SEALING GASKETS for Tunnel Lining Segments

presented by Andreas Diener, CTS Cordes Germany
at Mala Aula Politekniki Warszawskiej, Gmach Glowny, Warszawa, Poland,
May 27th , 2025

TU

Gasketed Tunnel Liner Segments in TBM-driven Tunnel Construction
- Proven technology since the early 1970's

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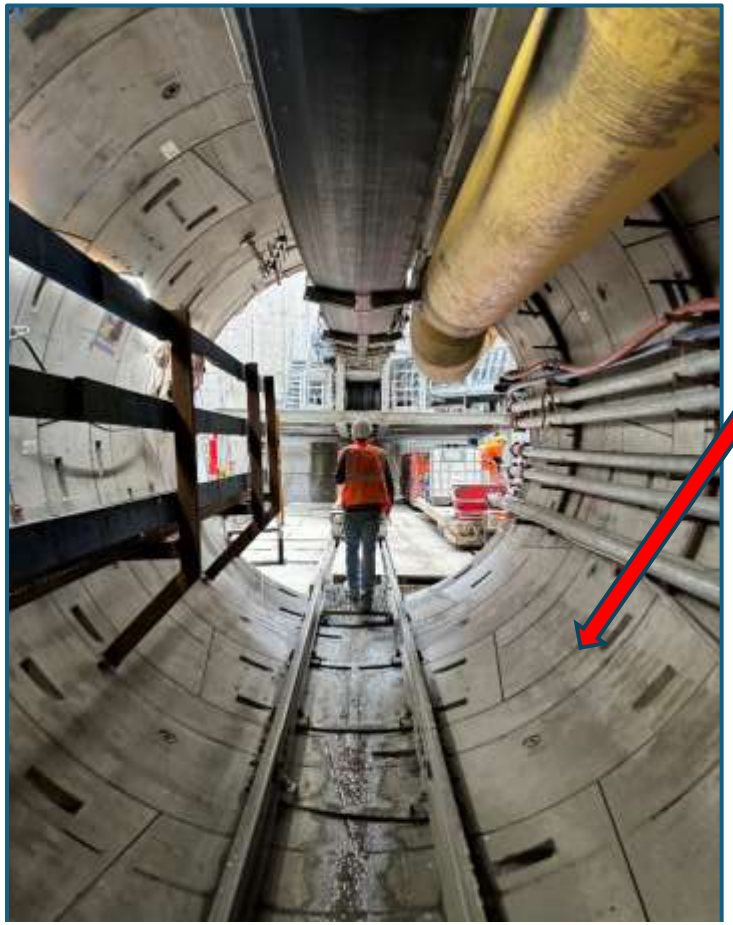
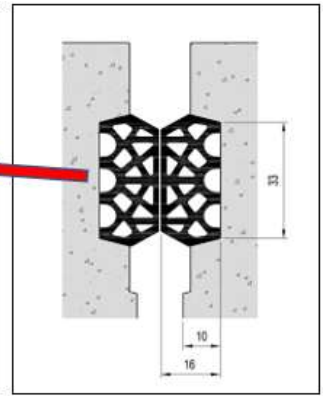
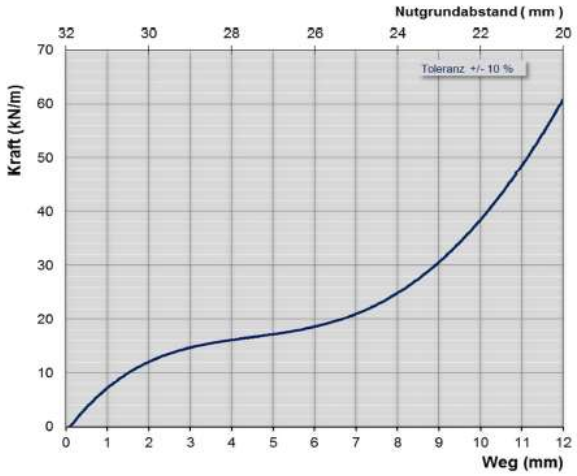
Tunnel Segment Sealing Gaskets - Application Situation





Kraft - Weg Diagramm von Profil
CTS 33 / 16 (W92069)



Seals GmbH & Co.KG

Where and when it all started ….

Andreas Diener, born in Hamburg, Germany
October 1964

1968 – 1973	Construction of River Elbe Highway Tubes 1, 2 and 3 TBM driven with cast iron segmental liners and sinking shaft elements
1974	Opening ceremony
1987 – 2011	PHOENIX Rubber, Hamburg
2012 – 2015	Dätwyler Rubber, Walteshausen
2016 - ……	CTS Cordes, Boizenburg near Hamburg

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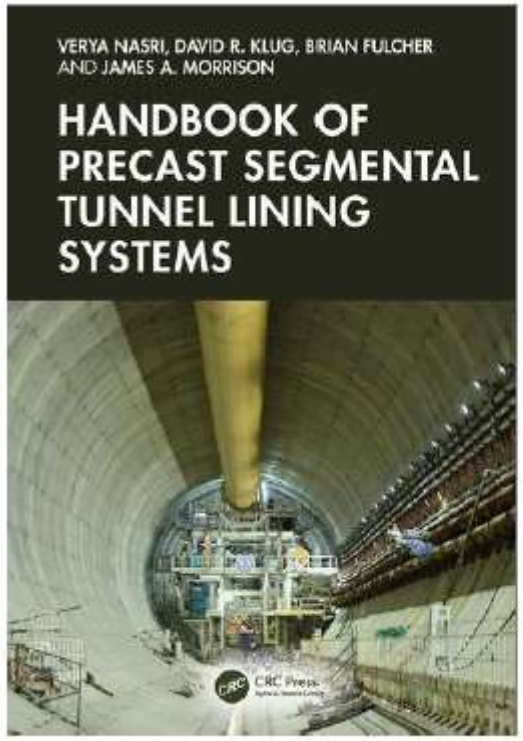
37 years later …



Jul 2024: 808pp 559 Color & 111 B/W illustrations

Handbook of Precast Segmental Tunnel Lining Systems

Edited By **Verya Nasri, David Klug, Brian Fulcher, James A. Morrison**

This comprehensive handbook covers all aspects of design, production, and construction of precast concrete tunnel segmental lining, with the best practices in the field included in one book for the first time.

New and current design methods and quantitative analyses are considered in line with ACI and ASTM codes, as well as a full selection of global standards for the reliable design of the product and all components. Also incorporated are new applications of science and technology, such as new admixtures, and the latest manufacturing processes and precisions, such as tight dimensional controls and high repeatability cycles.

With detailed guidance from world-leading practitioners, this is the definitive international technical and practical manual on these linings, forming a one-stop reference for tunnel engineers and an invaluable resource for advanced students in civil, mechanical, and mining engineering.

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55 years of tunnel segment gasket history …

Precast Segmental Tunnel Linings Handbook
Chapter 7 – Gasket Systems for Sealing Segmental Tunnel Linings

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Chapter 7 – Gasket Systems for Sealing Segmental Tunnel Linings

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Precast Segmental Tunnel Linings
Design, Production and Installation Handbook

Chapter 7
Gasket Systems for Sealing Segmental Tunnel Linings

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History: Cast Iron Segments since 1870 – Joints sealed with caulked lead

London Undergorund - 1870

Hamburg St. Pauli – Old Elbetunnel 1907 bis 1911

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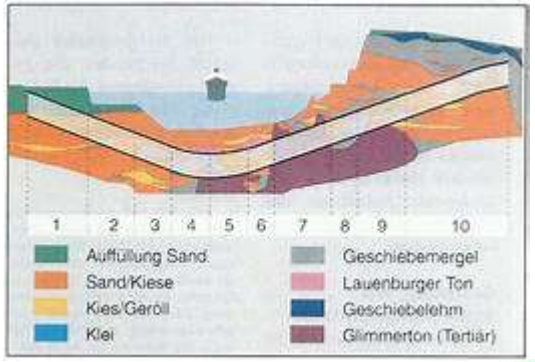
Elastomer Compression Gaskets firstly used on the Elbe River Crossing Road Tunnels in Hamburg, Germany (1968-1975)



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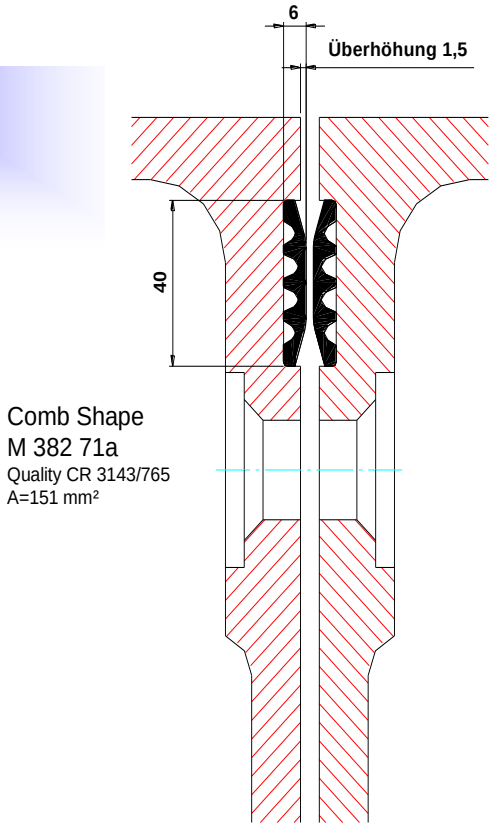

Comb Shape
M 382 71a
Quality CR 3143/765
A=151 mm²

1968 – 1975
Neuer Elbtunnel, Los 2, Hamburg,
up hill section, air pressure shield driving method ,
Segment Outer - Ø 10,83 m
Ring Width 1125 mm
Segments 15+1
3 Tubes of 1100 m length,
GGG 60-Segments (iron), d = 27 cm

City-Metro Davidstraße, Hamburg 1973

Metro Nürnberg 1974

Startseite

weiter klicken

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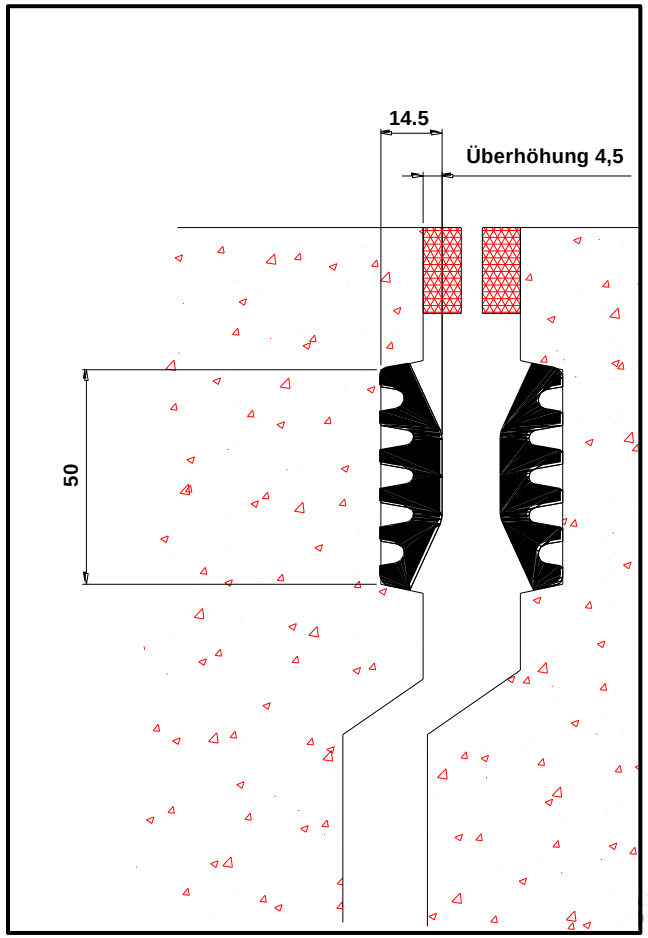
The Era of Comb Shape Profiles for Cast-iron and Concrete Segments

1986 – 1989:

Metro Berlin, Lot D79
Shield Driving Method
Outer Diameter - Ø 6,40 m
Ring width 1100 mm
segments per ring: 7+1
3 tubes of 1080 m Länge,
B45 – concrete segments

1976: Metro Hong Kong
1977: Pre Metro Antwerp I (CR Rubber)
1981: Pre Metro Anterp II (EPDM Rubber)
1989: Edmonton LRT



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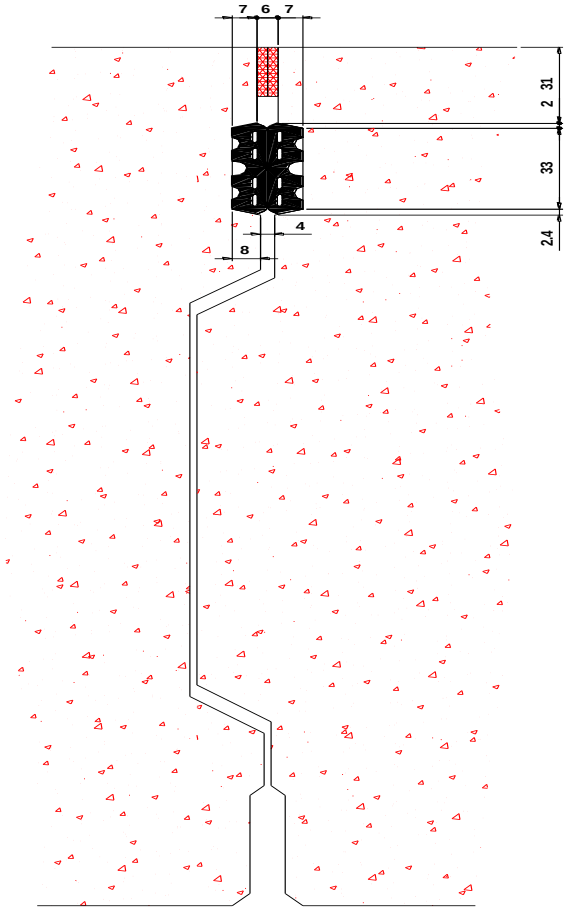
Era of „Hollow Chamber Profiles“ for Concrete Segments …
allowing larger ring building tolerances

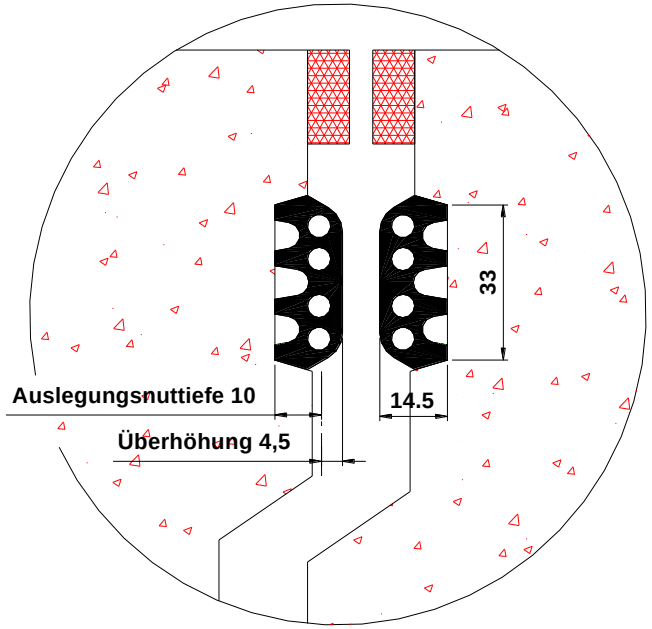
1984 – 1985
Sewage Collector Tunnel
Sheffield "Don Valley" No.2
outer diameter: Ø 4,47 m
Ring width 750 mm
segments per ring 7+1
concrete segments

further references

Hera, Collider Tunnel Hamburg 1985
TGV Atlantique 1986
Metro Moscow 1987
Metro Athens 1993

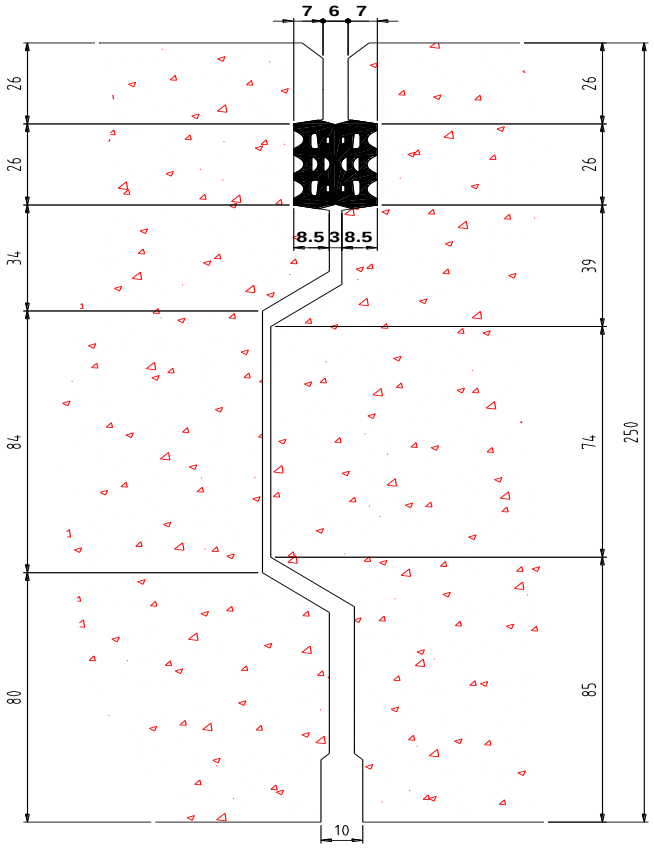


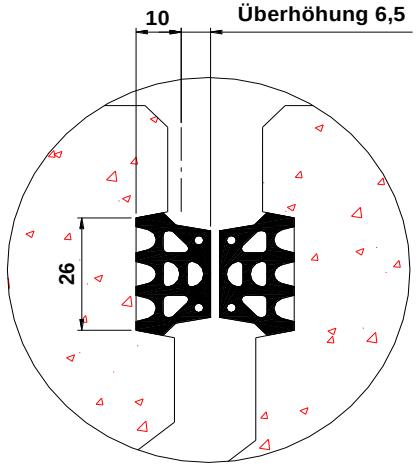
Hollow chamber
„single decker“profile
M 383 64
Quality CR
A=316 mm²



Era of „Double-Decker Profiles“ allowing larger ring building tolerances and coping with higher water pressures

1996 – 1999
Metro Tokyo Route 12
outer diameter - Ø 5,30 m
Ring width 1000 mm
segments per ring: 5+1
concrete segments





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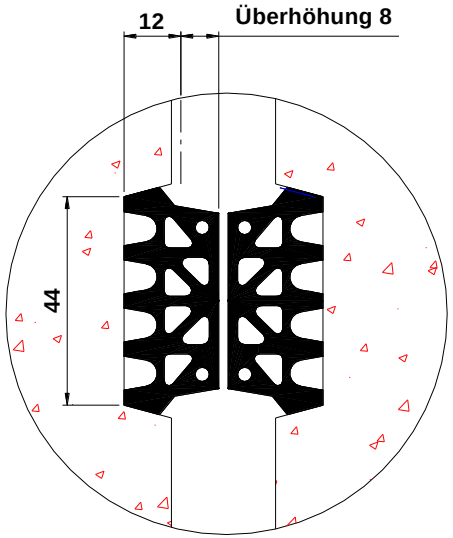
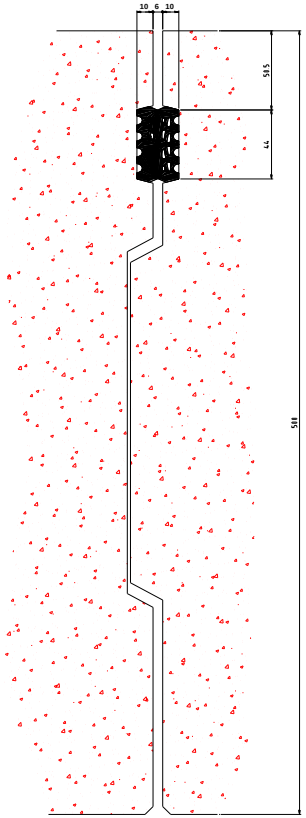
Era of Large Diameter High Pressure Rail & Traffic Tunnels



Hollow Chamber Profile
two rowed
M 385 73
Quality EPDM
A=521 mm²



1999 – 2002
Wesertunnel (4 bar)
outer diameter - Ø 11,30 m
ring width 1500 mm
segments per ring: 6+1
B55 concrete segments

further projects:

Sophiaspoortunnel 2000

Herrentunnel Lübeck, 2002

DB Katzenbergtunnel , 2003

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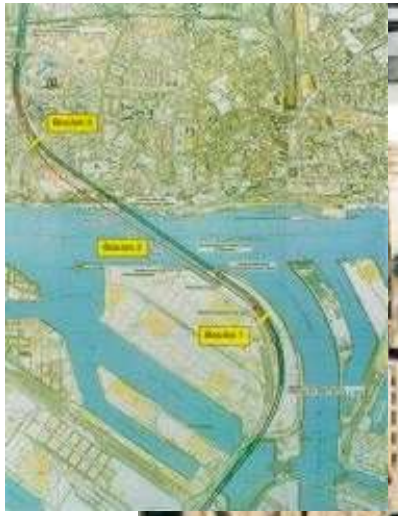
„Double Decker“ Profiles can meet higher water-proofing requirements especially for large diameter traffic tunnels

Example: 4th river Elbe crossing tube 1997 - 2003



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Era of Large Diameter Road and Railway Tunnels

Project-specific approval testing for all German Railway Tunnels since late 1990‘s

Project	Outer Tunnel-Ø (m)	Profile Shape (mm)	Groove Bottom Width (mm)	Working pressure (bar)	Gap (mm)
Tunnel TGV Atlantique, France	9,04	33 x 16	33	3,5	4,0
Pajares I-IV, Spain	9,50	33 x 24	33	15,0	4,0
Groene Hart Tunnel, Netherlands	14,50	36 x 19.5	36	4,0	4,0
Tunel del Perthus, France/Spain	9,50	36 x 19.5	36	18,0	4,0
Hallandsastunnel, Sweden	10,12	44 x 20	44	2,2	4,0
Katzenbergtunnel, Lörrach, Germany	10,80	44 x 24	44	10,0	6,0
New “Schlüchterner Tunnel”, Germany	9,90	44 x 20	44	4,0	6,0
New „Kaiser-Wilhelm-Tunnel“, Germany	9,80	44 x 20	44	3,0	6,0
Tunel de Sorbas, Spain	9,75	44 x 20	44	4,0	6,0
BEG H3-4 Münster-Wiesing, Austria	12,63	44 x 20	44	4,0	6,0
BEG H-8 Jennbach, Austria	12,63	44 x 20	44	4,0	6,0
Finnetunnel, Leipzig, Germany	10,50	44 x 20	44	6,1	6,0
Oberer Fildertunnel, Stuttgart, Germany	10,50	44 x 20	44	6,0	6,0
Boßlertunnel, Aichelbach, Germany	10,50	44 x 20	44	6,0	6,0
Tunnel Rastatt, Germany	10,60	44 x 20	44	4,0	6,0
Unterer Fildertunnel Stuttgart, Germany	10,50	44 x 20	44	2,5	6,0
Albvorlandtunnel, Wendlingen, Germany	10,50	44 x 20	44	5,0	8,0

Involvement by STUVA in 2004

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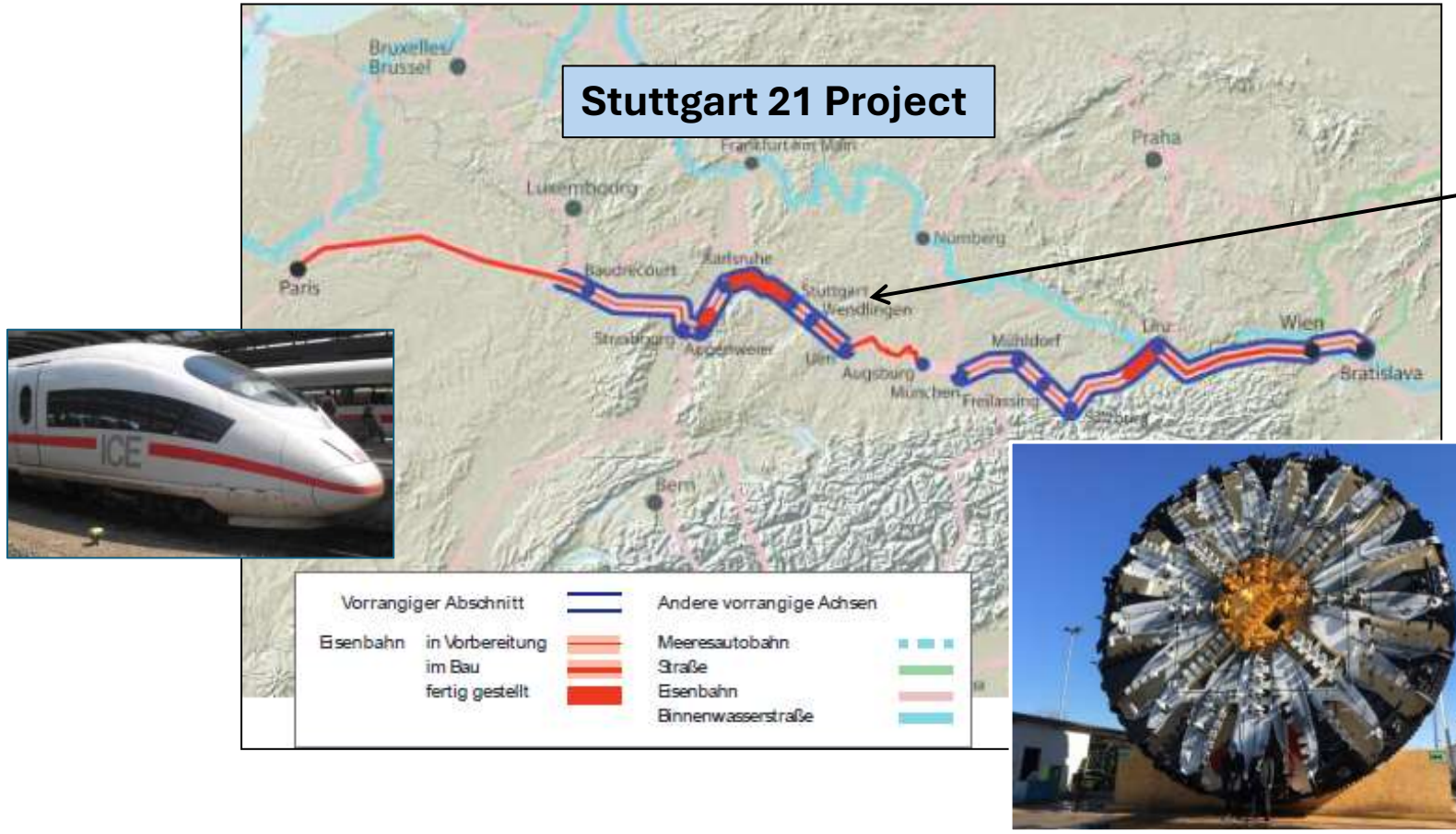
Special Specification Requirements by German Railway Authority on Albvorlandtunnel



Central East – West:
Bratislava - Paris

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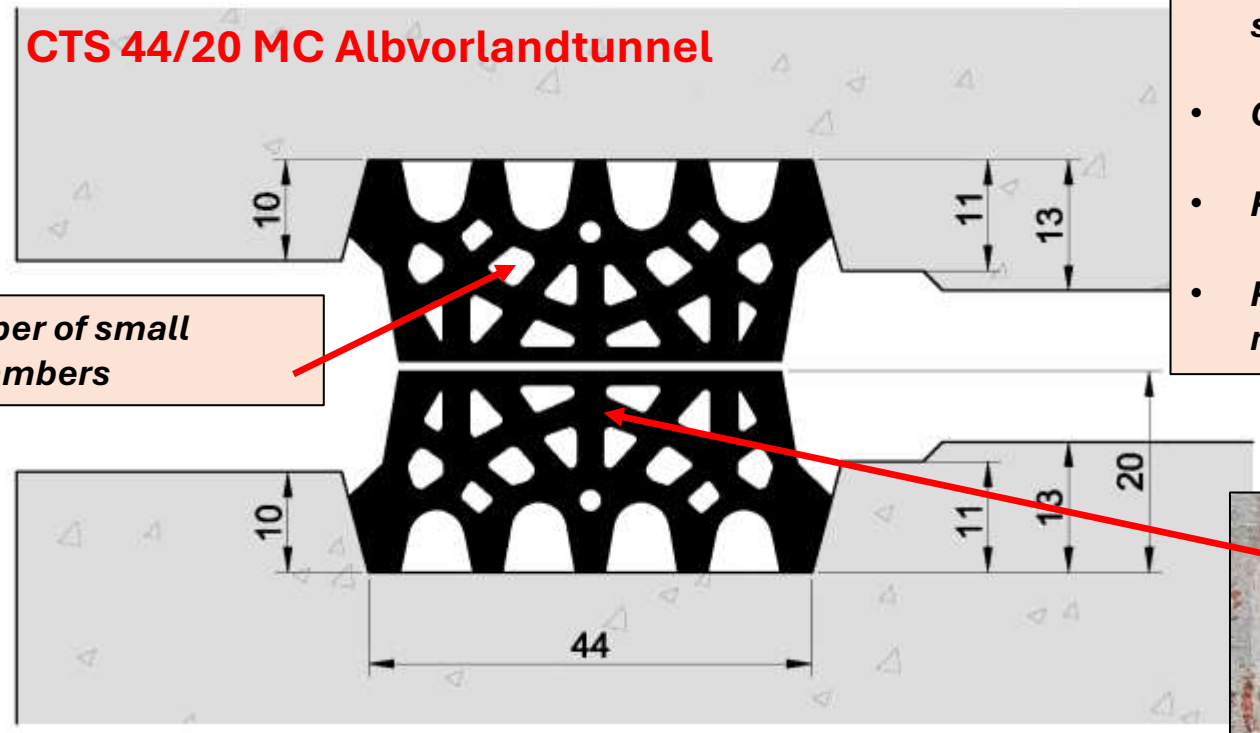
New Profile Geometry Concept „Archway-shape-design”

CTS Cordes ‘MC Profile’ (‘Magic Curve’) – new patend since 2018



Large number of small hollow-chambers

- *Improved sealing capacity at larger gap scenarios*
- *Overcoming offset-related weaknesses*
- *Reduced restoring force*
- *Reduced infiltration of gasket corner material (injection molding)*

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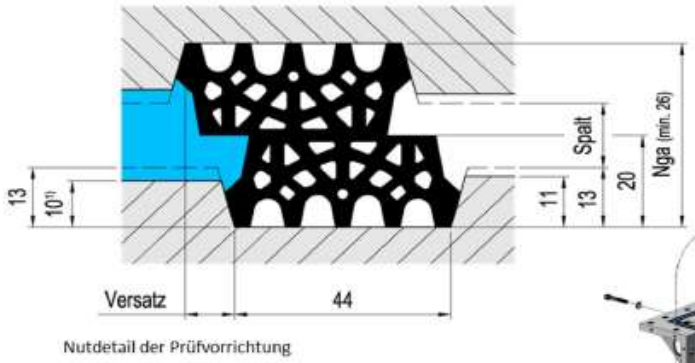
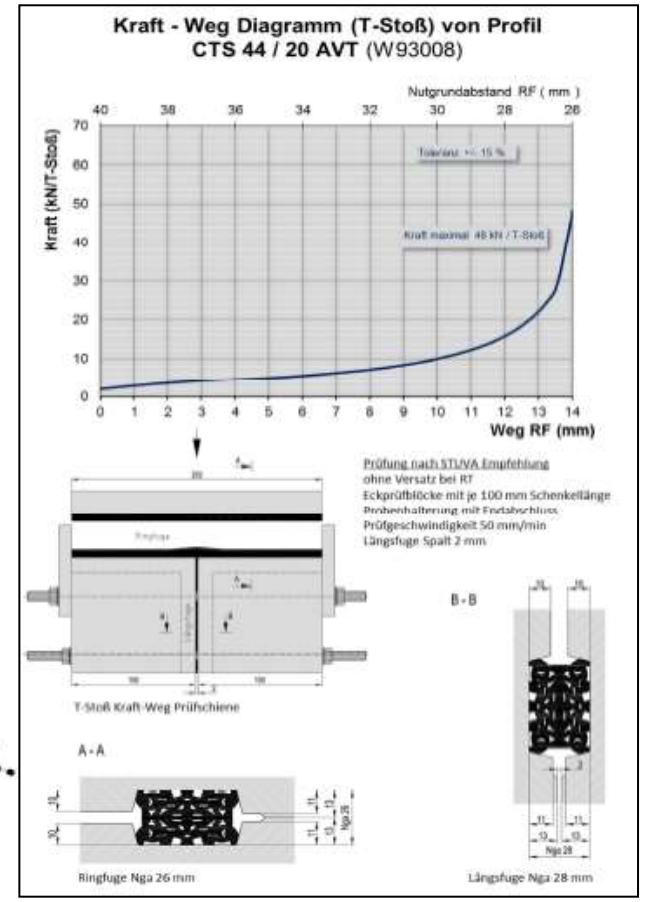
Gasket Testing Program for Albvorlandtunnel in accordance with German STUVA Recommendation

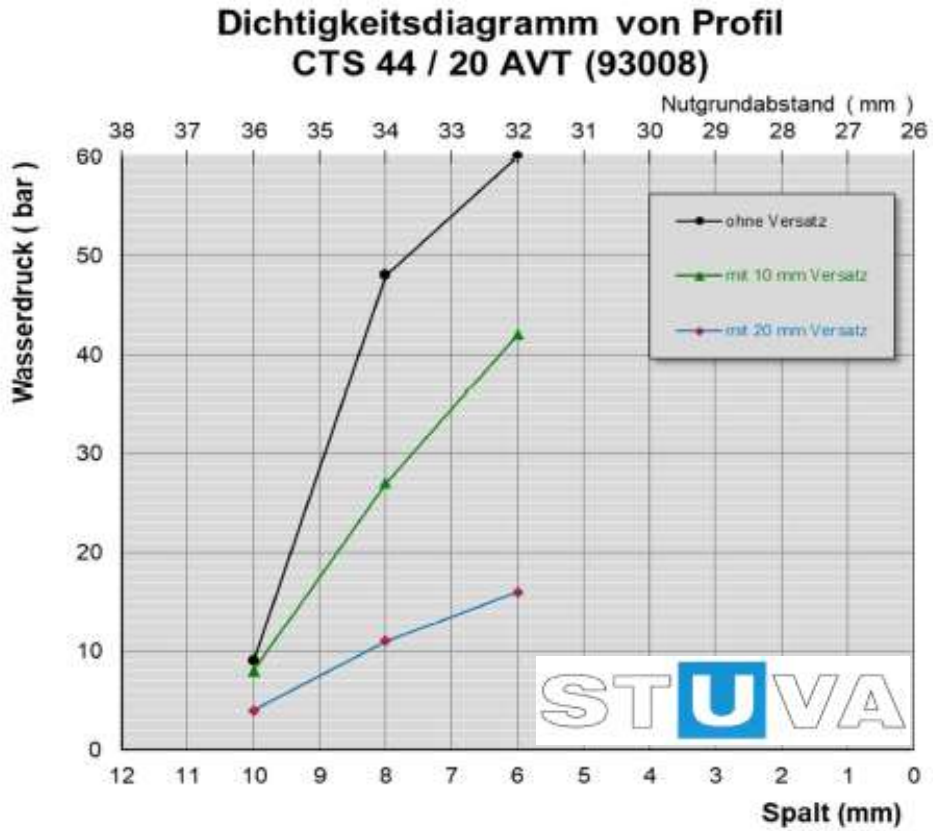


Nutdetail der Prüfvorrichtung

T-Stoß-Prüfvorrichtung aus Stahl
Drucksteigerung < 20 bar 1bar/5 min
> 20 bar 2bar/5 min

STUVA





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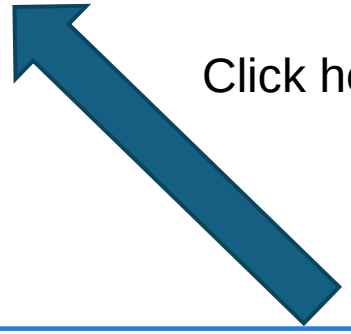
Sealing profile CTS 44-20 „Albvorlandtunnel” – Load-Deflection Behavior

video



Click here..

Movie: Load-Deflection Behavior of profile CTS 44/20 AVT

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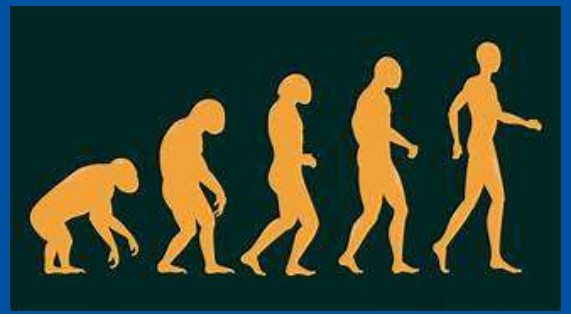
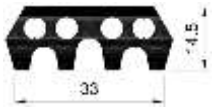
Evolution in profile geometry designs



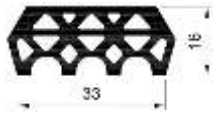
CR Rubber

EPDM rubber

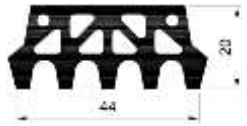
1970‘s



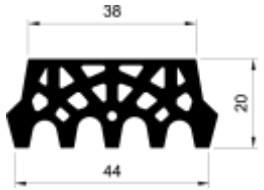
1980‘s



1990‘s



2000



since 2017

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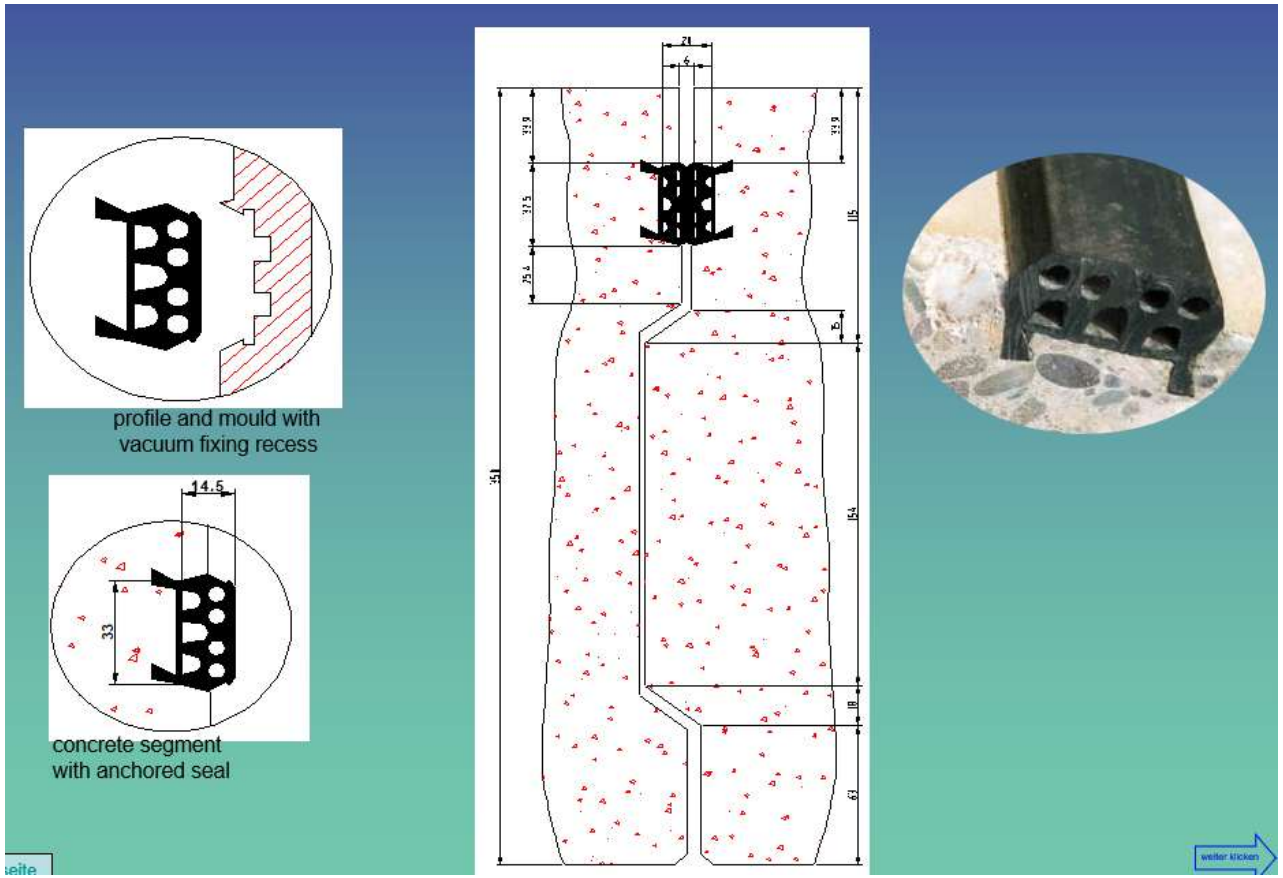
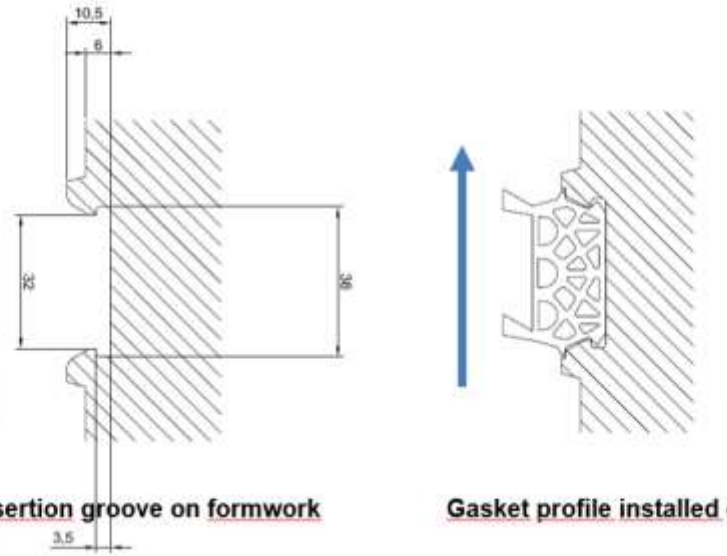
Another Milestone: Era of cast-in (anchored) gaskets



***Essential aspect*: „Anchoring feet alligned diagonally upwards“**



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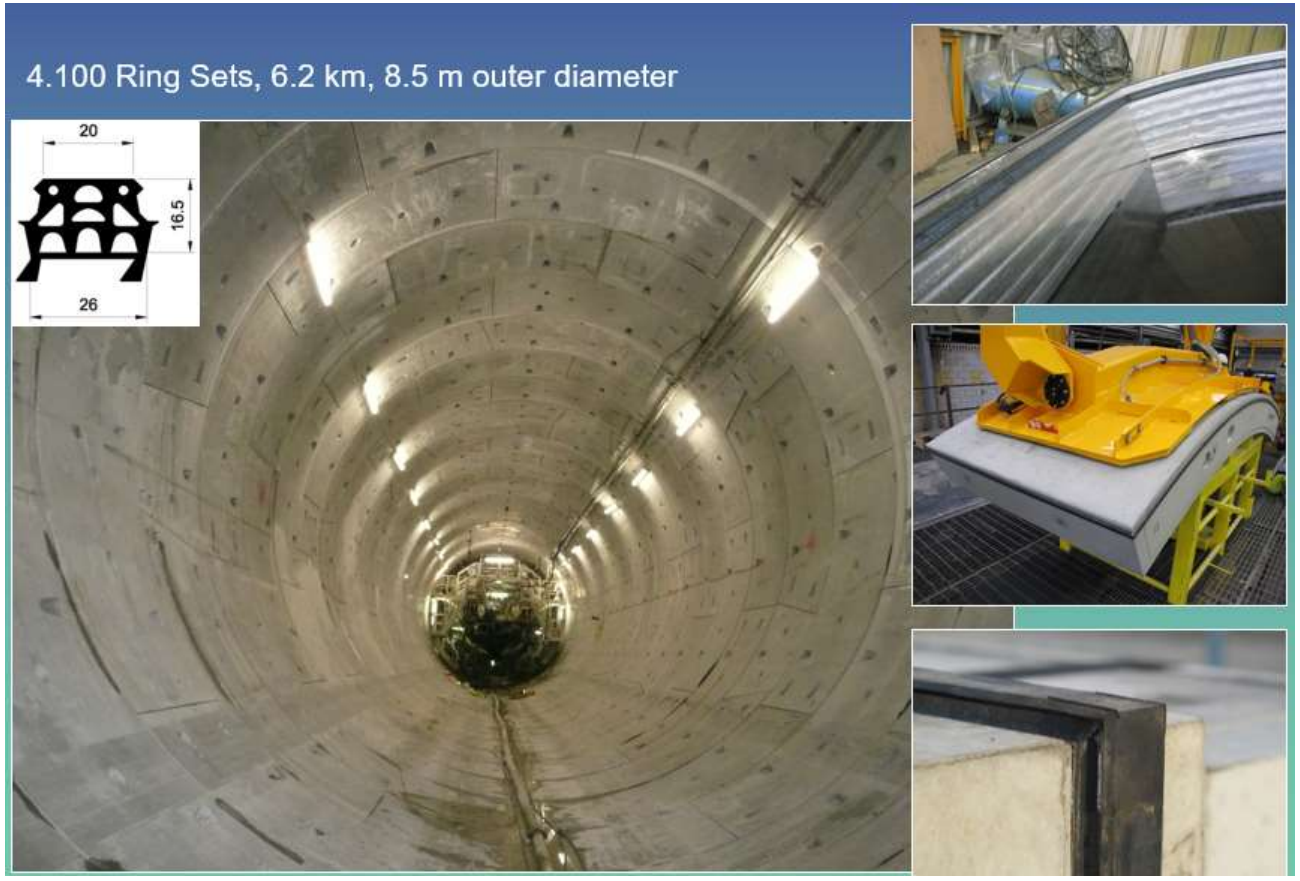
Era of cast-in (anchored) gaskets – Pilot Project in 2011: Lee Tunnel, UK London



- Better water-proofing performance due to less failures on concrete groove side
- Better water-proofing performance due to additional barriers against water penetration underneath the sealing profile
- Saving of time and costs for gasket groove repair measures on concrete segments before gasket installation
- Much better and safer bond to segments avoiding gaskets coming lose, especially during key stone insertion (*up to 5 times higher bonding force compared with glued-on gaskets)*
- No issues with gaskets falling off the segments during outside storage
  due to insufficient gluing and influences of weathering (*rain, frost*,)
- Better working conditions and higher safety for segment production staff due to abolition of solvents *(which are used in all standard brands of tunnel gasket installation adhesives)*
- Cost savings related to installation equipment (*spray guns & pressing frames*), purchase of adhesives & cleaner, stock for hazardous goods, disposal of empty tins, protection measures and safety gear for workers, etc.
- Environment-friendly work place
- Decisive reduction of gasket installation process time (*in average from 15 to 3 minutes, depending on segment/gasket frame size*)

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Milestone Projects: Anchored Gaskets with CTS Cordes MC-Design

Example: Brisbane Cross River Rail Tunnel, Australia

Picture by Russel Vine for SpatialSource-Australia

PRECAST CONCRETE ELEMENTS

Integrated seals for railway tunnel in Brisbane

Publication: German BWI Magazine, issued 01-2023

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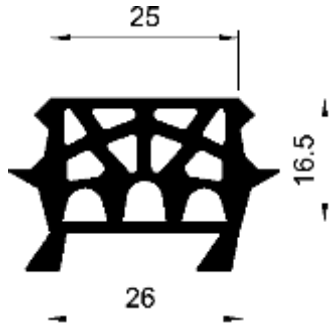
Milestone Projects: Anchored Gaskets with CTS Cordes MC-Design

Example: Brisbane Cross River Rail Tunnel, Australia

Brisbane Cross River Rail Tunnel, Australia
Profile CTS 26/16.5 MC anchored



Tested at 15 mm offset and 7 mm gap
Test pessure: 9 bar

Length of tunnel:
2 x 3.8 km = 7.6 km twin tube

Number of segments:
4470 rings, 1.7 m wide,
6+0 ring design,
26.820 segments in total

Contractor:
CPB-Ghella-BAM-JV

Client:
CrossRiverRail, Queensland

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Extension and Junction of the European HSR Network - Brenner Base Tunnel

North – South:

The **Brenner Route** through the Alps, a system of totally 230 km of tunnels, rock overburden up to 1720 m

Inn Valley Approaching Tunnels ***(diameter: 12.63 m):***

- ***H 3-4 Münster-Wiesing Tunnel*** *(2 x 5.8 km completed in 2011)*
- ***H-8 Jennbach Tunnel*** *(2 x 3.5 km completed in 2010)*

Brenner Base Main Tunnel Sections ***(diameters 9.5 – 10.5 m, total lengths: 2 x 43 km, approx. 2 x 37 km with TBM and segmental lining)***

- ***Section H-33 Tuffles – Pfons*** *(2 x 3 km NATM)*
- ***Section H-41 Sillschlucht – Pfons*** *(2 x 8,2 km TBM)*
- ***Section H-52 Hochstegen*** *(2 x 5 km Drill & Blast)*
- ***Section H-53 Pfons - Brenner*** *(2 x 7.5 km TBM)*
- ***Section Mauls 2-3*** *(2 x 19 km TBM, 2 x 0.8 km NATM)*
- ***Section H71 Eisack River Crossing*** *(2 x 2.25 km NATM)*

Brenner Base Exploration , Service and Linking tunnels:
Another 21 km of TBM and NATM tunnel works with diameters <10 m

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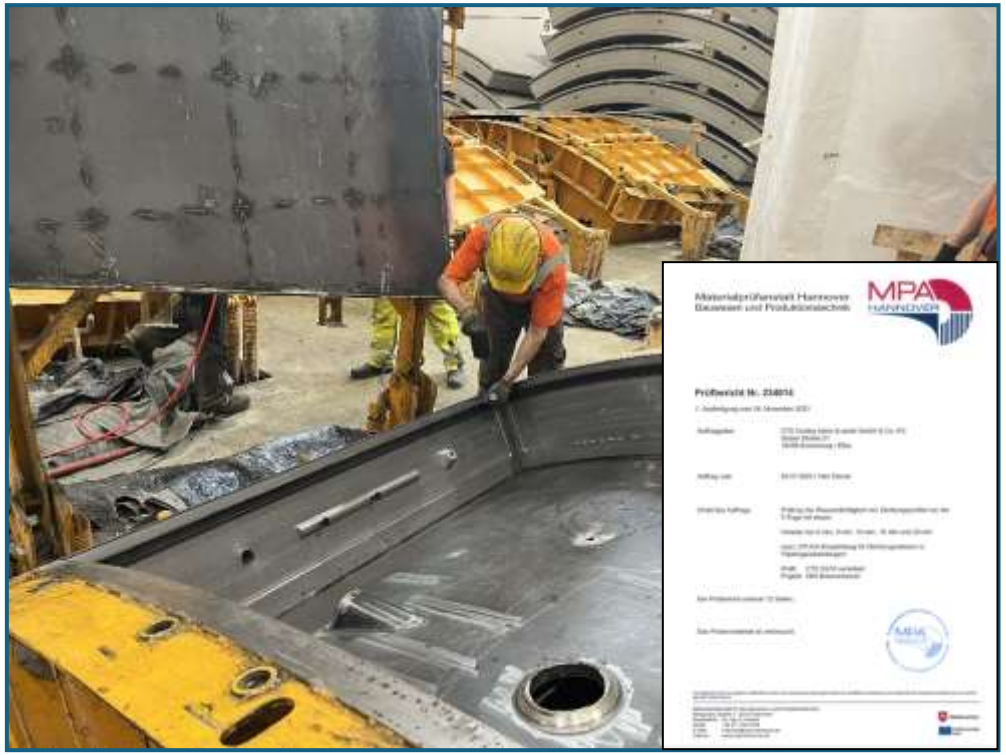
Current major projects – Brenner Base Tunnel

Profile CTS 33/16 anchored
Contractor: ARGE BBT H53 – PORR-MARTI JV
Designer: ATE Austrian Tunnel Engineers
Client: BBT Gesellschaft

2 x 7.5 km = 15 km tunnel



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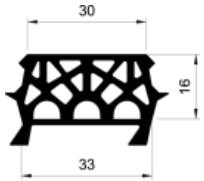
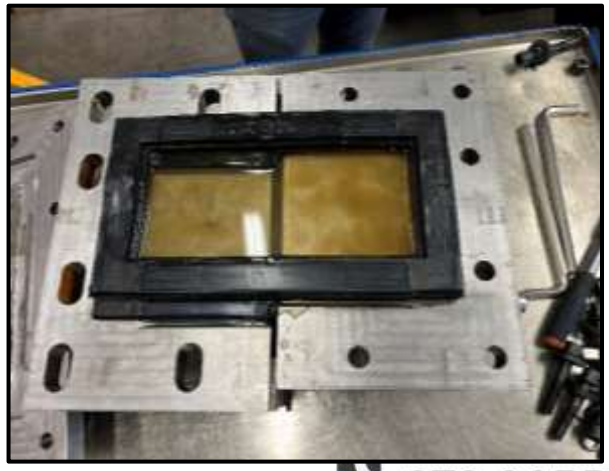
Current major projects – Brenner Base Tunnel

Waterproofing test requirements:



Test Pressure:	**4 bar**
Gap:	**7 mm**
Offset:	**0 to 20 mm max.**
Initial Load deflection force:	**Max. 62 kN/m**
Short-term-relaxation:	**min. 30% loss of stress (43.4 kN/m)**

Average values achieved in MPA-Test series:
Intitial Load: 59 kN/m / 39 after short term relaxation (5 minutes)



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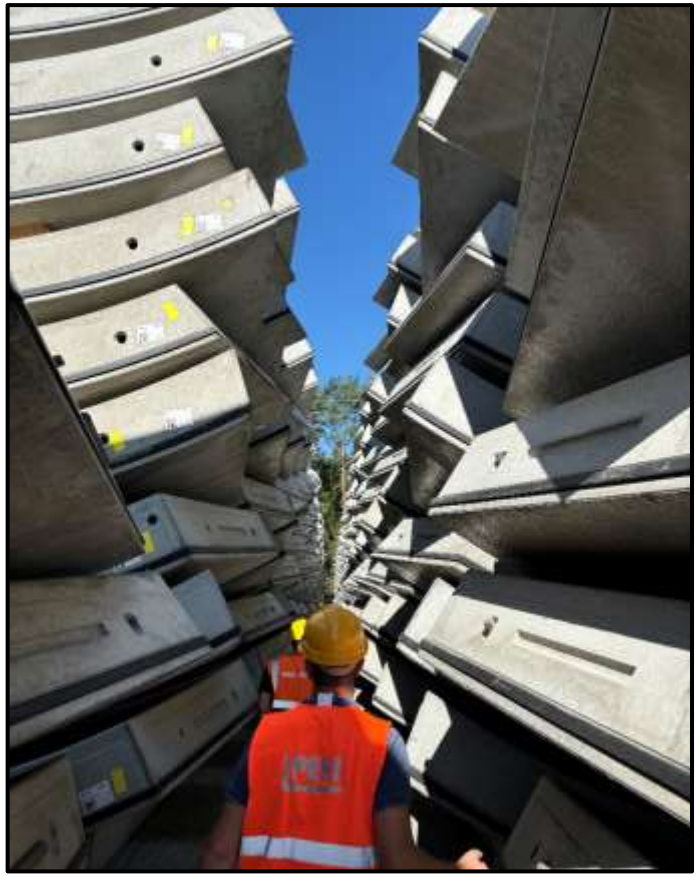
Current major projects – Brenner Base Tunnel



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Future “Green” Projects with Gasketed Segment Liner Systems

FWT Hamburg, Germany – Hot Steam Heat Supply Tunnel

Various projects to replace heating systems fed by coal-fired powerplants in and around the city of Hamburg, Germany:

- **Geothermical sources found in 1.300 m depth → Hot water infeed into existing heating system**
- **Turning overcapacites from windmills into heat → Hot water infeed into existing heating system**
- **Use of industrial waste heat in the Hamburg harbour → Hot steam supply for new heating systems**

hamburg.de

Funded by the European Union
NextGenerationEU

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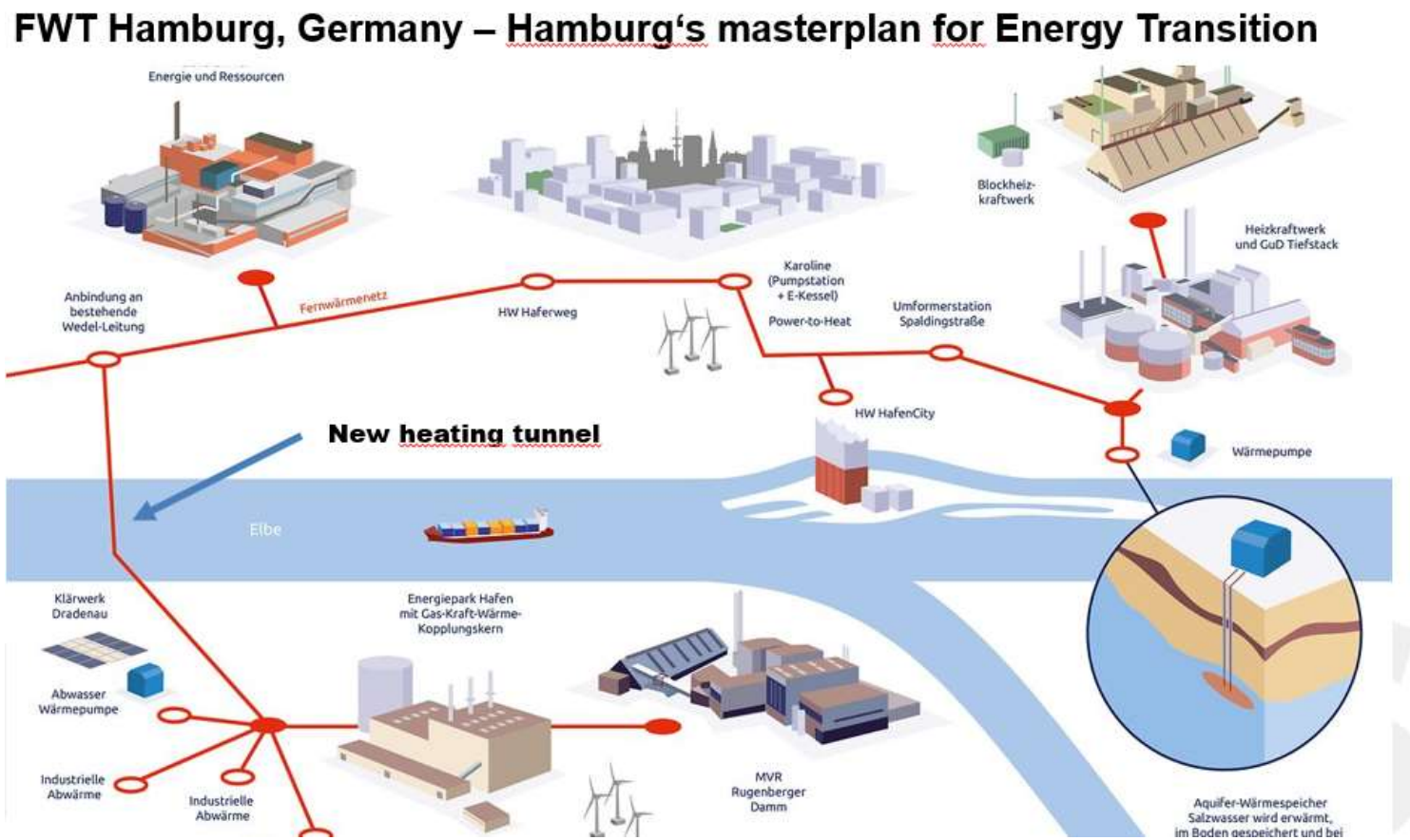
Future “Green” Projects with gasketed Segment Liner Systems



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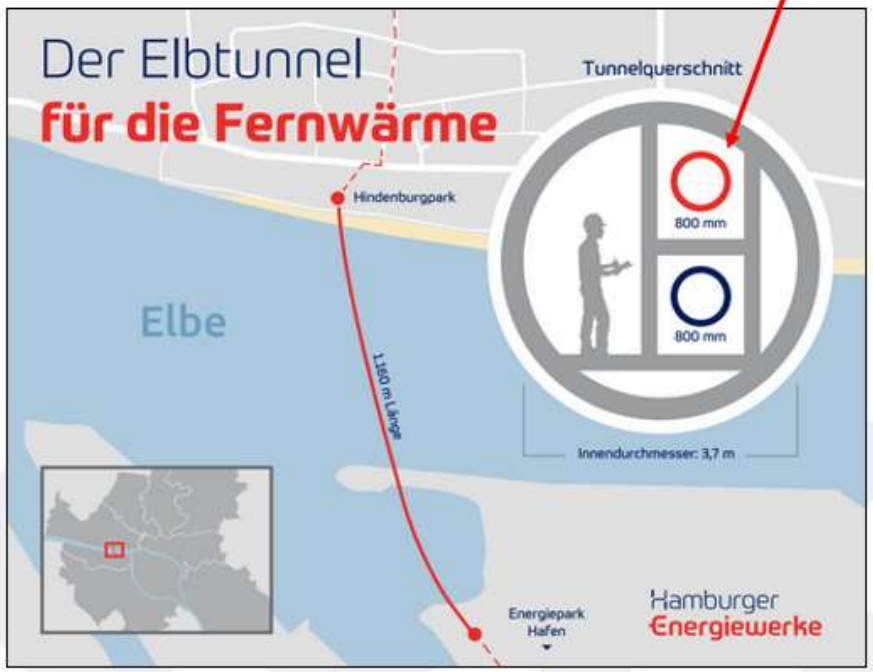
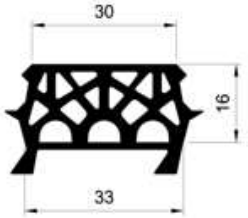
Future “Green” Projects with gasketed Segment Liner Systems

FWT Hamburg, Germany

Profile CTS 33/16 anchored
Contractor: Implenia
Client: Hamburger Energiewerke

circular system





STUVATEC

Profil Typ CTS 33/16 „verankert“ der Firma CTS Cordes tubes & seals GmbH & Co. KG

Fernwärmetunnel, Hamburg

Dichtigkeitsversuche in einer Stahlprüfform

Schlussbericht

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Future “Green” Projects with Gasketed Segment Liner Systems

Electric Power Supply Tunnel “ElbX”

700 km long underground electric power cable capacity: 4 Gigawatt

CTS CORDES tubes & Seals GmbH & Co.KG

Future “Green” Projects with gasketed Segment Liner Systems

SuedLink

Ein Vorhaben von TenneT TRANSNET BW

ARGE Tunnel ElbX

POWER FÜR DIE ZUKUNFT

Electric Power Supply Tunnel “ElbX”

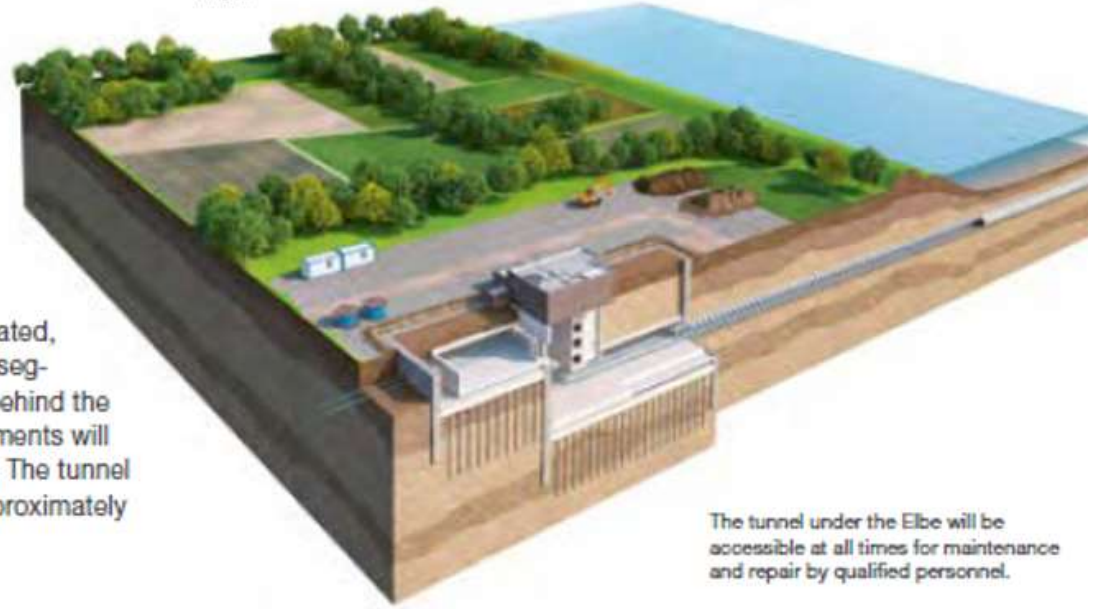
Owners: TENNET and TRANSNET BW

Contractor: PORR – W&F

Designer: IC Consulenten

Special structures: The Elbe crossing (ElbX)

To cross the Elbe river, a roughly five-kilometre tunnel is being dug near Glückstadt, in Schleswig-Holstein. It will be accessible via two shafts. As the tunnel is being excavated, reinforced concrete rings (“tubbing segments”) will be positioned directly behind the cutting wheel. Several of these segments will form a closed tube-shaped section. The tunnel will have an internal diameter of approximately four metres.



The tunnel under the Elbe will be accessible at all times for maintenance and repair by qualified personnel.

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Future “Green” Projects with Gasketed Segment Liner Systems

CTS 26/16.5 MC anchored
Test pressure: 10 bar
Gap: 0 – 4 mm
Offset: 0 – 15 mm

Electric Power Supply Tunnel “ElbX”

Windindustrie in Deutschland
Ein Projekt des BWE
BWE
Bundesverband WindEnergie

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Future “Green” Projects with Gasketed Segment Liner Systems

RAG Ibbenbüren Pit Water Collector Tunnel, Germany

German Ruhrkohle AG (RAG) is committed to pass over all closing coal mines safe and clean to the next generation taking care of the surrounding environment. Focus: Management & treatment of pit water and renaturation projects

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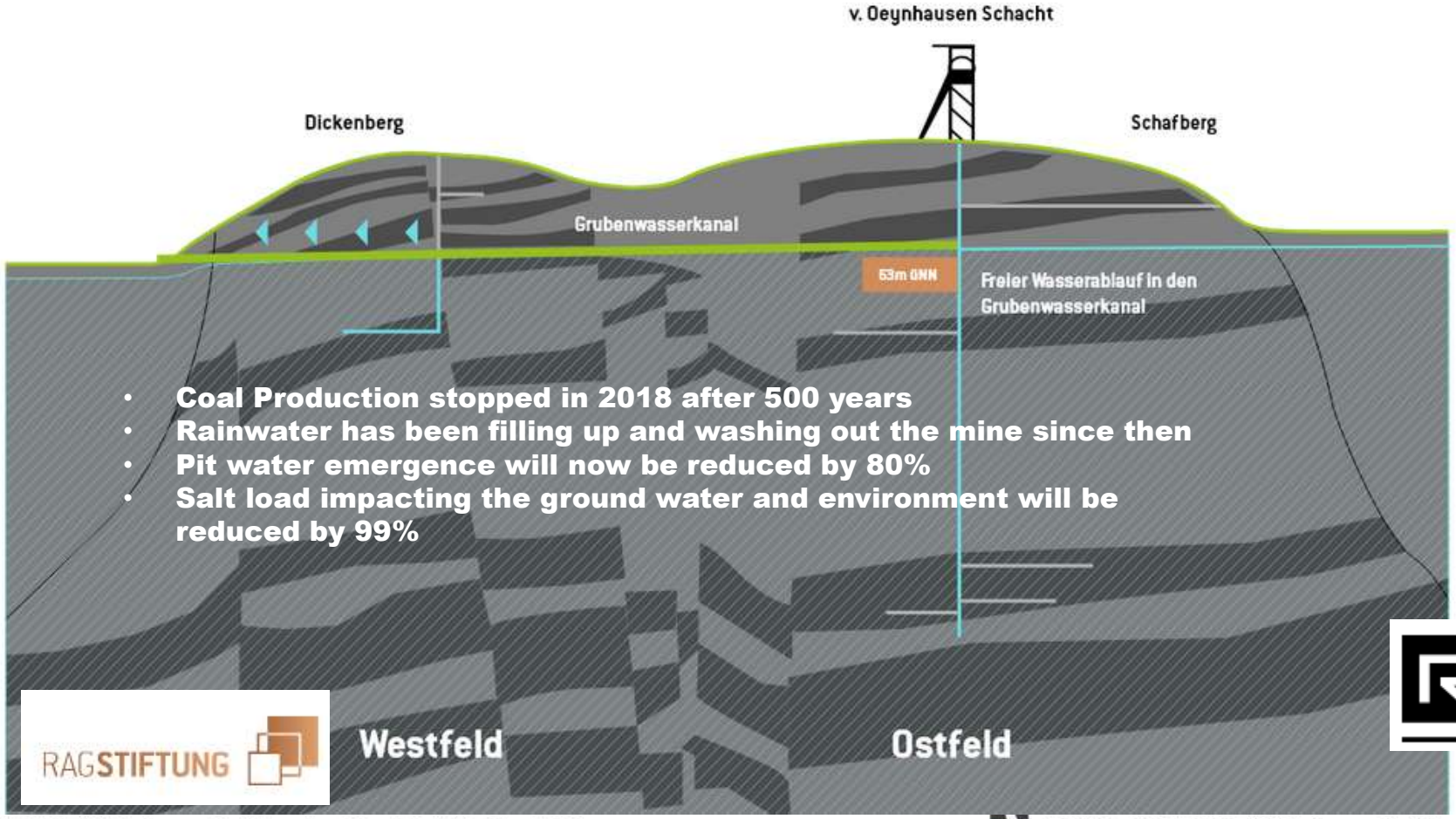
Future “Green” Projects with Gasketed Segment Liner Systems
- Ibbenbüren Pit Water Collector Tunnel, Germany



- **Coal Production stopped in 2018 after 500 years**
- **Rainwater has been filling up and washing out the mine since then**
- **Pit water emergence will now be reduced by 80%**
- **Salt load impacting the ground water and environment will be reduced by 99%**

RAGSTIFTUNG

RAG

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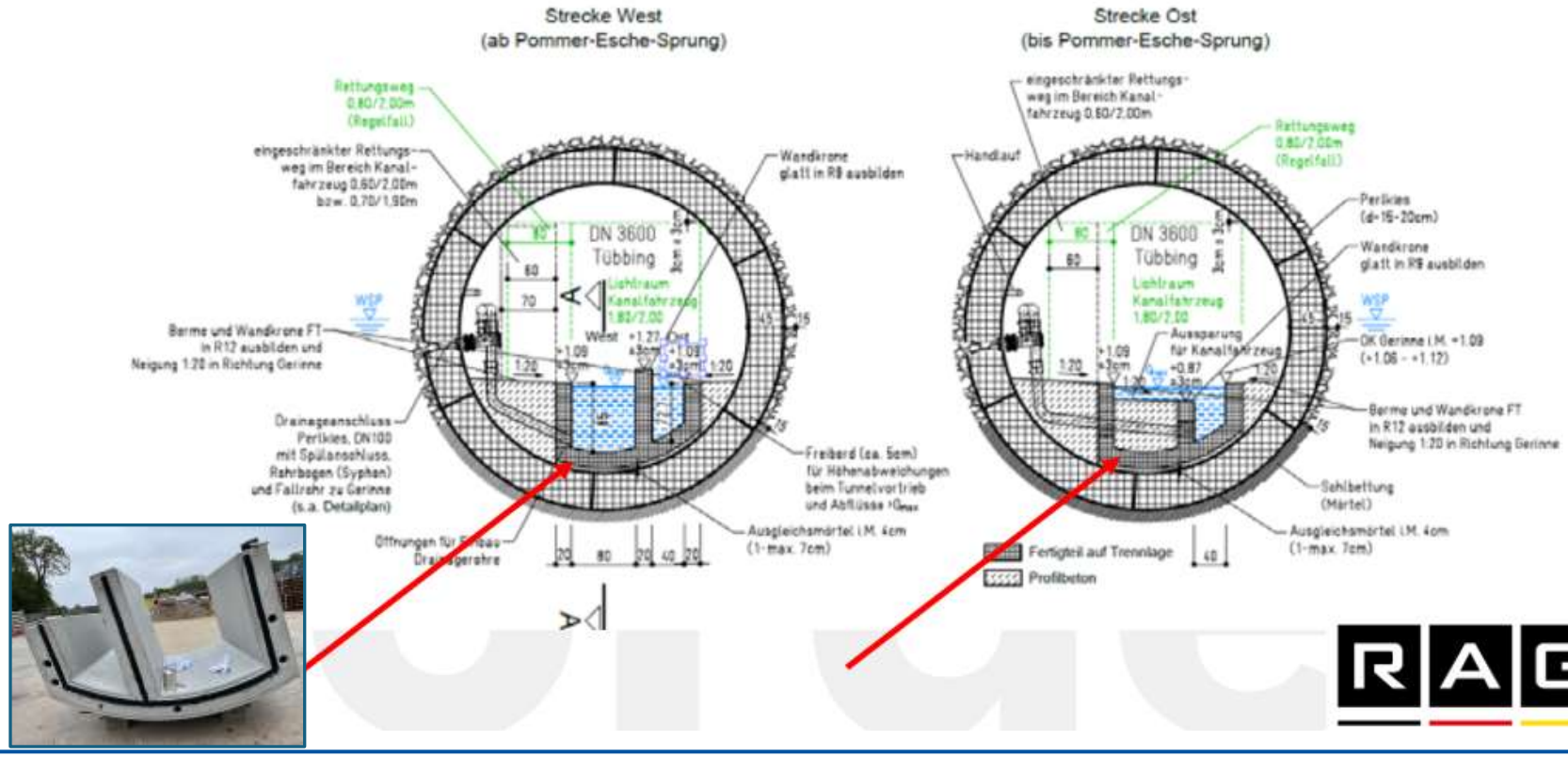
Future “Green” Projects with Gasketed Segment Liner Systems

RAG Ibbenbüren Pit Water Collector Tunnel – Channel Segments



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Future “Green” Projects with Gasketed Segment Liner Systems

RAG Ibbenbüren Pit Water Collector Tunnel, Germany

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Future “Green” Projects with Gasketed Segment Liner Systems

GREEN Compound Developments - Alternative Fillers

1.) Sustainable Substitute Products to Carbon Black:
Burning trees from plantation instead of burning raw oil
→*substantial reduction of CO^2 emission*

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Future “Green” Projects with Gasketed Segment Liner Systems

GREEN Compound Developments - Alternative Softeners:

1.) Sustainable vegetable oil used as softeners
instead of mineral oil

→ *substantial reduction of CO^2 emission and protection of resources*

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Future “Green” Projects with Gasketed Segment Liner Systems

GREEN Compound Developments – Devulcanized Rubber

1.) Recycling by Devulcanization (break-up sulfur-linked double chains)
→ high potential to increase sustainability if produced with green energy

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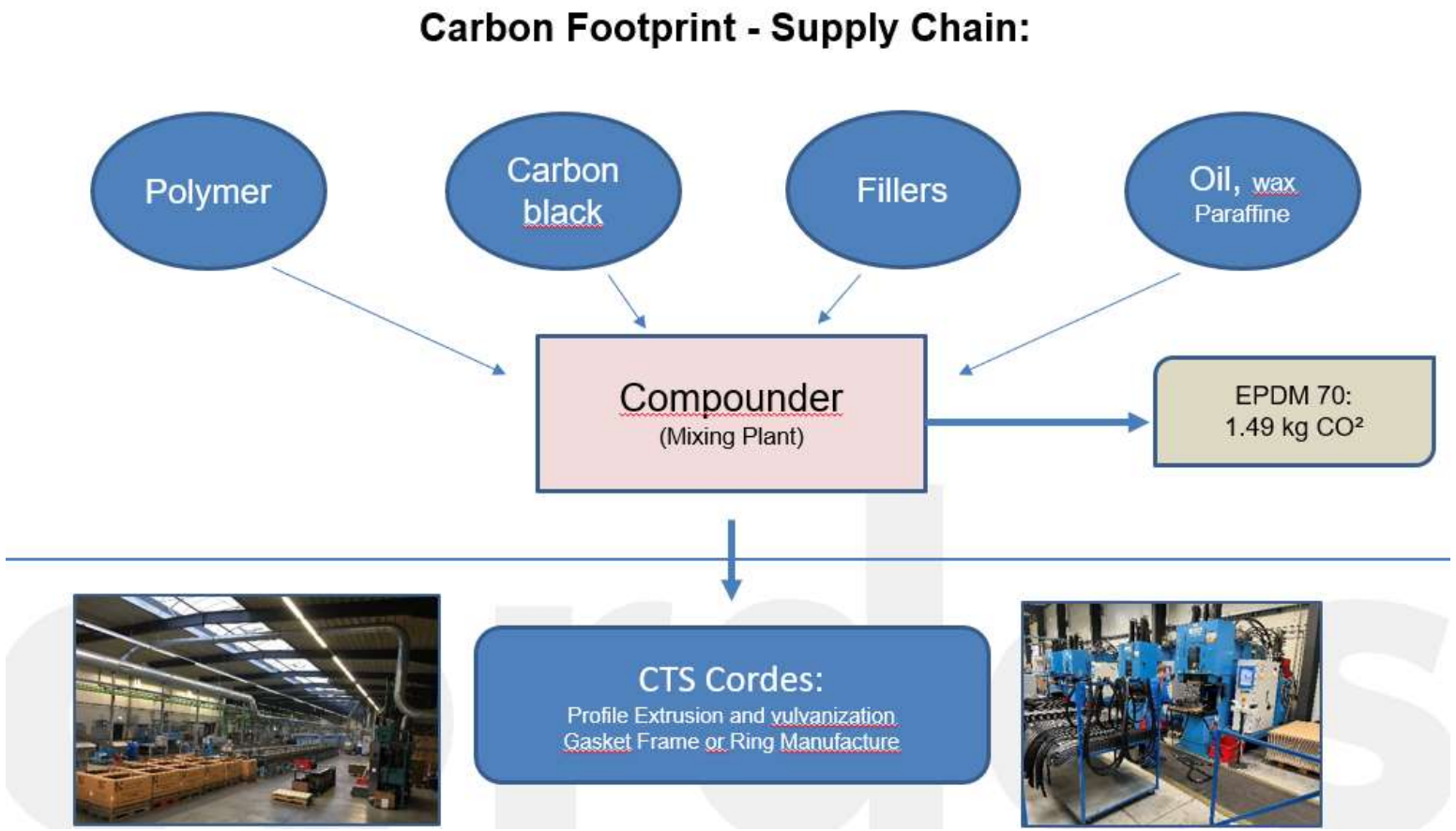
Future “Green” Projects with Gasketed Segment Liner Systems



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Future “Green” Projects with Gasketed Segment Liner Systems

Energy Transition at CTS Cordes:

Overcapacities in summertime shared with neighboring factories

Electric company cars and E-Bikes fueled with solar power

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Future “Green” Projects with Gasketed Segment Liner Systems

THANK YOU !