STRESS ANALYSIS OF BURIED PIPELINE

"VELDSTREKKING" ACCORDING NEN3650

Date: Zo 20-Jan-2002
Time: 16:19:04

Project: IMPROVEMENTS OF FUTURE DEVELOPMENTS

Jobnr: PV2002

ABSTRACT:

This calculation was originally made for personal use only. It was performed to verify the formulas and the calculation method used. It is a "veldstrekking" calculation according the example of NEN 3650 addendum C11.

There are several formulas that are taken from other standards like the local standard: Pijpleidingcode and Geo-Tubomechanica.

This report proofs that the NEN 3650 and NEN 3651 are not sufficiently documented to perform a stress calculation for buried pipelines.
In other words NEN 3650 and NEN 3651 lack the information to perform these calculations.

Where the results in this report deviate from NEN 3650 C11, the later is incorrect and should be adjusted.

All positive contributions are welcome.

REFERENCES:

NEN 3650 appendix C11 issue 1992 by NNI
Pijpleidingcode 1972 by Provincie Zuid-Holland
Geo-Tubomechanica 1977 by Provinciale Waterstaat Zuid-Holland
"Beams on Elastic Foundation" 1967 M. Hetenyi

REV	BY	DATE	DESCRIPTION	CHECKED	PROJECT APPROVAL	THIRD PARTY APPROVAL
1	PVo	Zo 20-Jan-2002	Removed dublings from page 7			
0	PVo	Wo 02-Jan-2002	First Issue	WGu	-	-

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A Preliminary for information only B For review C Authorized for construction	**WEB SITE EXAMPLE**	**1**	**A**

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Veldstrekkingsberekening conform NEN3650
door Paul W.H. Voorhaar

VERIFICATIE MODEL MET
REKENVOOBEELD UIT BIJL. C11

Onzekerheidsfactoren conform blz. 145:

Onzekerheidsfactor: $Onz\_factor_{q\_p} := 1.1$

Onzekerheidsfactor: $Onz\_factor_{k\_v} := 1.3$

Onzekerheidsfactor $Onz\_factor_{\delta\_grond} := 1.0$ (Normaal 1.4)

Rekenfactoren conform blz. 55 en blz. 30:

Rekenfactor inwendige druk: $Rek\_factor_{p} := 1.39$

Rekenfactor temperatuur: $Rek\_factor_{t} := 1.25$

Rekenfactor Q totaal: $Rek\_factor_{q} := 1.5$

Rekenfactor uitvoeringsz. en zetting: $Rek\_factor_{\delta} := 1.5$

Wanddikte factor (blz. 30): $Rek\_factor_{wand} := 1.5$

LEIDING-GEGEVENS

Uitwendige diameter: $D_e := 219.1 \cdot mm$

Wanddikte: $d_d := 8.18 \cdot mm$

Tolerantie: $tol := 12.5 \cdot \%\cdot d_d$ $tol = 1.023 \cdot mm$

Corrosie: $corr := 0.5 \cdot mm$

Rekgrens materiaal: $R_e := 241 \cdot MPa$ COLD $R_{eb} := 215 \cdot MPa$ HOT

Elasticiteits modulus: $E := 206000 \cdot MPa$

Ontwerpdruk: $P_d := 70 \cdot bar$

Installatie temperatuur: $t_{in} := 15$

Ontwerp temperatuur 1 $t_o := 100$

Ontwerp temperatuur 2 $t_{o2} := 100$

Uitzettingscoefficient: $\alpha_g := 11.6 \cdot 10^{-6}$

Passieve grondbelasting: $q_p := 10.29 \cdot \frac{N}{mm} \cdot \frac{1}{D_e}$

Neutrale grondbelasting: $q_n := 4.34 \cdot \frac{N}{mm} \cdot \frac{1}{D_e}$

Vertikale beddingconstante: $k_v := 0.0065 \cdot \frac{N}{mm^3}$

Verkeersbelasting: $Q_{verkeer} := 8.59 \cdot \frac{N}{mm}$

Vertikale grondverplaatsing: $\delta_{grond} := 30 \cdot mm$

Uitvoeringszakking: $\delta_{uitv} := 0 \cdot mm$

Belastinghoek bovenlast op leiding: $\alpha := 180 \cdot deg$

Ondersteuningshoek leiding: $\beta := 70 \cdot deg$

Klinkpercentage $\mu := 0.15$

Temperatuursverschil 1: $\delta T := t_o - t_{in}$ $\quad \delta T := \delta T \cdot Rek\_factor_t$

Temperatuursverschil 2: $\delta T2 := \left| t_{in} - t_{o2} \right|$ $\quad \delta T2 := \delta T2 \cdot Rek\_factor_t$

Netto wand: $d_n := d_d - corr$

Minimum wanddikte: $d := d_d - corr - tol$ $\quad d = 6.657 \cdot mm$

Lijnbelasting: $Q_p := D_e \cdot q_p$ $\quad Q_p = 10.29 \cdot \frac{N}{mm}$

$Q_n := D_e \cdot q_n$ $\quad Q_n = 4.34 \cdot \frac{N}{mm}$

$\delta_y := 0 \cdot mm$

Zie blz 153 of NEN 3650

$$f_k := \frac{1 \cdot MPa}{1 \cdot MPa + \frac{Q_p - Q_n}{\left(\mu \cdot D_e - \delta_y\right) \cdot 0.8}}$$

Klinkfactor: $f_k = 0.815$

$Q_k := Q_n + f_k \cdot \left(Q_p - Q_n\right)$ $\quad Q_k = 9.192 \cdot \frac{N}{mm}$

$Q_{tot} := Rek\_factor_q \cdot \left(Q_k \cdot Onz\_factor_{q\_p} + Q_{verkeer}\right)$ $\quad Q_{tot} = 28.052 \cdot \frac{N}{mm}$

$Q_{tot2} := Rek\_factor_q \cdot \left(Q_p \cdot Onz\_factor_{q\_p} + Q_{verkeer}\right)$ $\quad Q_{tot2} = 29.863 \cdot \frac{N}{mm}$

$\delta_y := Rek\_factor_\delta \cdot \left(\delta_{uitv} + Onz\_factor_{\delta\_grond} \cdot \delta_{grond}\right)$ $\quad \delta_y = 45 \cdot mm$

$P_o := Rek\_factor_p \cdot P_d$ $\quad P_o = 97.3 \cdot bar$

$S_p := P_o \cdot \frac{D_e - d}{2 \cdot d}$ $\quad S_p = 155.243 \cdot MPa$

$$d_{min} := \frac{P_d \cdot \left(D_e - d\right) \cdot 0.5 \cdot Rek\_factor_{wand}}{R_{eb}}$$ $\quad d_{min} = 5.188 \cdot mm$

Inside diameter: $D_i := D_e - 2 \cdot d_n$

Moment of inertia: $I_{buis} := \frac{\pi}{64} \cdot \left(D_e^4 - D_i^4\right)$

Weerstands moment: $W_{buis} := \frac{I_{buis}}{0.5 \cdot D_e}$ $\quad W_{buis} = 2.605 \cdot 10^5 \cdot mm^3$

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Momentfactor top:

$$K_t := \frac{\alpha}{16\cdot\pi}\cdot\frac{1}{\sin\left(\frac{\alpha}{2}\right)} + \frac{3}{8\cdot\pi}\cdot\cos\left(\frac{\alpha}{2}\right) + \frac{1}{6\cdot\pi}\cdot\sin\left(\frac{\alpha}{2}\right)^2 - \sin\left(\frac{\alpha}{2}\right)\cdot\left(\frac{1}{4} - \frac{\alpha}{8\cdot\pi}\right) + \frac{1}{2\cdot\pi} \ldots$$

$$+ \frac{\beta}{16\cdot\pi}\cdot\frac{1}{\sin\left(\frac{\beta}{2}\right)} + \frac{3}{8\cdot\pi}\cdot\cos\left(\frac{\beta}{2}\right) - \frac{1}{6\cdot\pi}\cdot\sin\left(\frac{\beta}{2}\right)^2 + \frac{\beta}{8\cdot\pi}\cdot\sin\left(\frac{\beta}{2}\right) - \frac{1}{2\cdot\pi}$$

$$v := \frac{1}{6\cdot\pi}\cdot\sin\left(\frac{\alpha}{2}\right)^2 - \frac{1}{6\cdot\pi}\cdot\sin\left(\frac{\beta}{2}\right)^2 \qquad v = 0.0356$$

Momentfactor side:

$$K_s := K_t - v - \frac{1}{2} + \frac{1}{4}\cdot\sin\left(\frac{\alpha}{2}\right)$$

Momentfactor bottom:

$$K_b := K_t - 2\cdot v + \frac{1}{4}\cdot\sin\left(\frac{\alpha}{2}\right) - \frac{1}{4}\cdot\sin\left(\frac{\beta}{2}\right)$$

$$k_y := \frac{1}{24}\cdot\sin(\alpha) + \frac{\frac{\alpha}{\pi} - 1}{4}\cdot\sin\left(\frac{\alpha}{2}\right) + \frac{3}{4\cdot\pi}\cdot\cos\left(\frac{\alpha}{2}\right) + \frac{1}{6}\cdot\operatorname{cotg}\left(\frac{\alpha}{2}\right) + \left(\frac{\alpha}{8\cdot\pi} - \frac{1}{6}\right)\cdot\frac{1}{\sin\left(\frac{\alpha}{2}\right)} \ldots$$

$$+ \frac{\alpha + \beta - 2\cdot\pi}{8} + \frac{1}{24}\cdot\sin(\beta) + \frac{\frac{\beta}{\pi} - 1}{4}\cdot\sin\left(\frac{\beta}{2}\right) + \frac{3}{4\cdot\pi}\cdot\cos\left(\frac{\beta}{2}\right) + \frac{1}{6}\cdot\operatorname{cotg}\left(\frac{\beta}{2}\right) \ldots$$

$$+ \left(\frac{\beta}{8\cdot\pi} - \frac{1}{6}\right)\cdot\frac{1}{\sin\left(\frac{\beta}{2}\right)}$$

Top	Side	Bottom	$k_y := \lvert k_y \rvert$
$K_t = 0.14113$	$K_s = -0.14446$	$K_b = 0.17654$	$k_y = 0.10237$

$$k_z := \frac{1}{4} + \frac{1}{24}\cdot\sin\left(\frac{\alpha}{2}\right)^2 - \frac{\alpha}{8\cdot\pi}\cdot\sin\left(\frac{\alpha}{2}\right) - \frac{\alpha}{16\cdot\pi}\cdot\frac{1}{\sin\left(\frac{\beta}{2}\right)} - \frac{3}{8\cdot\pi}\cdot\cos\left(\frac{\alpha}{2}\right) \ldots$$

$$+ \frac{1}{24}\cdot\sin\left(\frac{\beta}{2}\right)^2 - \frac{\beta}{8\cdot\pi}\cdot\sin\left(\frac{\beta}{2}\right) - \frac{\beta}{16\cdot\pi}\cdot\frac{1}{\sin\left(\frac{\beta}{2}\right)} - \frac{3}{8\cdot\pi}\cdot\cos\left(\frac{\beta}{2}\right)$$

$k_z := \lvert k_z \rvert$ $\qquad k_z = 0.09663$

$\frac{k_y}{2} = 0.05118$ $\qquad k_y\cdot\sin(50\cdot\text{deg})\cdot\frac{2}{3} = 0.05228$

$W_w := \frac{1}{6}\cdot(d_n)^2$ $\qquad I_w := \frac{1}{12}\cdot(d_n)^3$ $\qquad r_g := 0.5\cdot(D_e - d_n)$

$W_w = 9.83\cdot\frac{mm^3}{mm}$ $\qquad I_w = 37.749\cdot\frac{mm^4}{mm}$ $\qquad r_g = 105.71\cdot mm$

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Time: 16:19:04

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$$f_{rr_0} := \frac{1}{1 + \frac{2 \cdot P_d \cdot r_g^3 \cdot k_y}{E \cdot I_w}}$$

Druk: $f_{rr} = 0.821$

Drukloos: $f_{rr_1} := 1$

$$S_{Q_{i,j}} := f_{rr_j} \cdot \frac{K_i \cdot Q_{tot} \cdot r_g}{W_w}$$

Druk / Drukloos

$$S_Q = \begin{pmatrix} 34.962 & 42.574 \\ -35.787 & -43.578 \\ 43.734 & 53.255 \end{pmatrix} \cdot MPa$$

0=top
1=zijde
2=bod

$$I_{pijp} := \frac{\pi}{64} \cdot \left(D_e^4 - D_i^4\right)$$

$$K = \begin{pmatrix} 0.141 \\ -0.144 \\ 0.177 \end{pmatrix}$$

0=top
1=zijde
2=bod

$$\lambda := \left(\frac{D_e \cdot k_v \cdot Onz\_factor_{k\_v}}{4 \cdot E \cdot I_{pijp}}\right)^{0.25}$$

$\lambda = 0.0005297061 \cdot \frac{1}{mm}$

$$L := \frac{20.87}{\lambda}$$

$L = 39.399 \cdot m$

Zettingszone

$L := if(L \le 40 \cdot m, 40 \cdot m, if(L \ge 100 \cdot m, 100 \cdot m, L))$ $L = 40 \cdot m$ Zie PLC V.4.A.1.c.2

$$\alpha := \frac{6 - \lambda^2 \cdot L^2}{6 \cdot (2 + \lambda \cdot L)}$$

$\alpha = -3.1837$

$$m' := 5 + 4 \cdot \frac{6 \cdot \alpha}{\lambda \cdot L}$$

$m' = 1.394$

$Q_{tot} = 28.052 \cdot \frac{N}{mm}$ $Q_{tot2} = 29.863 \cdot \frac{N}{mm}$

$$q_z := \delta_y - \frac{m'}{384} \cdot \frac{q_z \cdot L^4}{E \cdot I_{pijp}}$$

$q_z = 0.0285 \cdot \frac{N}{mm}$ $Q_n = 4.34 \cdot \frac{N}{mm}$

Als q_z < = Q_n dan volgt de buis de zetting
In dat geval is Q_c gelijk aan q_z,
in het andere geval is Q_c gelijk aan Q_{tot}.

$Q_1 := q_z$ $Q_2 := Q_{tot}$

$Q_c = 0.028 \cdot \frac{N}{mm}$

c = 1	berekende hulpwaarde	c = 1	buis volgt zetting	c = 2	buis volgt zetting niet

$$l := \frac{\pi}{c \cdot \lambda}$$

$l = 5.931 \cdot m$ Oplegzone

Constanten van Hetenyi (zie Geo-Tubomechanica blz. 375)

Locatie max. moment: $x = 254.679 \cdot mm$ $\lambda \cdot x = 0.134905$ $\lambda \cdot x = 7.73 \cdot deg$

Locatie min.moment: $b = 4702.005 \cdot mm$

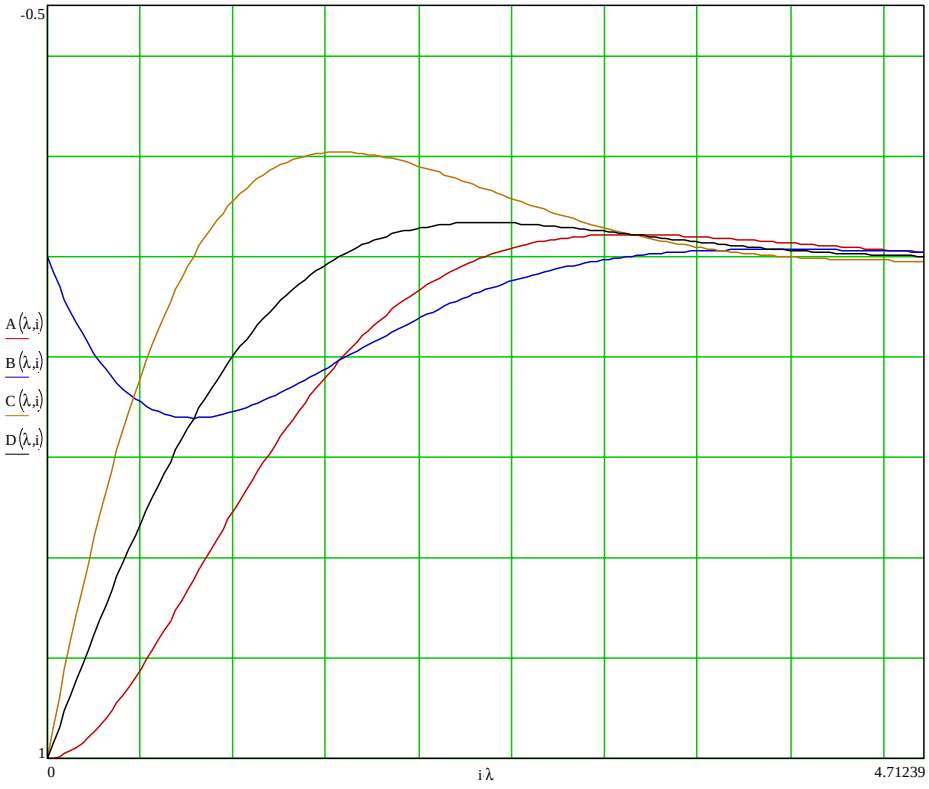
$A(\lambda, x) := e^{-\lambda \cdot x} \cdot (\cos(\lambda \cdot x) + \sin(\lambda \cdot x))$ $A(\lambda, x) = 0.983$

$B(\lambda, x) := e^{-\lambda \cdot x} \cdot \sin(\lambda \cdot x)$ $B(\lambda, x) = 0.118$

$C(\lambda, x) := e^{-\lambda \cdot x} \cdot (\cos(\lambda \cdot x) - \sin(\lambda \cdot x))$ $C(\lambda, x) = 0.748$

$D(\lambda, x) := e^{-\lambda \cdot x} \cdot \cos(\lambda \cdot x)$ $D(\lambda, x) = 0.866$

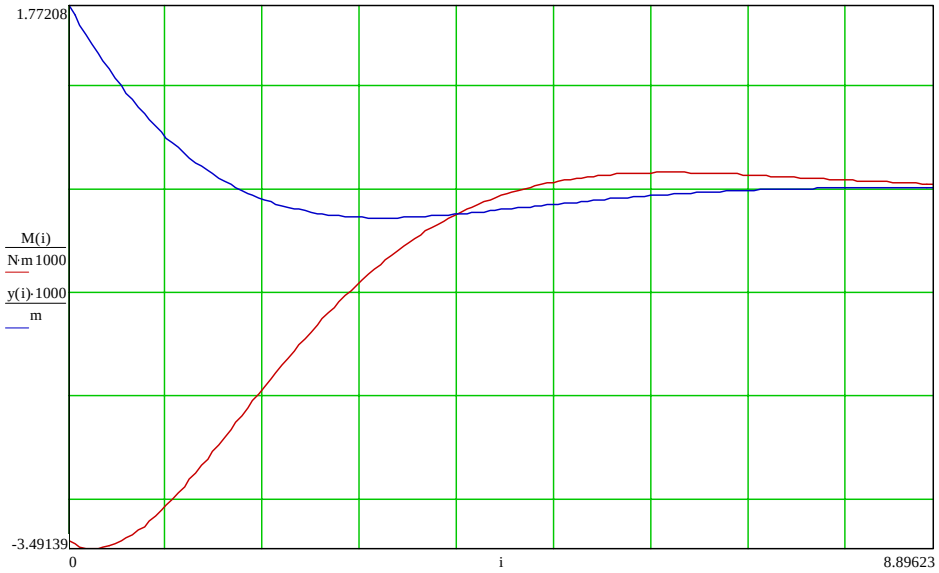
Grafiek van de berekende waarden ter verificatie met de literatuur



$$M(x) := \frac{-(Q_c \cdot L)}{2 \cdot \lambda} \cdot (B(\lambda, x) - \alpha \cdot A(\lambda, x)) \qquad M(x) = -3.492 \cdot 10^6 \cdot N \cdot mm$$

$$\frac{M(x)}{W_{buis}} = -13.403 \cdot MPa$$

Indrukking van de grond t.p.v. A1



Indrukking van de grond t.p.v. A:

$$y_a := \frac{Q_c \cdot \lambda \cdot L}{k_v \cdot D_e} \cdot (1 - \alpha)$$

$L = 40000 \cdot mm$

$y_a = 1.772 \cdot mm$

$y(0 \cdot mm) = 1.772 \cdot mm$

Indrukking van de grond t.p.v. A1:

$x = 254.679 \cdot mm$

$$y(x) := \frac{Q_c \cdot \lambda \cdot L}{k_v \cdot D_e} \cdot (D(\lambda, x) - \alpha \cdot C(\lambda, x))$$

$y(x) = 1.376 \cdot mm$

Uitvoeringszetting t.p.v. C:

Volgens NEN3650 blz 204

$$y_c := \frac{5 \cdot Q_c \cdot L^4}{384 \cdot E \cdot I_{buis}} + \frac{2 \cdot Q_c \cdot \alpha \cdot L^3}{32 \cdot E \cdot I_{buis} \cdot \lambda}$$

$y_c = 45 \cdot mm$

$\delta_y = 45 \cdot mm$

$$M_a := \frac{Q_c \cdot L \cdot \alpha}{2 \cdot \lambda}$$

$M_a = -3422230.367 \cdot N \cdot mm$

$$M_{a1} := \frac{-Q_c \cdot L \cdot e^{-\lambda \cdot x}}{2 \cdot \lambda} \cdot ((1 - \alpha) \cdot \sin(\lambda \cdot x) - \alpha \cdot \cos(\lambda \cdot x))$$

$M_{a1} = -3491689.797 \cdot N \cdot mm$

$$M_c := \frac{Q_c \cdot L^2}{8} + M_a$$

$M_c = 2271760.623 \cdot N \cdot mm$

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Deze spanningen zijn de secundaire membraanspanningen zie pag 204 van NEN 3650

$S_{b\_a} := \frac{M_a}{W_{buis}}$ $S_{b\_a} = -13.137 \cdot MPa$

$S_{b\_a1} := \frac{M_{a1}}{W_{buis}}$ $S_{b\_a1} = -13.403 \cdot MPa$

$S_{b\_c} := \frac{M_c}{W_{buis}}$ $S_{b\_c} = 8.721 \cdot MPa$

$Q_{r\_a} := k_v \cdot y_a \cdot D_e$ $Q_{r\_a} = 2.524 \cdot \frac{N}{mm}$

$Q_{r\_a1} := k_v \cdot y(x) \cdot D_e$ $Q_{r\_a1} = 1.959 \cdot \frac{N}{mm}$

$Ki_t = 0.071$ $K_0 := Ki_t$

$Ki_s = -0.082$ $K_1 := Ki_s$

$Ki_b = 0.122$ $K_2 := Ki_b$

$k_y := ki_y$ $k_y = 0.061$

$$f_{rr_0} := \frac{1}{1 + \frac{2 \cdot P_d \cdot r_g^3 \cdot k_y}{E \cdot I_w}}$$

$f_{rr} = \begin{pmatrix} 0.885 \\ 1 \end{pmatrix}$ Druk / Drukloos

Volgens NEN3650 blz. 203
Punt A1: Oplegzone
Punt A: Grens oplegzone,zettingsgebied
Punt C: Midden van zettingsgebied

In punt A

$$S_{l\_a_{i,j}} := f_{rr_j} \cdot \frac{K_i \cdot Q_{r\_a} \cdot r_g}{W_w}$$

	Druk	Drukloos	
$S_{l\_a} =$	1.706	1.927	0=top
	−1.97	−2.225	1=zijde
	2.931	3.311	2=bod

$\cdot MPa$

In punt A1

$$S_{l\_a1_{i,j}} := f_{rr_j} \cdot \frac{K_i \cdot Q_{r\_a1} \cdot r_g}{W_w}$$

	Druk	Drukloos	
$S_{l\_a1} =$	1.324	1.496	0=top
	−1.529	−1.728	1=zijde
	2.275	2.571	2=bod

$\cdot MPa$

Indirect niet ondersteund

$K_0 := Kio_t$ $K_1 := Kio_s$ $K_2 := Kio_b$ $k_y := kio_y$ $k_y = 0.042$

$$f_{rr_0} := \frac{1}{1 + \frac{2 \cdot P_d \cdot r_g^3 \cdot k_y}{E \cdot I_w}}$$

$K = \begin{pmatrix} 0.07 \\ -0.062 \\ 0.055 \end{pmatrix}$ $f_{rr} = \begin{pmatrix} 0.918 \\ 1 \end{pmatrix}$

In punt C

$$S_{l\_c_{i,j}} := f_{rr_j} \cdot \frac{K_i \cdot Q_c \cdot r_g}{W_w}$$

	Druk	Drukloos	
$S_{l\_c} =$	0.02	0.021	0=top
	−0.017	−0.019	1=zijde
	0.015	0.017	2=bod

MPa

Formule voor vervangende spanning volgens von Mises:

$$S_v(x,y) := \sqrt{(x^2 + y^2 - x \cdot y)}$$

Summary

$S_p = 155.243$ MPa

	Druk	Drukloos	
$S_Q =$	34.962	42.574	0=top
	−35.787	−43.578	1=zijde
	43.734	53.255	2=bod

MPa

$S_{pl} := 0.3 \cdot S_p$

$S_{pl} = 46.573$ MPa

$S_{l\_a} =$	1.706	1.927	0=top
	−1.97	−2.225	1=zijde
	2.931	3.311	2=bod

MPa

$S_{b\_a} = -13.137$ MPa

$S_{l\_a1} =$	1.324	1.496	0=top
	−1.529	−1.728	1=zijde
	2.275	2.571	2=bod

MPa

$S_{b\_a1} = -13.403$ MPa

$S_{l\_c} =$	0.02	0.021	0=top
	−0.017	−0.019	1=zijde
	0.015	0.017	2=bod

MPa

$S_{b\_c} = 8.721$ MPa

$S_t := \alpha_g \cdot \delta T \cdot E$

$S_t = 253.895$ MPa

FASE I Bovenbelasting

$S_x := 0 \cdot MPa$

$S_x = 0$ MPa

$S_y := S_Q^{<1>}$

$S_y =$	42.574		0=top
	−43.578		1=zijde
	53.255		2=bod

MPa

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Time: 16:19:04

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Jobnr: PV2002

FASE II Bovenbelasting + Uitvoeringszakking

$S_{x\_a} := S_{b\_a} \cdot c$ $\quad S_{x\_a} = \begin{pmatrix} 13.137 \\ 0 \\ -13.137 \end{pmatrix} \cdot MPa$ 0=top 1=zijde 2=bod

$S_{y\_a} := S_Q^{<1>} + S_{l\_a}^{<1>}$ $\quad S_{y\_a} = \begin{pmatrix} 44.5 \\ -45.803 \\ 56.566 \end{pmatrix} \cdot MPa$ 0=top 1=zijde 2=bod

$S_{x\_a1} := S_{b\_a1} \cdot c$ $\quad S_{x\_a1} = \begin{pmatrix} 13.403 \\ 0 \\ -13.403 \end{pmatrix} \cdot MPa$ 0=top 1=zijde 2=bod

$S_{y\_a1} := S_Q^{<1>} + S_{l\_a1}^{<1>}$ $\quad S_{y\_a1} = \begin{pmatrix} 44.07 \\ -45.305 \\ 55.825 \end{pmatrix} \cdot MPa$ 0=top 1=zijde 2=bod

$S_{x\_c} := S_{b\_c} \cdot c$ $\quad S_{x\_c} = \begin{pmatrix} -8.721 \\ 0 \\ 8.721 \end{pmatrix} \cdot MPa$ 0=top 1=zijde 2=bod

$S_{y\_c} := S_Q^{<1>} + S_{l\_c}^{<1>}$ $\quad S_{y\_c} = \begin{pmatrix} 42.595 \\ -43.597 \\ 53.272 \end{pmatrix} \cdot MPa$ 0=top 1=zijde 2=bod

FASE III Bovenbelasting, Uitvoeringszakking + Inw. Druk

$S_{x\_a} := S_{pl} + S_{b\_a} \cdot c$ $\quad S_{x\_a} = \begin{pmatrix} 59.71 \\ 46.573 \\ 33.436 \end{pmatrix} \cdot MPa$ 0=top 1=zijde 2=bod

$S_{y\_a} := S_p + S_Q^{<0>} + S_{l\_a}^{<0>}$ $\quad S_{y\_a} = \begin{pmatrix} 191.911 \\ 117.487 \\ 201.908 \end{pmatrix} \cdot MPa$ 0=top 1=zijde 2=bod

$S_{x\_a1} := S_{pl} + S_{b\_a1} \cdot c$ $\quad S_{x\_a1} = \begin{pmatrix} 59.976 \\ 46.573 \\ 33.17 \end{pmatrix} \cdot MPa$ 0=top 1=zijde 2=bod

$S_{y\_a1} := S_p + S_Q^{<0>} + S_{l\_a1}^{<0>}$ $\quad S_{y\_a1} = \begin{pmatrix} 191.53 \\ 117.927 \\ 201.253 \end{pmatrix} \cdot MPa$ 0=top 1=zijde 2=bod

$S_{x\_c} := S_{pl} + S_{b\_c} \cdot c$ $\quad S_{x\_c} = \begin{pmatrix} 37.852 \\ 46.573 \\ 55.294 \end{pmatrix} \cdot MPa$ 0=top 1=zijde 2=bod

$S_{y\_c} := S_p + S_Q^{<0>} + S_{l\_c}^{<0>}$ $\quad S_{y\_c} = \begin{pmatrix} 190.225 \\ 119.439 \\ 198.993 \end{pmatrix} \cdot MPa$ 0=top 1=zijde 2=bod

FASE IV Bovenbelasting, Uitv. zakking, Inw. druk + temp. stijging

$S_{x\_a} := S_{pl} + S_{b\_a} \cdot c - S_t$

$$S_{x\_a} = \begin{pmatrix} -194.185 \\ -207.322 \\ -220.459 \end{pmatrix} \cdot MPa$$

0=top
1=zijde
2=bod

$$S_{y\_a} = \begin{pmatrix} 191.911 \\ 117.487 \\ 201.908 \end{pmatrix} \cdot MPa$$

0=top
1=zijde
2=bod

$S_{x\_a1} := S_{pl} + S_{b\_a1} \cdot c - S_t$

$$S_{x\_a1} = \begin{pmatrix} -193.919 \\ -207.322 \\ -220.725 \end{pmatrix} \cdot MPa$$

0=top
1=zijde
2=bod

$$S_{y\_a1} = \begin{pmatrix} 191.53 \\ 117.927 \\ 201.253 \end{pmatrix} \cdot MPa$$

0=top
1=zijde
2=bod

$S_{x\_c} := S_{pl} + S_{b\_c} \cdot c - S_t$

$$S_{x\_c} = \begin{pmatrix} -216.043 \\ -207.322 \\ -198.601 \end{pmatrix} \cdot MPa$$

0=top
1=zijde
2=bod

$$S_{y\_c} = \begin{pmatrix} 190.225 \\ 119.439 \\ 198.993 \end{pmatrix} \cdot MPa$$

0=top
1=zijde
2=bod

$S_t := \alpha_g \cdot \delta T2 \cdot E$ $\quad S_t = 253.895 \cdot MPa$

FASE V Bovenbelasting, Uitv. zakking, Inw. druk + temp. daling

$S_{x\_a} := S_{pl} + S_{b\_a} \cdot c - S_t$

$$S_{x\_a} = \begin{pmatrix} -194.185 \\ -207.322 \\ -220.459 \end{pmatrix} \cdot MPa$$

0=top
1=zijde
2=bod

$S_{x\_a1} := S_{pl} + S_{b\_a1} \cdot c - S_t$

$$S_{x\_a1} = \begin{pmatrix} -193.919 \\ -207.322 \\ -220.725 \end{pmatrix} \cdot MPa$$

0=top
1=zijde
2=bod

$S_{x\_c} := S_{pl} + S_{b\_c} \cdot c - S_t$

$$S_{x\_c} = \begin{pmatrix} -216.043 \\ -207.322 \\ -198.601 \end{pmatrix} \cdot MPa$$

0=top
1=zijde
2=bod

STRESS ANALYSIS OF BURIED PIPELINE

"VELDSTREKKING" ACCORDING NEN3650

Date: Zo 20-Jan-2002
Time: 16:19:04

Project: IMPROVEMENTS OF FUTURE DEVELOPMENTS
Jobnr: PV2002

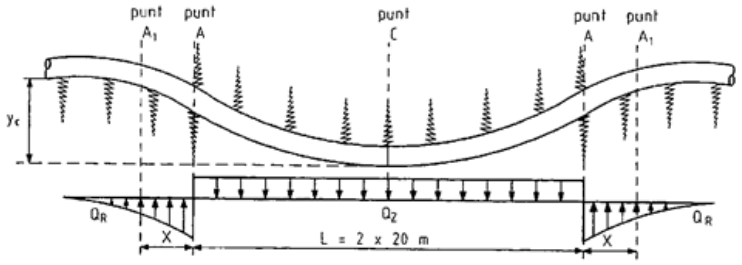
Resultaten op punt a, a1 en c voor:

Fase I
Fase II
Fase III
Fase IV
Fase V

$$Sv\_top\_a = \begin{bmatrix} 42.574 \\ 39.601 \\ 170.106 \\ 334.371 \\ 334.371 \end{bmatrix} \cdot MPa \qquad Sv\_side\_a = \begin{bmatrix} 43.578 \\ 45.803 \\ 102.472 \\ 284.856 \\ 284.856 \end{bmatrix} \cdot MPa \qquad Sv\_bott\_a = \begin{bmatrix} 53.255 \\ 64.151 \\ 187.44 \\ 365.898 \\ 365.898 \end{bmatrix} \cdot MPa$$

$$Sv\_top\_a1 = \begin{bmatrix} 42.574 \\ 39.129 \\ 169.687 \\ 333.81 \\ 333.81 \end{bmatrix} \cdot MPa \qquad Sv\_side\_a1 = \begin{bmatrix} 43.578 \\ 45.305 \\ 102.877 \\ 285.198 \\ 285.198 \end{bmatrix} \cdot MPa \qquad Sv\_bott\_a1 = \begin{bmatrix} 53.255 \\ 63.596 \\ 186.889 \\ 365.573 \\ 365.573 \end{bmatrix} \cdot MPa$$

$$Sv\_top\_c = \begin{bmatrix} 42.574 \\ 47.559 \\ 174.407 \\ 352.075 \\ 352.075 \end{bmatrix} \cdot MPa \qquad Sv\_side\_c = \begin{bmatrix} 43.578 \\ 43.597 \\ 104.27 \\ 286.375 \\ 286.375 \end{bmatrix} \cdot MPa \qquad Sv\_bott\_c = \begin{bmatrix} 53.255 \\ 49.491 \\ 177.911 \\ 344.327 \\ 344.327 \end{bmatrix} \cdot MPa$$



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