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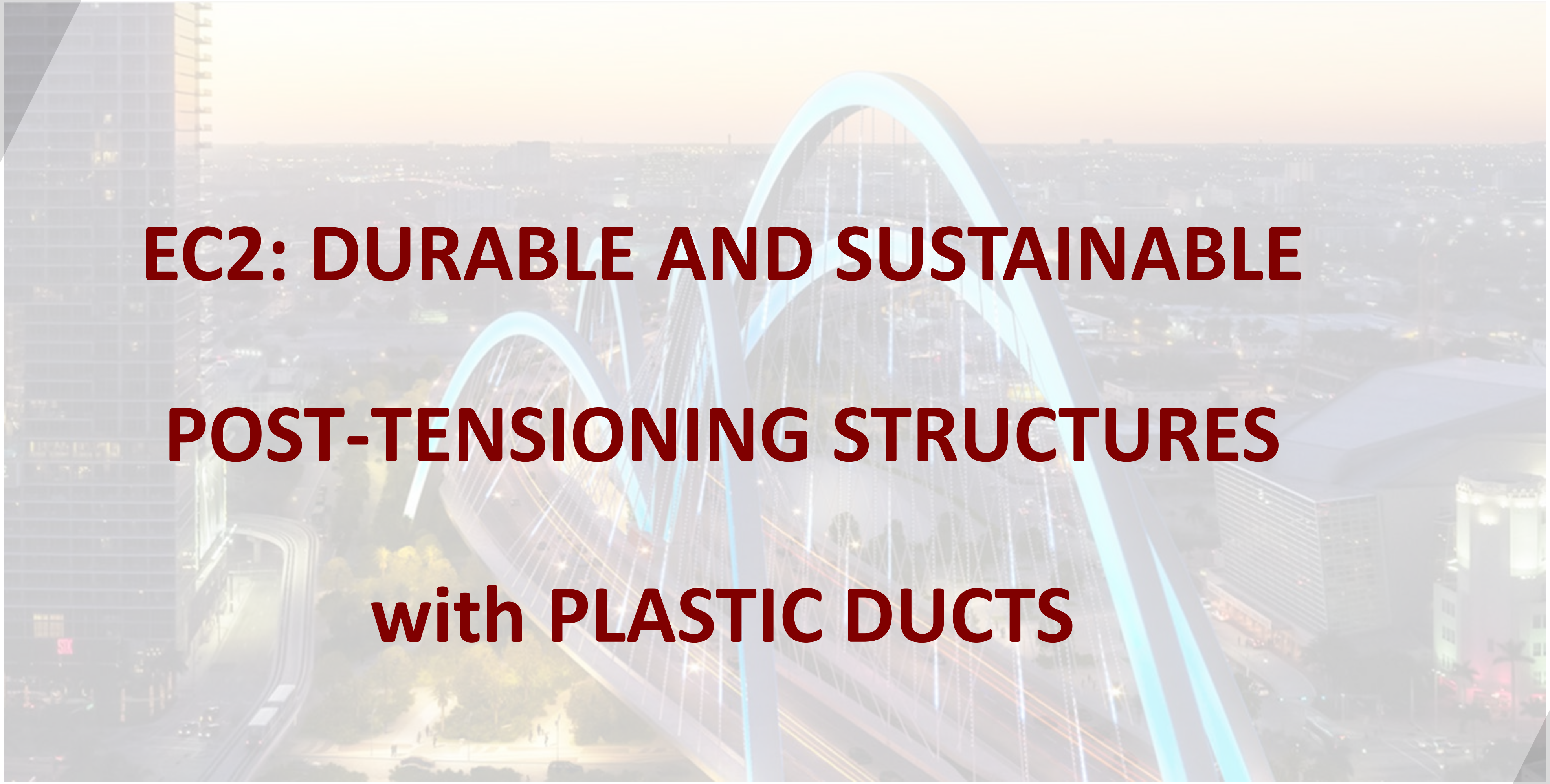
**Klaus Lanzinger**
**General Technologies, Inc.**



# EC2: DURABLE AND SUSTAINABLE

# POST-TENSIONING STRUCTURES

# with PLASTIC DUCTS

**Klaus Lanzinger**
**General Technologies, Inc.**

# Content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# ASTRA 12 010:

- Tendons at risk from **chloride exposure**, **fatigue or stray currents**.
- **Corrosion damage** to tendons has therefore been discovered time and again.
- Collapses of bridges or buildings are known from abroad.
- The **corrosion condition** of prestressing steels in metallic ducts **cannot be assessed** by means of non-destructive methods.

# ASTRA 12 010:

- For these reasons, in addition to metal ducts, **plastic ducts** have been used in Switzerland since the 1990s.
- In addition to **improved corrosion protection**, this also achieves **improved fatigue** behavior of the tendons.
- Additional advantages for tendons with PL3 (EIT):
  - Protection against stray currents
  - Monitor corrosion protection over the entire service life

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1. Introduction
2. **History of plastic ducts in bonded PT**
3. Selection of tendon protection levels
4. Advantages of plastic ducts
5. Conclusion

# History

**1968-1974:** Chillon Viaduct Switzerland:
1st use of corrugated plastic ducts

**2000:** ***fib*** **bulletin no. 7** (54 p.) “Corrugated plastic ducts for internal bonded post-tensioning“

2002: UK concrete society Technical Report TR47 “Durable post-tensioned concrete structures“

**2006:** ***fib*** **bulletin no. 33**
**“Durability of post-tensioning tendons"**

**2014:** *fib* **bulletin no. 75** (180 p.)
"Polymer-duct systems for internal bonded post-tensioning“

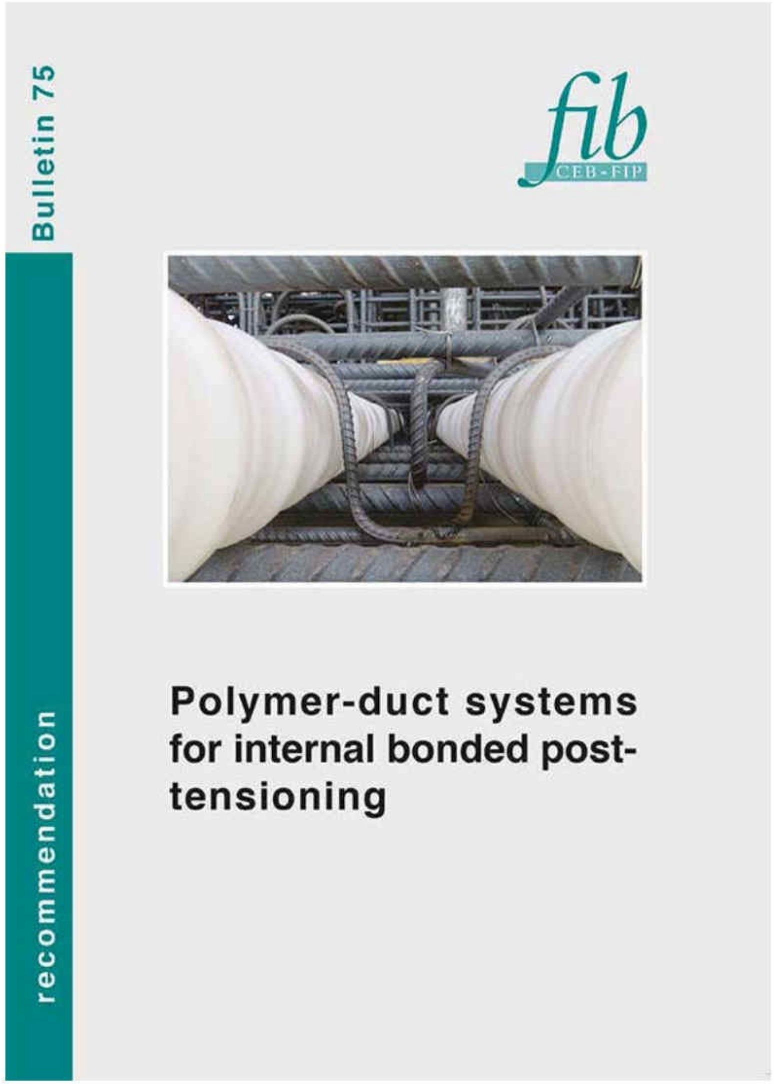
**2016:** EAD 160004-00-0301

“Post-tensioning kits for prestressing of structures”

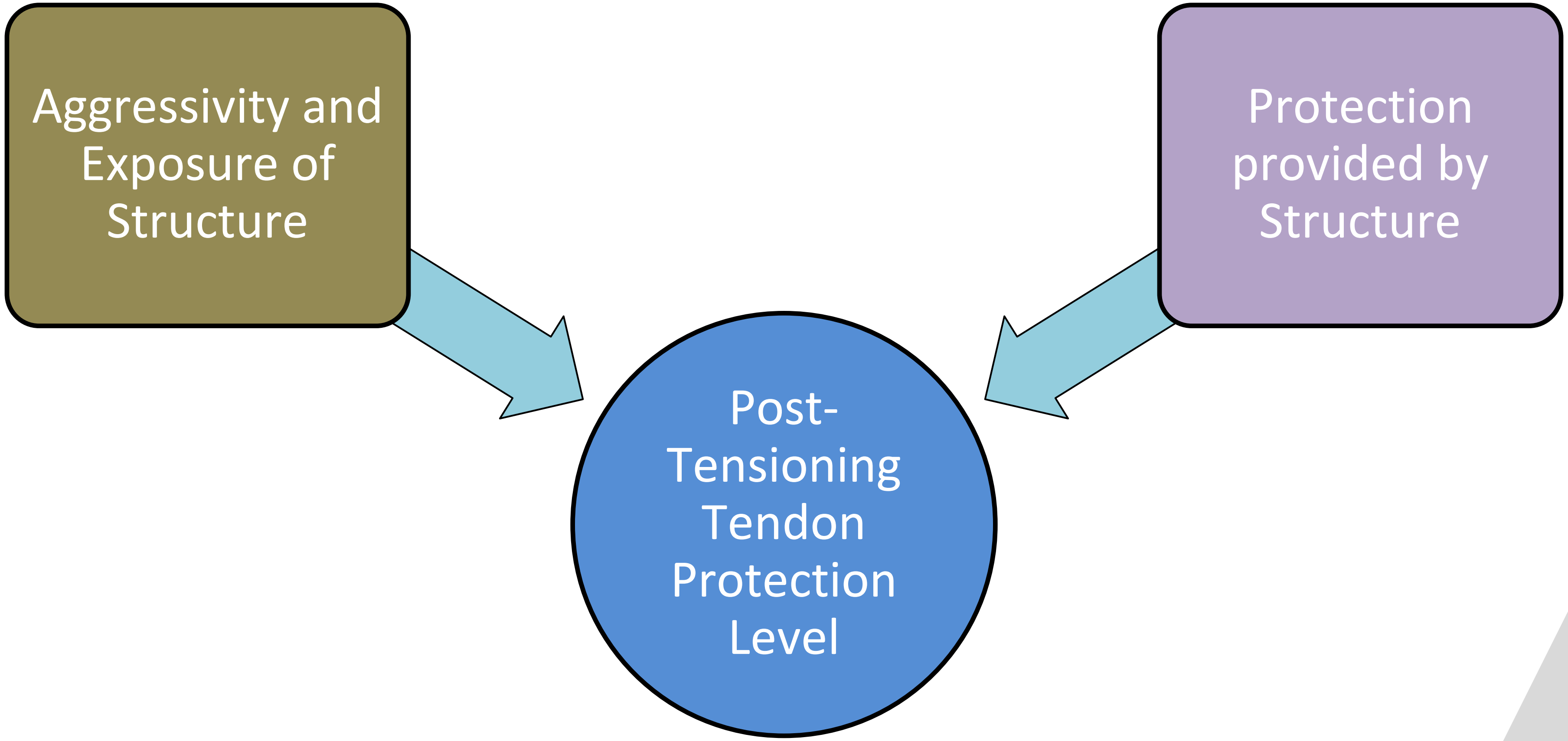
2019: PTI-ASBI M50.3-19 "Specifications for Multistrand and Grouted Post-Tensioning“

**2023:** Eurocode 2 “Design of concrete structures”

**2024:** *fib* bulletin no. 113 (revision of no. 75)



# Tendon Protection Level acc. to *fib* bulletin no. 33



Aggressivity and Exposure of Structure

# Aggressivity and Exposure (EN 206-1:2003)

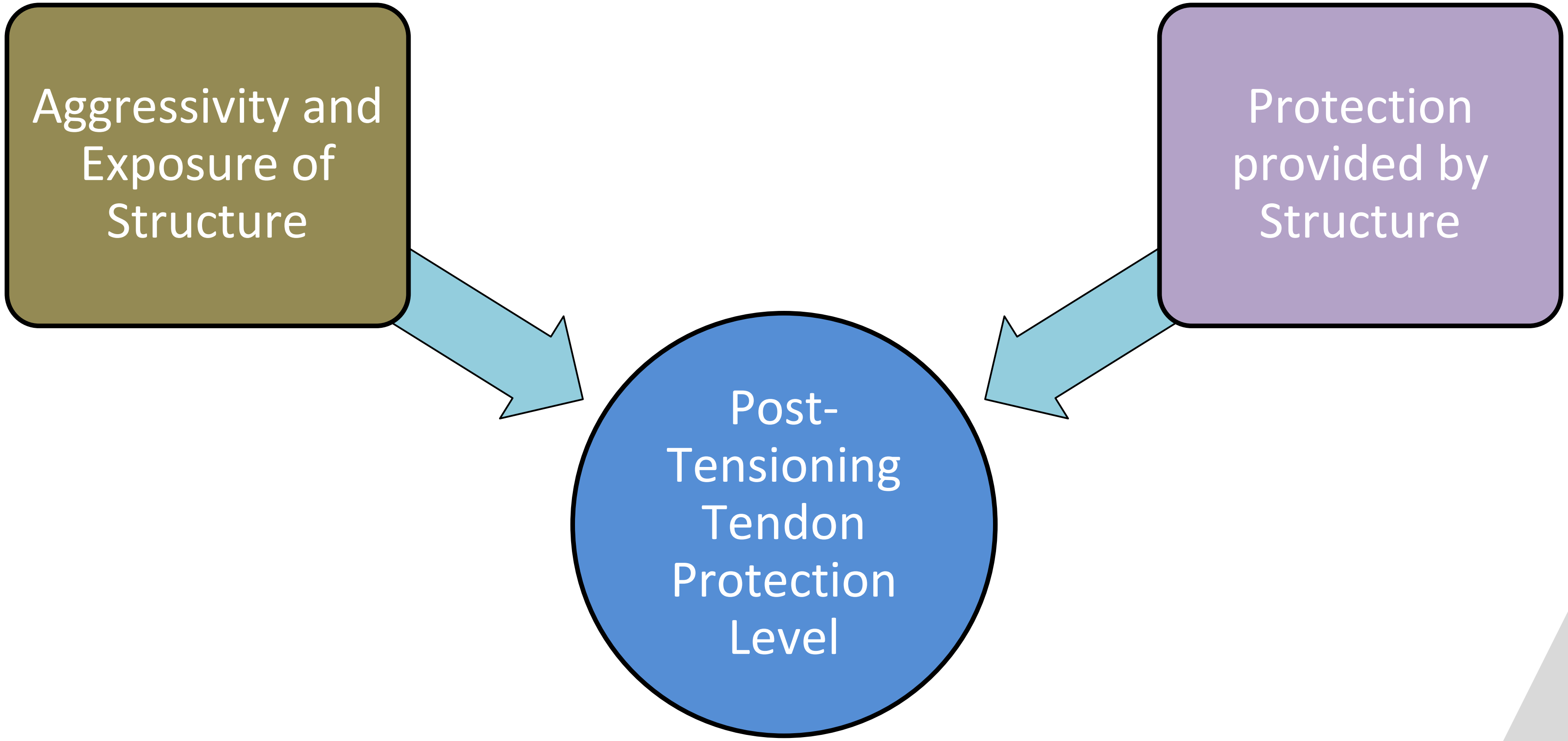
- X0: no risk of corrosion or attack
- XC1-XC4: corrosion induced by carbonation
- XD1-XD3: corrosion induced by chlorides other than from sea water
- XS1-XS3: corrosion induced by chlorides from sea water
- XF1-XF4: freeze/thaw attack with or without de-icing agents
- XA1-XA3: chemical attack

# Protection provided by the structure:

Protection provided by Structure

- Concrete quality and cover
- Waterproofing/surface protection systems
- Drainage system
- Expansion joints
- Construction joints
- Tendon layout
- Access for inspection and maintenance

# Tendon Protection Level acc. to *fib* bulletin no. 33



# Example:

- Project is located in a northern climate that has **freeze/thaw** with moderate saturation with deicing agents (XF2 = “high”)

- the protection provided by the structure is “high”

➡ This yields a tendon with a PL2

<table>
<tr><td colspan="2" rowspan="2">PL</td><td colspan="3">Protection Provided by Structure (2)</td></tr>
<tr><td>High</td><td>Medium</td><td>Low</td></tr>
<tr><td rowspan="3">Aggressivity/Exposure (1)</td><td>Low</td><td>PL1</td><td></td><td></td></tr>
<tr><td>Medium</td><td></td><td>PL2</td><td></td></tr>
<tr><td>High</td><td></td><td></td><td>PL3</td></tr>
</table>

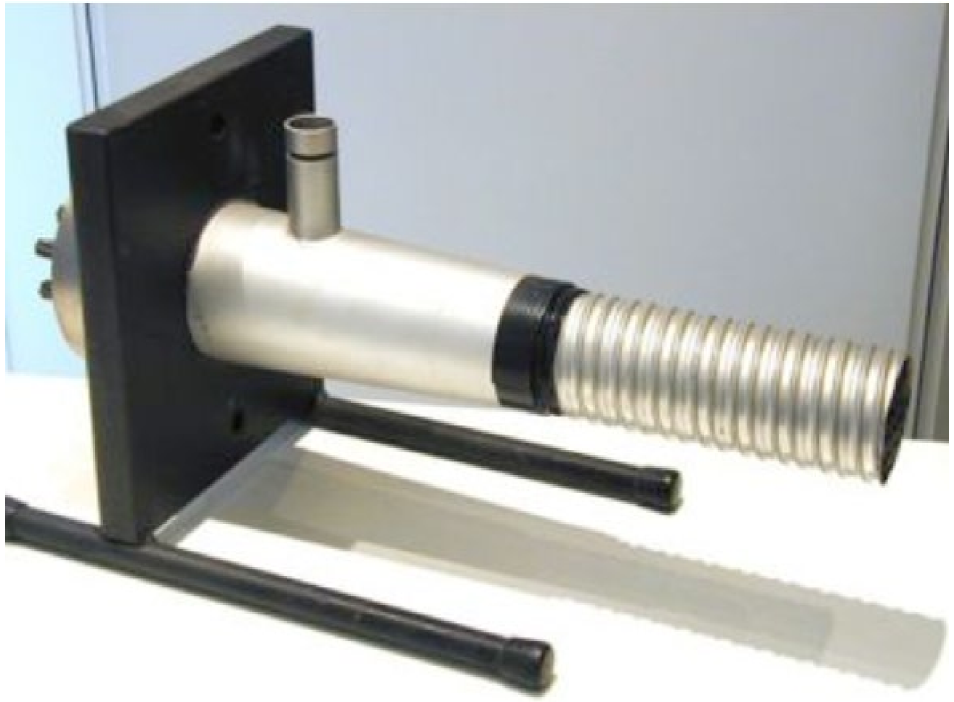
# PL1:

Requirements:

- Duct sufficient stiff and tight
- Filling material chemically stable
- Filling without voids

Examples:

- Metal ducts (EN523, 524 and cement grout (EN 445-447)



[Source: *fib* bulletin no. 33]

# PL2:

Requirements:

- Envelope water- and vapour tight over entire length
- Envelope material chemical stable
- System testing (*fib* B75)

Examples:

- Corrugated plastic ducts
- Permanent protection cap

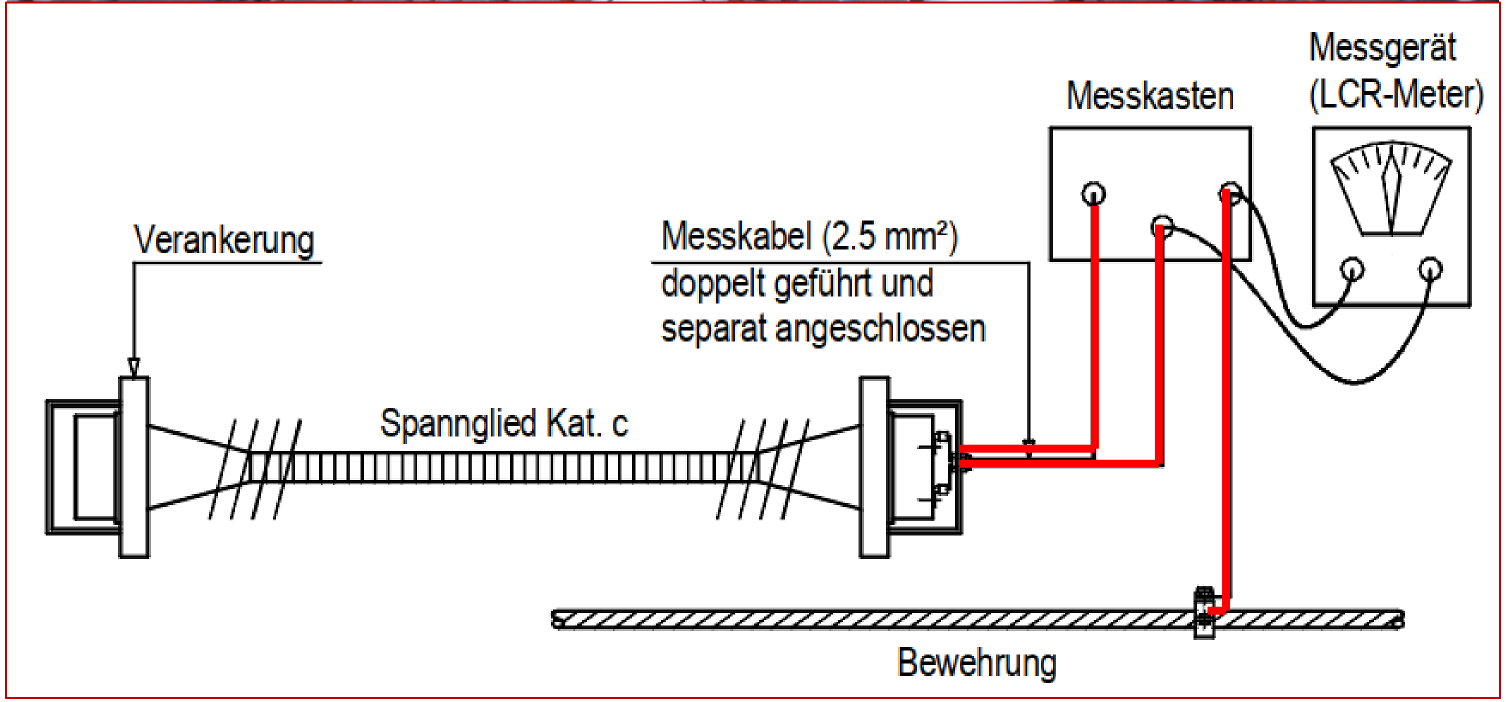
# PL3:

## Requirements:

- Monitoring at any time

## Examples:

- Electrically Isolated Tendons (EIT)




[Source: ASTRA 12010]

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# Friction losses:

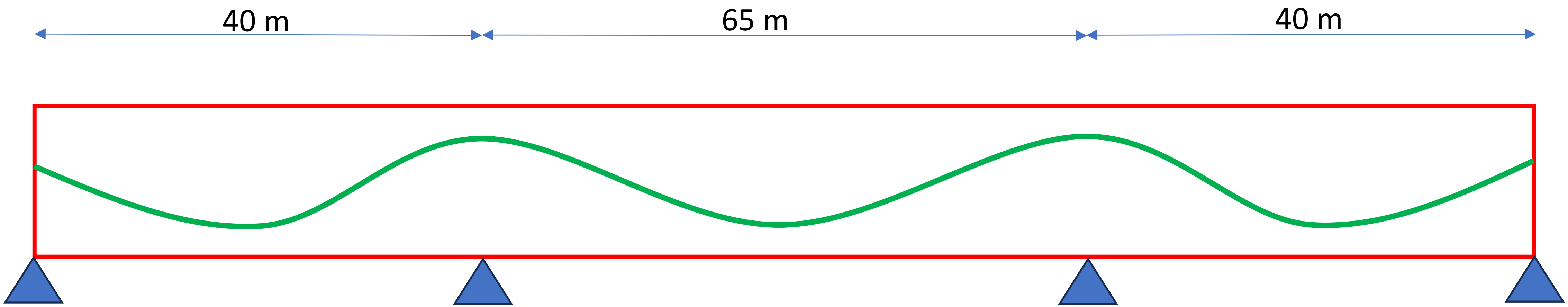
$$P(x) = P_0 * e^{-\mu(\alpha + k * x)}$$

- Prestressing force in tendons reduced by friction
- Friction depends on tendon geometry and **friction coefficient μ**

Metal duct: μ = 0,20

Plastic duct: **μ = 0,12**

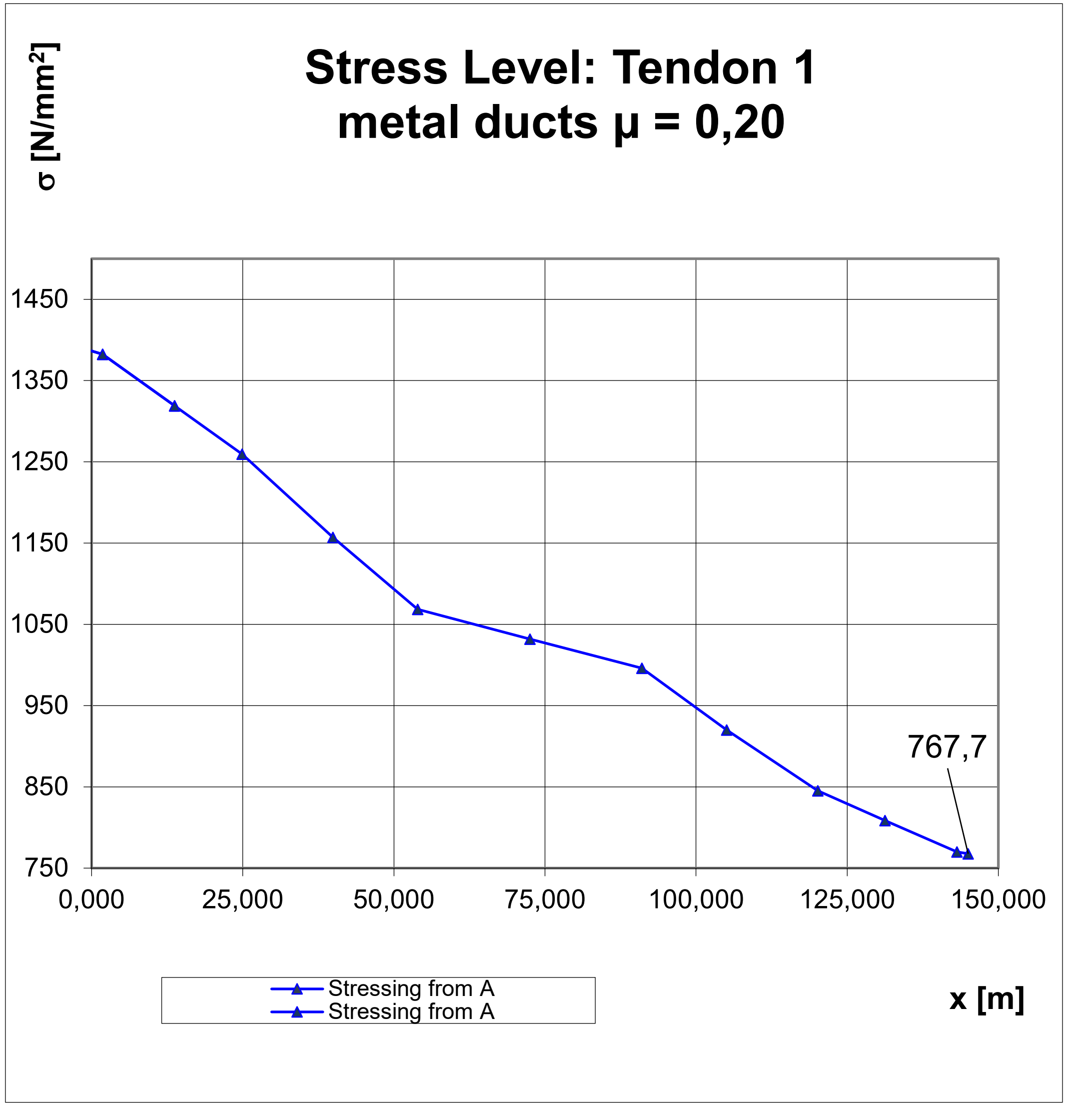
# Example 1: Bridge Project

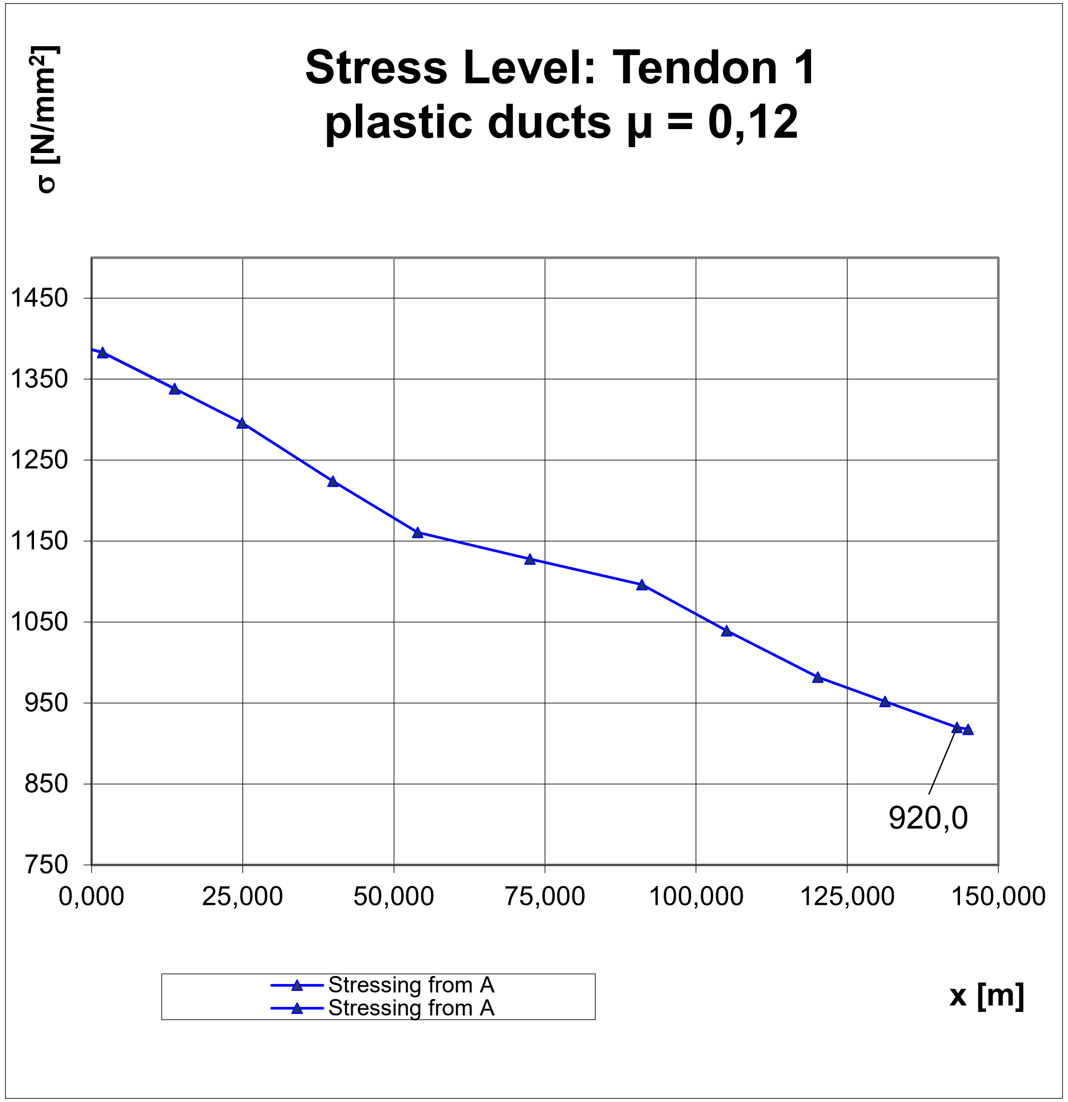



Hollow box girder with 3 spans, total 145 m

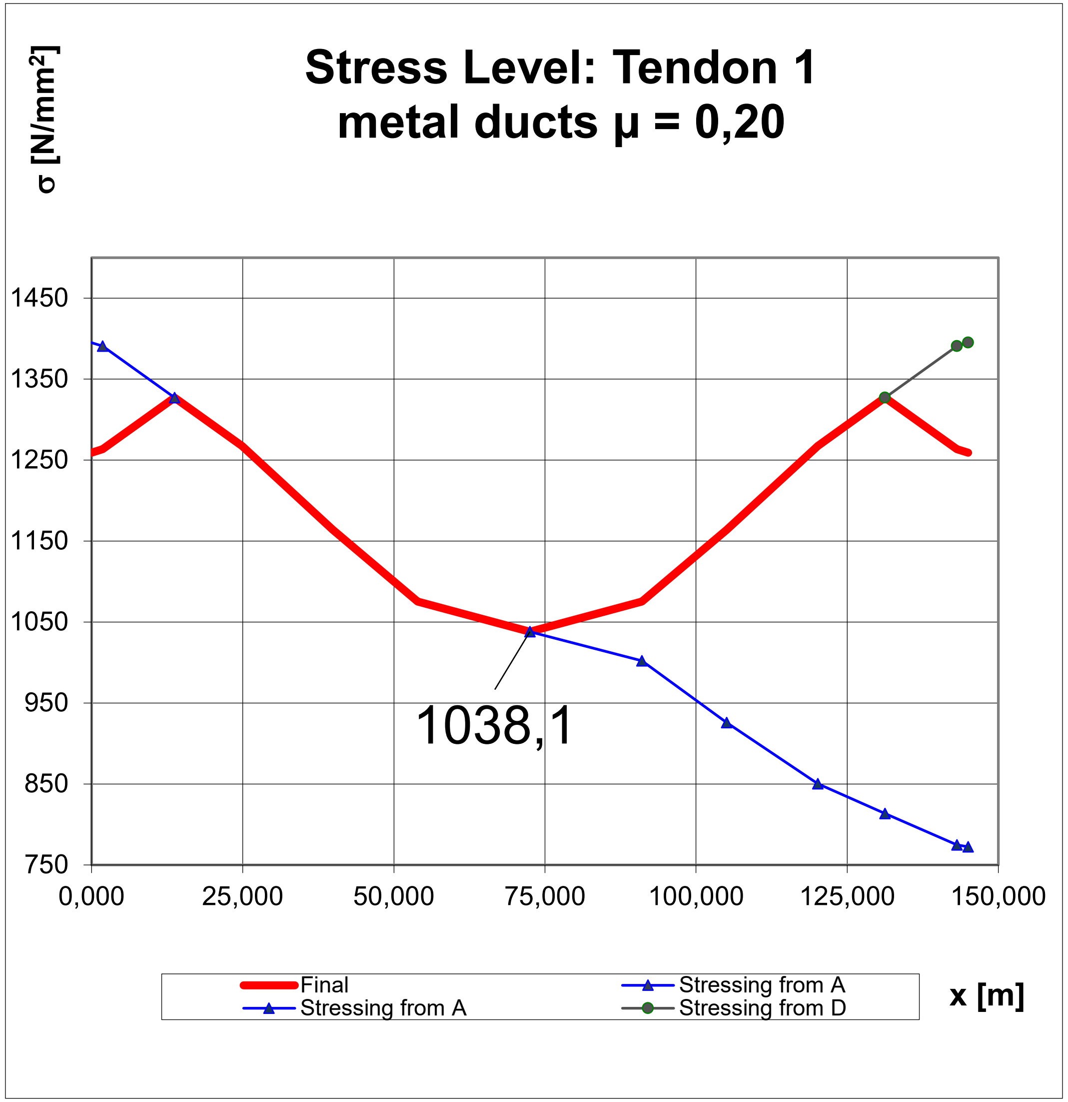
Tendons with horizontal and vertical deviation

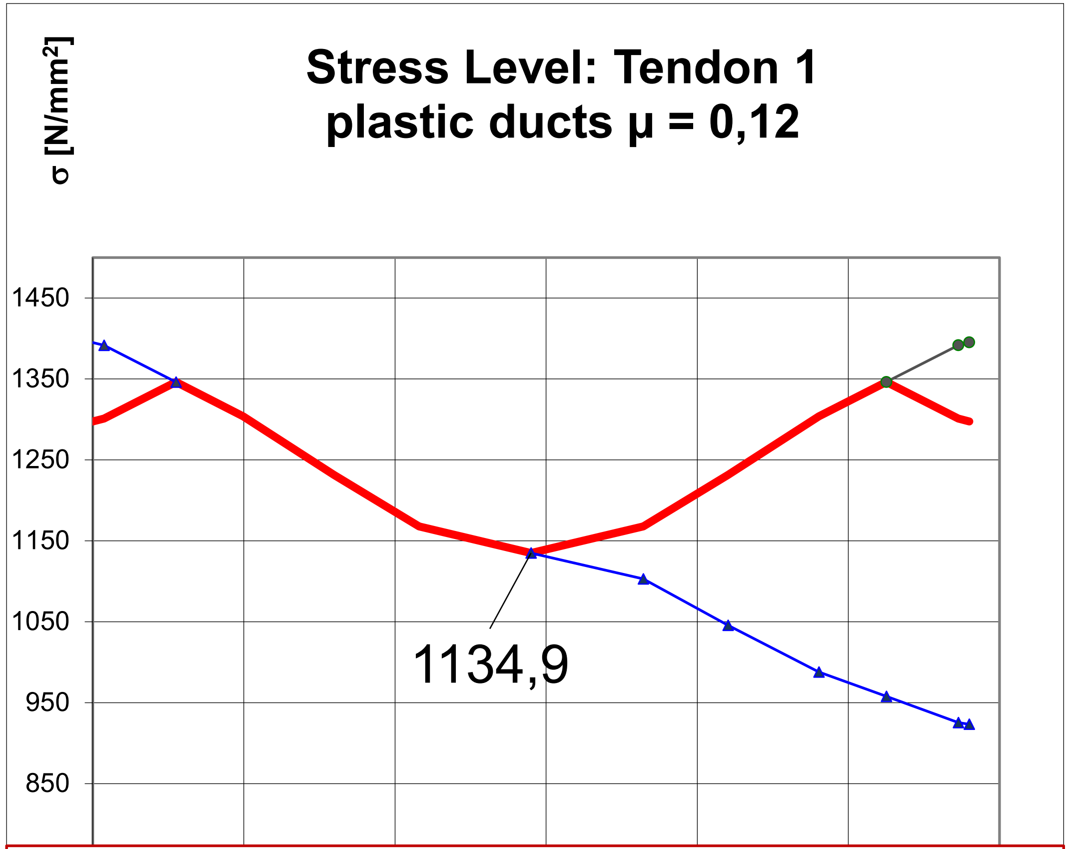
# Advantage: friction losses



# Advantage: friction losses




Stress = 1.135 N/mm²

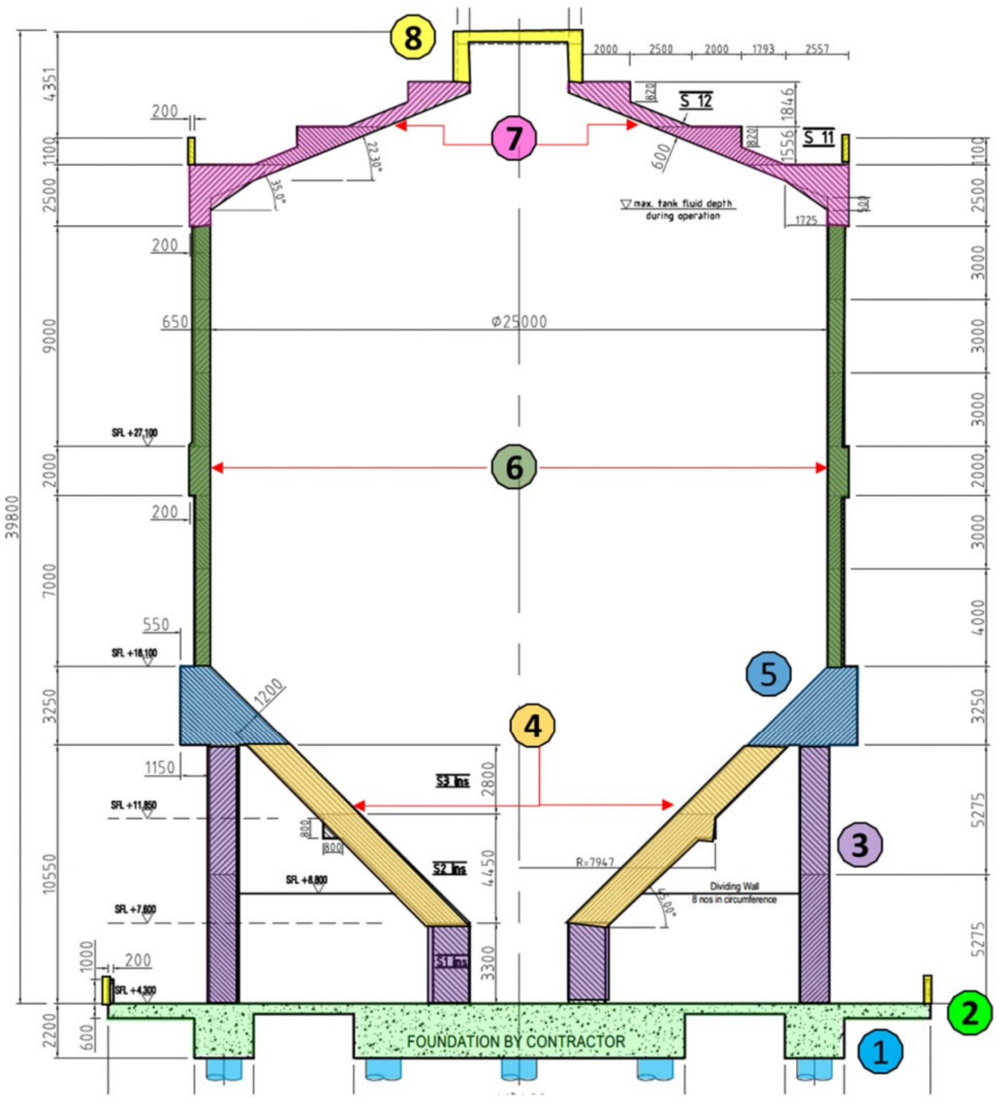
**= 9% above metal ducts.**

**➔ Less Prestressing Steel**

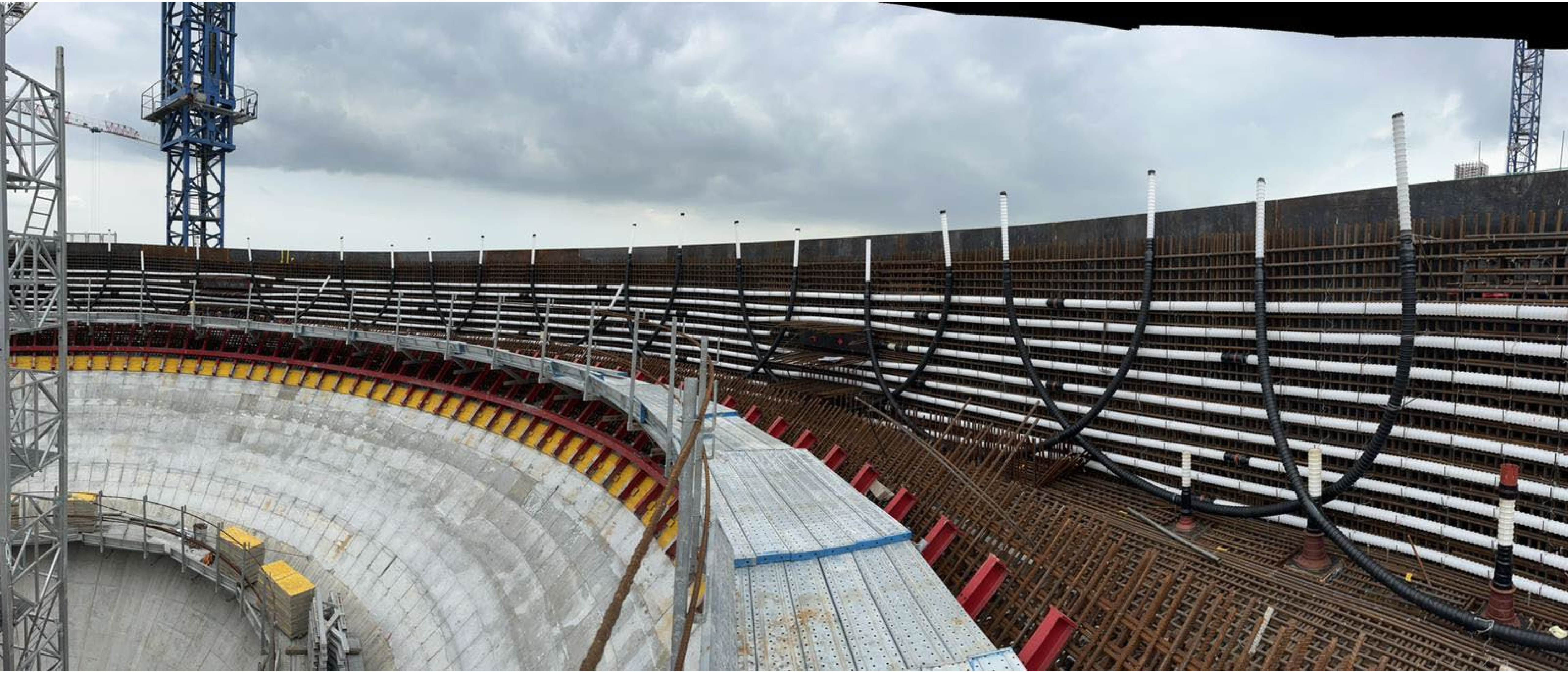
# Example 2: Digester Tank

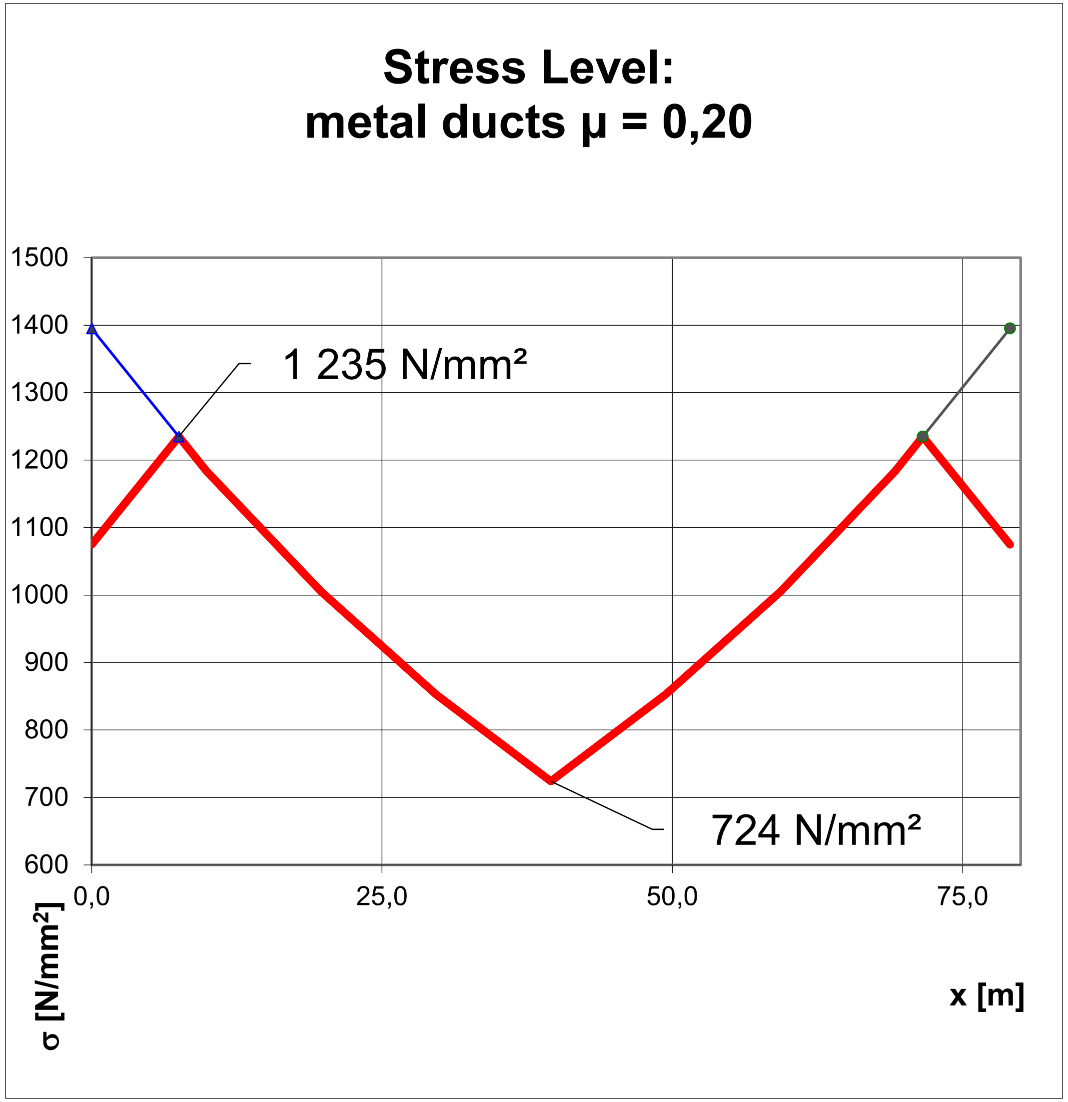
- Top and bottom cone
- Diameter: 25 m
- Height: 40 m
- Wall t = 65 cm

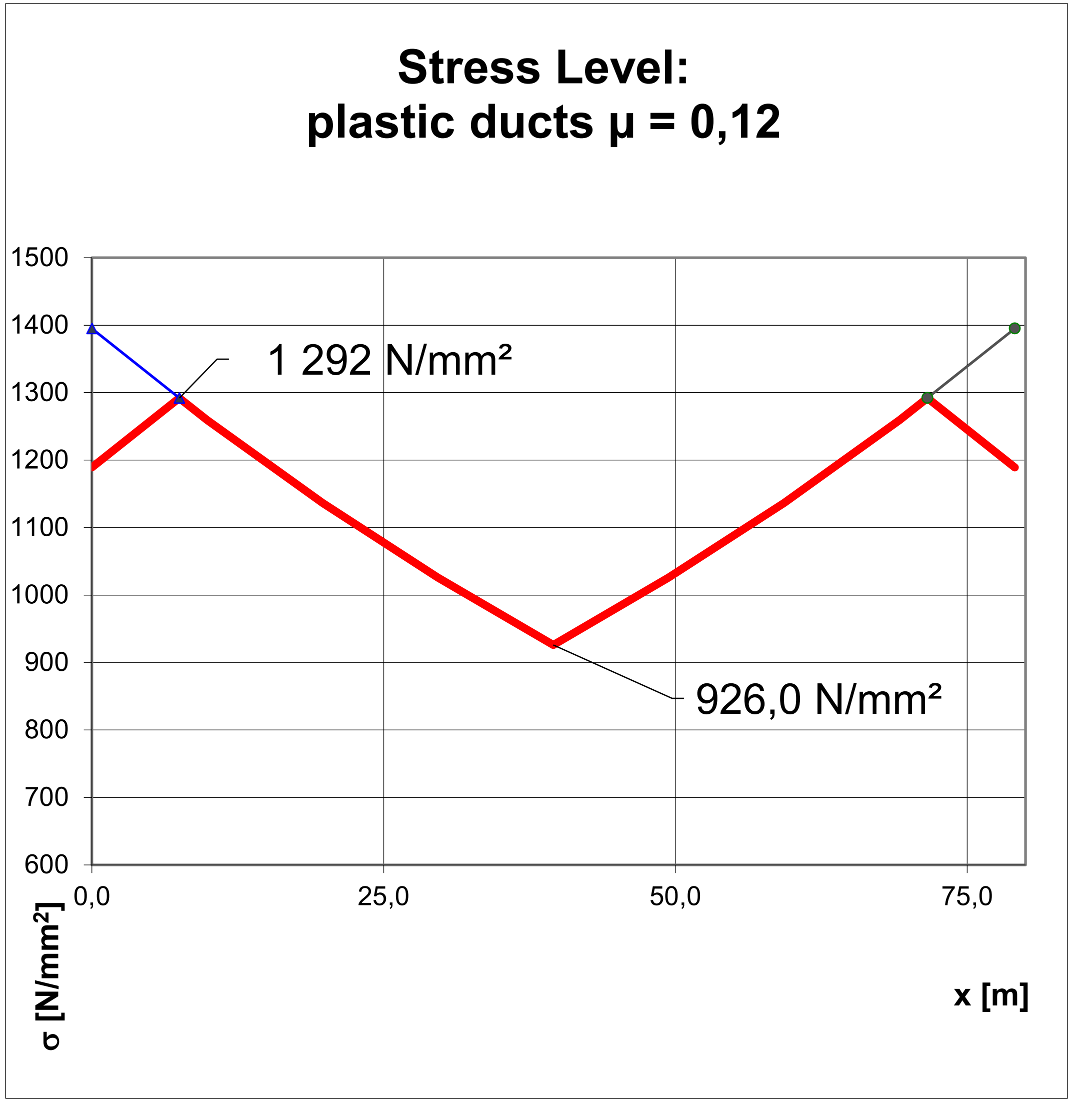
- Horizontal PT: Ring anchorages without buttresses
- Tendons type 12 x 15,7 mm
- Tendons comprise 360°, stressing pockets staggered at 90°



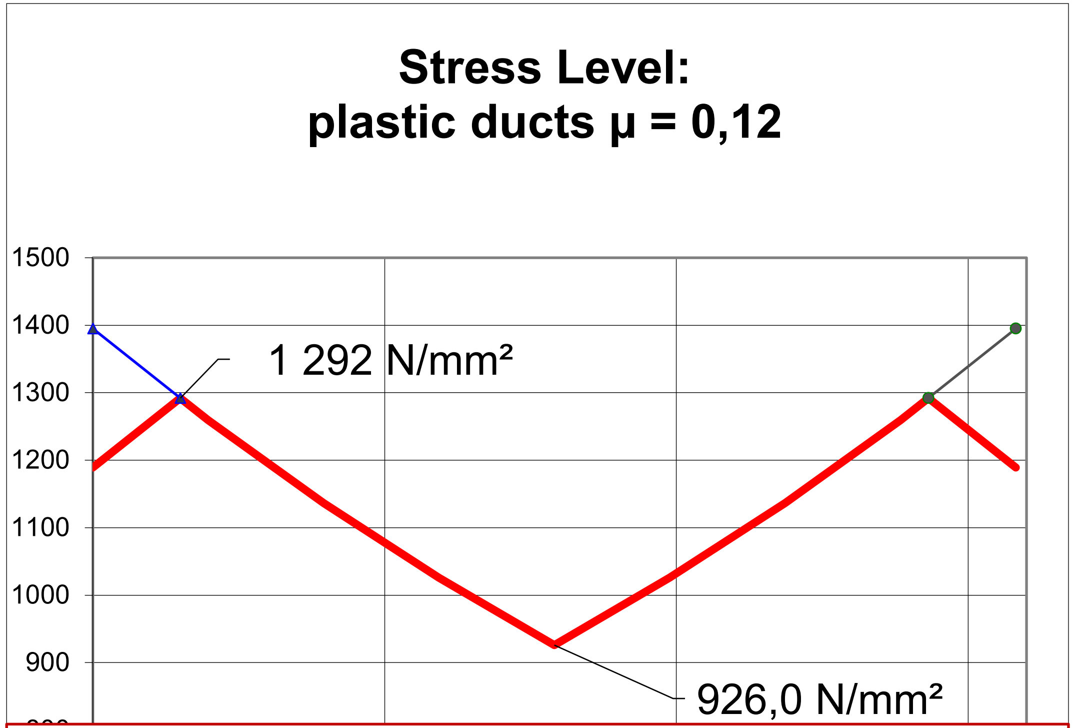
# Advantage: friction losses




Stress Level:
metal ducts μ = 0,20
1500
1400
1300
1200
1100
1000
900
800
700
600
0,0
25,0
50,0
75,0
1 235 N/mm²
724 N/mm²
σ [N/mm²]
x [m]


Stress Level:
plastic ducts μ = 0,12
1500
1400
1300
1200
1100
1000
900
800
700
600
0,0
25,0
50,0
75,0
1 292 N/mm²
926,0 N/mm²
σ [N/mm²]
x [m]

# Advantage: friction losses




**Stress = 926 N/mm²**

**= 28% above metal ducts.**

**➔Significantly Less Prestressing Steel**

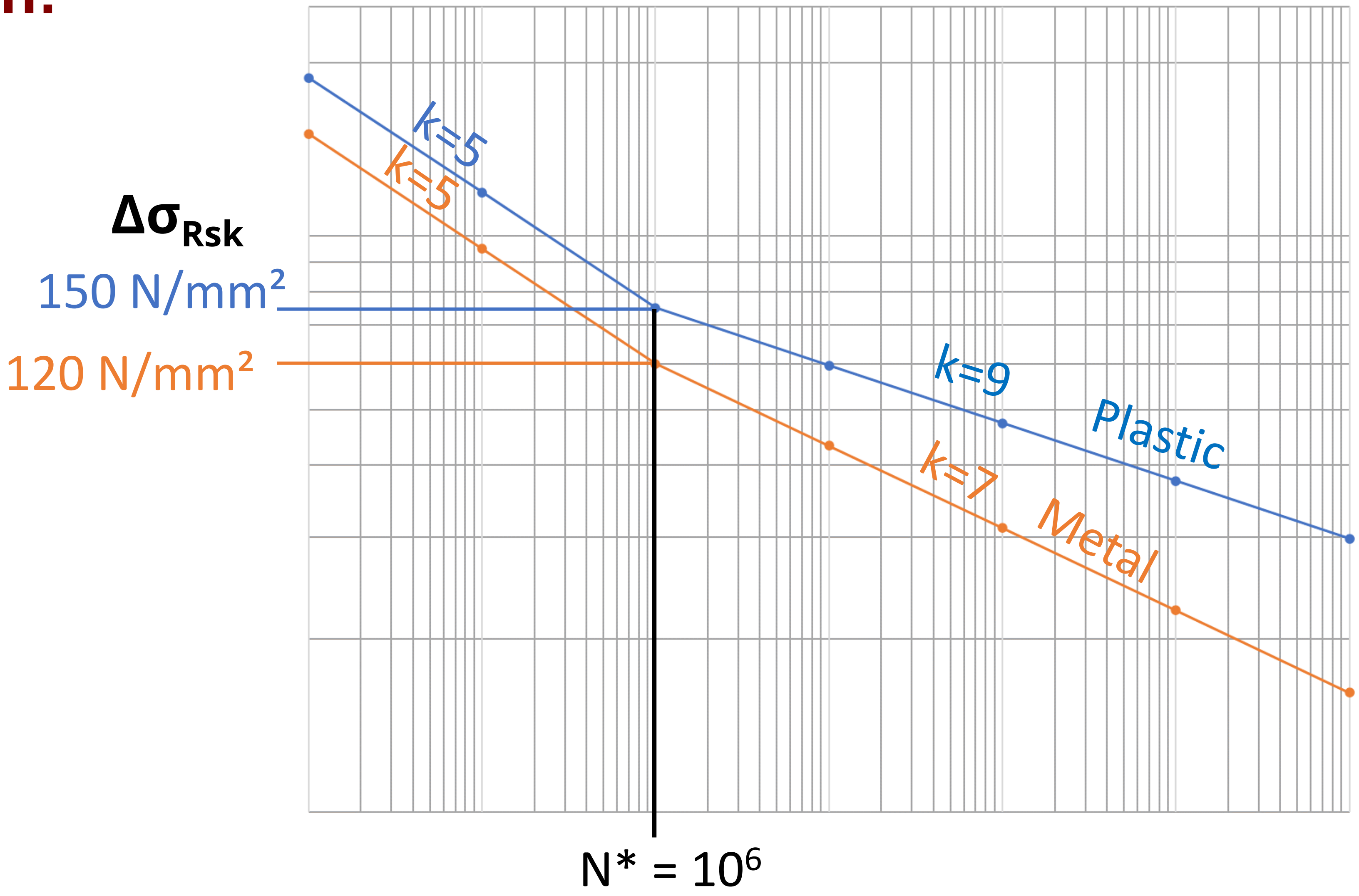
# Fatigue strength:

- Prestressing steel installed in plastic ducts has a **significantly improved fatigue resistance** over prestressing steel installed in metal ducts

- $\Delta\sigma_{Rsk}$ can be set at 150 N/mm² when using plastic ducts versus 120 N/mm² with metal ducts (EC 2, EN 1992:2023)

- Outstanding fatigue strength proven in several research reports e.g. Eskola (1996): fatigue strength of PT beams roughly doubled

# Fatigue strength:




fatigue strength

according to

EN 1992-1-1:2023

# Crack width (EC2:2023):

**Table 9.2 (NDP) — Verifications, stress and crack width limits for durability**

<table>
<tr><th rowspan="3">Exposure Class</th><th colspan="2">Reinforced members and prestressed members without bonded tendons and with bonded tendons with Protection Levels 2 or 3 according to 5.4.1(4)</th><th colspan="3">Prestressed members with bonded tendons with Protection Level 1 according to 5.4.1(4) and pretensioned members.</th></tr>
<tr><th colspan="2">combination of actions</th><th colspan="3">combination of actions</th></tr>
<tr><th>quasi-permanent</th><th>characteristic</th><th>quasi-permanent</th><th>frequent</th><th>characteristic</th></tr>
<tr><td>X0, XC1</td><td>–</td><td rowspan="2">–</td><td>–</td><td>$w_{lim,cal} = 0,2\ mm \cdot k_{surf}$</td><td rowspan="2">–</td></tr>
<tr><td>XC2, XC3, XC4</td><td rowspan="2">$w_{lim,cal} = 0,3\ mm \cdot k_{surf}$</td><td>Decom-pression [b]</td><td>$w_{lim,cal} = 0,2\ mm \cdot k_{surf}$</td></tr>
<tr><td>XD1, XD2, XD3<br>XS1, XS2, XS3</td><td rowspan="2">$\sigma_c \leq 0,6 f_{ck}$ [a,c]</td><td rowspan="2">–</td><td rowspan="2">Decompression[b]</td><td rowspan="2">$\sigma_c \leq 0,6 f_{ck}$ [a,c]</td></tr>
<tr><td>XF1, XF3<br>XF2, XF4</td><td>–</td></tr>
</table>

# Crack width (EC2:2023):

Example: bridge with waterproofing on top surface:

- Top: XC3
- Bottom: XC4, XF2

**<u>Option 1:</u>** PL1 (bonded metal ducts):

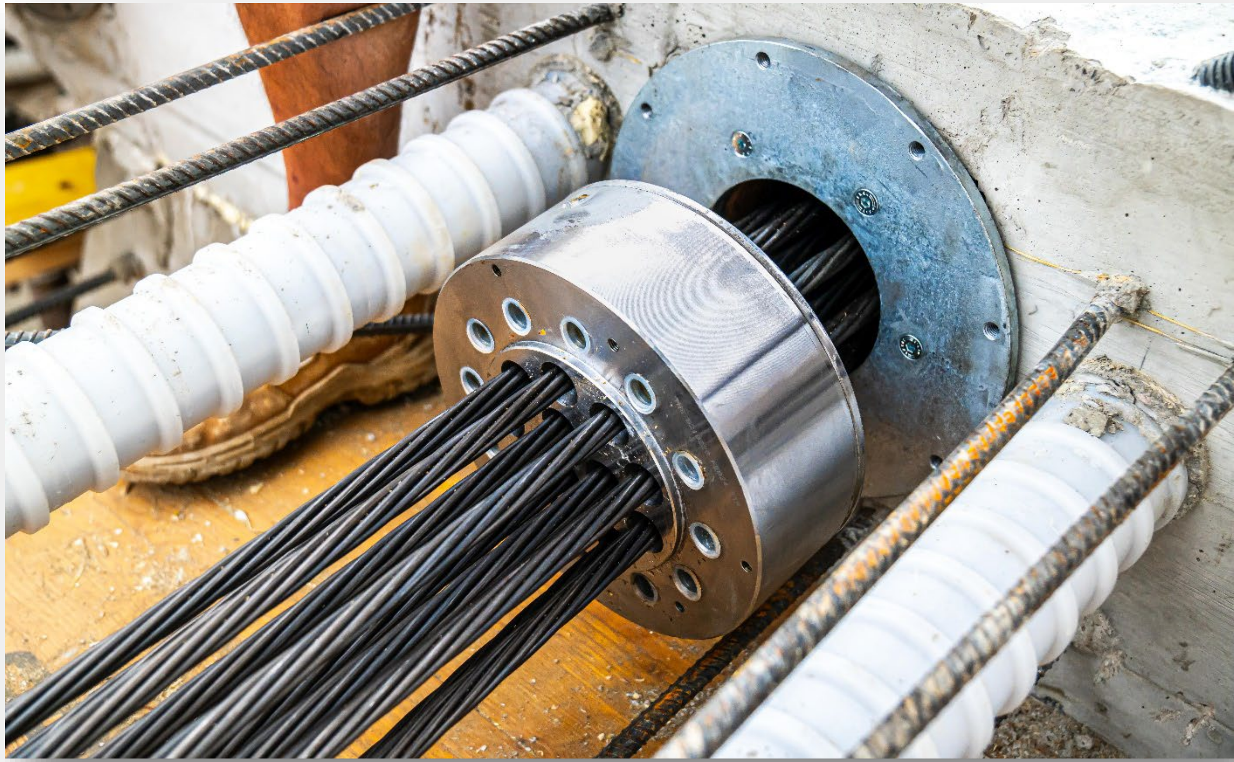
→ Decompression required for long term loads (=no tensile stresses in the cross section)

→ Usually **lots of tendons** are required especially with big dead load

# Crack width (EC2:2023):

Example: bridge with waterproofing on top surface:

- Top: XC3
- Bottom: XC4, XF2



**Option 2:** PL2 or 3 (plastic ducts):

→ Cracking 0,3mm is allowed, decompression not required

→ **Less prestressing steel required**

# Concrete cover [EC2:2023]:

## 6.5.2.2:

…

(4) For prestressing tendons, the cover values in Table 6.3 and Table 6.4 should be increased by $\Delta c_{min.p}$ except where the internal bonded post-tensioning systems are provided with protection level 2 or 3 (= plastic ducts)

$\Delta c_{min.p}$ = additional minimum cover for prestressing tendons

= + 10 mm unless the National Annex gives a different value

## Plastic Ducts and Eurocode 2 [2023]:

- Favours use of PL2 and PL3 systems over PL1

- Less restrictive requirement on the **crack control** with impact on prestressing steel quantities

- **Concrete cover requirement** can be decisive in case of transverse tendons in the bridge decks, which are often located in the same layer with reinforcement to maximize the tendon eccentricity

# Plastic Ducts → Durable and Sustainable PT-Structures:

- Improved durability/sustainability due to improved corrosion protection
- Reduced friction losses (μ = 0,10-0,14)
- Monitoring possible through use of EIT (Electrically Isolated Tendons)
- Improvement of fatigue resistance with polymer ducts has been recognized in several standards [SIA 262 (2003) and **EC2** (2023)]


# Kiitos huomiostanne.

KLanzinger@gti-usa.net

www.gti-usa.net