# Čelični elementi za zemne strukture SuperCor

# Plan prezentacije

- O nama (ViaCon Group and Viacon Romania)
- SuperCor Case studija
- Metod proračuna - Pregled

# ViaCon Group

ViaCon Group je osnovan u Švedskoj i Norveškoj 1986. godine.

Trenutno Grupu čini 30 kompanija iz 18 zemalja: Czech Republic, Denmark, Estonia, Finland, Lithuania, Latvia, Norway, Poland, Sweden, Ukraine, Belarus, Hungary, Slovakia, Romania, Austria, Georgia and Turkey.

## U decembru 2010. ViaCon se pridružio SafeRoad Group

SAFEROAD Group nudi visokokvalitetna rešenja za bezbednost na putu kako vlastima, tako i izvođačima uključenim u infrastrukurne poslove.

Grupa ima podružnice u 21 državi sa ukupnim brojem od 2.500 zaposlenih.


Projektna rešenja
koja se primenjuju svuda u svetu

# Preko 25 godina iskustva

Naš doprinos razvoju struktura od valovitog čelika je bez presedana. Jedini se možemo pohvaliti da smo na poljskom tržištu imali više od 20 Im SITU testova koje smo iskoristili da neprestano unapređujemo kvalitet nosivosti, troškove optimizacije, kvalitet proizvoda, kao i implementaciju novih oblika i prateća tehnička rešenja.

## Antikorozivna zaštita strukturnih panela

– *Dubina galvanizacije*

| Svojstva | Usklađeno sa EN ISO 1461 | |
|---|---|---|
| | Minimalna debljina premaza [µm] | Minimalna prosečna debljina premaza [µm] |
| Elementi i debljine:<br>>6 mm<br>>3 mm do ≤6 mm<br>≥1,5 mm do ≤3mm | <br>70<br>55<br>45 | <br>85<br>70<br>55 |
| Srafovi, vijci i kuke | 40 | 50 |
| Base channels | 55 | 70 |

– Sistemi farbanja za debljinu od 2x120 µm (jednostrano)

# SuperCor Strukture

# SuperCor® Strukture se koriste za projektne strukture:

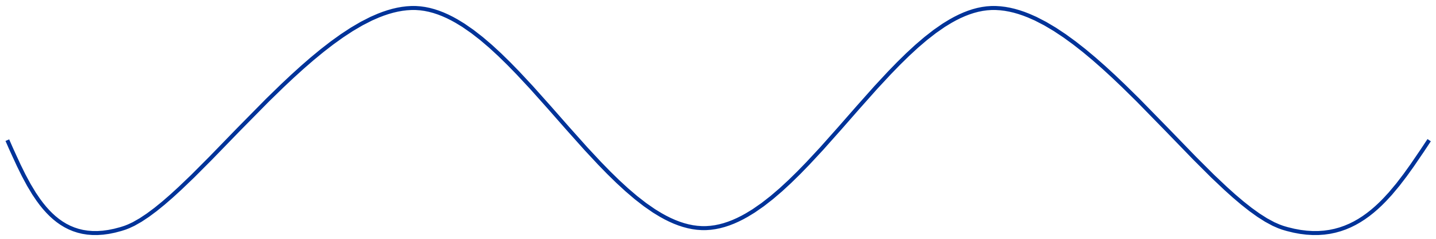
- Mostova
- Vijadukta
- Tunela
- Nadvožnjaka za pešake
- Podzemnih prolaza
- Poljoprivrednih prolaza
- Ekodukta
- Hangara
- Skloništa (civilna i vojna)
- Skladišta

# Profili žljebova

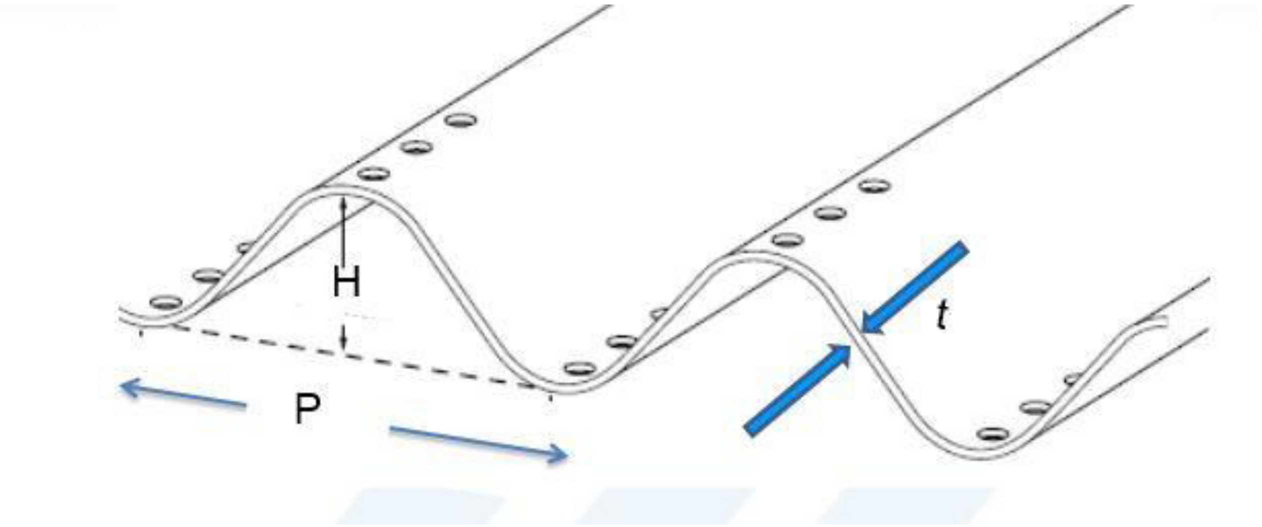
HelCor® – žljeb 68x13mm, 125x26mm

MultiPlate MP200 – žljeb 200x55mm

SuperCor® – žljeb 381x140mm



# SuperCor profili žljebova




Visina žljeba (H) = 140 mm

Širina žljeba (P) = 381 mm

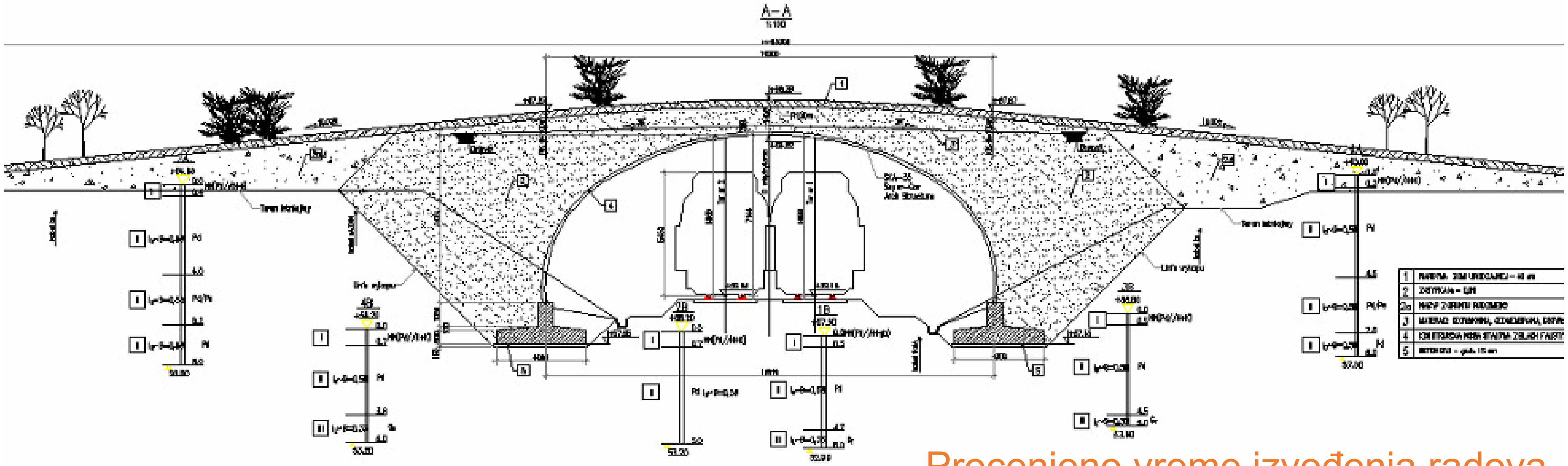
Raspoložive debljine panela (t) = 5.5mm, 6mm, 7mm, 8mm*

Nowa Ruda Bypass – Nekad

ViaCon

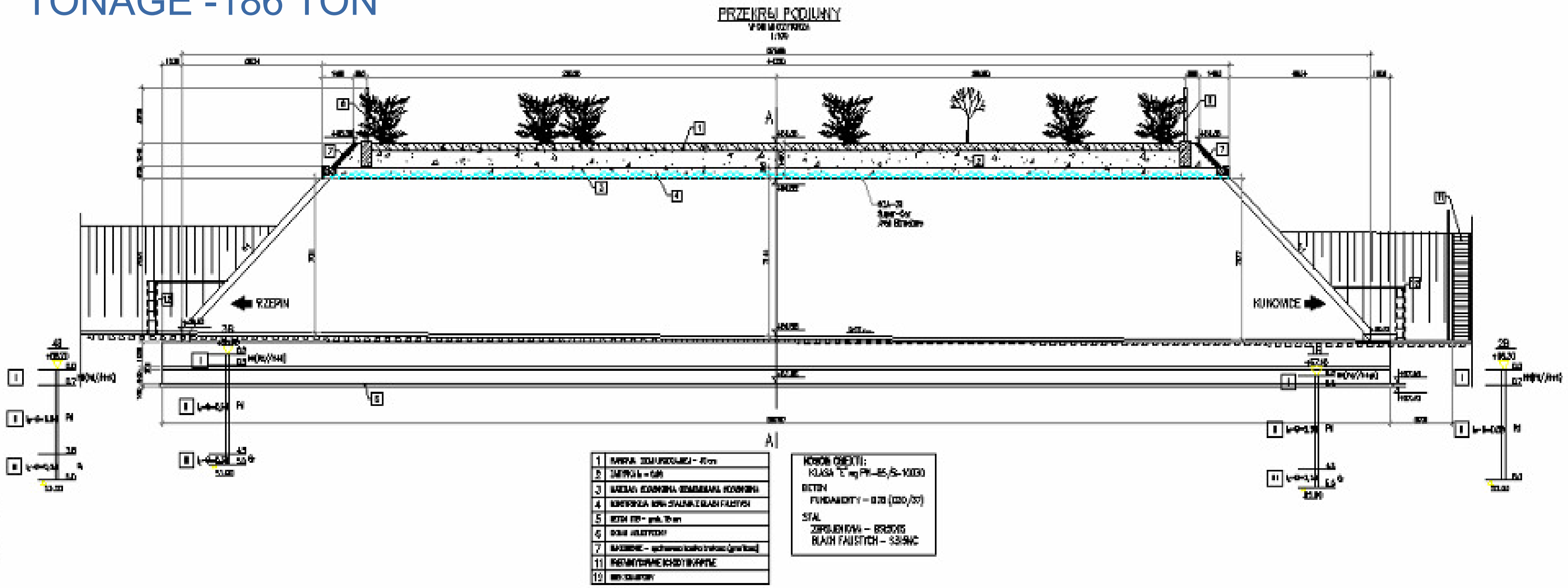
Nowa Ruda Bypass – sad

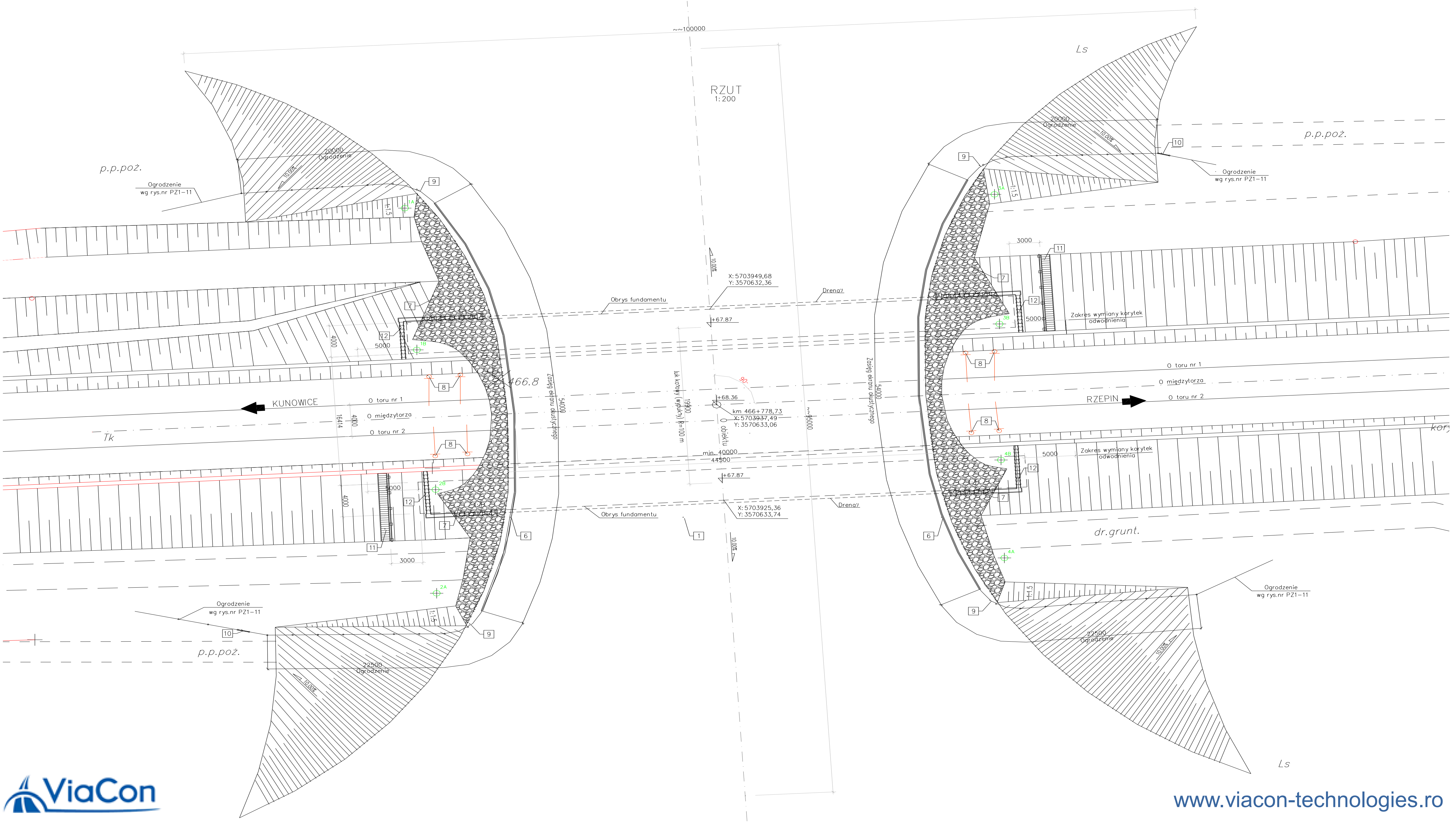
# REALIZACIJA DVA PRELAZA ZA ŽIVOTINJE PREKO E20 ŽELEZNIČKE LINIJE




671 PLATES/STRUCTURE
TONAGE -186 TON

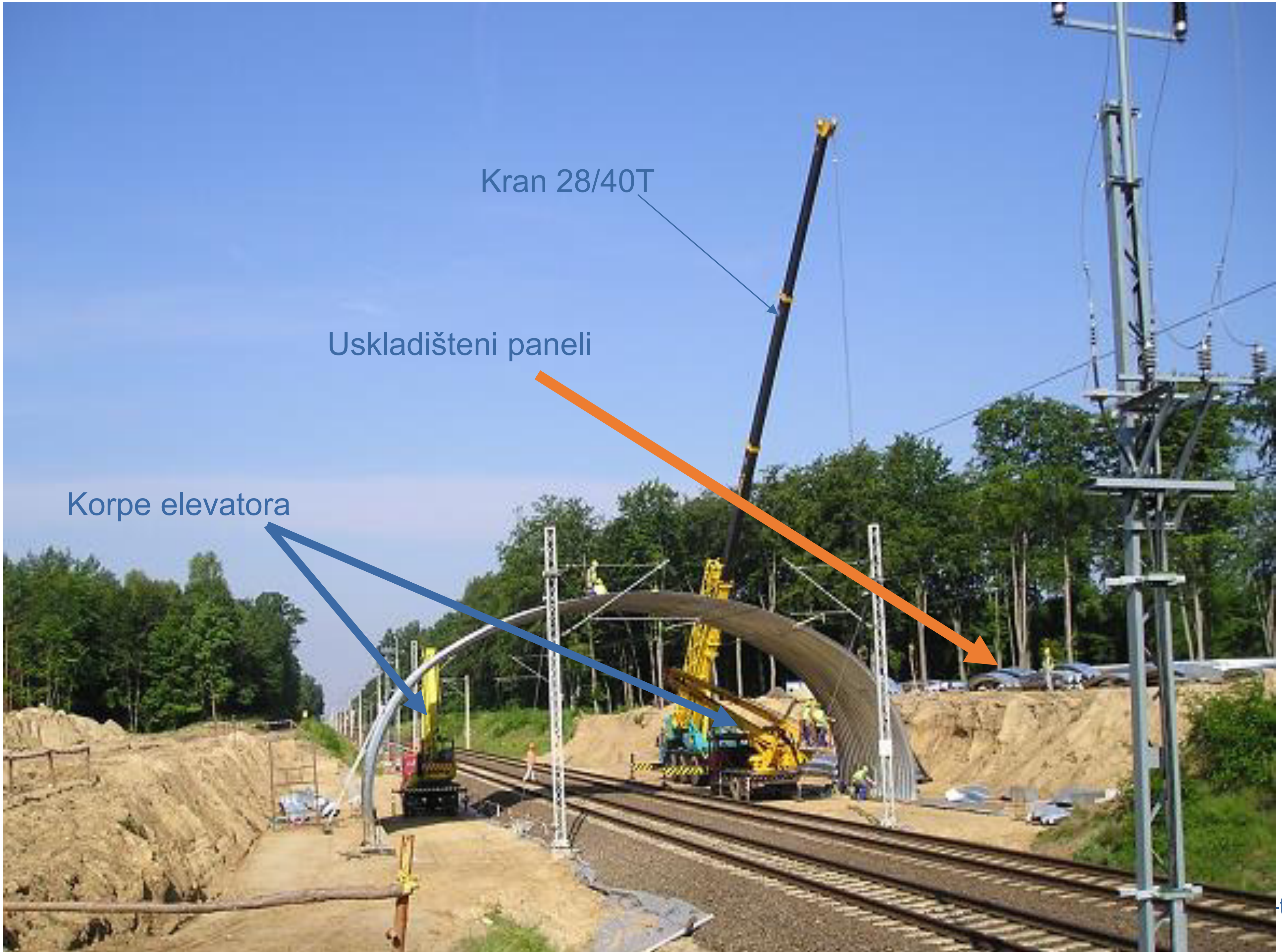
Procenjeno vreme izvođenja radova
22 dana





~~100000
RZUT
1:200
p.p.poż.
Ogrodzenie
wg rys.nr PZ1–11
20000
Ogrodzenie
22500
Ogrodzenie
Ls
KUNOWICE
RZEPIN
0 toru nr 1
0 międzytorza
0 toru nr 2
Tk
dr.grunt.
Obrys fundamentu
Drenaż
Zakres wymiany korytek odwodnienia
X: 5703949,68
Y: 3570632,36
X: 5703925,36
Y: 3570633,74
km 466+778,73
X: 5703937,49
Y: 3570633,06
+67.87
+68.36
466.8
Zasięg ekranu akustycznego
54000
min. 40000
44500
~~95000
16414
4000
5000
3000
1:1,5
10,00%


Popunjen temelj
Nepopunjen temelj


Kran 28/40T
Uskladišteni paneli
Korpe elevatora

Ojačana rebra

Glavna struktura

Baza kanala


Anker zavrtnji
Alat za zavrtanje
Baza kanala
Tačka šrafljenja


PAZOŁA
PAZOŁA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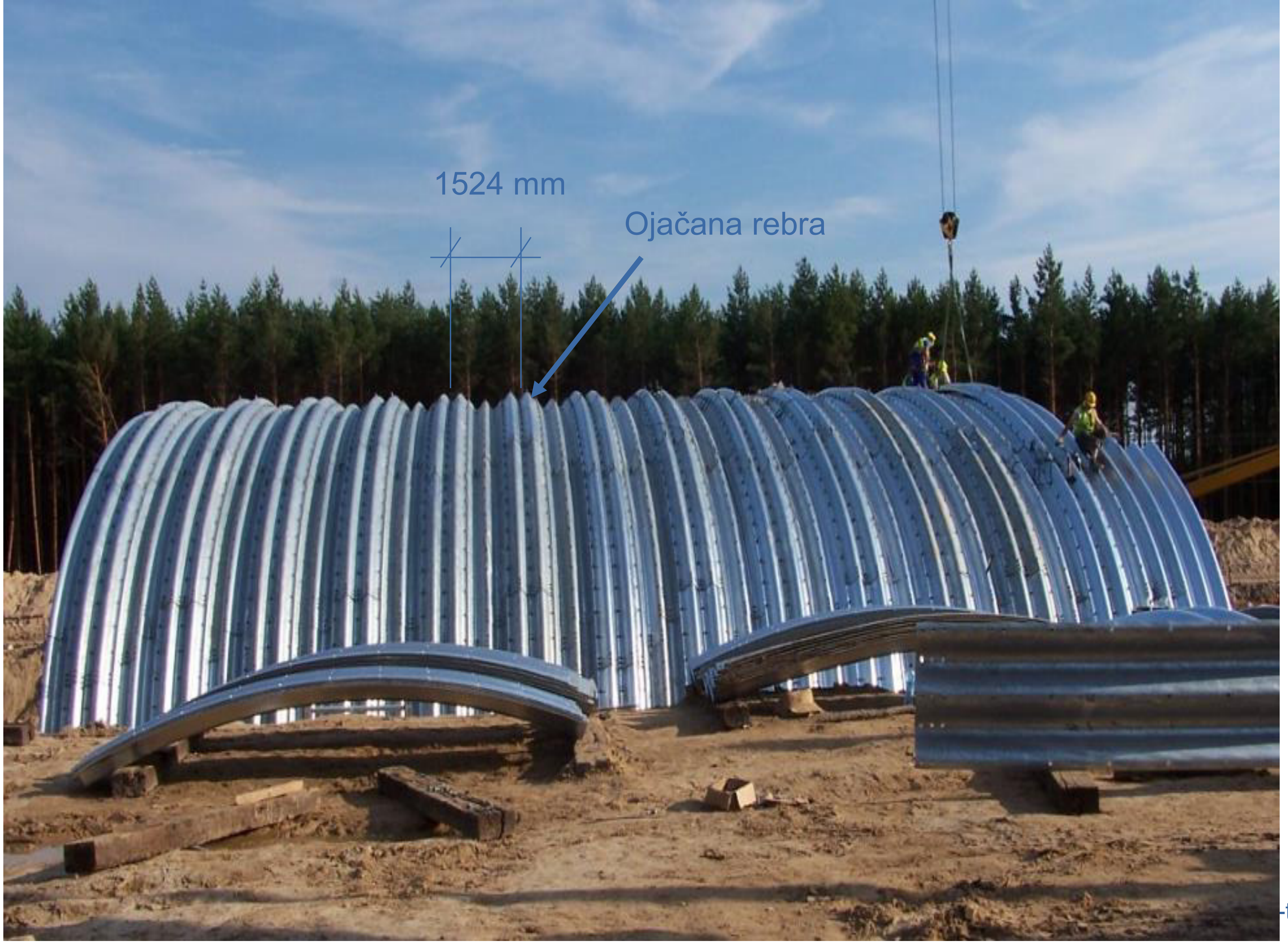
Steel collar/lost formwork
(čelični okovratnik/oplata-??)


Collar/lost formwork
(okovratnik/oplata-??)

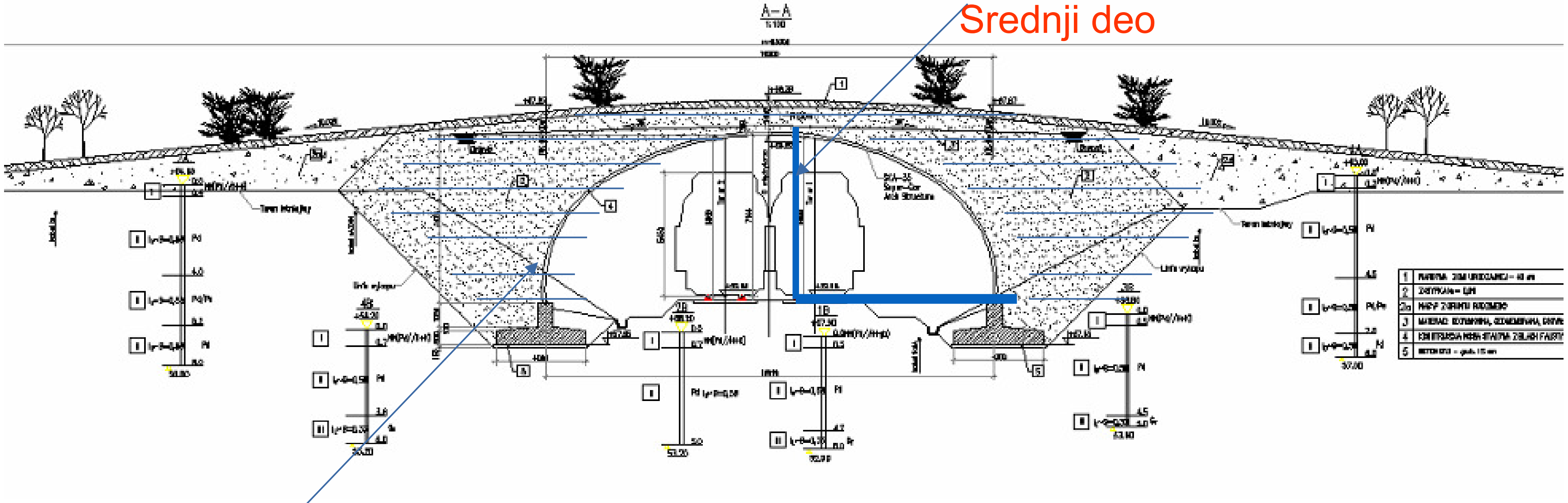

1524 mm
Ojačana rebra

ViaCon

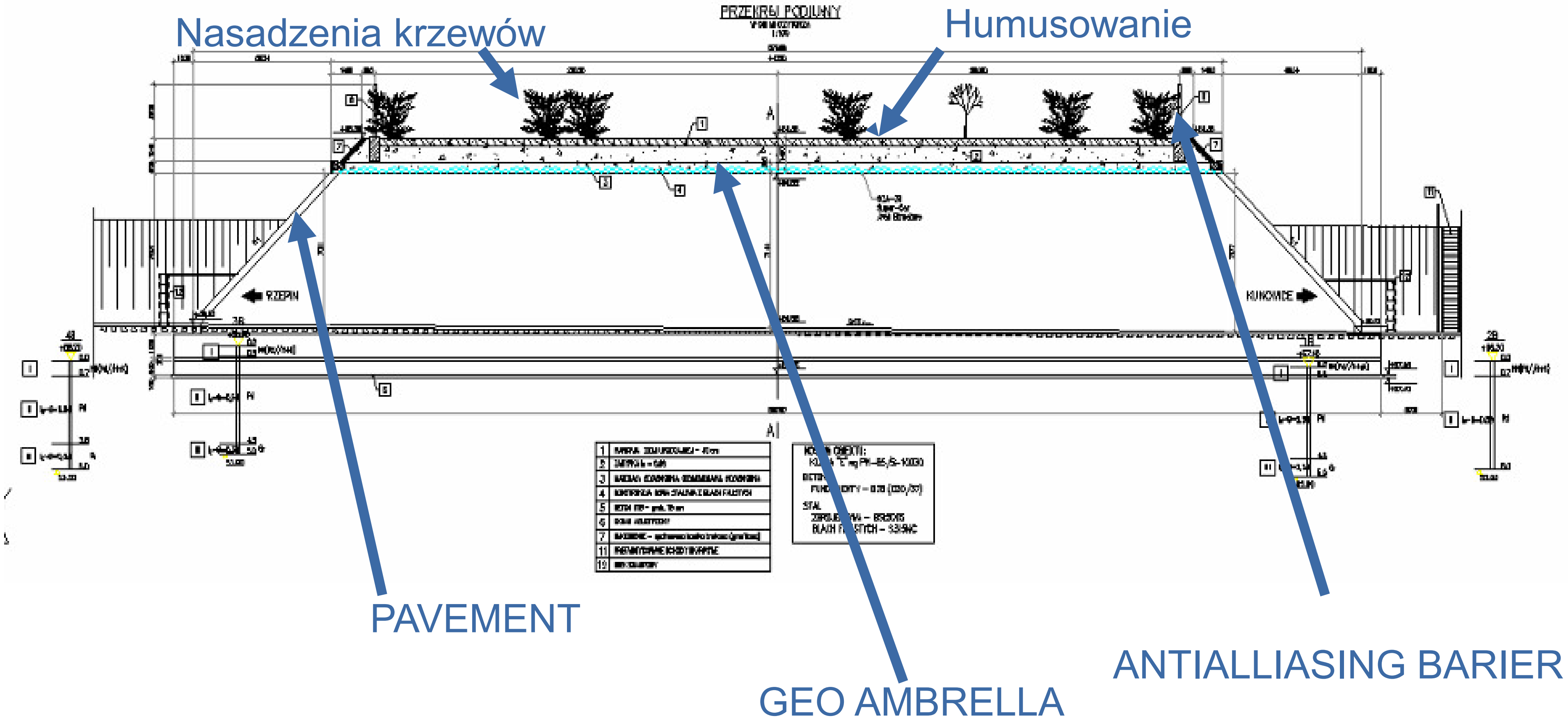
nologies.ro

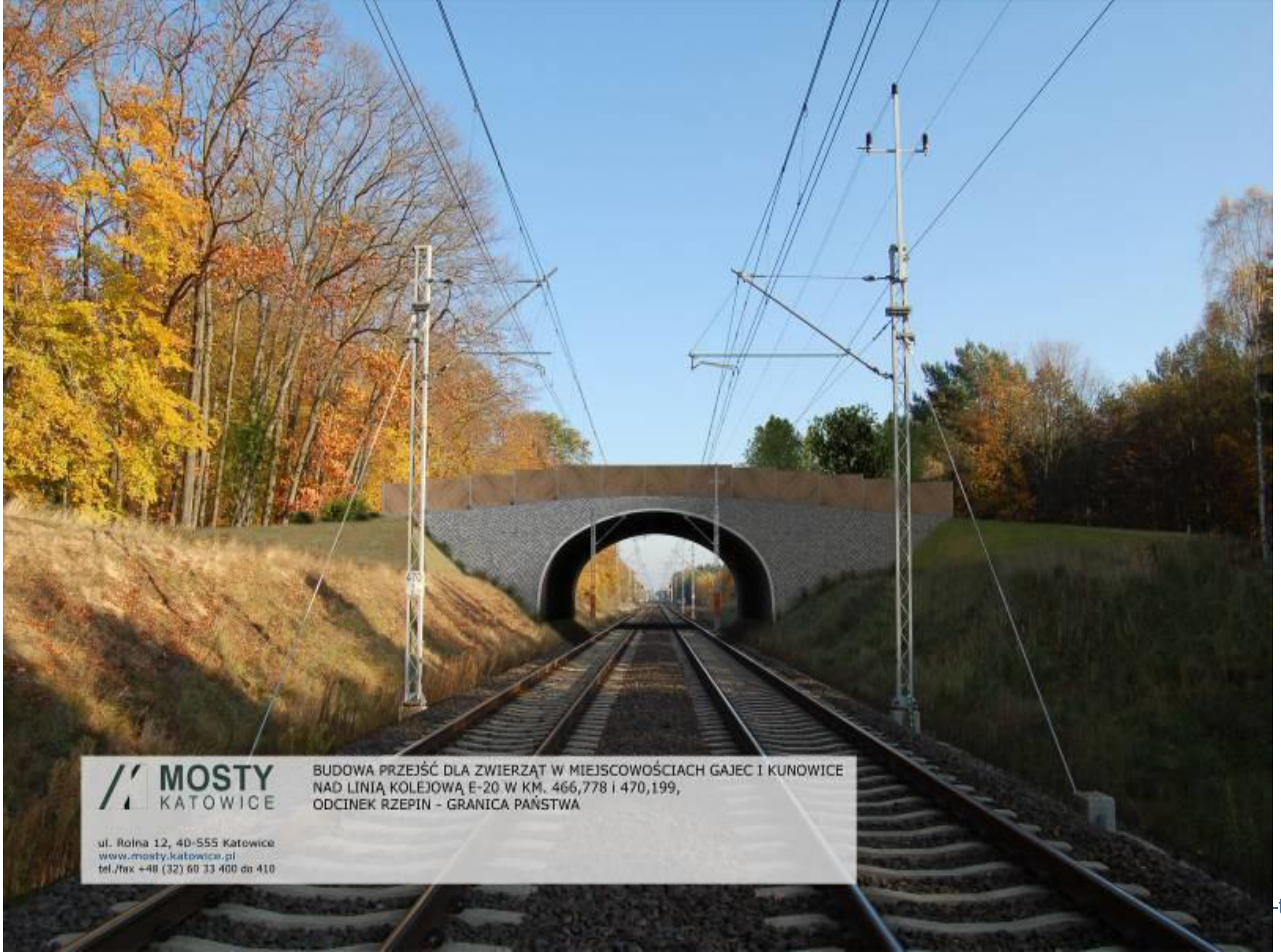
# Zemljani radovi i kontrola oblika

Kontrola skretanja
Vreme punjenja( max 2%S),
Srednji deo



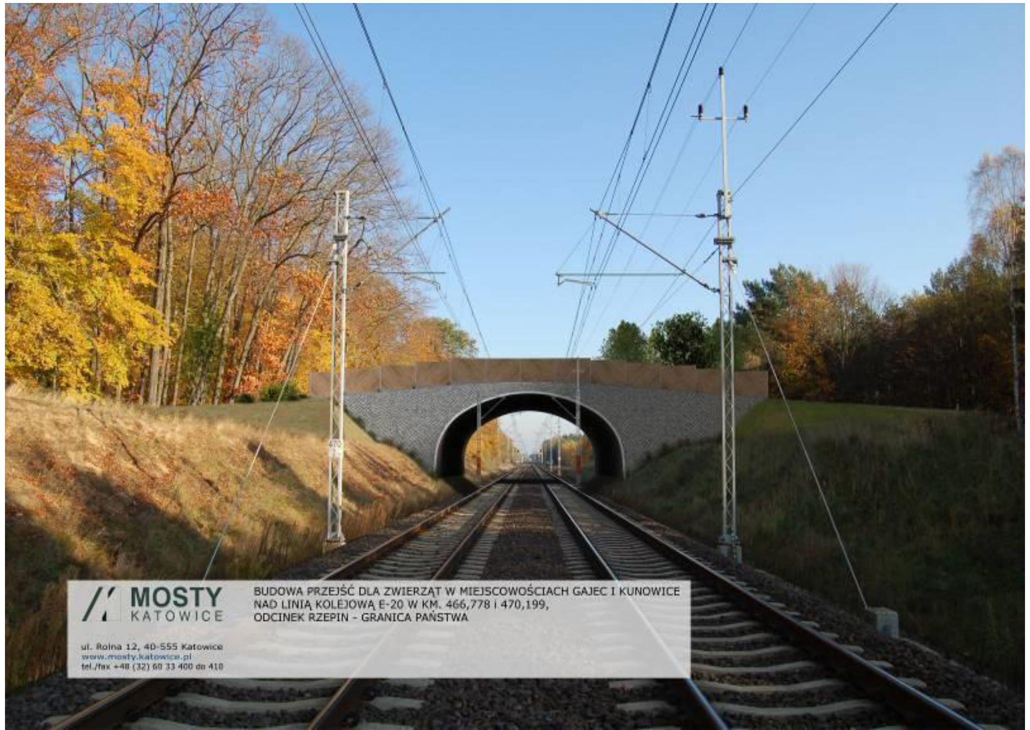

Punjenje slojevima od 0,3 [m]
98 % STANDARDNA PROCTOR GUSTINA
Napomena: SIMETRIČNO ZATRPAVANJE


Nasadzenia krzewów
Humusowanie
PRZEKRÓJ PODŁUŻNY
RZEPIN
KUNOWICE
PAVEMENT
GEO AMBRELLA
ANTIALLIASING BARIER

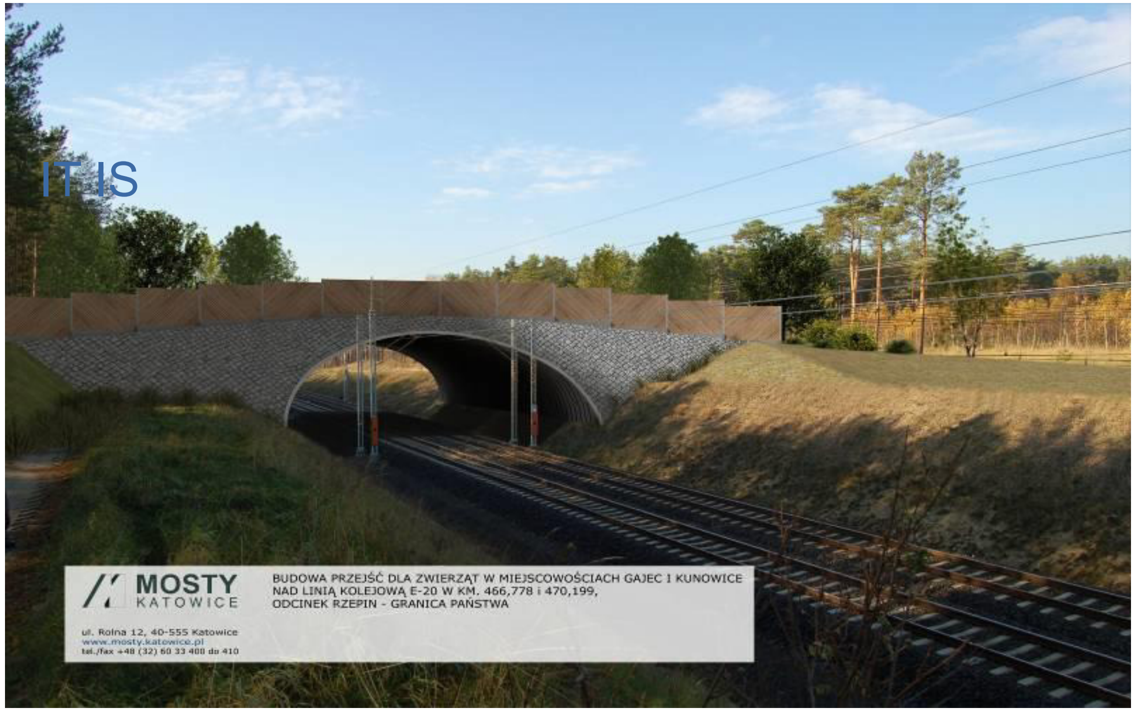

MOSTY
KATOWICE
BUDOWA PRZEJŚĆ DLA ZWIERZĄT W MIEJSCOWOŚCIACH GAJEC I KUNOWICE
NAD LINIĄ KOLEJOWĄ E-20 W KM. 466,778 I 470,199,
ODCINEK RZEPIN - GRANICA PAŃSTWA
ul. Rolna 12, 40-555 Katowice
www.mosty.katowice.pl
tel./fax +48 (32) 60 33 400 do 410

PRE

POSLE 19 DANA




IT IS



# E20 Železnička Linija Berlin Varšava u Rzepinu – PRE

ViaCon

www.viacon-technologies.ro

E20 Železnička Linija Berlin Varšava u Rzepinu - SADA


Most na reci Zgłowiączka u Vroclavu– PRE

SuperCor® - Most na reci Zgłowiączka u Vroclavu– sada

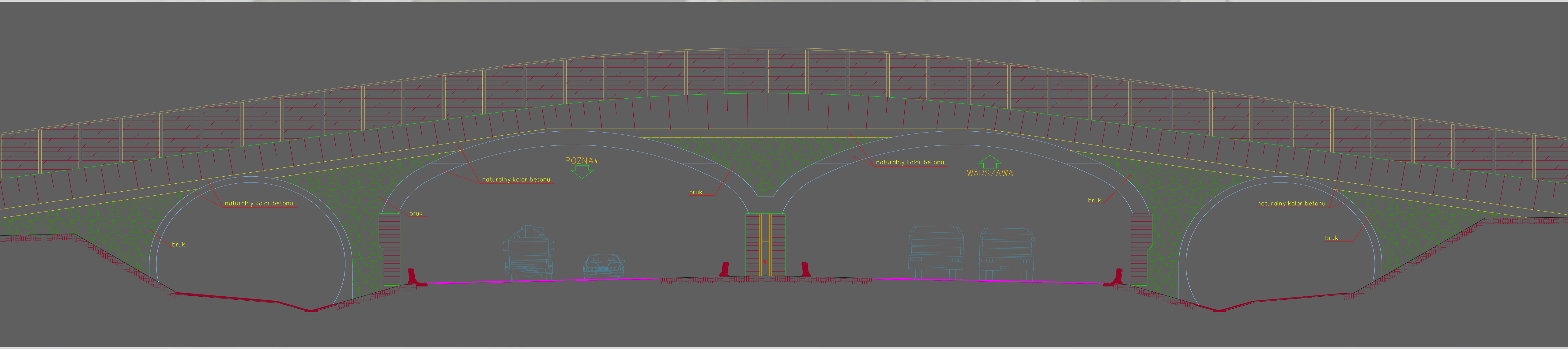
SuperCor® - Most na reci Zgłowiączka u Vroclavu– sada

www.viacon-technologies.ro

A2 Autoput Berlin Varšava Konin –
Kolo sekcija – PRE

www.viacon-technologies.ro

| | SuperCor SC-57S | MultiPlate MP200 G-30 |
|---|---|---|
| Raspon [m] | 17,7 | 9,4 |
| Uspon [m] | 5,5 | 8,1 |
| Debljina ploče [mm] | 7,0 | 7,0 |
| Žljebanje [mmxmm] | 381x140 | 200x55 |
| Dužina [m] | ~60 m | ~76 m |




# A2 Autoput Berlin Varšava Konin – Kolo sekcija – DIZAJN

ViaCon

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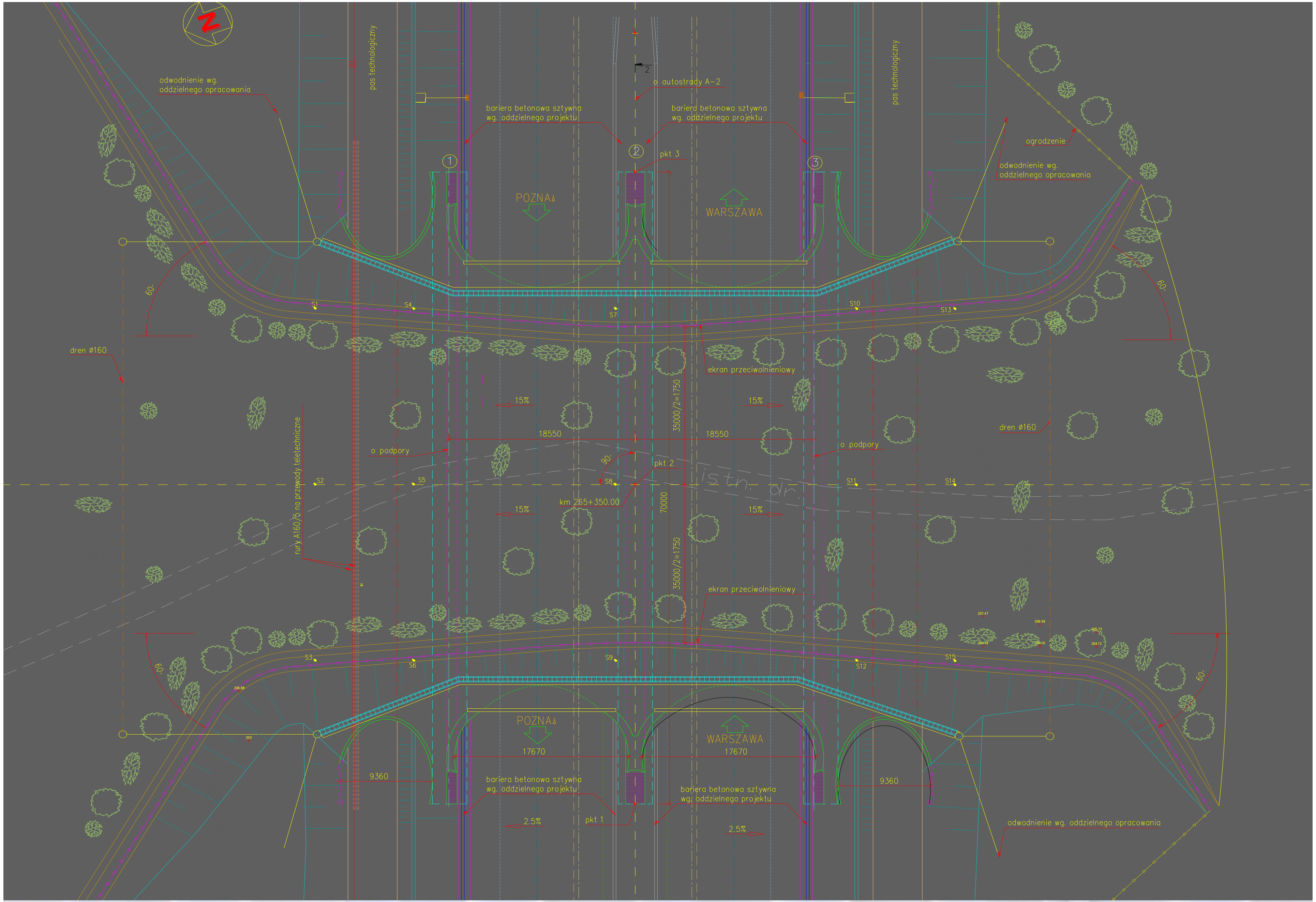


odwodnienie wg. oddzielnego opracowania
pas technologiczny
o autostrady A-2
bariera betonowa sztywna wg. oddzielnego projektu
bariera betonowa sztywna wg. oddzielnego projektu
ogrodzenie
odwodnienie wg. oddzielnego opracowania
pkt 3
POZNAŃ
WARSZAWA
dren ø160
ekran przeciwolnieniowy
15%
15%
18550
18550
35000/2=1750
o podpory
o podpory
dren ø160
pkt 2
km 265+350.00
istn. dr.
70000
15%
15%
rury A160/5 na przewody teletechniczne
35000/2=1750
ekran przeciwolnieniowy
POZNAŃ
WARSZAWA
17670
17670
9360
9360
bariera betonowa sztywna wg. oddzielnego projektu
bariera betonowa sztywna wg. oddzielnego projektu
pkt 1
2.5%
2.5%
odwodnienie wg. oddzielnego opracowania


ViaCon

A2 Autoput Berlin Varšava Konin –
Kolo sekcija – sada

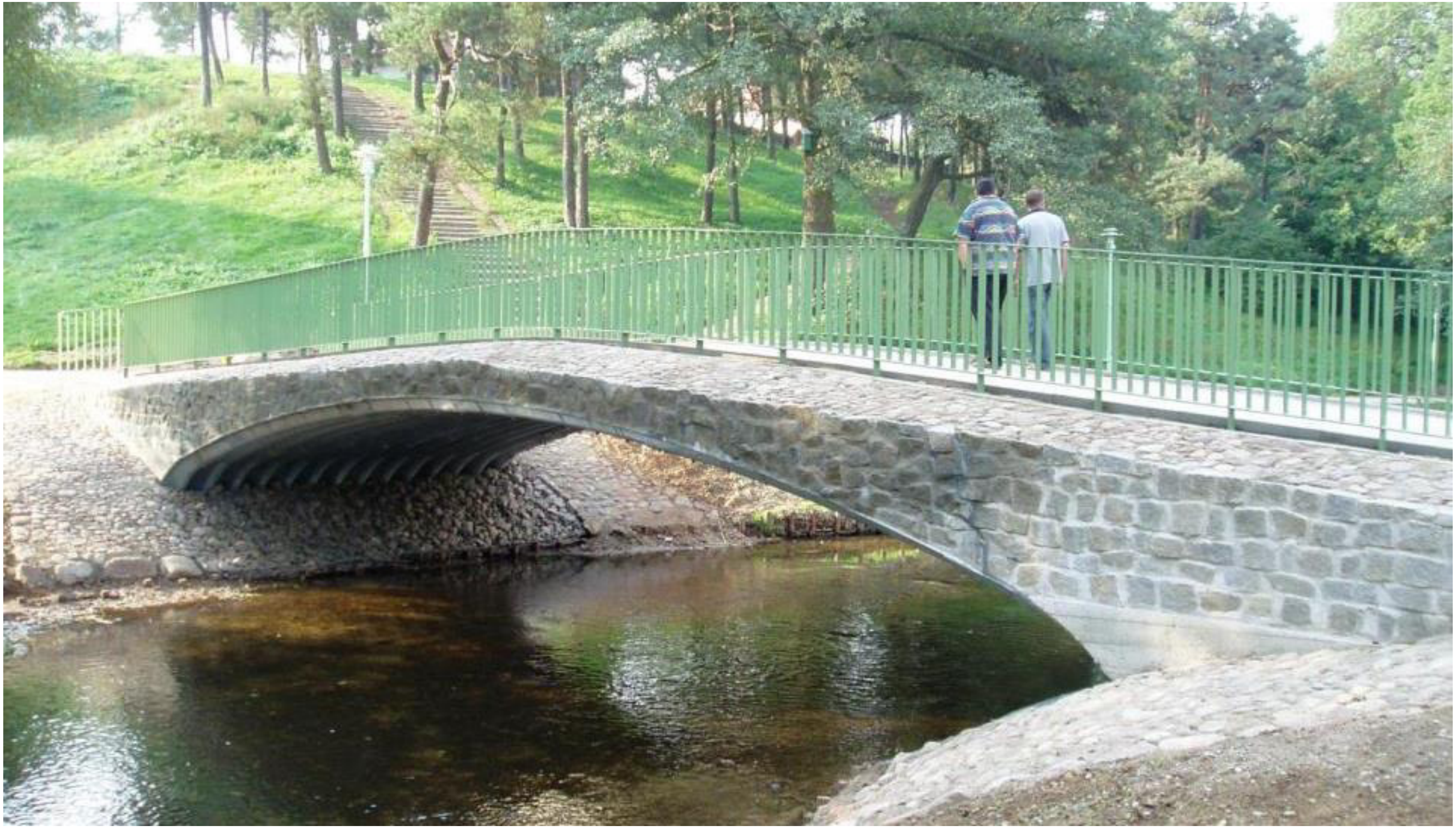
A2 Autoput Berlin Varšava Konin –
Kolo sekcija – sada

ViaCon

ViaCon

S7- Expresss Road (brz put) u Kjelceu (obilaznica)

S7- Expresss Road (brz put) u Kjelceu (obilaznica)



Pešački most u Suvalki

Obilaznica u Sovnou

Vijadukt iznad železničke pruge u Herburtovu

S5 Brz put Poznanj –Vroclav
Ravič-Korzenjsko sekcija

SuperCor® - Modernizacija zemljanog puta
i Sprzymierzeńców ulice u Svidnjici – Faza I

SuperCor® - Lublin S17 Brz put Kurov-Lublin-Piaski
Sekcija

Pešački podvožnjak- Švedska


Lafarge
Canada Inc.
CP
361032

Ožarov obilaznica nacionalni put No 74

Ožarov obilaznica nacionalni put No 74

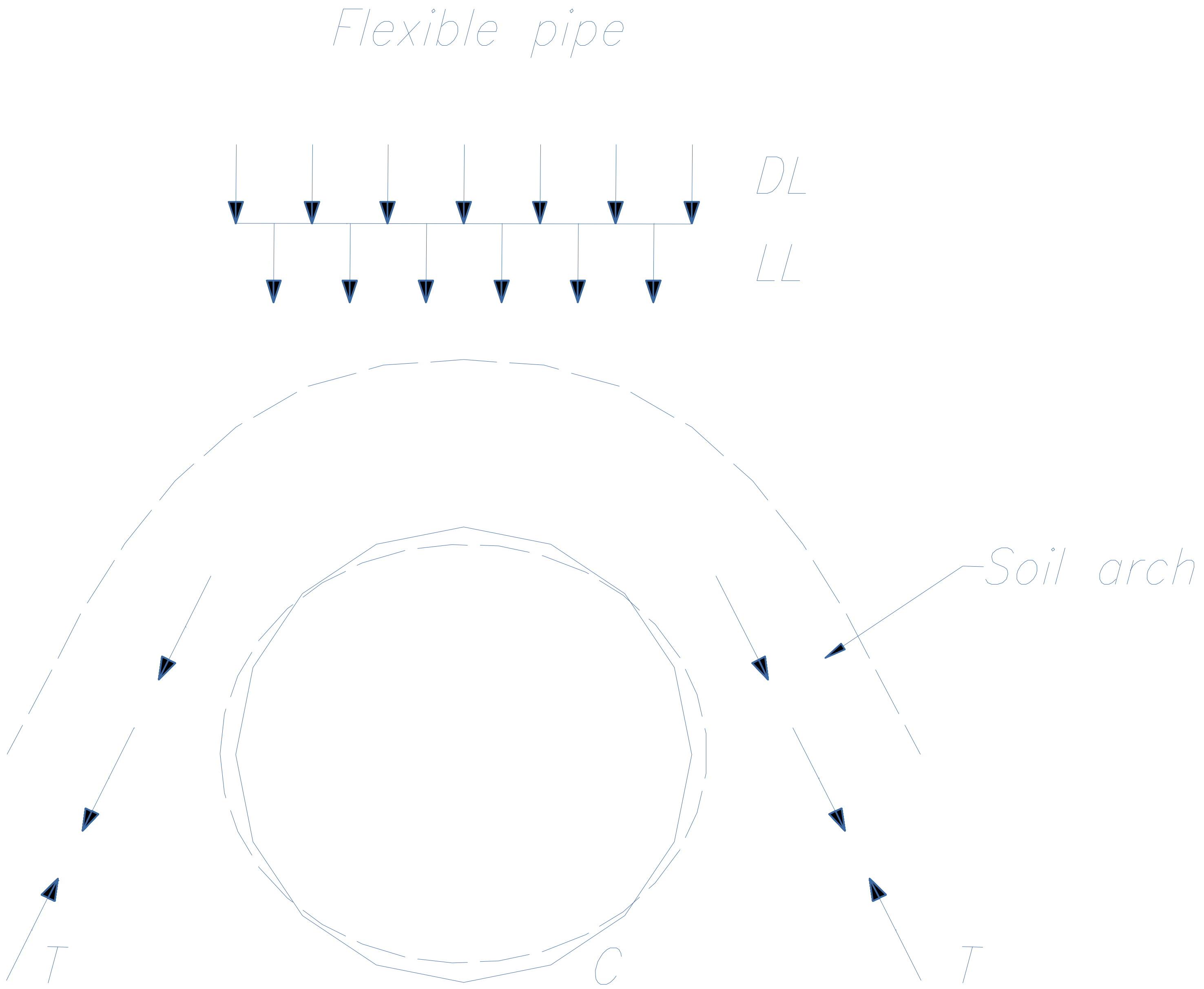
ViaCon

Lublin obilaznica nacionalni put No 74

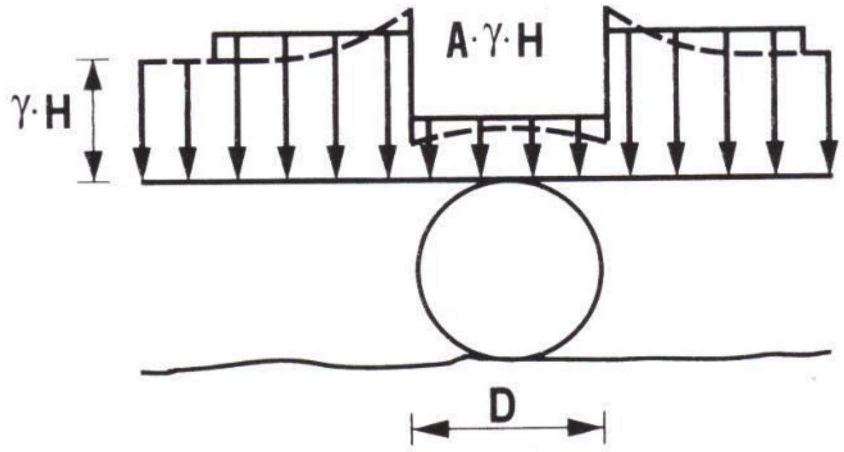
# Metode dizajna

- Iowa formula
- Ring compression theory
- Ontario Code
- AASHTO
- Duncan
- Vaslestad
- CHBDC
- Scottish
- Pettersson and Sundquist (SDM)
- FEM – CandeCad, Plaxis, Abacus, CANDE

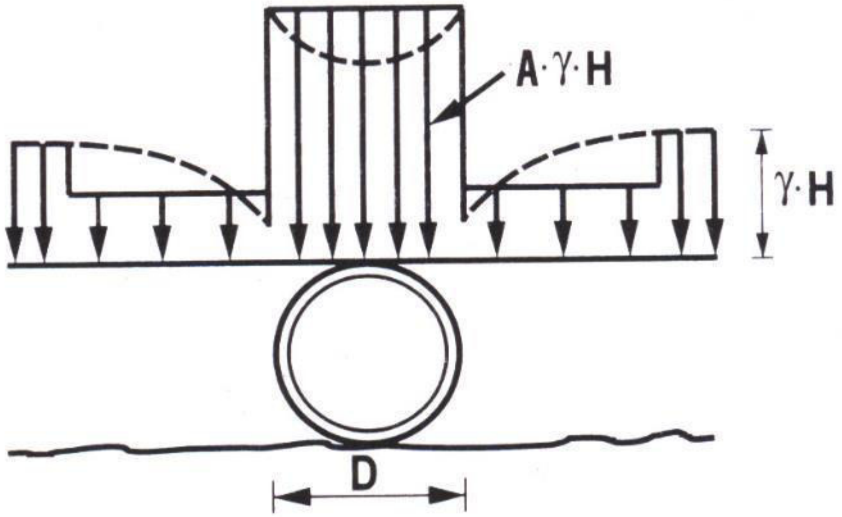
# Arching effect



# Raspodela opterećenja




Fleksibilna cev




Rigidna cev

# Sundquist-Petterson Method

Mogućnost analize celog profila strukture panela od najviše do najniže tačke šrafljenja kao i zamora materijala.

U obzir se uzimaju sile potiska i sile savijanja.

Makismalne sile naprezanja čelika se izračunavaju Navijerovom jednačinom:

$$\sigma = \frac{N_{d,s}}{A_{s1}} + \frac{M_{d,s}}{W_1} < f_{yd}$$

$N_{d,s}$- sile potiska (normalne)

$A_{s1}$ –površina poprečnog preseka

$M_{d,s}$- moment savijanja

$W_1$ –sekcija modula

# Calculation according to "Design of long span flexible metal culverts" by Lars Pettersson and Håkan Sundquist

Update 5

eferenced files

Reference:I:\! A_Projektanci\Projekty\Eksport\2015\203 - Carting track overpas\Projektanci\LM1\REF\References_u5.xmc

eferenced files

Reference:C:\Program Files\MathCad References\Russian LL vehicle .xmcd

ofile A

ofile B

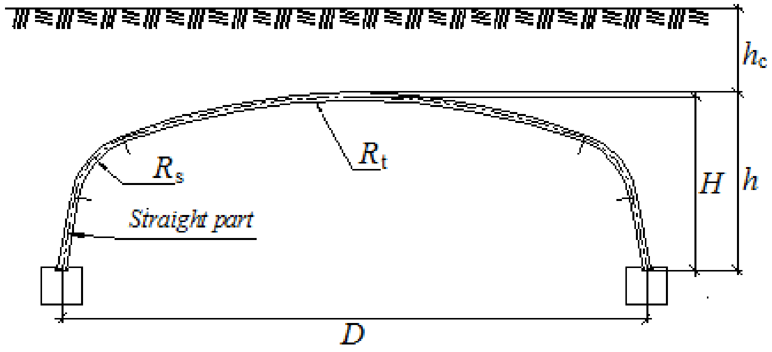
ofile C

ofile D

ofile E

ofile F

ofile G




G. Box culvert.

## Input

### *Partial coefficients*

Safety class: $\gamma_d := 1.0$

Serviceability limit state: $\varphi\gamma_{s.s} := \begin{pmatrix} 1 \\ 1 \end{pmatrix}$ $\varphi\gamma_{t.s} := \begin{pmatrix} 1 \\ 0 \end{pmatrix}$

Ultimate limit state: $\varphi\gamma_{s.u} := \begin{pmatrix} 1.2 \\ 0.9 \end{pmatrix}$ $\varphi\gamma_{t.u} := \begin{pmatrix} 1.5 \\ 0 \end{pmatrix}$

Partial factors: $\gamma_{M0} := 1.00$

$\gamma_{M1.steel} := 1.00$

$\gamma_{M2} := 1.25$

$\gamma_{Ff} := 1.00$

$\gamma_{Mf} := 1.35$

Adjustment factor for LM1: $\alpha_Q := 1.0$ $\alpha_q := 1.0$

### *Define the geometry*

**Culvert profile:** profile := "G"

Possible values are "A", "B",..., "G" corresponding to the figures on the previous page.

The following parameters are defined in the figures on the previous page. For profiles A and B, all radiis should be set equal to R. For profiles C and D, $R_c$ should be set equal to $R_s$. For profile E, $R_s$ should be set equal to $R_t$. For profile F, $R_b$ should be set equal to $R_c$. For profile G, $R_b$ and $R_c$ should be set equal to $R_t$

$H := 2.815m$ $h_c := 0.8m$ $D := 12.38m$ $R_t := 11.5m$ $R_s := 1.086m$ $R_b := R_t$ $R_c := R_t$

Depth of cover at the position of the bolted connections: $h_f := h_c$

Multiple structure : ○ YES ◉ NO

Space between two structures: $a_s := 0m$

Steel profile

$t := 7mm$ Thickness of the plate.

$h_{corr} := 140mm$ Height of the corrugation.

$c_{val} := 381mm$ Wavelength.

$R := 76.2mm$ Radii of curvature.

$E := 206GPa$ $f_{yk} := 315MPa$ $f_{uk} := 390MPa$ Young's modulus, yield stress and ultimate stress.

Bolts

$d_{bolt} := 20mm$ Diameter of the bolt.

$A_{s.b} := 245mm^2$ Cross sectional area.

$f_{u.bolt.k} := 800MPa$ Ultimate stress.

If there are only two bolt rows, a zero should be put at the first position of the following two vectors.

Number of bolts per meter in each row: $n := (5.25\ \ 5.25\ \ 5.25)^T$

Distance from the edge of the sheet to the centre of each row of bolts: $a := (38\ \ 114\ \ 190)^T mm$

Length of the pressure zone when calculating the tension in the bolts due to moment: $p_{zone} := 10mm$

Distance from the centre of a hole to a free edge or to the centre of an adjacent hole measured in the direction of force. It should never exceed 3*d.

| | MP150 | MP200 | | | SuperCor |
|---|---|---|---|---|---|
| | | 10 bolts/m | 15 bolts/m | 20 bolts/m | |
| e1 | 3d | 3d | 50mm | 50mm | 3d |

$e_1 := 3d_{bolt}$

Parameters to calculate fatigue

$\Delta\tau_{C.bolts} := 100MPa$ Detail 15 from table 8.1 EN 1993-1-9

$\Delta\sigma_{C.bolts} := 50MPa$ Detail 14 from table 8.1 EN 1993-1-9

$\Delta\sigma_{C.plate} := 125MPa$ Detail 5 from table 8.1 EN 1993-1-9

$\Delta\sigma_{C.plate.connection} := 90MPa$ Detail 11 from table 8.1 EN 1993-1-9

Long distance traffic
Medium distance tra

Type of traffic acc. to table 4.7 EN 1991-2

$N_{obs.} := 2 \cdot 10^6 \cdot \frac{1}{yr}$ Number of tacks acc. to table 4.5 EN 1991-2

$LifeTime := 10yr$

## *Design*

SLS

Ensuring safety aganst the onset of yielding in the serviceability limit state

$f_{yk} = 315 \cdot MPa$

$f_{yd} := \frac{f_{yk}}{\gamma_{M0}}$ $f_{yd} = 315 \cdot MPa$

$\sigma := \frac{N_{d.s}}{A_s} + \frac{M_{sd.s}}{W_s}$

$$\sigma = \begin{pmatrix} 213.6 \\ 74.6 \\ 213.6 \\ 74.6 \\ 213.6 \\ 74.6 \\ 213.6 \\ 74.6 \end{pmatrix} \cdot MPa \qquad check\left(\overrightarrow{|\sigma|}, \frac{f_{yk}}{\gamma_{M0}}\right) = \begin{pmatrix} "OK!" \\ "OK!" \\ "OK!" \\ "OK!" \\ "OK!" \\ "OK!" \\ "OK!" \\ "OK!" \end{pmatrix}$$

$N_{s.surr} = 24.7 \cdot \frac{kN}{m}$ $M_{s.surr} = -4.5 \cdot \frac{kNm}{m}$

$$\max(\varphi\gamma_{s.s}) \cdot \left(\frac{N_{s.surr}}{A_s} + \frac{M_{s.surr}}{W_s}\right) = -12.7 \cdot MPa$$

$$check\left[\left(\max(\varphi\gamma_{s.s}) \cdot \left|\frac{N_{s.surr}}{A_s} + \frac{M_{s.surr}}{W_s}\right|\right), \frac{f_{yk}}{\gamma_{M0}}\right] = "OK!"$$

## Calculation of bending moment capacity

Bending moment capacity: $M_{y.Rk} := f_{yk} \cdot Z_s = 125 \cdot \frac{kN \cdot m}{m}$

## Calculation of normal force capacity

Normal force capacity: $N_{Rk} := f_{yk} \cdot A_s = 2916.5 \cdot \frac{kN}{m}$

## Calculation of capacity

$$\eta := \frac{Z_s}{W_s}$$

$$N_{cr.1} := secO\left(h_{c.red}, R_t, \frac{E_{s.k}}{\gamma_{m.soil}}, E \cdot I_s, \frac{f_{yk}}{\gamma_{M1.steel}}, A_s, 0\right)$$

$$N_{cr.1} = 439.83 \cdot \frac{kN}{m}$$

$$\alpha_{c.1} := \max\left(0.8, \eta^2 \cdot \frac{N_{cr.1}}{A_s \cdot \frac{f_{yk}}{\gamma_{M1.steel}}}\right)$$

$$\left(\frac{N_{d.u}}{N_{cr.1}}\right)^{\alpha_{c.1}} = \begin{pmatrix} 0.9 \\ 0.56 \\ 0.88 \\ 0.55 \\ 0.81 \\ 0.47 \\ 0.79 \\ 0.45 \end{pmatrix} \qquad check\left[\left(\frac{N_{d.u}}{N_{cr.1}}\right)^{\alpha_{c.1}}, 1\right] = \begin{pmatrix} \text{"OK!"} \\ \text{"OK!"} \\ \text{"OK!"} \\ \text{"OK!"} \\ \text{"OK!"} \\ \text{"OK!"} \\ \text{"OK!"} \\ \text{"OK!"} \end{pmatrix}$$

Ensuring safety against exceeding the capacity of the bolted connections

*Ultimate limit*

**Shear capacity:**

$$F_{b.Rd} := \frac{2.5 \cdot f_{uk} \cdot d_{bolt} \cdot t}{\gamma_{M2}} = 109.2 \cdot kN$$

$$F_{v.Rd} := \frac{0.6 \cdot f_{u.bolt.k} \cdot A_{s.b}}{\gamma_{M2}} = 94.1 \cdot kN$$

**Tension capacity:**

$$F_{t.Rd} := \frac{0.9 \cdot f_{u.bolt.k} \cdot A_{s.b}}{\gamma_{M2}} = 141.1 \cdot kN$$

*Capacity check*

**Shear :**

$$\frac{F_{v.ULS}}{\min(F_{v.Rd}, F_{b.Rd})} \le 1.00$$

$$\frac{F_{v.ULS}}{\min(F_{v.Rd}, F_{b.Rd})} = 0.26 \qquad check\left[\left(\frac{F_{v.ULS}}{\min(F_{v.Rd}, F_{b.Rd})}\right), 1\right] = \text{"OK!"}$$

**Tension :**

$$\frac{F_{t.ULS}}{F_{t.Rd}} \le 1.00$$

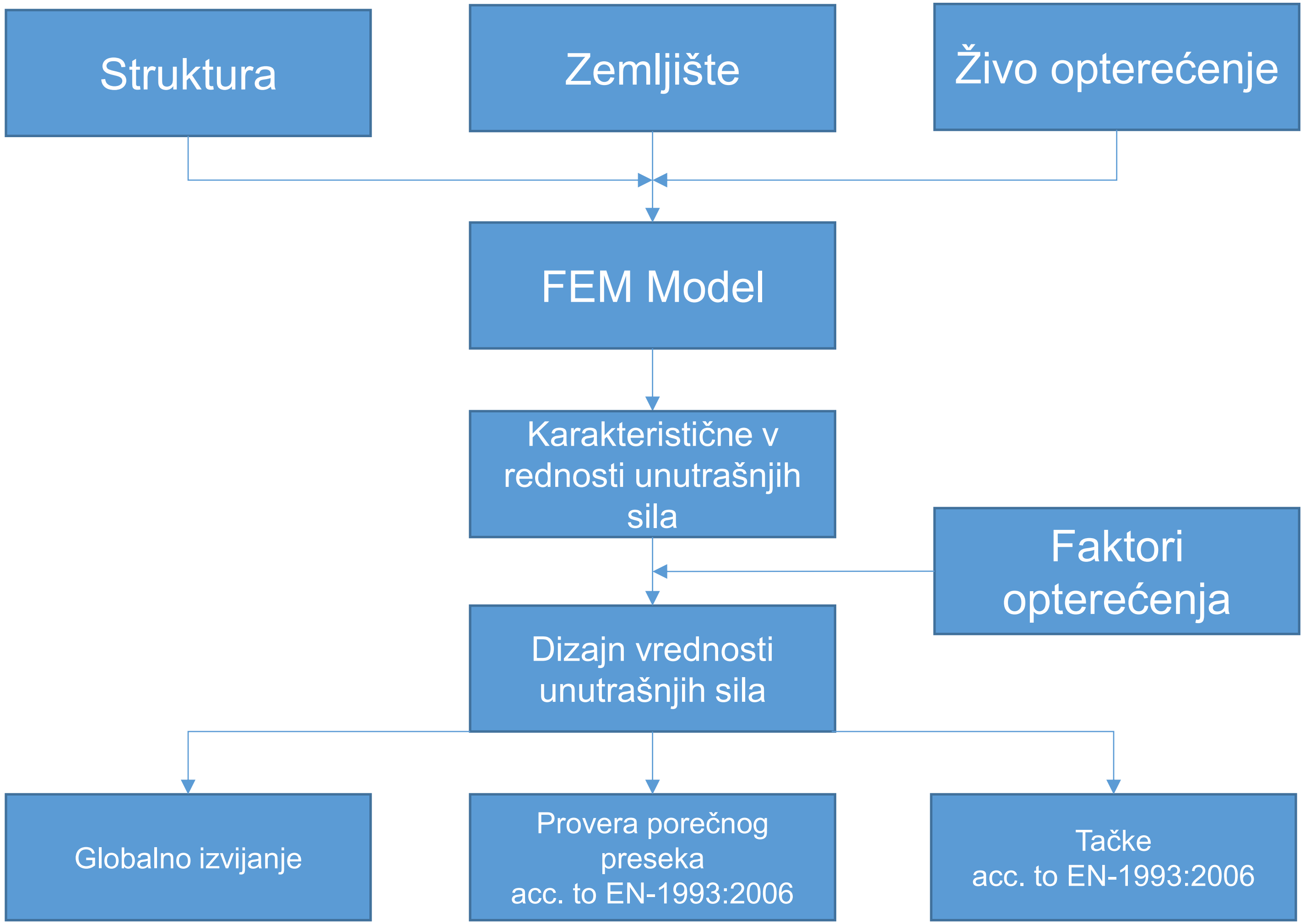
$$\frac{F_{t.ULS}}{F_{t.Rd}} = 0.52 \qquad check\left[\left(\frac{F_{t.ULS}}{F_{t.Rd}}\right), 1\right] = \text{"OK!"}$$

**Interaction formula :**

$$\frac{F_{v.ULS}}{\min(F_{v.Rd}, F_{b.Rd})} + \frac{F_{t.ULS}}{1.4 F_{t.Rd}} \le 1.00$$

$$\frac{F_{v.ULS}}{\min(F_{v.Rd}, F_{b.Rd})} + \frac{F_{t.ULS}}{1.4 F_{t.Rd}} = 0.63 \qquad check\left[\left(\frac{F_{v.ULS}}{\min(F_{v.Rd}, F_{b.Rd})} + \frac{F_{t.ULS}}{1.4 F_{t.Rd}}\right), 1\right] = \text{"OK!"}$$

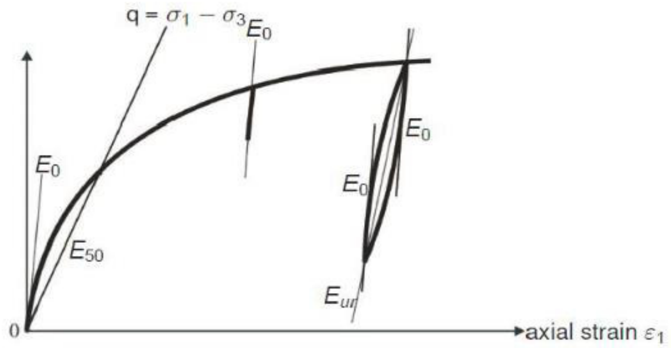
# Projektovanje putem FEM-a



# 2D elements models (soil)

Linear elastic model:

E – Youngs's modulus
v – Poisson ratio




Elasto-plastic model

Mohr-Coulomb

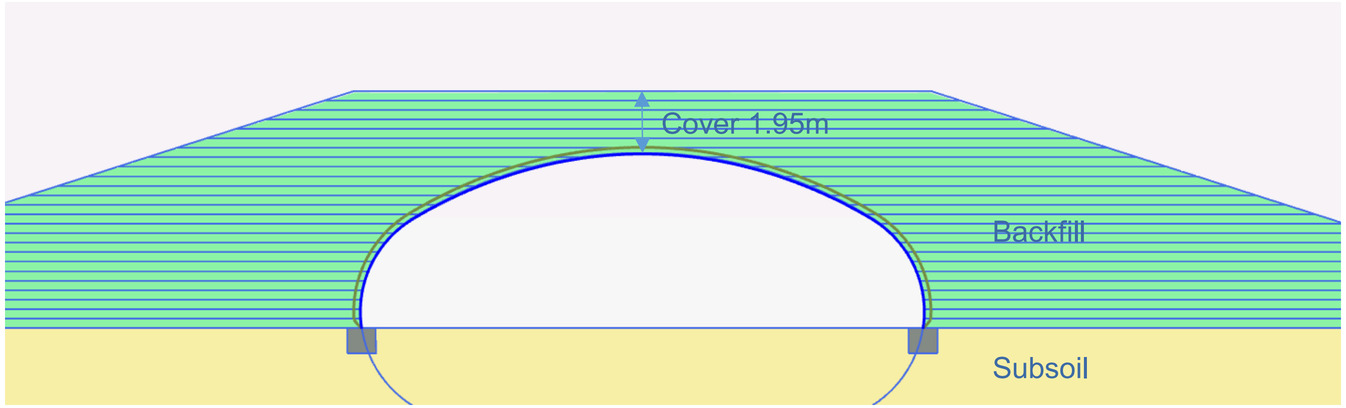
Hardening soil

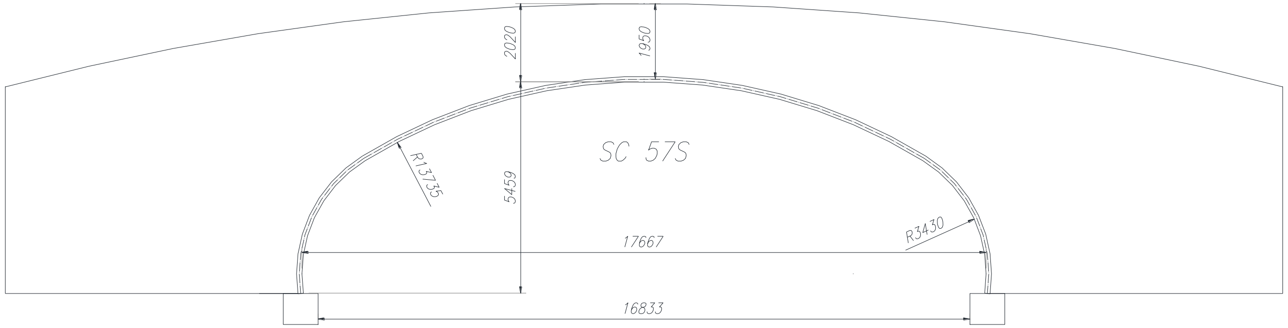
MC main parameters:
E – triaxial loading stiffness E≈E50
v – Poisson ratio
Φ – friction angle
C - cohesion

HR main parameters:
E50 – triaxial loading stiffness
Eur – triaxial unloading stiffness Eoed≈2.5E50
Eoed – edometric loading stiffness Eoed≈E50
Φ – friction angle
C - cohesion

# Soil model - based on field test in Rydzyna

## Model of structure SC 57S

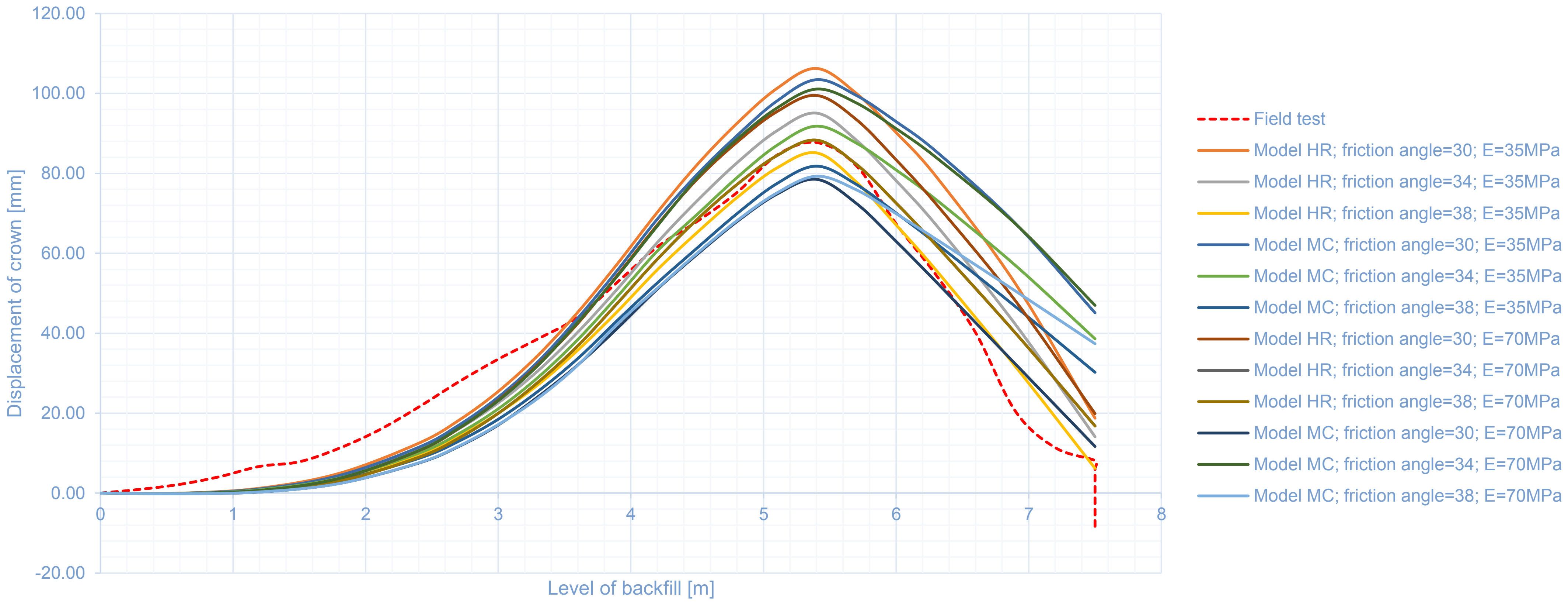


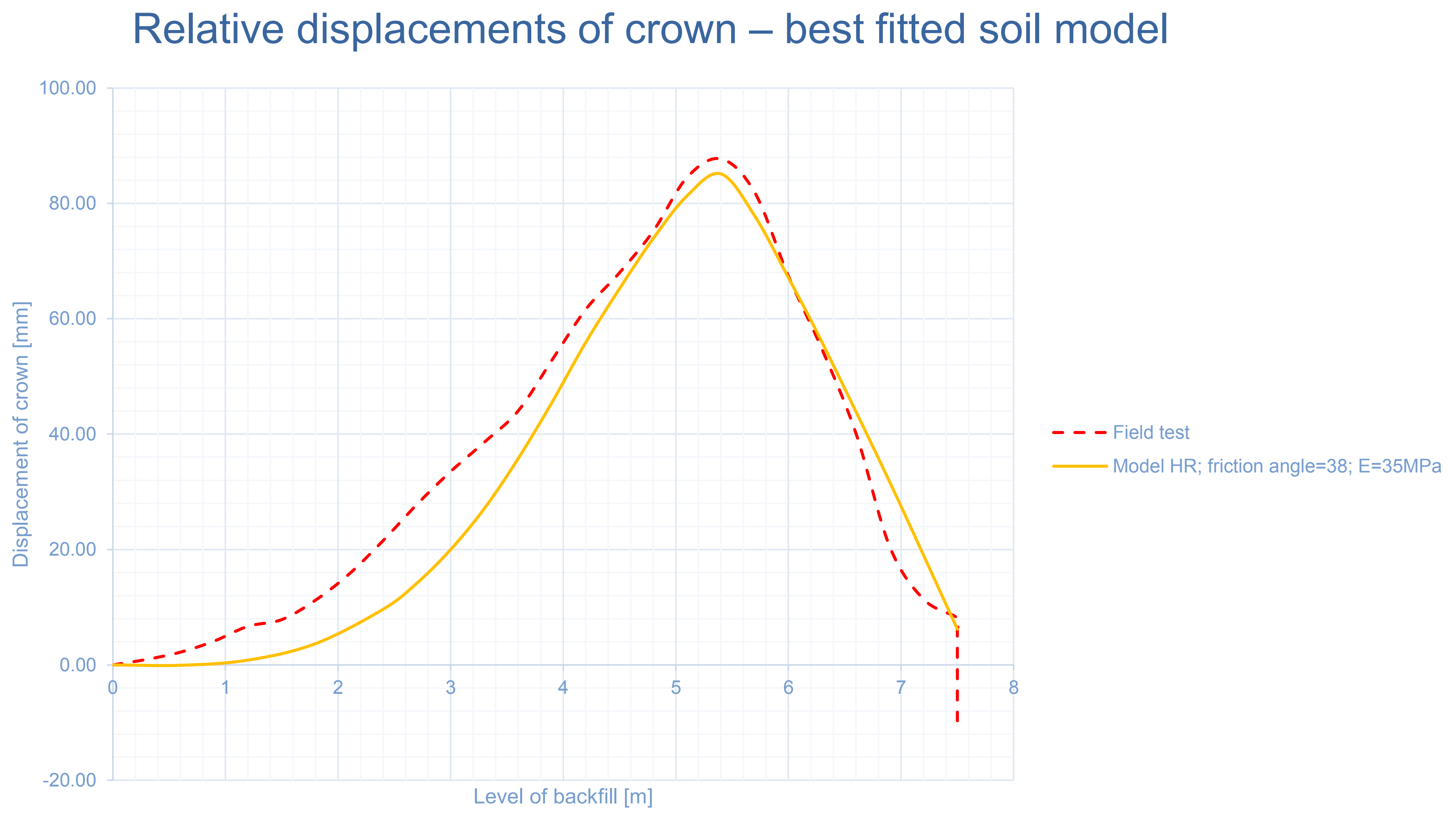

Backfill material:
- Medim sands
- 1.8<Cc<2.0
- Cu=6.63
- Compaction degree= 0.98-1.0
- Volumetric weight of soil: 1.95 kN/m3

# Soil model - based on field test in Rydzyna

## Relative displacements of crown



# Soil model - based on field test in Rydzyna



# Soil model - based on field test in Rydzyna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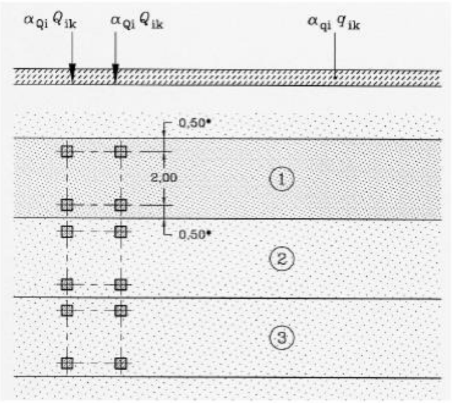
# Live loads

## Example – LM1

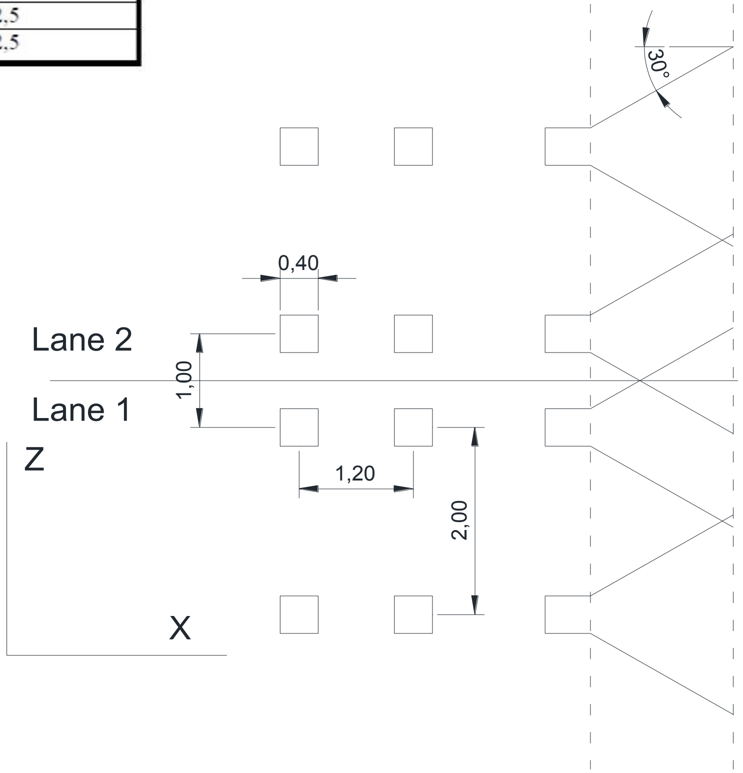
**Table 4.2 - Load model 1 : characteristic values**

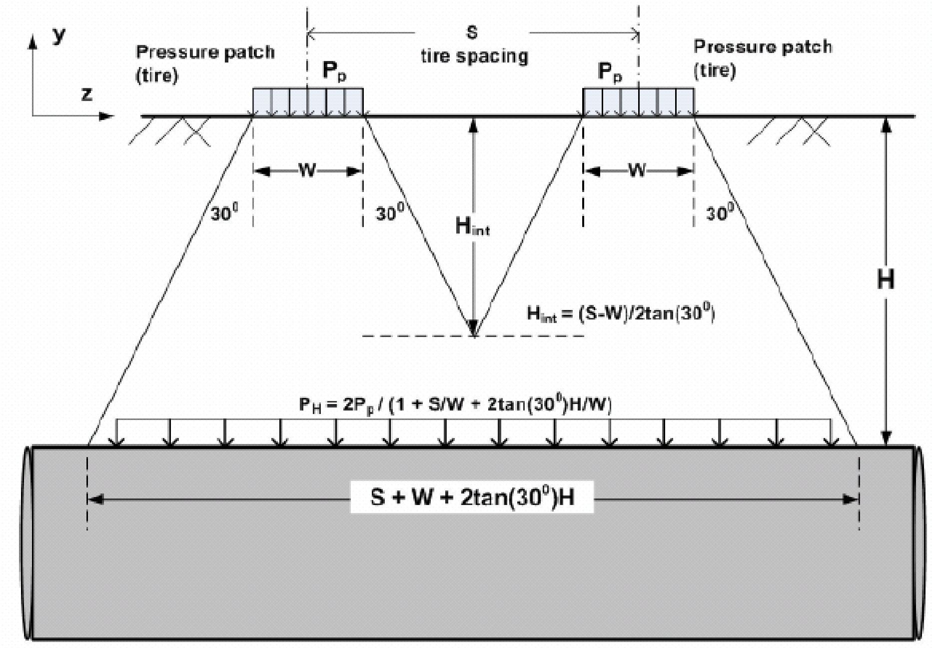
| Location | Tandem system *TS* | *UDL* system |
|---|---|---|
| | Axle loads $Q_{ik}$ (kN) | $q_{ik}$ (or $q_{rk}$) (kN/m$^2$) |
| Lane Number 1 | 300 | 9 |
| Lane Number 2 | 200 | 2,5 |
| Lane Number 3 | 100 | 2,5 |
| Other lanes | 0 | 2,5 |
| Remaining area ($q_{rk}$) | 0 | 2,5 |

The details of Load Model 1 are illustrated in Figure 4.2a.



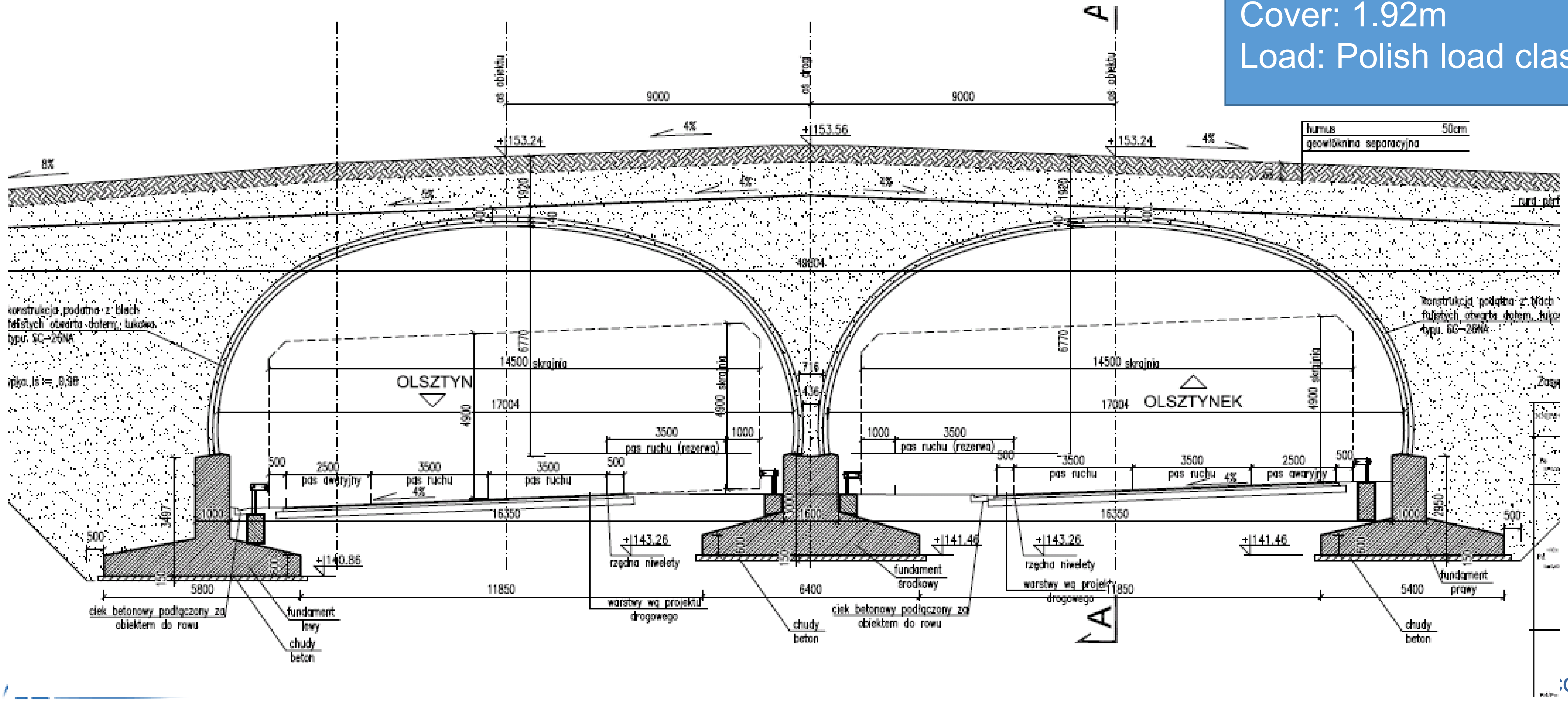

**Key**
(1) Lane Nr. 1 : $Q_{1k}$ = 300 kN ; $q_{1k}$ = 9 kN/m$^2$
(2) Lane Nr. 2 : $Q_{2k}$ = 200 kN ; $q_{2k}$ = 2,5 kN/m$^2$
(3) Lane Nr. 3 : $Q_{3k}$ = 100 kN ; $q_{3k}$ = 2,5 kN/m$^2$
* For $w_l$ = 3,00 m



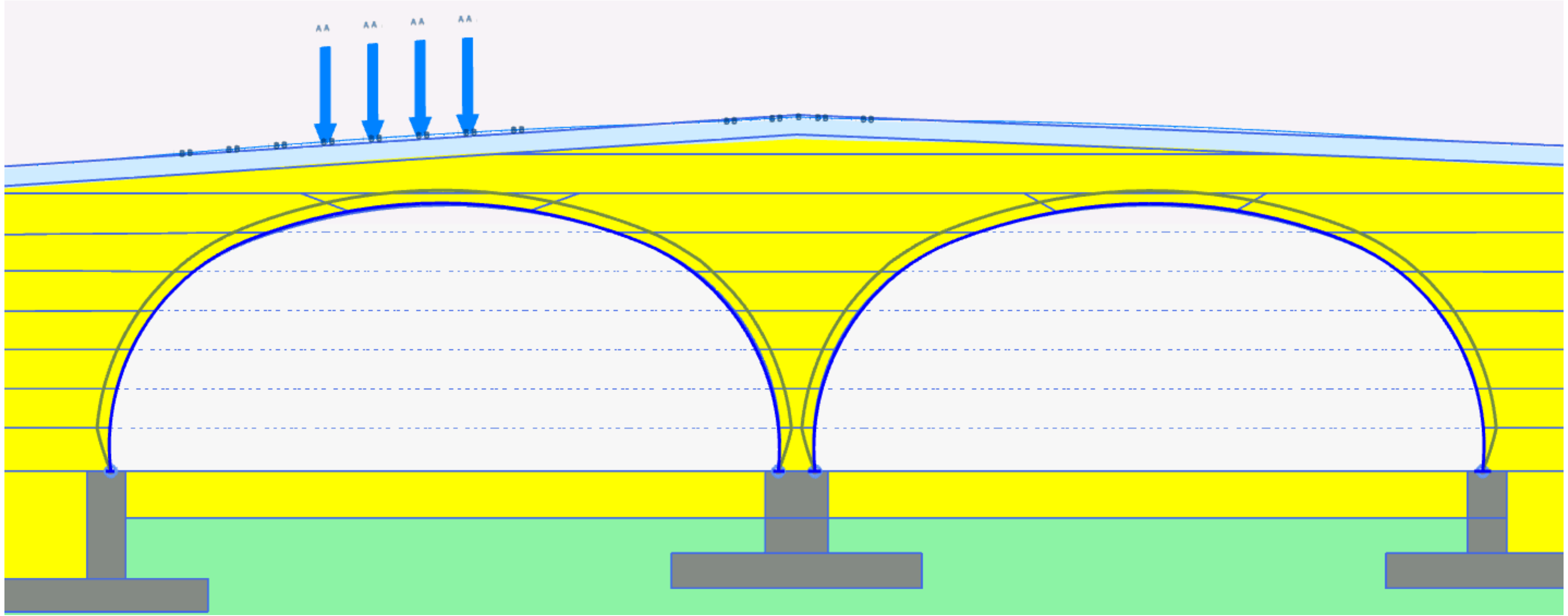



# Example – DK 51 Olsztyn-Olsztynek, *Structure3*

Structure parameters:
Profile: SC-26NA
Span: 17.00m
Rise: 6.72 m
Cover: 1.92m
Load: Polish load class E (240kN)



# Example – DK 51 Olsztyn-Olsztynek, *Structure3*



Structural elements

Corrugation: 381x140mm
Plate thickness: 7.0mm
Ribs: -
Steel: S315MC

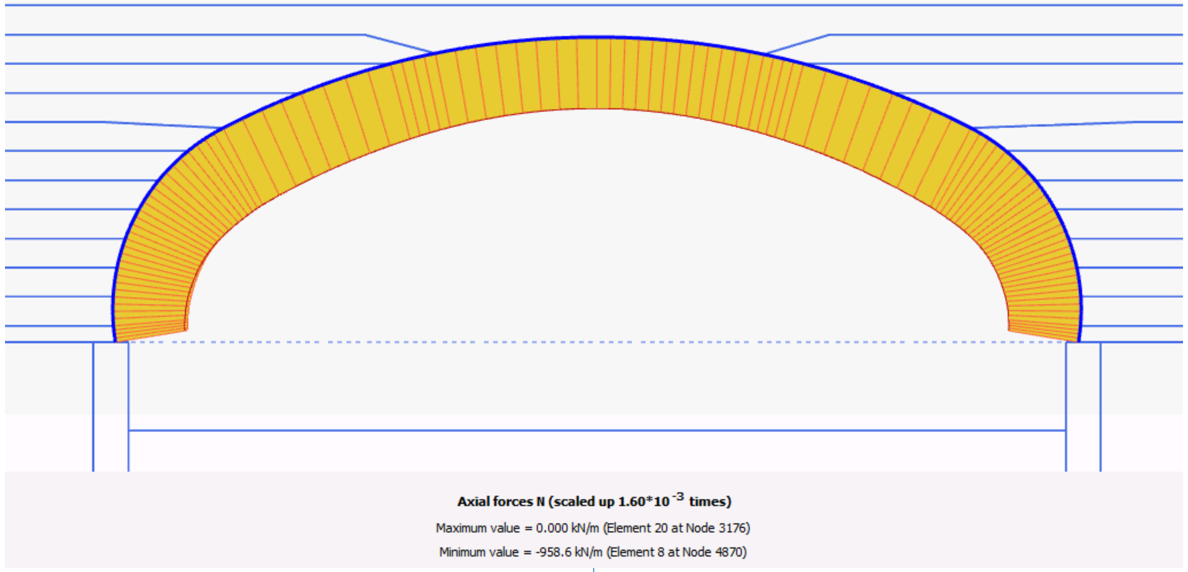
Soil elements

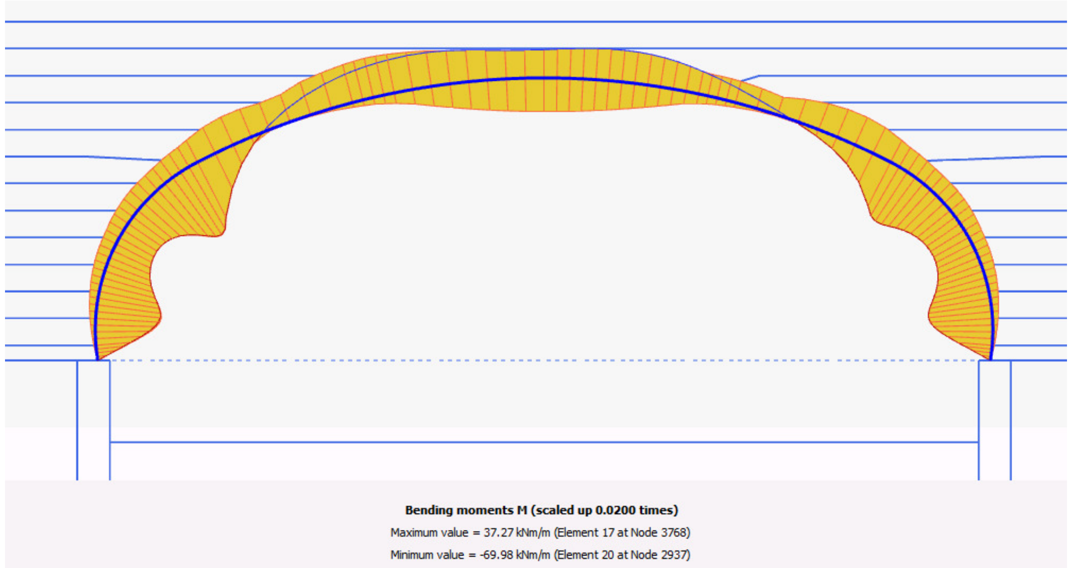
Backfill:
Model: Hardening soil
Friction angle: 38 deg
Modulus of soil (E50): 35 MPa

Soil under foundations (sand):
Model: Mohr-Coulomb
Friction angle: 35 deg
Cohesion: 0kPa
Modulus of soil: 70 MPa

# Example – DK 51 Olsztyn-Olsztynek, *Structure4*

## Envelopes of internal forces



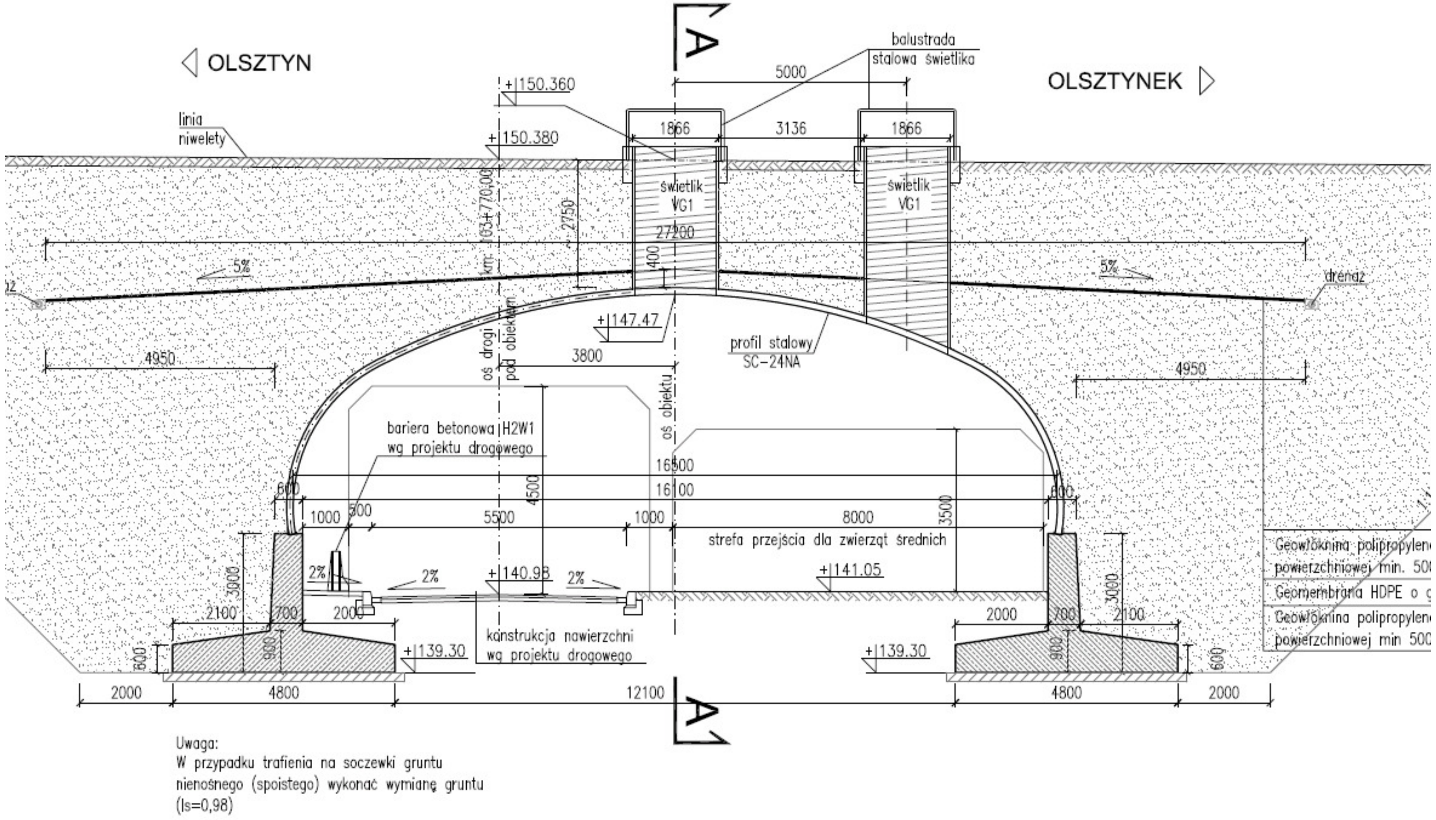

<u>Axial force:</u>

- Dead load: 795.3kN/m
- Live load: 163.3kN/m
- DL+LL: 958.6 kN/m

<u>Bending moments:</u>

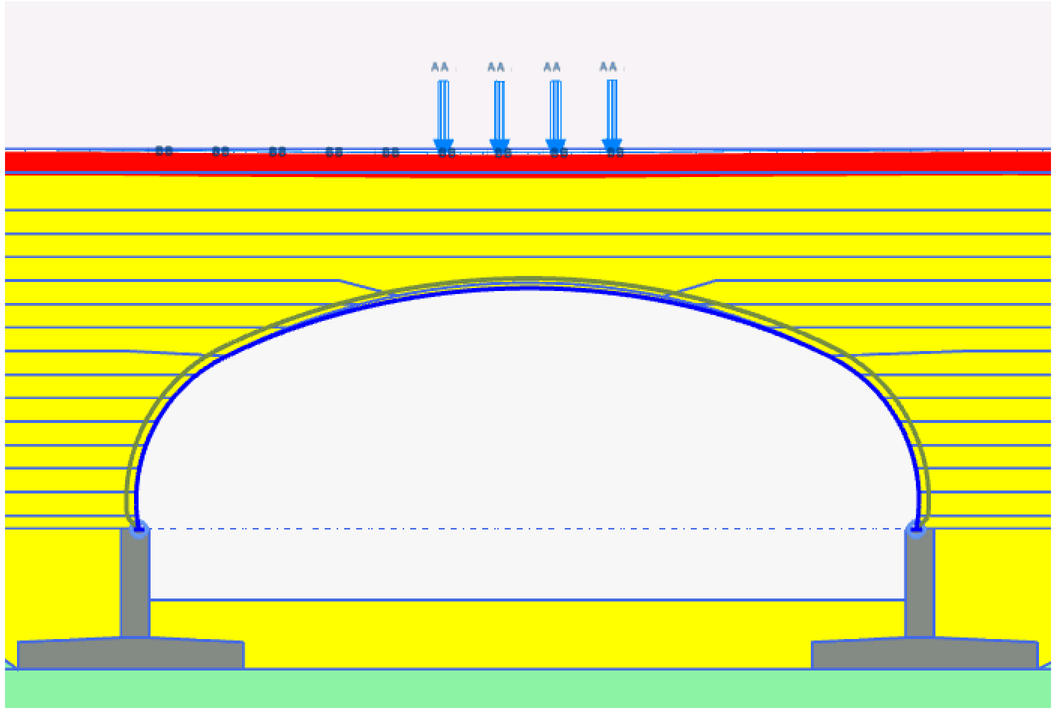
- Dead load: 48.15kN/m
- Live load: 21.47kN/m
- DL+LL: 69.62 kN/m

# Example – DK 51 Olsztyn-Olsztynek, *Structure4*




Structure parameters:
Profile: SC-24NA
Span: 16.50m
Rise: 5.17 m
Cover: 2.75m
Load: Polish load class A (800kN)

# Example – DK 51 Olsztyn-Olsztynek, *Structure4*



Structural elements

Corrugation: 381x140mm
Plate thickness: 8.0mm
Ribs: -
Steel: S315MC

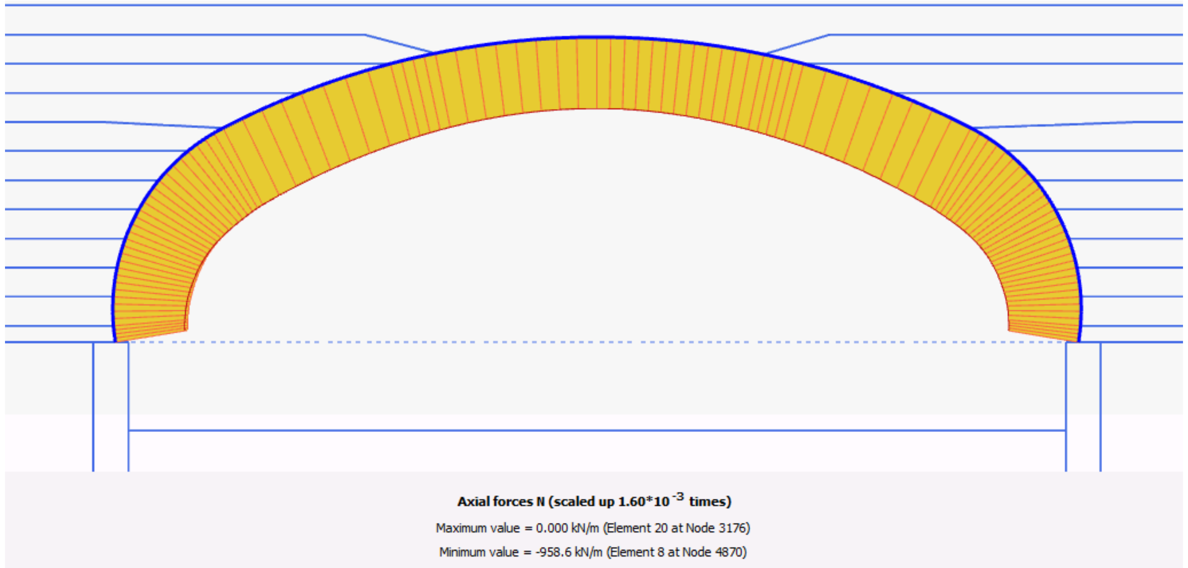
Soil elements

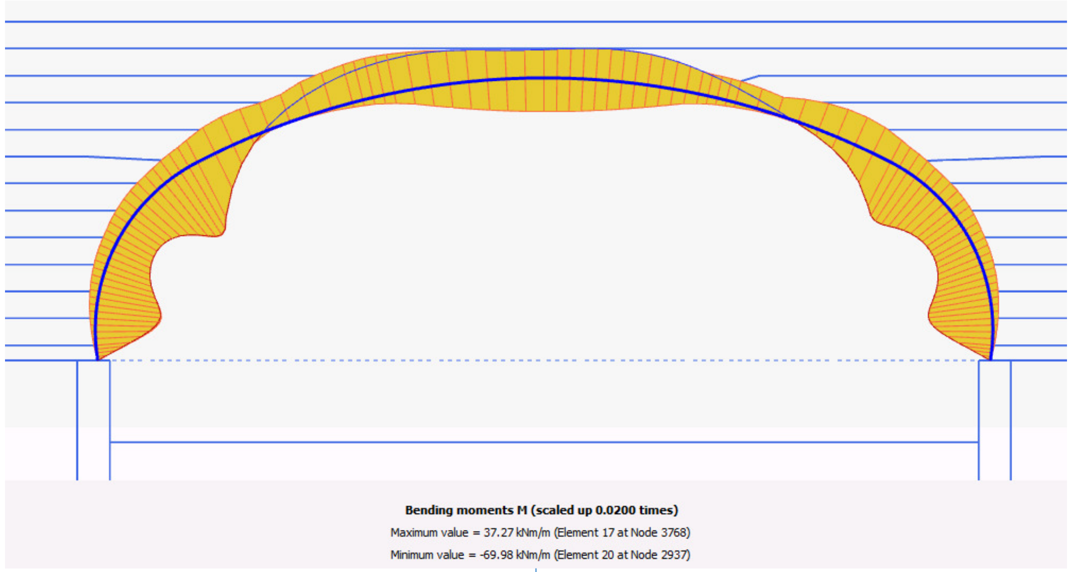
Soil under foundations (sand):
Model: Mohr-Coulomb
Friction angle: 35 deg
Cohesion: 0kPa
Modulus of soil : 70 MPa

Backfill:
Model: Hardening soil
Friction angle: 38 deg
Modulus of soil (E50): 35 MPa

# Example – DK 51 Olsztyn-Olsztynek, *Structure4*

## Envelopes of internal forces




<u>Axial force:</u>

- Dead load: 795.3kN/m
- Live load: 163.3kN/m
- DL+LL: 958.6 kN/m

<u>Bending moments:</u>

- Dead load: 48.15kN/m
- Live load: 21.47kN/m
- DL+LL: 69.62 kN/m

# Example – DK 51 Olsztyn-Olsztynek, *Structure4*

## Capacity of plate

| Parameters of plate | | | |
|---|---|---|---|
| **Corrugation** | Plate thickness<br>t | Cross section area<br>A | Plastic modulus<br>Wpl |
| **[mm]** | [mm] | [mm2/mm] | [mm3/mm] |
| **381x140** | 8.0 | 10.6 | 455.3 |

- Flexure:

- Compression:

# Example – DK 51 Olsztyn-Olsztynek, *Structure4*

## Stress in servicability limit state

Das Bildelement mit der Beziehungs-ID rId1 wurde in der Datei nicht gefunden.

Where:
A – cross section area,
Ws – section modulus.

# Example – DK 51 Olsztyn-Olsztynek, *Structure4*

## Stress in servicability limit state

Das Bildelement mit der Beziehungs-ID rId1 wurde in der Datei nicht gefunden.

Where:
A – cross section area,
Ws – section modulus.

# Example – DK 51 Olsztyn-Olsztynek, *Structure4*

## Stress in servicability limit state

***Resistance to global buckling:***

Requirement:

$$T_L < R_b$$

Critical buckling stress:

$$R_b = 1.2\phi_b \cdot C_n \cdot (E \cdot I)^{\frac{1}{3}} \cdot (\phi_s \cdot M_s \cdot K_b)^{\frac{2}{3}} R_h$$

where:

$R_b$ - nominal axial force in culvert wall to cause general buckling

$\phi_b = 0.7$ - resistance factor for general buckling

$C_n := 0.55$ - scalar calibration factor to account for some nonlinear effects

$E = 206 \cdot GPa$ - modulus of elasticity of pipe wall material

$I = 24434.6 \cdot \frac{mm^4}{mm}$ - moment of inertia of stiffened culvert wall per unit length

$\phi_s = 0.9$ - resistance factor for soil

$M_s := 2ksi$ - constrained modulus of embedment table 12.12.3.4-1

$\nu = 0.22$ - Poisson's ratio of soil

$K_b := \frac{(1 - 2 \cdot \nu)}{1 - \nu^2} = 0.588$

$R_h := \frac{11.4}{11 + \frac{S}{H}} = 0.671$ - correction factor for backfill geometry

$S = 16.5 m$ - culvert span

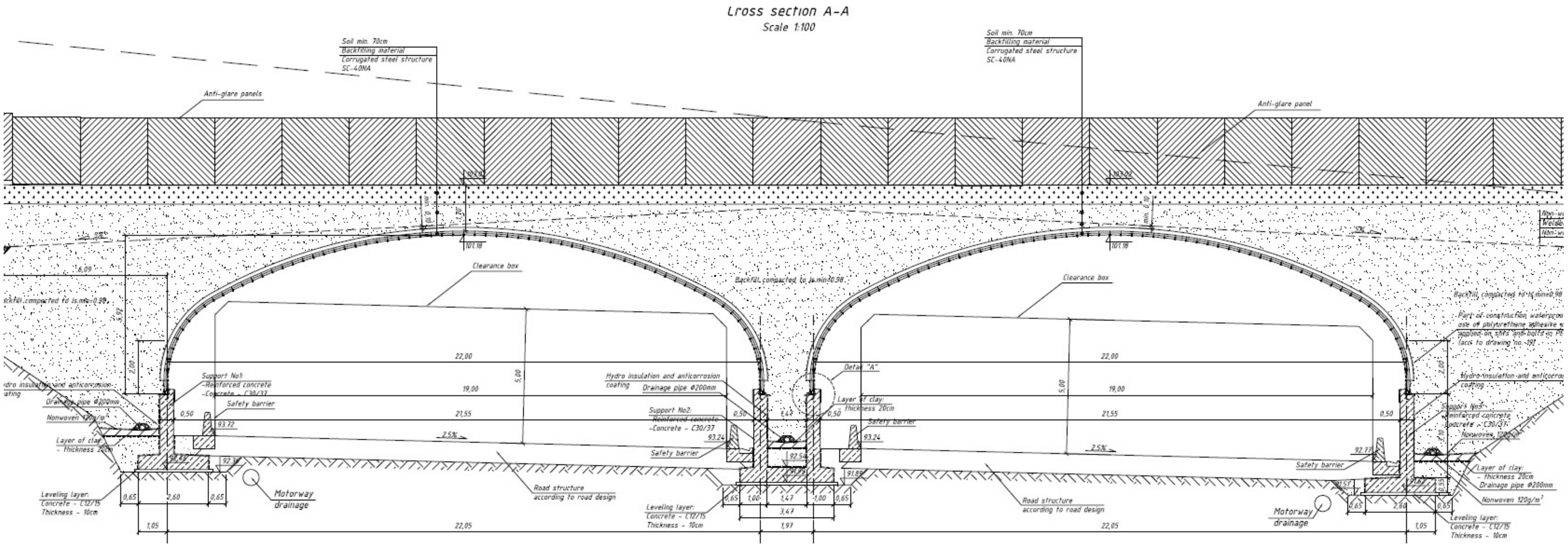
$H = 2.75 m$ - depth of fill over top of culvert

$$R_b := 1.2\phi_b \cdot C_n \cdot (E \cdot I)^{\frac{1}{3}} \cdot (\phi_s \cdot M_s \cdot K_b)^{\frac{2}{3}} R_h = 1998.7 \cdot \frac{kN}{m}$$

$$T_L = 1437.9 \cdot \frac{kN}{m}$$

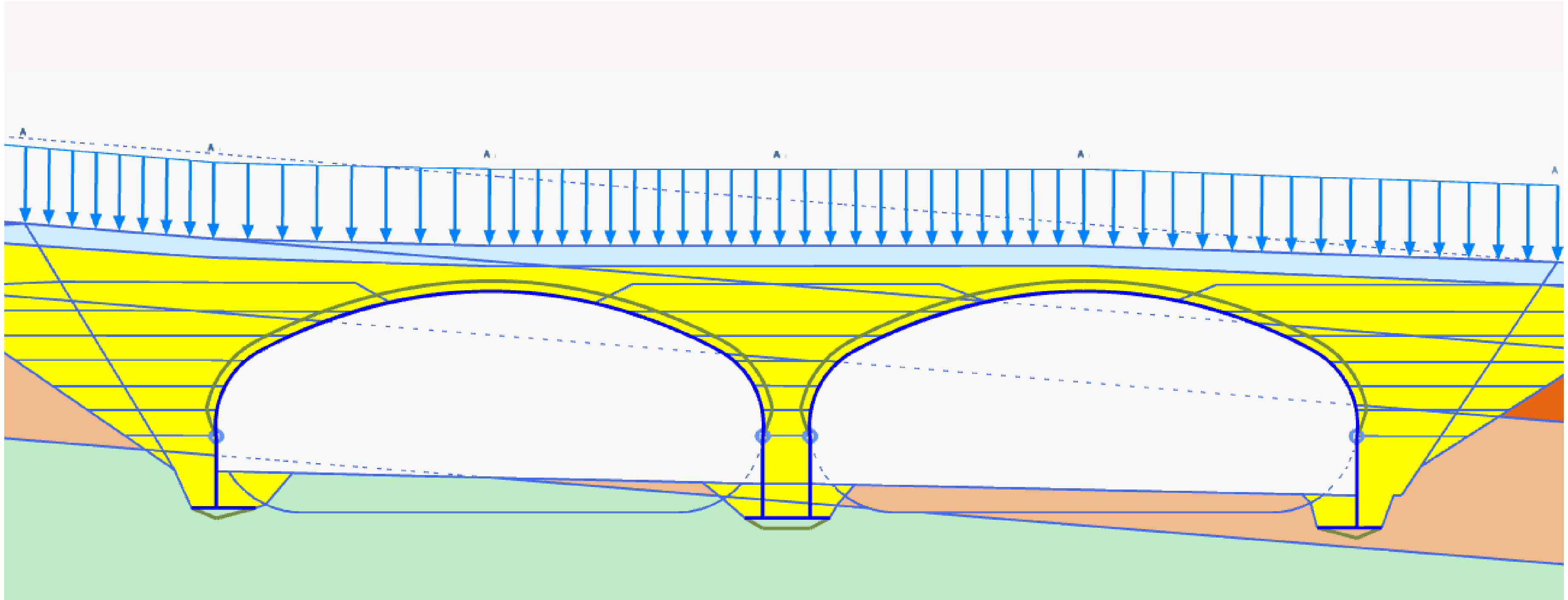
$check(T_L, R_b) = $ "OK"

# Example – Norther Marmara Motorway, Animal Overpass




Structure parameters:
Profile: SC-40NA
Span: 22.00m
Rise: 5.92 m
Cover: 1.70m
Load: 10kPa

# Example – Norther Marmara Motorway, Animal Overpass



Structural elements

Corrugation: 381x140mm
Plate thickness: 7.0mm
Ribs: 7.0mm c/c 1524mm
Steel: S315MC

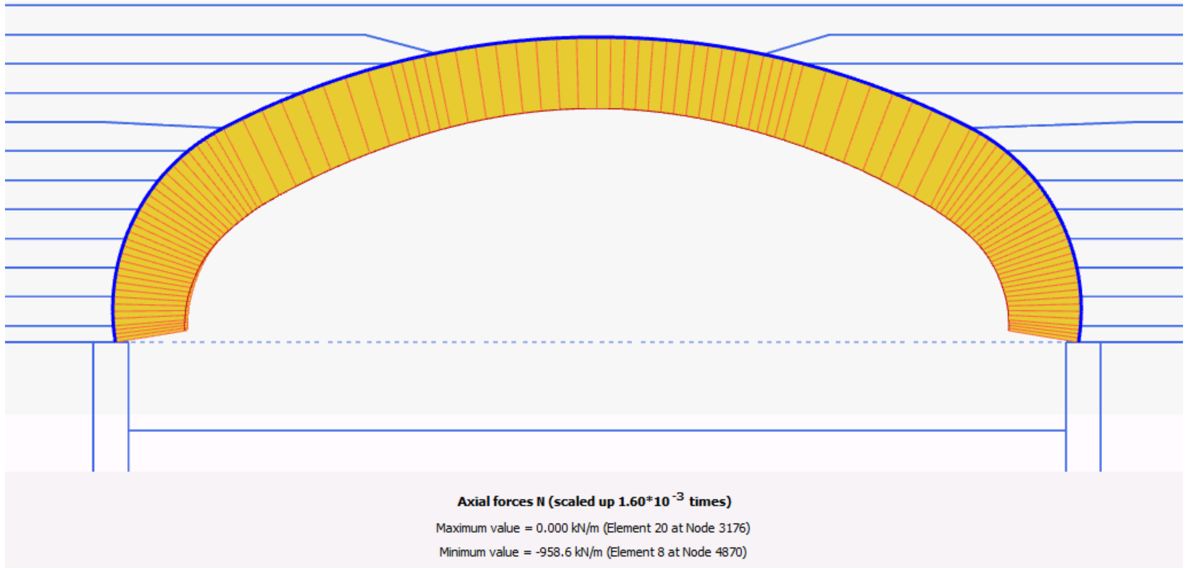
Soil elements

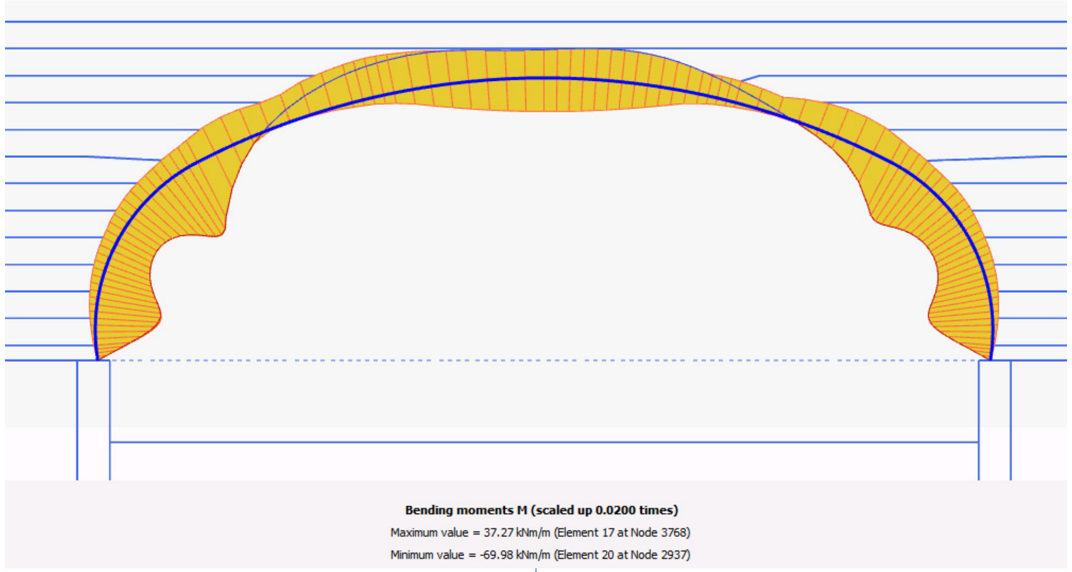
Backfill:
Model: Hardening soil
Friction angle: 38 deg
Modulus of soil (E50): 40 MPa

Soil under foundations (rocks):
Model: Mohr-Coulomb
Friction angle: 38 deg
Cohesion: 100kPa
Modulus of soil (E50): 350 MPa

# Example – DK 51 Olsztyn-Olsztynek, *Obiekt 4*

## Envelopes of internal forces




Axial force:
- Dead load: 795.3kN/m
- Live load: 163.3kN/m
- DL+LL: 958.6 kN/m

Bending moments:
- Dead load: 48.15kN/m
- Live load: 21.47kN/m
- DL+LL: 69.62 kN/m

# Thank you for your attention

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