

Pile design

	Pile design using Swedish P-y curves	Status :	Page : 1
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## Appendix

1. STRAIGHT PILE: Input receipt
2. IMPERFECT PILE: Input receipt

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## **1. GENERAL**

A steel pile is evaluated using a non-linear analysis.

The pile pinned a bottom and is unrestrained at top.

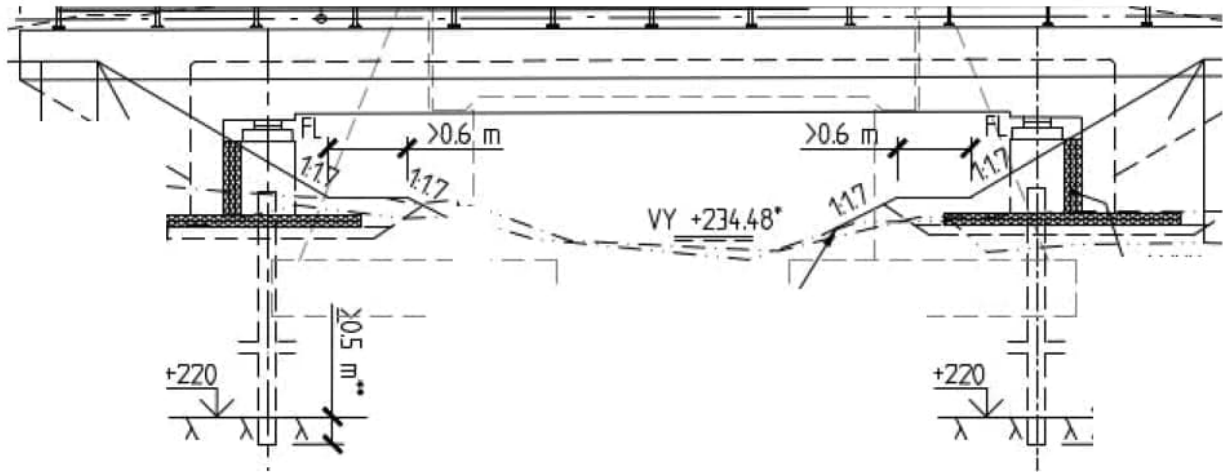
The movement of superstructure due to movements results in forced translation ( $\delta_H$ ).

An eccentric imperfection ( $e_{exc}$ ) when installing bearings relative to piles is considered.

Also imperfection of piles ( $\delta_0$ ) is considered.

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## 1.1 OVERVIEW

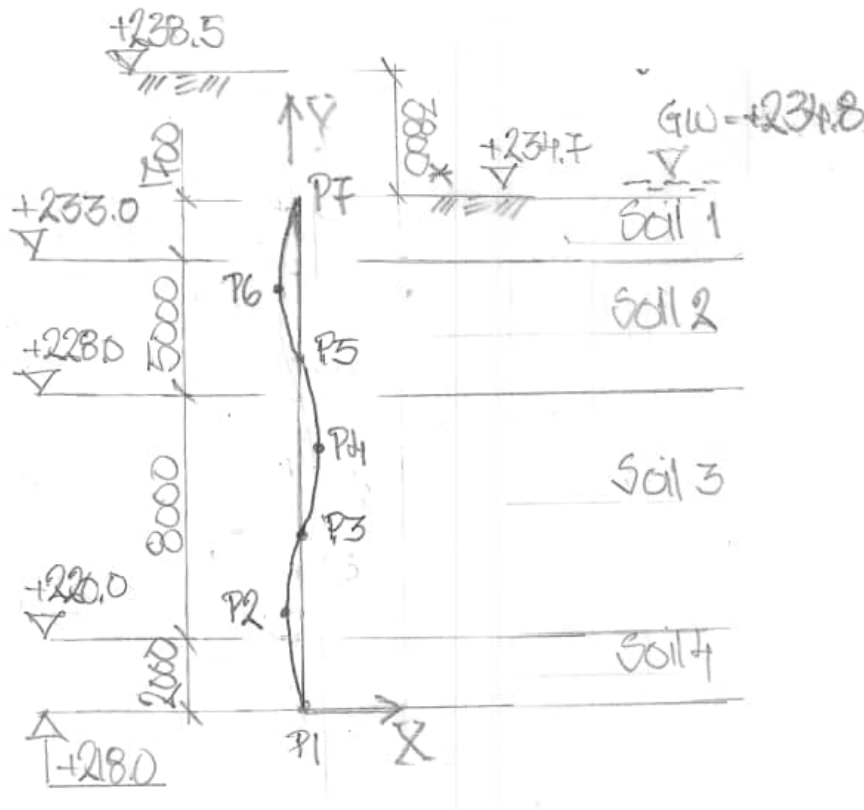


### ELEVATION

FL = Fixed bearings

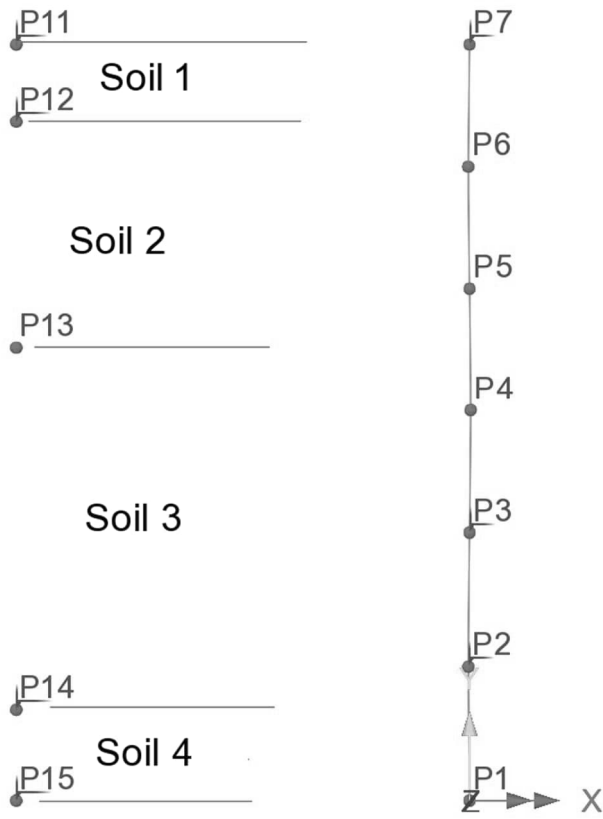
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## 1.2 Soil material



Soil	H	$\gamma$	$\gamma'$	Stiffness	Material
1	1.7	18	10	"Mycket låg"	"Sand"
2	5.0	20	13	"Medelhög"	"Sandig morän"
3	8.0	20	13	"Medelhög"	"Grusig morän"
4	2.0	20	13	"Hög"	"Blockig morän"
-	m	kN/m <sup>3</sup>	kN/m <sup>2</sup>	-	-

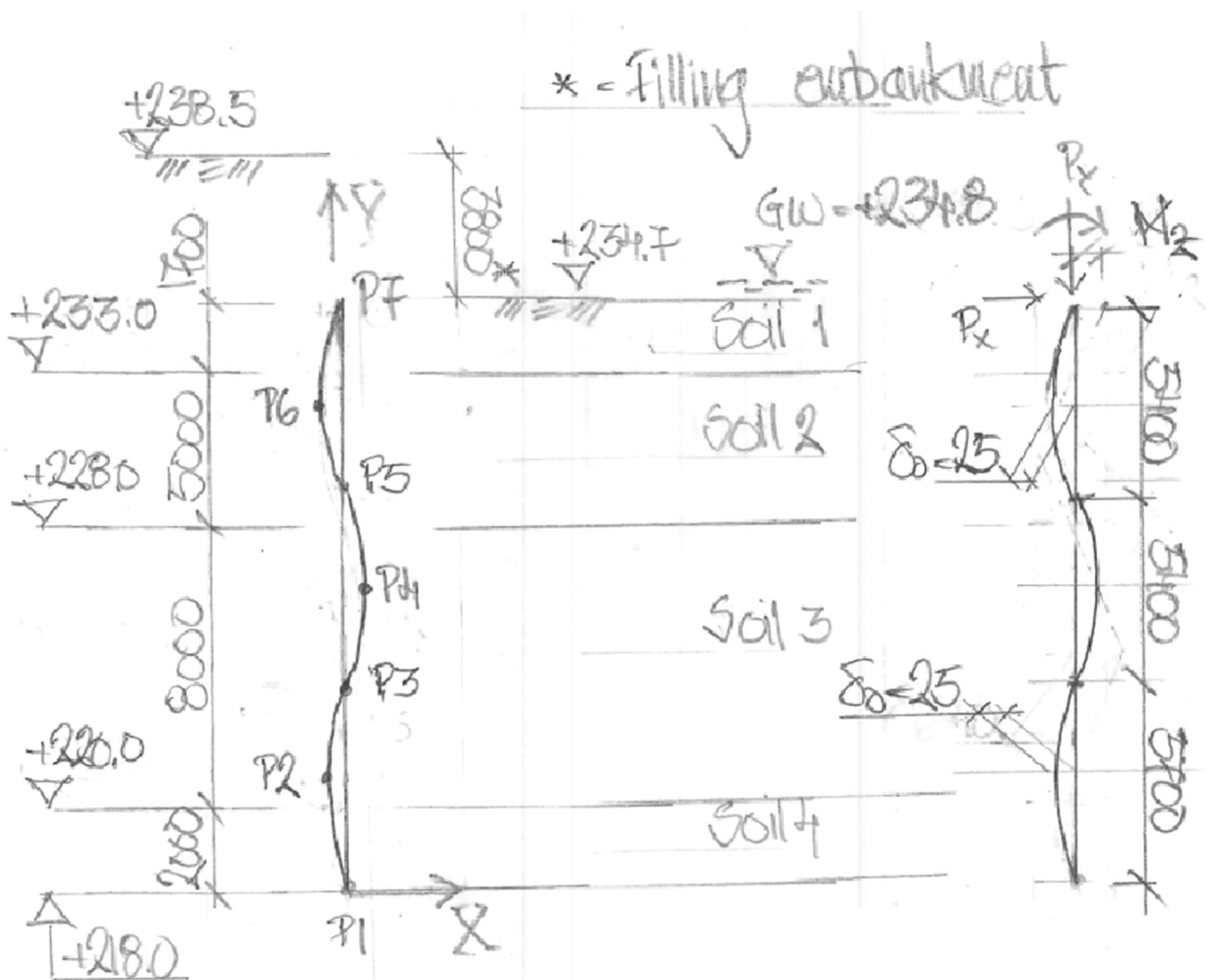
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### 1.3 PILE IMPERFECTIONS

Assumed pile imperfections.



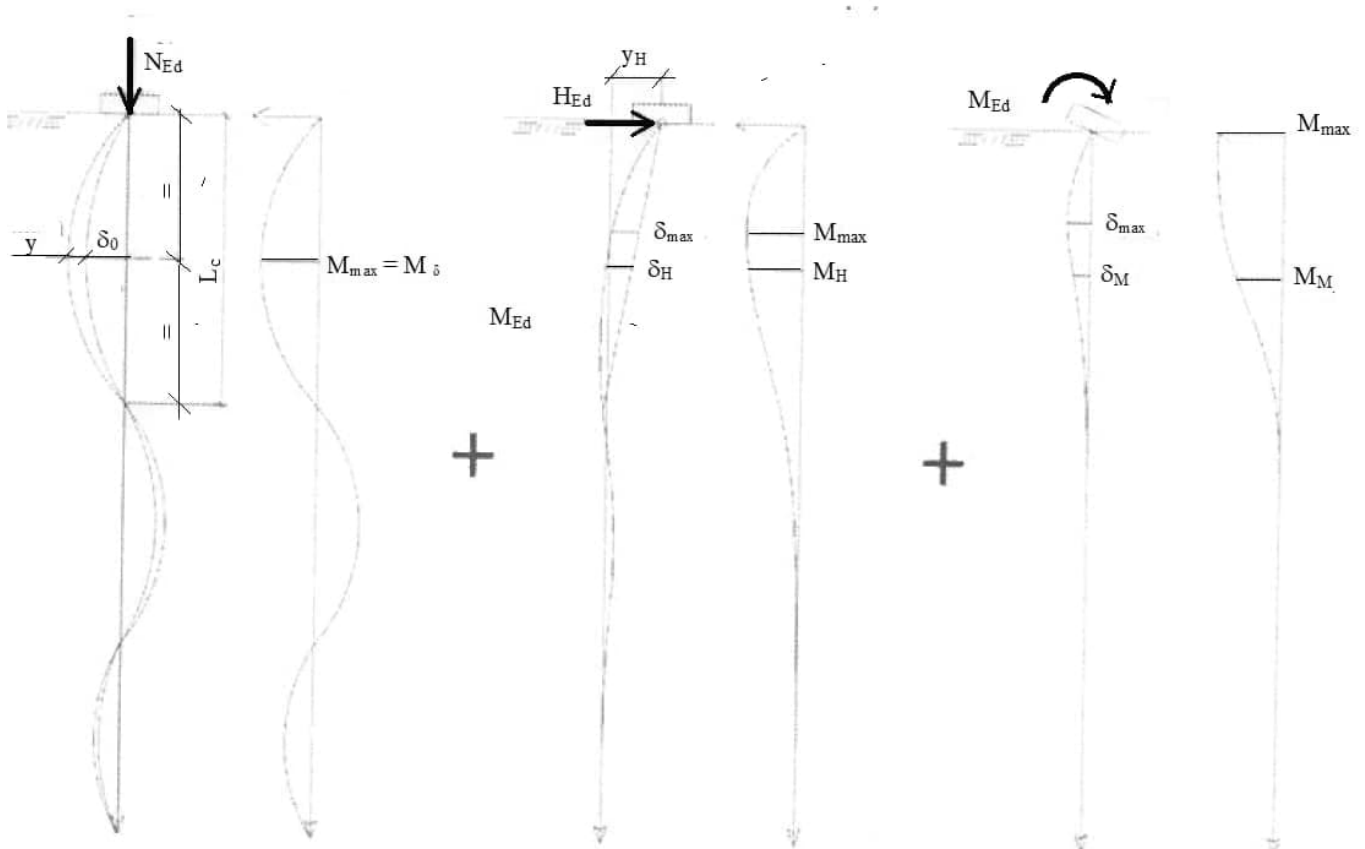
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		Date :	Created :

## 1.4 GEOTECHNICAL THEORY

Below are the effects of initial imperfections ( $\delta_0$ ), horizontal force ( $H_{Ed}$ ) and moment ( $M_{Ed}$ ). What is seen is that  $M_{max}$  do not act a same location.

It can also be seen that soil resistance is lowest at top of pile where  $H_{Ed}$  and  $M_{Ed}$  are acting. Generally, soil reaches maximal pressure (yield strength) near top of pile since load effect is highest and soil strength is often weakest. Once the load effect reaches yield strength no additional lateral soil force will act, thus initial imperfections will give less contribution to design load effect since  $M_{max}$  is located lower than for horizontal force and moment.

Two analyses will be performed to verify this assumption. The first analysis is without initial imperfections and the second including.



Initial imperfection

Horizontal force  
( $y_H \rightarrow H_{Ed}$ )

Moment  
( $M_{Ed} = N_{Ed} \cdot e_{exc}$ )

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### 1.5 Swedish P-y curves

P-y curves are determined using TRVINFRA-00227 appendix 3.

Since soil height varies on either side of pile due to embankment both are considered.

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### 1.5.1 Lateral stiffness

$$K = \min(k_k \cdot d; K_{max}) = \min(n_h \cdot z; K_{max}) \left[ \frac{kN}{m^2} \right]$$

#### Excluding embankment

Soil	z	n <sub>h</sub>	K <sub>max</sub>	n <sub>h</sub> · z	K
1	0	1500	2.40	0	0
-"-	1.7	1500	2.40	2.55	2,40
2	1.7	4500	18.00	7.65	4,50
-"-	4.0	4500	18.00	18.00	18,00
-"-	4.2	4500	18.00	18.90	18.00
-"-	6.7	4500	18.00	30.15	18,00
3	6.7	4500	18.00	30.15	18,00
-"-	10.7	4500	18.00	48.15	18,00
-"-	14.7	4500	18.00	66.15	18,00
4	14.7	7500	30.00	66.15	30,00
-"-	16.7	7500	30.00	125.25	30,00
-	m	kN/m <sup>3</sup>	kN/m <sup>2</sup>	MN/m <sup>2</sup>	MN/m <sup>2</sup>

#### Including embankment (h = 3.8 m)

Soil	z	n <sub>h</sub>	K <sub>max</sub>	n <sub>h</sub> · z	K
1	3.8	1500	2.40	5.70	2,40
-"-	5.5	1500	2.40	8.25	2,40
2	5.5	4500	18.00	24.75	18,00
-"-	8.0	4500	18.00	36.00	18,00
-"-	10.5	4500	18.00	47.25	18,00
3	10.5	4500	18.00	47.25	18,00
-"-	15.5	4500	18.00	69.75	18,00
-"-	18.5	4500	18.00	83.25	18,00
4	18.5	7500	30.00	138.75	30,00
-"-	20.5	7500	30.00	153.75	30,00
-	m	kN/m <sup>3</sup>	kN/m <sup>2</sup>	MN/m <sup>2</sup>	kN/m <sup>2</sup>

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### 1.5.2 Maximum soil pressure

$$q_k = 3K_p \cdot \sigma'_v \left[ \frac{kN}{m^2} \right]$$

#### Excluding embankment

Soil	z	$\phi_k$	$K_p$	$\sigma'_v$	$q_k$	$F = d \cdot q_k$
1	0	26.7	2.63	0	0	0
-"	1.7	26.7	2.63	17	134	43
2	1.7	29.1	2.89	17	147	47
-"	4.2	29.1	2.89	50	429	136
-"	6.7	29.1	2.89	82	710	226
3	6.7	28.5	2.82	82	693	221
-"	10.7	28.5	2.82	134	1133	362
-"	14.7	28.5	2.82	186	1573	502
4	14.7	42.0	5.05	186	2817	899
-"	16.7	42.0	5.05	212	3212	1025
-	m	deg	kN/m <sup>2</sup>	kN/m <sup>2</sup>	kN/m <sup>2</sup>	kN/m

#### Including embankment (h = 3.8 m)

Soil	z	$\phi_k$	$K_p$	$\sigma'_v$	$q_k$	$F = d \cdot q_k$
1	3.8	26.7	2.63	76*	599	191
-"	5.5	26.7	2.63	93	733	234
2	5.5	29.1	2.89	93	806	257
-"	8.0	29.1	2.89	75	1088	347
-"	10.5	29.1	2.89	158	1369	437
3	10.5	28.5	2.82	158	1337	427
-"	14.5	28.5	2.82	210	1777	567
-"	18.5	28.5	2.82	262	2216	707
4	18.5	42.0	5.05	262	3969	1266
-"	20.5	42.0	5.05	288	4363	1392
-	m	deg	kN/m <sup>2</sup>	kN/m <sup>2</sup>	kN/m <sup>2</sup>	kN/m

$$* = 3.8 \text{ m} \cdot 20 \frac{kN}{m^3} = 76 kPa$$

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## 2. SYSTEM ANALYSIS

### 2.1 GENERAL

The pile structure is modelled in 2D using FEM-program.

The pile is modelled using 2D beam elements (BMI2).

Soil is modelled using non-linear springs (JNT3).

The pile is considered pinned at bottom and free at top.

Two models are studied as seen below.

Modell	Imperfections
Pile_straight	No
Pile_spline	Yes

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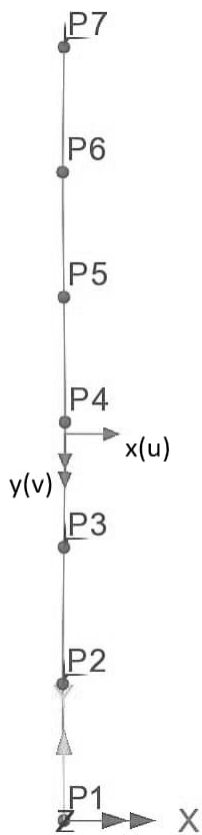
## 2.2 SKETCH SYSTEM ANALYSIS

### 2.2.1 Geometry

Points (P1-P7) and line (L1-L6) including coordinate systems.

*Global: X-Y-Z*

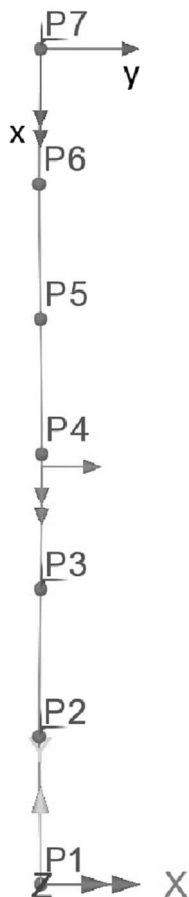
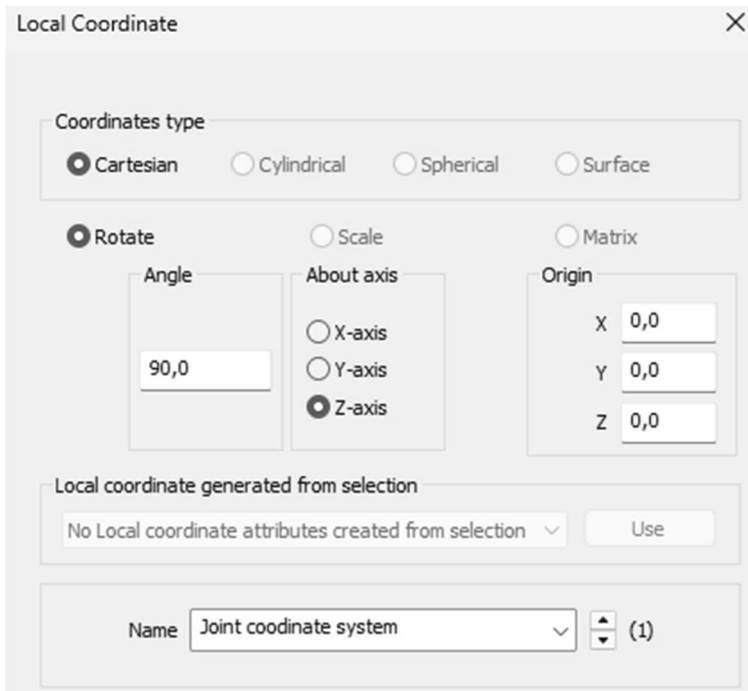
*Local line coordinate system: x-y*



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### 2.2.2 Local coordinate system

Due to imperfections the *Local line coordinate system*: x-y can not be used for definition joint elements, thus coordinate system Joint coordinate system is created.



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### 2.2.3 Cross section properties

The properties include the effect of concrete (C35/45) and corrosion ( $t_r$ ) of pile ( $\phi 323.9 \times 12.5$ ).

$$d = D - 2t_{rm} = 323.9 - 2 \times 2.4 \text{ mm} = 319 \text{ mm}$$

$$A = 9.805 \cdot 10^{-3} \text{ m}^2$$

$$I = 1.406 \cdot 10^{-4} \text{ m}^4$$

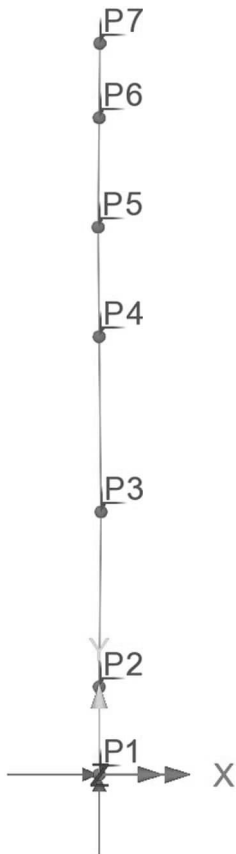
$$E_{sk} = 210 \text{ GPa} \quad \rightarrow E = \frac{\alpha_s \cdot \mu_s \cdot E_{sk}}{\gamma_{M0}} = \frac{0.9 \cdot 1.0 \cdot 210 \text{ GPa}}{1.0} = 189 \text{ GPa}$$

-

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### 2.2.4 Boundary

Pile is pinned at bottom (P1).



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### 2.2.5 MESH: Beam element (BMI2)

Pile is modelled as thick beam as seen below.

Name	Element length	End release: Start	End release: End
Pile	0.5 m	None	None



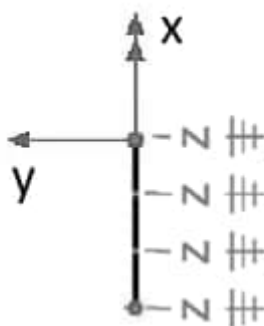
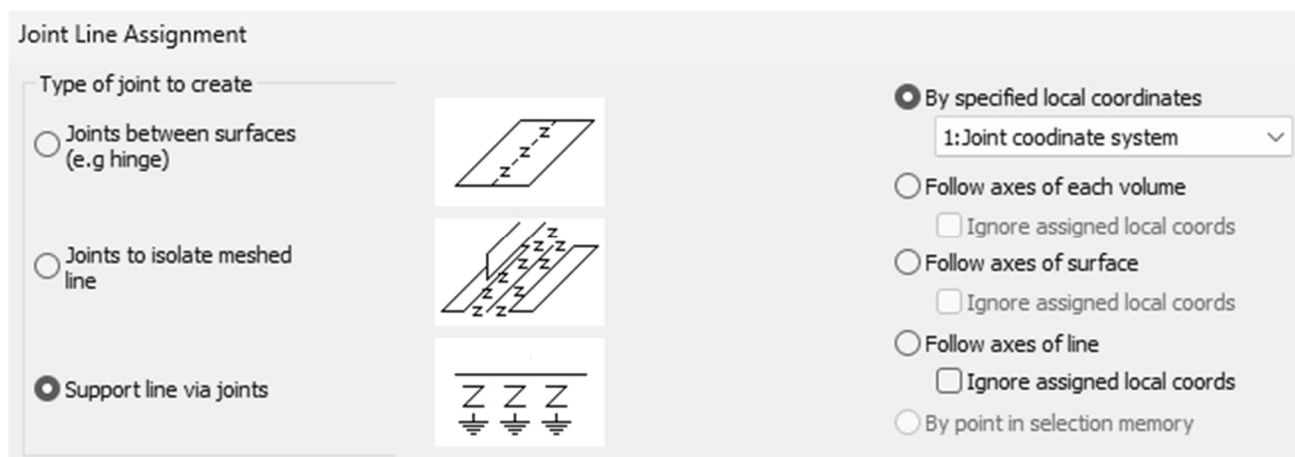
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### 2.2.6 Joint element between lines (JNT3 )

Connection between soil and pile is of type joint element, see presentation below. The joint has no rotational stiffness in order achieve a hinge.

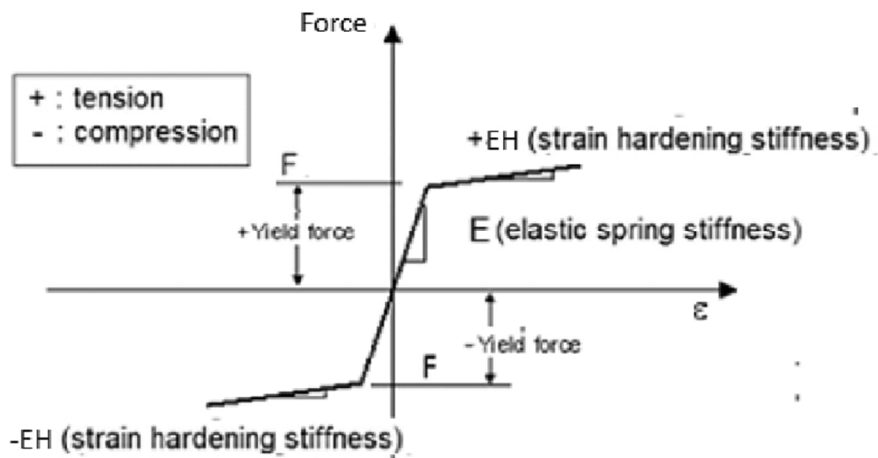
The joint uses nonlinear material termed *Elasto-Plastic (Tension and Compression Equal)*. They vary along pile. This is handled using *Line Variation*.

The joint are introduced as same location as nodes along beam element.



### Principle sketch

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The properties “E” and “F” are vary over distance. This is handled by introducing a line variation.

### Remark

Since lateral resistance is higher excluding embankment, this is used in system analysis since weaker soil material generates more load effect in pile.

### 2.2.6.1 Elastic spring stiffness (Elastic spring stiffness $\therefore$ E)

See page 7 (excluding embankment).

Line Variation

Type: Interpolation

Specify order

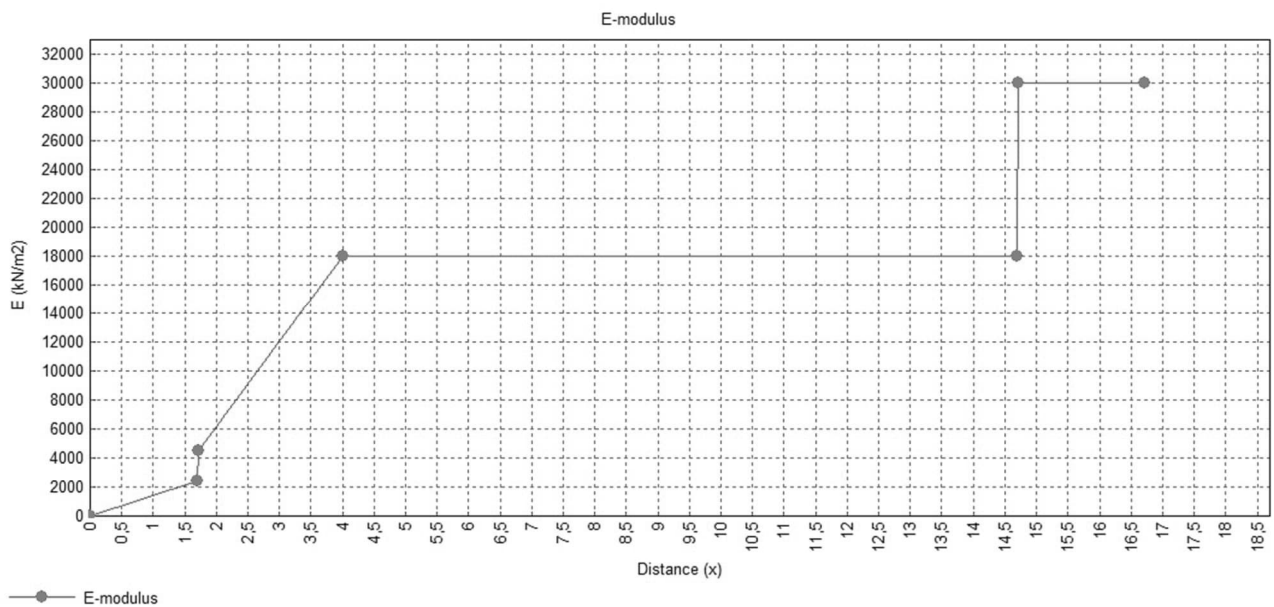
Order: Linear

Equal spacing assumed

Distance type: Actual

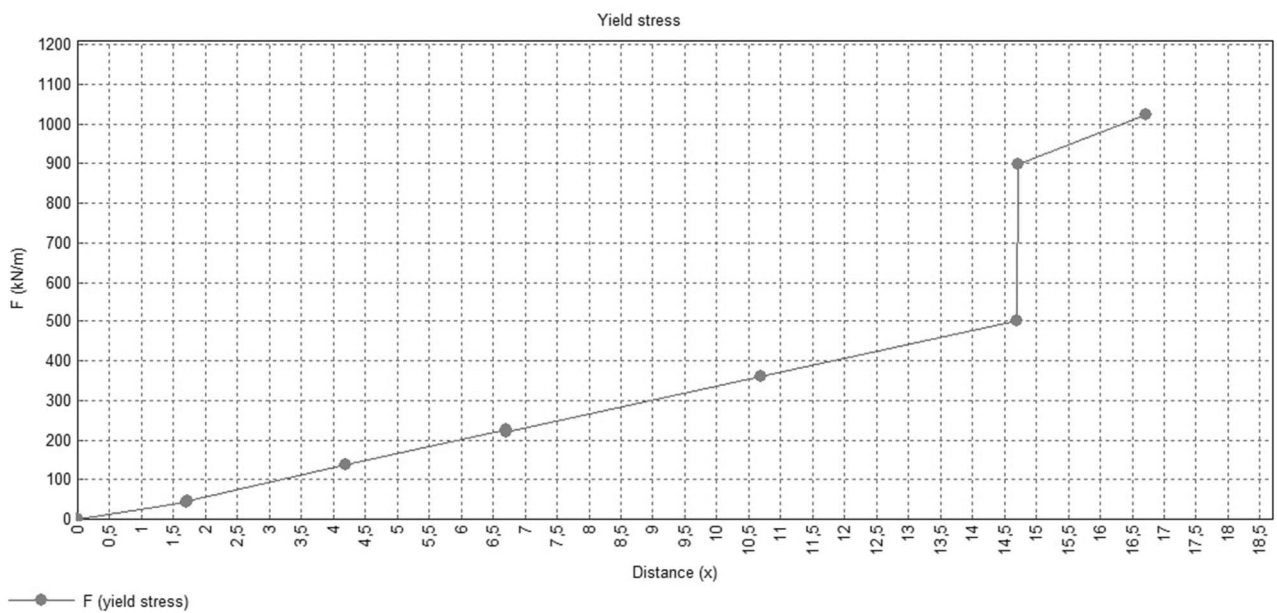
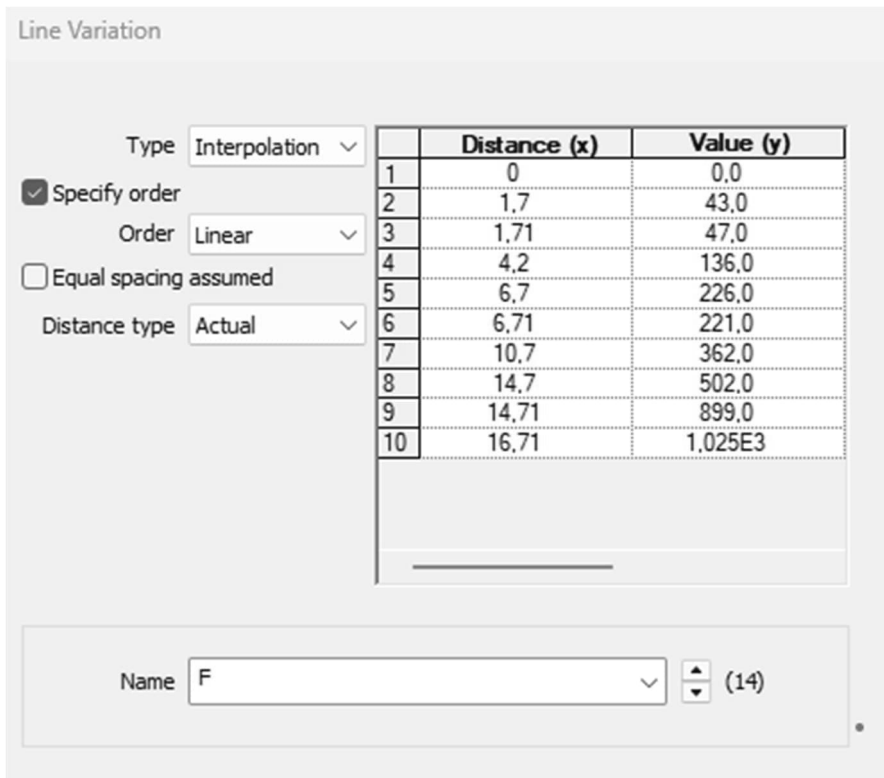
	Distance (x)	Value (y)
1	0	0,0
2	1,7	2,4E3
3	1,71	4,5E3
4	4	18,0E3
5	4,2	18,0E3
6	6,7	18,0E3
7	6,71	18,0E3
8	10,7	18,0E3
9	14,7	18,0E3
10	14,71	30,0E3
11	16,71	30,0E3

Name: E  (1)



### 2.2.6.2 Maximum soil pressure (Yield force $\therefore$ F)

See page 8 (excluding embankment).

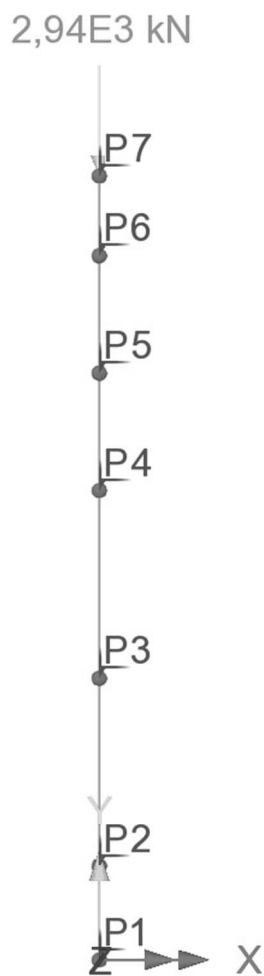


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### 3. LOADS

#### 3.1 VERTICAL LOAD

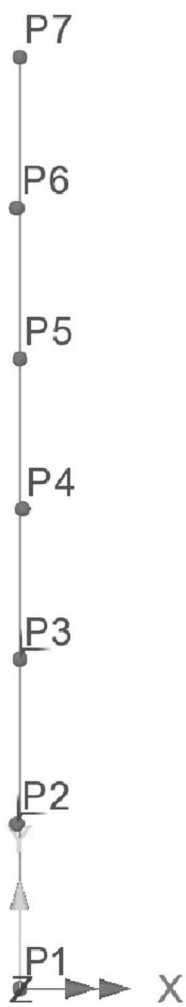
$N_{Ed} = 2940 \text{ kN}$



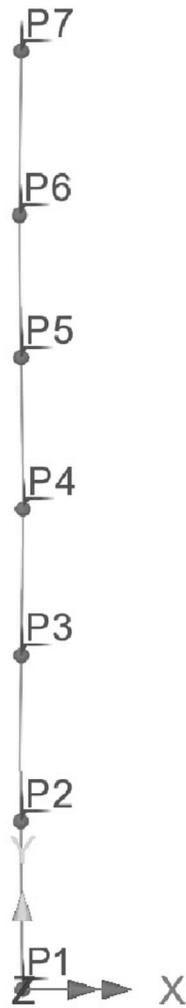
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### 3.2 INITIAL IMPERFECTIONS

Two models are studied. Either with or without imperfections, see page 3.



Straight pile



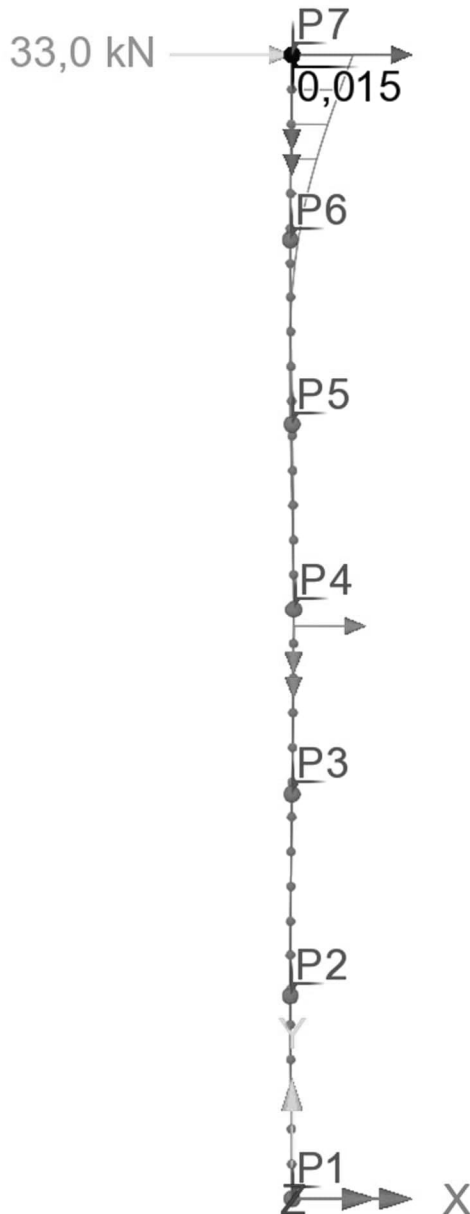
Spline pile

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### 3.3 HORIZONTAL LOAD

The horizontal load acts due to movement ( $y_H$ ) of superstructure.

$$y_H = 15 \text{ mm} \rightarrow H_{Ed} = 33 \text{ kN}$$



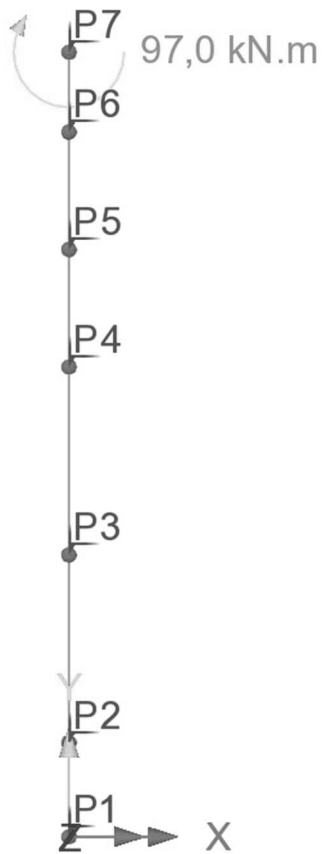
Scale: 1: 177,432  
Zoom: 100,0  
Eye: (-3,52589E-3; 3,20537E-3; 0,999989)  
Nonlinear analysis  
Analysis: Analysis 1  
Loadcase: 2:Loadcase 1, 1:Increment 1  
Results file: t2~Analysis 1.mys  
Maximum displacement 0,0151696 at node 1  
Deformation exaggeration: 58,4828  
Peak/value entity: Displacement  
Peak/value component: DX (Units: m)  
Peak range(%): 100,0  
Peak/value maximum 0,0151691 at node 1  
Peak/value minimum -0,44968E-3 at node 12

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### 3.4 MOMENT LOAD

The moment load arises due to excentric bearing load.

$$e_{exc} = 33 \text{ mm} \rightarrow M_{Ed} = e_{exc} \cdot N_{Ed} = 0.033 \text{ m} \cdot 2940 \text{ kN} = 97 \text{ kNm}$$



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## 4. SUMMARY RESULTS

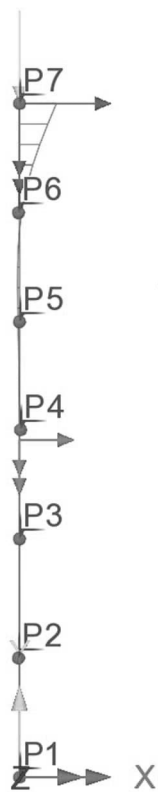
### 4.1 STRAIGHT PILE

See appendix 1 (∴ Pile\_straight).

#### 4.1.1 Buckling load

$$N_{cr} = s \cdot N_{Ed} = 2.208 \cdot 2940 \text{ kN} = 6491 \text{ kN}$$

2,94E3 kN



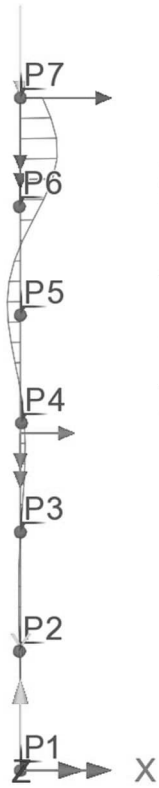
Scale: 1: 182,714  
Zoom: 79,7194  
Eye: (-3,52589E-3; 3,20537E-3; 0,999989)  
Eigenvalue analysis  
Analysis: Analysis 2  
Loadcase: 3:Loadcase 2, 2:Mode 1 Load Factor = 2.20759  
Results file: Pile\_straight~Analysis 2.mys  
Eigenvalue: 2,20759  
Natural frequency: 0,236472  
Error norm: 0,168023E-12  
Maximum displacement 1,0 at node 1  
Deformation exaggeration: 0,913568

### Mode 1

Load factor 2.208

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2,94E3 kN



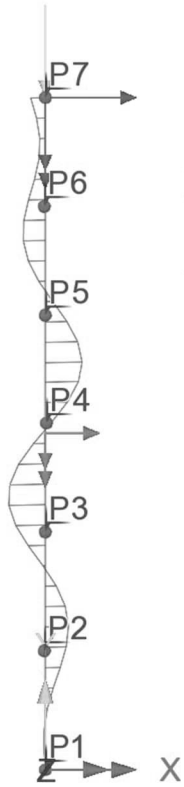
Scale: 1: 182,714  
Zoom: 79,7194  
Eye: (-3,52589E-3; 3,20537E-3; 0,999989)  
Eigenvalue analysis  
Analysis: Analysis 2  
Loadcase: 3:Loadcase 2, 2:Mode 2 Load Factor = 12.1031  
Results file: Pile\_straight~Analysis 2.mys  
Eigenvalue: 12,1031  
Natural frequency: 0,553693  
Error norm: 25,0926E-12  
Maximum displacement 1,0 at node 5  
Deformation exaggeration: 0,913568

Mode 2

Load factor 12.103

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2,94E3 kN



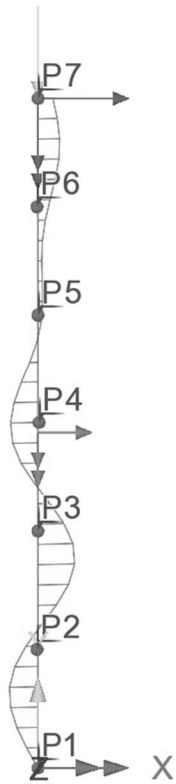
Scale: 1: 182,714  
Zoom: 79,7194  
Eye: (-3,52589E-3; 3,20537E-3; 0,999989)  
Eigenvalue analysis  
Analysis: Analysis 2  
Loadcase: 3:Loadcase 2, 2:Mode 3 Load Factor = 15.8698  
Results file: Pile\_straight~Analysis 2.mys  
Eigenvalue: 15,8698  
Natural frequency: 0,634024  
Error norm: 2,55508E-9  
Maximum displacement 1,0 at node 15  
Deformation exaggeration: 0,913568

Mode 3

Load factor 15.870

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2,94E3 kN



Scale: 1: 182,714  
Zoom: 79,7194  
Eye: (-3,52589E-3; 3,20537E-3; 0,999989)  
Eigenvalue analysis  
Analysis: Analysis 2  
Loadcase: 3:Loadcase 2, 2:Mode 4 Load Factor = 16.1768  
Results file: Pile\_straight~Analysis 2.mys  
Eigenvalue: 16,1768  
Natural frequency: 0,640128  
Error norm: 25,5365E-9  
Maximum displacement 1,0 at node 25  
Deformation exaggeration: 0,913568

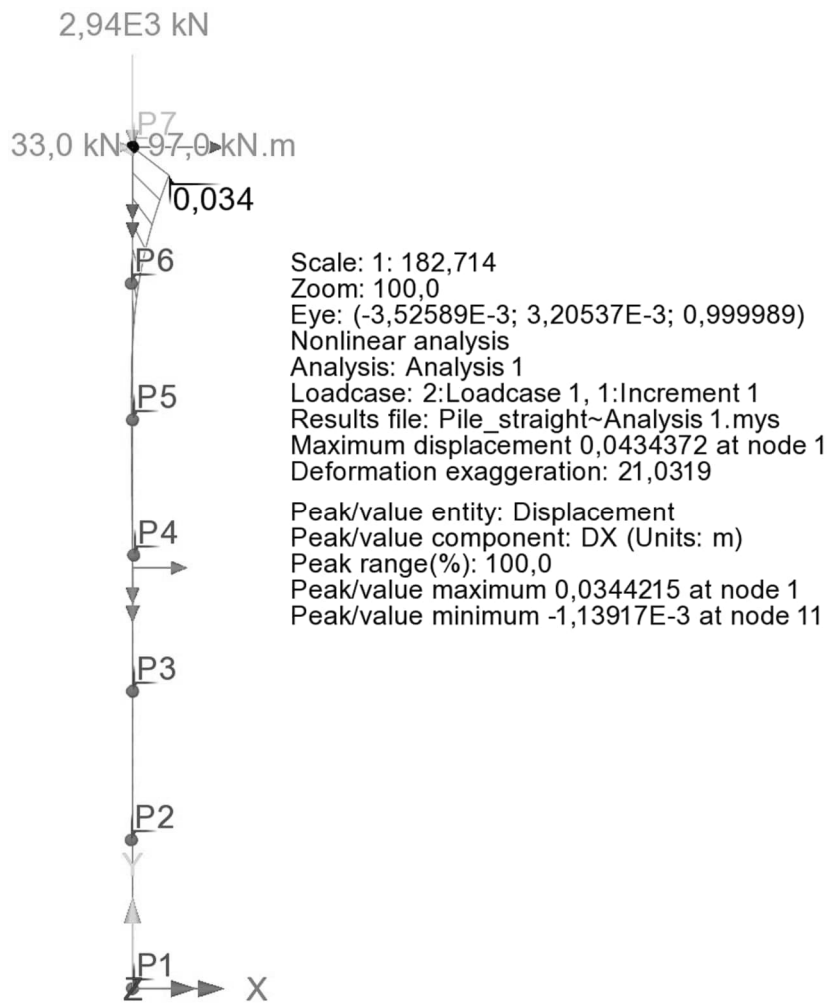
Mode 4

Load factor 16.177

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#### 4.1.2 Deformations

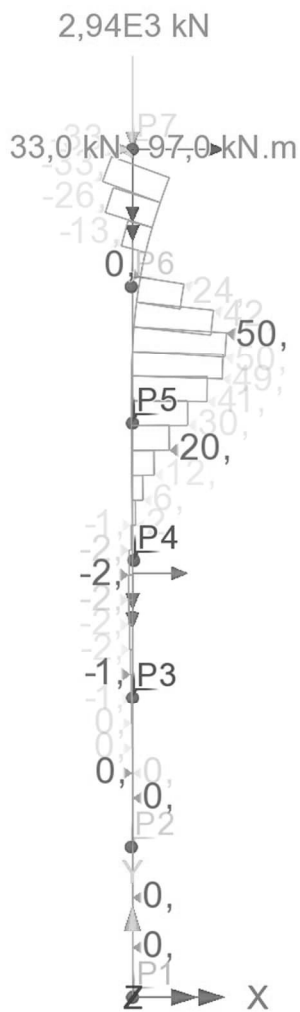
$$N_{Ed} = 2940\text{kN}, H_{Ed} = 33\text{kN} \ \& \ M_{Ed} = 97\text{kNm} \ \rightarrow \max Dx = 34 \text{ mm}$$



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#### 4.1.3 Shear forces: $F_y$

$$N_{Ed} = 2940\text{kN}, H_{Ed} = 33\text{kN} \ \& \ M_{Ed} = 97\text{kNm} \ \rightarrow \max F_y = 50\text{ kN}$$



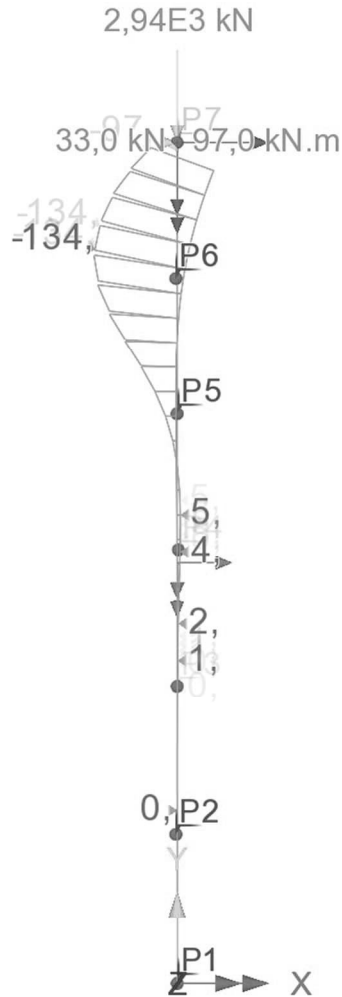
Scale: 1: 182,714  
Zoom: 100,0  
Eye: (-3,52589E-3; 3,20537E-3; 0,999989)  
Nonlinear analysis  
Analysis: Analysis 1  
Loadcase: 2:Loadcase 1, 1:Increment 1  
Results file: Pile\_straight~Analysis 1.mys  
Maximum displacement 0,0434372 at node 1  
Deformation exaggeration: 21,0319

Diagram entity: Force/Moment - Thick 2D Beam  
Diagram component:  $F_y$  (Units: kN)  
Diagram maximum 49,8239 at node 8 of element 7  
Diagram minimum -32,9129 at node 1 of element 1  
Diagram scale: 1: 0,200707  
Peak/value entity: Displacement  
Peak/value component: DX (Units: m)  
Peak range(%): 100,0  
Peak/value maximum 0,0344215 at node 1  
Peak/value minimum -1,13917E-3 at node 11

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#### 4.1.4 Moment: Mz

$$N_{Ed} = 2940\text{kN}, H_{Ed} = 33\text{kN} \ \& \ M_{Ed} = 97\text{kNm} \ \rightarrow \max Mz = 134\text{ kNm}$$



Scale: 1: 182,714  
Zoom: 100,0  
Eye: (-3,52589E-3; 3,20537E-3; 0,999989)  
Nonlinear analysis  
Analysis: Analysis 1  
Loadcase: 2:Loadcase 1, 1:Increment 1  
Results file: Pile\_straight~Analysis 1.mys  
Maximum displacement 0,0434372 at node 1  
Deformation exaggeration: 21,0319

Diagram entity: Force/Moment - Thick 2D Beam  
Diagram component: Mz (Units: kN.m)  
Diagram maximum 5,00919 at Internal point 10 of element  
Diagram minimum -133,813 at node 5 of element 3  
Diagram scale: 1: 0,0747313  
Peak/value entity: Force/Moment - Thick 2D Beam  
Peak/value component: Mz (Units: kN.m)  
Peak range(%): 100,0  
Peak/value maximum 5,0999 at node 16 of element 14  
Peak/value minimum -133,861 at node 6 of element 4

	Pile design using Swedish P-y curves	Status :	Page : 32
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## 4.2 INITIALLY IMPERFECT PILE

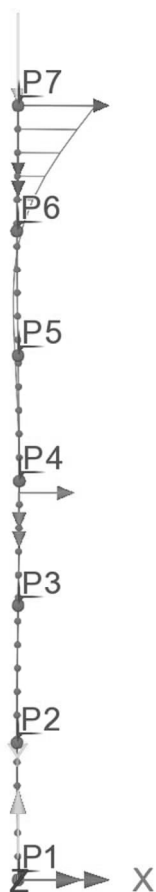
See appendix 2 (.: Pile\_spline).

### 4.2.1 Buckling load

The buckling load is almost the same as straight pile, see value inside parenthesis.

$$N_{cr} = s \cdot N_{Ed} = 2.206 \cdot 2940 \text{ kN} = 6485 \text{ kN} (6491 \text{ kN})$$

2,94E3 kN



Scale: 1: 177,432  
Zoom: 89,2857  
Eye: (-3,52589E-3; 3,20537E-3; 0,999989)  
Eigenvalue analysis  
Analysis: Analysis 2  
Loadcase: 3:Loadcase 2, 2:Mode 1 Load Factor = 2.20556  
Results file: t2~Analysis 2.mys  
Eigenvalue: 2,20556  
Natural frequency: 0,236363  
Error norm: 0,146834E-12  
Maximum displacement 1,0 at node 1  
Deformation exaggeration: 1,66069  
Peak/value entity: Displacement  
Peak/value component: DX (Units: m)  
Peak range(%): 100,0  
Peak/value maximum 0,999971 at node 1  
Peak/value minimum -0,0536968 at node 11

### Mode 1

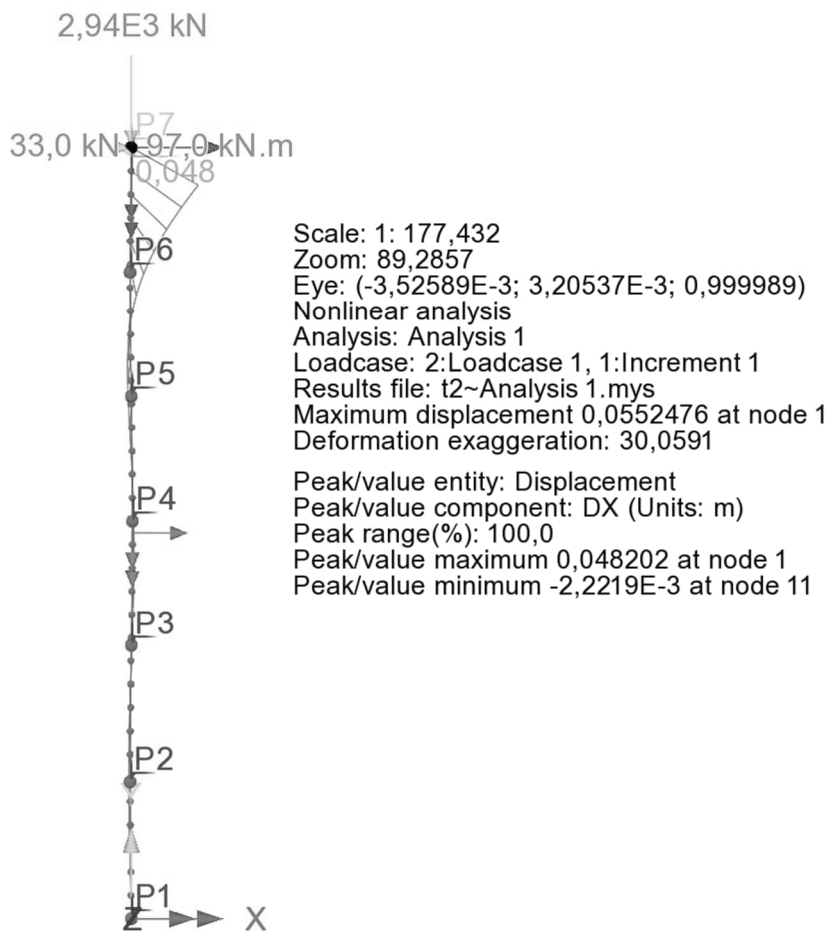
Load factor 2.206

	Pile design using Swedish P-y curves	Status :	Page : 33
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#### 4.2.2 Deformations

The deformation is almost twice as straight pile, see value inside parenthesis.

$$N_{Ed} = 2940\text{kN}, H_{Ed} = 33\text{kN} \ \& \ M_{Ed} = 97\text{kNm} \ \rightarrow \max Dx = 48 \text{ mm} \ (34 \text{ mm})$$

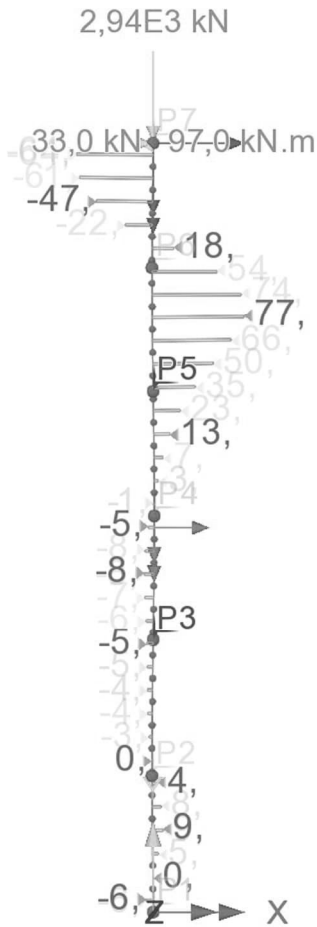


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### 4.2.3 Shear forces: Fy

The shear forces more than twice as straight pile, see value inside parenthesis.

$$N_{Ed} = 2940\text{kN}, H_{Ed} = 33\text{kN} \ \& \ M_{Ed} = 97\text{kNm} \ \rightarrow \max Fy = 77 \text{ kN} \ (50 \text{ kN})$$



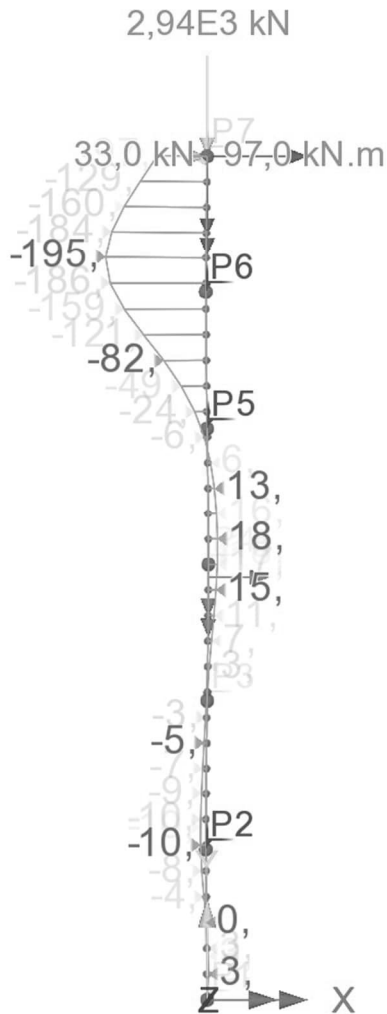
Scale: 1: 177,432  
Zoom: 89,2857  
Eye: (-3,52589E-3; 3,20537E-3; 0,999989)  
Nonlinear analysis  
Analysis: Analysis 1  
Loadcase: 2:Loadcase 1, 1:Increment 1  
Results file: t2~Analysis 1.mys

Diagram entity: Force/Moment - Thick 2D Beam  
Diagram component: Fy (Units: kN)  
Diagram maximum 76,5913 at node 9 of element 8  
Diagram minimum -63,6881 at node 1 of element 1  
Diagram scale: 1: 0,130563  
Peak/value entity: Force/Moment - Thick 2D Beam  
Peak/value component: Fy (Units: kN)  
Peak range(%): 100,0  
Peak/value maximum 75,495 at node 9 of element 7  
Peak/value minimum -63,6881 at node 1 of element 1

	Pile design using Swedish P-y curves	Status :	Page : 35
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#### 4.1.4 Moment: Mz

$$N_{Ed} = 2940\text{kN}, H_{Ed} = 33\text{kN} \ \& \ M_{Ed} = 97\text{kNm} \ \rightarrow \max Mz = 195\text{kNm} \ (134\text{kNm})$$



Scale: 1: 177,432  
Zoom: 89,2857  
Eye: (-3,52589E-3; 3,20537E-3; 0,999989)  
Nonlinear analysis  
Analysis: Analysis 1  
Loadcase: 2:Loadcase 1, 1:Increment 1  
Results file: t2~Analysis 1.mys  
Diagram entity: Force/Moment - Thick 2D Beam  
Diagram component: Mz (Units: kN.m)  
Diagram maximum 17,7971 at node 17 of element 15  
Diagram minimum -195,193 at node 6 of element 4  
Diagram scale: 1: 0,0512313  
Peak/value entity: Force/Moment - Thick 2D Beam  
Peak/value component: Mz (Units: kN.m)  
Peak range(%): 100,0  
Peak/value maximum 17,7971 at node 17 of element 15  
Peak/value minimum -195,193 at node 6 of element 4

	Pile design using Swedish P-y curves	Status :	Page : 36
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## 5. VERIFICATION CAPACITY

### 5.1 Bending moment

$$\frac{N_{Ed}}{N_{Rd}} + \frac{M_{Ed}}{M_{Rd}} = \frac{2940kN}{5393kN} + \frac{195kNm}{404kNm} \cong 1.0$$

### 5.2 Shear capacity

$$\frac{V_{Ed}}{V_{Rd}} = \frac{77kN}{1982kN} = 0.04 < 1.0$$

**Title: Input receipt**

**LUSAS version:** 23.0-1c3  
**Model Units:** kN,m,t,s,C  
**Report Units:** kN,m,t,s,C

**Model Title:**  
**Model File:** Pile straight

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## APPENDIX 1

### Points

Point	X coordinate	Y coordinate	Z coordinate
1	0,000	0,000	0,000
2	-0,025	2,950	0,000
3	0,000	5,900	0,000
4	0,025	8,600	0,000
5	0,000	11,300	0,000
6	-0,025	14,000	0,000
7	0,000	16,700	0,000
11	-10,000	16,700	0,000
12	-10,000	15,000	0,000
13	-10,000	10,000	0,000
14	-10,000	2,000	0,000
15	-10,000	0,000	0,000

APPENDIX 1

**Lines**

Line	Points	Line	Points
1	7:1		

### Line Mesh (Elements showing results)

**Attribute: 2 Title: Pile**

Sub Type = Line Mesh Element Type = BMI2

Mesh spacing	Element size	Start node end releases:	End node end releases:
Irregular	0,5	None	None

Assignment to Lines:

1

**Attribute: 4 Title: Joint element: soil**

Sub Type = Line Mesh Element Type = JNT3

Mesh spacing	Start node end releases:	End node end releases:
Uniform	None	None

Assignment to Lines: Local Coordinates = Joint coordinate system (Local x is joint x), Single feature insertion type : grounded

1

APPENDIX 1

Attribute: 1 Title: Pile

Sub Type = Line Geometric

Assigned in: Analysis 1

Property	Symbol	Value
Cross sectional area	A	0,010
Second moment of area about y axis	Iyy	0,000
Second moment of area about z axis	Izz	0,000
Product moment of area	Iyz	0,000
Torsional constant	J	0,000
Eccentricity in local z direction, relative to specified origin	ez0	0,000
Eccentricity in local y direction, relative to specified origin	ey0	0,000
Eccentricity in local z direction, relative to beam centroid	ez	0,000
Eccentricity in local y direction, relative to beam centroid	ey	0,000
Wagner constant 1st moment of square radius about y (Iyr)	Iyr	0,000
Wagner constant 1st moment of square radius about z (Izr)	Izr	0,000
Wagner constant 4th moment of area about origin (Irr)	Irr	0,000
Wagner constant 2nd moment of warping about origin (Iwr)	Iwr	0,000
Effective shear area in local z direction	Asz	0,000
Effective shear area in local y direction	Asy	0,010
Radius of gyration about y axis	ky	0,000
Radius of gyration about z axis	kz	0,120
y axis extreme fibre, top	yt	0,000
y axis extreme fibre, bottom	yb	0,000
z axis extreme fibre, top	zt	0,000
z axis extreme fibre, bottom	zb	0,000
Shape code identifier	Type	-1
Element type	elementType	"2D Thick Beam"
Reinforcement	reinforcement	None

Assignment to Lines:

1

APPENDIX 1

**Attribute: 1 Title: Steel**

Sub Type = Isotropic Material

Assigned in: Analysis 1

Property	Symbol	Value
Young's modulus	E	189000000,000
Poisson's ratio	nu	0,300
Density	rho	0,000

Loadcase ID: 2 Title: Loadcase 1

Assignment to Lines:

1

**Attribute: 2 Title: Joint material: Soil**

Sub Type = Joint Material, Elasto-Plastic (Tension and Compression Equal)

Assigned in: Analysis 1

	u	v
Number of degrees of freedom	nDOF	2
Joint type	JointType	"Plane stress / plane strain / 2D axisymmetric membra
Assignment type	Assignment	"Line"
Yield force	F[0]	0,000
Yield force	F[1]	F
Hardening stiffness	H[0]	0,000
Hardening stiffness	H[1]	10,000
Elastic spring stiffness	K[0]	0,000
Elastic spring stiffness	K[1]	E
Mass	M[0]	0,000
Mass	M[1]	0,000
Mass position	MassPosition	"Between nodes"

Loadcase ID: 2 Title: Loadcase 1

Assignment to Lines:

1

**Attribute: 1 Title: E**

Sub Type = Interpolation Variation

Property	Symbol	Value
Interpolation order	type	"Linear"
Distance type	distType	"Actual"
Distance	distance	0,000
Distance	distance	1,700
Distance	distance	1,710
Distance	distance	4,000
Distance	distance	4,200
Distance	distance	6,700
Distance	distance	6,710
Distance	distance	10,700
Distance	distance	14,700
Distance	distance	14,710
Distance	distance	16,710
Function	expression	"0.0"
Function	expression	"2.4E3"
Function	expression	"4.5E3"
Function	expression	"18.0E3"
Function	expression	"18.0E3"
Function	expression	"18.0E3"
Function	expression	"18.0E3"
Function	expression	"18.0E3"
Function	expression	"30.0E3"
Function	expression	"30.0E3"

**Attribute: 4 Title: F**

Sub Type = Interpolation Variation

Property	Symbol	Value
Interpolation order	type	"Linear"
Distance type	distType	"Actual"
Distance	distance	0,000
Distance	distance	1,700
Distance	distance	1,710
Distance	distance	4,200
Distance	distance	6,700
Distance	distance	6,710
Distance	distance	10,700
Distance	distance	14,700
Distance	distance	14,710
Distance	distance	16,710
Function	expression	"0.0"
Function	expression	"43.0"
Function	expression	"47.0"
Function	expression	"136.0"
Function	expression	"226.0"
Function	expression	"221.0"
Function	expression	"362.0"
Function	expression	"502.0"
Function	expression	"899.0"
Function	expression	"1.025E3"

APPENDIX 1

**Attribute: 1 Title: Pinned**

**Sub Type = Structural Support**

**Assigned in: Analysis 1**

Property	Symbol	Value
Translation in X	U	"R"
Translation in Y	V	"R"
Rotation about Z	THZ	"F"
Pore pressure	pore	"C"

**Loadcase ID: 2 Title: Loadcase 1**

**Assignment to Points:**

1

APPENDIX 1

**Attribute: 3 Title: Lager krafter**

Sub Type = Concentrated Load

Property	Symbol	Value
Concentrated load in X Dir	PX	2940,000
Concentrated load in Y Dir	PY	33,000
Concentrated load in Z Dir	PZ	0,000
Moment about X axis	MX	0,000
Moment about Y axis	MY	0,000
Moment about Z axis	MZ	-97,000
Moment about hinge nodes	L2	0,000
Pore pressure flux	PorePressure	0,000
Bi moment	Mb	0,000

Loadcase ID: 2 Title: Loadcase 1 Factor = 1.0

Assignment to Points:

7

**Attribute: 9 Title: N = 2940 kN**

Sub Type = Concentrated Load

Property	Symbol	Value
Concentrated load in X Dir	PX	2940,000
Concentrated load in Y Dir	PY	0,000
Concentrated load in Z Dir	PZ	0,000
Moment about X axis	MX	0,000
Moment about Y axis	MY	0,000
Moment about Z axis	MZ	0,000
Moment about hinge nodes	L2	0,000
Pore pressure flux	PorePressure	0,000
Bi moment	Mb	0,000

Loadcase ID: 3 Title: Loadcase 2 Factor = 1.0

Assignment to Points:

7

APPENDIX 1

**Attribute: 1 Title: Joint coordinate system**

Sub Type = Local Coordinates

Property	Symbol	Value
Attribute type	type	"Cartesian"
Rotation angle	angle	270,000
Origin	originPos[0]	0,000
Origin	originPos[1]	0,000
Origin	originPos[2]	0,000
Type	plane	"XY_Angle"

Assignment to Points:

7

**Loadcases**

Loadcase	Gravity	Title	Analysis	Type
2		Loadcase 1	Analysis 1	
3		Loadcase 2	Analysis 2	

Gravity (when chosen) is applied as a body force of  $-9,81000\text{m/s}^2$  in the Y direction

**Title: Input receipt**

**LUSAS version:** 23.0-1c3  
**Model Units:** kN,m,t,s,C  
**Report Units:** kN,m,t,s,C

**Model Title:**  
**Model File:** Pile spline

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<b>Loadcase</b>	<b>10</b>

## APPENDIX 2

### Points

Point	X coordinate	Y coordinate	Z coordinate
1	0,000	0,000	0,000
2	-0,025	2,950	0,000
3	0,000	5,900	0,000
4	0,025	8,600	0,000
5	0,000	11,300	0,000
6	-0,025	14,000	0,000
7	0,000	16,700	0,000
11	-10,000	16,700	0,000
12	-10,000	15,000	0,000
13	-10,000	10,000	0,000
14	-10,000	2,000	0,000
15	-10,000	0,000	0,000

## Splines

Splines	Points	Splines	Points
1	1;2;3;4;5;6;7	-	-

### Line Mesh (Elements showing results)

**Attribute: 2 Title: Pile**

Sub Type = Line Mesh Element Type = BMI2

Mesh spacing	Element size	Start node end releases:	End node end releases:
Irregular	0,5	None	None

Assignment to Lines:

1

**Attribute: 4 Title: Joint element: soil**

Sub Type = Line Mesh Element Type = JNT3

Mesh spacing	Start node end releases:	End node end releases:
Uniform	None	None

Assignment to Lines: Local Coordinates = Joint coordinate system (Local x is joint x), Single feature insertion type : grounded

1

APPENDIX 2

Attribute: 1 Title: Pile

Sub Type = Line Geometric

Assigned in: Analysis 1

Property	Symbol	Value
Cross sectional area	A	0,010
Second moment of area about y axis	Iyy	0,000
Second moment of area about z axis	Izz	0,000
Product moment of area	Iyz	0,000
Torsional constant	J	0,000
Eccentricity in local z direction, relative to specified origin	ez0	0,000
Eccentricity in local y direction, relative to specified origin	ey0	0,000
Eccentricity in local z direction, relative to beam centroid	ez	0,000
Eccentricity in local y direction, relative to beam centroid	ey	0,000
Wagner constant 1st moment of square radius about y (Iyr)	Iyr	0,000
Wagner constant 1st moment of square radius about z (Izr)	Izr	0,000
Wagner constant 4th moment of area about origin (Irr)	Irr	0,000
Wagner constant 2nd moment of warping about origin (Iwr)	Iwr	0,000
Effective shear area in local z direction	Asz	0,000
Effective shear area in local y direction	Asy	0,010
Radius of gyration about y axis	ky	0,000
Radius of gyration about z axis	kz	0,120
y axis extreme fibre, top	yt	0,000
y axis extreme fibre, bottom	yb	0,000
z axis extreme fibre, top	zt	0,000
z axis extreme fibre, bottom	zb	0,000
Shape code identifier	Type	-1
Element type	elementType	"2D Thick Beam"
Reinforcement	reinforcement	None

Assignment to Lines:

1

APPENDIX 2

**Attribute: 1 Title: Steel**

Sub Type = Isotropic Material

Assigned in: Analysis 1

Property	Symbol	Value
Young's modulus	E	189000000,000
Poisson's ratio	nu	0,300
Density	rho	0,000

Loadcase ID: 2 Title: Loadcase 1

Assignment to Lines:

1

**Attribute: 2 Title: Joint material: Soil**

Sub Type = Joint Material, Elasto-Plastic (Tension and Compression Equal)

Assigned in: Analysis 1

	u	v
Number of degrees of freedom	nDOF	2
Joint type	JointType	"Plane stress / plane strain / 2D axisymmetric membra
Assignment type	Assignment	"Line"
Yield force	F[0]	0,000
Yield force	F[1]	F
Hardening stiffness	H[0]	0,000
Hardening stiffness	H[1]	10,000
Elastic spring stiffness	K[0]	0,000
Elastic spring stiffness	K[1]	E
Mass	M[0]	0,000
Mass	M[1]	0,000
Mass position	MassPosition	"Between nodes"

Loadcase ID: 2 Title: Loadcase 1

Assignment to Lines:

1

**Attribute: 1 Title: E**

Sub Type = Interpolation Variation

Property	Symbol	Value
Interpolation order	type	"Linear"
Distance type	distType	"Actual"
Distance	distance	0,000
Distance	distance	1,700
Distance	distance	1,710
Distance	distance	4,000
Distance	distance	4,200
Distance	distance	6,700
Distance	distance	6,710
Distance	distance	10,700
Distance	distance	14,700
Distance	distance	14,710
Distance	distance	16,710
Function	expression	"0.0"
Function	expression	"2.4E3"
Function	expression	"4.5E3"
Function	expression	"18.0E3"
Function	expression	"18.0E3"
Function	expression	"18.0E3"
Function	expression	"18.0E3"
Function	expression	"18.0E3"
Function	expression	"18.0E3"
Function	expression	"30.0E3"
Function	expression	"30.0E3"

APPENDIX 2

Attribute: 4 Title: F

Sub Type = Interpolation Variation

Property	Symbol	Value
Interpolation order	type	"Linear"
Distance type	distType	"Actual"
Distance	distance	0,000
Distance	distance	1,700
Distance	distance	1,710
Distance	distance	4,200
Distance	distance	6,700
Distance	distance	6,710
Distance	distance	10,700
Distance	distance	14,700
Distance	distance	14,710
Distance	distance	16,710
Function	expression	"0.0"
Function	expression	"43.0"
Function	expression	"47.0"
Function	expression	"136.0"
Function	expression	"226.0"
Function	expression	"221.0"
Function	expression	"362.0"
Function	expression	"502.0"
Function	expression	"899.0"
Function	expression	"1.025E3"

APPENDIX 2

**Attribute: 1 Title: Pinned**

**Sub Type = Structural Support**

**Assigned in: Analysis 1**

Property	Symbol	Value
Translation in X	U	"R"
Translation in Y	V	"R"
Rotation about Z	THZ	"F"
Pore pressure	pore	"C"

**Loadcase ID: 2 Title: Loadcase 1**

**Assignment to Points:**

1

**Attribute: 3 Title: Lager krafter**

Sub Type = Concentrated Load

Property	Symbol	Value
Concentrated load in X Dir	PX	2940,000
Concentrated load in Y Dir	PY	33,000
Concentrated load in Z Dir	PZ	0,000
Moment about X axis	MX	0,000
Moment about Y axis	MY	0,000
Moment about Z axis	MZ	-97,000
Moment about hinge nodes	L2	0,000
Pore pressure flux	PorePressure	0,000
Bi moment	Mb	0,000

Loadcase ID: 2 Title: Loadcase 1 Factor = 1.0

Assignment to Points:

7

**Attribute: 9 Title: N = 2940 kN**

Sub Type = Concentrated Load

Property	Symbol	Value
Concentrated load in X Dir	PX	2940,000
Concentrated load in Y Dir	PY	0,000
Concentrated load in Z Dir	PZ	0,000
Moment about X axis	MX	0,000
Moment about Y axis	MY	0,000
Moment about Z axis	MZ	0,000
Moment about hinge nodes	L2	0,000
Pore pressure flux	PorePressure	0,000
Bi moment	Mb	0,000

Loadcase ID: 3 Title: Loadcase 2 Factor = 1.0

Assignment to Points:

7

**Attribute: 1 Title: Joint coordinate system**

Sub Type = Local Coordinates

Property	Symbol	Value
Attribute type	type	"Cartesian"
Rotation angle	angle	270,000
Origin	originPos[0]	0,000
Origin	originPos[1]	0,000
Origin	originPos[2]	0,000
Type	plane	"XY_Angle"

Assignment to Points:

7

**Loadcases**

Loadcase	Gravity	Title	Analysis	Type
2		Loadcase 1	Analysis 1	
3		Loadcase 2	Analysis 2	

Gravity (when chosen) is applied as a body force of  $-9,81000\text{m/s}^2$  in the Y direction