How many high-rise outer wall systems around the world are fire safe?

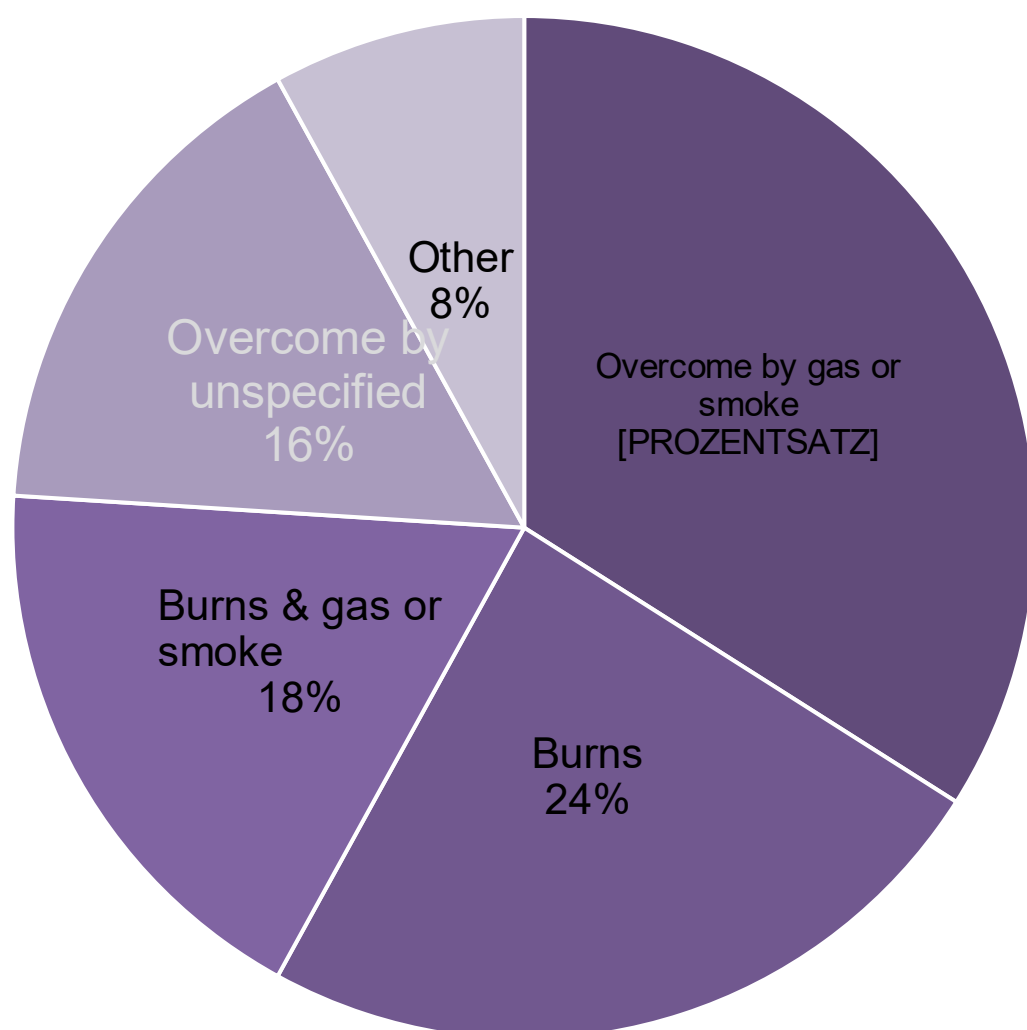




# The development of Stamisol A2 membranes for the UK building market



## Death resulting from building fires



### Example UK Statistics

- 163,039 fires
- 252 fire related deaths
- 3,083 had to have hospital treatment due to smoke inhalation

(Source: Home Office Data. Sept. 2019)



# A2-s1,d0 membrane Stamisol Safe One: Features and benefits



- A1 membranes have been developed for “Non Combustibility “ with no smoke and no hot droplets
- **BUT** Stamisol Safe One A2-s1,d0 membranes have been developed to also give water proofness, breathability and UV protection to buildings
- W1 waterproof protection to EN ISO 20811 for building protection at 7000 mm
- 5000 h UV resistance to EN ISO 13859-2 (current ageing test 700 hrs)
- Independent fire tests of EN13501-1

## Why breather membranes behind cladding?

### Thermal and waterproof insulation protection





# Stamisol Safe One for fire safety and residents' wellbeing



## The benefits of an A2-s1,d0 membrane:

- Euroclass A2-s1,d0
- W1 waterproofing
- Breathable
- UV solar shielding
- Heat control
- Completes the A2 building envelope behind cladding in front of thermal blocks



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## A2-s1,d0 vertical membranes are ideal for



- Buildings higher than 18 meters
- Hospitals, retirement homes, rehab centers
- Universities
- Schools, nurseries
- Office buildings with high public traffic
- Transport facilities
  
- Vertical walls, both open and closed facade
- Should meet the requirement of Building Regs for breathability, weather tightness and condensation control when fitted correctly



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Canton de Berne



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# Materials compatible for an approved A2 vertical membrane

- Weatherboard
- Steel
- Aluminium
- Concrete blocks
- Brick
- Stone
- Bitumen cement boards
- Copper



## Why A2-s1,d0 membranes are so important



### **Euroclass A2-s1,d0**

**A2** Non combustible

**s1** Gives a guarantee of limited fumes and smoke

**d0** Gives a guarantee of non-burning droplets

- Material composition of glass fibre fabric with a special coating
- Stringent quality procedures to ISO 9001 with independent certification
- Meets Euroclass EN 13501-1/2



# Importance of product certification



## Always ask to see:

- The independent test certificate to meet A2-s1,d0
- Life time guarantee for non-combustibility

## Confirmation the product meets:

- EN 13501-1
- CE Marked
- ISO 9001
- Is UV resistant tested
- Breathable
- Has a W1 water protection

## An independent test

### Confidence

#### An independent test gives:

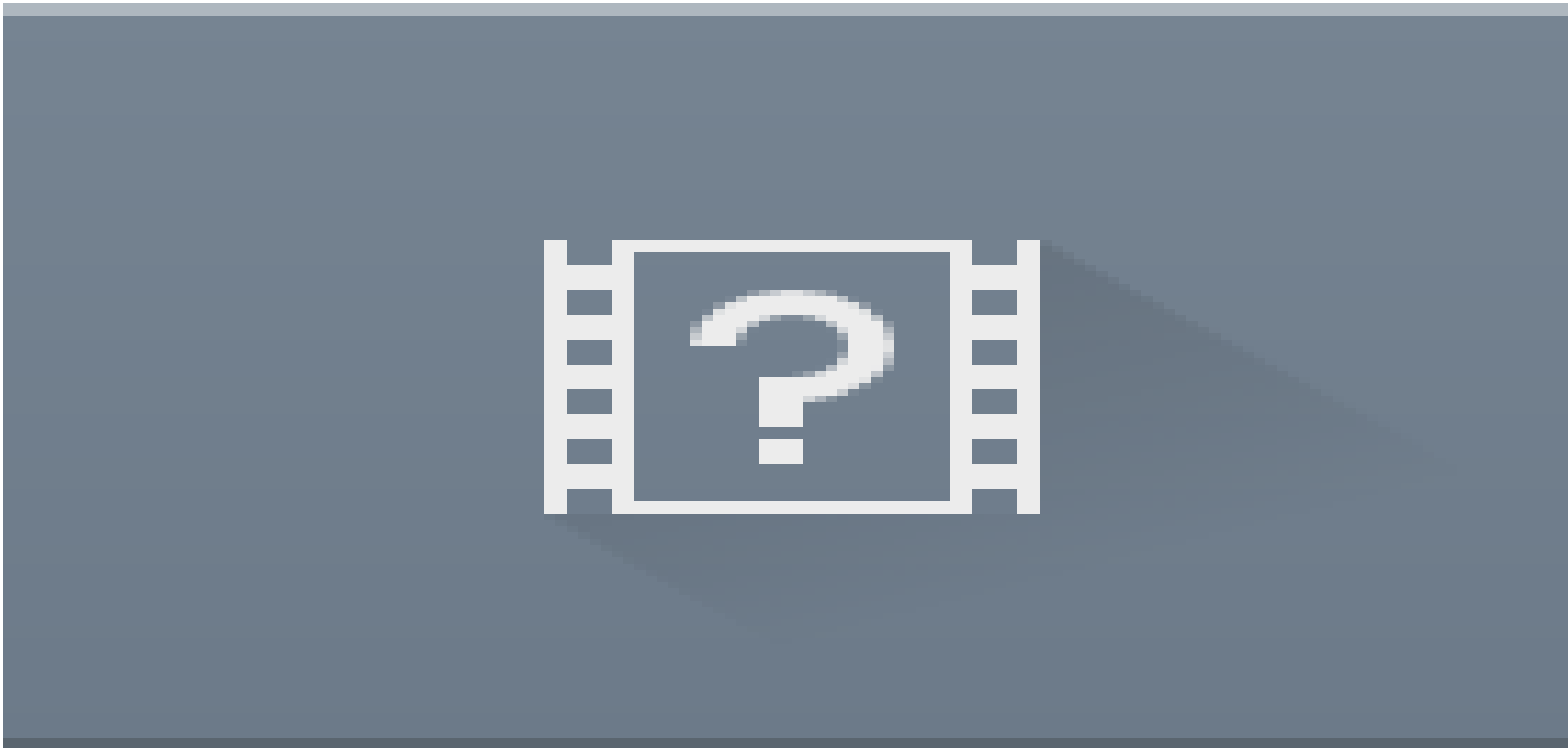
- Confidence to the buyer.
- It ensures no in-house data.
- It is a document that gives guarantee of performance.
- It confirms the temperature and test time of the product for fire smoke and hot droplets.

### The density of smoke





# The 3 key tests: Fire & smoke, waterproof, breathability



## What fire means to building occupiers

### Fire and Smoke



### Office Fire

- Possible loss of life
- Hospitalisation
- Future health issues
- Loss of confidence
- Loss of confidence in employer
- Fear of enclosed spaces



# What fire means to an employer

## Do you want

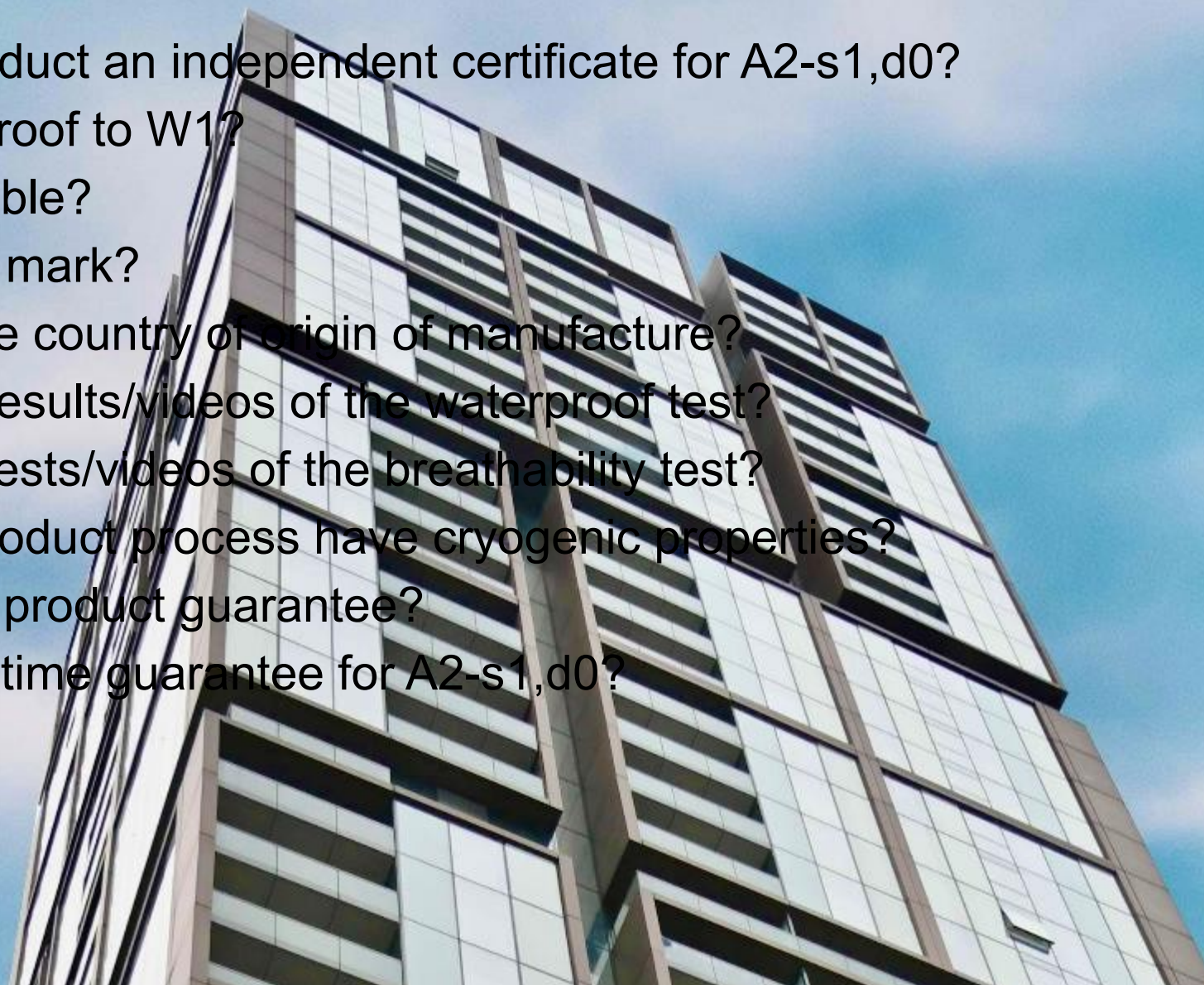
- The possibility of loss of life
- Your building shutdown
- Risk of investigation of fitting combustible materials
- Insurance claim rejection
- Increased insurance costs
- Reputation damage

## After a fire



## Questions to ask when looking at vertical wall membranes

- Has the product an independent certificate for A2-s1,d0?
- Is it water proof to W1?
- Is it breathable?
- Has it a CE mark?
- Where is the country of origin of manufacture?
- Have they results/videos of the waterproof test?
- Have they tests/videos of the breathability test?
- Does the product process have cryogenic properties?
- What is the product guarantee?
- Has it a life time guarantee for A2-s1,d0?





# Be aware of fitting second best



## For safety is it acceptable for a company to state

- “We tested in accordance with EN/BS standards but have no independent test certificate.”
- “The staff know bits of buildings docs but not all, they are complicated and wordy, we rely on others to be the experts.”
- “We fitted cheaper products to save money.”

## Contact

For more information please contact:

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[stamisol@sergeferrari.com](mailto:stamisol@sergeferrari.com)

[www.stamisol.com](http://www.stamisol.com)



# Membrane structures and embodied carbon reduction

**Marijke Mollaert**

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Full Professor

**Zehra Eryuruk**

Ph.D. Candidate

**Carol Monticelli**

Ph.D. M.Sc. Arch,  
Associate Professor

**Alessandra Zanelli**

Ph.D. M.Sc. Arch,  
Full Professor

**TEXTILES HUB @POLIMI**

[www.textilearchitecture.polimi.it](http://www.textilearchitecture.polimi.it)

## Introduction

Case studies

Comparison

Conclusions

Reflections



# Membrane structures and embodied carbon reduction

Membrane structures are lightweight, which is an enormous advantage.  
Can we do even more to assure 'environmental performance'?



Kanton Bern  
Canton de Berne



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# Membrane structures and embodied carbon reduction

Should we already turn into 'waste'  
What still can be used  
Or what can be recycled?



Extract Raw  
Material



Transport



Manufacture



Distribute



Construct  
or  
Install



Operate  
Maintain  
Repair



Demolish



Haul



Dispose  
or  
Recycle





<https://adventuresinbad.com/a-visit-to-the-land-of-changpa-nomads-and-sapphire-lakes/>



<https://theupcyclemovement.com/blogs/commissions/siemens-gamesa-wind-turbine-tarp>

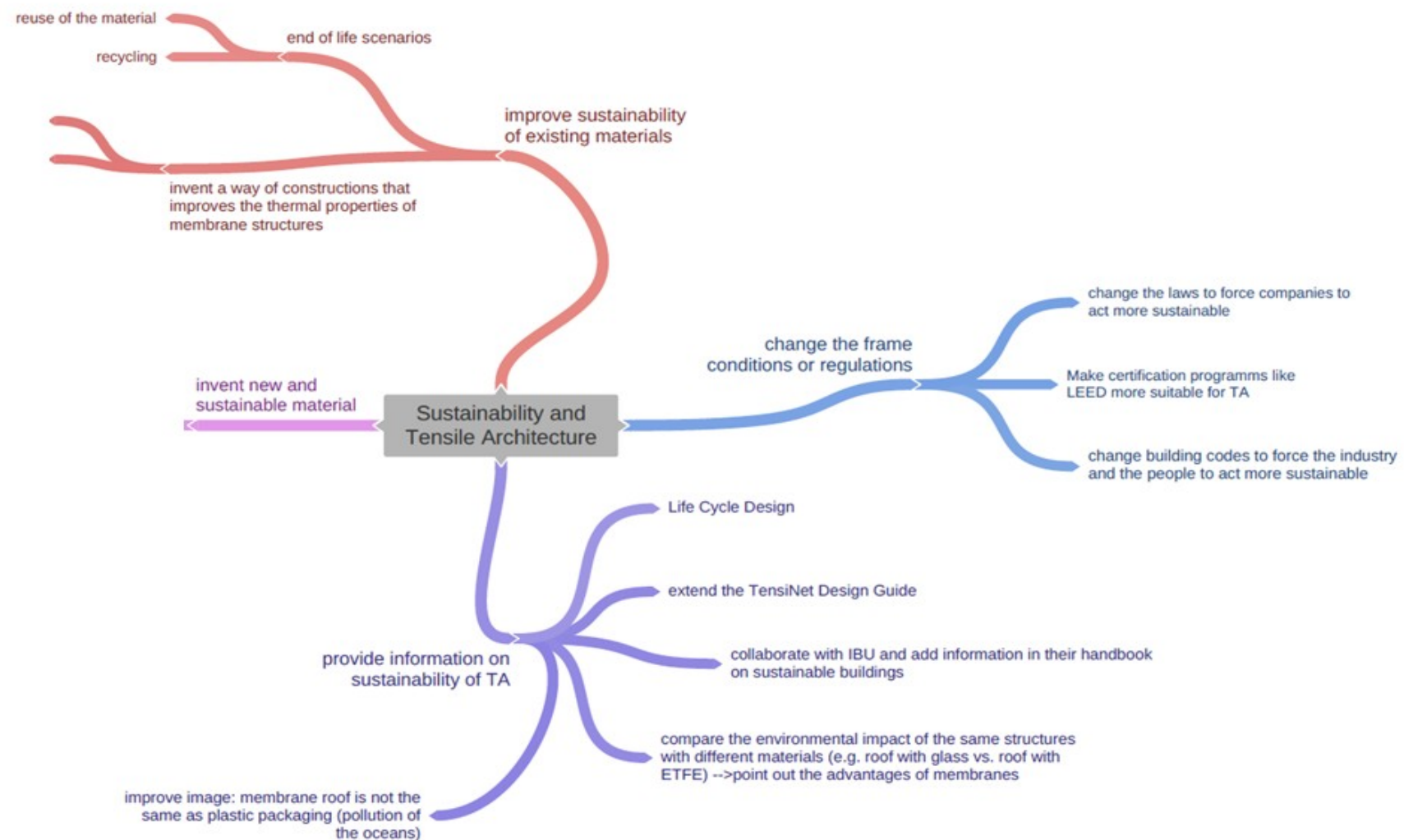


# Sustainability

Provide information on the sustainability of Textile Architecture

Improve the sustainability of existing materials

Compare the environmental impact of similar structures with different materials



© Lea Bath for Tensinet WG  
Sustainability and Comfort of Membranes

Introduction  
Case studies  
Comparison  
Conclusions  
Reflections



# Case study of a permanent membrane - Elpse



Kanton Bern  
Canton de Berne



ADVANCED  
BUILDING SKINS

## Elspe Grandstand Cover

Built: 1978, refurbished: 2015

Size: 77m long and 40m wide

Covered floor area: 2200m<sup>2</sup>

Service life: membrane (façade) 35 years and steel (load bearing) 70 years

Only 2 materials are considered for the LCA: **technical textile** and **steel**

**Tool:** OneClickLCA, Ecoinvent Database, Circularity tool of OneClickLCA

**Method:** LCA according to the standards EN15804+A2, ISO 14040



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# Elspe Grandstand Cover

Membrane material used: 4600m<sup>2</sup>

PVC-coated polyester, 1550 gr/m<sup>2</sup>

Steel frame: 30000kg (estimated total)

## *End-of-life*

Steel: recycled 88%

Membrane material: incinerated or ...

# Elspe Grandstand Cover

## GWP, A1..C4

The membrane material has a high contribution due to the replacement after 37 years

## Global warming kg CO<sub>2</sub>e - Resource types

This is a drilldown chart. Click on the chart to view details

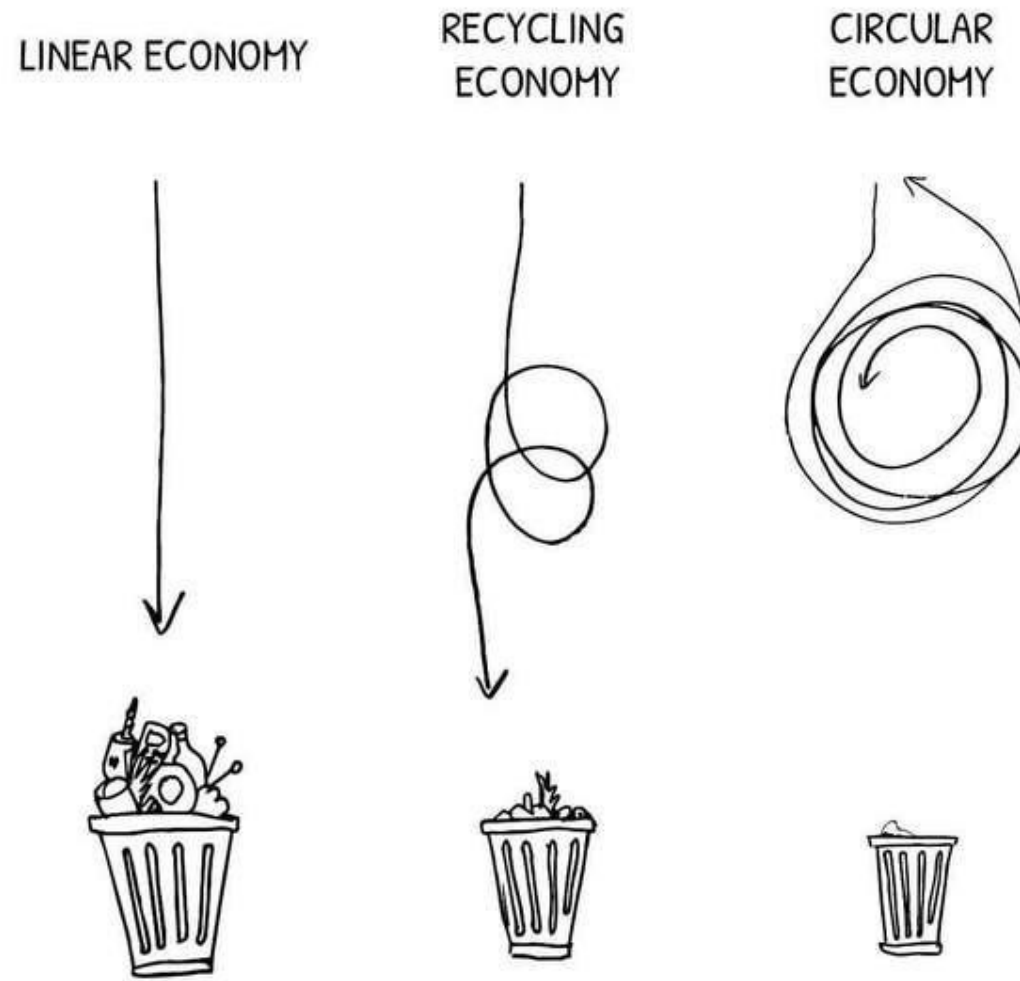


● metal - 51.1%

● plasticMembraneRoofing - 48.9%



# Circular economy



<https://audrey-ngomsik.medium.com/the-textile-industry-the-circular-economy-and-us-baeb22874f8d>

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## Recycling for Steel: high

Mountain of scrap metal ready for recycling



[https://www.freepik.com/premium-photo/mountain-scrap-metal-ready-recycling\\_14563873.htm#page=25&query=landfill&position=13&from\\_view=keyword](https://www.freepik.com/premium-photo/mountain-scrap-metal-ready-recycling_14563873.htm#page=25&query=landfill&position=13&from_view=keyword)



# Elspe Grandstand Cover

	<b>Recovered</b> (in used material) Renewable material Recycled material Reused material content	<b>Returned</b> (after use) Materials recycled	<b>Circularity score</b> Average (materials recovered + materials returned)/2
Steel	88%	100%	94%

# Elspe Grandstand Cover

	<b>Recovered</b> (in used material) Renewable material Recycled material Reused material content	<b>Returned</b> (after use) Materials recycled Materials <b>down-cycled</b> - 50% of the score included	<b>Circularity score</b> Average (materials recovered + materials returned)/2
Steel	88%	100%	94%
Coated fabrics	?	?	?



# Elspe Grandstand Cover

	<b>Recovered</b> (in used material) Renewable material Recycled material Reused material content	<b>Returned</b> (after use) Materials recycled Materials <b>down-cycled</b> - 50% of the score included	<b>Circularity score</b> Average (materials recovered + materials returned)/2
Steel	88%	100%	94%
ETFE-foil	0%	100%	<b>25%</b>

# Elspe Grandstand Cover

## elspe test circularity - Building Circularity Project basic information

EOL for the membrane:

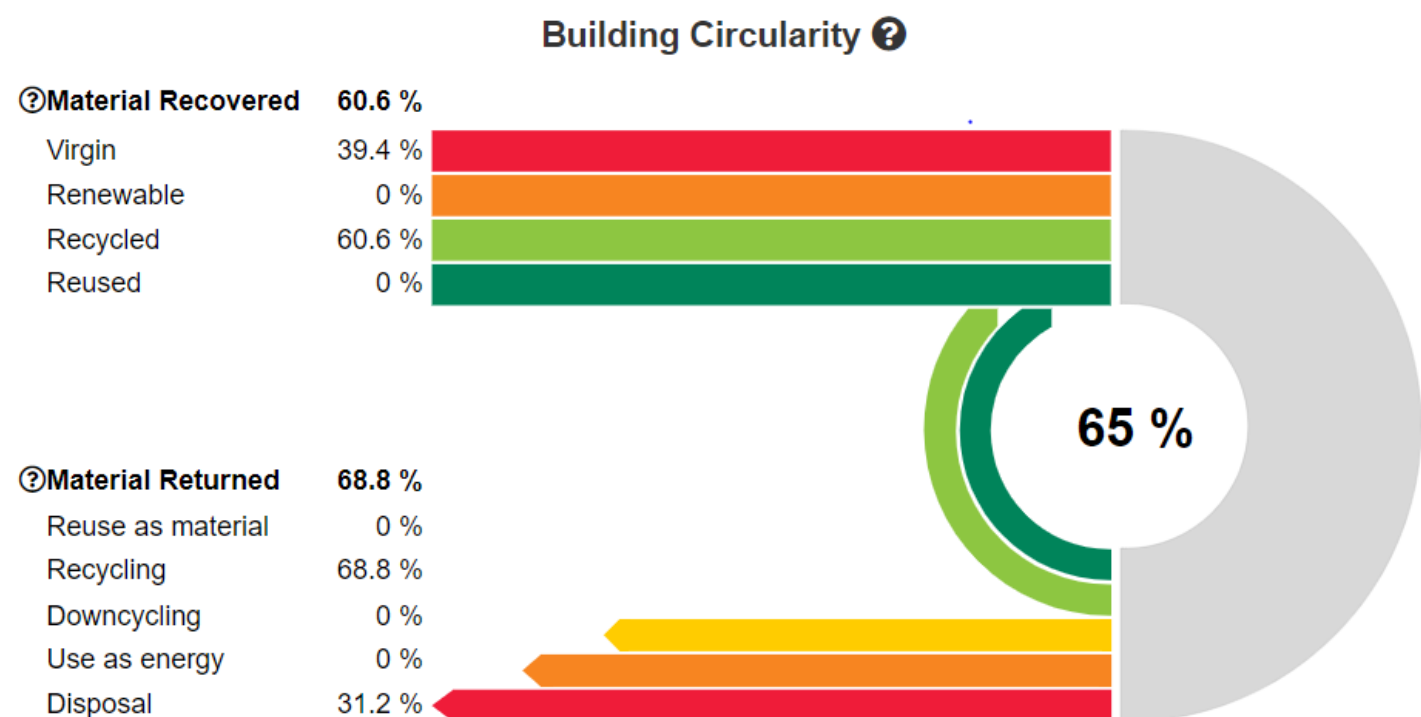
**landfill**

Building circularity score:

**65%**

Steel circularity: 94%

Membrane circularity: **0%**





# Is incineration the best option for membranes?



<https://www.clf.org/blog/whats-wrong-with-burning-our-trash-anyway/>

## Elspe Grandstand Cover

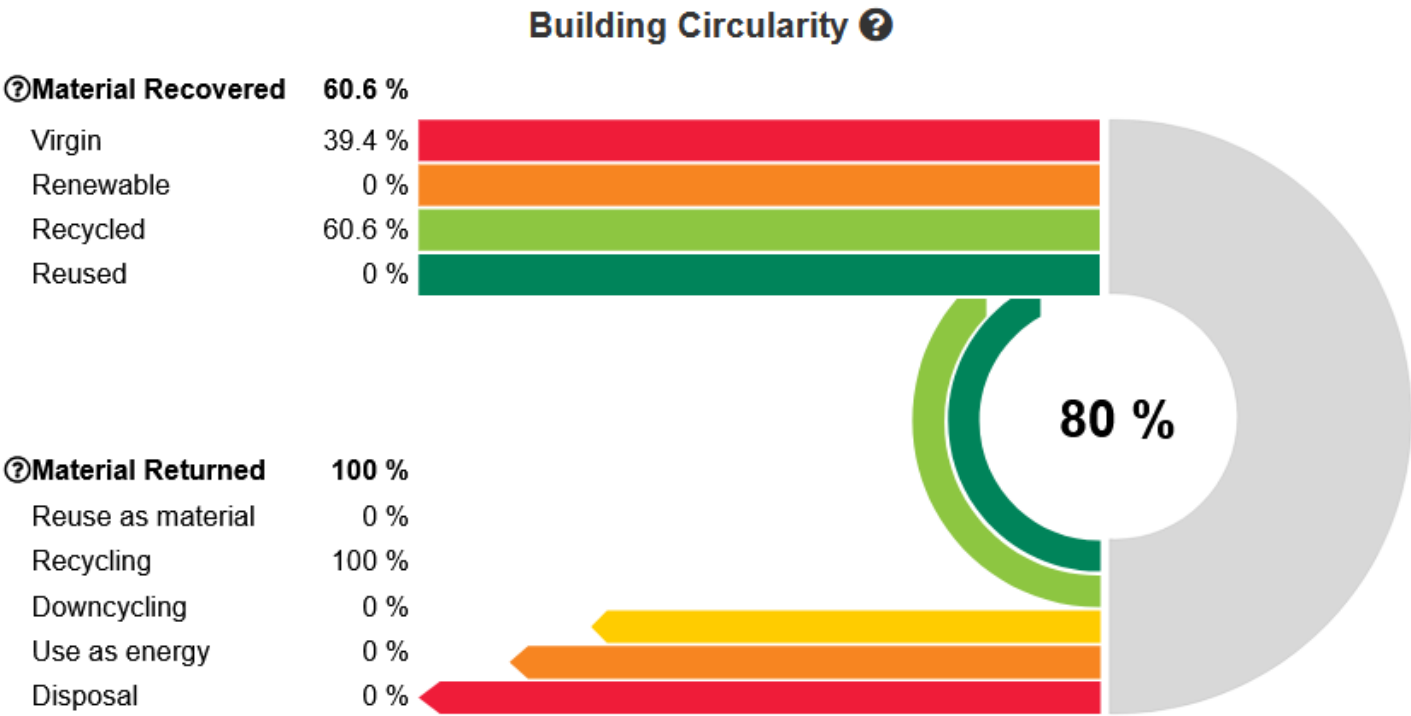
elspe test circularity - Building Circularity Project basic information

EOL for the membrane:  
plastic-based material  
**recycling**

Building circularity score:  
**80%**

Steel circularity: 94%

Membrane circularity:  
**50%**







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## OCMW Zoutleeuw

Built: 2012 for permanent use

Size: 16m long and 9m wide

Floor area: 64m<sup>2</sup>

Service life: membrane 25 years and steel (load bearing) 50 years

2 materials are considered for the LCA: **technical textile** and **stainless steel**

**Tool:** OneClickLCA, Ecoinvent Database

**Method:** LCA according to the standards EN15804 +A2, ISO14040



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Membrane material used: 135m<sup>2</sup> or 121,5kg

PVC-coated polyester, 900 gr/m<sup>2</sup>

Steel frame: 460kg (estimated total including columns, corner plates, edge and system cables)

*End-of-life*

Steel: recycled 84,4%

Membrane material: incinerated or recyclable???

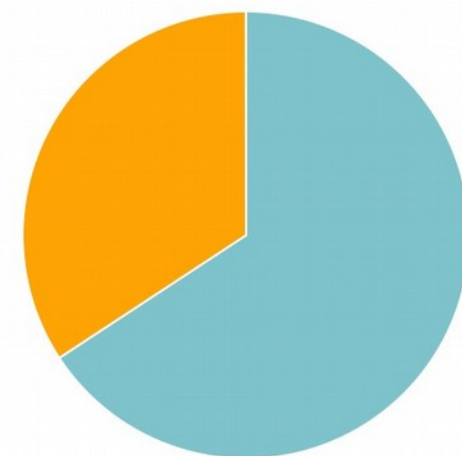
## GWP, A1..C4

The membrane material has a high contribution due to the replacement after 25 years

Global warming kg CO<sub>2</sub>e - Resource types

This is a drilldown chart. Click on the chart to view details

● plasticMembraneRoofing - 65.8% ● metal - 34.2%





# OCMW Zoutleeuw

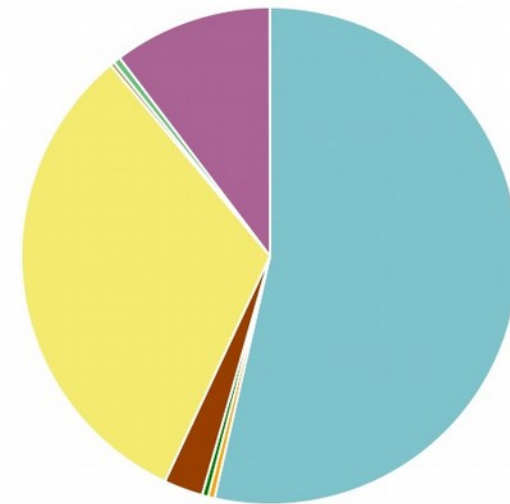
 3 Tons CO<sub>2</sub>e <sup>9</sup>

 0.93 kg CO<sub>2</sub>e / m<sup>2</sup> / year <sup>9</sup>

Section	Result category	Global warming kg CO <sub>2</sub> e
<b>A1-A3</b>	<b>Construction Materials</b>	<b>1,59E+03</b>
A4	Transportation to site	2,44E+01
A5	Construction/installation process	7,52E+01
B3	Repair	0,00E+00
<b>B4-B5</b>	<b>Material replacement + refurbishment</b>	<b>9,48E+02</b>
B6	Energy use	0,00E+00
B7	Water use	
C1-C4	End of life	3,28E+02
D	External impacts (not included in totals)	-8,85E+02
<b>Total</b>		<b>2,96E+03</b>

Global warming kg CO<sub>2</sub>e - Life-cycle stages

- A1-A3 Materials - 53.6%
- A4-leg2 Transportation - leg 2 - 0.4%
- B4-B5 Replacement - 32.0%
- C3 Waste processing - 0.5%
- A4 Transportation - 0.4%
- A5 Construction - 2.5%
- C2 Waste transportation - 0.3%
- C4 Waste disposal - 10.3%



## Case study of a temporary membrane - Temporactive





# Temporactive Pavilion - second life cycle

Built for 1 week: 2019, rebuilt for 4 months: 2022

Size: 14 m long and 7 m wide

Floor area: 98m<sup>2</sup>

Service life: membrane (envelope) 5 years in PVC for temporary uses and steel and GFRP (load bearing) 30 years

3 materials are considered for the LCA: **technical textile**, **GFRP** and **steel**

**Tool:** Rhinoceros® GrasshopperTM with the plug-in Tortuga , Ecoinvent Database, Simapro

**Method:** LCA according to the standards EN15804 +A2, ISO14040

# Temporactive Pavilion - second life cycle

Membrane material used: 130m<sup>2</sup>

PVC crystal - film with a printed serigraphy 500µm film

GFRP + Steel cables and connectors: 350kg (estimated total)

## *End-of-life*

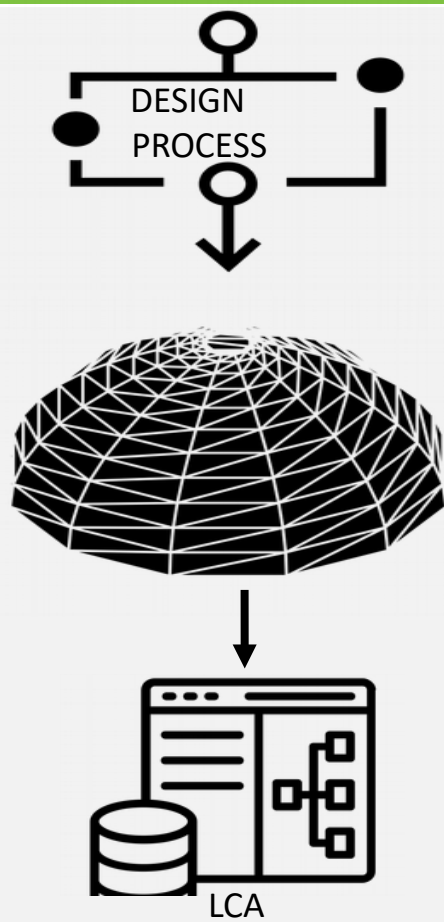
Steel: recyclable

GFRP: recyclable????

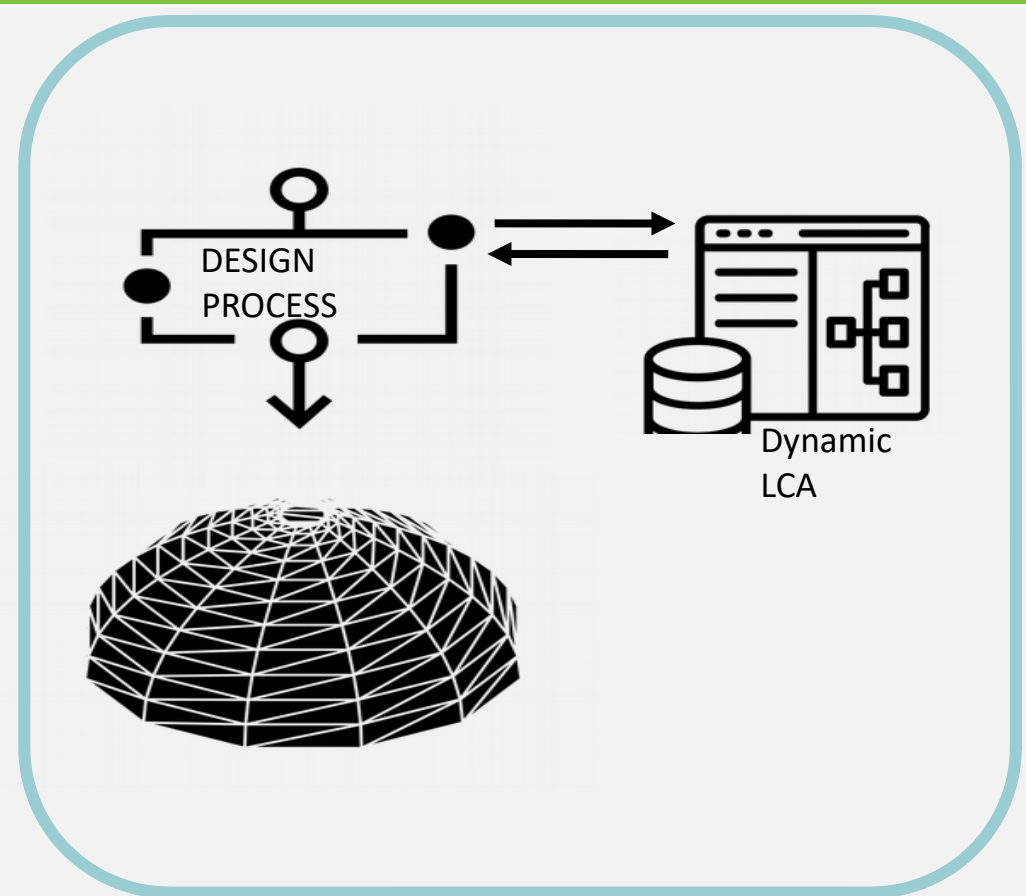
Membrane material: incinerated or recyclable???



# Temporactive Pavilion - second life cycle



**Current LCA practice**

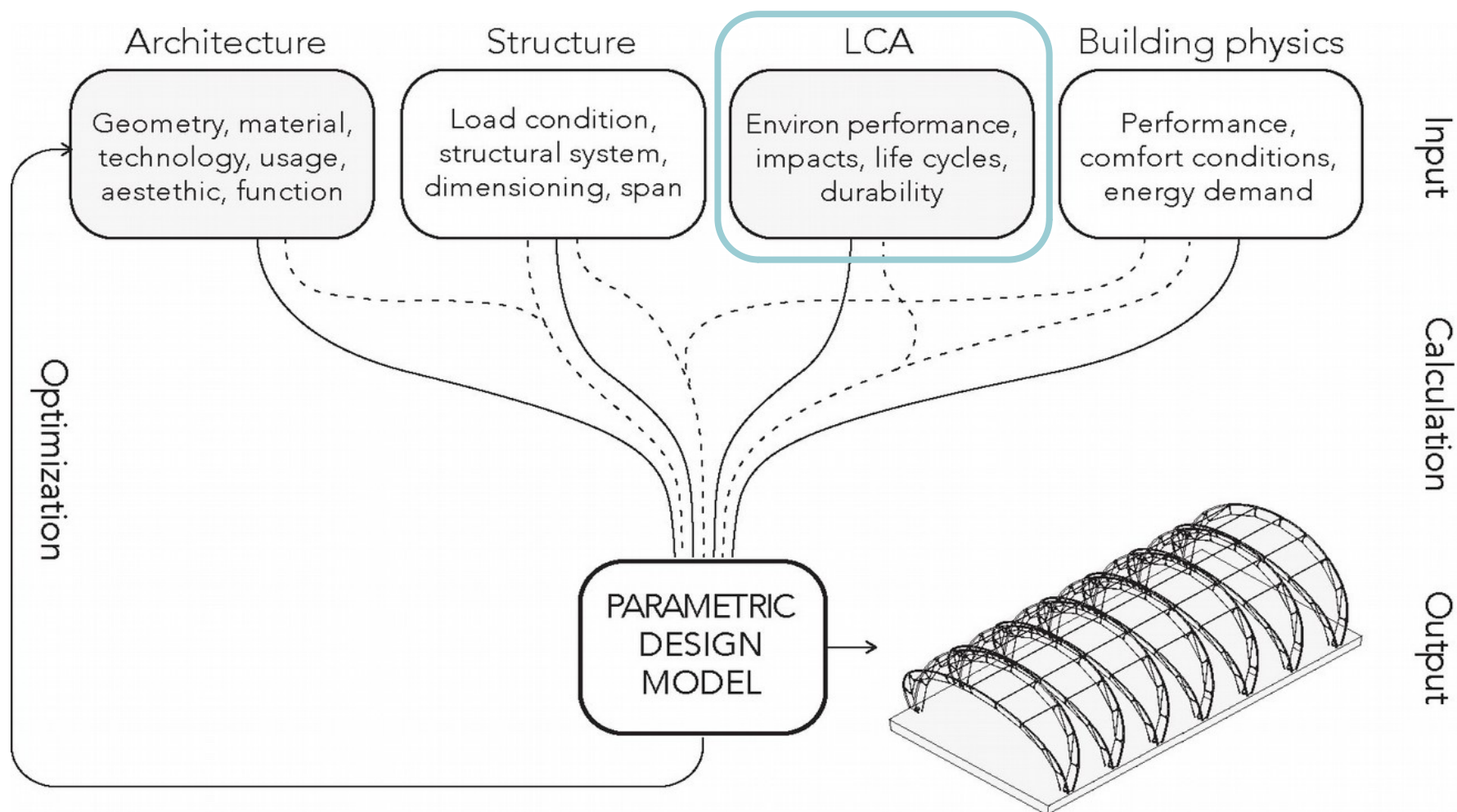


**LCA-integrated design approach**

Credits of this analysis: Mazzola C., Monticelli C., Viscuso S., Zanelli A., 2019



# Temporactive Pavilion - second life cycle



Credits of this analysis: Mazzola C., Monticelli C., Viscuso S., Zanelli A., 2019





# Temporactive Pavilion - 3 designs for the structure



Credits of this analysis: Mazzola C., Monticelli C., Viscuso S., Zanelli A., 2019



# Temporactive Pavilion - 3 designs for the structure

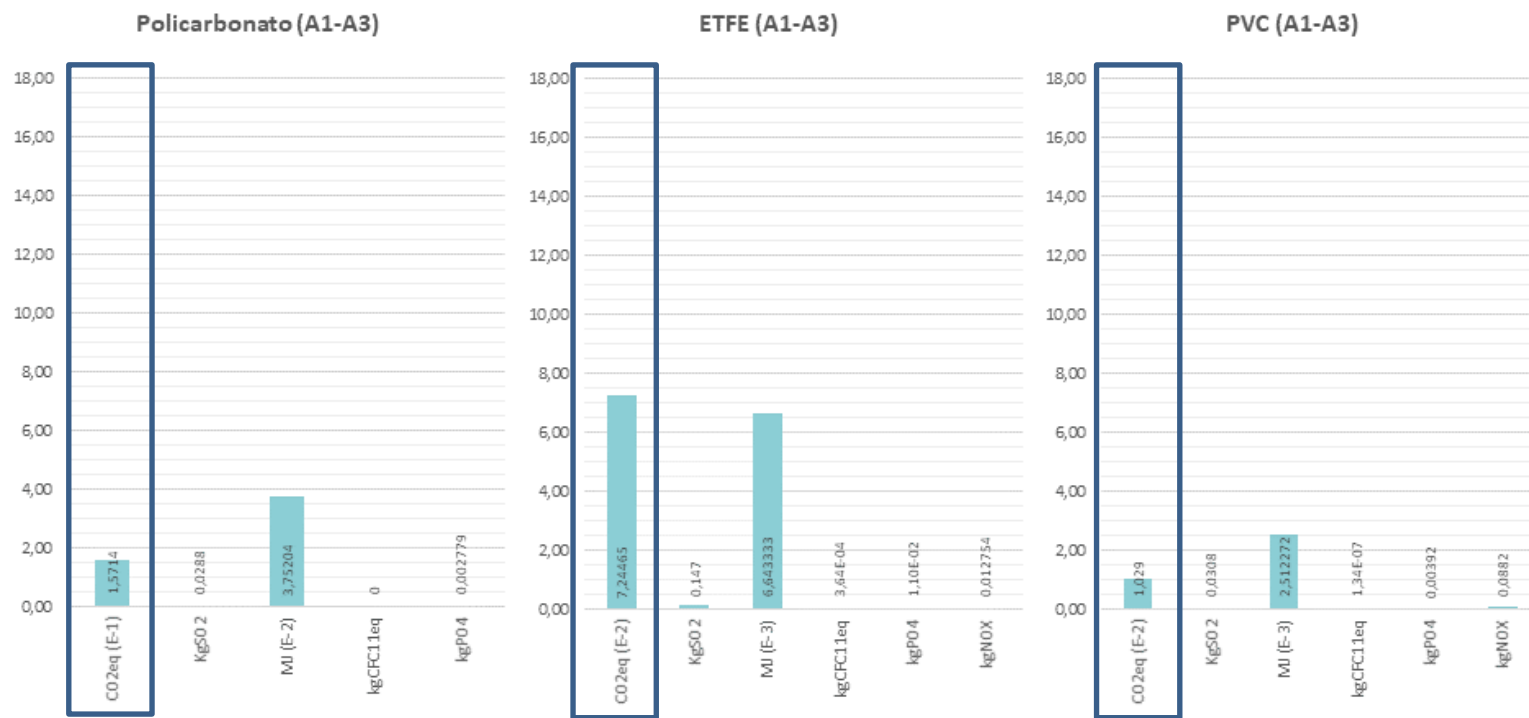
		OPTION 1 Steel	OPTION 2 CLT	OPTION 3 GFRP hybrid
PRODUCTION PROCESS	Environmental impact	● ●	●	● ●
	Production waste	●	● ● ●	●
TRANSPORTATION PHASE	Storage volume	● ●	● ● ●	●
	Weight	● ●	● ● ●	●
INSTALLATION PROCESS	Need for building machinery	● ●	● ● ●	●
	Expertise of the installers	● ●	● ●	●
	Erection time	●	●	●
USE PHASE	Material durability	●	●	●
	Maintenability	●	● ●	●
END OF LIFE SCENARIO	Recyclability	●	● ●	● ● ●

Credits of this analysis: Mazzola C., Monticelli C., Viscuso S., Zanelli A., 2019





# Temporactive Pavilion - 3 options for the skin



Membrane material selected for the 1 week usage

PVC crystal

**ENVIRONMENTAL IMPACT** in relation to the **LIFE SPAN** of the building

Credits of this analysis: Cortellazzi C., Viscuso S., Monticelli C., 2022



Introduction  
Case studies  
**Comparison**  
Conclusions  
Reflections



# Comparison of the 3 case studies

	Elspe (larger span)	Zoutleeuw	Temporactive, as built (very lightweight)
Service life structure	70 y	50 y	10 y
Service life skin	35 y	25 y	1 week (1° cycle), 6 months (2° months) repeatedly used
Size	77m x 40m	16m x 9m	14m x 7m
	2200 m <sup>2</sup>	64 m <sup>2</sup>	98 m <sup>2</sup> (rectangular)
Structure	30000 kg	460 kg	721 kg
Skin	4600 m <sup>2</sup>	135 m <sup>2</sup>	130 m <sup>2</sup>
	7500 kg	122 kg	90 kg
Self-weight/m <sup>2</sup>	17kg/m <sup>2</sup>	9kg/m <sup>2</sup>	8kg/m <sup>2</sup>
% Skin (self-weight)	20%	21%	11%
A1-A3 (materials) Structure GWP	76200 kg CO <sub>2</sub> eq	952 kg CO <sub>2</sub> eq	5636 kg CO <sub>2</sub> eq
A1-A3 Skin GWP	38400 kg CO <sub>2</sub> eq	637 kg CO <sub>2</sub> eq	4623 kg CO <sub>2</sub> eq
B4-B5 (replacement) Skin GWP	39100 kg CO <sub>2</sub> eq	948 kg CO <sub>2</sub> eq	-
Structure GWP/m <sup>2</sup>	34,64 kg CO <sub>2</sub> eq/m <sup>2</sup>	14,88 kg CO <sub>2</sub> eq/m <sup>2</sup>	57,50 kg CO <sub>2</sub> eq
Skin GWP/m <sup>2</sup>	35,22 kg CO <sub>2</sub> eq/m <sup>2</sup>	24,77 kg CO <sub>2</sub> eq/m <sup>2</sup>	47,17 kg CO <sub>2</sub> eq
Total GWP/m <sup>2</sup>	69,87 kg CO <sub>2</sub> eq/m <sup>2</sup>	39,65 kg CO <sub>2</sub> eq/m <sup>2</sup>	104,67 kg CO <sub>2</sub> eq
% Skin (GWP)	50%	62%	45%



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Canton de Berne



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Total GWP/m <sup>2</sup> /year	<b>1 kg CO<sub>2</sub>eq/m<sup>2</sup>/year</b>	<b>0,8 kg CO<sub>2</sub>eq/m<sup>2</sup>/year</b>	<b>10,5 CO<sub>2</sub>eq/m<sup>2</sup>/year</b>
% Skin (GWP)	<b>50%</b>	<b>62%</b>	<b>45%</b>



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Introduction  
Case studies  
Comparison  
**Conclusions**  
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# Conclusion

Each membrane structure is different, each case study is different, the comparison is difficult

The analysis during the design includes the selection of the material(s) for the structure and for the skin

**Long-lasting** membrane structures are beneficial for the lifecycle and the environmental performances



Is re-use possible?





The structure's nine tensegrity modules are tent-like.  
Made of waste PVC truck side curtains and reused stud framing.



MARK RICHARDSON  
[ps://www.designboom](http://www.designboom.com)

Is recycling possible? Polyloop?



<https://polyloop.fr/>



# Is recycling possible? Polyloop?

A reliable **recycling technology** for flexible PVC-composites

**Material regeneration:** high quality ready-to-use recycled plastic materials

Reduce or even eliminate the quantity of waste to be landfilled



# Is recycling possible? Polyloop?

Smart Factory approach: **compact**, modular and transportable recycling equipment for recycling “at home”

**Decentralised** equipment

The unit is adaptable, configurable for existing production plants



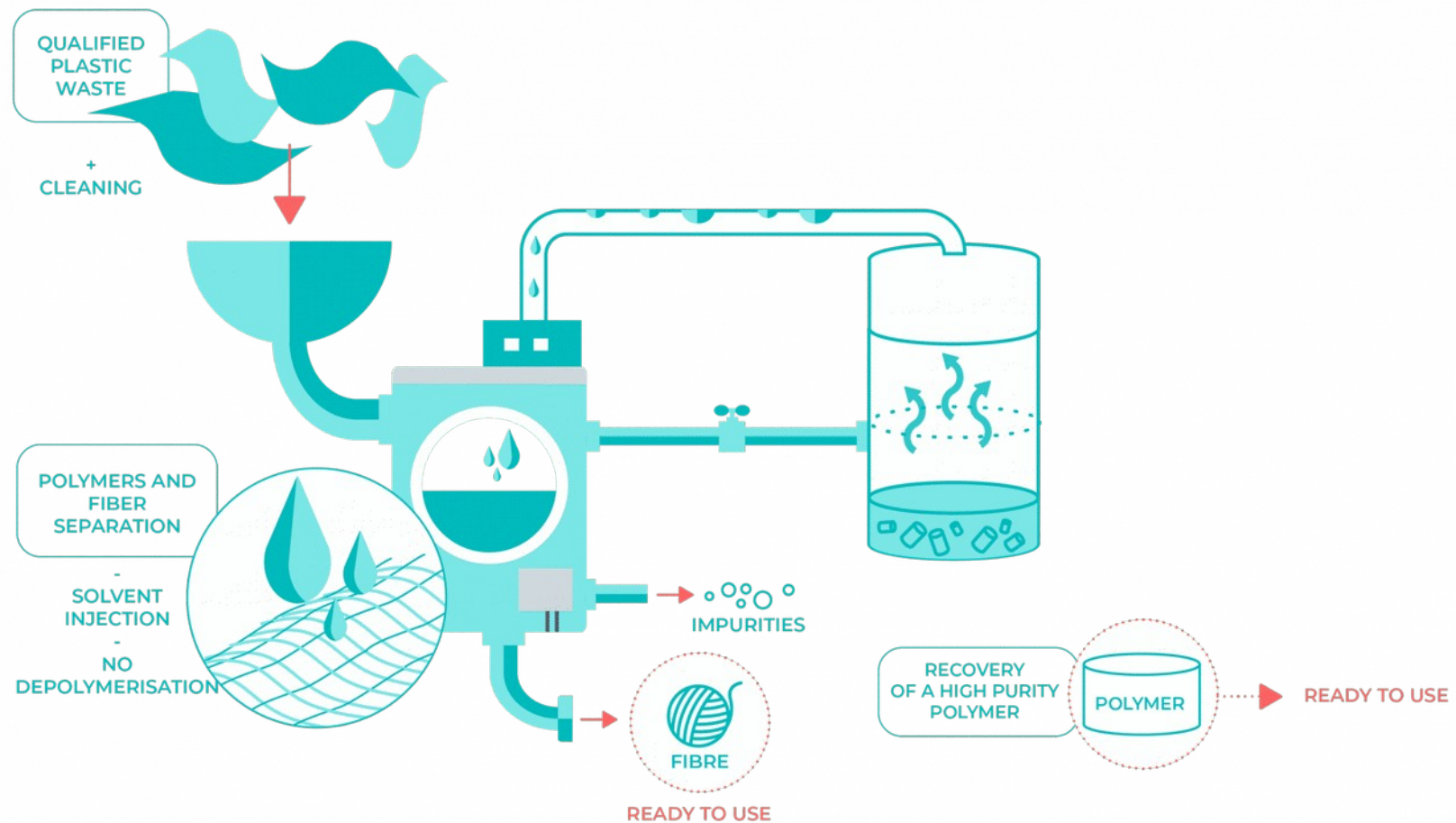


# Is recycling possible? Polyloop?

POLYLOOP is based on the patent

Solvent-Targeted Recovery and Precipitation (STRAP)

Is co-sponsored by ADEME, the French Agency for Ecological Transition



## Challenges

Reuse, remanufacture and recycle what still has potentials, also after the use

Empower current materials towards circularity

Develop new materials, biodegradable, biobased ...

Zero  
waste



# Challenges



The importance of the activities of the TensiNet  
WG Sustainability & Comfort

Develop PCRs for membranes

Publish EPD data



## THANK YOU FOR YOUR KIND ATTENTION

**Marijke Mollaert**  
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**Zehra Eryuruk**  
Ph.D. Candidate

**Carol Monticelli**  
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[www.textilearchitecture.polimi.it](http://www.textilearchitecture.polimi.it)



# Sustainability aspects in lightweight construction: How can education improve the state of the art of sustainable construction?

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Karsten Moritz, IMS BAUHAUS® Archineer® Institutes e.V., Dessau, Germany,

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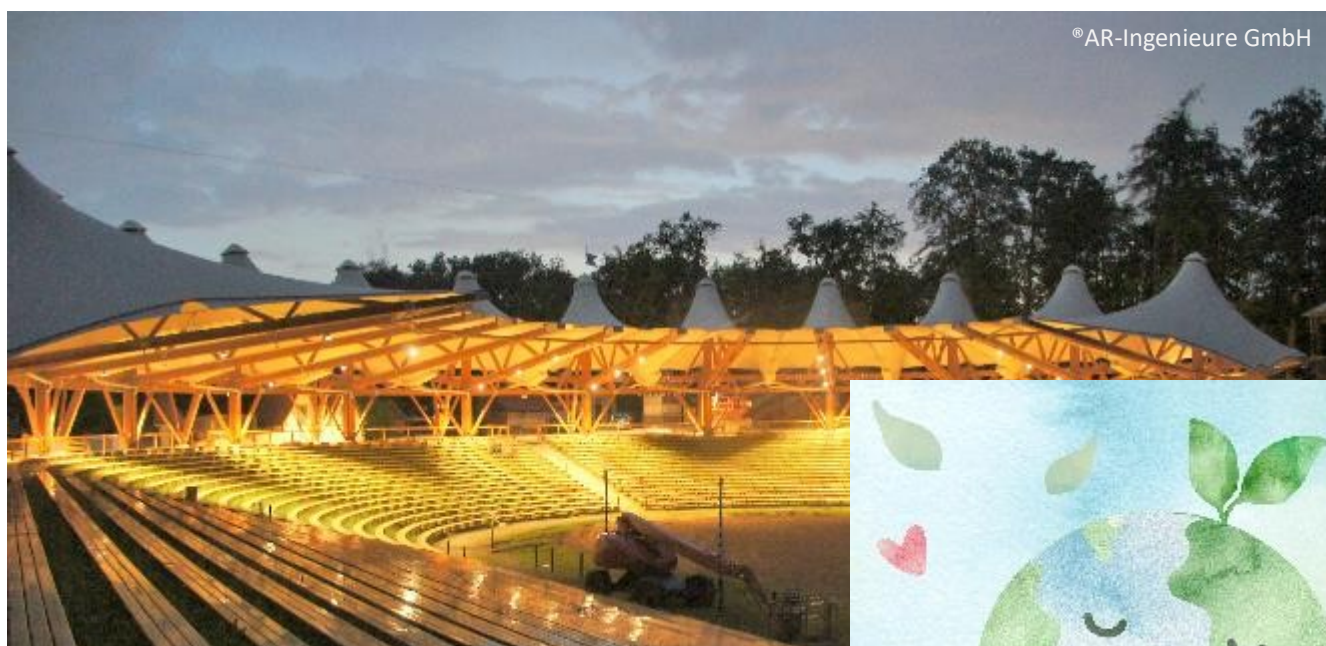
## Speaker

Sarah von der Weth, IMS BAUHAUS® Archineer® Institutes e.V., Dessau, Germany,

[sarah.von-der-weth@ims-institute.org](mailto:sarah.von-der-weth@ims-institute.org)



## Introduction



©AR-Ingenieure GmbH



©Mehler Technologies | AMA Prize – Best product of the year 2021



Urban Radiative Cooling Membrane

For Outdoor Comfort in Hot Humid Climates

©snono studio | VENTISCAPES – Urban Radiative Cooling Membranes | AMA Prize – Idea of the year 2021

©IMS BAUHAUS® Archineer® Institutes e.V.

Courtesy of the Architectural Membrane Association e.V.





# Agenda

- » Current state and postulated goals
- » Education of sustainability aspects
- » Example for teaching sustainability in lightweight constructions
- » Outlook



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# Agenda

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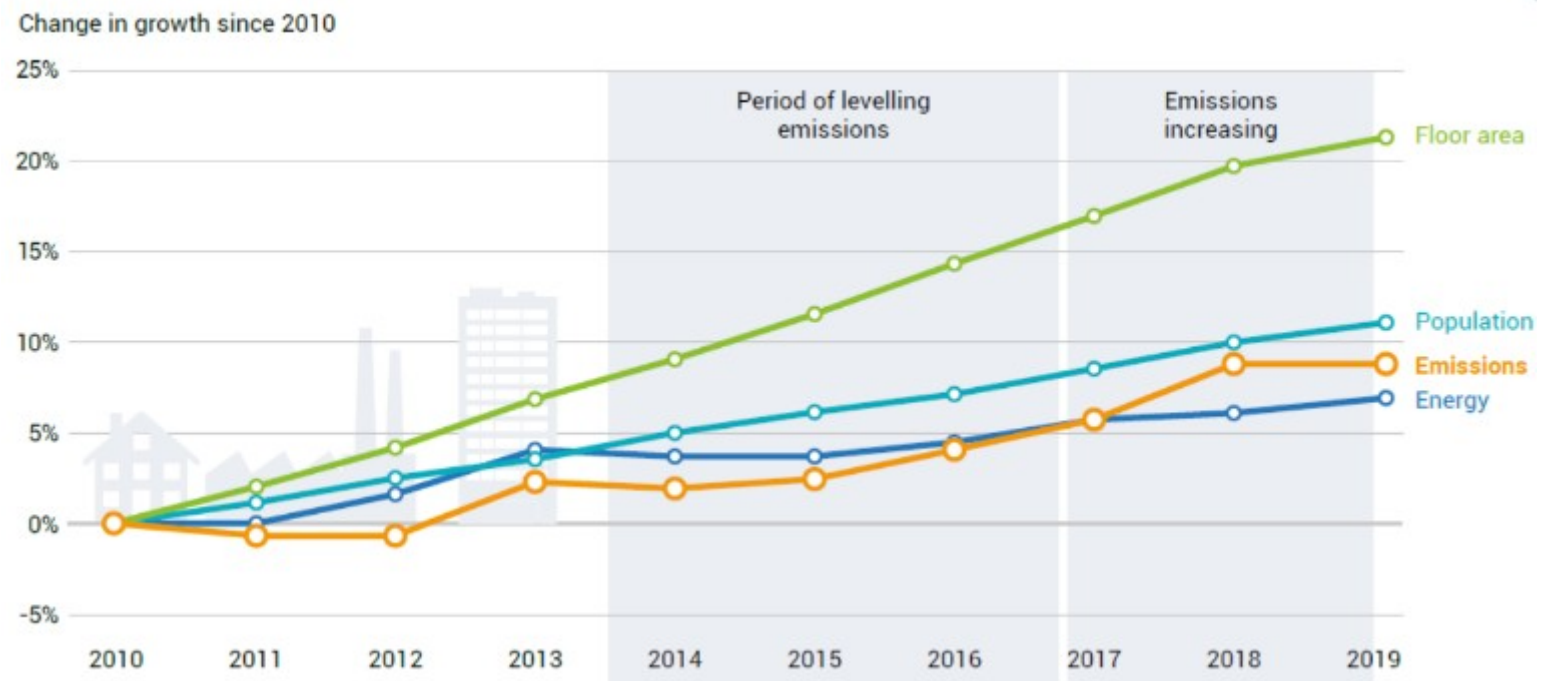
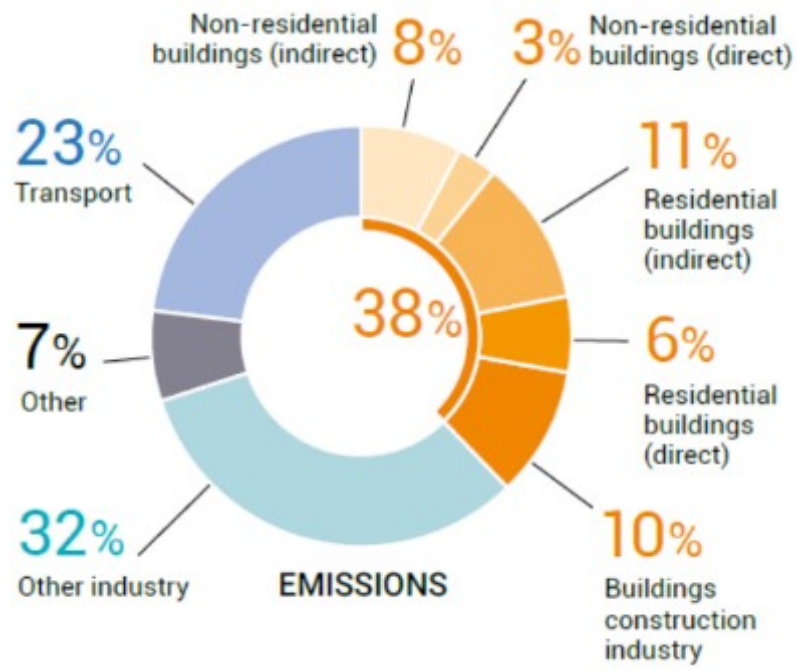


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# Current state and postulated goals



UN Environment Programme, Global Alliance of Building and Construction, 2020 Global Status Report, for Buildings and Construction, 12/2020

# Current state and postulated goals



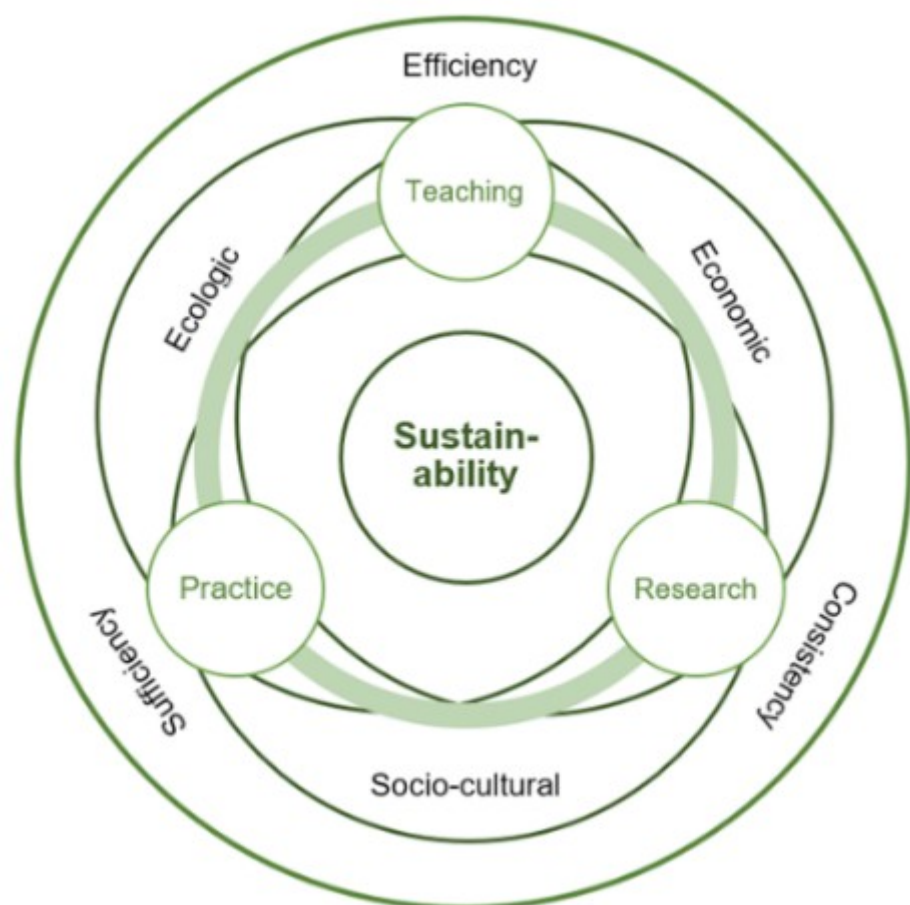


# Agenda

- » Current state and postulated goals
- » Education of sustainability aspects
- » Example for teaching sustainability in lightweight constructions
- » Outlook

## Education of sustainability aspects

### Teaching sustainability in engineering education



Framework of sustainability aspects

- » Centre: Sustainability
- » Basic Pillars: Ecologic, Economic, Socio-cultural
- » Strategies: Efficiency, Sufficiency, Consistency
- » Connectors: Teaching, Research, Practice



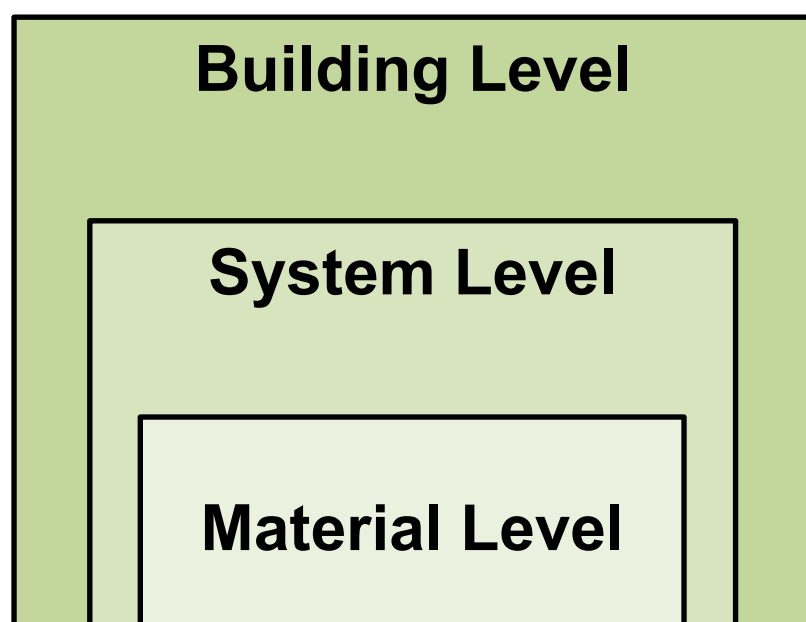
# Education of sustainability aspects

## Teaching sustainability in engineering education

- » Anchoring sustainability in the study programme from the very beginning
- » Interdisciplinary work and thinking right from the start
- » Minimizing emissions, energy consumptions and resources in construction should become the most important design aspect for engineers

# Education of sustainability aspects

## Teaching sustainability in engineering education

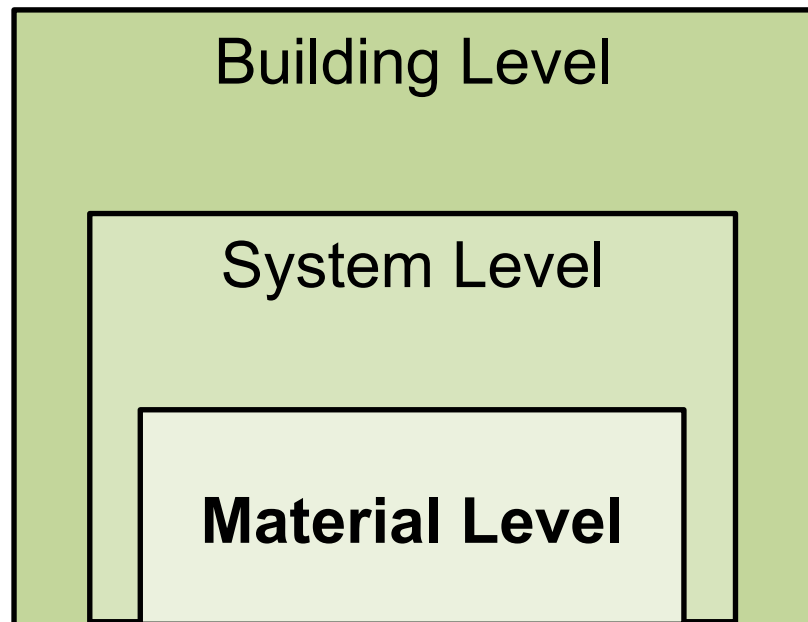


- » Bottom-to-Top principle in sustainability education
- » This teaching concept will develop an understanding of the environmental impact of:
  - Level 1 - building materials
  - Level 2 - building systems and components
  - Level 3 - complete building structures



# Education of sustainability aspects

## Teaching sustainability in engineering education



### Material level:

- » Deepening the knowledge of (new) structural materials including raw materials and their origin as well as availability, production processes, energy consumption, environmental impact and durability
- » Knowledge about Environmental Product Declarations (EPDs): report which tells the life cycle story of a product

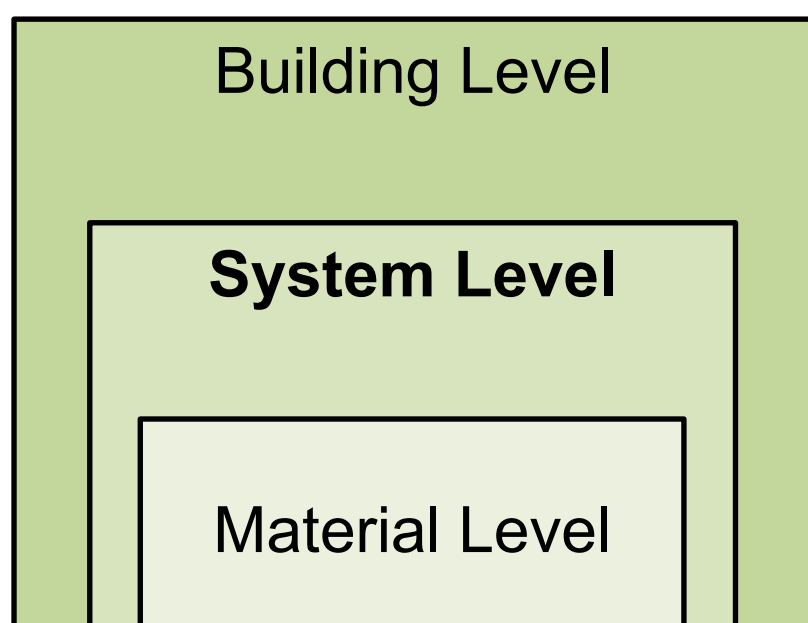


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# Education of sustainability aspects

## Teaching sustainability in engineering education



### System level:

- » Investigation of different structural systems made of different materials or using different construction methods
- » Evaluation of the LCA of single components based on first structural calculations
- » Building physics aspects, (e.g. heat transfer through building components) are included



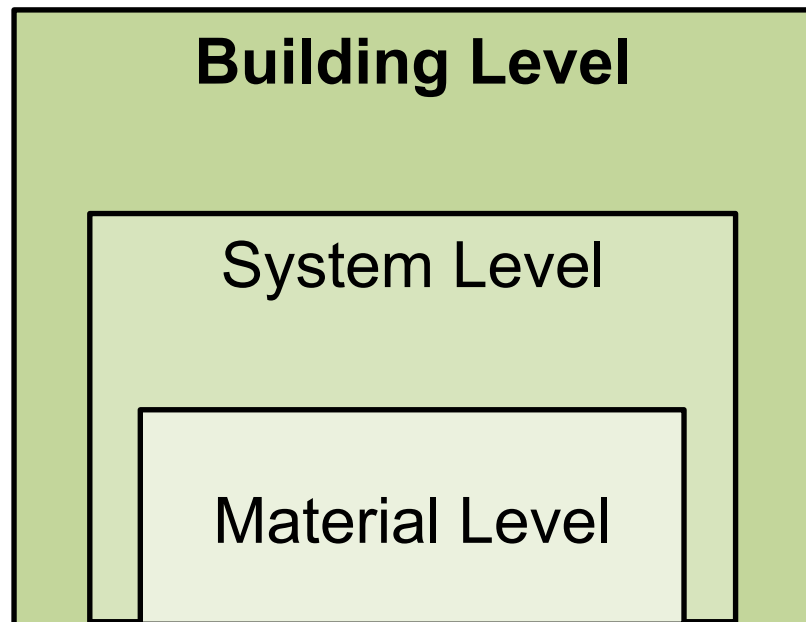
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# Education of sustainability aspects

## Teaching sustainability in engineering education

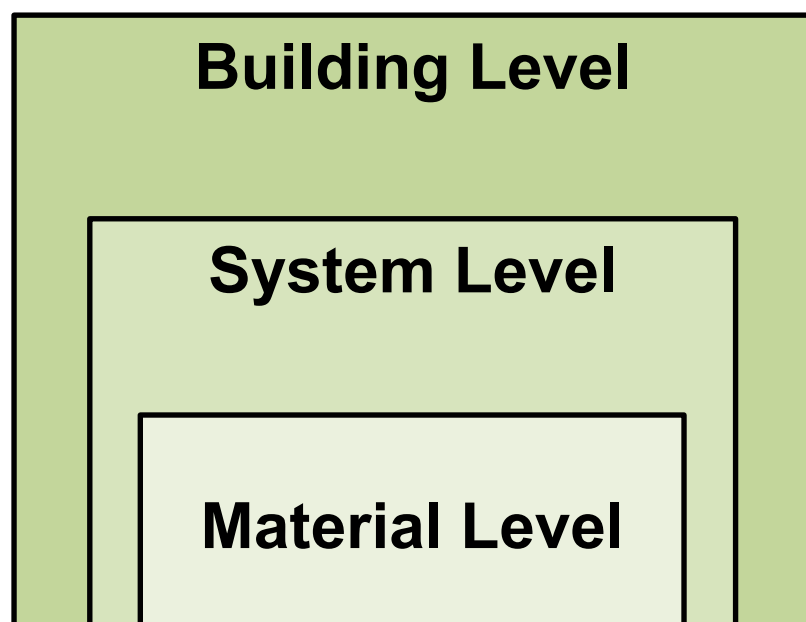


### Building level:

- » LCA of the total structure
- » Comparison and evaluation of different solutions of structural systems and their effects on the LCA
- » The interactions with the environment are intended to be taken into account

# Education of sustainability aspects

## Teaching sustainability in engineering education



- » Decision-making aids to combine structures and materials with regard to the LCA of a building
- » Knowledge about adjustment methods to improve the LCA to a desired certification (e.g. DGNB, BREEAM, LEED)
- » The engineer should be a valuable partner also in terms of sustainability



# Education of sustainability aspects

## Education of lightweight structures and tensile architecture

Basic Course Archineer® in Membrane Structures	Advanced Courses Lightweight and Membrane Structures	Specialist Engineer Membrane Structures	Master (M. Eng.) Membrane Structures
<ul style="list-style-type: none"><li>• Basic course for those interested in membrane constructions</li><li>• No admission requirements</li><li>• Certificate, protected title</li><li>• Time frame: ~ 6 months</li><li>• First course in 2021</li></ul>	<ul style="list-style-type: none"><li>• Advanced training modules on special topics such as the design of membrane structures, statics, construction, installation, operations, building physics, sustainability, etc.</li><li>• No admission requirements</li><li>• Certificate</li><li>• Time frame: ~ 1 month</li><li>• First course in 2023</li></ul>	<ul style="list-style-type: none"><li>• Advanced course in cooperation with the Saxony-Anhalt Chamber of Engineers</li><li>• Admission requirements: authorization to use the professional title "engineer"; participation in basic course (or at least equivalent); proof of sufficient practical experience and above-average theoretical knowledge</li><li>• Certificate for applying for the professional title of specialist engineer in membrane construction</li><li>• Time frame: ~ 3 months</li><li>• First course in 2022 / 2023</li></ul>	<ul style="list-style-type: none"><li>• Postgraduate studies</li><li>• Admission requirements: completed studies, e.g. architecture, structural or civil engineering, machine engineering, etc.</li><li>• University of applied sciences degree (M. Eng.)</li><li>• Time frame: ~ 2 years</li><li>• First course in 2006 (The course will end at the HS Anhalt in 2024, a restart is planned at the HfT in Stuttgart)</li></ul>



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# Education of sustainability aspects

## Education of lightweight structures and tensile architecture

Basic Course Archineer® in Membrane Structures
<ul style="list-style-type: none"><li>• Basic course for those interested in membrane constructions</li><li>• No admission requirements</li><li>• Certificate, protected title</li><li>• Time frame: ~ 6 months</li><li>• First course in 2021</li></ul>

- » The course is aimed at anyone who wants to learn more about membrane and lightweight construction
- » It covers all practice-relevant topics such as architectural design of lightweight structures, statics and building construction, detailing, patterning, assembly, testing of materials and components, **sustainability**
- » **Material level:** membrane materials and environmental product declarations, sustainability concepts



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# Education of sustainability aspects

## Education of lightweight structures and tensile architecture

### Advanced Courses Lightweight and Membrane Structures

- Advanced training modules on special topics such as the design of membrane structures, statics, construction, installation, operations, building physics, sustainability, etc.
- No admission requirements
- Certificate
- Time frame: ~ 1 month
- First course in 2023

- » This course will pick up special aspects of the basic course and advanced topics and deepen them
- » Enable participants to integrate sustainability into their design
- » **Material level / system level / building level:** e.g. selected modules about life cycle analysis (LCA), certification programmes or building physics

# Education of sustainability aspects

## Education of lightweight structures and tensile architecture

### Specialist Engineer Membrane Structures

- Advanced course in cooperation with the Saxony-Anhalt Chamber of Engineers
- Admission requirements: authorization to use the professional title "engineer"; participation in basic course (or at least equivalent); proof of sufficient practical experience and above-average theoretical knowledge
- Certificate for applying for the professional title of specialist engineer in membrane construction
- Time frame: ~ 3 months
- First course in 2022 / 2023

- » Worldwide first training programme for specialist engineers in cooperation with the Saxony-Anhalt Chamber of Engineers
- » Completion of the course entitles to apply for the professional title of a specialist engineer at the Chamber of Engineers
- » Open to all engineers who have sufficient practical experience and theoretical knowledge in the field of membrane structures
- » **System level / building level:** Sustainability aspects based on structural calculations



## Education of lightweight structures and tensile architecture

### Master (M. Eng.) Membrane Structures

- Postgraduate studies
- Admission requirements: completed studies, e.g. architecture, structural or civil engineering, machine engineering, etc.
- University of applied sciences degree (M. Eng.)
- Time frame: ~ 2 years
- First course in 2006 (The course will end at the HS Anhalt in 2024, a restart is planned at the HfT in Stuttgart)

- » The Master Membrane Structures (M.Eng.) is a postgraduate course primarily aimed at architects and engineers
- » It was introduced in 2006 and won't be continued at the Anhalt university of applied sciences in the year 2024
- » With a planned restart at the Stuttgart University of Applied Sciences, sustainability will become a significant role in the teaching concept
- » **Material level / system level / building level**



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## Agenda

- » Current state and postulated goals
- » Education of sustainability aspects
- » **Example for teaching sustainability in  
lightweight constructions**
- » Outlook



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## Lightweight construction categories

- » Lightweight means optimal construction and saving material (resources, emissions, energy and waste) where it makes sense
- » Lightweight means to optimize the supporting structure, which transfer external loads over large distances or areas
- » Lightweight means to use high-strength but light materials or extremely thin, double-curved components (e.g. textile fabrics made of high-strength yarns or thin foils)
- » Lightweight constructions can be assigned to the following three categories:  
**material / structural / system lightweight construction**

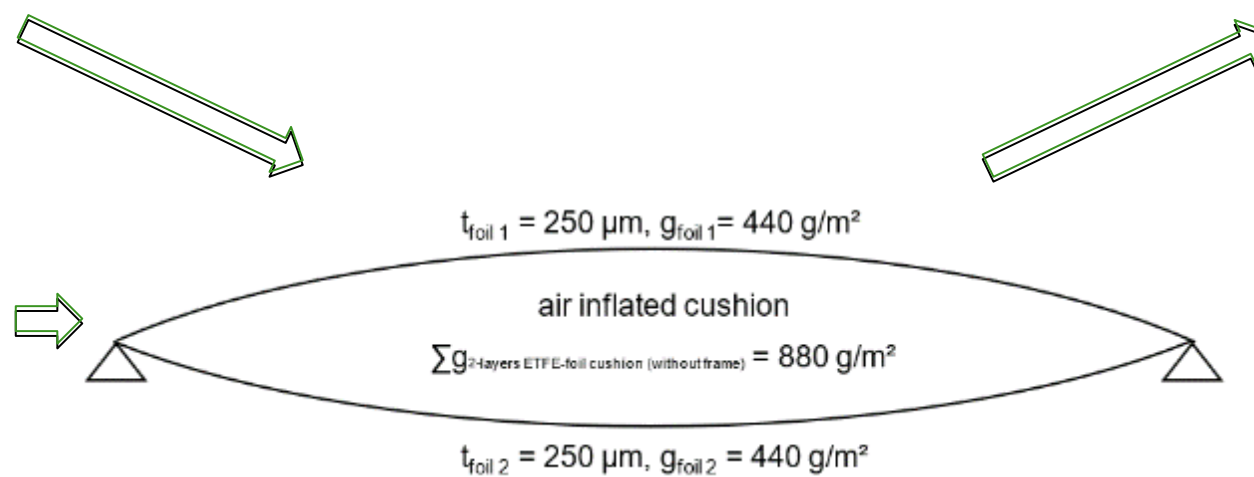


## Material lightweight construction

Materials that have high strength with the lowest possible weight

Material weight is a factors in the LCA (non-renewable energies inherent in each material, transport, assembly and disassembly, preparation for reuse

Coated textiles used in lightweight construction are often composite materials, which are currently difficult to recycle



Moritz, K., Entwurfsaspekte von ETFE-Folienpneus, Innovativ Konstruieren, Detail Business Information GmbH, München, 09/2009

Air-supported foil cushions form an extremely light construction compared to other transparent roof coverings (1/50 to 1/100 of the weight of a solid structure, such as concrete or glass)

The primary supporting structure has to transmit less load to the foundations, which allows the distance between the beams and the support grid to be increased → save of weight

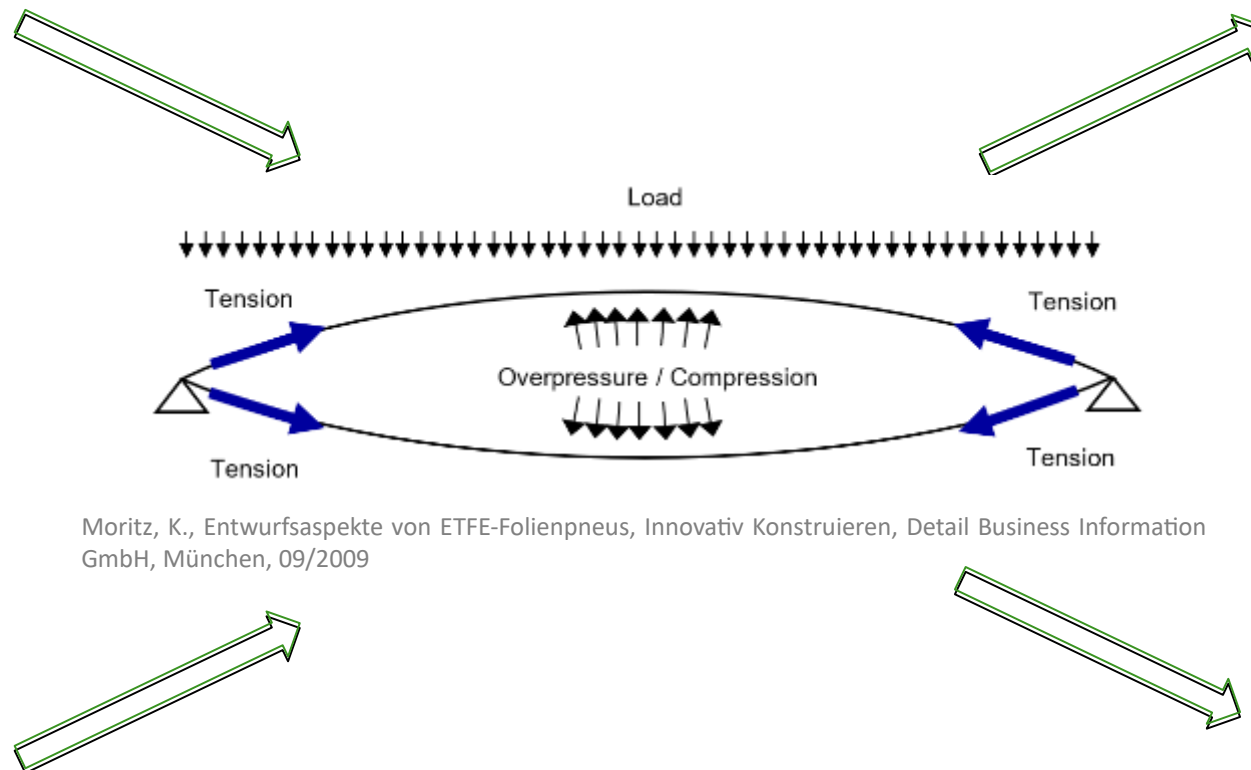




## Structural lightweight construction

Optimized supporting structures / elements by using filigree component cross-sections that are adapted to the material, the construction and the stress

Avoiding bending stress, by preferring tensile / compressive stress; short-circuiting forces; supporting elements that are based on the force path of the shape-determining load case or adaptive systems reacting on the load distribution; ...



Moritz, K., Entwurfsaspekte von ETFE-Folienpneus, Innovativ Konstruieren, Detail Business Information GmbH, München, 09/2009

Cushion structures consists out of tension elements and one pressure element, no bending (minimal cross sections) → no stability problems

The internal pressure and thus its shape can be adapt to the size and distribution of the external loads



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## System lightweight construction

Controllable or variable systems that fulfill several functions by changing their shape or properties (multifunctional components)

Structure: transport loads

Design: different lighting of interior spaces for illumination of facades



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Shading: variable printed / coloured layer for mobile sun protection systems

Energy: photovoltaic modules, solar collectors, algae reactors

Coatings: electro- or photochromic or electro- or phototropic and also low-E



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# Agenda

- » Current state and postulated goals
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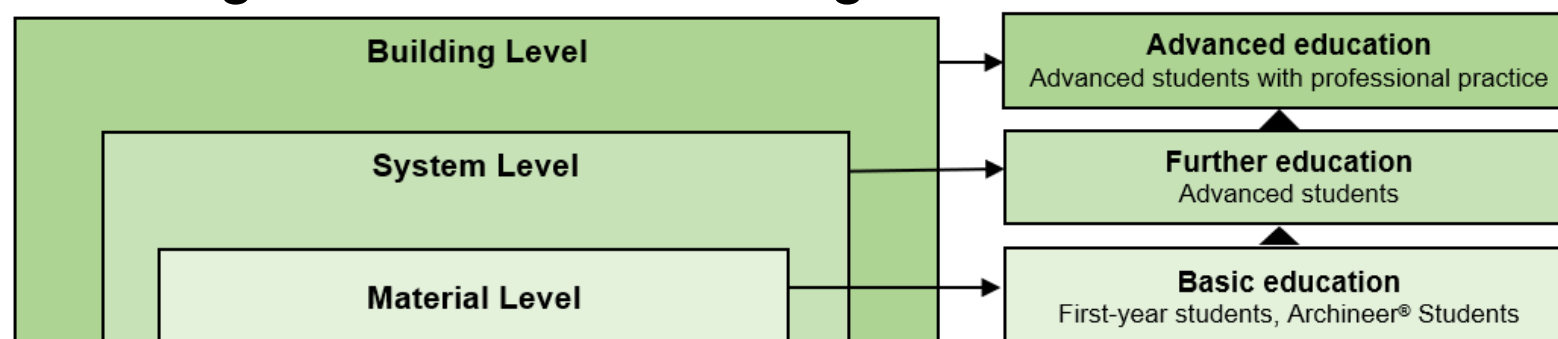


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## Conclusion and Outlook

- » A teaching concept was presented which integrates sustainability into the teaching of architects and engineers



- » Lightweight constructions such as tensile structures can make a significant contribution to sustainable building due to the effective use of the material with low mass and the multifunctionality of the structure or its parts
- » The IMS BAUHAUS® Archineer® Institutes e.V. implements the presented teaching concept in the upcoming education programme to fill a knowledge gap in this field and provide planners with a well-based education



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THANK YOU FOR YOUR INTEREST AND I LOOK FORWARD TO YOUR  
INTEREST IN CONTRIBUTING TO THE KNOWLEDGE TRANSFER



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