Pretensioned double girder bridge

TABLE OF CONTENT

Part

Appendix

Part A : CALCULATION ASSUMPTIONS

Pretensioned double girder bridge

CONTENTS

1. GENERAL / MEASUREMENT

1.1 CONSTRUCTION TYPE

The bridge is designed as a prestressed bridge with two spans and constructed with two main girders.

All abutments have bearing.

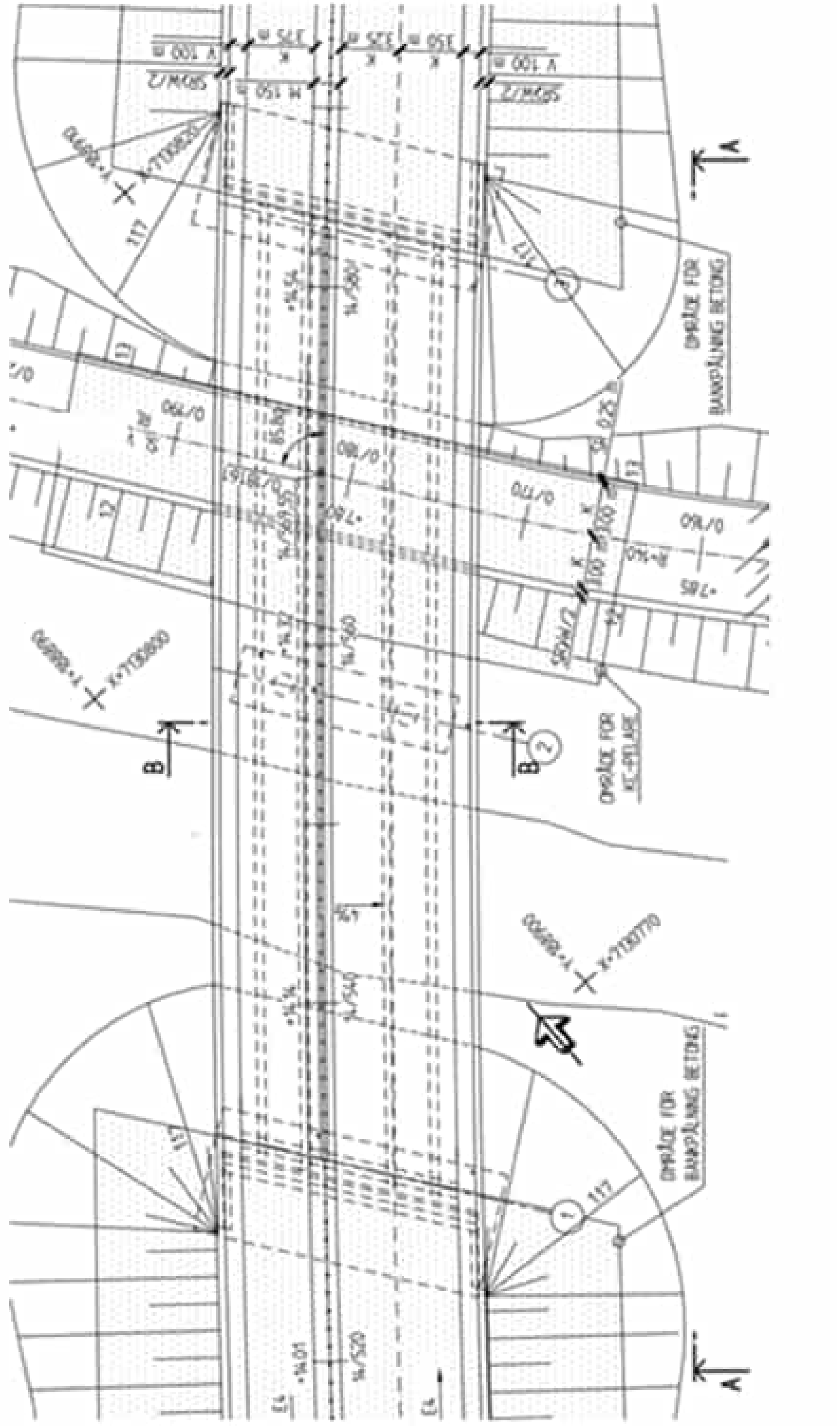
End abutements have moving joints.

All foundation are carried out with concrete piles.

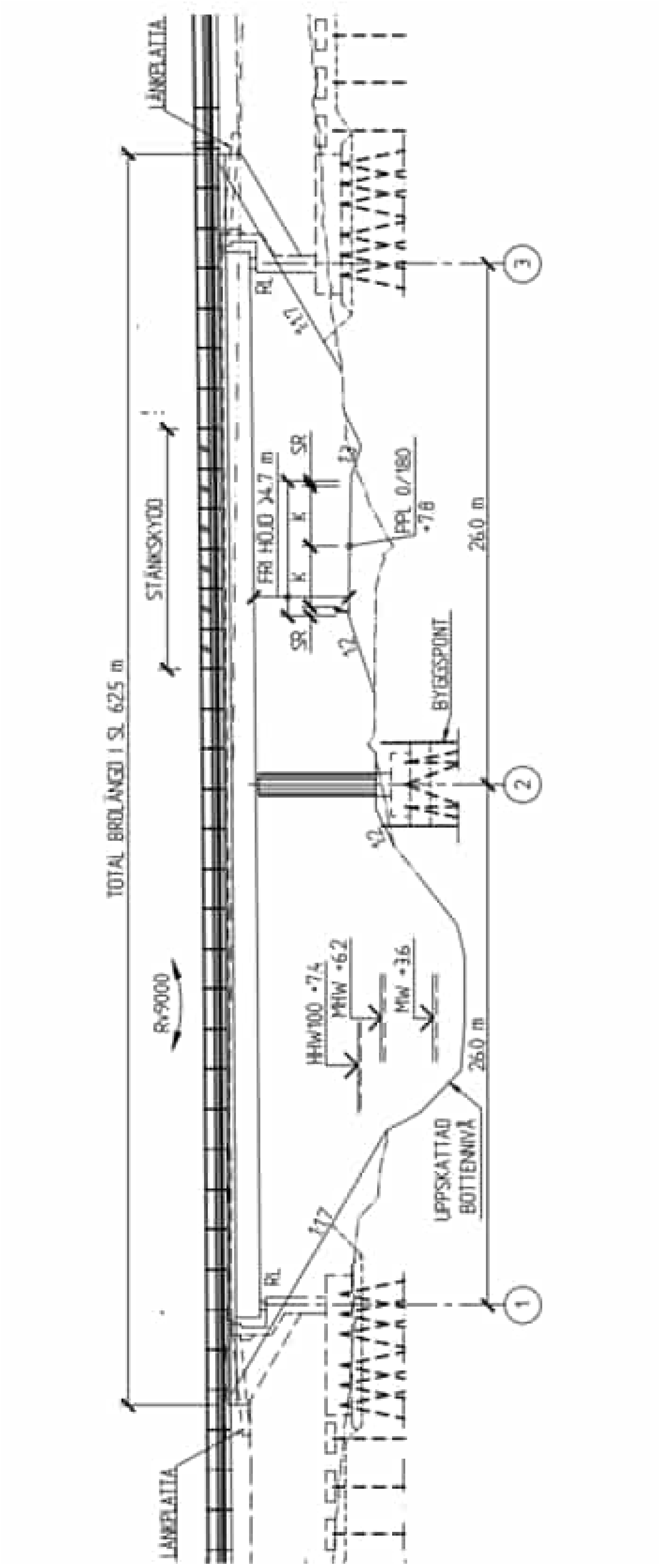
Link plates are installed at each support.

1.2 MEASUREMENTS

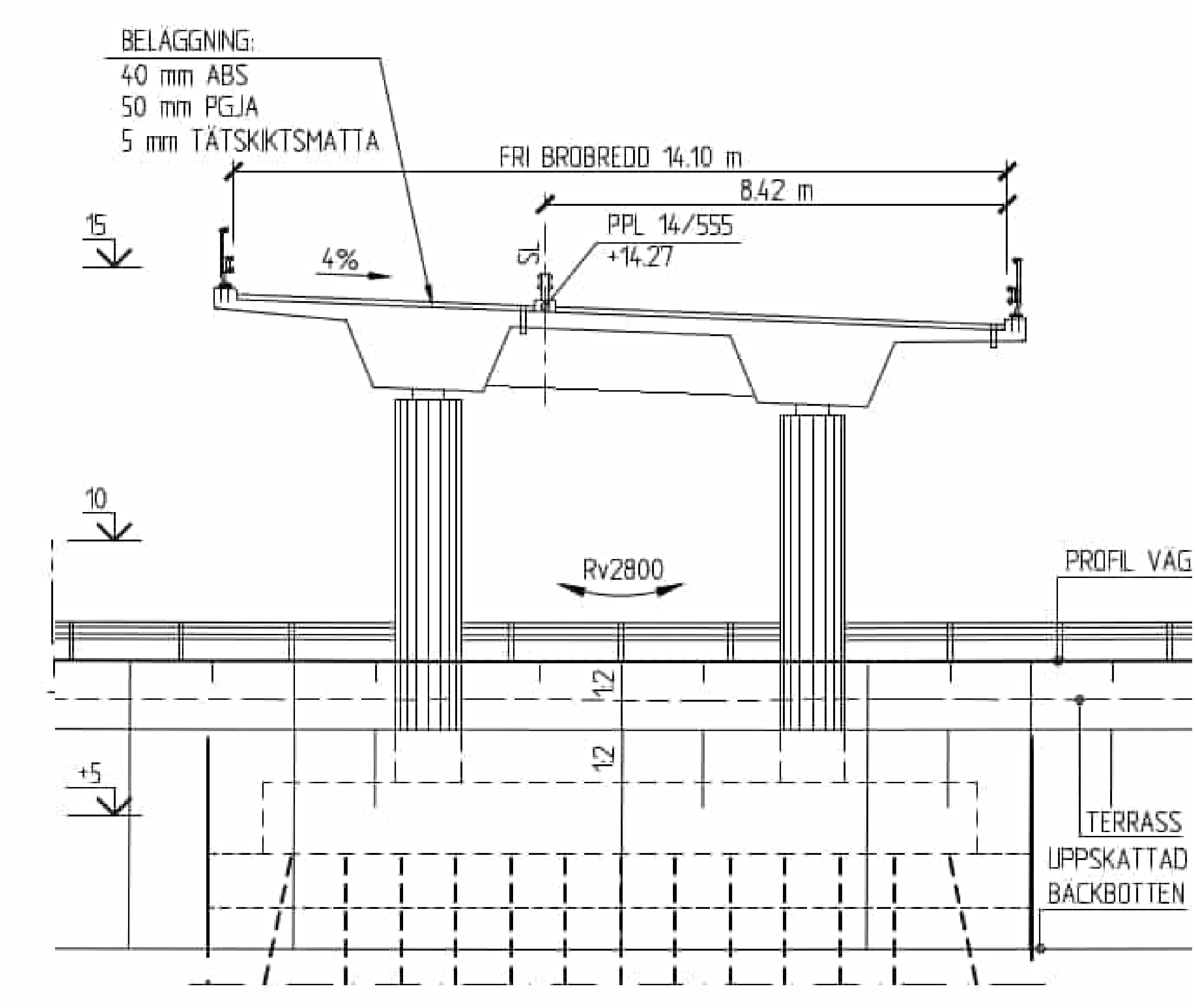
1.2.1 Theoretical geometry



PLAN
Overview

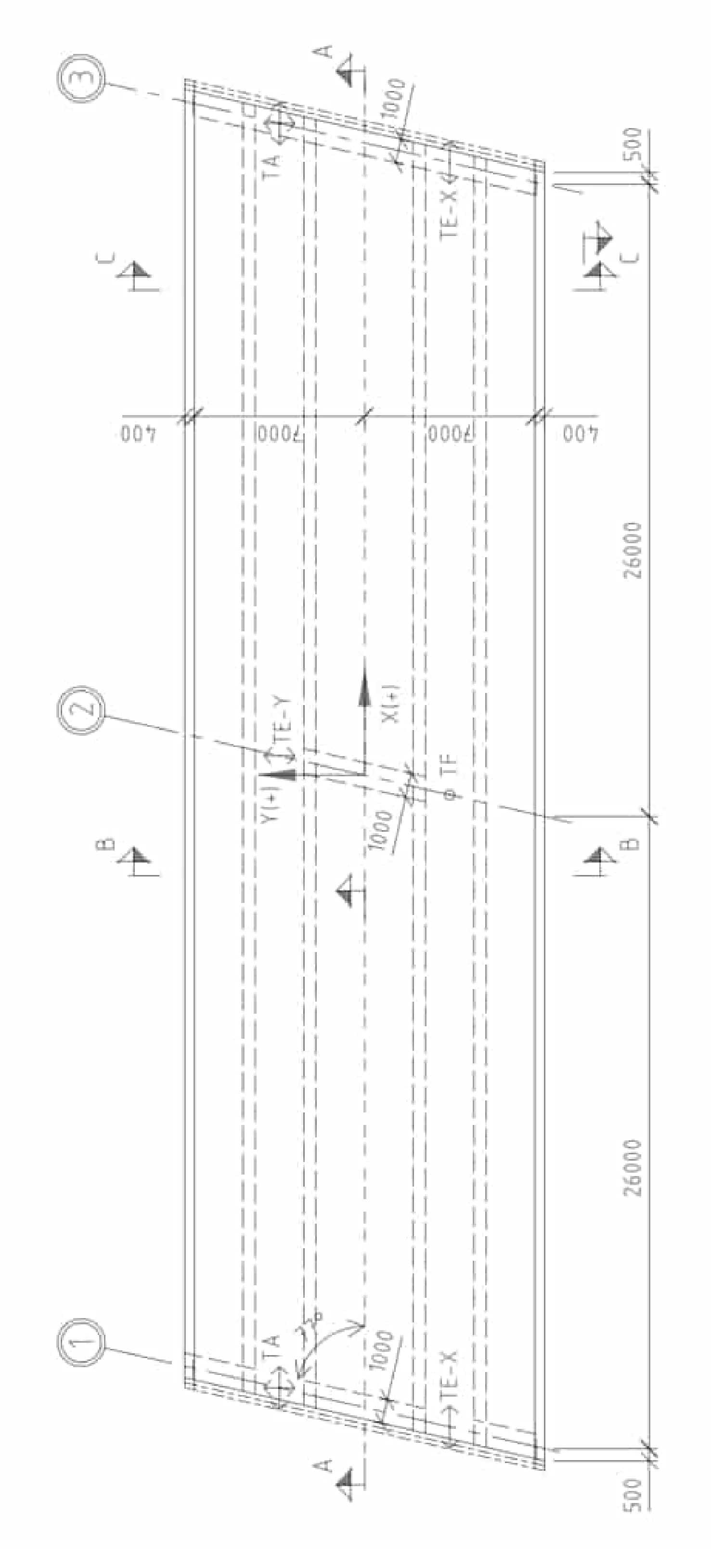

LÄNKPLATTA
TOTAL BROLÄNGD I SL 62.5 m
STÄNKSKYDD
R=9000
RL
1:1.7
FRI HÖJD >4.7 m
SR
K
K
SR
1:2
PPL 0/180
+7.8
26.0 m
BYGGSPONT
HHW100 +7.4
MHW +6.2
MW +3.6
26.0 m
UPPSKATTAD BOTTENNIVÅ
1:2
1:1.7
RL
3
2
1
LÄNKPLATTA

SECTION A-A

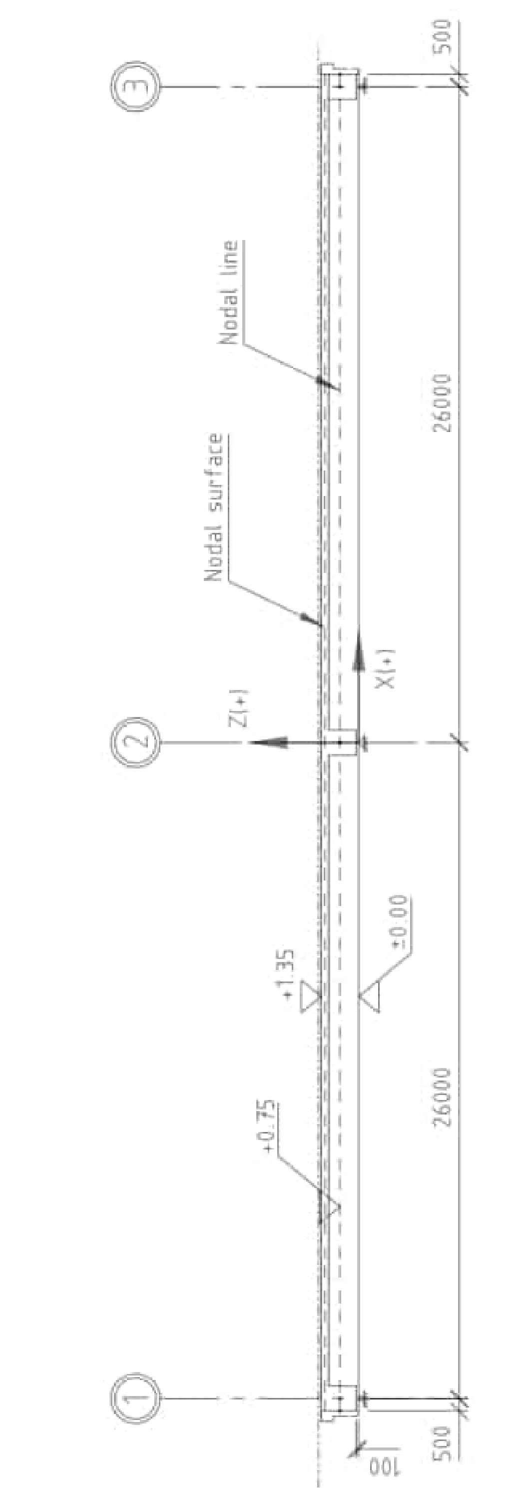

BELÄGGNING:
40 mm ABS
50 mm PGJA
5 mm TÄTSKIKTSMATTA
FRI BROBREDD 14.10 m
8.42 m
PPL 14/555
+14.27
SL
15
4%
10
Rv2800
PROFIL VÄG
1:2
1:2
+5
TERRASS
UPPSKATTAD
BÄCKBOTTEN

SECTION B-B

1.2.2 Simplified geometry (used for calculatuons)

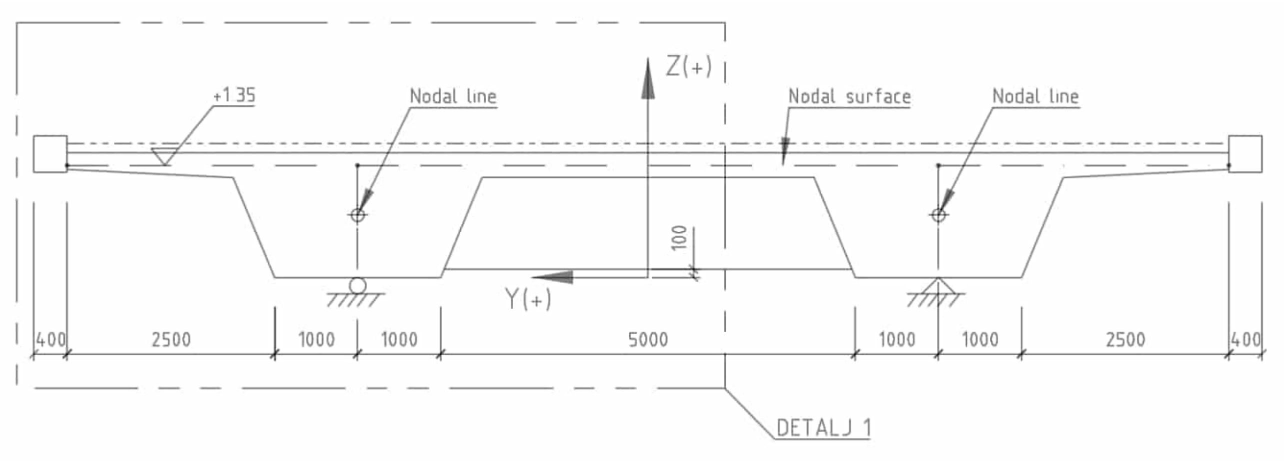


PLAN

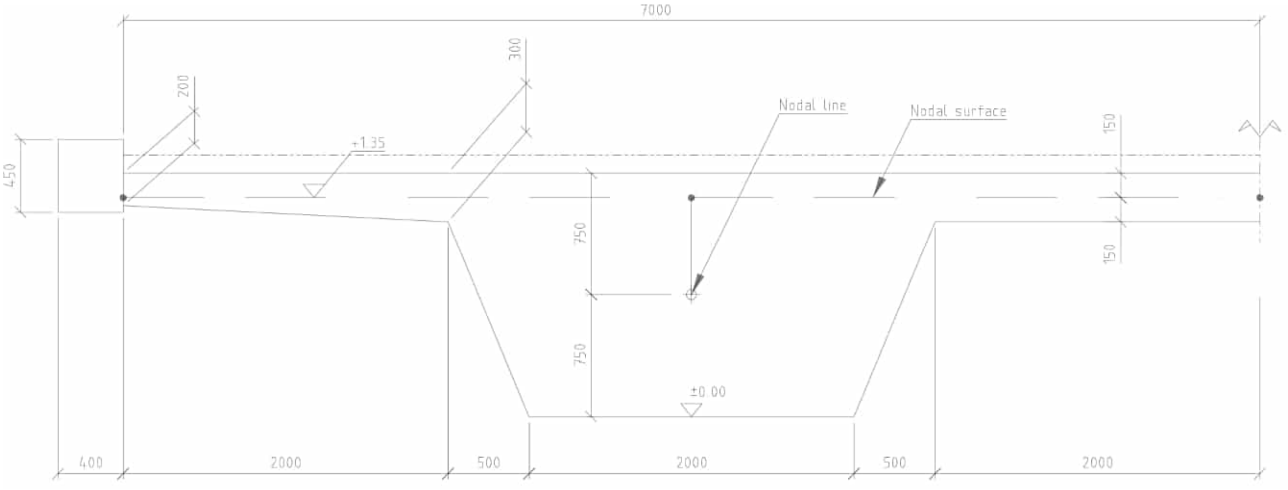


3
2
1
500
26000
26000
500
100
Nodal line
Nodal surface
Z(+)
X(+)
+1.35
±0.00
+0.75

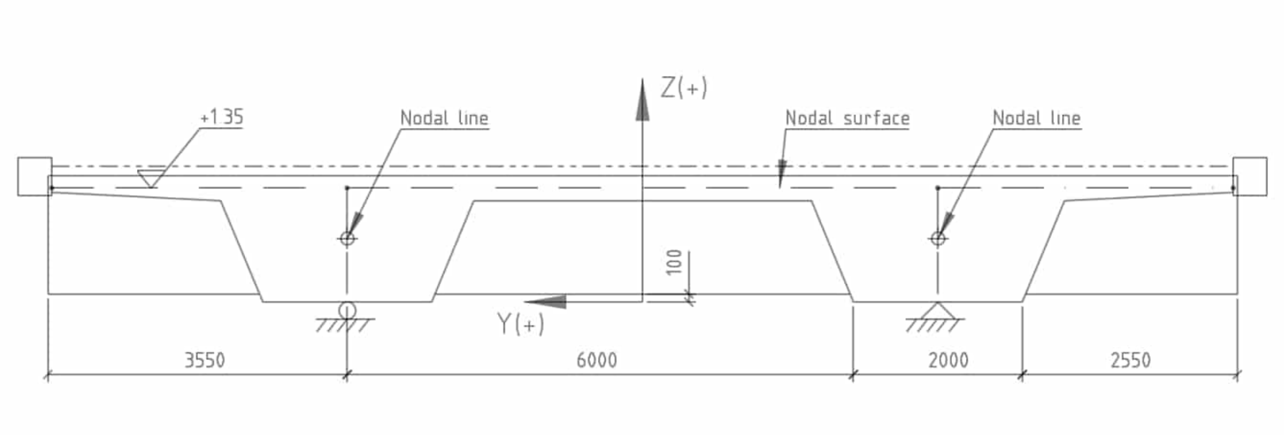
SECTION A-A



SECTION B-B
At support in middle.



DETAIL 1



SECTION C-C
At end supports.

1.3 FOUNDATION

Foundation consists of concrete piles Hercules HP270-0816 (SP3).

	Support 1	Support 2	Support 3
Section	14/531	14/557	14/583
Level PPL	+14.08	+14.29	+14.57
Level bridge center	+14.03	+14.24	+14.52
Level bottom of slab	+7.60	+3.50	+8.09
Level top of piles	+7.80	+3.70	+8.29
Level bottom of pile	-13.5	-9.0	-4.0
Pile length	~21	~13	~12
-	m	m	m

4 CODE DOCUMENTS

Documents	Version	Name
SS-EN 1990-1997	-	Svensk Standard Eurokod 1-7
TRVINFRA-00226	2.0	KRAV, Bro och broliknande konstruktion, Allmänna krav
TRVINFRA-00227	2.0	KRAV, Bro och broliknande konstruktion, Byggande
TRVINFRA-00228	2.0	KRAV, Bro och broliknande konstruktion, Brounderhåll
TRVINFRA-00331	2.0	KRAV, Bro och broliknande konstruktion, Bärighetsberäkning
TSFS 2018:57		Transportstyrelsens föreskrifter och allmänna råd om tillämpning av eurokoder
TDOK 2013:0667	2.0	Trafikverkets tekniska krav för geokonstruktioner. TK Geo 13
TDOK 2013:0668	2.0	Trafikverkets tekniska råd för geokonstruktioner. TR Geo 13
AMA Anläggning 23		AMA, Svensk Byggtjänst
TDOK 2023:0125	2.0	TRVAMA Anläggning 23
SS 137006:2015	-	Betongkonstruktioner – Utförande – Tillämpning av SS-EN 13670:2009 i Sverige

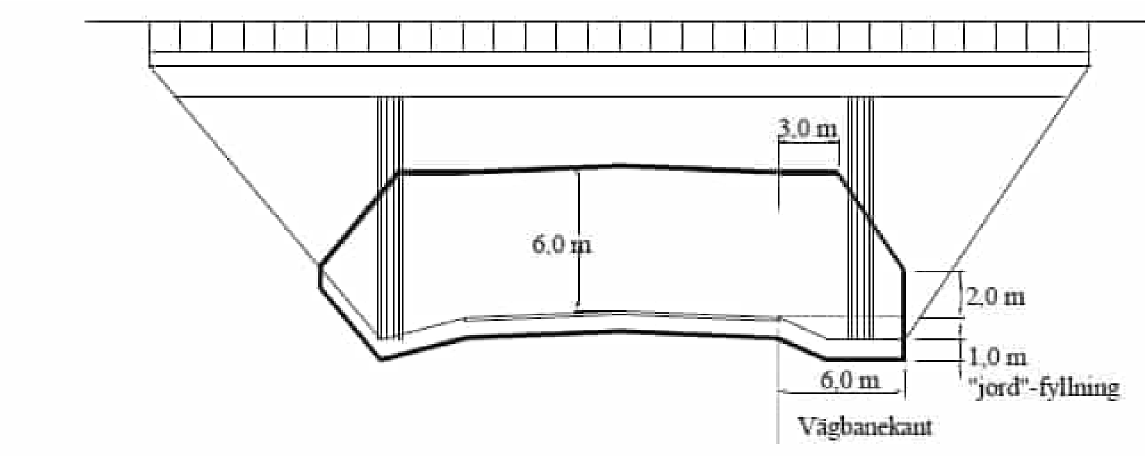
1.5 TECHNICAL SERVICE LIFE

Technical life span 120 years (L100).

1.6 ENVIRONMENT

Exponeringsklasser är bestämda enligt TSFS 2018:57avsnitt 5.3.2.3 samt SS-EN 206-1.

In TSFS 2021:57 figure 1.1, the road environment is defined according to the figure below. Which means that the superstructure including edge beam is within the area ± 9 m (∴ 6 m + 6.5 m /2 from the center of underlying road.



1.7 MATERIAL

Concrete : C35/45 & C40/50 (CEM I 42.5 N, Anläggningscement klass N)

Reinforcement : B500B

Compacted fill : ”Förtärkningslagermaterial” according to AMA CEB.415

Backfill : ”Grovkrossad sprängsten” according to AMA CEB.524

Surfacing : 5 mm waterproofing mat, 50 mm PGJA and 40 mm ABS (total 95 mm).

Pretension: VSL 15ϕ16 (f_{yk} / f_{uk} = 1640 MPa/1860 MPa)

Concrete (see SS-EN 1992-1-1, Table 3.1): C35/45 (f_{ck} = 35 MPa) for superstucture
C30/37 (f_{ck} = 30 MPa) for substructure

Reinforcement (SS-EN 10080 & SS 212540): K500CT (f_{yk} = 500MPa)

1.8 GEOTECHNICAL CLASS

Geotechnical class GK2

1.9 SAFETY CLASS

Geotechnical resistance:	SK 2
Bridge structure :	SK 3

1.10 CONCRETE COVER AND CRACK CRITERIA

Class identification bridge components :

Bridge components	Exposure class 1.)	Life spann	max vct_{ekv} 2.)	ζ 3.)
Substructure incl. linkplate:				
▫ Wingwall towards filling	XD1/XF4	L100	0.45	1.5
▫ Wingwall from filling	XD1/XF4	L100	0.45	1.5
▫ Abutment below ground	XC2/XF3	L100	0.50	1.0
▫ Abutment in air	XC4/XF3	L100	0.50	1.2
▫ Bottomslab in general	XC2/XF3	L100	0.50	1.0
▫ Bottomslab underside	XC2/XF3	L100	0.50	1.0
▫ Linkslab in general	XD3/XF2	L100	0.40	1.8
▫ Linkslab underside	XD3/XF2	L100	0.40	1.8
Superstructure:				
▫ Edge beam	XD3/XF4	L100	0.40	1.8
▫ Bridge deck	XD1/XF4	L100	0.40	1.5

Footnote:

1.) TRVINFRA-00227 section 5.3.2.3

2.) TSFS table 12.1

3.) TSFS table 12.3

Design parameters low corrosion sensitive reinforcement (rebars):

$c_{min.dur}$: minimum cover with regard to environmental impact

$c_{min.b}$: minimum cover with regard to adhesion requirements
Δc_{dev} : execution tolerance
$c_{min} = \max(c_{min.b;} c_{min.dur}; 10mm)$: SS-EN 1992-1-1 eq. 4.2
$c_{nom} = c_{min} + \Delta c_{dev}$: SS-EN 1992-1-1 eq. 4.1, noted as BM on the drawing

Construction part	$c_{min.dur}$ 1.)	$c_{min.b}$ 2.)	c_{min}	c_{dev} 3.)	c_{nom}	$w_{k,till}$ 4.)
Substructure including link slab:						
▫ Wing wall against fill	30	20	30	10	40	0.20
▫ Wing wall from fill	30	20	30	10	40	0.20
▫ Frame legs below ground	20	20	20	10	30	0.40
▫ Frame legs above ground	25	20	25	10	35	0.30
▫ Bottom slab (general)	20	20	20	10	30	0.40
▫ Underside of bottom slab	20	20	20	10	30	0.40
▫ Link slab (general)	45	20	45	10	55	0.15
▫ Underside of link slab	45	20	45	10	60 5.)	0.15
Superstructure:						
▫ Edge beam	45	20	45	10	55	0.15
▫ Bridge deck	25	20	25	10	35	0.20
-	mm	mm	mm	mm	mm	mm

Footnotes:
1.) TSFS table 12.1
2.) SS-EN 1992-1-1 section 4.4.1.2 table 4.2
3.) SS-EN 1992-1-1 section 4.4.1.3
4.) TSFS tabele 12.2
5.) TSFS chapter 12 paragraph 3§ $k_1 = c_{min}$ + 15 mm vhen casting against building foil.

Design parameters high corrosion sensitive reinforcement (pretension):

$c_{min.dur}$: minimum cover with regard to environmental impact

$c_{min.b}$: minimum cover with regard to adhesion requirements
Δc_{dev} : execution tolerance
$c_{min} = \max(c_{min.b;} c_{min.dur}; 10mm)$: SS-EN 1992-1-1 eq. 4.2
$c_{nom} = c_{min} + \Delta c_{dev}$: SS-EN 1992-1-1 eq. 4.1, noted as BM on the drawing

Construction part	$c_{min.dur}$ 1.)	$c_{min.b}$ 2.)	c_{min}	c_{dev} 3.)	c_{nom}	$w_{k,till}$ 4.)
Superstructure:						
▫ Top bridge deck	25	90	90	10	100	*
▫ Other part of bridge deck	25	90	90	10	100	*
	mm	mm	mm	mm	mm	mm

Footnotes:

1.) TSFS table 12.1

2.) SS-EN 1992-1-1 section 4.4.1.2 (3) specifies pretension tube ϕ90

3.) SS-EN 1992-1-1 section 4.4.1.3

4.) TSFS table 12.2 states that crack width is not needed when ”tensile stress” for SLS-F is less than $f_{ctk.0.05}/\zeta$

2. SYSTEM ANALYSIS

-

2.1 GENERAL

The bridge is built using pretensioned concrete in longitudinal direction. The bridge has 2 girders.

The bridge is curved with radius 1200 m with skewed support lines.

The system analysis is performed using a simplified geometry.

The bridge is founded on concrete piles.

Supports 1 & 3 have movable bearings in longitudinal direction.

Support 2 has fixed bearing in longitudinal direction.

Edge beams are not modelled statically since considered inactive. This assumption is considered on safe side. The assumption will facilitate future replacement of edge beams.

The superstructure consists of components bridge deck, longitudinal girders and transversal girders at each support.

Bridge deck is defined by using shell elements applied to nodal surface in superstructure.

Longitudinal beams are defined using beam elements applied to nodal line in superstructure.

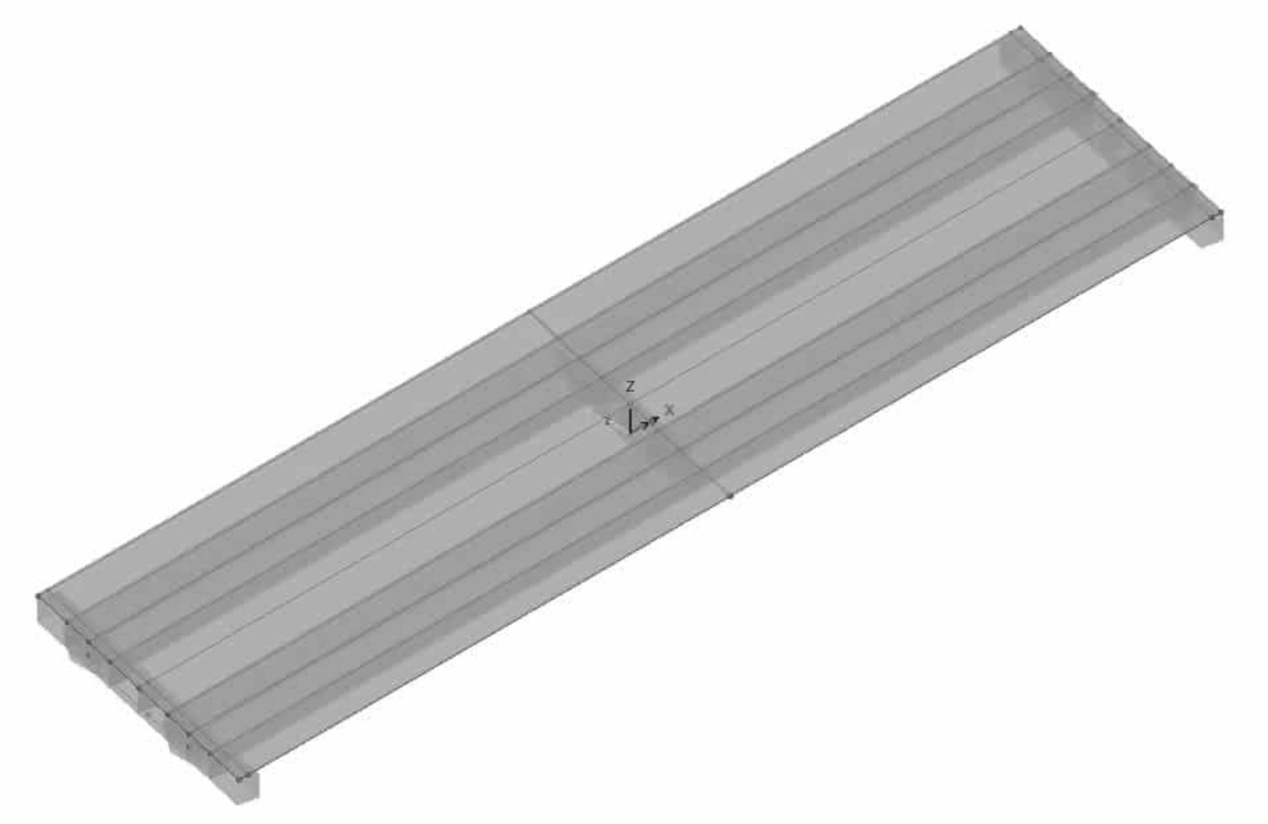
Transversal beams defined relative nodal surface in superstructure.

Longitudinal beam will be connected to bridge deck using Rigid constraints (= Tied Mesh).

Entire structure is modelled using isotropic material.

The bearings are modelled as Joint elements with no rotational stiffness.

At each support, “super-nodes” are introduced at the level of the UK bearing. These “super-nodes” are rigidly connected to each bearing to obtain reaction forces at each support.



OVERVIEW

Appendices:

Appendix	Namn
1	Input recipt
2	Results reactions
3	Results bearings
4	Resuls longitudinal girders
5	Results transversal girders
6	Results bridge deck

2.2 SKETCH SYSTEM ANALYSIS

2.2.1 Geometry

To describe geometry first POINTS are defined.

Beam elements are defined by applying attributes to LINES.

Shell elements are defined by applying attributes to SURFACES.

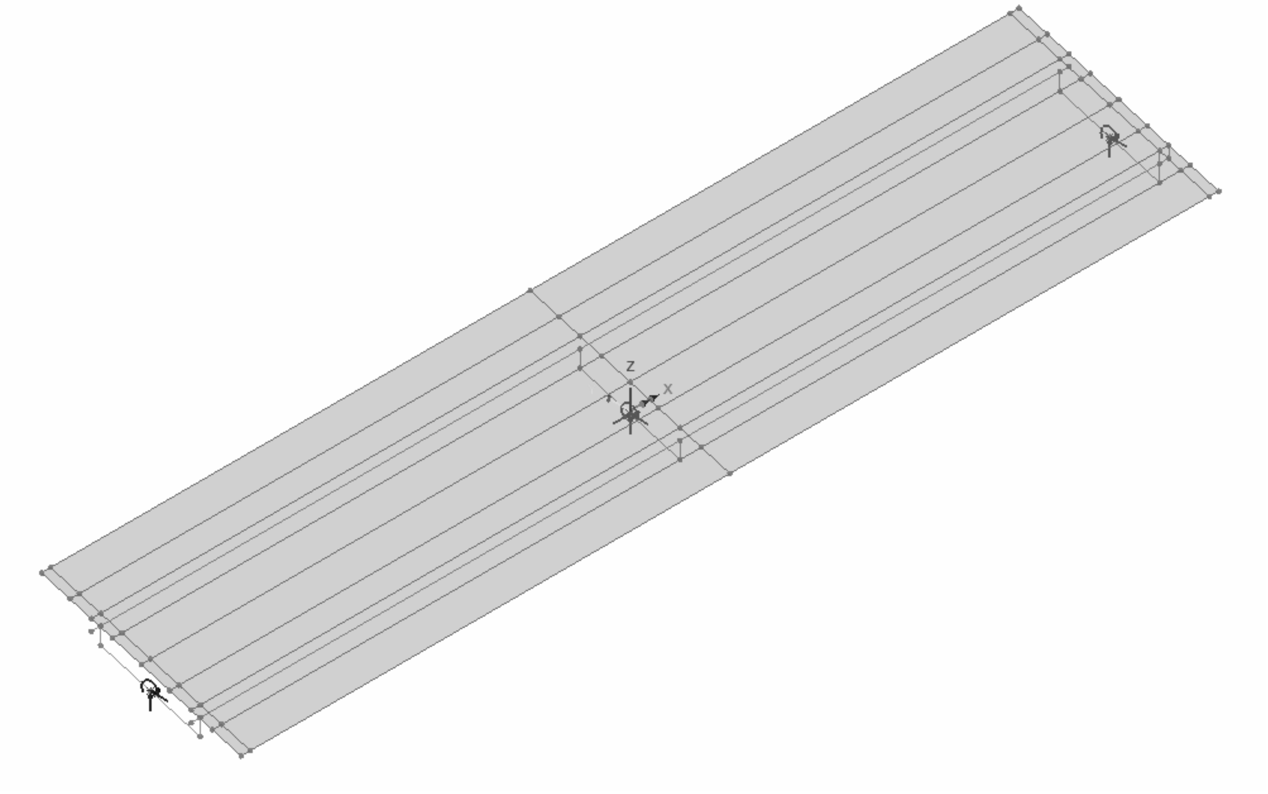
Attached pictures are retrieved from graphical sketches generated by FEM-program of POINTS, LINES and SURFACES.

All coordinates needed to describe POINTS are found in attachment 1.

All POINTS needed to describe LINES are found in attachment 1.

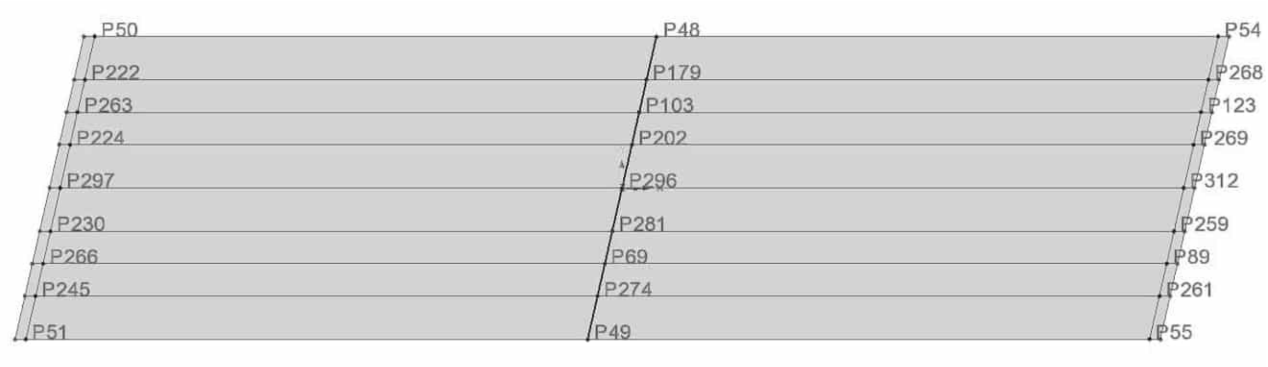
All LINES need to describe SURFACE are found in attachment 1.

Overview:

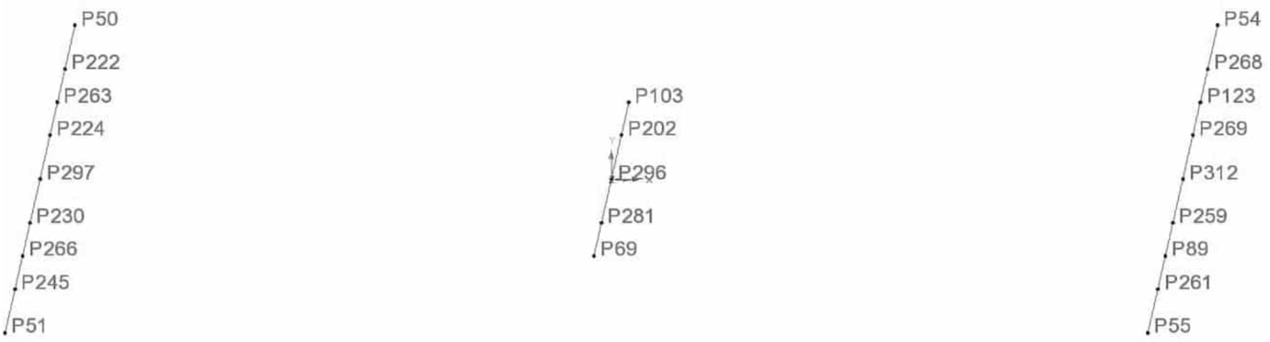


2.2.1.1 Geometry : POINTS

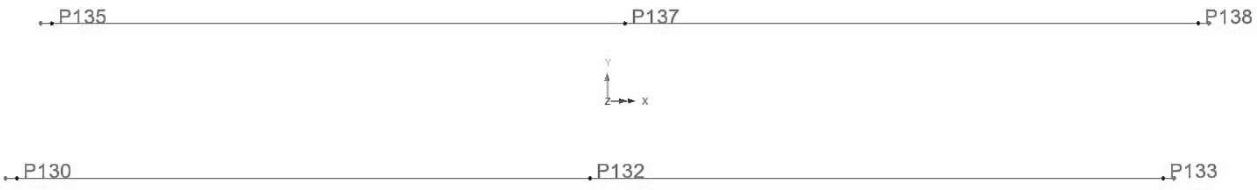
Bridge deck (nodal surface):



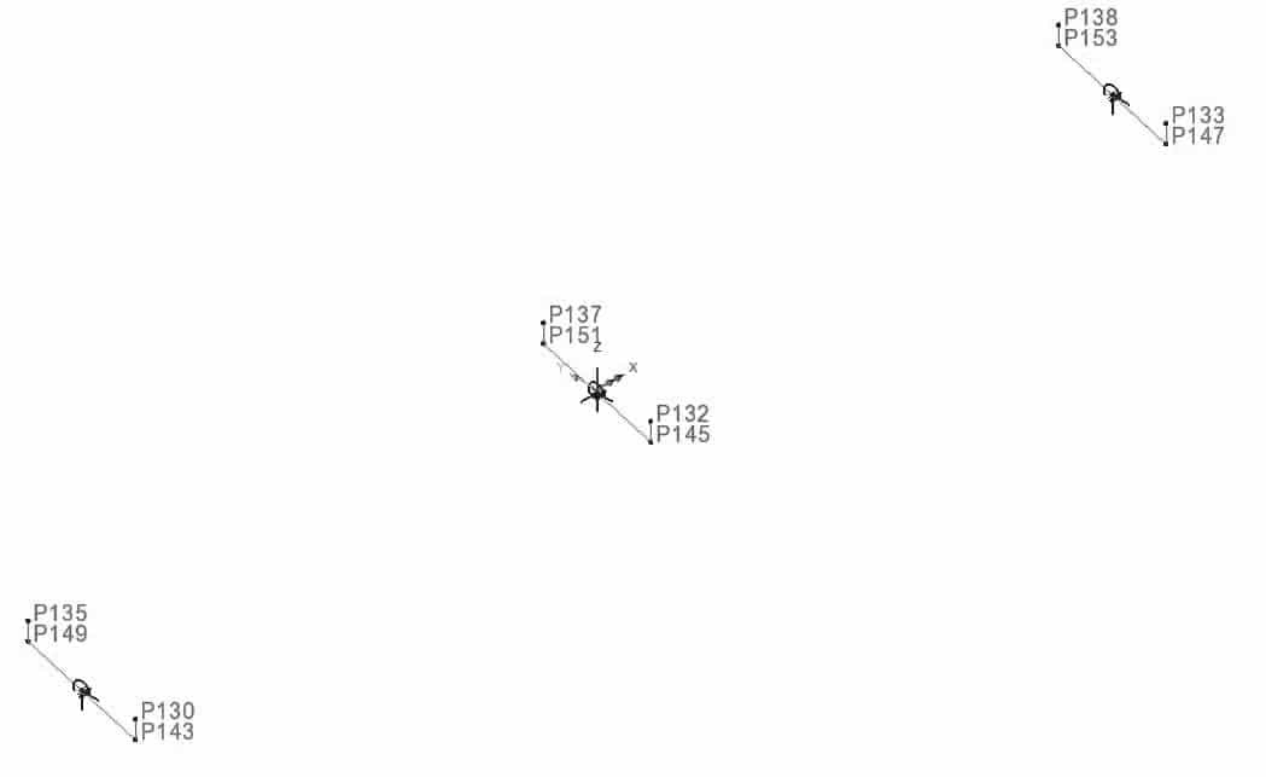
Transversal girders:



Longitudinal beams (nodal line 1-2):

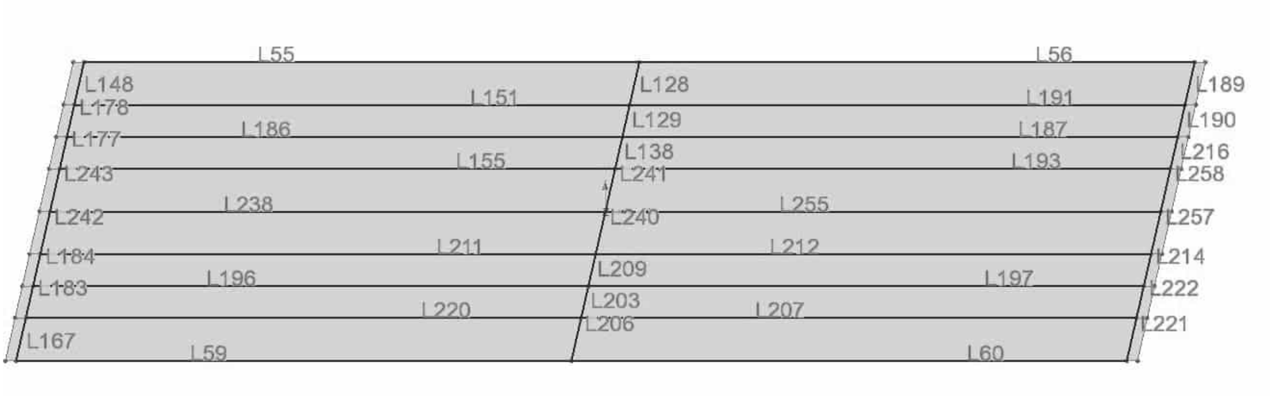


Bearings and supernodes:



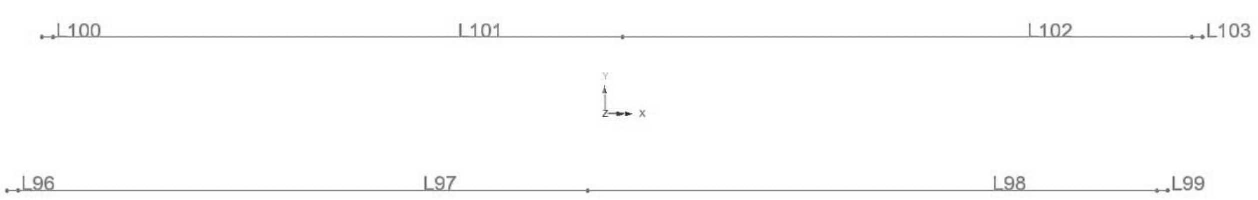
2.2.1.2 Geometry: LINES

Bridge deck (nodal surface):

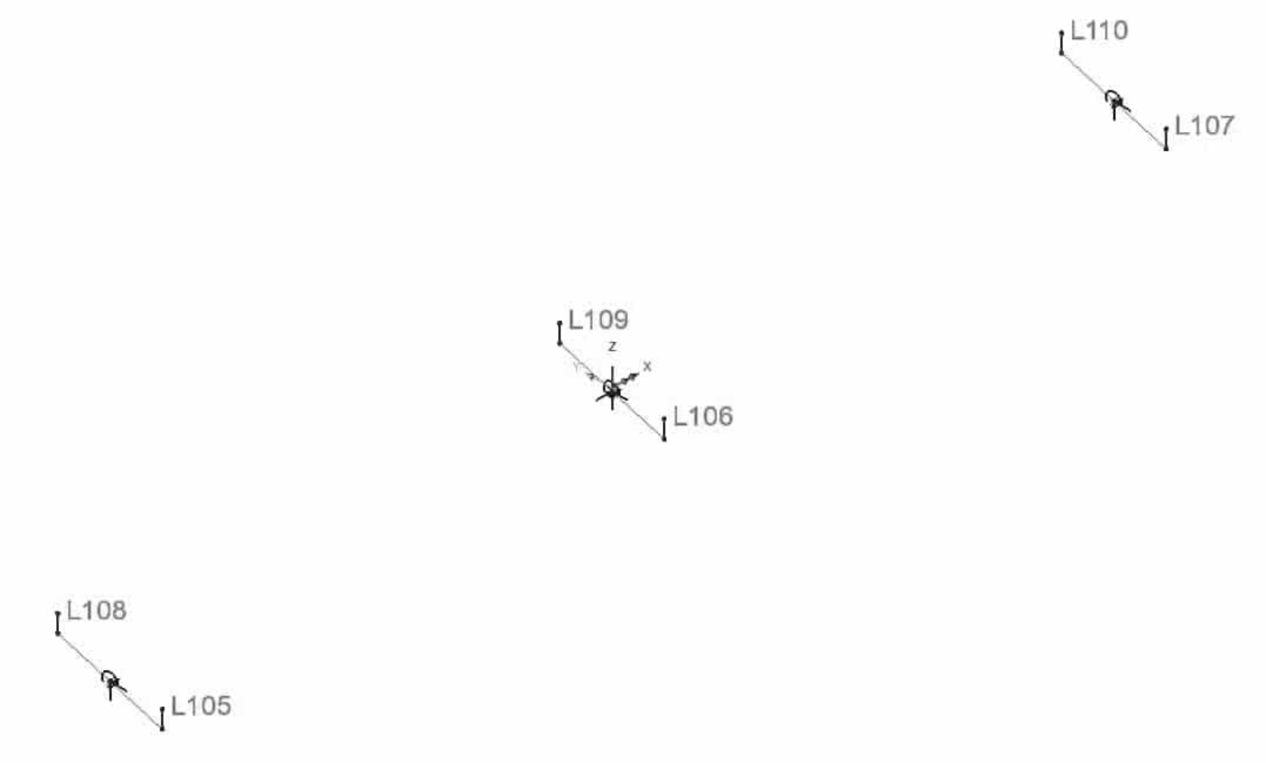


Transversal girders:

Longitudinal girders (nodal line 1-2):

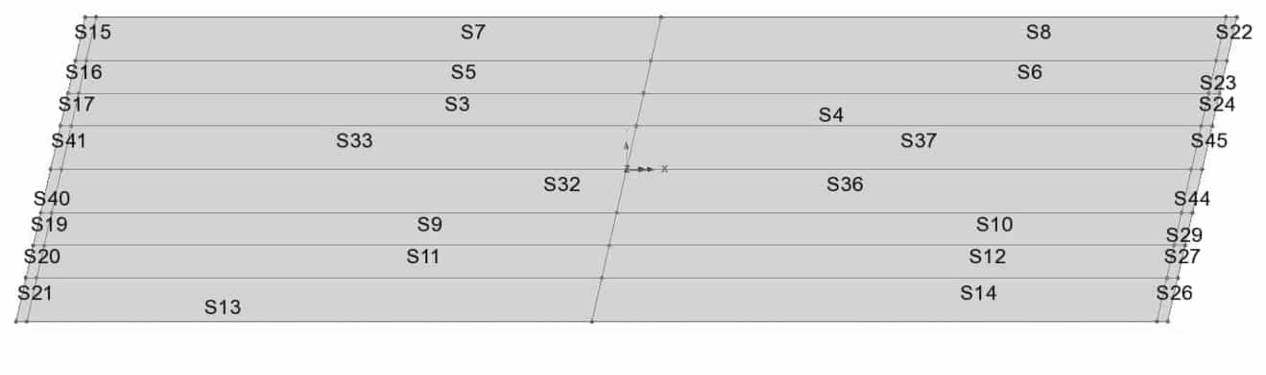


Bearings and supernodes:



2.2.1.3 Geometry: SURFACES

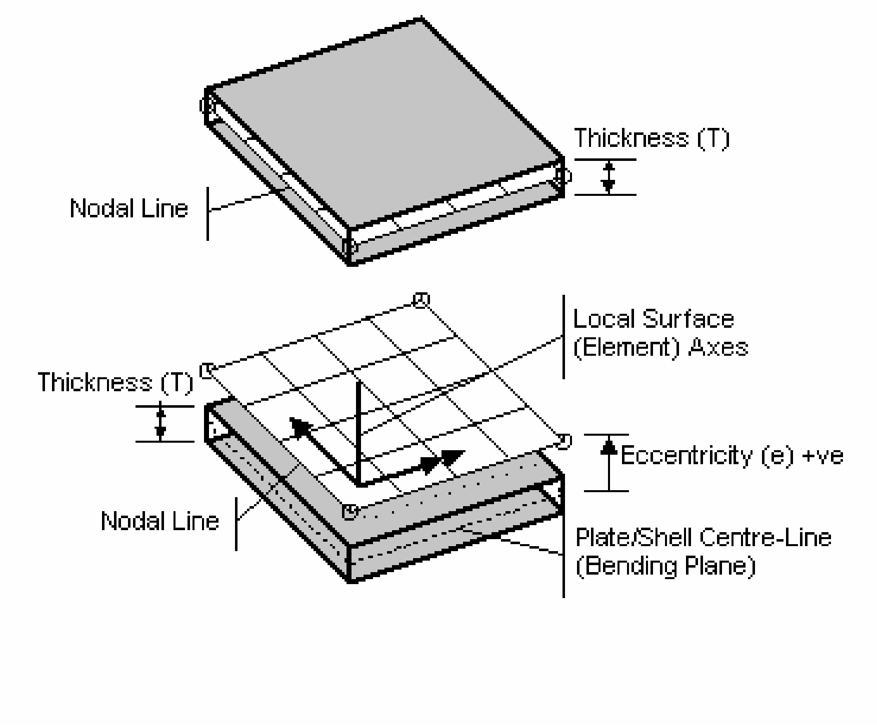
Bridge deck (nodal surface):



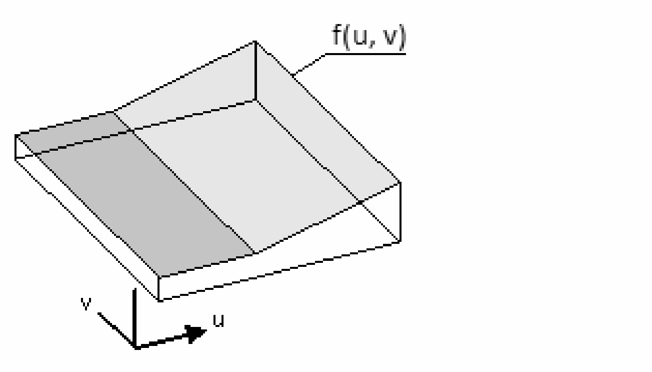
2.3 CROSS SECTION PROPERTIES

2.3.1 Shell element

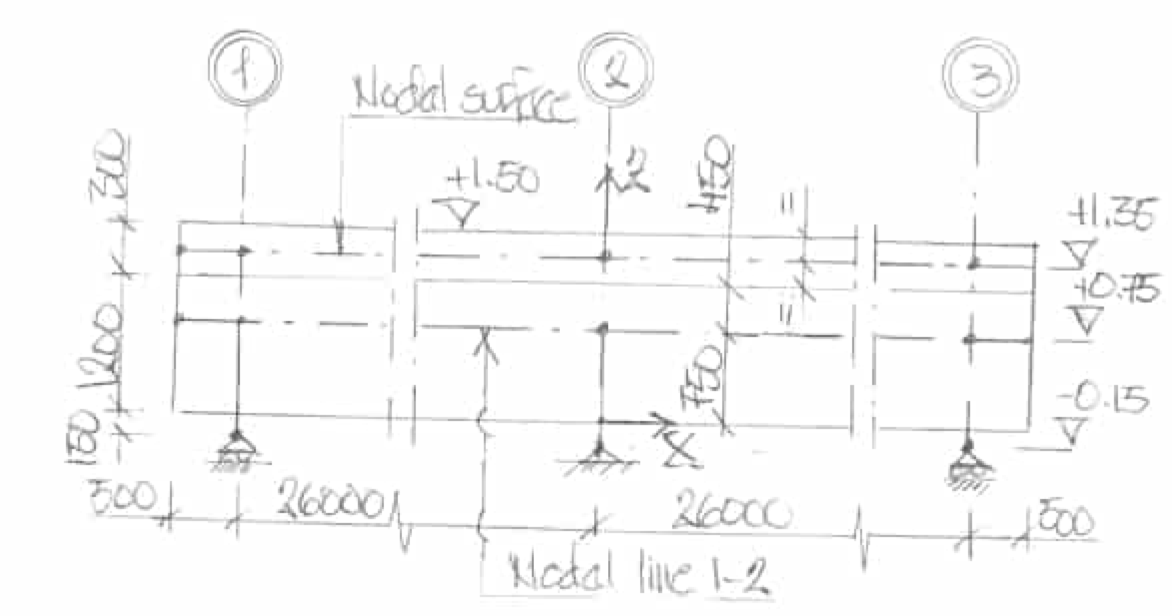
Principle figures of geometry associated to shell elements (”Thick shell” / QTS4) are seen below.

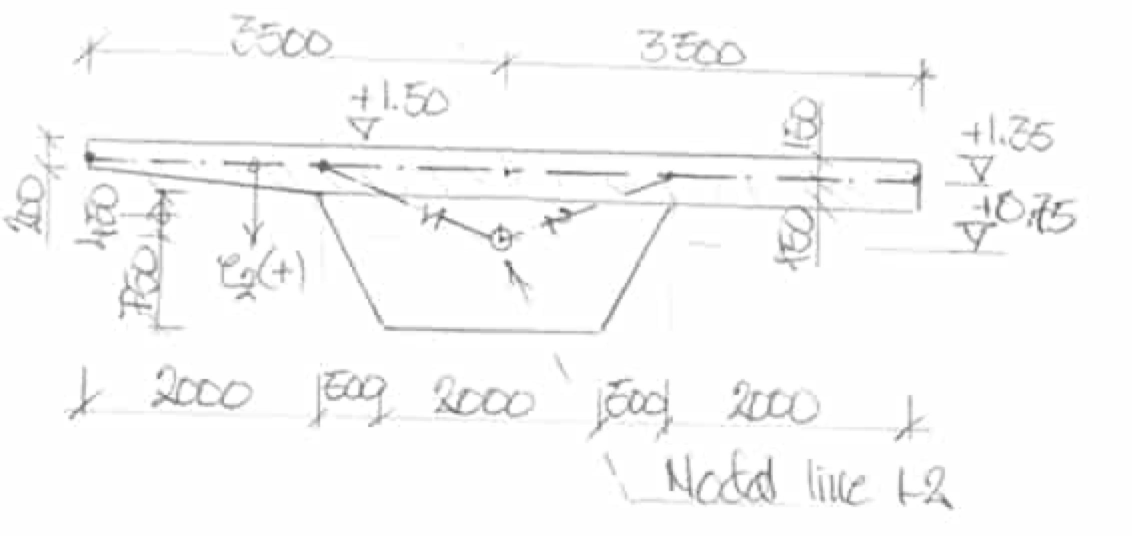


Varying thickness in shell element is handled using ”Function variation”. This makes it possible to create a function f(u,v) as seen below.



Geometry superstructure:





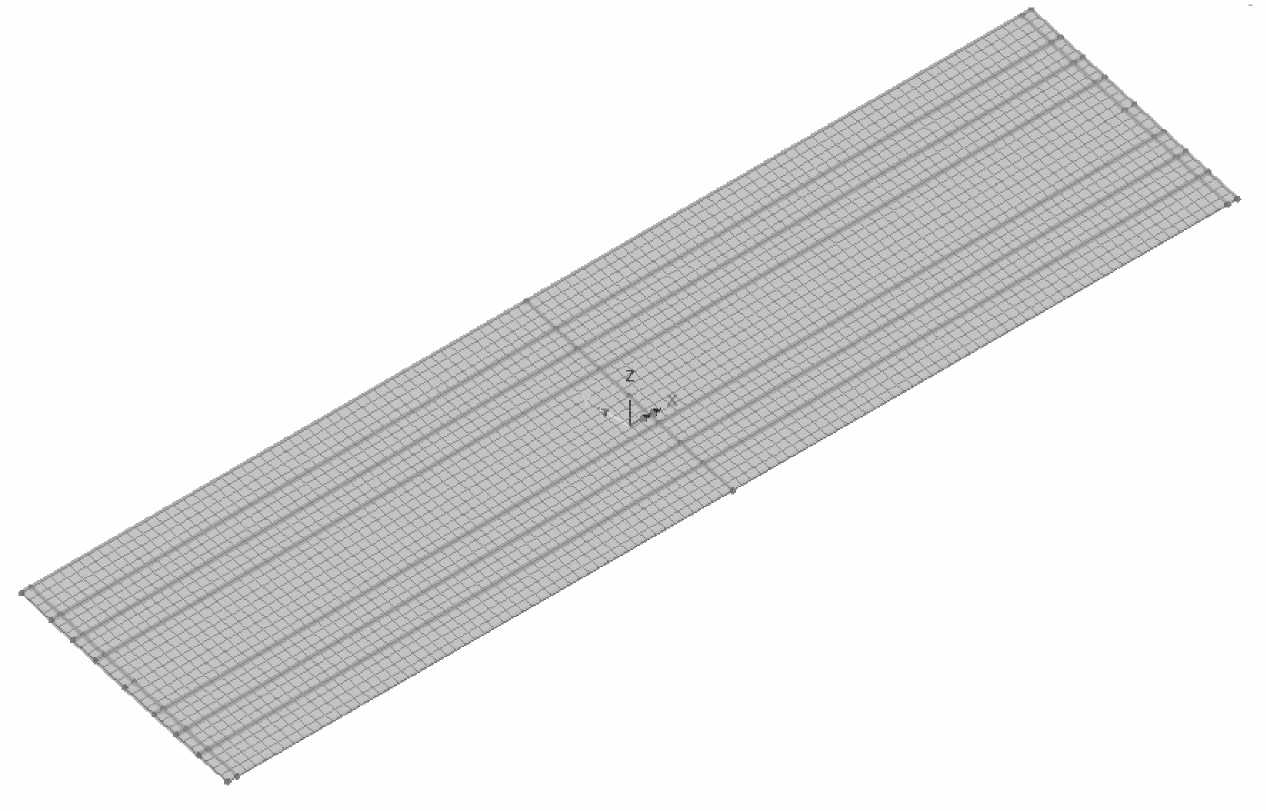
Surface function thickness :

Variation	Funktion(u,v)	Remark
t1	$0.30- 0.10 \cdot v$	Outer deck left side
t2	0.30	Inner deck
t3	$0.20 + 0.10 \cdot v$	Outer deck right
-	M	-

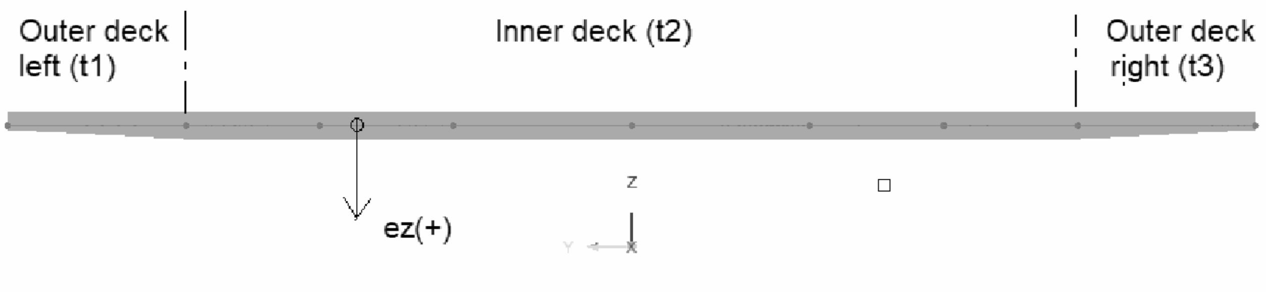
Surface function eccentricities:

Variation	Funktion(u,v)	Remark
e1	$-0.05 \cdot v$	Outer deck left side
e2	0	Inner deck
e3	$-0.05 + 0.05 \cdot v$	Outer deck right
-	m	-

Bridge deck:



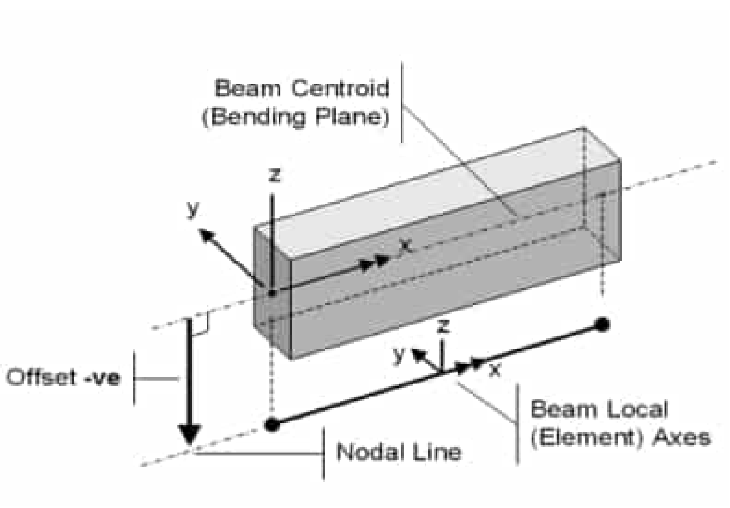
Overview



Section in transversal direction

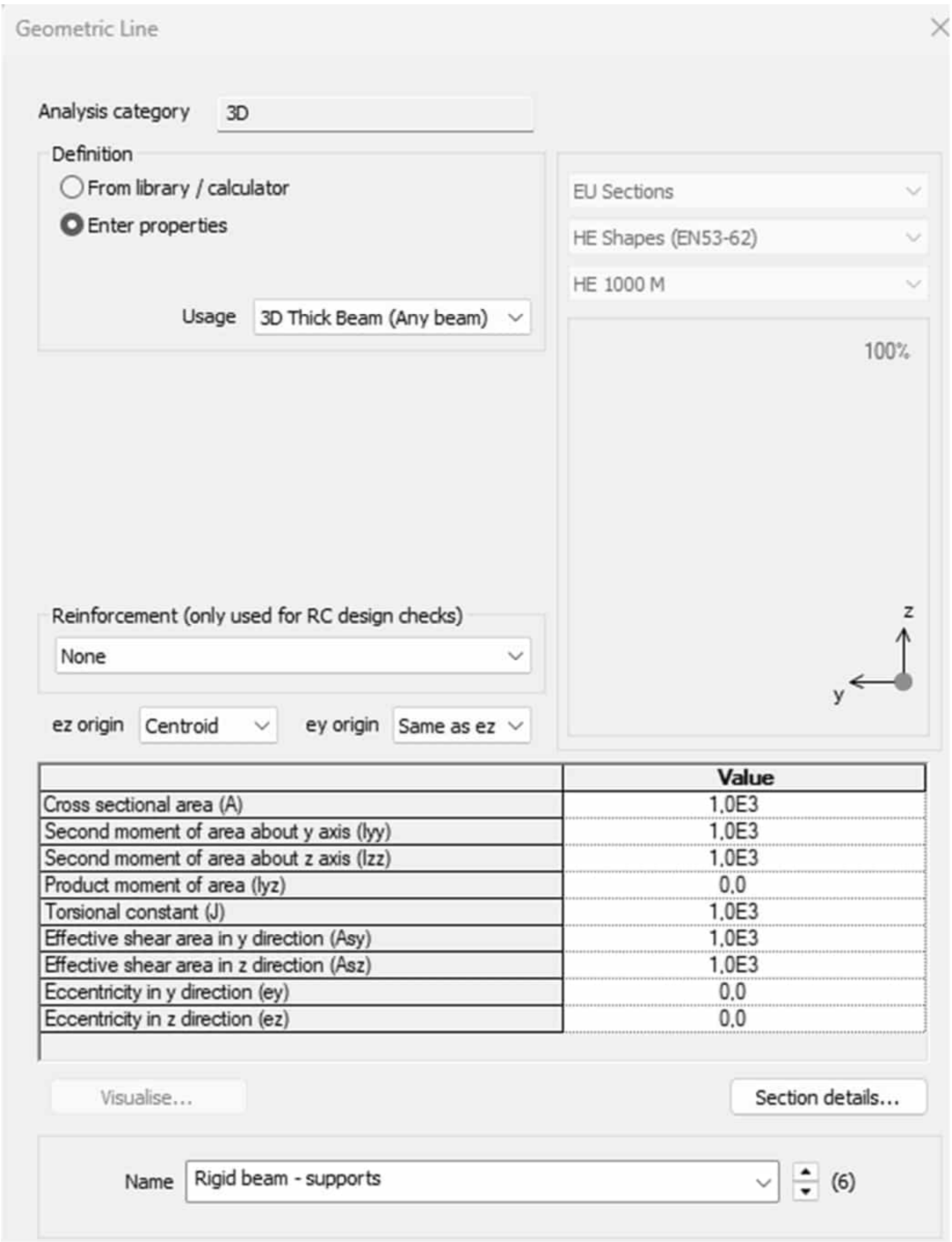
2.3.2 3D-beams (”Thick beam” / BMS3)

Principal sketch of geometry associated to 3D beam elements are seen below.



2.3.2.1 Rigid beams at supports

A fictive rigid beam is introduced at bottom of each support. The beam has infinite stiffness in all directions.



Analysis category: 3D

Definition
○ From library / calculator
● Enter properties

Usage: 3D Thick Beam (Any beam)

EU Sections
HE Shapes (EN53-62)
HE 1000 M

Reinforcement (only used for RC design checks): None

ez origin: Centroid
ey origin: Same as ez

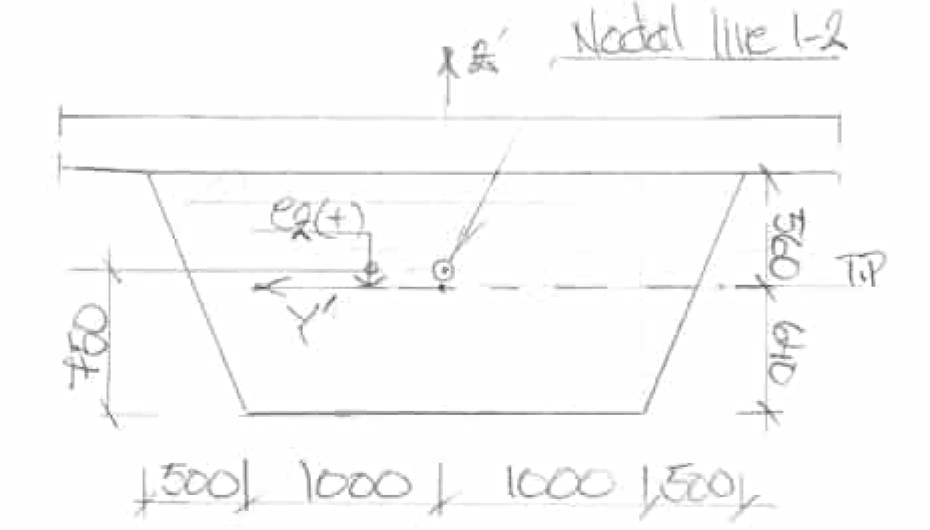
	Value
Cross sectional area (A)	1,0E3
Second moment of area about y axis (Iyy)	1,0E3
Second moment of area about z axis (Izz)	1,0E3
Product moment of area (Iyz)	0,0
Torsional constant (J)	1,0E3
Effective shear area in y direction (Asy)	1,0E3
Effective shear area in z direction (Asz)	1,0E3
Eccentricity in y direction (ey)	0,0
Eccentricity in z direction (ez)	0,0

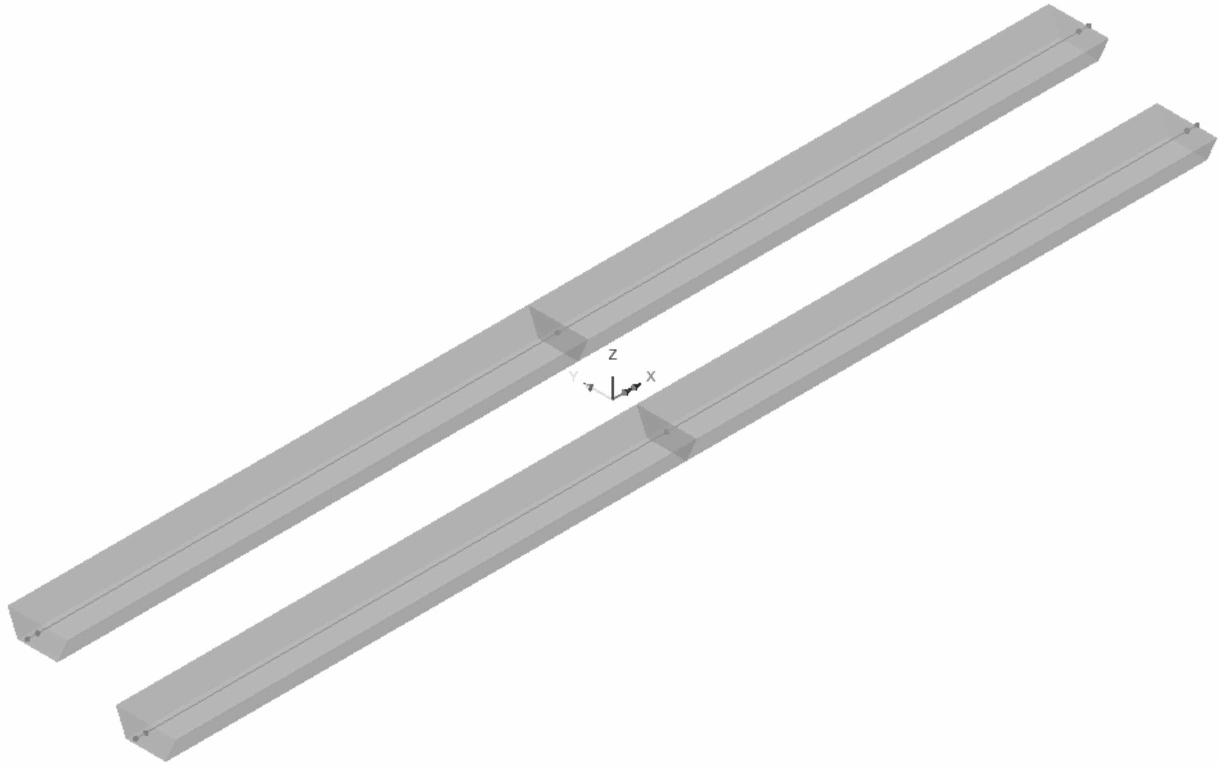
Name: Rigid beam - supports (6)

Overview

2.3.2.2 Longitudinal girdes

Determination of cross section properties is performed using function *Section Property Calculator*. The girders are defined as an arbitrary section termed ”Trapets”.

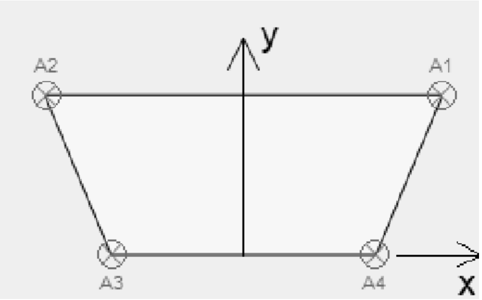




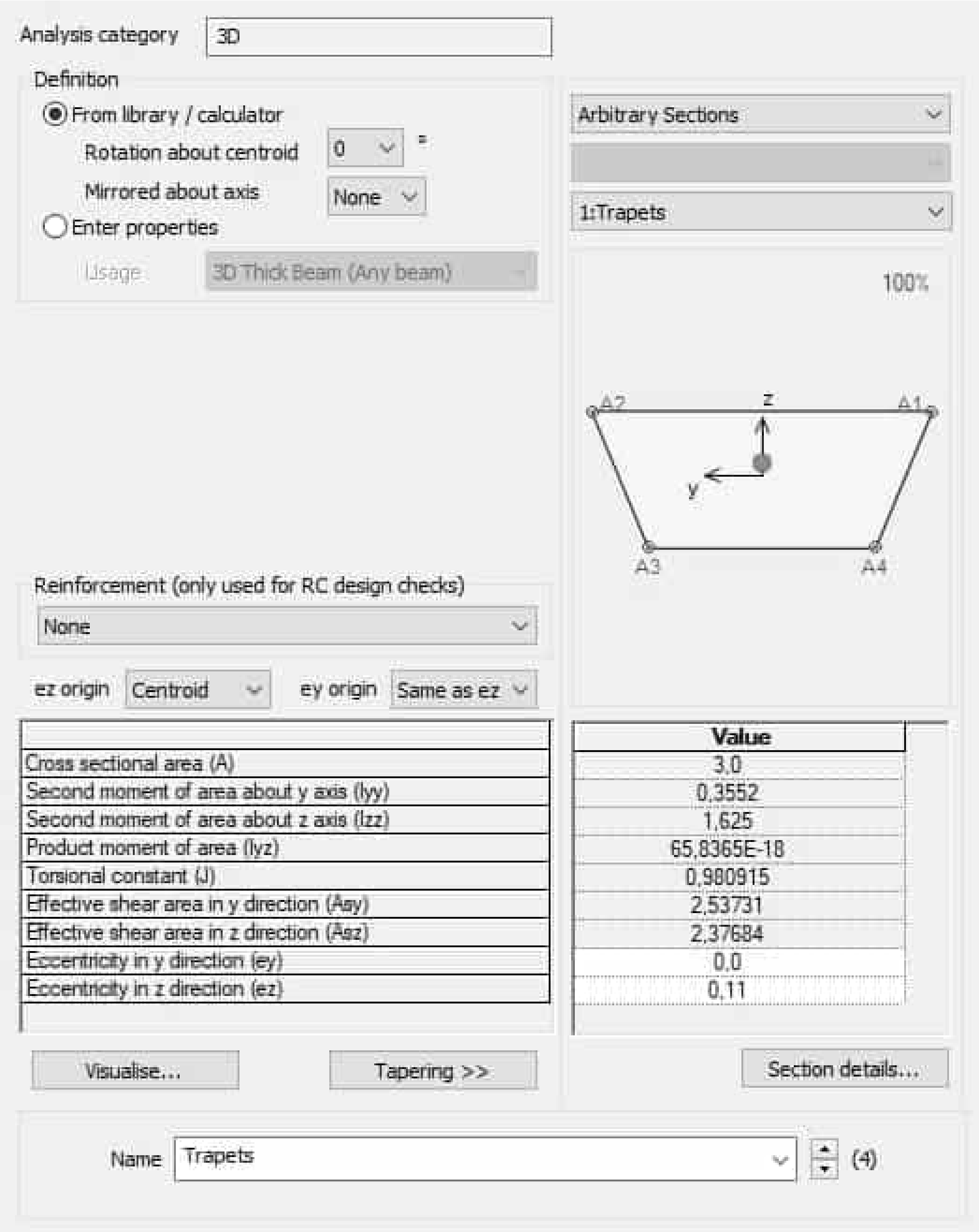
Overview

Input - arbitrary crossections

Punkt	x	y
A1	1.50	1.20
A2	-1.50	1.20
A3	-1.00	0
A4	1.00	0
-	m	m



Results cross section



Analysis category: 3D

Definition

● From library / calculator

Rotation about centroid: 0

Mirrored about axis: None

○ Enter properties

Usage: 3D Thick Beam (Any beam)

1:Trapets

Reinforcement (only used for RC design checks): None

ez origin: Centroid

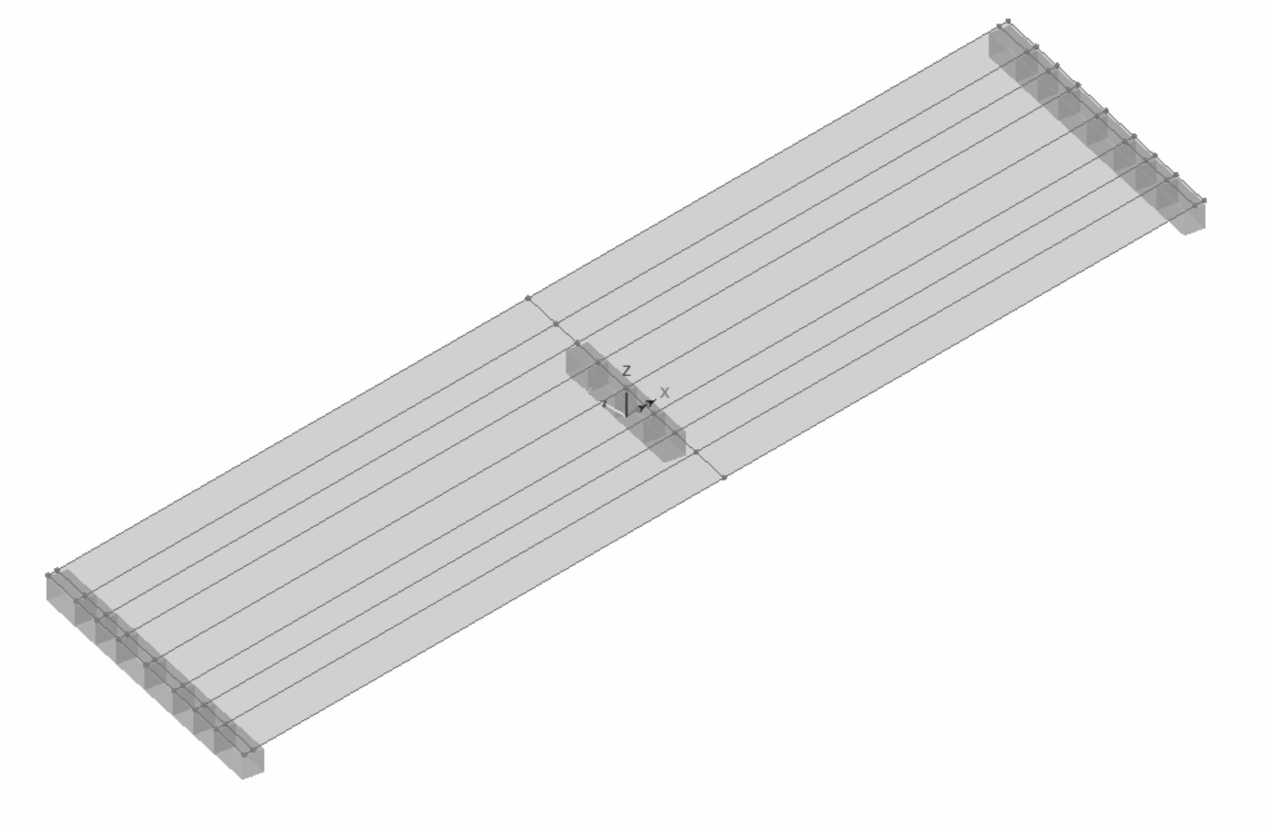
ey origin: Same as ez

	Value
Cross sectional area (A)	3,0
Second moment of area about y axis (Iyy)	0,3552
Second moment of area about z axis (Izz)	1,625
Product moment of area (Iyz)	65,8365E-18
Torsional constant (J)	0,980915
Effective shear area in y direction (Asy)	2,53731
Effective shear area in z direction (Asz)	2,37684
Eccentricity in y direction (ey)	0,0
Eccentricity in z direction (ez)	0,11

Name: Trapets (4)

2.3.2.3 Transversal girders

There are 3 transversal girders (TVB 1, TVB 2 and TVB 3) as visualized below.

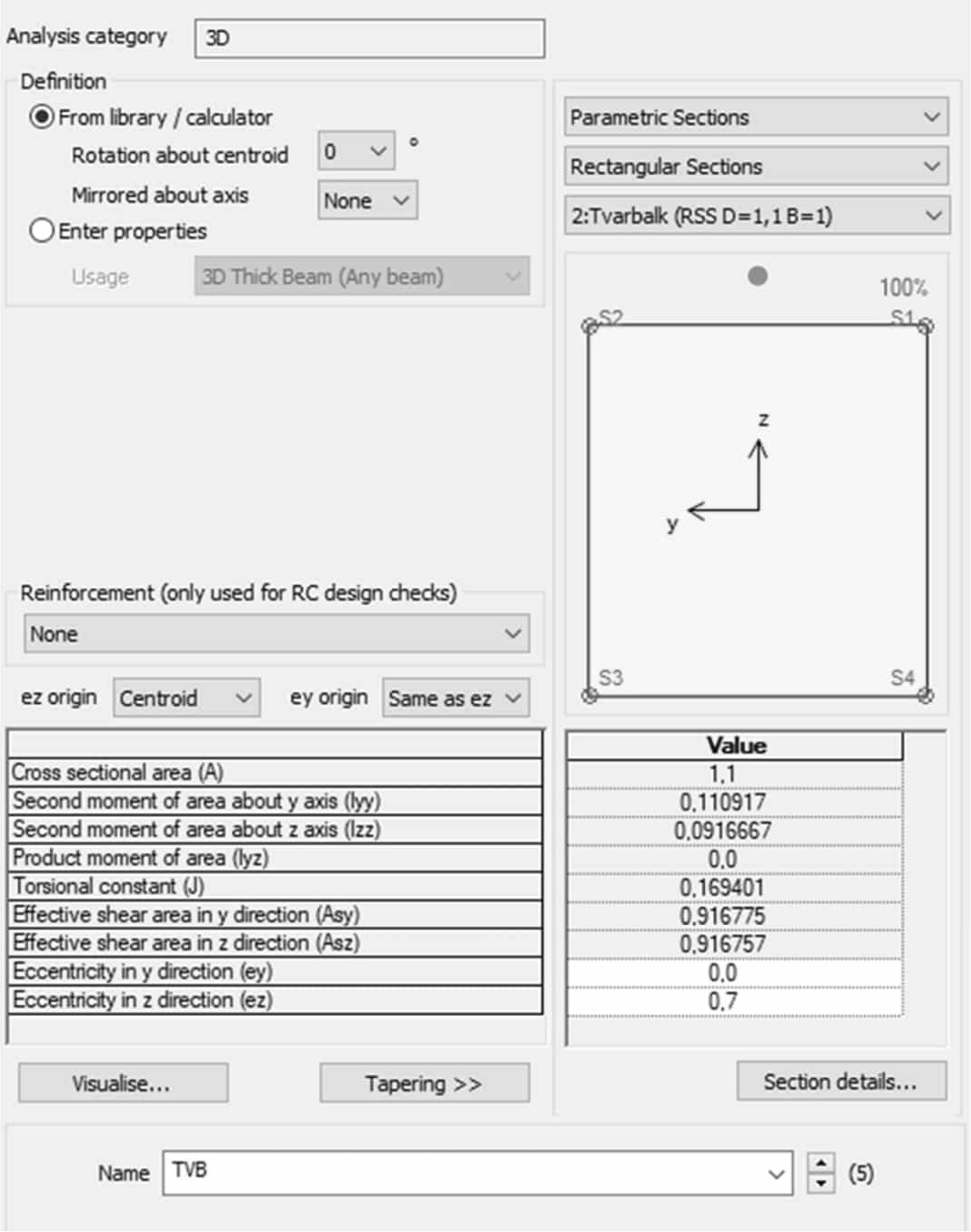


Overview

Input – cross section

Data	TVB
D	1.10
B	1.00
-	m

Result – cross sections



Analysis category: 3D

Definition

◉ From library / calculator

Rotation about centroid: 0 °

Mirrored about axis: None

○ Enter properties

Usage: 3D Thick Beam (Any beam)

Parametric Sections

Rectangular Sections

2:Tvarbalk (RSS D=1,1 B=1)

Reinforcement (only used for RC design checks): None

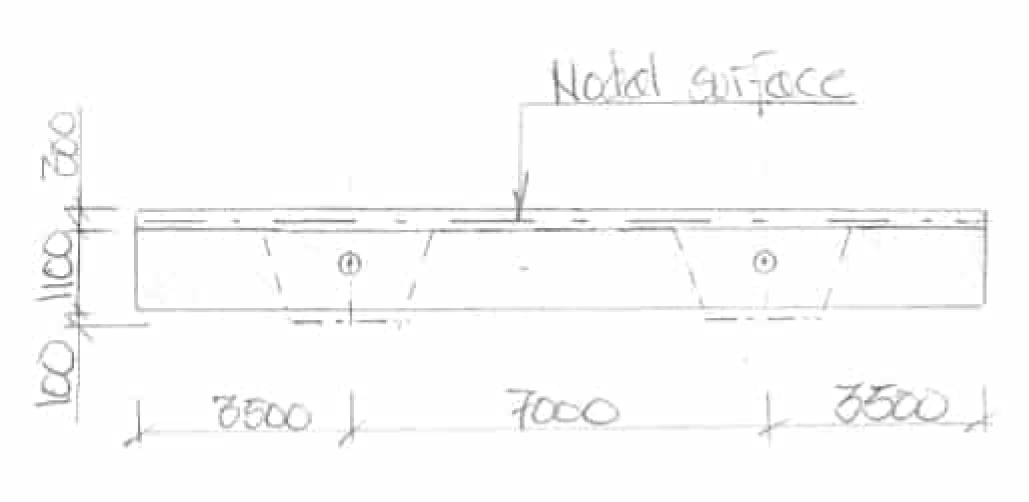
ez origin: Centroid

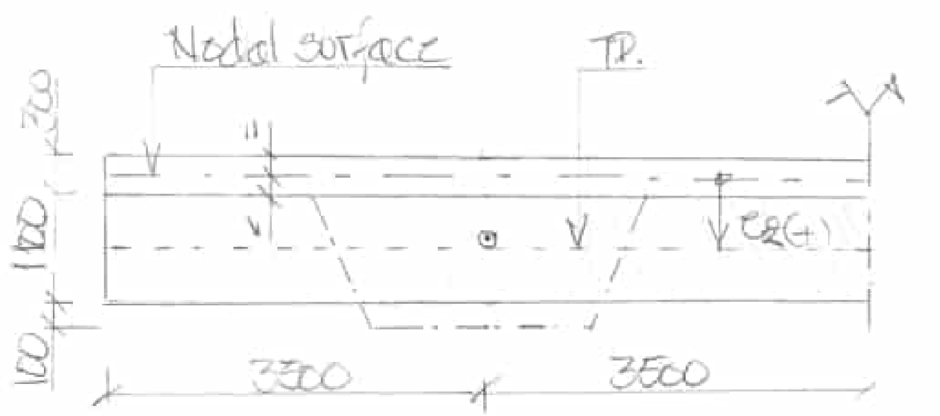
ey origin: Same as ez

	Value
Cross sectional area (A)	1,1
Second moment of area about y axis (Iyy)	0,110917
Second moment of area about z axis (Izz)	0,0916667
Product moment of area (Iyz)	0,0
Torsional constant (J)	0,169401
Effective shear area in y direction (Asy)	0,916775
Effective shear area in z direction (Asz)	0,916757
Eccentricity in y direction (ey)	0,0
Eccentricity in z direction (ez)	0,7

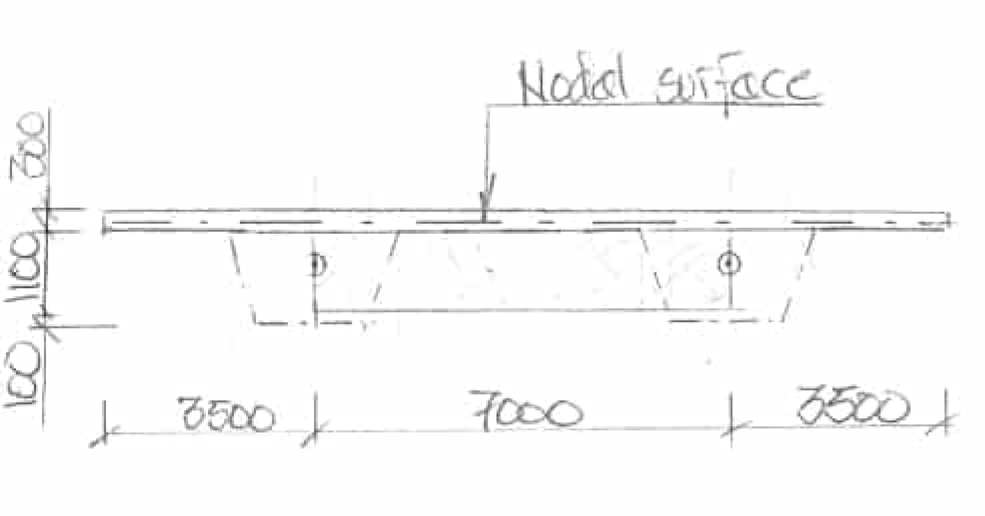
Name: TVB (5)

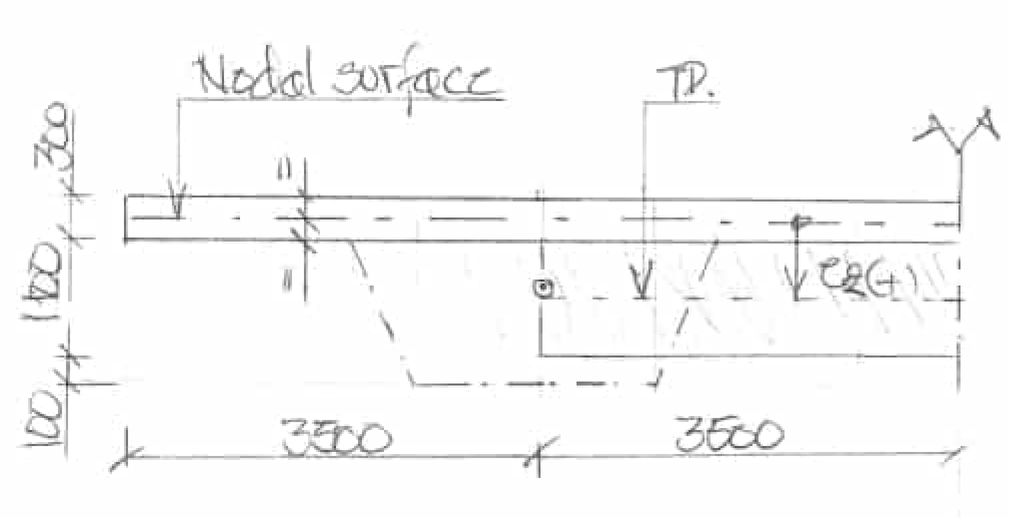
Geometry transversal girder at en supports (TVB 1 & TVB 3):





Geometry transversal girder at mid support (TVB 2):

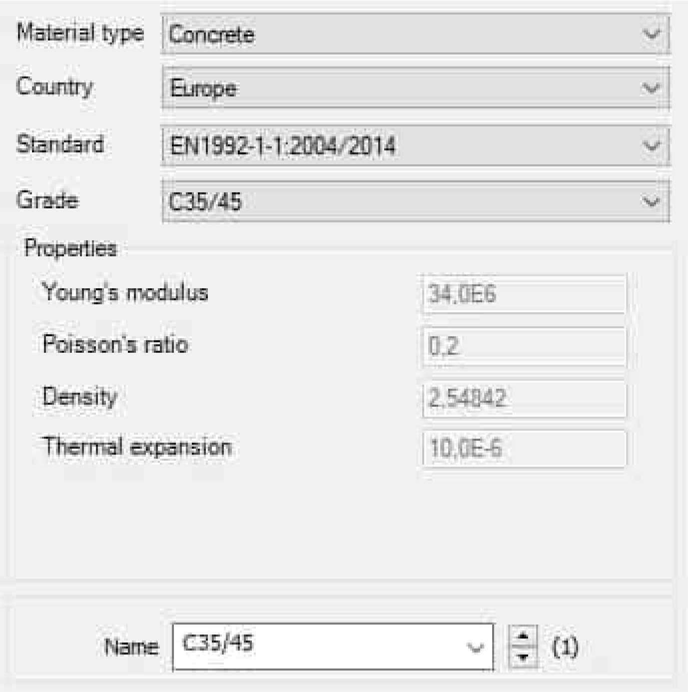




2.4 MATERIAL

The transverse contraction coefficient for uncracked concrete is assumed to be 0.2 for uncracked concrete according to SS-EN 1992-1-1, section 3.1.3 (4). Material properties corresponding to uncracked concrete are applied to all structural components in the system calculation.

Superstructure C34/45 : $E_{cm} = 34$ GPa



Material type	Concrete
Country	Europe
Standard	EN1992-1-1:2004/2014
Grade	C35/45

Properties

Young's modulus	34,0E6
Poisson's ratio	0,2
Density	2,54842
Thermal expansion	10,0E-6

Name C35/45 (1)

2.5 BOUNDARY CONDITIONS

All boundary conditions at each support are modelled as *Point Supports.*

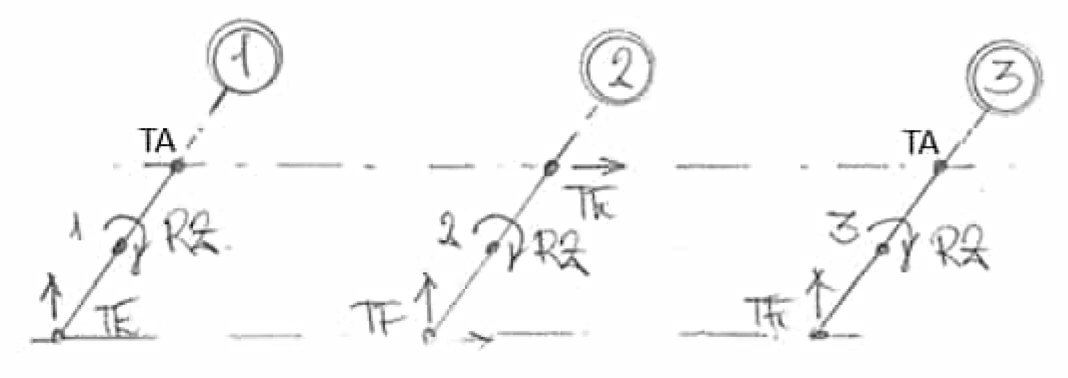
The boundary conditions in these “super-nodes” are modelled according to a local coordinate system oriented parallel to each support line as shown in the figure. This is intended to obtain reactions transformed into the directions of each support line.

Support	Point	Direction	TX	TY	TZ	RX	RY	RZ
1	P154	Local	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
2	P155	Local	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
3	P156	Local	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
-	-	-	kN/m	kN/m	kN/m	kNm/rad	kNm/rad	kNm/rad

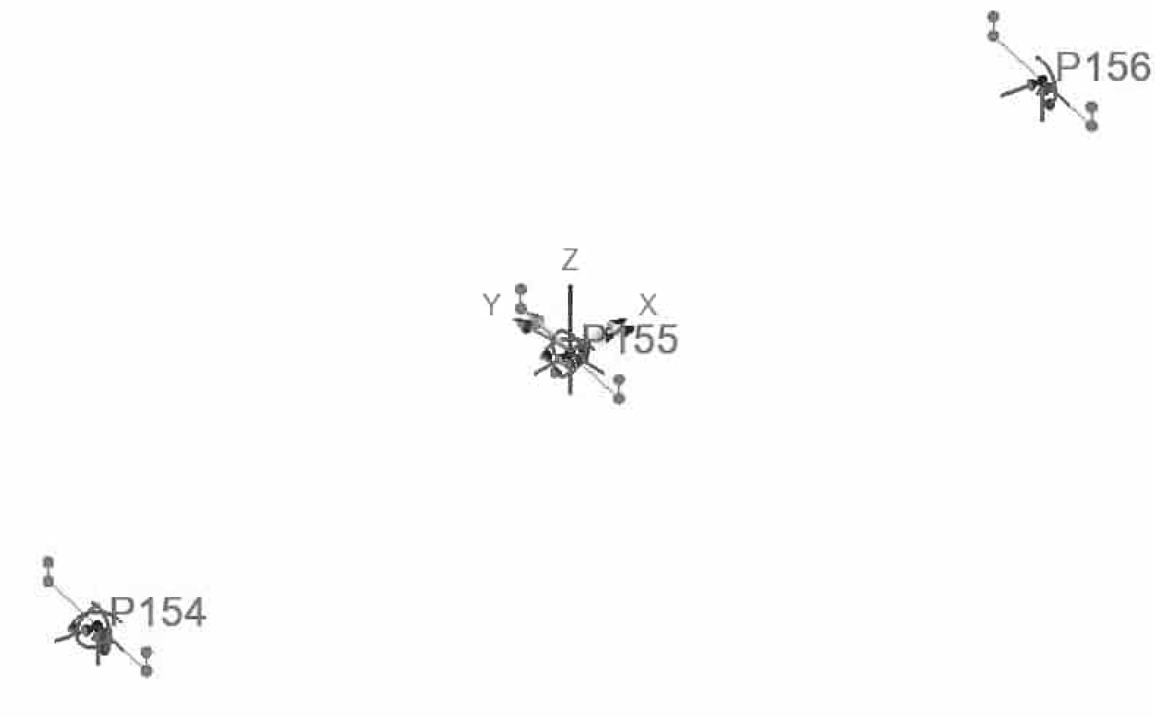
Bearings are are connected to rigid support beams called "rigid beams-supports."

For these to be able to withstand bearing forces, they must be made rotationally stiff, see page A2:35-36. This corresponds to RX = "Fixed" and RY = "Fixed."

RZ is "Fixed." This is due to the incline of the supports and the design of the bearings regarding orientation and placement. To prevent each support from rotating freely under bearing forces, this "super-node" must be locked against rotation in the plane, see sketch below.

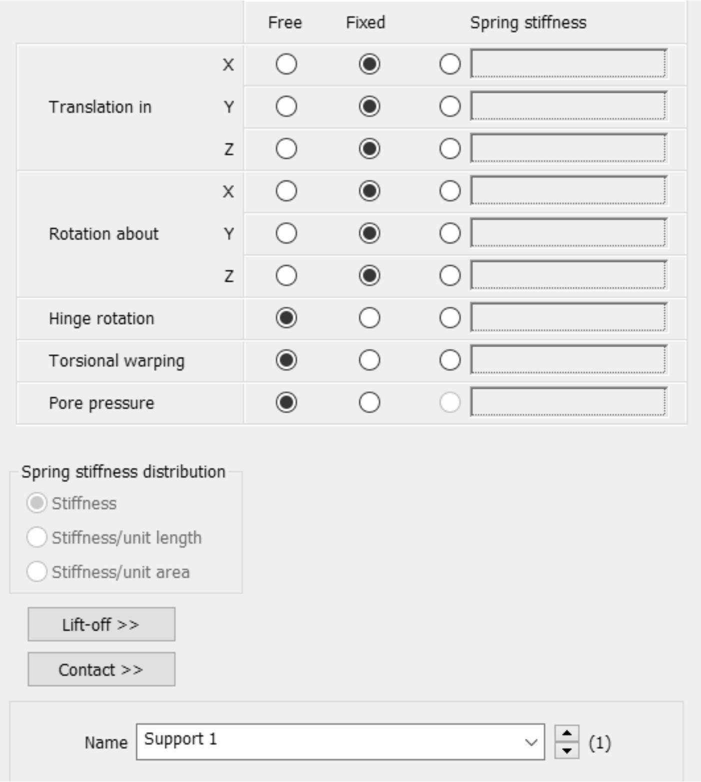


PLAN



Overview

Supernode – support 1:

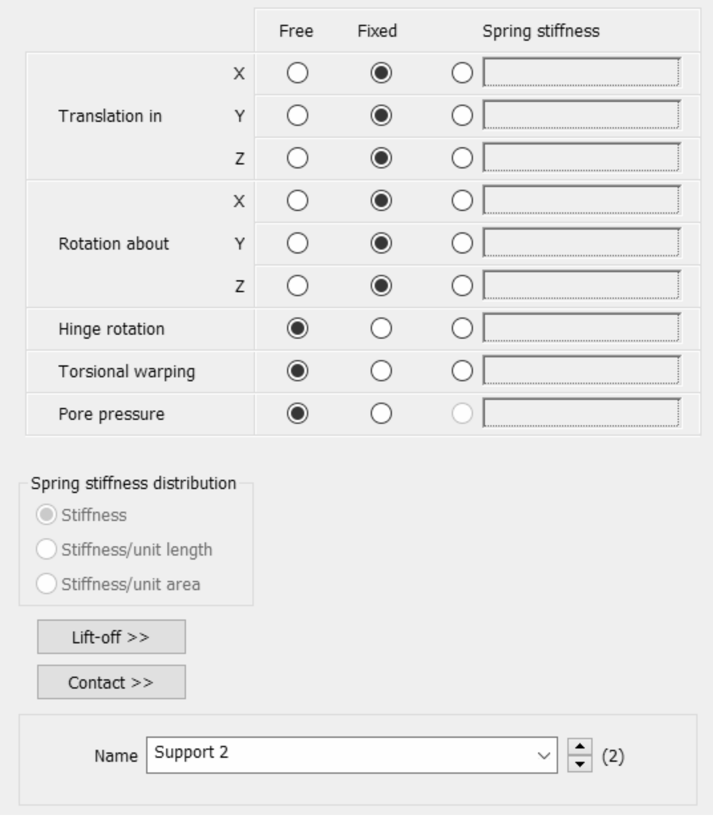


		Free	Fixed	Spring stiffness
Translation in	X	○	●	○
	Y	○	●	○
	Z	○	●	○
Rotation about	X	○	●	○
	Y	○	●	○
	Z	○	●	○
Hinge rotation		●	○	○
Torsional warping		●	○	○
Pore pressure		●	○	○

Spring stiffness distribution
● Stiffness
○ Stiffness/unit length
○ Stiffness/unit area

Name Support 1 (1)

Supernode – support 2:

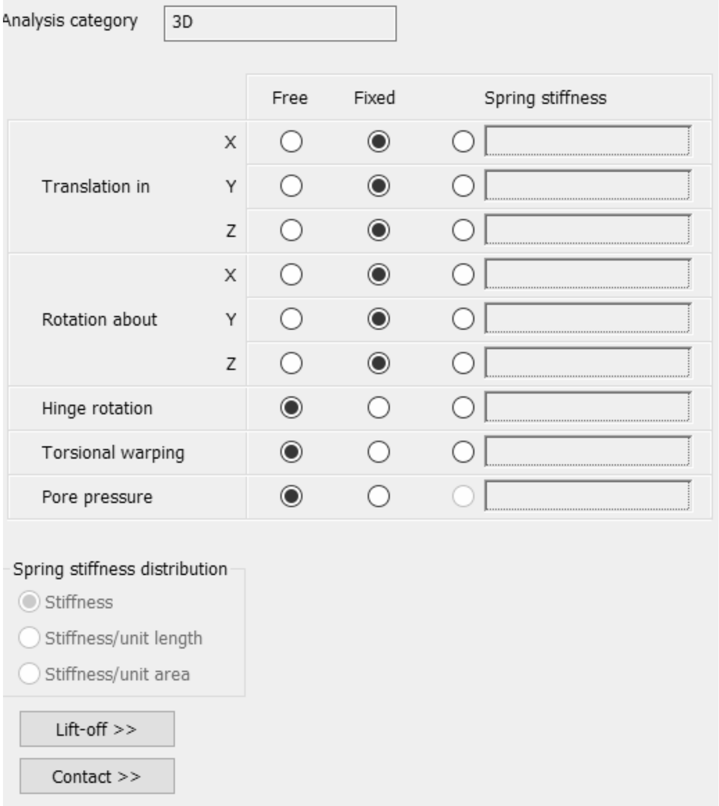


		Free	Fixed	Spring stiffness
Translation in	X	○	●	○
	Y	○	●	○
	Z	○	●	○
Rotation about	X	○	●	○
	Y	○	●	○
	Z	○	●	○
Hinge rotation		●	○	○
Torsional warping		●	○	○
Pore pressure		●	○	○

Spring stiffness distribution
● Stiffness
○ Stiffness/unit length
○ Stiffness/unit area

Name Support 2 (2)

Supernode – support 3:



Analysis category: 3D

		Free	Fixed	Spring stiffness
Translation in	X	○	●	○
	Y	○	●	○
	Z	○	●	○
Rotation about	X	○	●	○
	Y	○	●	○
	Z	○	●	○
Hinge rotation		●	○	○
Torsional warping		●	○	○
Pore pressure		●	○	○

Spring stiffness distribution
- ● Stiffness
- ○ Stiffness/unit length
- ○ Stiffness/unit area

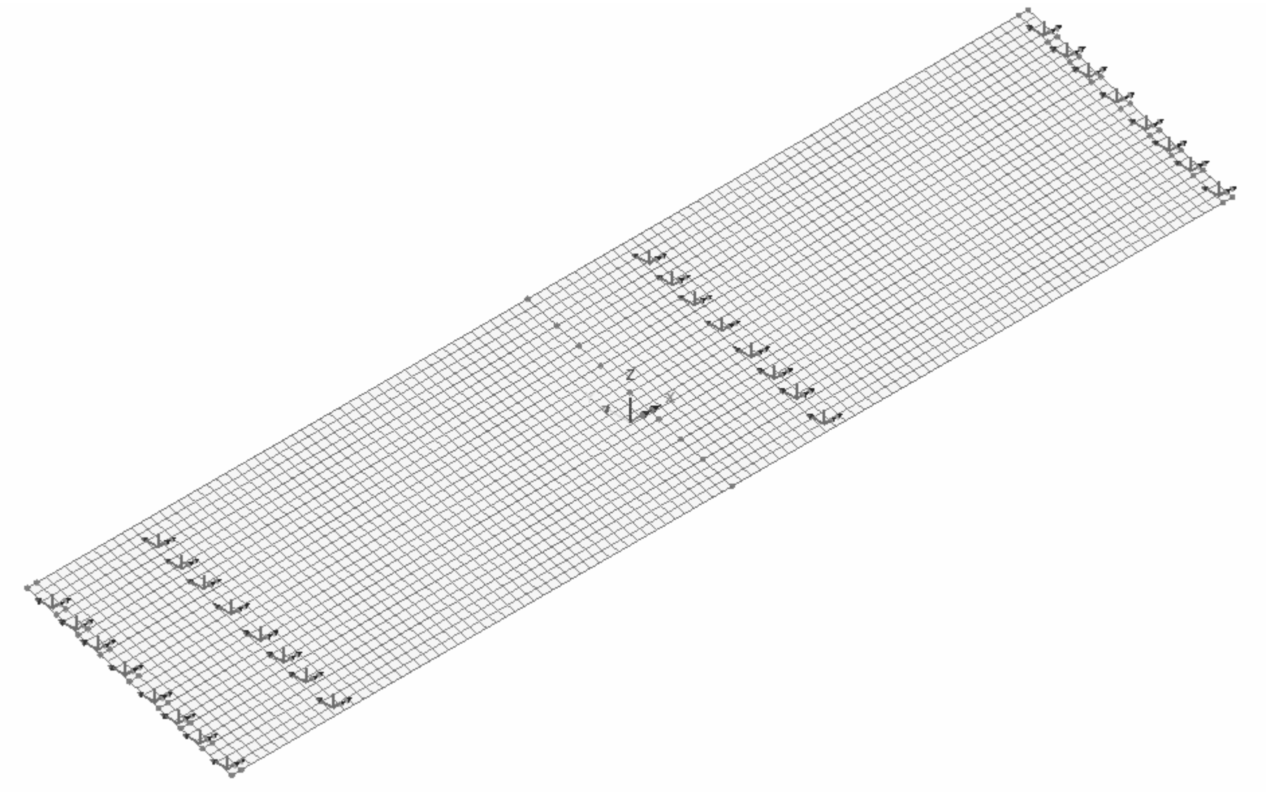
2.6 MESH

2.6.1 Shell element (QTS4): linear

Bridge deck is model using shell elements.

Shell elements are modelled with various subdivisions as seen below.

Type	x-divisions	y-divisions
Element 1 x 3	1	3
Element 1 x 4	1	4
Element 52 x 3	52	3
Element 52 x 4	52	4



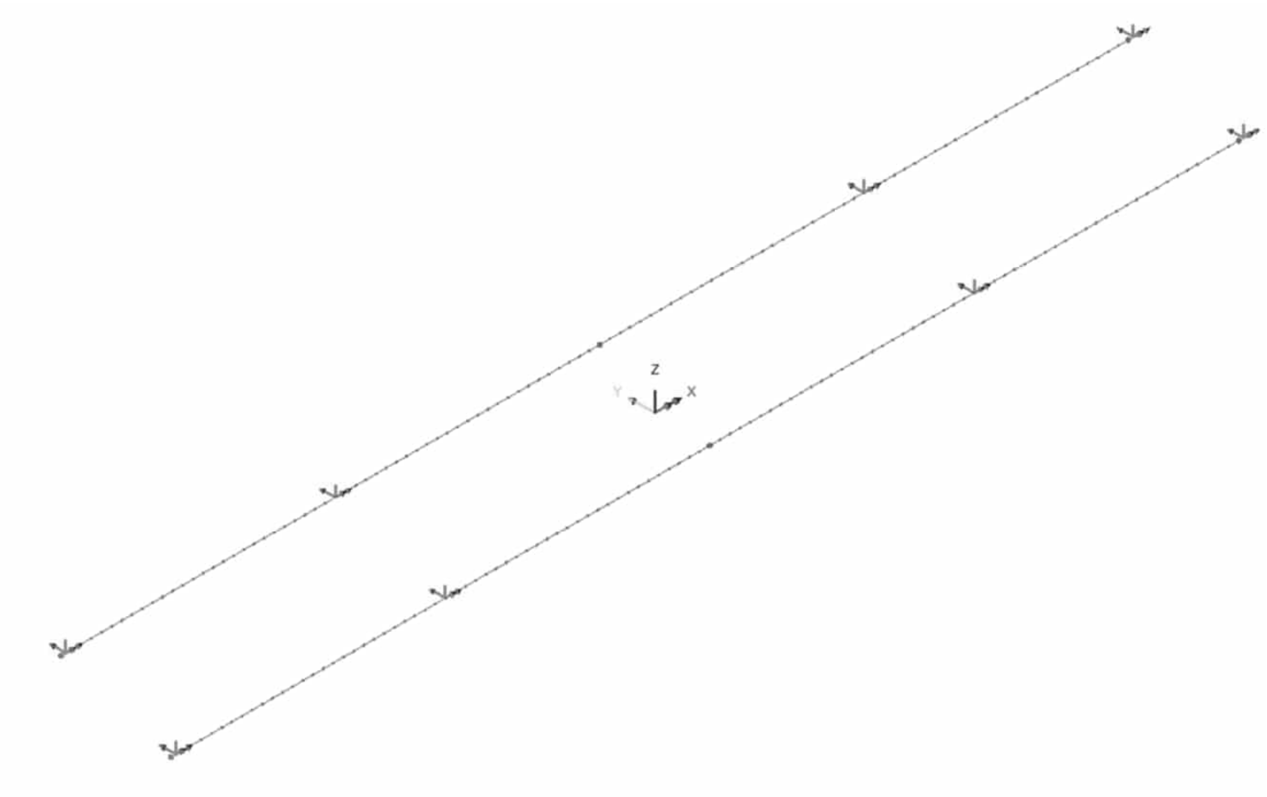
2.6.2 Beam element (BMI21) : linear

Longitudinal & transversal girders in superstructure are modelled using beam elements. This also applies to rigid beam at supports.

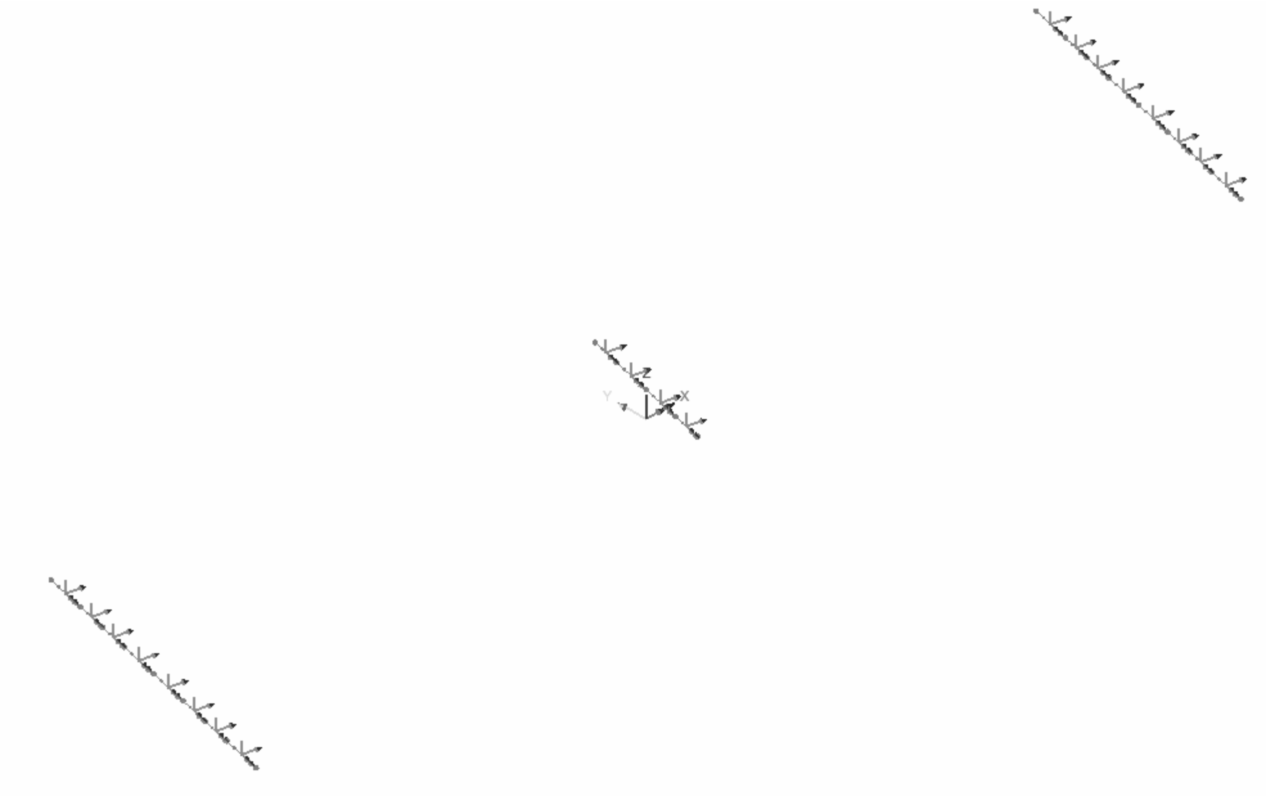
Beams elements are modelled with various subdivisions as seen below.

Name	Divisions	End release: Start	End release: End	Structure
Element 1	1	None	None	Girder
Element 3	3	None	None	Girder
Element 4	4	None	None	Girder
Element 52	52	None	None	Girder
Support	1	None	None	Rigid beam support

2.6.2.1 Longitudinal girders

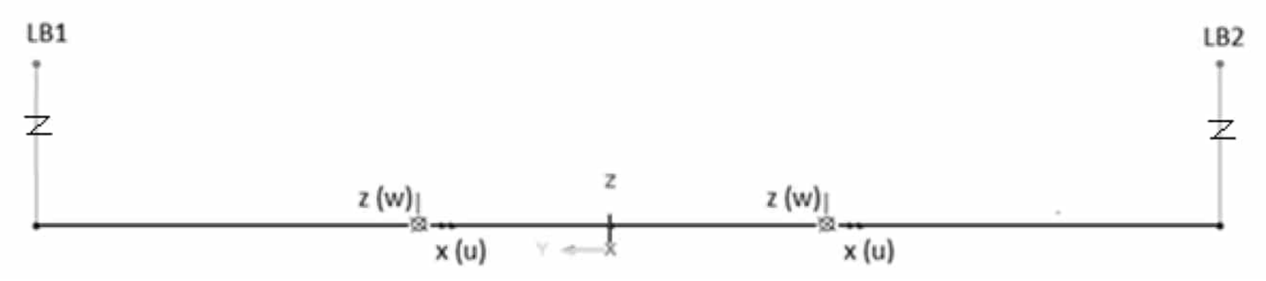


2.6.2.2 Transversal griders

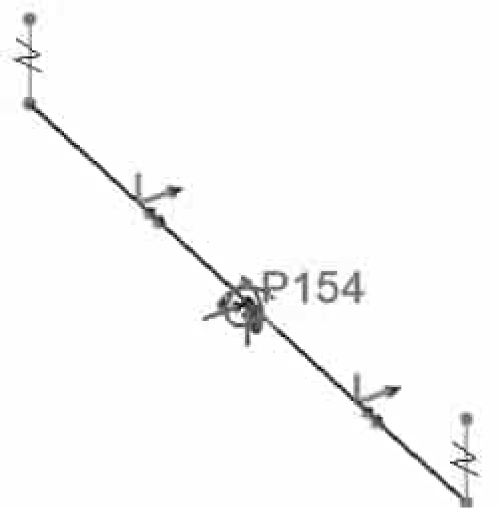


2.6.2.3 Rigid beams at supports

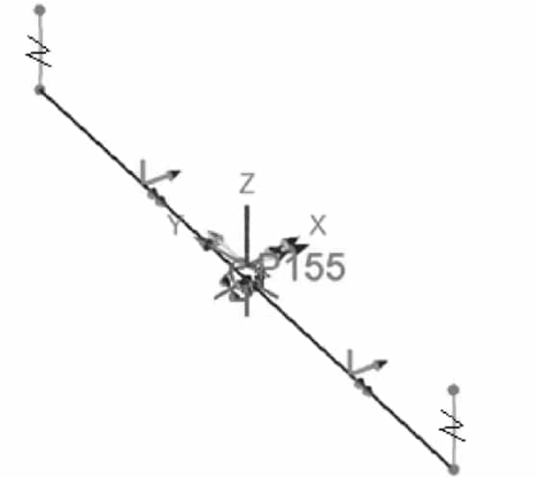
Bearings (joints) are conected to boundary supports (”supernodes”) with fictious rigid beams as seen below.



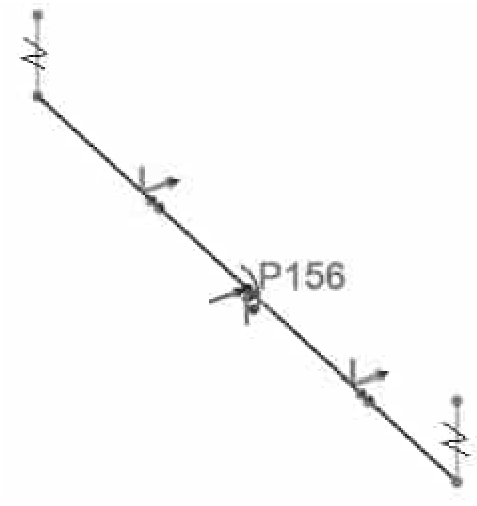
Rigid beam supernode – support 1:



Rigid beam supernode – support 2:



Rigid beam supernode – support 3:



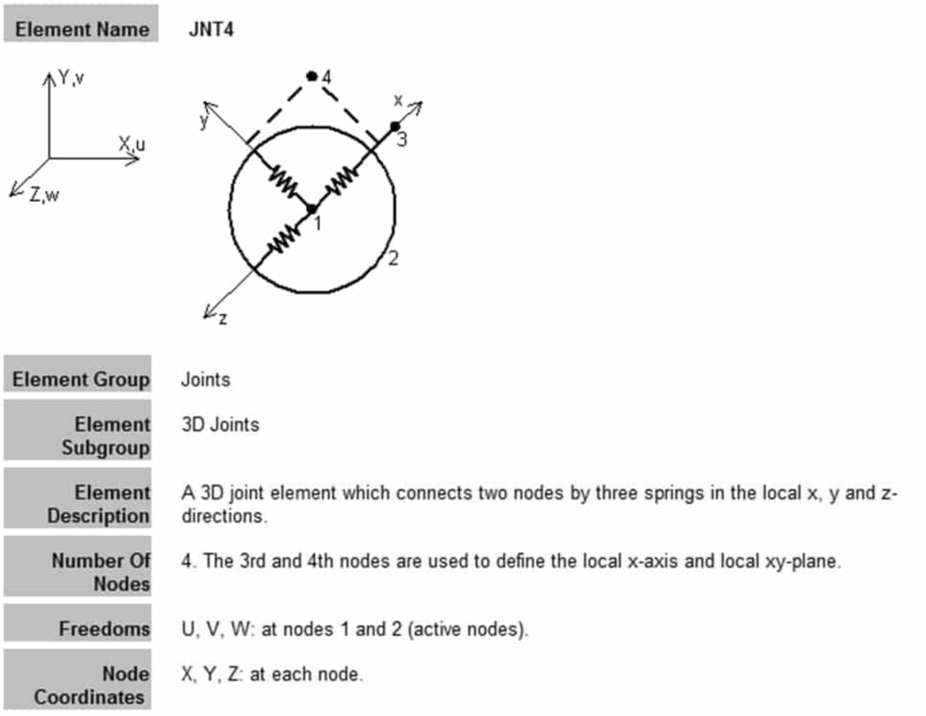
2.6.3 Joint elements between points (JNT4): linear

Bearings are modelled using joint element, see presentation below.

Element type: Joint no rotational stiffness

Assignment type: Between two features (manual)

Mesh direction: Nodal line (master) → Node rigid beam (slave)



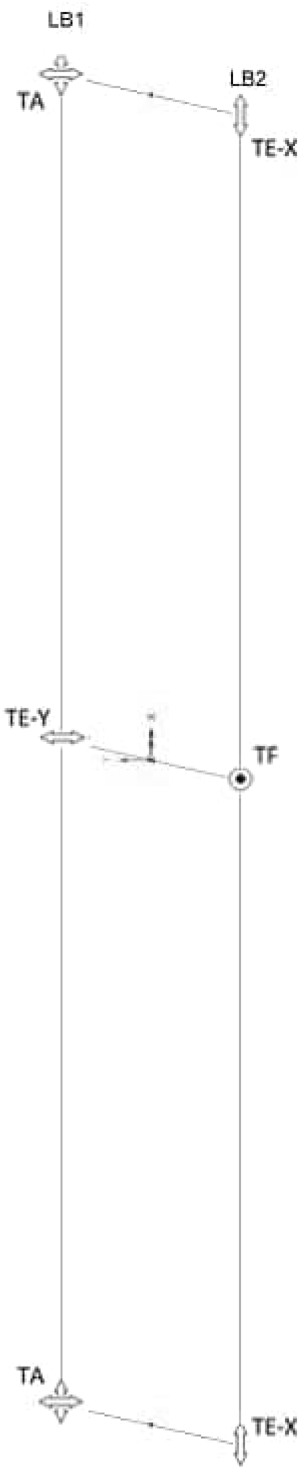
Element Name	JNT4
Element Group	Joints
Element Subgroup	3D Joints
Element Description	A 3D joint element which connects two nodes by three springs in the local x, y and z-directions.
Number Of Nodes	4. The 3rd and 4th nodes are used to define the local x-axis and local xy-plane.
Freedoms	U, V, W: at nodes 1 and 2 (active nodes).
Node Coordinates	X, Y, Z: at each node.

Joint materials ("Joint no rotational stiffness"):

Material	u (X)	v (Y)	w (Z)
Joint material - TF	1E+06	1E+06	1E+06
Joint material - TA	1E+06	0	0
Joint material - TE:X	1E+06	1E+06	0
Joint material - TE:Y	1E+06	0	1E+06
-	kN/m	kN/m	kN/m

Remark

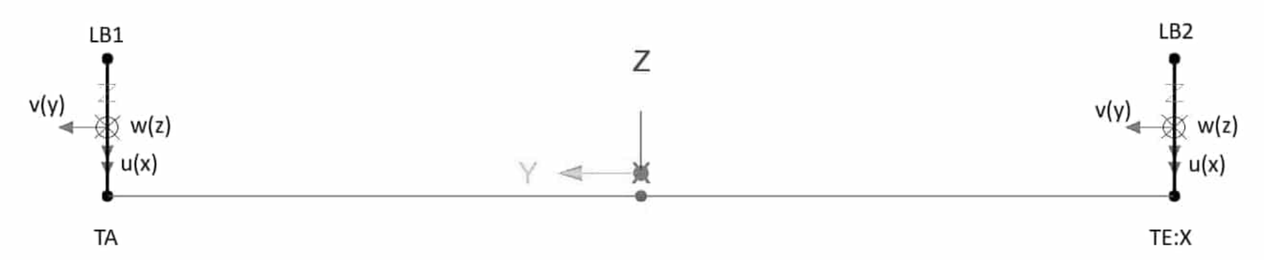
The local coordinate system in rigid beams is denoted x(u), u(v), and z(w).
The global coordinate system is denoted X, Y, and Z.
These two coordinate systems differ from each other. When describing bearings, the local coordinate system is applied.



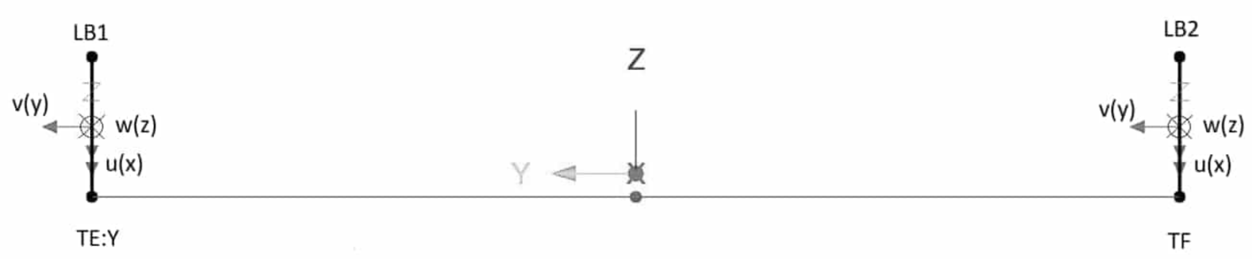
<u>PLAN</u>
Overview bearing types

	Part A – CALCULATION ASSUMPTION Pretensioned double girder bridge	Status :	Page: A2:39
		Date:	Created:

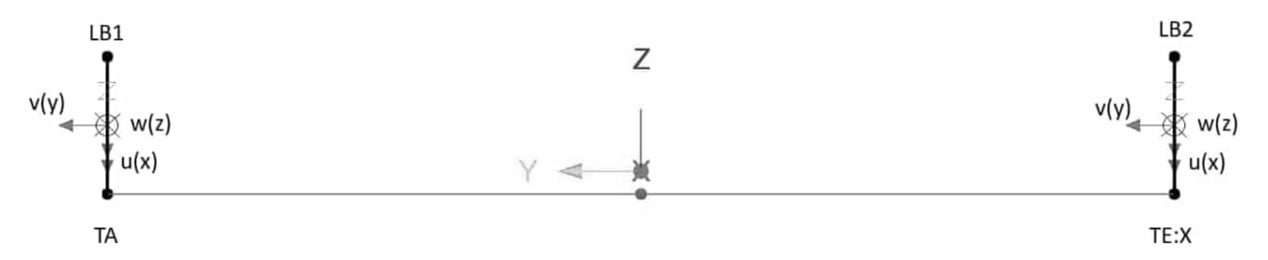
Bearings – support 1:



Bearings – support 2:



Bearings – support 3:



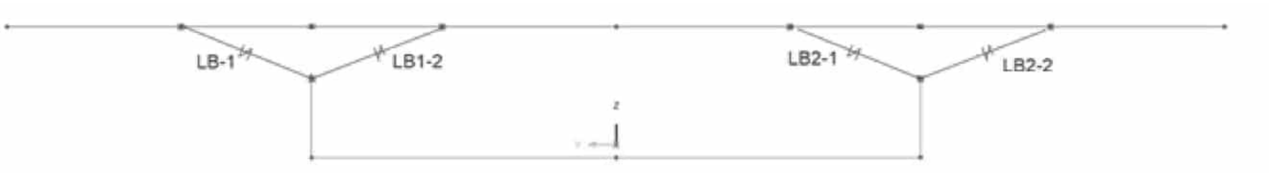
2.6.4 Stel anslutning (Tied Mesh)

Deck is modelled as shell elements. They are defined by nodal surface.

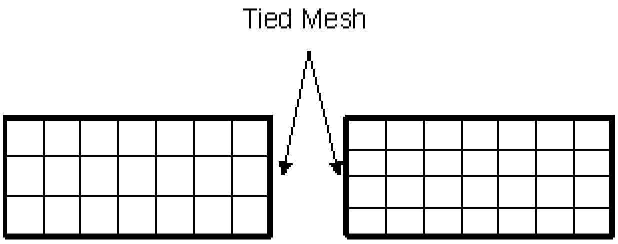
Ribs are modelled as rectangular beam elements. They are defined by nodal lines.

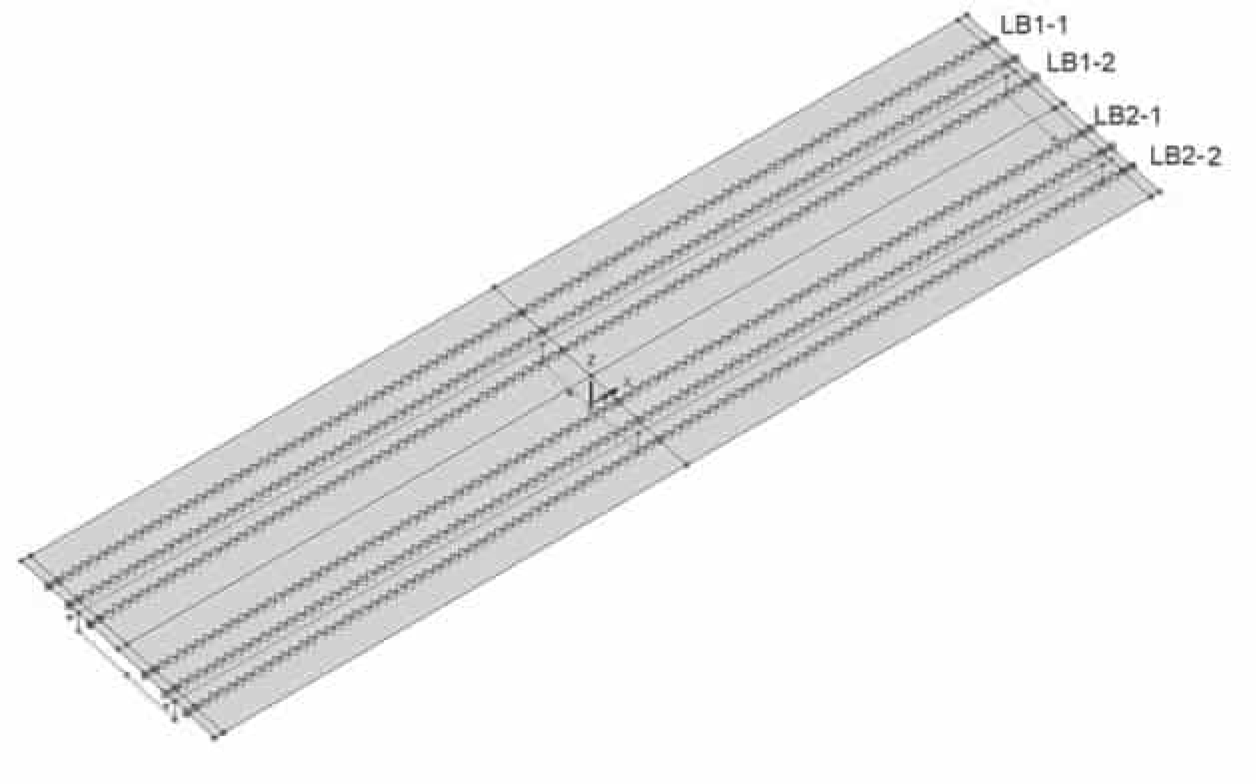
Longitudinal girders are tied to bridge deck using constant constraints.

Longitudinal girder are master nodes.



Connection Tied Mesh”: type Rigid constraint

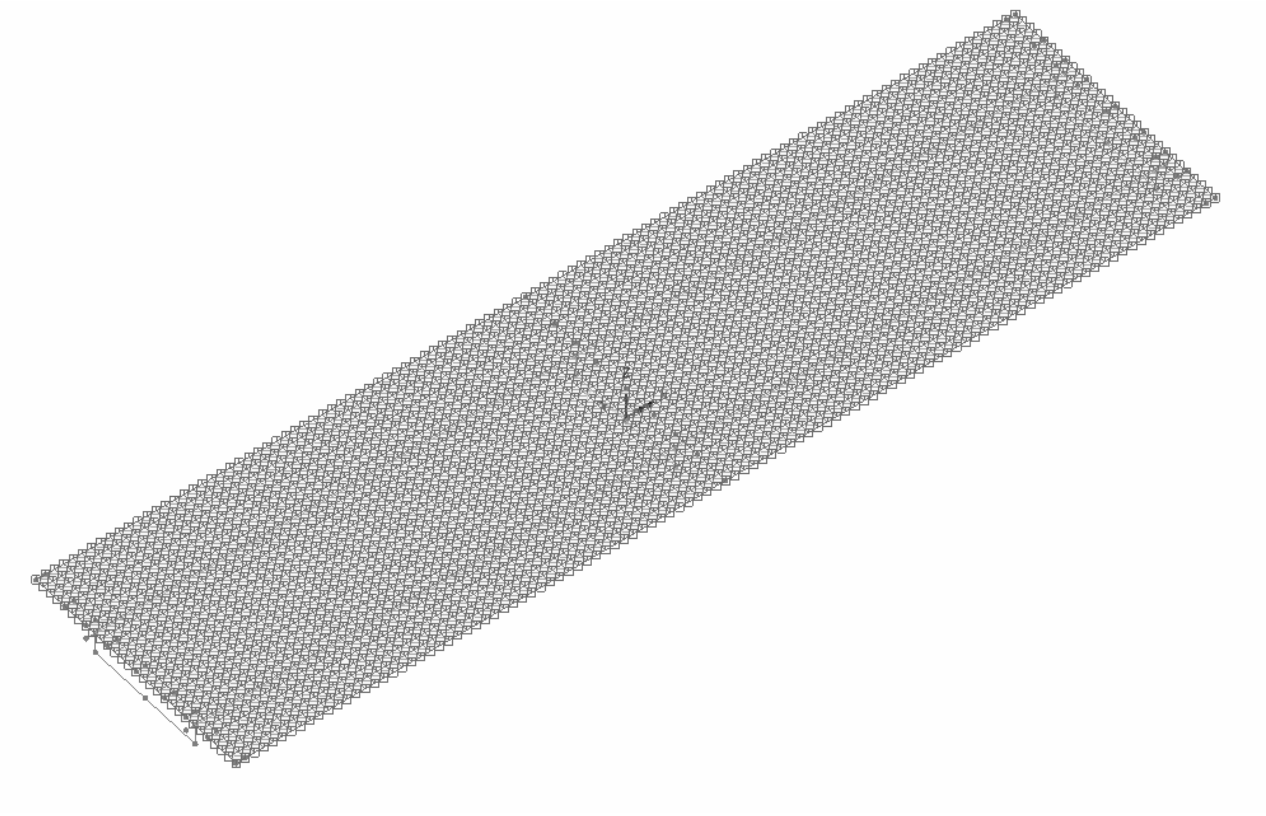




Overview

2.7 SEARCH AREA

Discrete load can be applied to structure as geometrical load areas. In FEM-program load areas are termed Search Area.



Search area : Bridge deck

2.8 SLICE RESULTANTS BEAMS/SHELLS

Slice resultant beams are needed at location of all girders.

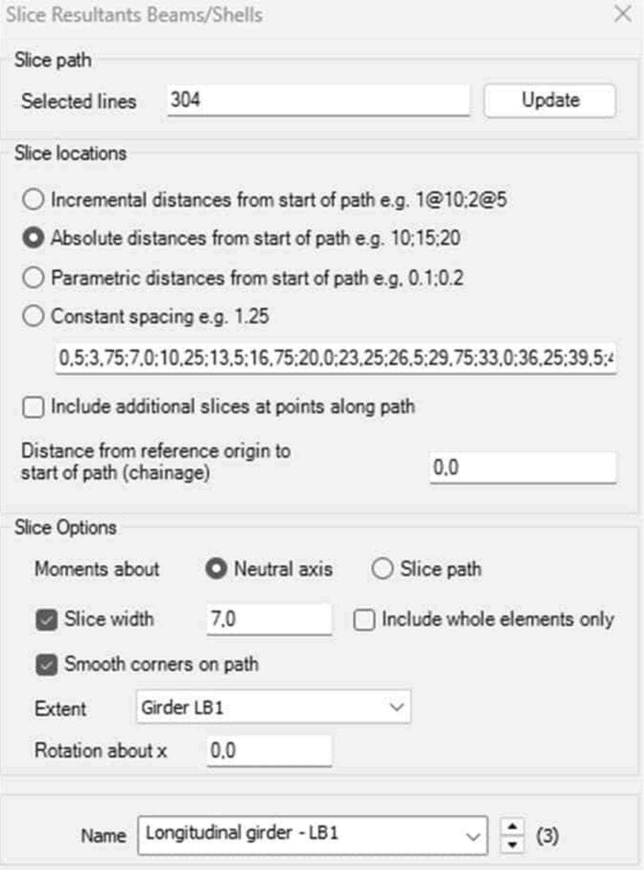
2.8.1 Longitudinal girders

Equivalent forces will be determined at the 8th subpoints for each main girders. This is done by examining the load effects in the Nodal surface and Nodal line for the respective main girders LB 1 and LB 2.

FEM-program uses script called 'Slice Resultant Beams/Shells' to handle this, see the presentation below.

Beam	Path line	Extent	Remark
LB1	304	Girder LB1	Width = 7.00 m
LB2	306	Girder LB2	Width = 7.00 m
-	-	-	-

2.8.1.1 Slice beam ball LB1



Slice Resultants Beams/Shells

Slice path

Selected lines: 304

Slice locations

○ Incremental distances from start of path e.g. 1@10;2@5
● Absolute distances from start of path e.g. 10;15;20
○ Parametric distances from start of path e.g. 0.1;0.2
○ Constant spacing e.g. 1.25

0,5;3,75;7,0;10,25;13,5;16,75;20,0;23,25;26,5;29,75;33,0;36,25;39,5;

☐ Include additional slices at points along path

Distance from reference origin to start of path (chainage): 0,0

Slice Options

Moments about ● Neutral axis ○ Slice path

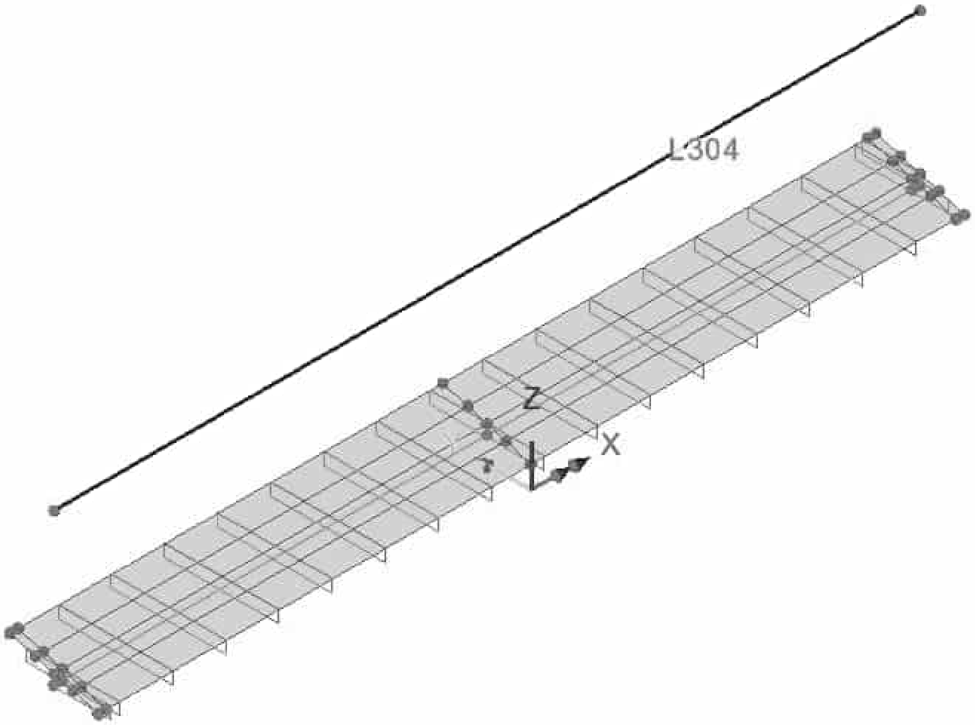
☑ Slice width 7,0 ☐ Include whole elements only

☑ Smooth corners on path

Extent: Girder LB1

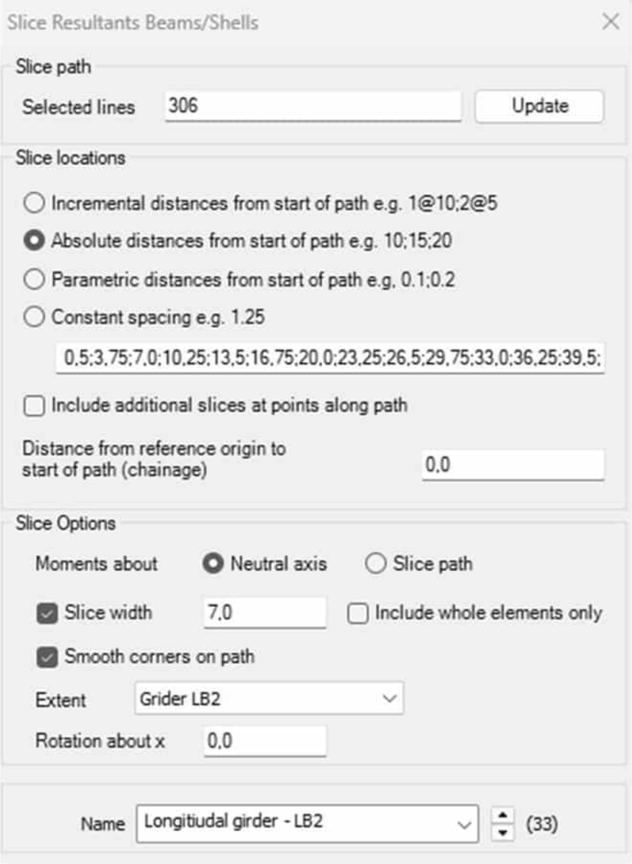
Rotation about x: 0,0

Name: Longitudinal girder - LB1 (3)



Overview

2.8.1.2 Slice beam ball LB2



Slice path

Selected lines: 306

Slice locations

○ Incremental distances from start of path e.g. 1@10;2@5

● Absolute distances from start of path e.g. 10;15;20

○ Parametric distances from start of path e.g. 0.1;0.2

○ Constant spacing e.g. 1.25

0,5;3,75;7,0;10,25;13,5;16,75;20,0;23,25;26,5;29,75;33,0;36,25;39,5;

☐ Include additional slices at points along path

Distance from reference origin to start of path (chainage): 0,0

Slice Options

Moments about: ● Neutral axis ○ Slice path

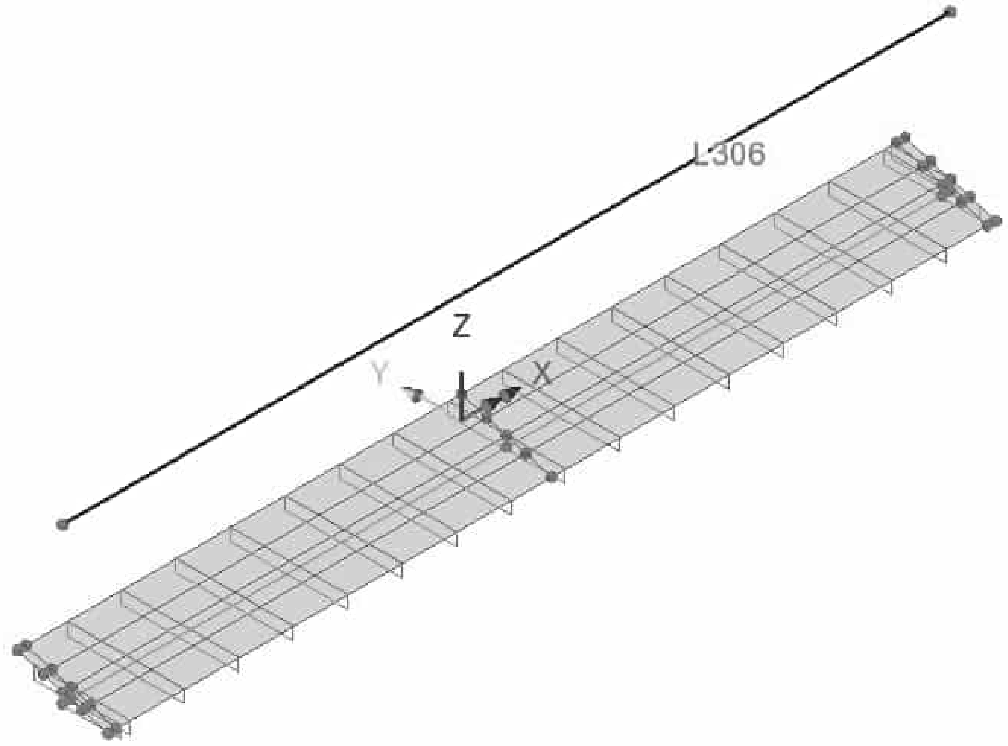
☑ Slice width: 7,0 ☐ Include whole elements only

☑ Smooth corners on path

Extent: Grider LB2

Rotation about x: 0,0

Name: Longitiudal girder - LB2 (33)



Overview

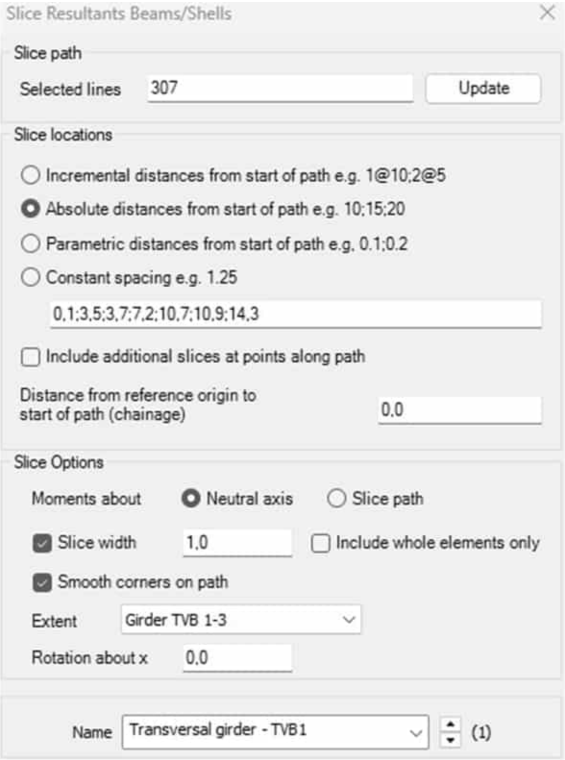
2.8.2 Transversal girders

Equivalent forces will be determined along t 8th subpoints for each main beam. This is done by examining the load effects in the Nodal surface and Nodal line for the respective main beams LB 1 and LB 2.

The FEM-program uses script called 'Slice Resultant Beams/Shells' to handle this, see the presentation below.

Beam	Path line	Extent	Remark
TVB1	307	Girder TVB 1-3	Width = 1.00 m
TVB2	309	Girder TVB 1-3	Width = 1.00 m
TVB3	308	Girder TVB 1-3	Width = 1.00 m
-	-	-	-

2.8.21.1 Slice beam ball TVB1



Slice Resultants Beams/Shells

Slice path

Selected lines: 307

Slice locations

○ Incremental distances from start of path e.g. 1@10;2@5

● Absolute distances from start of path e.g. 10;15;20

○ Parametric distances from start of path e.g. 0.1;0.2

○ Constant spacing e.g. 1.25

0,1;3,5;3,7;7,2;10,7;10,9;14,3

☐ Include additional slices at points along path

Distance from reference origin to start of path (chainage): 0,0

Slice Options

Moments about: ● Neutral axis ○ Slice path

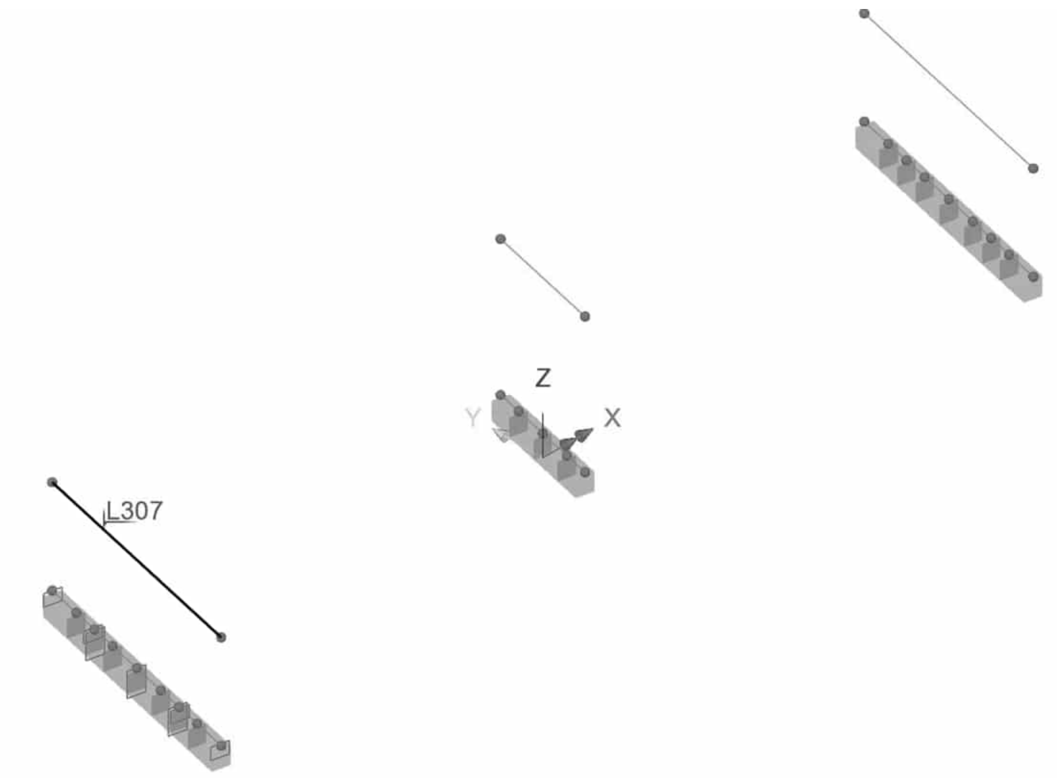
☑ Slice width: 1,0 ☐ Include whole elements only

☑ Smooth corners on path

Extent: Girder TVB 1-3

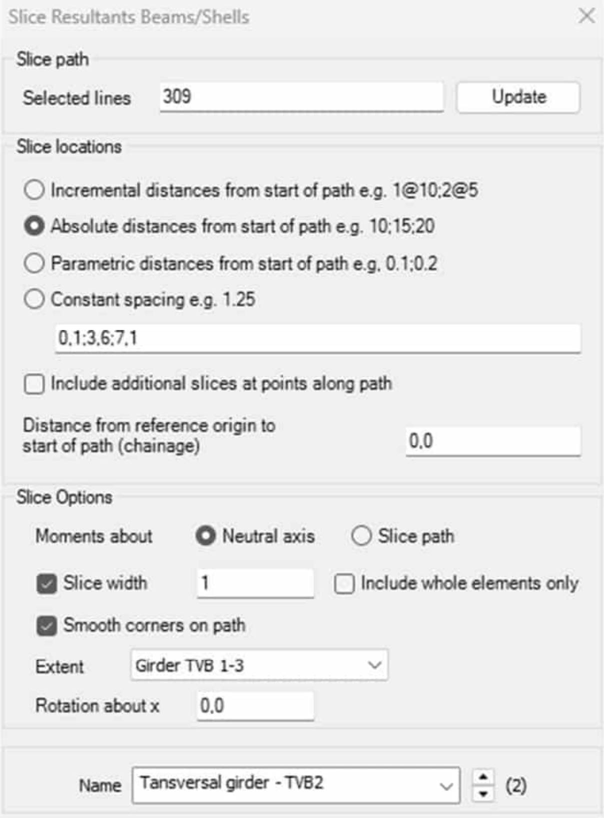
Rotation about x: 0,0

Name: Transversal girder - TVB1 (1)



Overview

2.8.2.2 Slice beam ball TVB2



Slice path

Selected lines: 309

Slice locations

○ Incremental distances from start of path e.g. 1@10;2@5
● Absolute distances from start of path e.g. 10;15;20
○ Parametric distances from start of path e.g. 0.1;0.2
○ Constant spacing e.g. 1.25

0,1;3,6;7,1

☐ Include additional slices at points along path

Distance from reference origin to start of path (chainage): 0,0

Slice Options

Moments about: ● Neutral axis ○ Slice path

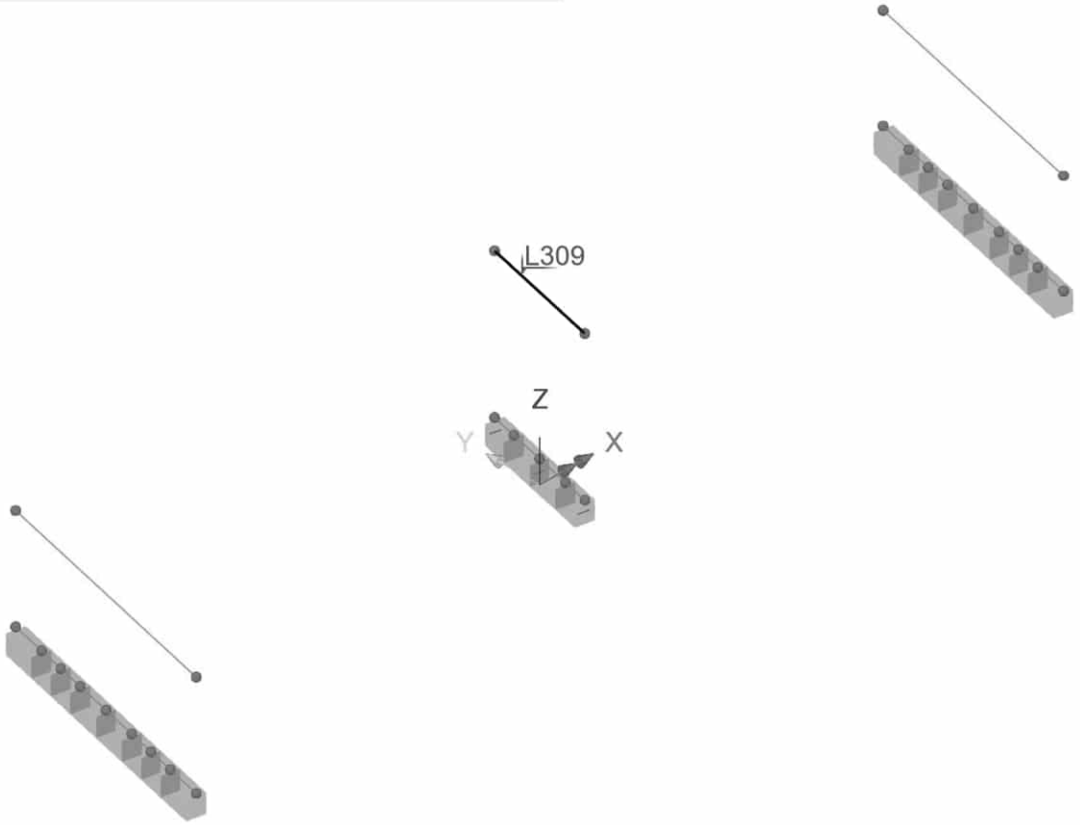
☑ Slice width: 1 ☐ Include whole elements only

☑ Smooth corners on path

Extent: Girder TVB 1-3

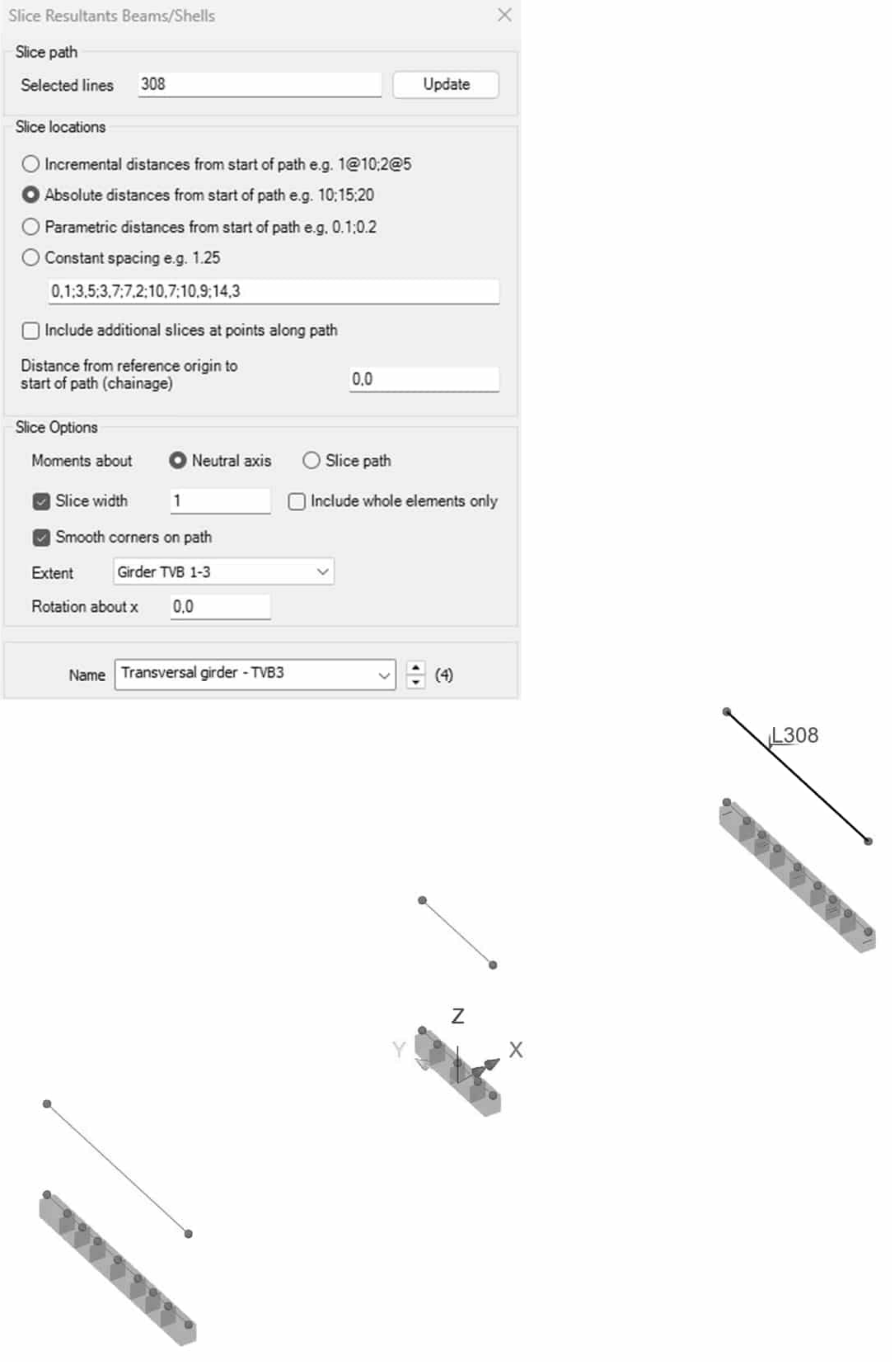
Rotation about x: 0,0

Name: Tansversal girder - TVB2 (2)



Overview

2.8.2.3 Slice beam ball TVB3



Slice Resultants Beams/Shells

Slice path

Selected lines: 308

Slice locations

○ Incremental distances from start of path e.g. 1@10;2@5

● Absolute distances from start of path e.g. 10;15;20

○ Parametric distances from start of path e.g. 0.1;0.2

○ Constant spacing e.g. 1.25

0,1;3,5;3,7;7,2;10,7;10,9;14,3

☐ Include additional slices at points along path

Distance from reference origin to start of path (chainage): 0,0

Slice Options

Moments about: ● Neutral axis ○ Slice path

☑ Slice width: 1 ☐ Include whole elements only

☑ Smooth corners on path

Extent: Girder TVB 1-3

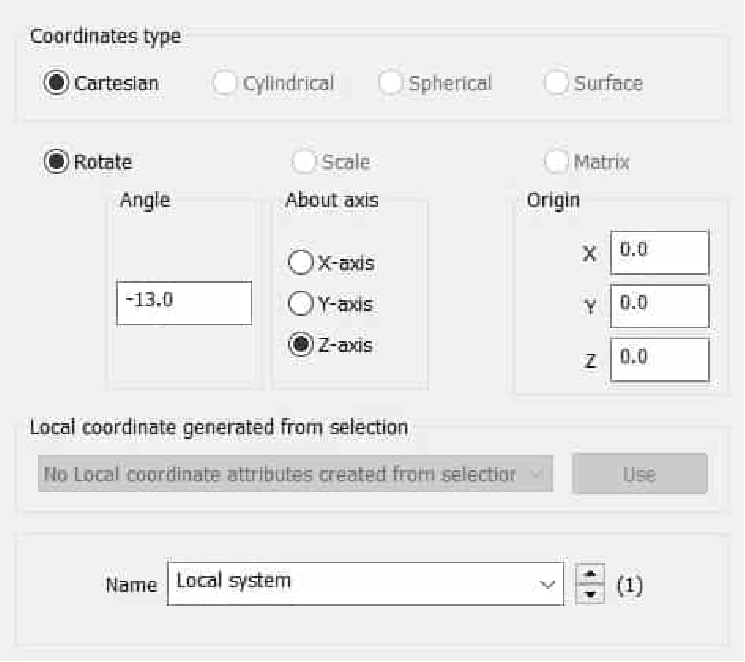
Rotation about x: 0,0

Name: Transversal girder - TVB3 (4)

Overview

2.9 LOCAL COORDINDATE SYSTEM

To obtain transformed reactions, guideline directions are established by creating a local coordinate system as described below. The system is applied at the positions of points P154, P155, and P156.



Coordinates type
● Cartesian ○ Cylindrical ○ Spherical ○ Surface

● Rotate ○ Scale ○ Matrix

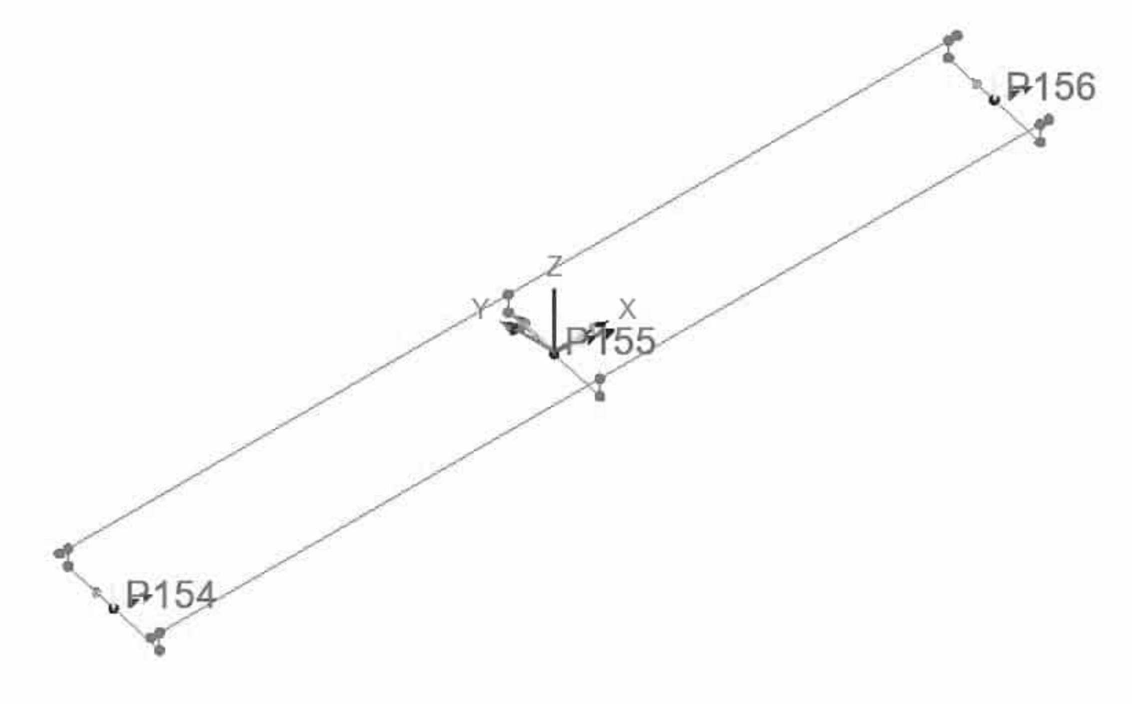
Angle: -13.0

About axis: ○ X-axis ○ Y-axis ● Z-axis

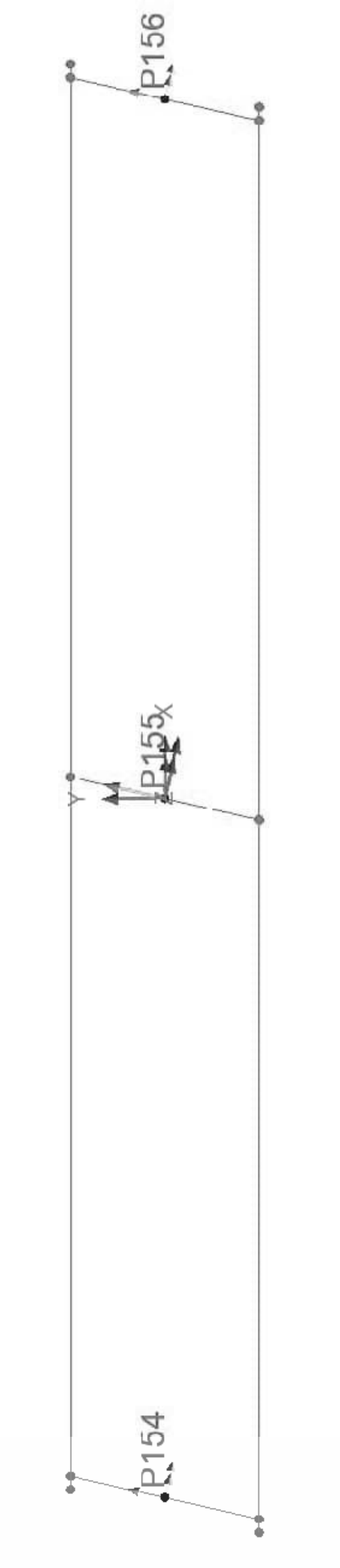
Origin
X 0.0
Y 0.0
Z 0.0

Local coordinate generated from selection
No Local coordinate attributes created from selectior

Name: Local system (1)



Overview



PLAN

2.10 FLANGE WIDTH

Determination of effective flange width according to SS-EN 1992-1-1, section 5.3.2.1.

The check below shows that the participating flange width corresponds to the gross cross-section, i.e., no reduction of the cross-section. When determining the equivalent internal forces for the main beams LB1 and LB2, the entire gross cross-section for half of the bridge is used. This also applies when determining the load-bearing capacity.

$$l_0 = 0.85L = 0.85 \cdot 26m = 22.1m$$

Controll ”cantilever” :

$$\min(0.2b_1 + 0.1l_0; 0.2l_0, b_1) = \min(0.2 \cdot 2.0m + 0.1 \cdot 22.1m\,; 0.2 \cdot 22.1m, 2.0m) = 2.0m$$

$$\rightarrow b_{ef.1} = 2.0m$$

Controll ”slab” between longitudinal girders :

$$\min(0.2b_2 + 0.1l_0; 0.2l_0, b_2) = \min(0.2 \cdot 2.0m + 0.1 \cdot 22.1m; 0.2 \cdot 22.1m; 2.0m) = 2.0m$$

$$\rightarrow b_{ef.2} = 2.0m$$

3. LASTER

3.1 DEAD WEIGHT

$\gamma_c = 25 \cdot \frac{kN}{m^3}$: betong

3.1.1 Loas bridge deck

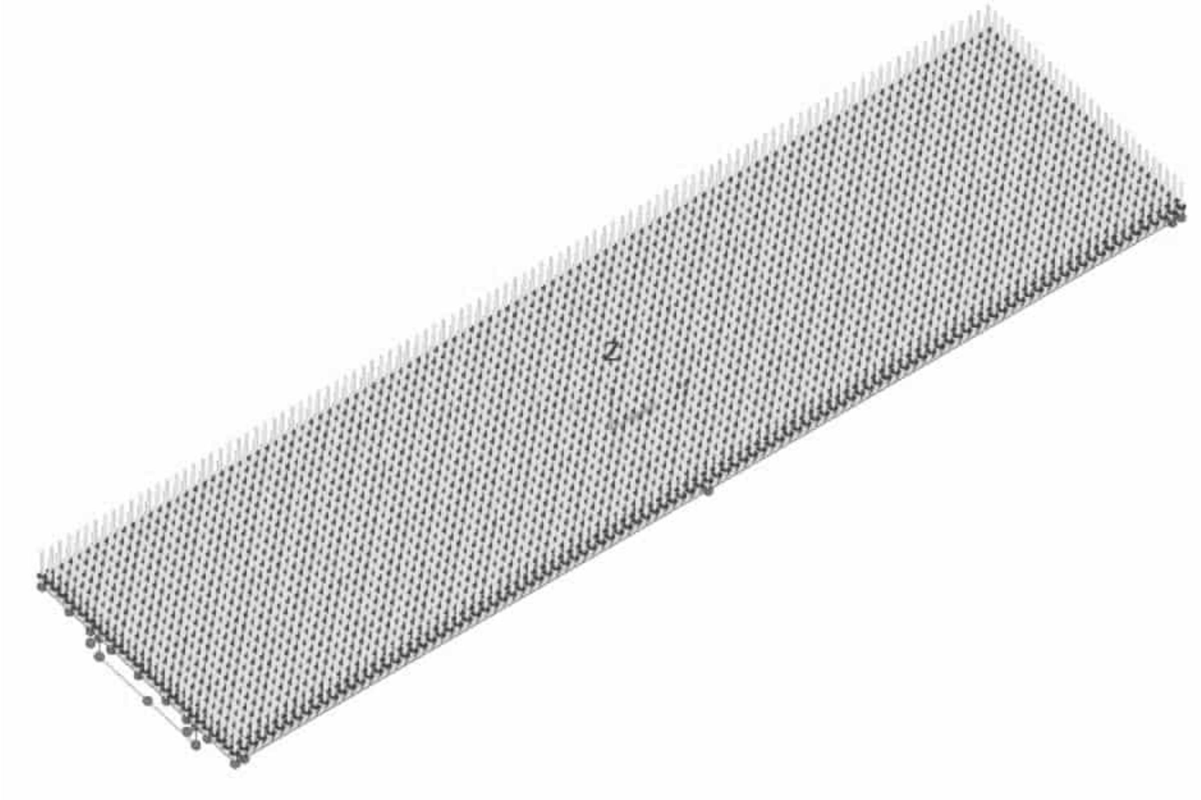
Load : EGEN 1

Structural loading : Body force

Linear acceleration in Z direction (a_z) : $-10\frac{m}{s^2}$

Load case : EGEN 1

Loading assignment: Assign to surfaces



Overview 3D

3.1.2 Longitudinal & transversal girders

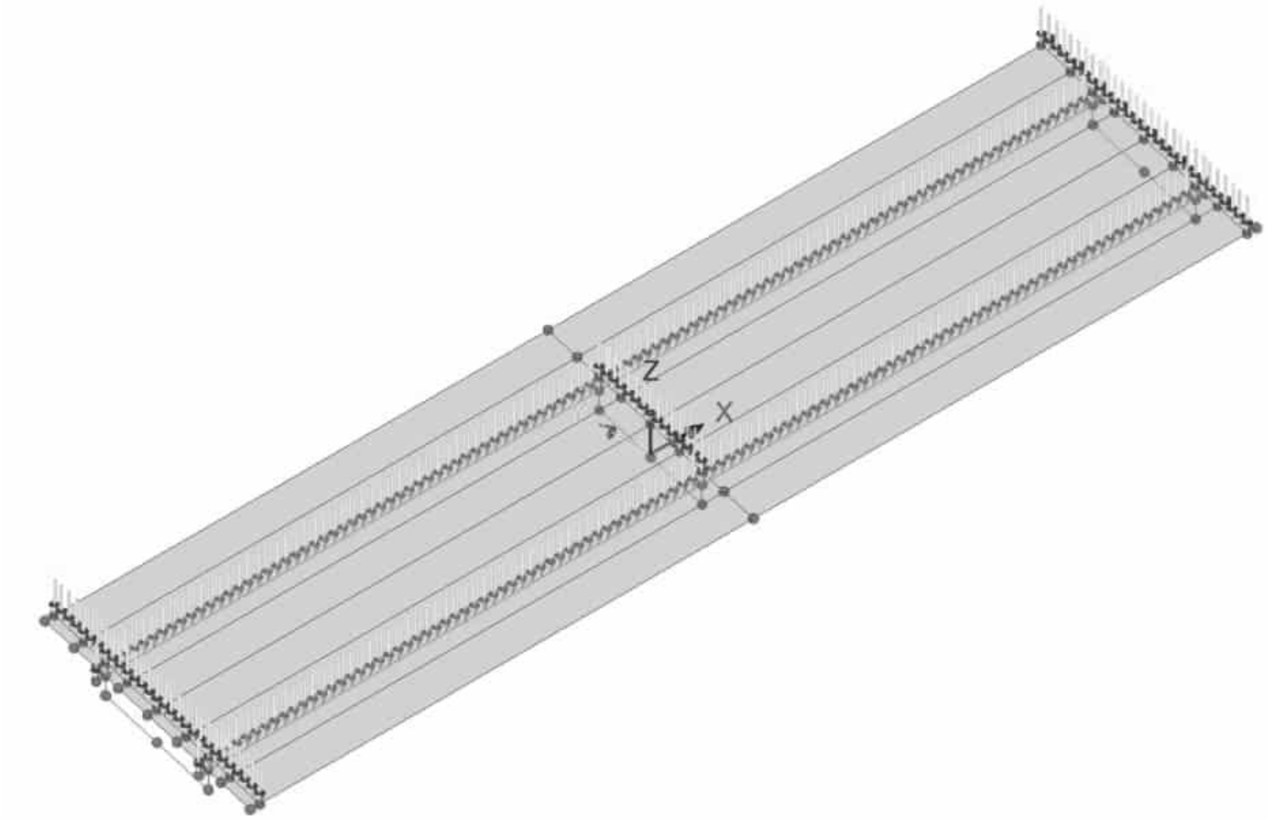
Load : EGEN 2

Structural loading : Body force

Linear acceleration in Z direction (a_z) : -10$\frac{m}{s^2}$

Load case : EGEN 2

Loading assignment: Assign to lines



Overview 3D

3.1.3 Edge beams & railings

Refers to both the railing on the divider beam and the edge beams.

Weight of divider beam incl. railing

$p_{räcke} = 0.5 \frac{kN}{m}$

$\rightarrow p_z = p_{räcke} + p_{KB} = 0.5 \frac{kN}{m} + 0.20m \cdot 0.40m \cdot 25 \frac{kN}{m^3} = -2 \frac{kN}{m}$

Remark
To be able to accommodate future reconstruction of the bridge deck, this load has not been considered in the system analysis.

Weight of edge beam incl. railing

A fictitious line load is applied to each edge beam as described below. The load also includes the bridge railing.

$$p_{r\ddot{a}cke} = 0.5\frac{kN}{m}$$

$$\rightarrow p_z = p_{r\ddot{a}cke} + p_{KB} = 0.5\frac{kN}{m} + 0.40m \cdot 0.45m \cdot 25\frac{kN}{m^3} = -5\frac{kN}{m}$$

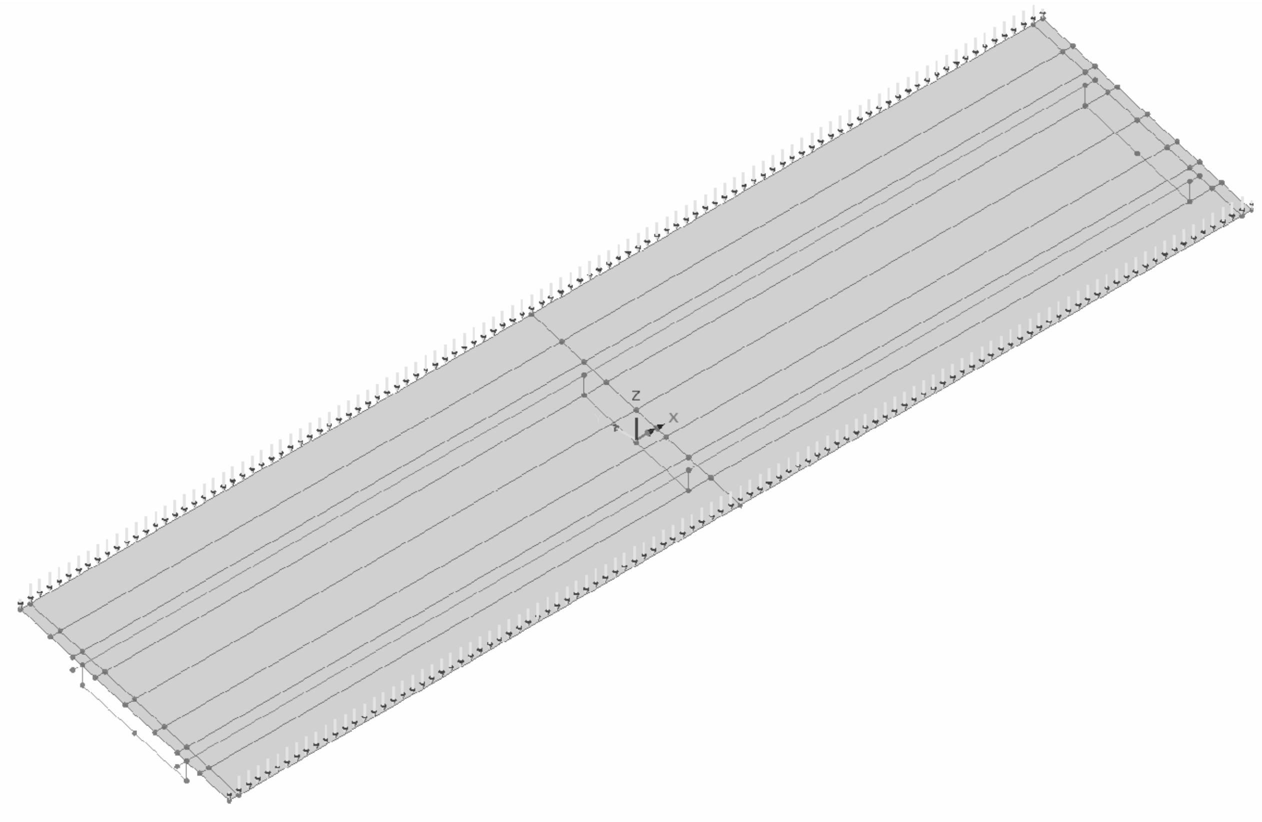
Load : EGEN 3

Structural loading : Body force

Line load (p_z) : -5 kN/m

Load case : EGEN 3

Loading assignment: Assign to lines



Overview 3D

3.1.4 Load combinations

Basic load combination EGEN:

Load case	Factor
EGEN 1	1.00
EGEN 2	1.00
EGEN 3	1.00

3.2 SURFACING

Thickness pavement with a thickness of 95 mm built as follows:

- Wearing course ABS 11	40 mm
- Combined protective and binder course PGJA	50 mm
- Waterproofing layer	5 mm

$\gamma = 23 \frac{kN}{m^3}$: course

$q_{matta} = 0.11kPa$: waterproofing

Surfacing load is seen below:

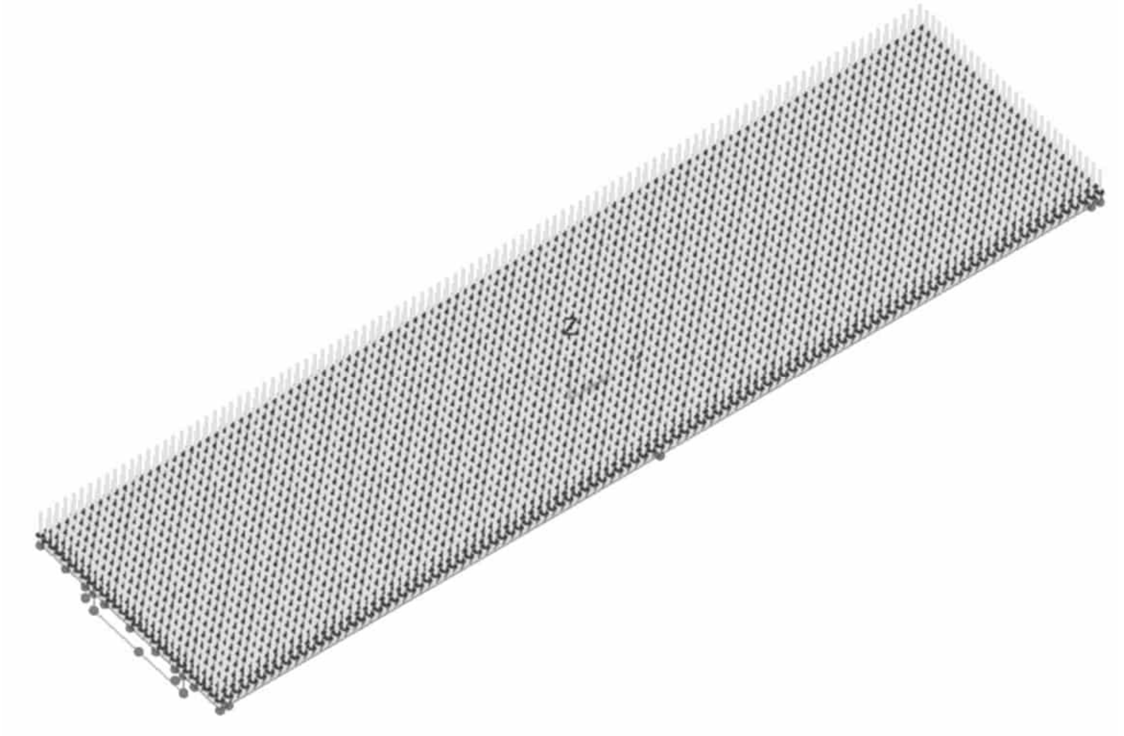
$$q_{belägg} = \gamma_{beläggning} \cdot t + q_{matta} = 23 \frac{kN}{m^3} \cdot 0.09m + 0.11kPa = 2.2kPa$$

Load : BELAGG

Structural loading : Global distributed

Load per unit area in Z direction (q_z) : -3 $\frac{kN}{m^2}$

Load case: BELAGG



Overview 3D

3.3 EARTH PRESSURE

$\gamma_{m.\phi} = 1.30$

$$\gamma = 22\frac{kN}{m^3}$$

$$\gamma' = 13\frac{kN}{m^3}$$

$$X_d = \frac{1}{\gamma_m} \cdot \eta \cdot \overline{X} \equiv \frac{1}{\gamma_m} \cdot X_k$$

$\rightarrow \varphi_d = arctan\left(\frac{tan\varphi_k}{\gamma_m}\right) = arctan\left(\frac{tan45°}{1.0}\right) = 45°$: design method D2

$\rightarrow \varphi_d = arctan\left(\frac{tan\varphi_k}{\gamma_m}\right) = arctan\left(\frac{tan45°}{1.3}\right) = 38°$: design method D3

Earth pressure coefficients are seen below.

$$K_o = 1 - sin(\varphi_d)$$

$$K_a = tan^2(45° - \frac{\varphi_d}{2})$$

$$K_p = tan^2(45° + \frac{\varphi_d}{2})$$

φ_d	K_a	K_0	K_p	Metod
38°	0.24	0.38	4.20	D3
45°	0.17	0.29	5.82	D2

Design is carried out according to method D2 according to TK Geo section 3.16.1.Dimensionering utförs enligt metod D2 enligt TK Geo avsnitt 3.16.1.

3.4 SUPPORT SETTLEMENT

The effect of support displacement shall be considered according to TRVINFRA-00227 section 7.2.1.1.1.1. Only vertical support displacement and horizontal support displacement in the longitudinal direction of the bridge need to be considered. In addition, it is stated that horizontal and vertical support displacements do not need to be combined.

The bridge is founded on pointed concrete piles. According to common calculation practice, a vertical settlement difference between supports corresponding to 10 mm is applied.

A horizontal support displacement in the bridge's longitudinal direction (x-direction) corresponding to ±5 mm is applied; however, only translation occurs, i.e., no associated restraint forces arise.

Note

TRVINFRA-00227 section 7.2-10 specifies ±5 mm for the control of expansion joints.

3.4.1 Vertical settlement

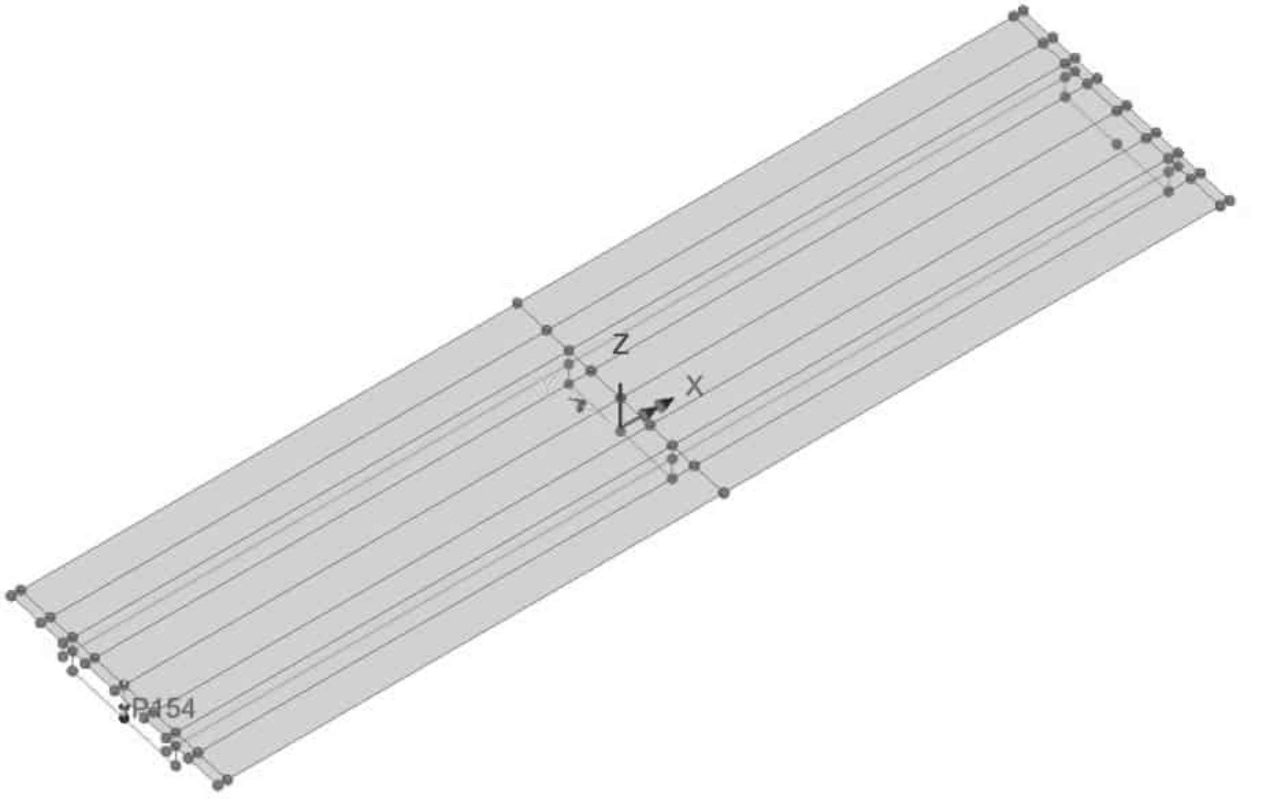
Load: STOD_1Z

Structural loading : Prescribed Displacement

Translation at point in Z direction : -0.010 m

Load case : STOD_1Z

Point : P154



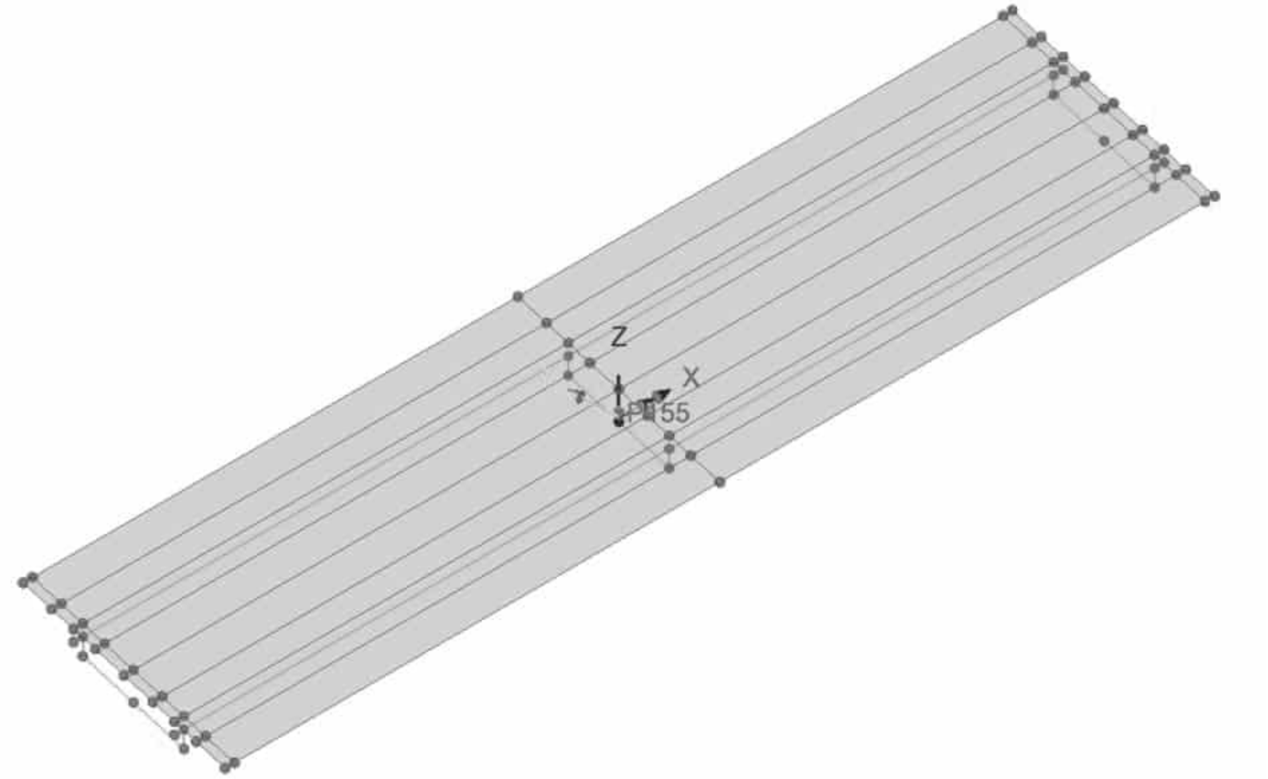
Load: STOD_2Z

Structural loading : Prescribed Displacement

Translation at point in Z direction : -0.010 m

Load case : STOD_2Z

Point : P155



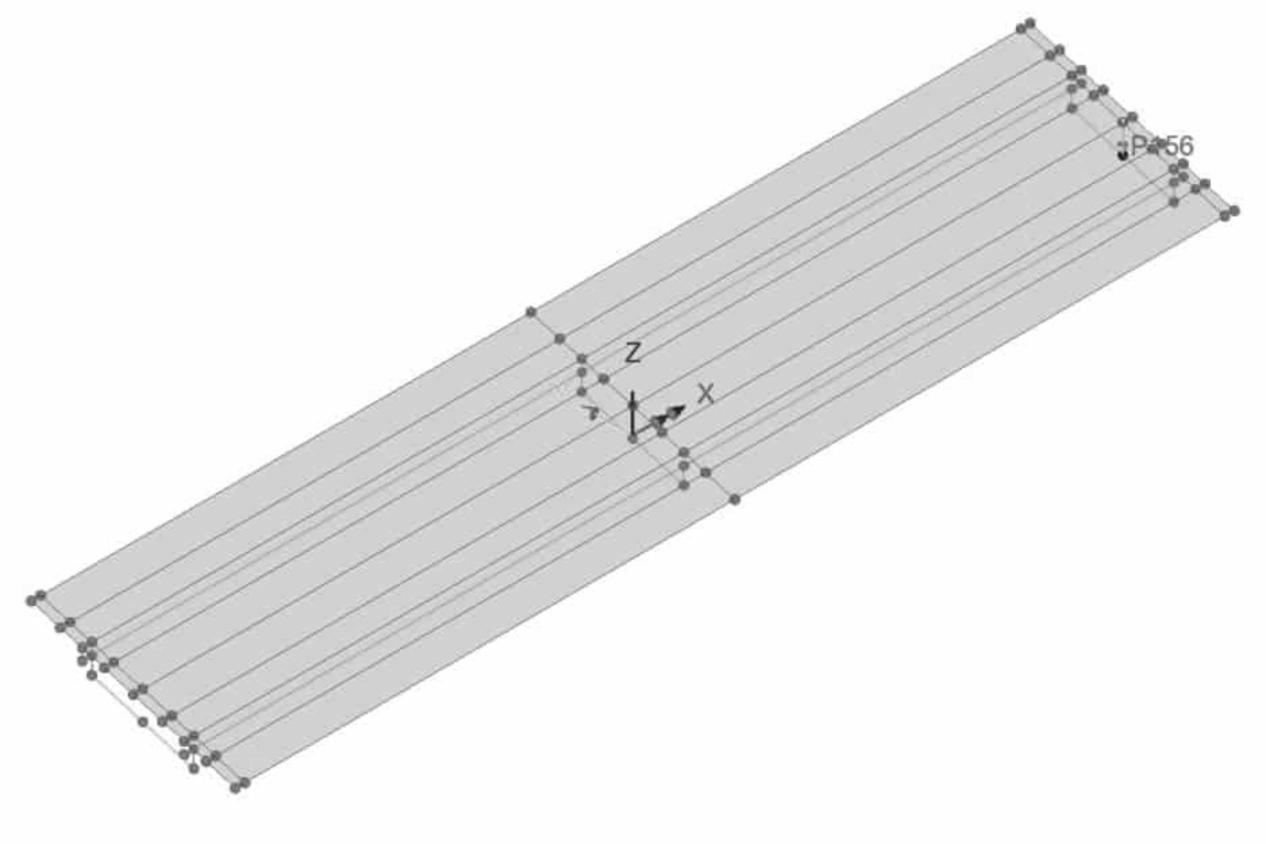
Load: STOD_3Z

Structural loading : Prescribed Displacement

Translation at point in Z direction : -0.010 m

Load case : STOD_3Z

Point : P156



3.4.2 Horizontal settlement

Horizontal settlement in longitudinal direction only causes translation.

Thus, this settlement is not included in the system calculation, since does not give rise to constraint forces.

3.4.3 Load combination

Load combination smart *STOD :*

Load case	Permanent factor	Variable factor
STOD_1Z	0	1
STOD_2Z	0	1
STOD_3Z	0	1

3.5 CREEP

Total creep is determined according to SS-EN 1992-1-1 §3.1.4 and TRVINFRA-00227 section 7.1.6.4 for RH 80% at time t1.

Time for first loading (= time when formwork was removed) is termed t0.

$t_0 = 5\,days$

$t_2 = 120\,years$

Bridge consists of parts with different thicknesses as seen below.

Creep is determine using Mathcad program PROG A001.

Superstructure (b = 2.5 m):
For t = 1.50 m → $\phi(t_2, t_0) = 1.9$: see page A3:19

$$\varepsilon_{cc}(t_1, t_0) = \phi(t_1, t_0) \cdot \frac{\sigma_c}{E_c}$$

To study the effect concrete stiffness according to SS-EN 1992-1-1 5.8.7 creep values seen below are used.

Load cases	φ
Permanent	1.9
Variable excluding temperature	0
Temperature	0.3*

* = According to Swedish work practice

$$E^{system} = \frac{E_{cm}}{1+\varphi}$$

Instead of adjusting E-modulus the load coefficients are adjusted.

$$f_{KRYMP} = \frac{1}{1+\varphi_{ef}} = \frac{1}{1+1.9} = 0.34$$

$$f_{STÖD} = \frac{1}{1+\varphi_{ef}} = \frac{1}{1+1.9} = 0.34$$

$$f_{JTEMP} = \frac{1}{1+\varphi_{ef}} = \frac{1}{1+0.3} = 0.77$$

Note:
According to TRVINFRA-00227 section 7.2.1.1.2.4, no reduction is permitted for uneven temperature across the cross-section. This is because this temperature variation is considered to have a very short duration (only over the day).

Object: Superstructure

INPUT

Number of sections

$N := 2\ pcs$

Geometry & concrete (C30/37, C35/45, C40/50 & C45/55)

Section	B	H	Concrete
1	2,5	1,5	C35/45
2	2,5	1,5	C35/45
-	m	m	-

Relative humidity

$RH := 80\%$

Time of loading (i.e. removal formwork)

$t_0 := 5\ days$

Studied time for determination of creep

$t_2 := 120\ year$ $\qquad t_2 = 43800\ days$

Input receipt

$f_{cm} = \begin{bmatrix} 43 & 43 \end{bmatrix} MPa$

CALCULATION

Area

$$A_c := B \cdot H$$

Perimeter exposed to "air"

$$u := 2 \cdot B$$

Effective thickness structure

$$h_0 := \frac{2 \cdot A_c}{u}$$

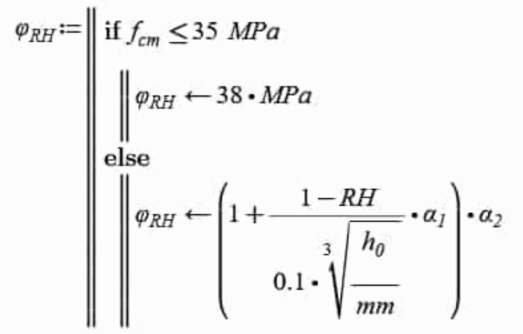
Creep coefficients

The expressions for determining the creep coefficients are taken from SS-EN 1992-1-1 Annex B.1.

$$\alpha_1 := \left(\frac{35 \cdot MPa}{f_{cm}}\right)^{0.7} = \begin{bmatrix} 0.87 \\ 0.87 \end{bmatrix}$$

$$\alpha_2 := \left(\frac{35 \cdot MPa}{f_{cm}}\right)^{0.2} = \begin{bmatrix} 0.96 \\ 0.96 \end{bmatrix}$$

$$\alpha_3 := \left(\frac{35 \cdot MPa}{f_{cm}}\right)^{0.5} = \begin{bmatrix} 0.902 \\ 0.902 \end{bmatrix}$$



$$\varphi_{RH} := \begin{array}{l} \text{if } f_{cm} \le 35\ MPa \\ \quad \varphi_{RH} \leftarrow 38 \cdot MPa \\ \text{else} \\ \quad \varphi_{RH} \leftarrow \left(1 + \dfrac{1 - RH}{0.1 \cdot \sqrt[3]{\dfrac{h_0}{mm}}} \cdot \alpha_1\right) \cdot \alpha_2 \end{array}$$

$$\varphi_{RH} = \begin{bmatrix} 1.105 \\ 1.105 \end{bmatrix}$$

$$\beta_0 := \frac{1}{0.1 + {t_0}^{0.20}} = 0.68$$

$$\beta_{fcm} := \frac{16.8}{\sqrt{\dfrac{f_{cm}}{MPa}}} = \begin{bmatrix} 2.56 \\ 2.56 \end{bmatrix}$$

```
$\beta_H :=$
    if $f_{cm} \le 35 \cdot MPa$
        $\beta_{H.max} \leftarrow 1500$
        if $1.5 \cdot \left(1 + (0.012 \cdot 100 \cdot RH)^{18}\right) \cdot \frac{h_0}{mm} + 250 > \beta_{H.max}$
            $\beta_H \leftarrow \beta_{H.max}$
        else
            $\beta_H \leftarrow 1.5 \cdot \left(1 + (0.012 \cdot 100 \cdot RH)^{18}\right) \cdot \frac{h_0}{mm} + 250$
    if $f_{cm} > 35 \cdot MPa$
        $\beta_{H.max} \leftarrow 1500 \cdot \alpha_3$
        if $1.5 \cdot \left(1 + (0.012 \cdot 100 \cdot RH)^{18}\right) \cdot \frac{h_0}{mm} + 250 > \beta_{H.max}$
            $\beta_H \leftarrow \beta_{H.max}$
        else
            $\beta_H \leftarrow 1.5 \cdot \left(1 + (0.012 \cdot 100 \cdot RH)^{18}\right) \cdot \frac{h_0}{mm} + 250 \cdot \alpha_3$
```

$$\beta_H = \begin{bmatrix} 1353 \\ 1353 \end{bmatrix}$$

$$\beta_c := \left(\frac{t_2 - t_0}{\beta_H + t_2 - t_0}\right)^{0.3} = \begin{bmatrix} 0.99 \\ 0.99 \end{bmatrix}$$

$$\varphi_{t0} := \varphi_{RH} \cdot \beta_{fcm} \cdot \beta_0 = \begin{bmatrix} 1.91 \\ 1.91 \end{bmatrix}$$

RESULTS

$$\varphi_{t2} := \varphi_{t0} \cdot \beta_c = \begin{bmatrix} 1.90 \\ 1.90 \end{bmatrix}$$

3.6 SHRINKAGE

Total shrinkage according to SS-EN 1992-1-1 §3.1.4 and TRVINFRA-00227 section 7.1.6.4 for RH 80% at time t_2.

Determination of load effect from shrinkage should consider the reduced concrete stiffness from creep.

$t_s = 0\ days$

$t_2 = 120\ years$

Shrinkage is determined using Mathcad program PROG A002 after time t_2.

Superstructure:

Shrinkage $\varepsilon_{cs} = 0.023\%$ is applied to all construction parts for safety. The movement corresponds to that which occurs due to an imaginary temperature load ∴ T = -23°C.

Remark

Shrinkage must be considered for service state (SLS) see SS-EN 1992-1-1 §2.3.2.2(1).

Shrinkage does not have to be used for ultimate state (ULS) see SS-EN 1992-1-1 §2.3.2.2(2).

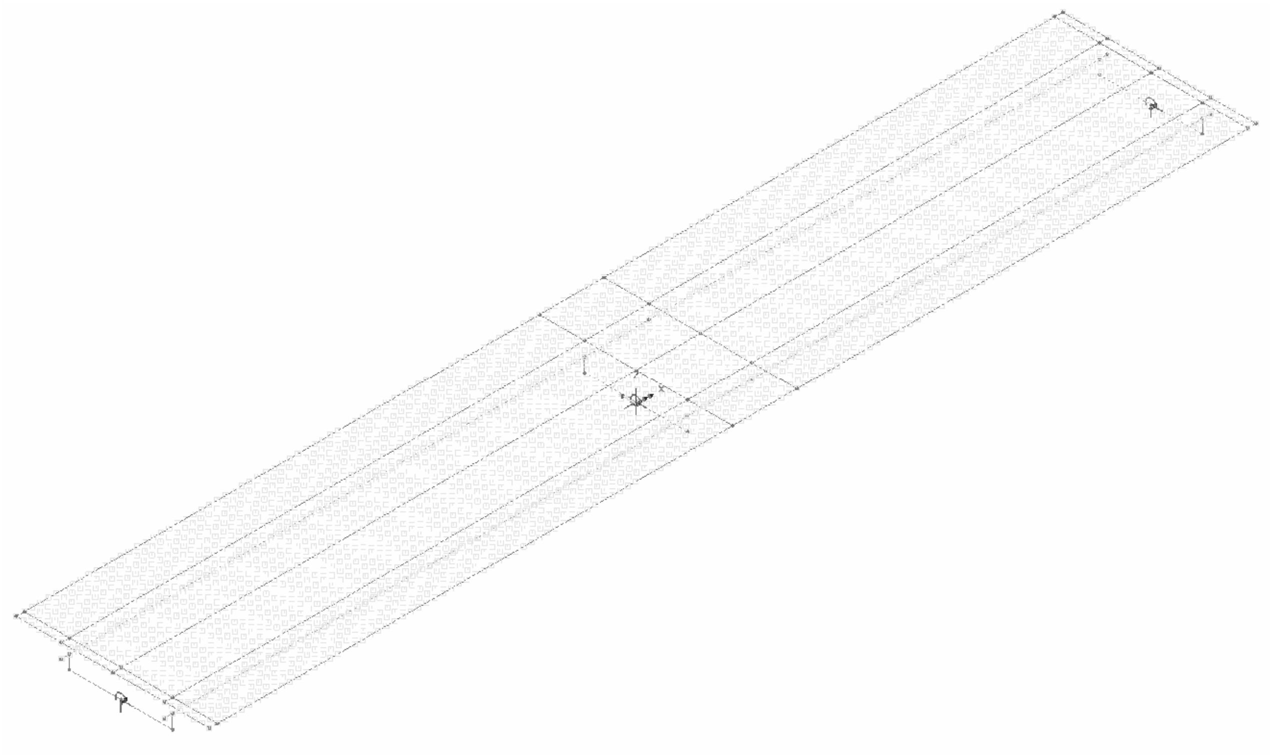
Loadcase : KRYMP

Structural loading : Temperature

Definition : Nodal lines & surfaces

Initial temperature : 0 °C

Final temperature : -23 °C



Remark

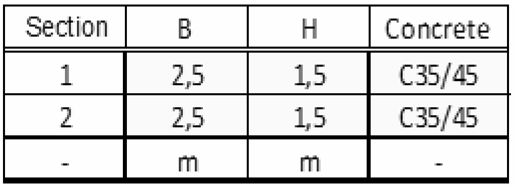
The load has been applied to the bridge deck, longitudinal girders & transversal beam in the superstructure. However, this does not produce any load effects, only translations.

Object: Superstructure

Number of sections

$N := 2\ pcs$

Geometry & concrete (C30/37, C35/45, C40/50 & C45/55)



Section	B	H	Concrete
1	2,5	1,5	C35/45
2	2,5	1,5	C35/45
-	m	m	-

Relative humidity

$RH := 80\%$

Time of load (i.e. removal formwork)

$t_0 := 5 \cdot days$

Studied time for determination of shrinkage

$t_2 := 120\ year$ $\qquad t_2 = 43800\ days$

Cement class (S, N, R)

$Klass := \text{“N”}$

Concrete age when drying starts

$t_s := 0 \cdot days$

Input receipt

$f_{cm} = [43\ \ 43]\ MPa$ $\qquad f_{ck} = [35\ \ 35]\ MPa$ $\qquad f_{cmo} = 10\ MPa$

CALCULATION

Area

$$A_c := B \cdot H$$

Perimeter exposed to "air"

$$u := 2 \cdot B$$

Effective thickness structure

$$h_0 := \frac{2 \cdot A_c}{u} = \begin{bmatrix} 1.5 \\ 1.5 \end{bmatrix} m$$

Basic value of drying shrinkage see SS-EN 1992-1-1, Annex B.2

$$\alpha_{ds1} := \left\| \begin{array}{l} \text{if } Klass = \text{“S”} \\ \quad \| \; 3.0 \\ \text{if } Klass = \text{“N”} \\ \quad \| \; 4.0 \\ \text{if } Klass = \text{“R”} \\ \quad \| \; 6.0 \end{array} \right| = 4.00$$

$$\alpha_{ds2} := \left\| \begin{array}{l} \text{if } Klass = \text{“S”} \\ \quad \| \; 0.13 \\ \text{if } Klass = \text{“N”} \\ \quad \| \; 0.12 \\ \text{if } Klass = \text{“R”} \\ \quad \| \; 0.11 \end{array} \right| = 0.12$$

$$RH_o := 100\%$$

$$\beta_{RH} := 1.55 \cdot \left(1 - \left(\frac{RH}{RH_o}\right)^3\right) = 0.76$$

$$\varepsilon_{cd.0} := 0.85 \cdot \left(\left(220 + 110 \cdot \alpha_{ds1}\right) \cdot e^{-\alpha_{ds2} \cdot \frac{f_{cm}}{f_{cmo}}}\right) \cdot 10^{-6} \cdot \beta_{RH} = \begin{bmatrix} 2.533 \cdot 10^{-4} \\ 2.533 \cdot 10^{-4} \end{bmatrix}$$

Basic drying shrinkage (SS-EN 1992-1-1, section 3.1.4, see equations 3.9 and 3.1

$$k_h := \text{linterp}\left(\left(\begin{bmatrix} 0 & 100 & 200 & 300 & 500 & 10^4 \end{bmatrix} \cdot mm\right), \begin{bmatrix} 1.00 & 1.00 & 0.85 & 0.75 & 0.70 & 0.70 \end{bmatrix}, h_0\right) = \begin{bmatrix} 0.70 \\ 0.70 \end{bmatrix}$$

$$\beta_{ds} := \frac{t_2 - t_s}{t_2 - t_s + 0.04 \cdot \sqrt{\left(\frac{h_0}{mm}\right)^3}} = \begin{bmatrix} 0.95 \\ 0.95 \end{bmatrix}$$

$$\varepsilon_{cd} := \beta_{ds} \cdot k_h \cdot \varepsilon_{cd.0} = \begin{bmatrix} 1.684 \cdot 10^{-4} \\ 1.684 \cdot 10^{-4} \end{bmatrix}$$

Autogenous-shrinkage, see EN 1992-1-1 §3.1.4, eqns. 3.11–3.13

$$\beta_{as} := 1 - e^{-0.2 \cdot \sqrt{t_2}} = 1.00$$

$$\varepsilon_{ca.\infty} := 2.5 \cdot \left(\frac{f_{ck}}{MPa} - 10\right) \cdot 10^{-6} = \begin{bmatrix} 6.25 \cdot 10^{-5} \\ 6.25 \cdot 10^{-5} \end{bmatrix}$$

$$\varepsilon_{ca} := \beta_{as} \cdot \varepsilon_{ca.\infty} = \begin{bmatrix} 6.25 \cdot 10^{-5} \\ 6.25 \cdot 10^{-5} \end{bmatrix}$$

RESULTS

Total shrinkage, see SS-EN 1992-1-1 §3.1.4, eqn. 3.8

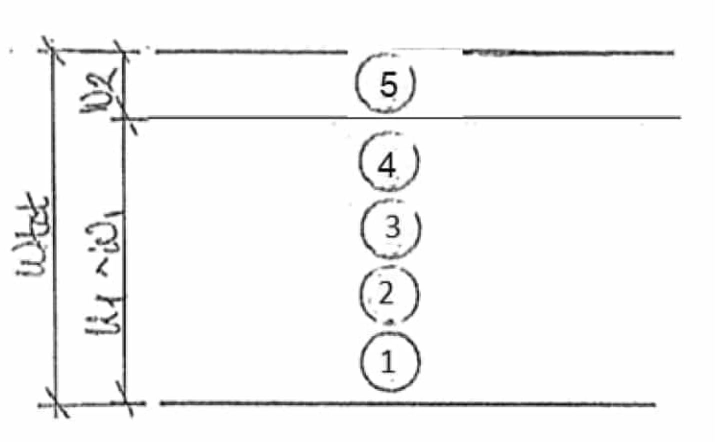
$$\varepsilon_{cs} := \varepsilon_{cd} + \varepsilon_{ca} = \begin{bmatrix} 2.309 \cdot 10^{-4} \\ 2.309 \cdot 10^{-4} \end{bmatrix}$$

3.7 TRAFFIC

Evaluation of vertical traffic is performed for LM 1 and LM 2 according to SS-EN 1991-2 section 4.3.

Evaluation will also be performed EG A/B = 180kN/300 kN according to TRVFS 2011:12 chapter 6 point 3§.

3.7.1 Traffic Lane division



Total traffic width : $w_{tot} = 14.1\,m$

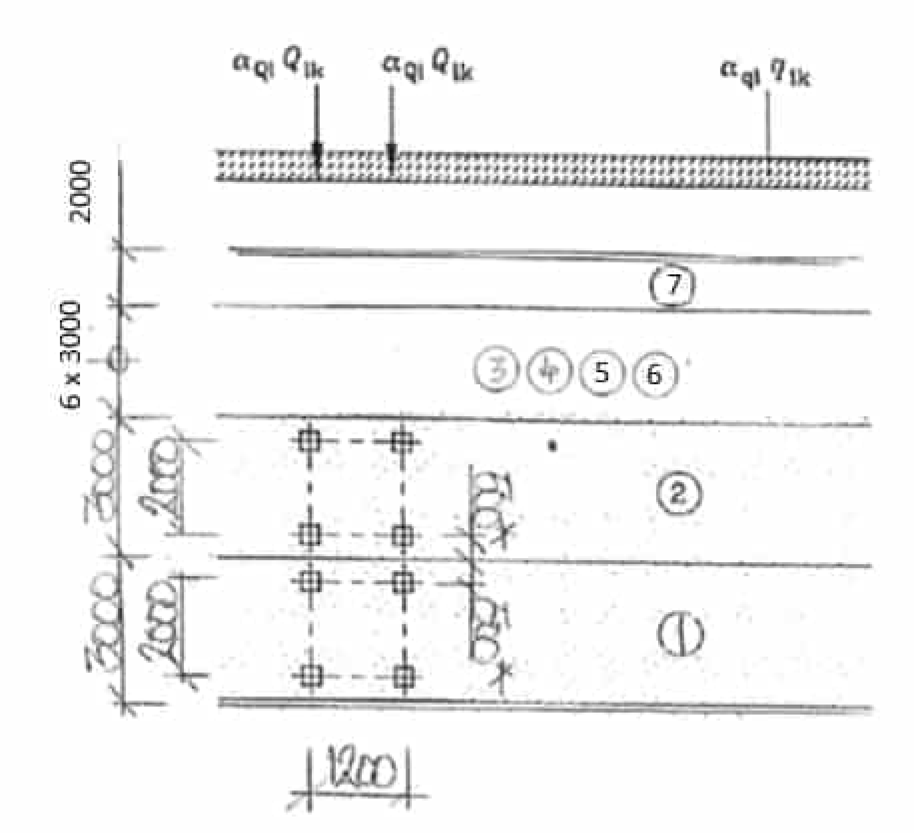
Number of traffic lanes : $n_1 = Integer\left[\frac{w_{tot}}{3.0m}\right] = 4\ lanes$

Full traffic width : $w_1 = 3.0m$

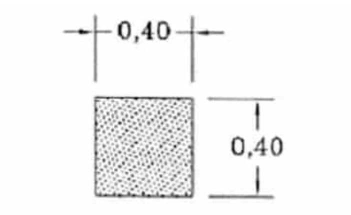
Remaining width : $w_2 = 2.1m$

3.7.2 Load model 1 (LM 1)

Characteristic values according to SS-EN 1991-2 §4.3.2.



* = When studying local effects 250 mm is to be assumed.



Axle loads:

α_Q : national adaptation factor according to TRVFS 2011:12 table 7.1

$Q'_k = \alpha_Q \cdot Q_k$: characteristic value including national adaptation factor

Traffic lane	Q_k	α_Q	Q'_k	Remark
1	300	0,9	270	LM1- 2 x 270 kN
2	200	0,9	180	LM1- 2 x 180 kN
3-6	100	0	0	No load
-	kN	-	kN	-

Surface loads:

α_q : national adaptation factor according to TRVFS 2011:12 table 7.1

$q'_k = \alpha_q \cdot q_k$: characteristic value including national adaptation factor

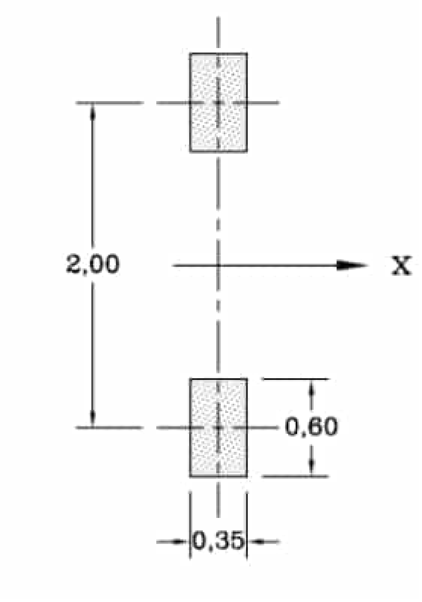
Traffic lande	q_k	α_q	q'_k
1	9.0	0.8	7.2
2-7	2.5	1.0	2.5
-	kPa	-	kPa

Remark

Evaluation is performed using Vehicle Load Optimisation (VLO), see section 3.7.4.

3.7.3 Load model 2 (LM 2)

Characteristic vertical load according to SS-EN 1991-2 §4.3.3.



$\beta_Q = \alpha_Q = 0.90$: national adaptation factor

$Q_k = 400$ kN : characteristic value

$Q'_k = \beta_k \cdot Q_k = 360$ kN : characteristic value including national adaptation factor

Tire pressure

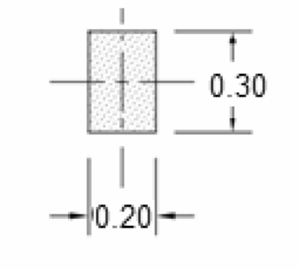
TSFS Chapter 11 Section 4 states that the same contact surface as LM 1 may be used.

3.7.4 Load model EG A/B

Calculation is performed using traffic load EG A/B = 180 kN/300 kN excluding dynamic factor.

Traffic load EG A/B are applied to two traffic lanes. Traffic on first lane is multiplied by 1.00 while second lane is multiplied 0.80.

The center distance between the wheel pressures is 2.0 meters according to TSFS chapter 11 §2.



Wheel pressure

$\varepsilon_{dyn} = 25\ \%$: dynamic factor [1.)]

$A' = A \cdot (1 + \varepsilon_{dyn}) = 180\ kN \cdot (1+0.25) = 225\ kN$: single load including dynamic factor

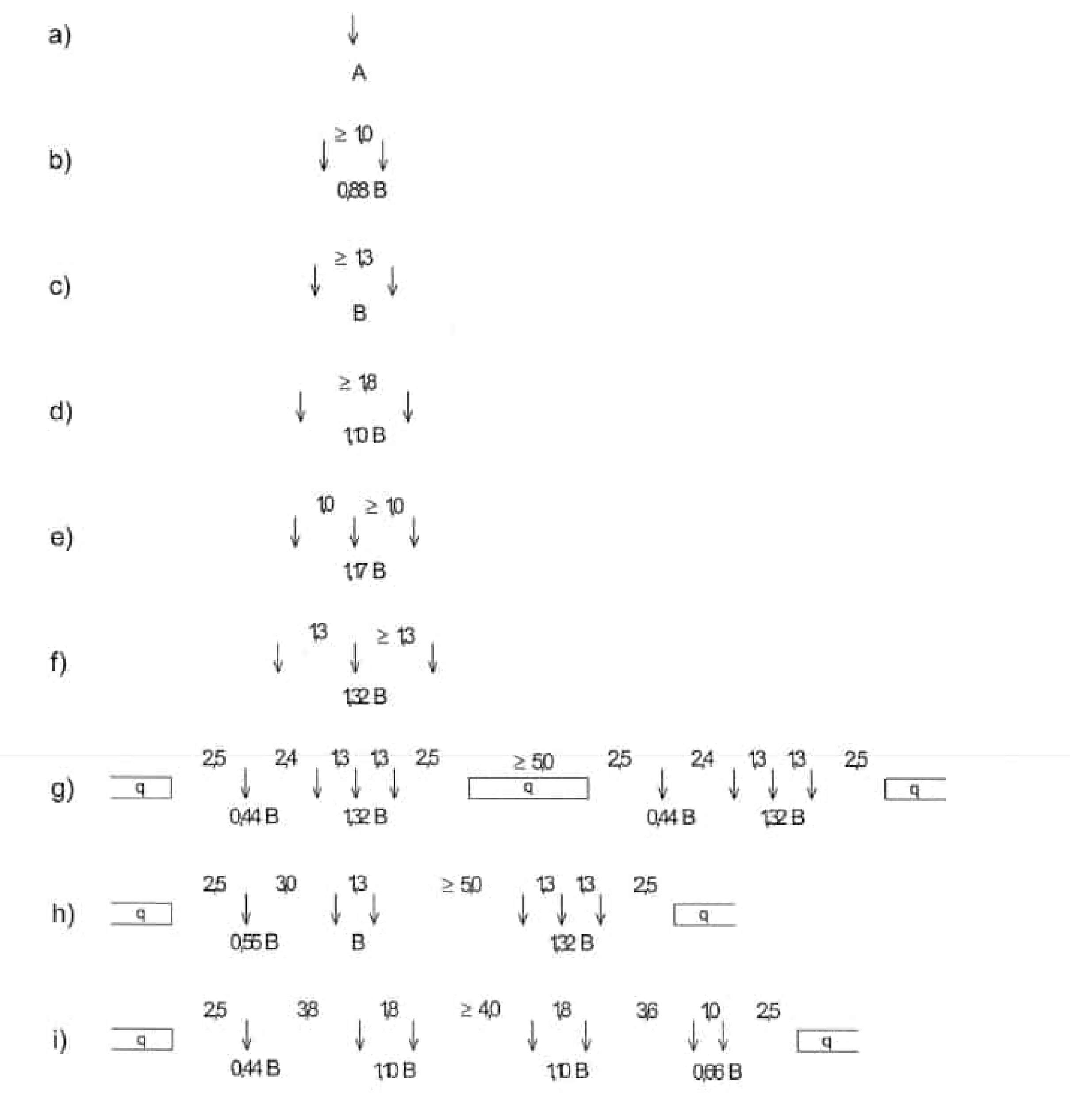
$B' = B \cdot (1 + \varepsilon_{dyn}) = 300\ kN \cdot (1+0.25) = 375\ kN$: tandem load including dynamic factor

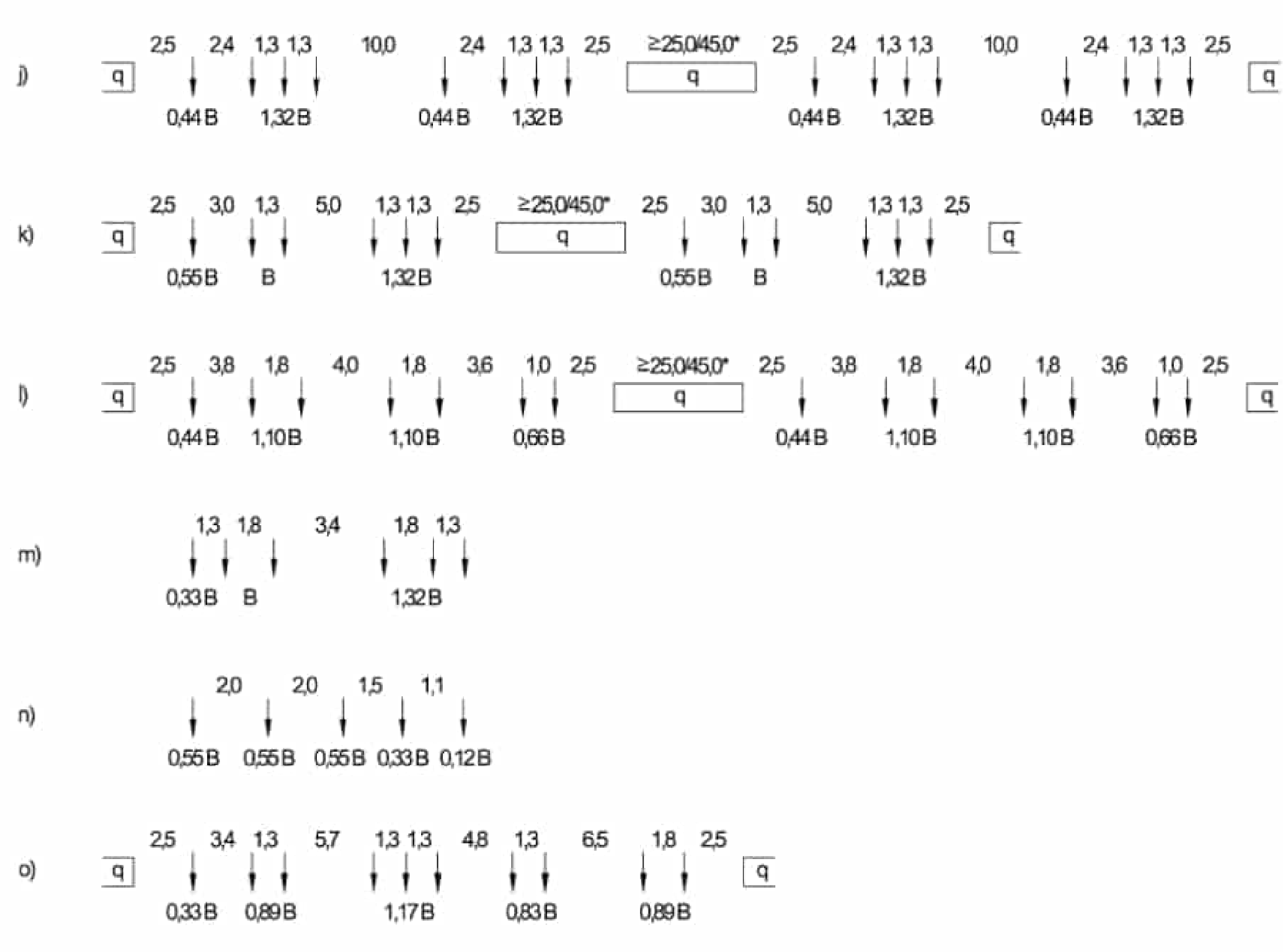
$p = 5 \frac{kN}{m}$: surface load

Footnote:

[1.)] TRVINFRA-00227 table 7.1-5 section 4.2.1(1) states apply 25 % ..

Graphic presentation of common vehicle types:
(Vehicle types according to TRVINFRA-00331 Appendix 1)





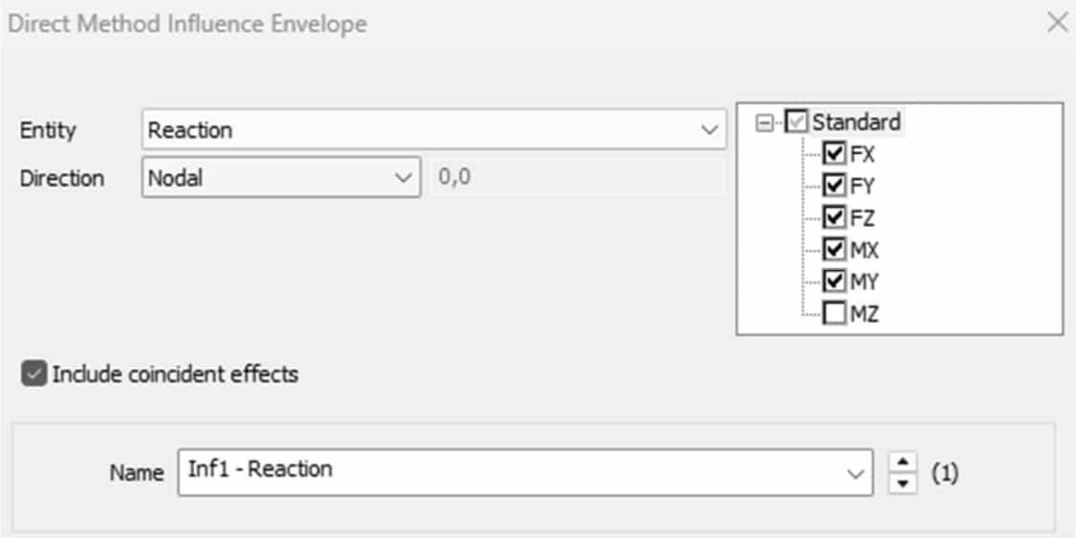
<u>Note:</u>
Evaluation is carried out with the script Vehicle Load Optimization (VLO), see sections 3.5.3 and 3.5.4.
Since there is no motorway, * = 45 m is applied according to TRVINFRA-00331 section 8.3.2.2.1 for vehicle types j, k, and l.

3.7.5 Vehicle Load Optimization (VLO)

3.7.5.1 Influence components

Influence surfaces are created using *Direct Method Influence Envelope.* This is done by applying *Influence components* seen below.

Inf1 – Reactions :



Direct Method Influence Envelope

Entity: Reaction

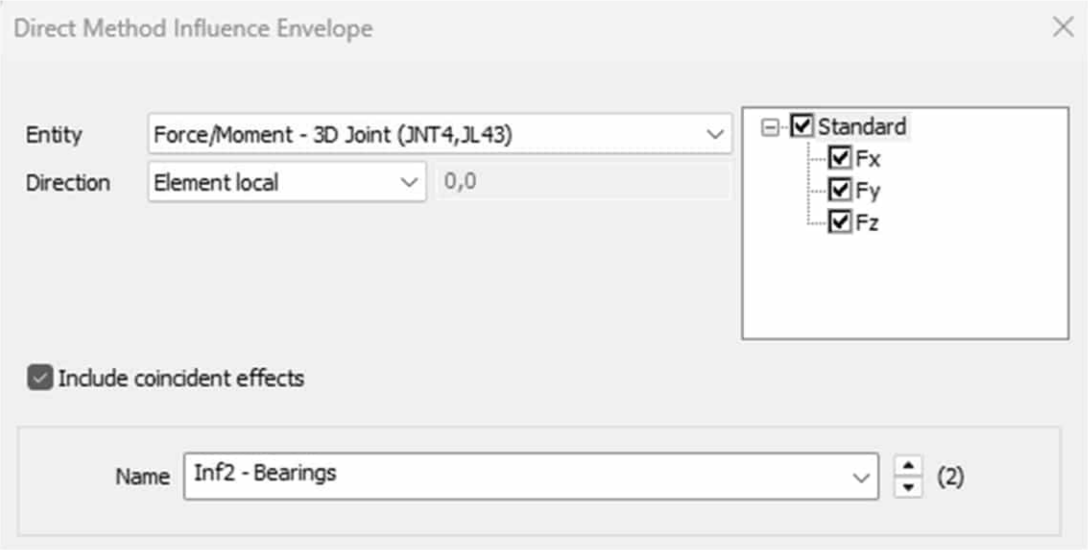
Direction: Nodal 0,0

☑ Standard
- ☑ FX
- ☑ FY
- ☑ FZ
- ☑ MX
- ☑ MY
- ☐ MZ

☑ Include coincident effects

Name: Inf1 - Reaction (1)

Inf2 – Bearings :



Direct Method Influence Envelope

Entity: Force/Moment - 3D Joint (JNT4,JL43)

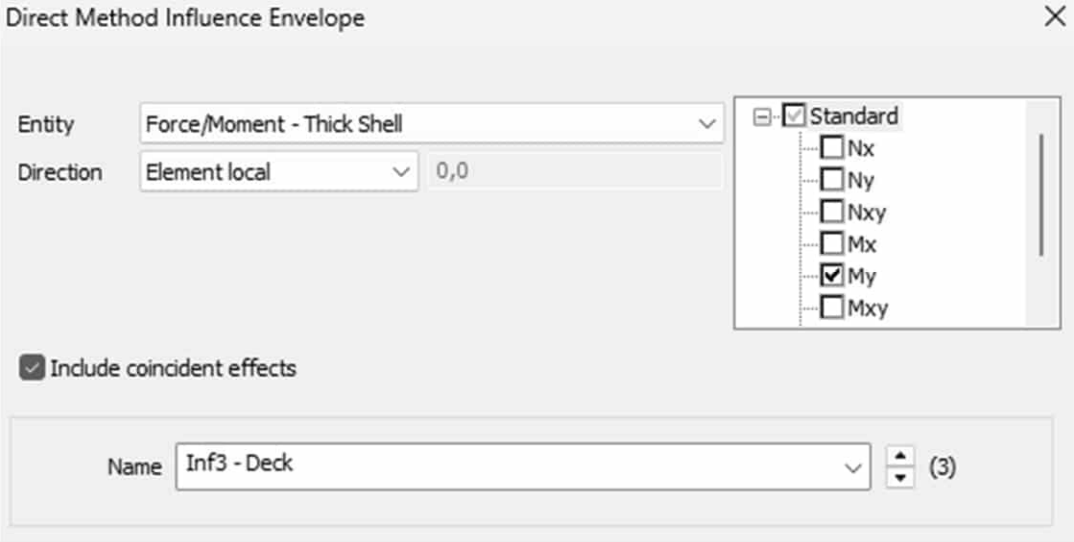
Direction: Element local 0,0

☑ Standard
- ☑ Fx
- ☑ Fy
- ☑ Fz

☑ Include coincident effects

Name: Inf2 - Bearings (2)

Inf3 – Deck :



Direct Method Influence Envelope

Entity: Force/Moment - Thick Shell

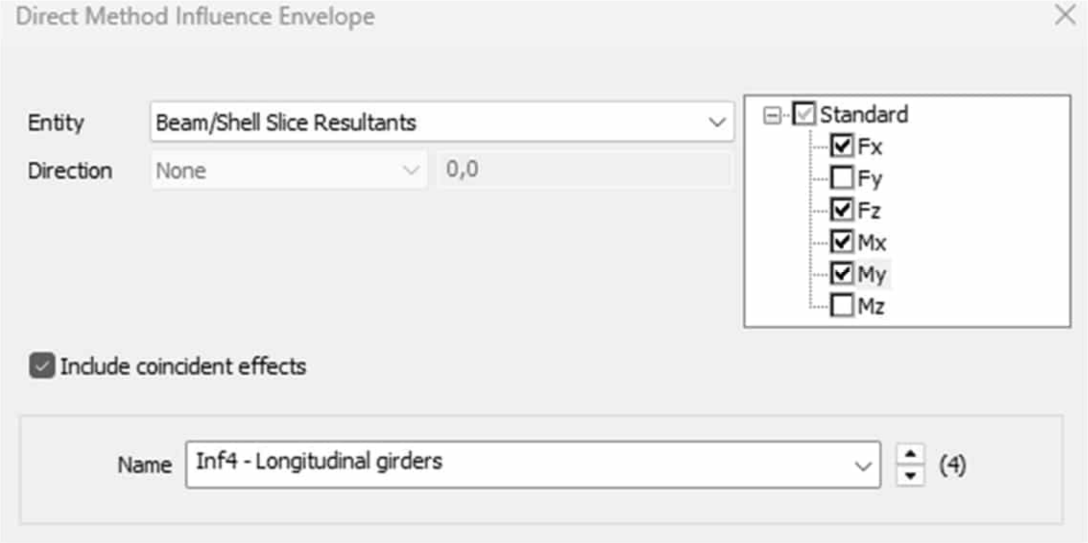
Direction: Element local 0,0

- ☑ Standard
  - ☐ Nx
  - ☐ Ny
  - ☐ Nxy
  - ☐ Mx
  - ☑ My
  - ☐ Mxy

☑ Include coincident effects

Name: Inf3 - Deck (3)

Inf4 – Longitudinal girders :



Direct Method Influence Envelope

Entity: Beam/Shell Slice Resultants

Direction: None 0,0

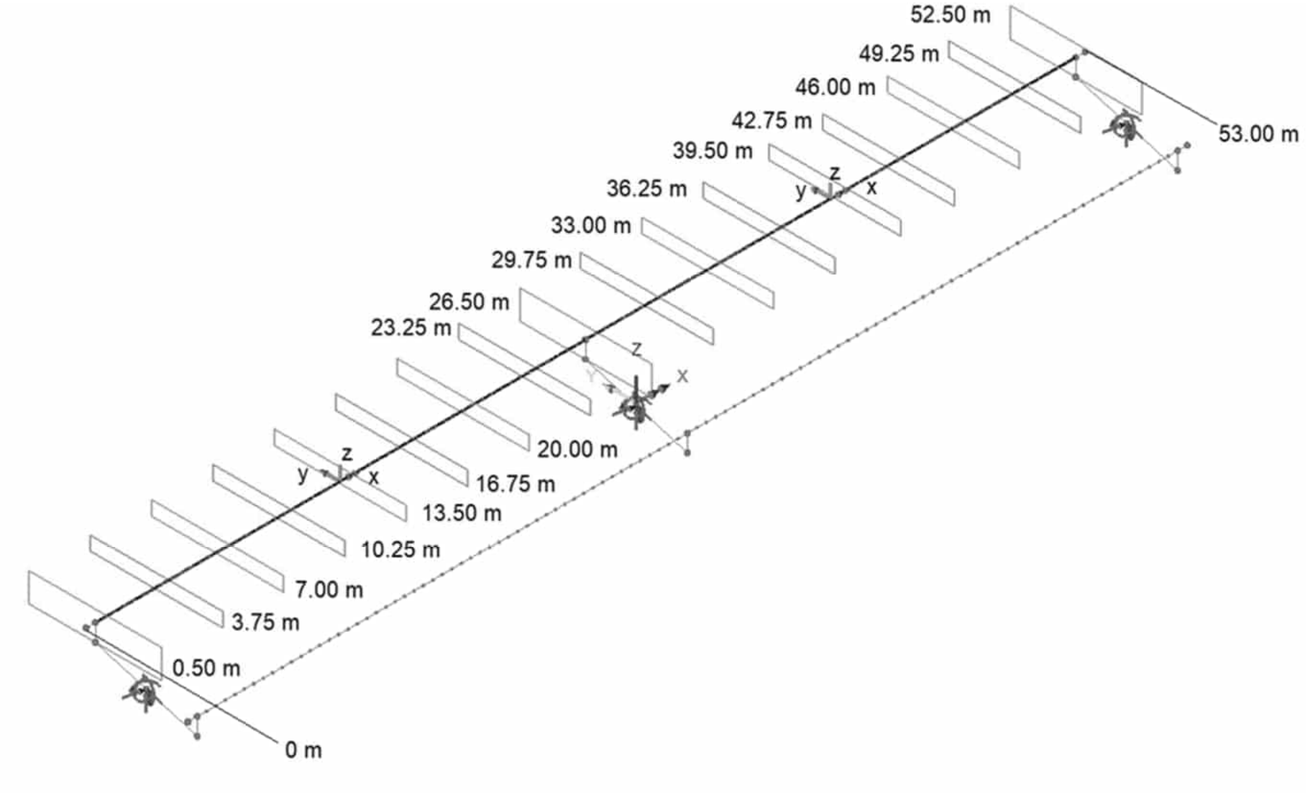
☑ Standard
- ☑ Fx
- ☐ Fy
- ☑ Fz
- ☑ Mx
- ☑ My
- ☐ Mz

☑ Include coincident effects

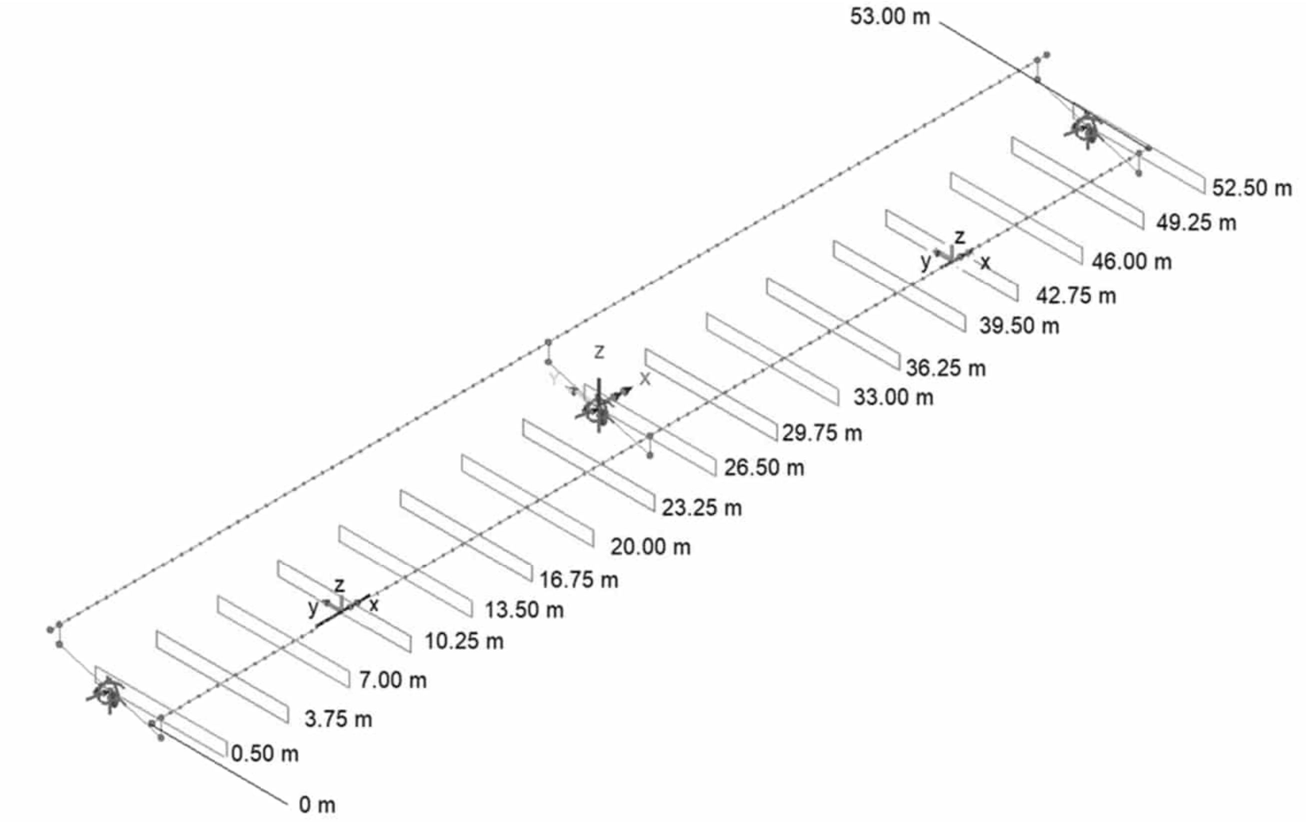
Name: Inf4 - Longitudinal girders (4)

<u>Definition *”Slice resultants beams/shells”*</u>

Each longitudinal girder (LB 1 & LB 2) has 19 *”slices”* according to sketches below, see also pages A2:445-47.

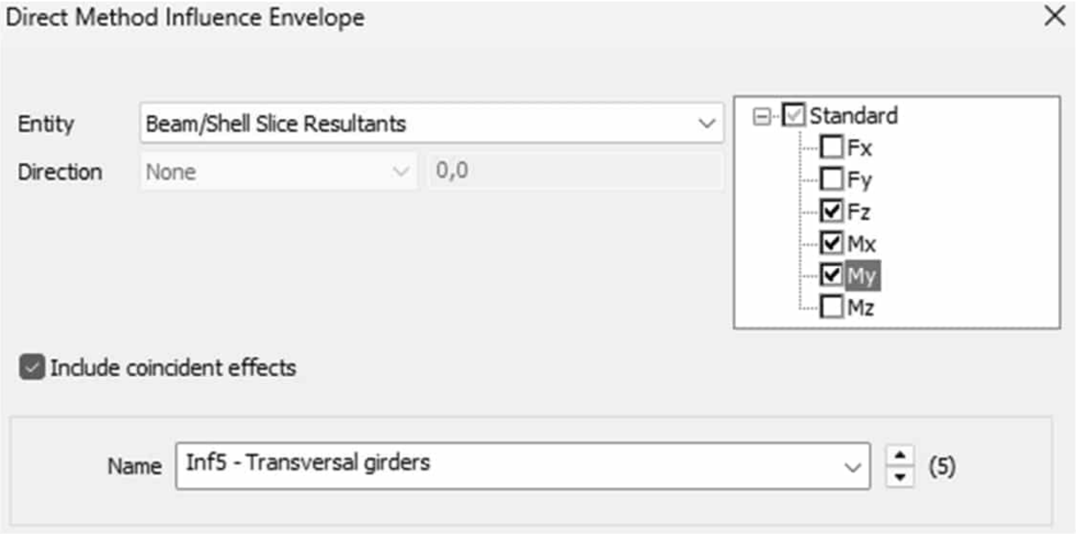


Slice LB1



Slice LB2

Inf5 – Transversal girders :



Direct Method Influence Envelope

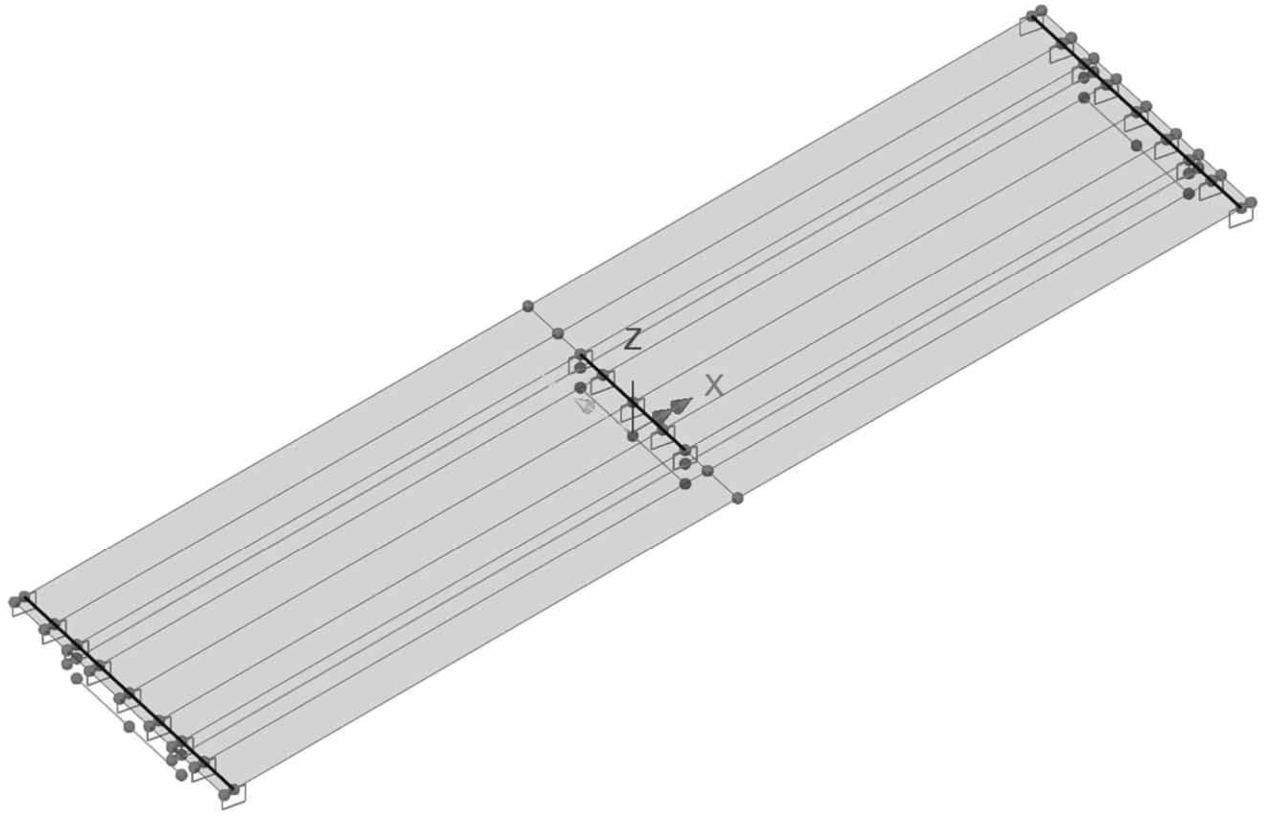
Entity: Beam/Shell Slice Resultants

Direction: None 0,0

☑ Standard
- ☐ Fx
- ☐ Fy
- ☑ Fz
- ☑ Mx
- ☑ My
- ☐ Mz

☑ Include coincident effects

Name: Inf5 - Transversal girders (5)



Overview

Influence surfaces :

Search area: Superstructure

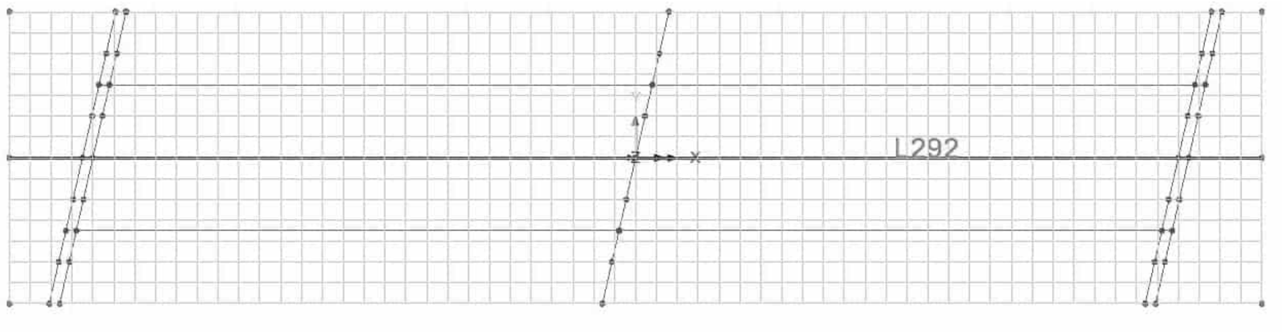
Definition type: Grid

Centerline (path): L292

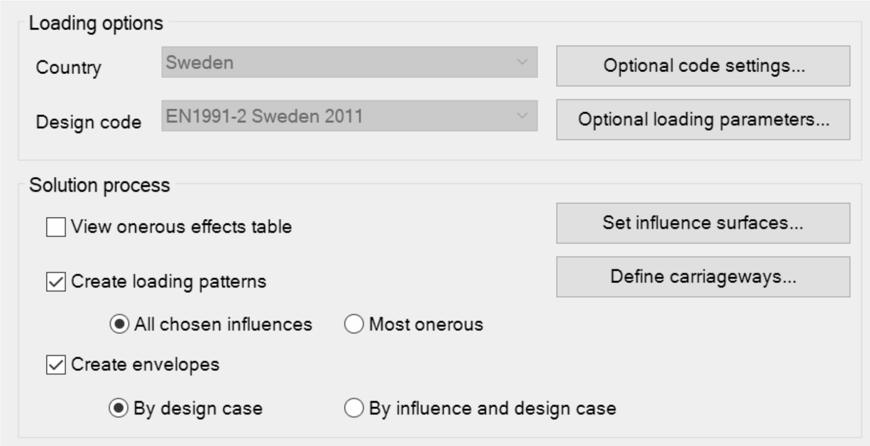
Transverse width: 14.0 m

Longitudinal spacing: 0.5 m

Transversal spacing: 0.5 m



Vehicle load optimisation options:


Loading options
Country: Sweden
Design code: EN1991-2 Sweden 2011

Solution process
☐ View onerous effects table
☑ Create loading patterns
● All chosen influences ○ Most onerous
☑ Create envelopes
● By design case ○ By influence and design case

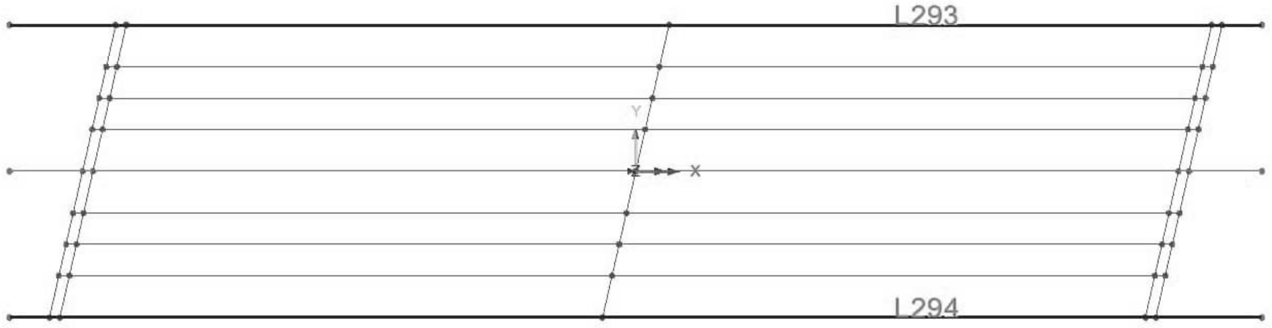
Vehicle longitudinal incremental movement: 0.5 m

Vehicle transverse incremental movement: 0.5 m

Vehicle direction: both

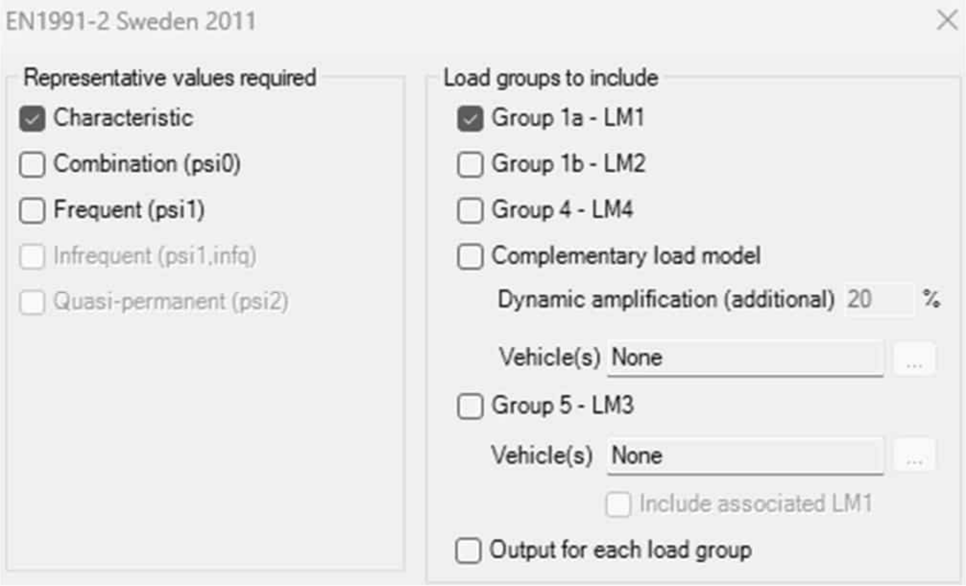
Definition of carriageway (kerbs): L293 & L294

Influence surfaces: Include all (positive & negative)



3.7.5.1 Envelope : LM 1

Load model 1 (LM1) defined in SS-EN 1991-2 section 4.3.2.



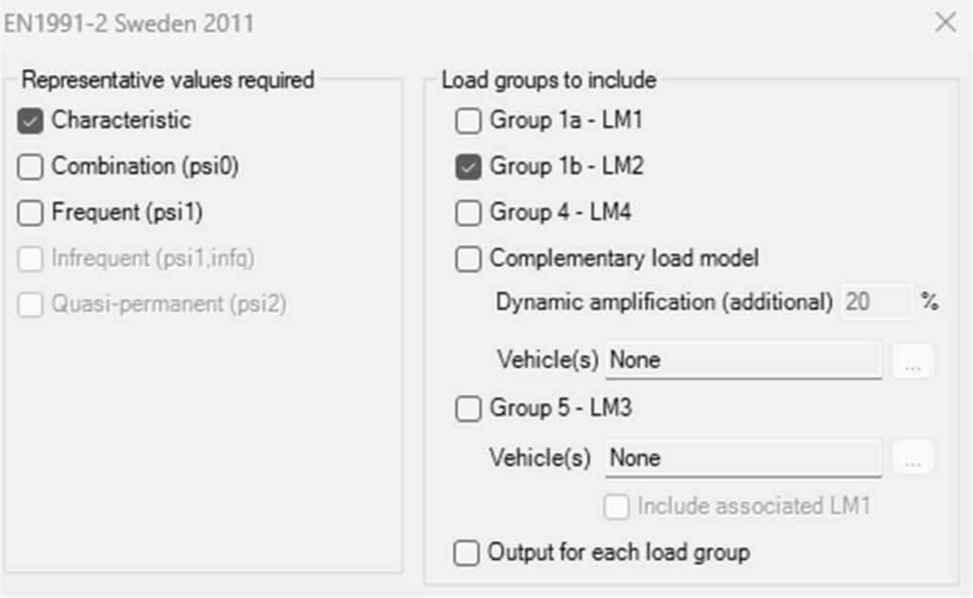
EN1991-2 Sweden 2011

Representative values required
☑ Characteristic
☐ Combination (psi0)
☐ Frequent (psi1)
☐ Infrequent (psi1,infq)
☐ Quasi-permanent (psi2)

Load groups to include
☑ Group 1a - LM1
☐ Group 1b - LM2
☐ Group 4 - LM4
☐ Complementary load model
Dynamic amplification (additional) 20 %
Vehicle(s) None
☐ Group 5 - LM3
Vehicle(s) None
☐ Include associated LM1
☐ Output for each load group

3.7.5.2 Envelope : LM 2

Load model 2 (LM2) defined in SS-EN 1991-2 section 4.3.3.



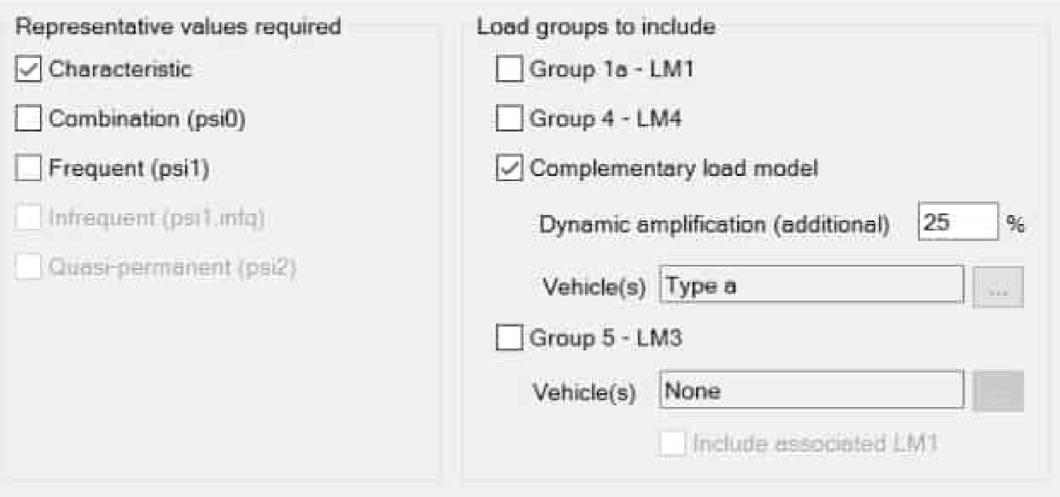
EN1991-2 Sweden 2011

Representative values required
☑ Characteristic
☐ Combination (psi0)
☐ Frequent (psi1)
☐ Infrequent (psi1,infq)
☐ Quasi-permanent (psi2)

Load groups to include
☐ Group 1a - LM1
☑ Group 1b - LM2
☐ Group 4 - LM4
☐ Complementary load model
Dynamic amplification (additional) 20 %
Vehicle(s) None
☐ Group 5 - LM3
Vehicle(s) None
☐ Include associated LM1
☐ Output for each load group

3.7.5.3 Envelope : EG A

EG A is defined as complementary load model with options seen below.



Representative values required
- ☑ Characteristic
- ☐ Combination (psi0)
- ☐ Frequent (psi1)
- ☐ Infrequent (psi1,infq)
- ☐ Quasi-permanent (psi2)

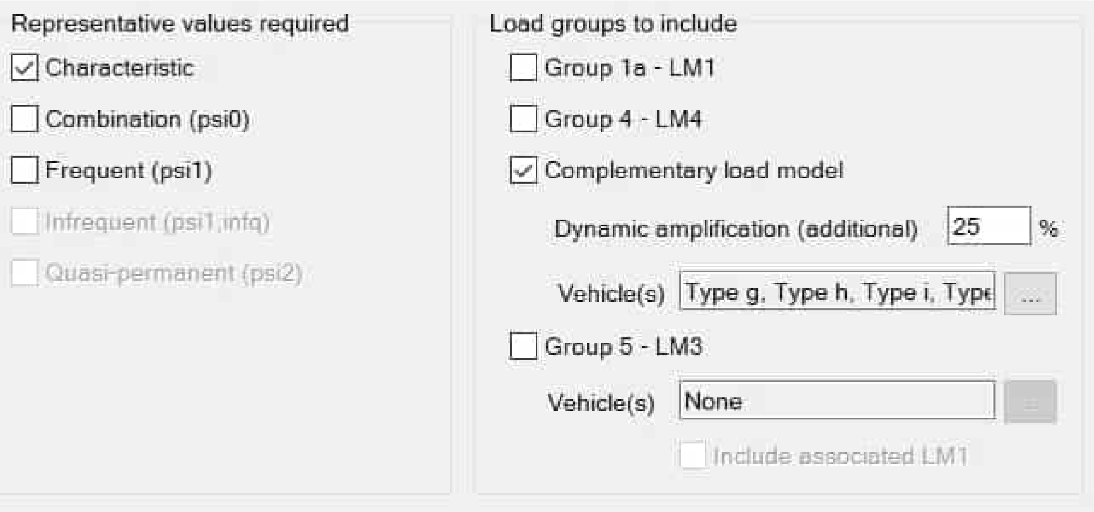
Load groups to include
- ☐ Group 1a - LM1
- ☐ Group 4 - LM4
- ☑ Complementary load model
  - Dynamic amplification (additional) 25 %
  - Vehicle(s) Type a
- ☐ Group 5 - LM3
  - Vehicle(s) None
  - ☐ Include associated LM1

Dynamic amplification (additional): 25 %

Vehicle selection: Type a

3.7.5.4 Envelope : EG B

EG B is defined as complementary load model with options seen below.



Representative values required
- ☑ Characteristic
- ☐ Combination (psi0)
- ☐ Frequent (psi1)
- ☐ Infrequent (psi1,infq)
- ☐ Quasi-permanent (psi2)

Load groups to include
- ☐ Group 1a - LM1
- ☐ Group 4 - LM4
- ☑ Complementary load model
  - Dynamic amplification (additional) 25 %
  - Vehicle(s) Type g, Type h, Type i, Type
- ☐ Group 5 - LM3
  - Vehicle(s) None
  - ☐ Include associated LM1

Dynamic amplification (additional): 25 %

Vehicle selection: Type b → o

3.7.5.5 Combined traffic load (TRAFIK)

There are a total 4 different traffic loads termed LM 1, LM2, EG A and EG B.

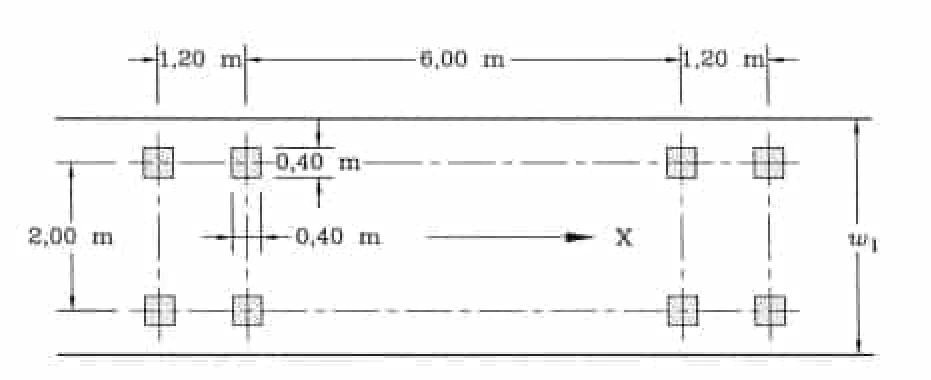
The envelope is used to identify the most onerous load effect.

Envelope TRAFIK :

Envelope
LM 1
LM 2
EG A
EG B

3.7.5.6 Fatigue model

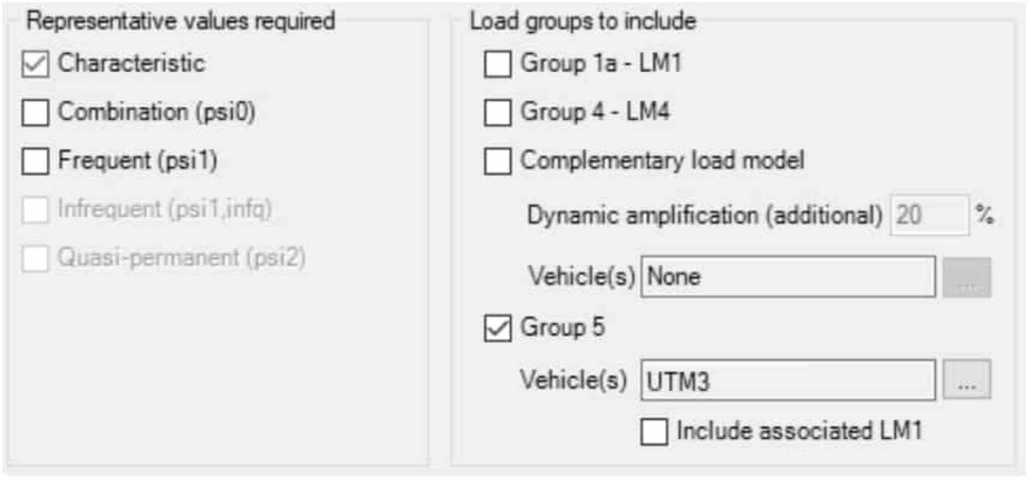
Fatigue model 3 (UTM3) defined in SS-EN 1991-2 section 4.6.4. The load is defined in Group 5 (special vehicle) in present version of software.



Q_k = 120 kN : characteristic value including nation adaptation factors.

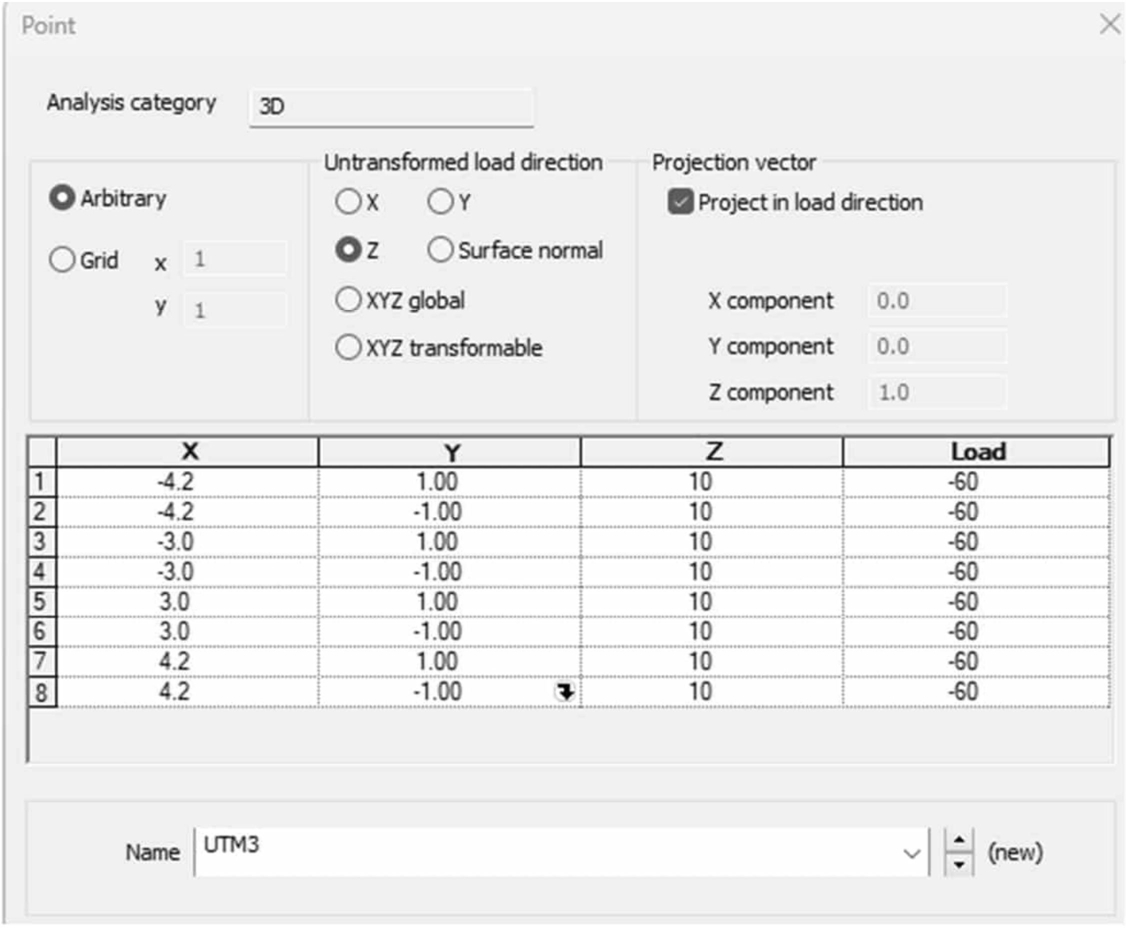
The load definition:

The load UTM3 is defined as a special vehicle in "load group 5".



Representative values required
- ☑ Characteristic
- ☐ Combination (psi0)
- ☐ Frequent (psi1)
- ☐ Infrequent (psi1,infq)
- ☐ Quasi-permanent (psi2)

Load groups to include
- ☐ Group 1a - LM1
- ☐ Group 4 - LM4
- ☐ Complementary load model
  - Dynamic amplification (additional) 20 %
  - Vehicle(s) None
- ☑ Group 5
  - Vehicle(s) UTM3
  - ☐ Include associated LM1



Point

Analysis category: 3D

- ● Arbitrary
- ○ Grid x 1 y 1

Untransformed load direction
- ○ X ○ Y
- ● Z ○ Surface normal
- ○ XYZ global
- ○ XYZ transformable

Projection vector
- ☑ Project in load direction
- X component 0.0
- Y component 0.0
- Z component 1.0

	X	Y	Z	Load
1	-4.2	1.00	10	-60
2	-4.2	-1.00	10	-60
3	-3.0	1.00	10	-60
4	-3.0	-1.00	10	-60
5	3.0	1.00	10	-60
6	3.0	-1.00	10	-60
7	4.2	1.00	10	-60
8	4.2	-1.00	10	-60

Name UTM3 (new)

3.8 BRAKING LOAD

Load acts at level of surfacing.

Braking load act on bridge deck and at top of end abutments. Both are to codsidered.

3.8.1 Braking load at top of abutment

Braking load according to SS-EN 1991-2 §4.9.2 acts on top of abutement at location of expansion joint.

$$Q_{broms} = 0.6\alpha_{Q1} \cdot Q_{1k} = 0.6 \cdot 0.9 \cdot 300kN = 162kN$$

Remark

This load case is not consider in systedmtta lastfall är inte införd i systemberäkning.

3.8.2 Braking load on bridge deck

Braking load is defined by SS-EN 1991-2 §4.4.1.

Load acts at level of surfacing.

L = 0.5 m + 26.0m + 26.0 m + 0.5 m = 53.0 m

Load modell LM 1 :

$$Q_{lk} = 0.6\alpha_{Q1} \cdot (2Q_{ik}) + 0.1\alpha_{q1} \cdot q_{1k} \cdot w_1 \cdot L$$

$$180kN \cdot \alpha_{Q1} \leq Q_{lk} \leq 900kN$$

$$Q_{broms} = 0.6 \cdot (2 \cdot 270kN) + 0.1 \cdot 7.2kPa \cdot 3.0m \cdot 53.0m = 324kN + 114kN = 438kN$$

Load model EG B = 300 kN (see TSFS chapter 11 §2) :

Typ o is dimensioning.

$$Q_{lk} = 0.35 \cdot \sum Q_{EG\ B} + 0.1 \cdot p \cdot L_q$$

$$Q_{lk} \leq 500kN$$

$$Q_{broms} = 0.35 \cdot (0.33 + 2 \cdot 0.89 + 1.17 + 0.83) \cdot B = 0.35 \cdot 4.11 \cdot 300kN$$

Remark

The braking force associated with LM 1 is applied on the safe side in the system calculation.

The impact of the resisting earth pressure against the frame legs is neglected on the safe side.

3.8.2.1 Load definition

The load case is applied at centre of the bridge deck as a line load with a load length of $0.5w_{tot}$ on the safe side.
Lastfallet är införd i centrum av brobana som en linjelast med lastlängd $0.5w_{tot}$ på säker sida.

$$p_x = \frac{Q_{broms}}{0.5w_{tot}} = \frac{438kN}{0.5 \cdot 14.0m} = 63\frac{kN}{m}$$

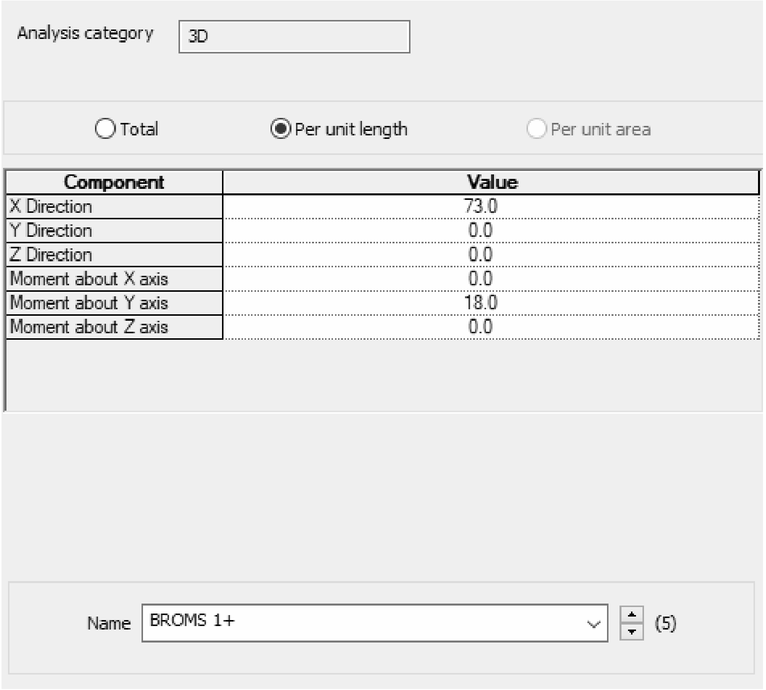
$$m_y = p_x \cdot (0.15m + t_{bel}) = 3\frac{kN}{m} \cdot (0.15m + 0.095m) = 15\frac{kNm}{m}.$$

Load case : BROMS 1+

Structural loading : Global distributed

Line load (p_x) : 63 kN/m

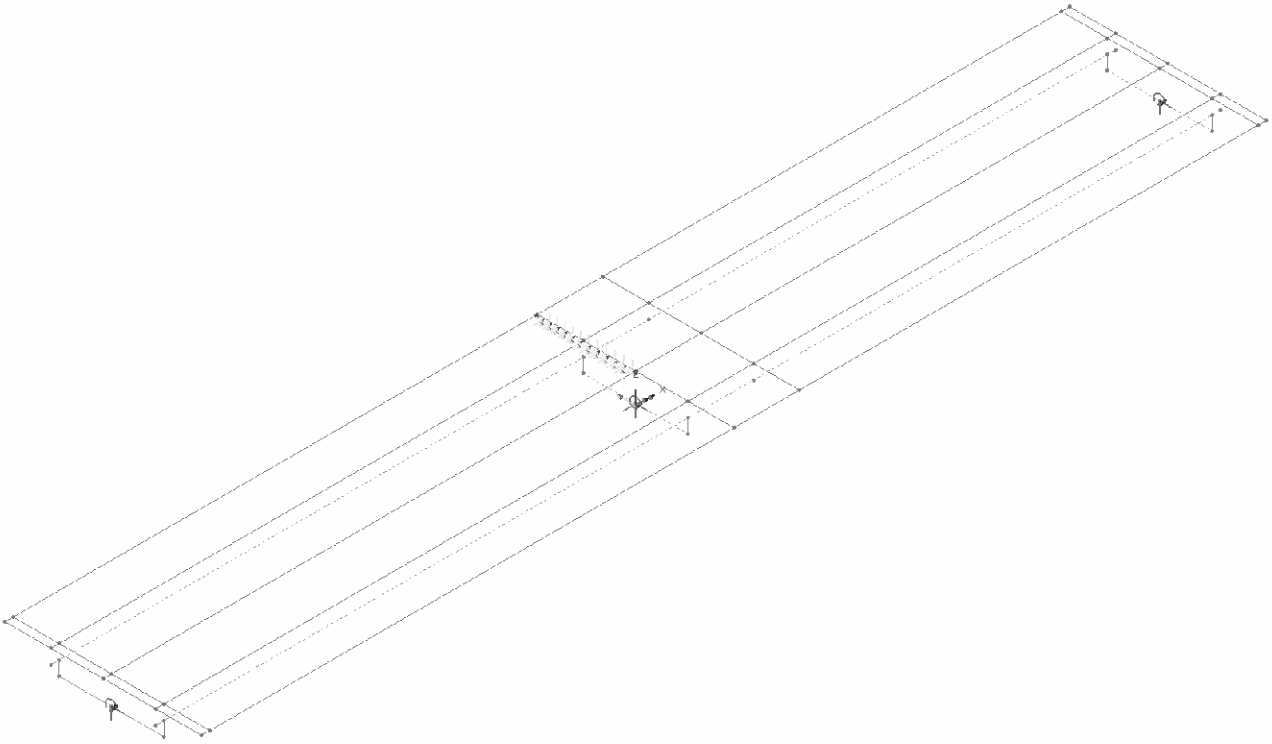
Line load (m_y) : 15 kNm/m


Analysis category: 3D

○ Total ● Per unit length ○ Per unit area

Component	Value
X Direction	73.0
Y Direction	0.0
Z Direction	0.0
Moment about X axis	0.0
Moment about Y axis	18.0
Moment about Z axis	0.0

Name: BROMS 1+ (5)

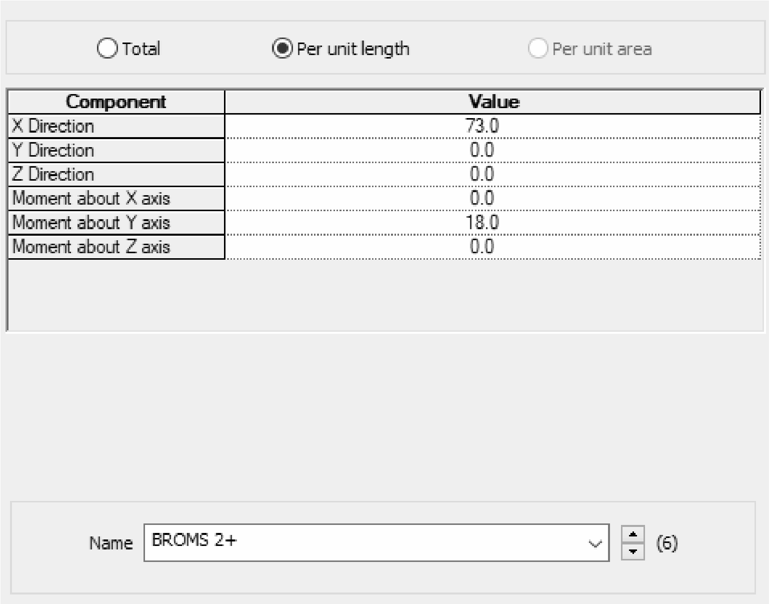


Load case : BROMS 2+

Structural loading : Global distributed

Line load (p_x) : 63 kN/m

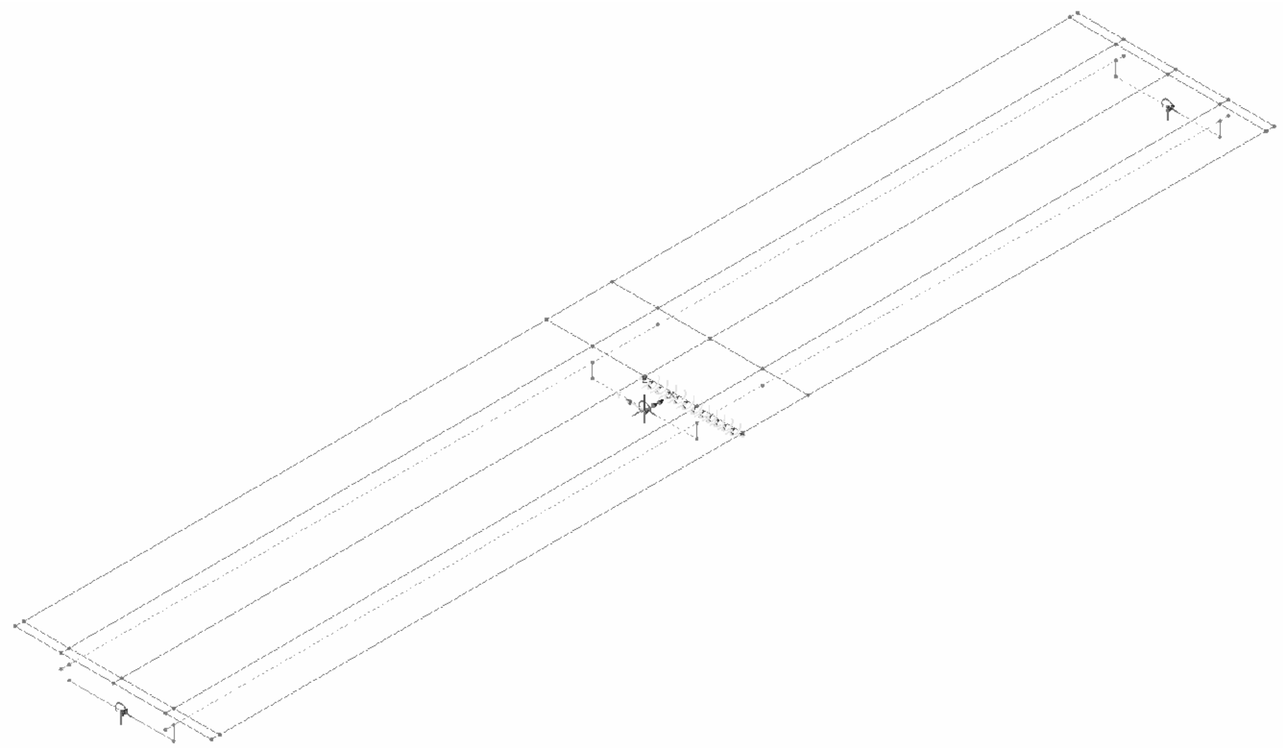
Line load (m_y) : 15 kNm/m



○ Total ● Per unit length ○ Per unit area

Component	Value
X Direction	73.0
Y Direction	0.0
Z Direction	0.0
Moment about X axis	0.0
Moment about Y axis	18.0
Moment about Z axis	0.0

Name: BROMS 2+ (6)



3.8.2.2 Load combination (BROMS)

Basic load cases :

Load case	Load	Factor
BROMS 1-	BROMS 1+	-1
BROMS 2-	BROMS 2+	-1

Envelope BROMS :

Load case
BROMS 1+
BROMS 1-
BROMS 2+
BROMS 2-

3.9 LATERAL FORCE

The lateral force is determined according to SS-EN 1991-2 §4.4.2. The load occurs orthogonal to the braking force and is considered to occur as a result of skew braking or centrifugal forces
(R = 1200 m).

Load model LM 1 :

$Q_{tk} = 0.25Q_{lk} = 0.25 \cdot 438kN = 110kN$: skewed braking

$Q_{tk.2} = \frac{40m}{R}\sum\alpha_{Qi} \cdot (2Q_{ik}) = \frac{40m}{1200m} \cdot 2 \cdot (270kN + 180kN) = 30kN$: centrifugal force

Lastmodell EG B = 300 kN (se TSFS kapitel 11 punkt 2§) :
Type o is considered dimensioning.

$Q_{tk} = 0.25Q_{lk} = 0.25 \cdot 431kN = 107kN$: skewed braking

$Q_{tk.2} = \frac{40m}{R} \cdot Q_v = \frac{40m}{1200m} \cdot (4.11 \cdot 300kN) = 41kN$: centrifugal force

Remark
Lateral force corresponding to vehicle LM1 is chosen in system analysis.

3.9.1 Load definition

The load is defined as a line load acting along the marked line.

The load is distributed over a width of 0.5L_{span} on the safe side.

$$p_y = \frac{Q_{sido}}{0.5L_{spann}} = \frac{110kN}{0.5 \cdot 26m} = 9\frac{kN}{m}$$

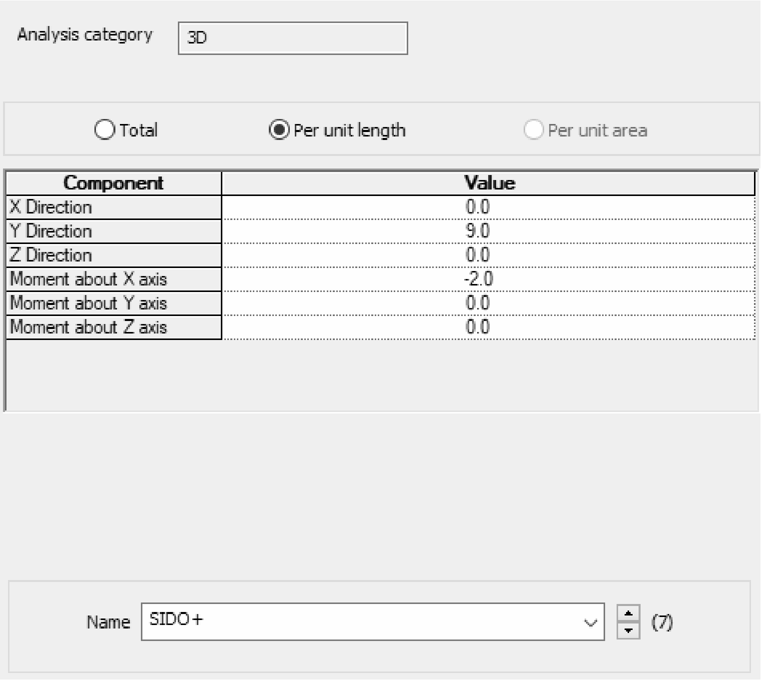
$$m_x = -p_y \cdot (0.15m + t_{bel}) = -9\frac{kN}{m} \cdot (0.15m + 0.095m) = -2\frac{kNm}{m}$$

Load case : SIDO+

Structural loading : Global distributed

Line load (p_y) : 9 kN/m

Line load (m_x) : -2 kNm/m

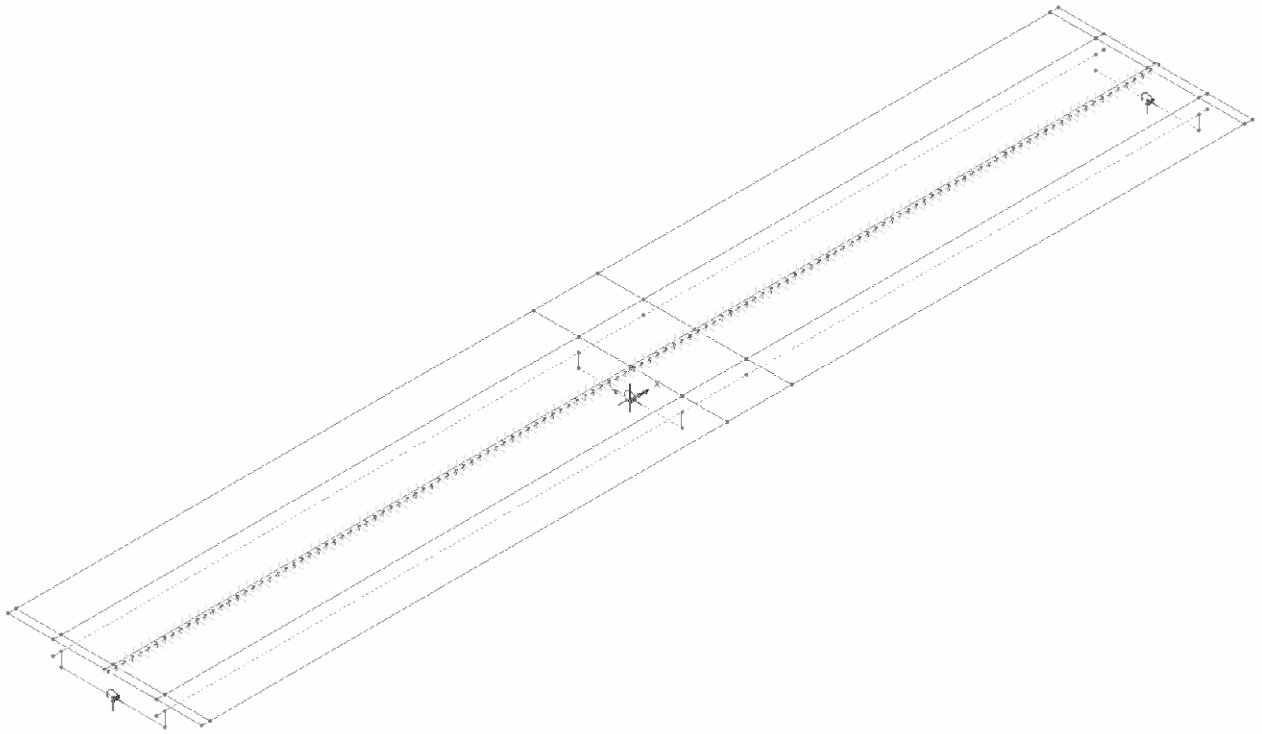


Analysis category: 3D

○ Total ● Per unit length ○ Per unit area

Component	Value
X Direction	0.0
Y Direction	9.0
Z Direction	0.0
Moment about X axis	-2.0
Moment about Y axis	0.0
Moment about Z axis	0.0

Name: SIDO+ (7)



3.9.2 Load combination

Basic load cases :

Load case	Load	Factor
SIDO-	SIDO+	-1

Envelope SIDO :

Load case
SIDO+
SIDO-

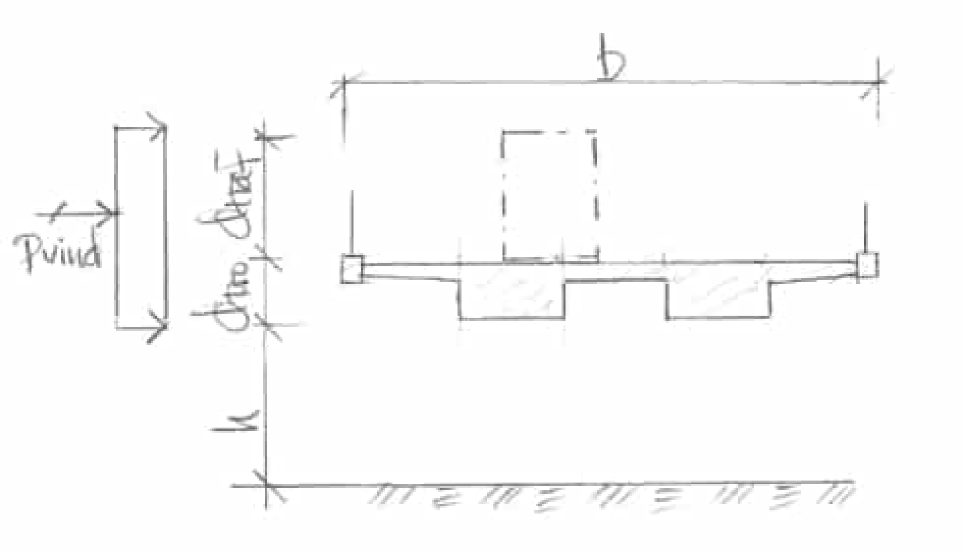
3.10 WIND LOAD

Wind load on bridges is defined by EN 1991-1-4 chapter 8.

Duration coefficients (see SS-EN 1990 attachment A2 table A2.1) :

$\psi_k = 1.00$
$\psi_0 = 0.30$
$\psi_1 = 0.20$
$\psi_2 = 0$

Load intensity:



Terrain type II is applied on safe side according to SS-EN 1991-1-4 table 4.1.

h = 7 m but 8 m is applied on safe side.

$v_b(Robertsfors; z = 10m; z_0 = 0.05m) = 23\frac{m}{s}$: TSFS chapter 7 figure 7.1

$q_p\left(h = 8m, Terrängtyp\ II, v_b = 23\frac{m}{s}\right) = 0.67kPa$: TSFS chapter 7 table 7.1

$q_b = \frac{1}{2} \cdot \rho \cdot v_b^2 = \frac{1}{2} \cdot 1.25\frac{kg}{m^3} \cdot \left(22\frac{m}{s}\right)^2 = 0.30\frac{kN}{m^2}$: SS-EN 1991-1-4 chapter 4.5

$c_e = \frac{q_p}{q_b} = \frac{0.67kPa}{0.30kPa} = 2.23$: SS-EN 1991-1-4 chapter 4.5

d_{bro} = $1.50m + (0.10m + 0.095m) = 1.70m$: construction height incl. pavement

d_{traf}^{red} = $2.0m - (0.10m + 0.095m) = 1.81m$: traffic height pavement

$$d_{tot} = 1.70m + 1.81m = 3.51m$$

$$\rightarrow \frac{b_{bro}}{d_{tot}} = \frac{14.0m}{3.51m} = 4.0$$

$c_{f.x}\left(\frac{b_{bro}}{d_{tot}} = 4.0\right) = 1.3$: SS-EN 1991-1-4 sketch 8.3

$$C = c_e \cdot c_{f.x} = 2.23 \cdot 1.3 = 2.90$$

$$\frac{A_{ref.x}}{L} = d_{tot}$$

Wind load structure (below pavement) :

$$\frac{A_{ref.x}^{bro}}{L} \equiv d_{bro}$$

$$p_{vind}^{bro} = \frac{F_w}{L} = \frac{1}{2} \cdot \rho \cdot v_b^2 \cdot C \cdot \frac{A_{ref.x}^{bro}}{L} = \frac{1}{2} \cdot 1.25\frac{kg}{m^3} \cdot \left(23\frac{m}{s}\right)^2 \cdot 2.90 \cdot 1.7m = 1.6\frac{kN}{m}$$

Wind load traffic (above pavement) :

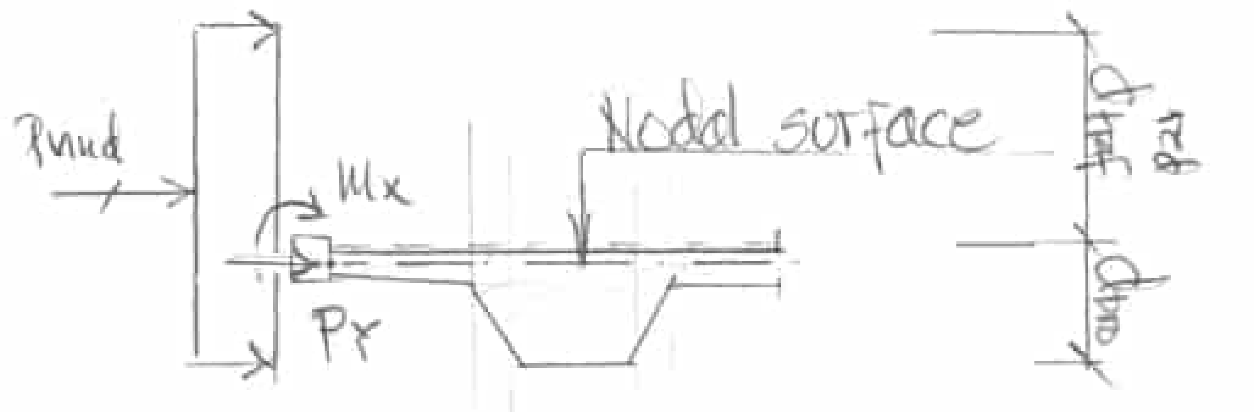
$$\frac{A_{ref.x}^{traf}}{L} \equiv d_{traf}^{res}$$

$$p_{vind}^{traf} = \frac{F_w}{L} = \frac{1}{2} \cdot \rho \cdot v_b^2 \cdot C \cdot \frac{A_{ref.x}^{bro}}{L} = \frac{1}{2} \cdot 1.25\frac{kg}{m^3} \cdot \left(23\frac{m}{s}\right)^2 \cdot 2.90 \cdot 1.81m = 1.7\frac{kN}{m}$$

3.10.1 Definition of load

Load is applied as a line load acting along each edge beam.

$$p_{vind} = p_{vind}^{bro} + p_{vind}^{trafik} = 1.6\,\frac{kN}{m} + 1.7\,\frac{kN}{m} = 3.3\,\frac{kN}{m}$$



$$p_y = 4\,\frac{kN}{m}$$

→

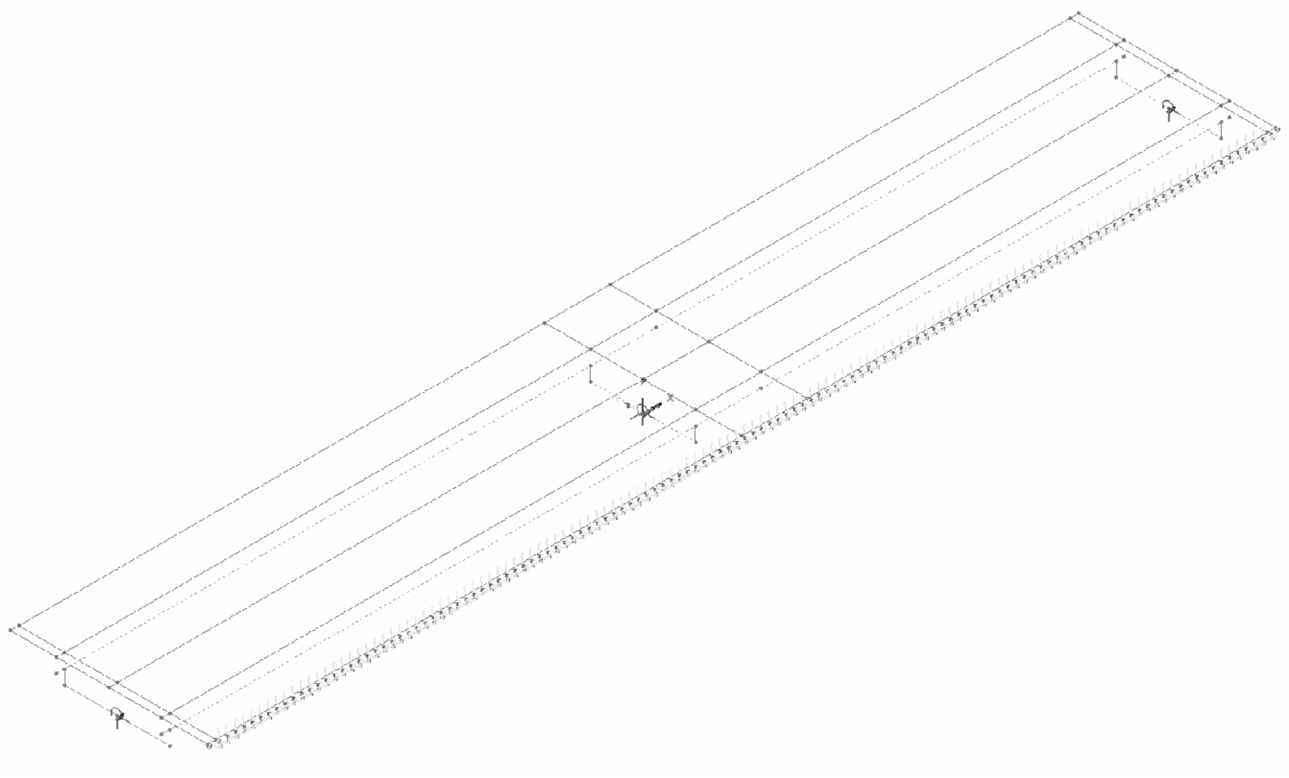
$$m_x = -p_y \cdot \left(\frac{d_{tot}}{2} - 1.35m\right) = -3.3\,\frac{kN}{m} \cdot \left(\frac{3.51m}{2} - 1.35m\right) = -2\,\frac{kNm}{m}$$

Load : VIND+

Structural loading : Global distributed

Line load in Y direction (p_y) : +4 $\frac{kN}{m}$

Line moment about X axis (m_x) : -2 $\frac{kNm}{m}$

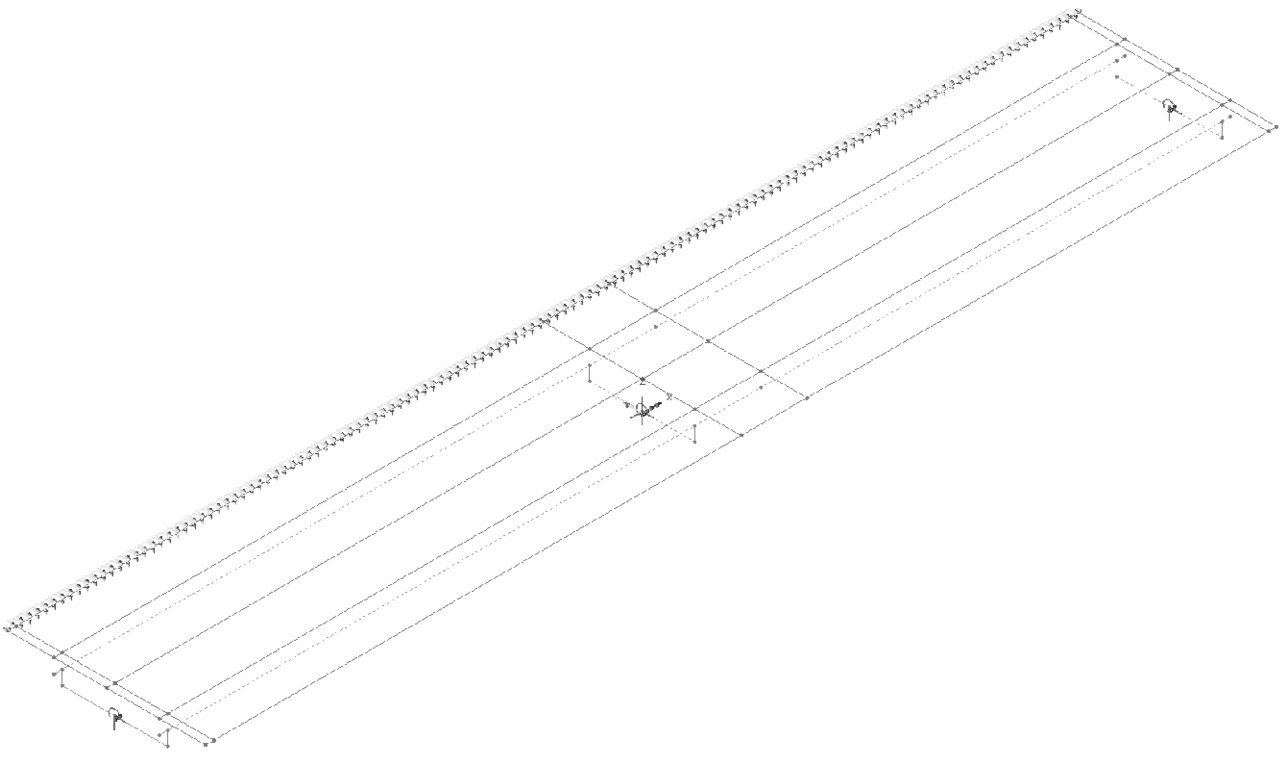


Load : VIND-

Structural loading : Global distributed

Line load in Y direction (p_y) : -4 $\frac{kN}{m}$

Line moment about X axis (m_x) : 2 $\frac{kNm}{m}$



3.10.2 Load combination

Envelope VIND :

Load case
VIND+
VIND-

3.11 SURCHARGE

TSFS chapter 11 section §8 describes load seen below.

$q_{ytlast.1} = 20kPa$: road width 6.0 m

$q_{ytlast.2} = 10kPa$: remaining width

$q_{\text{över}}\ (s) = K_0 \cdot q_{ytlast}$

3.12 TEMPERATURE

Temperature effect bridges according to TSFS section B.3.2.5 and EN 1991-1-5 chapter 6.

Effect in service state see SS-EN 1992-1-1 §2.3.1.2. If used then apply effect of gradual cracking according to SS-EN 1992-1-1 §5.4(3).

Effect in ultimate state is not required according to SS-EN 1992-1-1 §2.3.1.2. If used apply reduced stiffness according to SS-EN 1992-1-1 §5.4(3).

Casting temperature, T_{mont} = +10° C : EN 1991-1-5A.1(3)

Expansion coefficient, $\alpha = 12 \cdot 10^{-6}$

Concrete beam ⇒ type 3

Ort : Ånäset

$T_{max} = +32℃$: TSFS chapter 8 sketch 8.1
$T_{min} = -40℃$: TSFS chapter 8 sketch 8.2

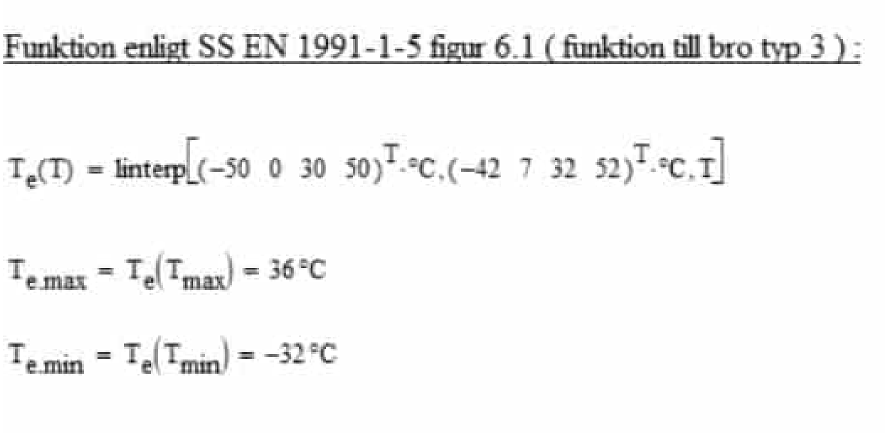
Duration coefficients :

Coefficients according to SS-EN 1990/A1 table A2.3

$\psi_0 = 0.60$
$\psi_1 = 0.60$
$\psi_2 = 0.50$

3.12.1 Even temperature over entire bridge (JTEMP)

Uniform temperature change across the entire bridge is given in EN 1991-1-5, section 6.1.3.3. This temperature change is seasonal and mainly causes translation from the bridge's movement centre in the direction of the respective support.



Funktion enligt SS EN 1991-1-5 figur 6.1 (funktion till bro typ 3) :

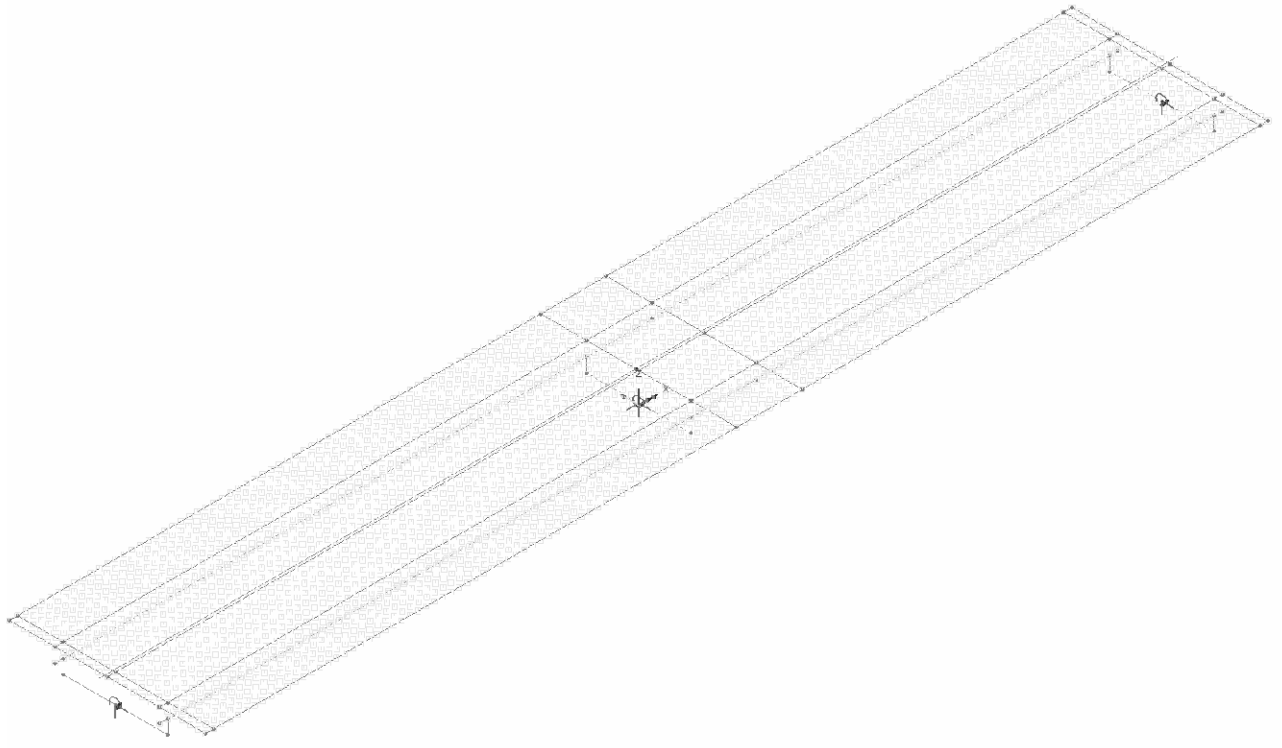
$T_e(T) = \text{linterp}\left[(-50\ \ 0\ \ 30\ \ 50)^T \cdot °C, (-42\ \ 7\ \ 32\ \ 52)^T \cdot °C, T\right]$

$T_{e.max} = T_e(T_{max}) = 36\,°C$

$T_{e.min} = T_e(T_{min}) = -32\,°C$

$$T^+ = T_{e.max} - T_0 = +36℃ - 10℃ = +26℃$$

$$T^- = T_{e.min} - T_0 = -32℃ - 10℃ = -42℃$$



Load : JTEMP+

Structural loading : Temperature

Definition : Nodal lines & surfaces

Final temperature : +26 C

Initial temperature : ±0 C

Load case : JTEMP+

Load : JTEMP-

Structural loading : Temperature

Definition : Nodal lines & surfaces

Final temperature : -42 C

Initial temperature : ±0 C

Load case : JTEMP-

Envelope JTEMP:

Load case
JTEMP+
JTEMP-

3.12.2 Uneven temperature of entire cross section (OJTEMP)

Determined according to EN 1991-1-5 § 6.1.4.1. When assessing the impact, a coating with a thickness of 100 mm ⇒ type 3

$k_{1.sur}$ = 0.7

$k_{2.sur}$ = 1.0

$\varDelta T_{max} = +15℃ \cdot k_{1.sur} = +11℃$: : upper surface warmer

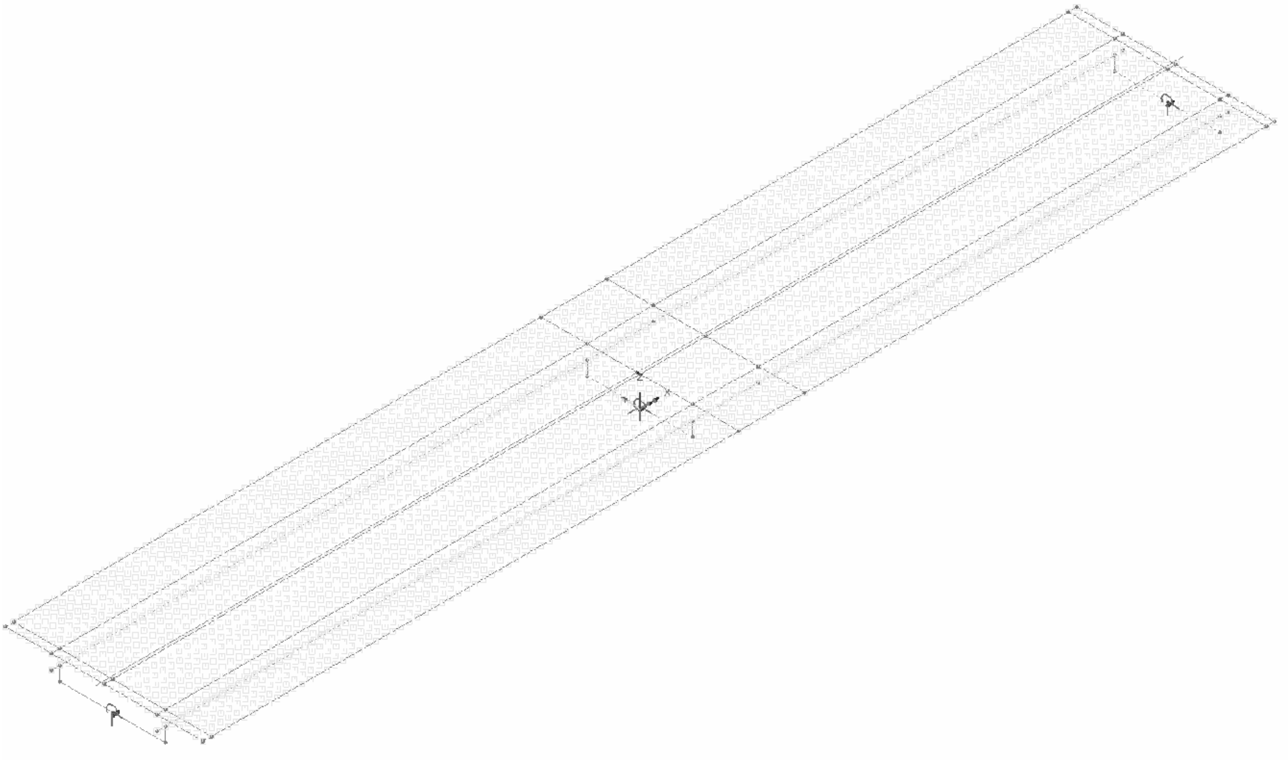
$\varDelta T_{min} = -8℃ \cdot k_{2.sur} = -8℃$: : lower surface warmer

The occurring temperature change ΔT refers to the linear difference between the temperature at the top and bottom of superstructure.

Uneven temperature is indicated as a temperature gradient $\frac{\delta T}{\delta Z}$ when defined in FEM-program.

$\left|\frac{\delta T^{max}}{\delta Z}\right| = \left|\frac{11℃}{1.5m}\right| = 8\frac{℃}{m}$: maximal temperature gradient

$\left|\frac{\delta T^{min}}{\delta Z}\right| = \left|\frac{-8℃}{1.5m}\right| = 6\frac{℃}{m}$: minimal temperature gradient



Loadcase : OJTEMP+

Structural loading : Temperature

Definition : Element

Final Z temperature gradient : +8 °C/m

Loadcase : OJTEMP-

Structural loading : Temperature

Definition : Element

Final Z temperature gradient : -6 °C/m

Envelope OJTEMP:

Load case
OJTEMP+
OJTEMP-

3.12.3 Load combination

Load combination according to SS-EN 1991-1-5 § 6.1.5.

Alternative 1 ($\omega_M = 0.75$) : $T + \omega_M \cdot \Delta T$

Alternative 2 ($\omega_N = 0.35$) : $\omega_N \cdot T + \Delta T$

Load combination smart TEMP-1 :

Load case	Permanent factor	Variable factor
JTEMP	0	1.00
OJTEMP	0	0.75

Load combination smart TEMP-2 :

Load case	Permanent factor	Variable factor
JTEMP	0	0.35
OJTEMP	0	1.00

Envelope TEMP :

Load case
TEMP-1
TEMP-2

3.13 FÖRSPÄNNING

Analysis of pre tensioned cable is studied at times : t_0 (5 days), t_1(30 days) and t_2 (120 years).

The preliminary location of cables is determined with program PROG B2.001.

The location is imported as a spread sheet into FEM-program as a tension profile. The location is defined with local coordinates associated to nodal lines (LB 1-3).

Initial prestress loss at time t0 is only due to friction. This is determined with FEM-program and program PROG B2.001.

Determination of time loses (η_t) is made in separate program PROG B2.002. Preliminary analysis will use losses seen below. They will be verified later during detailed design.

Time	η_t	Load combination	Load case
t0	0 %	PT-T0	1.00 x PT-T0
t1	6 %	PT-T1	0.94 x PT-T0
t2	16 %	PT-T2	0.84 x PT-T0

3.13.1 General

Pre tensions system VSL 6-15.

Material :

$f_{p0.1k} = 1640\ MPa$

$f_{pk} = 1860\ MPa$

$E_{sk} = 195\ GPa$

$\mu = 0.18$

$k = 0.005 \cdot \frac{1}{m}$

Casting tube :
80 mm / 86 mm

Slip during locking:
6 mm

Permissible curvature :
$R_{\min} = 5.7m$

Cabel area :
$A_p = 15 \cdot 150\ mm^2 = 2250\ mm^2$

Anchor plate :
290 mm x 290 mm (same for both passiv and active anchorage)

Ultimate load :
$F_u = 2250\ mm^2 \cdot 1860\ MPa = 4185\ kN$

Permissible stress before locking :
See SS-EN 1992-1-1 section 5.10.2.1

$\sigma_{p,\max}^{före} = \min(0.8 f_{pk}; 0.9 f_{p0.1k}) = \min(1488\ MPa; 1476\ MPa) = 1476\ MPa$

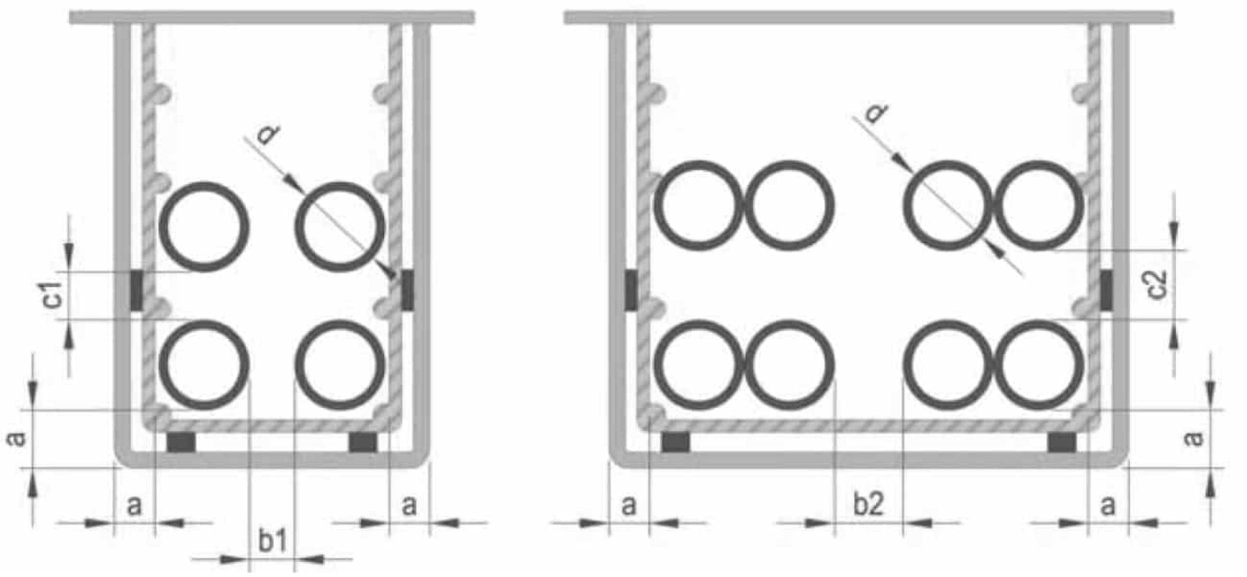
Permissible stress after locking :
See SS-EN 1992-1-1 section 5.10.3

$\sigma_{p,\max}^{efter} = \min(0.75 f_{pk}; 0.85 f_{p0.1k}) = \min(1395\ MPa; 1394\ MPa) = 1394\ MPa$

3.13.2 Execution

Associated to pre tension system VSL 6-15.

Recommended measurements :



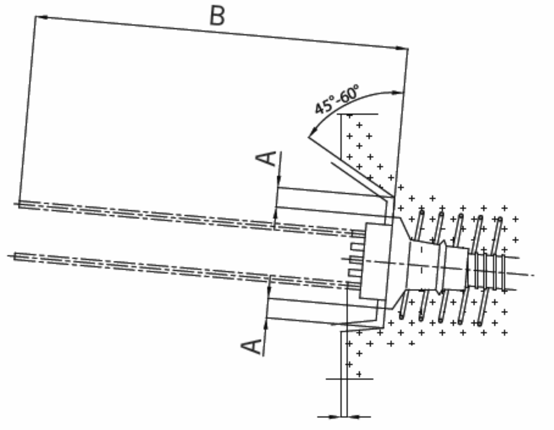
d = 90 mm

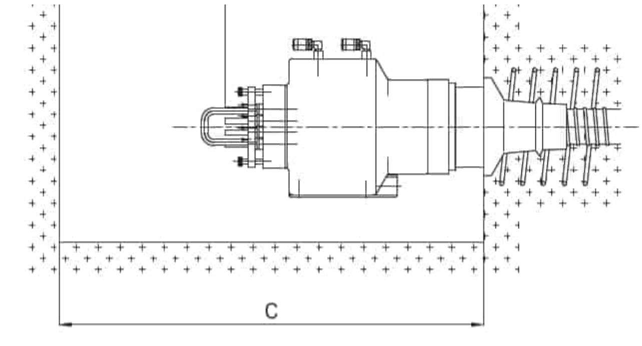
a > 50 mm

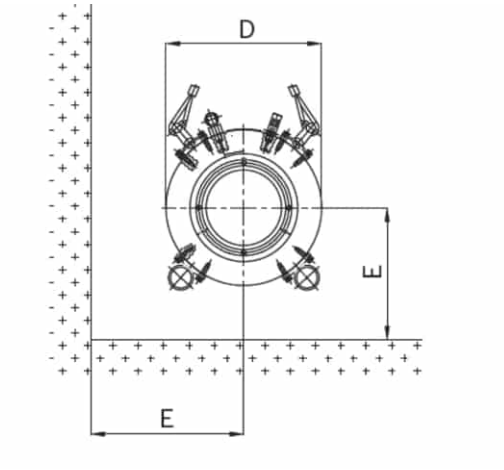
b1, c1 > 0.7d = 63 mm but 100 chosen !

b2, c2 > 1.0d = 90 mm but 100 mm chosen !

Demand for space during tensioning :





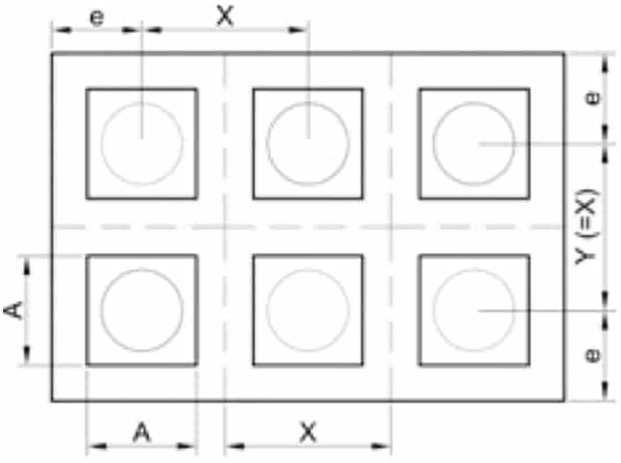


A = 70 mm

B = 1200 mm

C = 1700 mm

Measurements of cables VSL 12-15 :



A = 290 mm

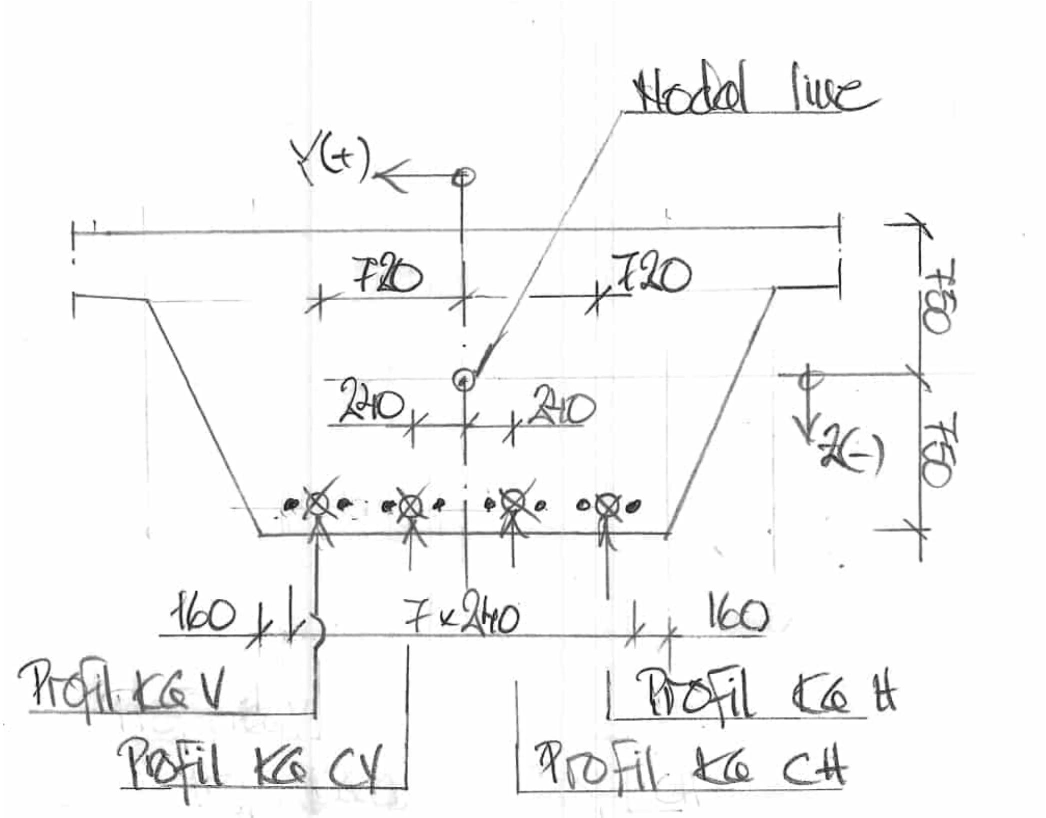
e ≥ 175 mm + TB

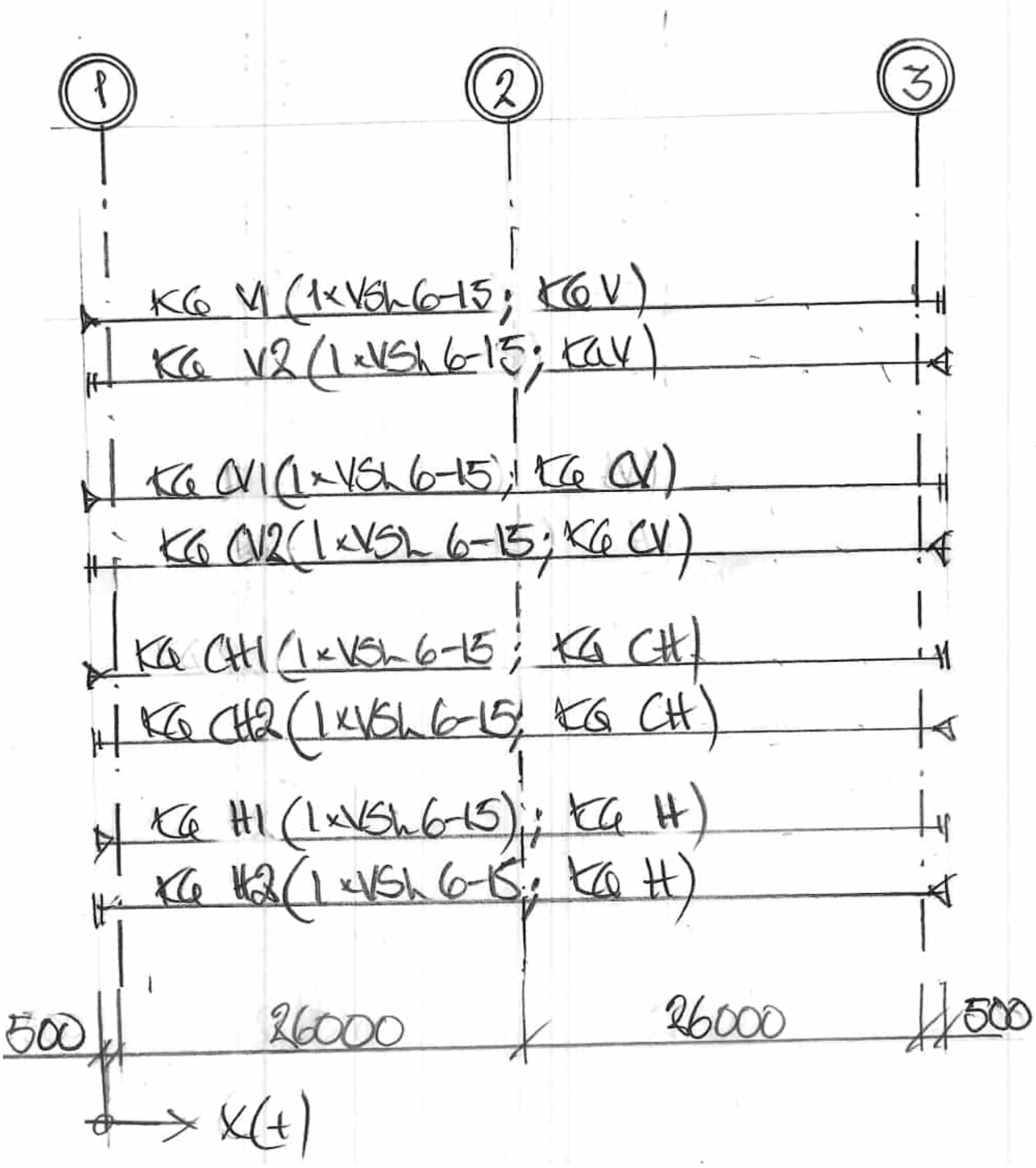
X ≥ 400 mm

3.13.3 Preliminary cable location

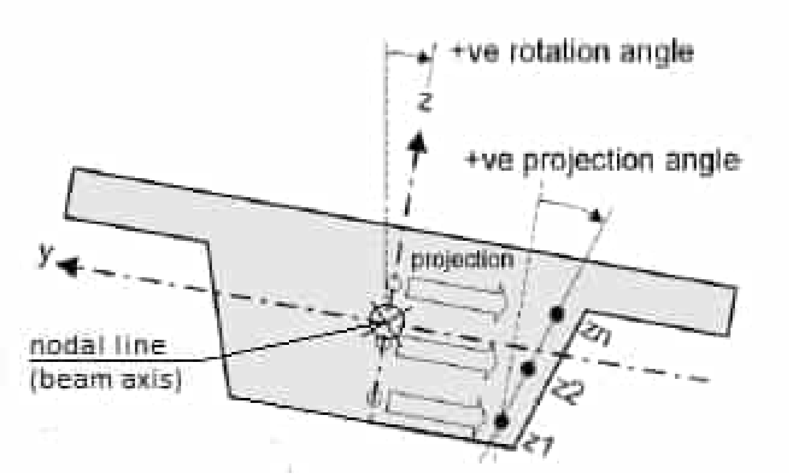
In the static model cables are simplified (= 4 cables are modelled as one fictive cable as seen below).

Profiles can be defined using “global coordinates” or as “local coordinates mapped to lines”. The later of this method is used. The nodal lines associated to LB 1 and LB 23 are used.




1
2
3
KG V1 (1×VSL 6-15; KG V)
KG V2 (1×VSL 6-15; KG V)
KG CV1 (1×VSL 6-15; KG CV)
KG CV2 (1×VSL 6-15; KG CV)
KG CH1 (1×VSL 6-15; KG CH)
KG CH2 (1×VSL 6-15; KG CH)
KG H1 (1×VSL 6-15); KG H)
KG H2 (1×VSL 6-15; KG H)
500
26000
26000
500
X(+)

Principle sketch:



Summary input - pretensioned cables:

Tendon load	Area	Slip	Left side	Right side	Max. prestress before	Min. prestress after	Pretension force	Location y(+)
KG V1	2250	3	Active	Passive	1476	1394	3320*	+0.72
KG V2	2250	3	Passive	Active	1476	1394	3320*	+0.72
KG CV1	2250	3	Active	Passive	1476	1394	3320*	+0.24
KG CV2	2250	3	Passive	Active	1476	1394	3320*	+0.24
KG CH1	2250	3	Active	Passive	1476	1394	3320*	-0.24
KG CH2	2250	3	Passive	Active	1476	1394	3320*	-0.24
KG H1	2250	3	Active	Passive	1476	1394	3320*	-0.72
KG H2	2250	3	Passive	Active	1476	1394	3320*	-0.72
-	mm^2	mm	-	-	MPa	MPa	kN	m

* = chosen prestress 1476 MPa

Beam	Location	Cables	Fictive load
LB 1	Left side	1	KG V1 (= 1 x VSL 6-15)
-“-	Left side	1	KG V2 (= 1 x VSL 6-15)
-“-	Left side	1	KG CV1 (= 1 x VSL 6-15)
-“-	Left side	1	KG CV2 (= 1 x VSL 6-15)
-“-	Right side	1	KG CH1 (= 1 x VSL 6-15)
-“-	Right side	1	KG CH2 (= 1 x VSL 6-15)
-“-	Right side	1	KG H1 (= 1 x VSL 6-15)
-“-	Right side	1	KG H2 (= 1 x VSL 6-15)
LB 2	Left side	1	KG V1 (= 1 x VSL 6-15)
-“-	Left side	1	KG V2 (= 1 x VSL 6-15)
-“-	Left side	1	KG CV1 (= 1 x VSL 6-15)
-“-	Left side	1	KG CV2 (= 1 x VSL 6-15)
-“-	Right side	1	KG CH1 (= 1 x VSL 6-15)
-“-	Right side	1	KG CH2 (= 1 x VSL 6-15)
-“-	Right side	1	KG H1 (= 1 x VSL 6-15)
-“-	Right side	1	KG H2 (= 1 x VSL 6-15)

3.13.4 Load definition

Profile is retrieved from page A3:83.

3.13.4.1 Tendon profile

Spread sheet input for KG V1 & KG V2:

x(+) : x´(+)

y(+) : -0.72 m

z(+): -0.75 m + y_p(+)

x(+)	z(+)
0	+0.45
0.50	+0.45
3.80	+0.18
8.50	-0.45
12.50	-0.60
18.50	-0.15
22.50	+0.35
26.50	+0.60
30.50	+0.35
34.50	-0.15
40.50	-0.60
44.50	-0.45
49.20	+0.18
52.50	+0.45
53.00	+0.45
m	m

Spread sheet input for KG CV1 & KG CV2:

x(+) : x´(+)

y(+) : -0.48 m

z(+): -0.75 m + y_p(+)

x(+)	z(+)
0	+0.45
0.50	+0.45
3.80	+0.18
8.50	-0.45
12.50	-0.60
18.50	-0.15
22.50	+0.35
26.50	+0.60
30.50	+0.35
34.50	-0.15
40.50	-0.60
44.50	-0.45
49.20	+0.18
52.50	+0.45
53.00	+0.45
m	m

Spread sheet input for KG CH1 & KG CH2:

x(+) : x´(+)

y(+) : +0.48 m

z(+): -0.75 m + $y_p(+)$

x(+)	z(+)
0	+0.45
0.50	+0.45
3.80	+0.18
8.50	-0.45
12.50	-0.60
18.50	-0.15
22.50	+0.35
26.50	+0.60
30.50	+0.35
34.50	-0.15
40.50	-0.60
44.50	-0.45
49.20	+0.18
52.50	+0.45
53.00	+0.45
m	m

Spread sheet input for KG H1 & KG H2:

x(+) : x´(+)

y(+) : -0.48 m

z(+): -0.75 m + y_p(+)

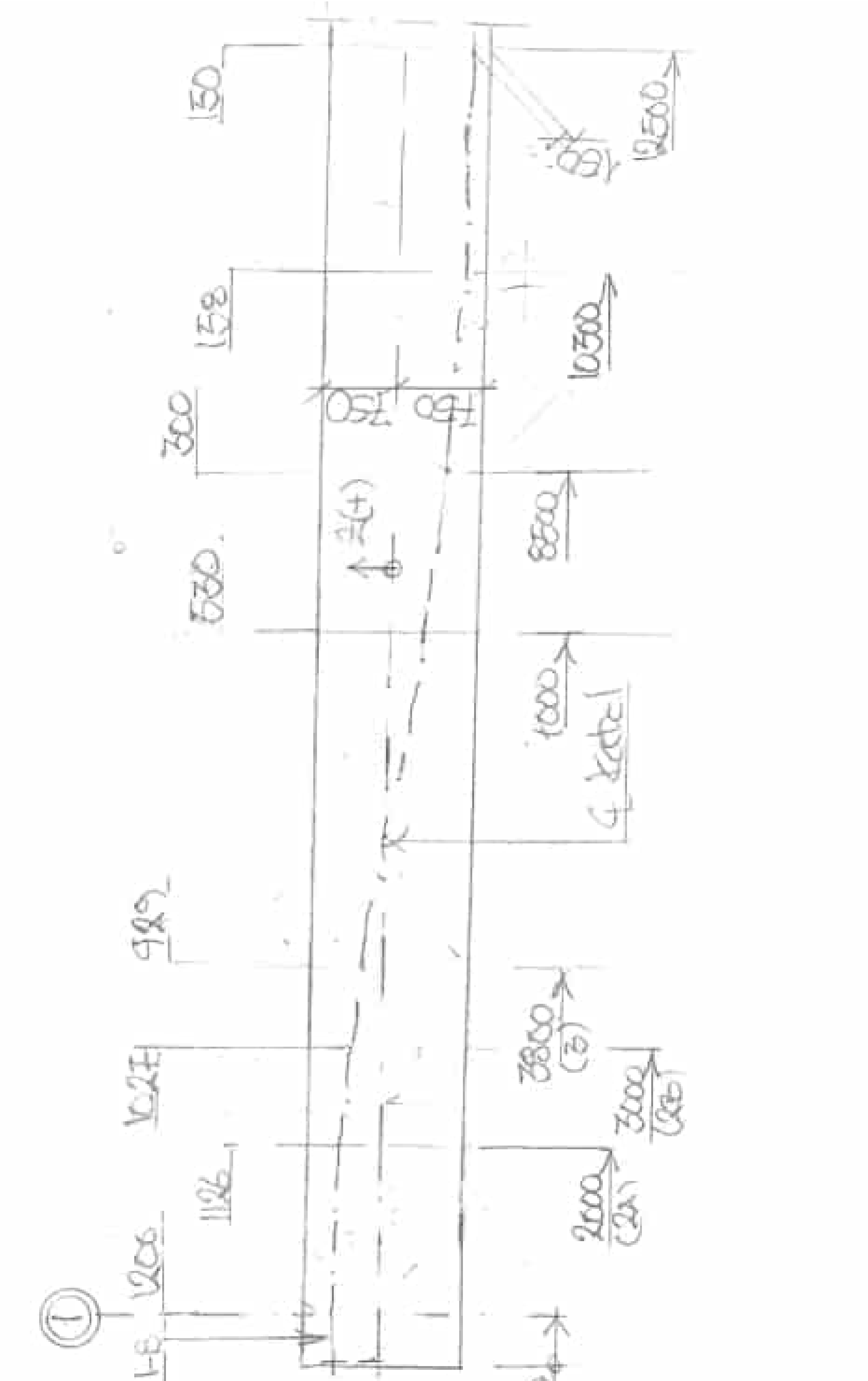
x(+)	z(+)
0	+0.45
0.50	+0.45
3.80	+0.18
8.50	-0.45
12.50	-0.60
18.50	-0.15
22.50	+0.35
26.50	+0.60
30.50	+0.35
34.50	-0.15
40.50	-0.60
44.50	-0.45
49.20	+0.18
52.50	+0.45
53.00	+0.45
m	m

A determination of the cable profile and verification of short-term losses is carried out using the calculation program B2.001, where all forms and partial results are reported.

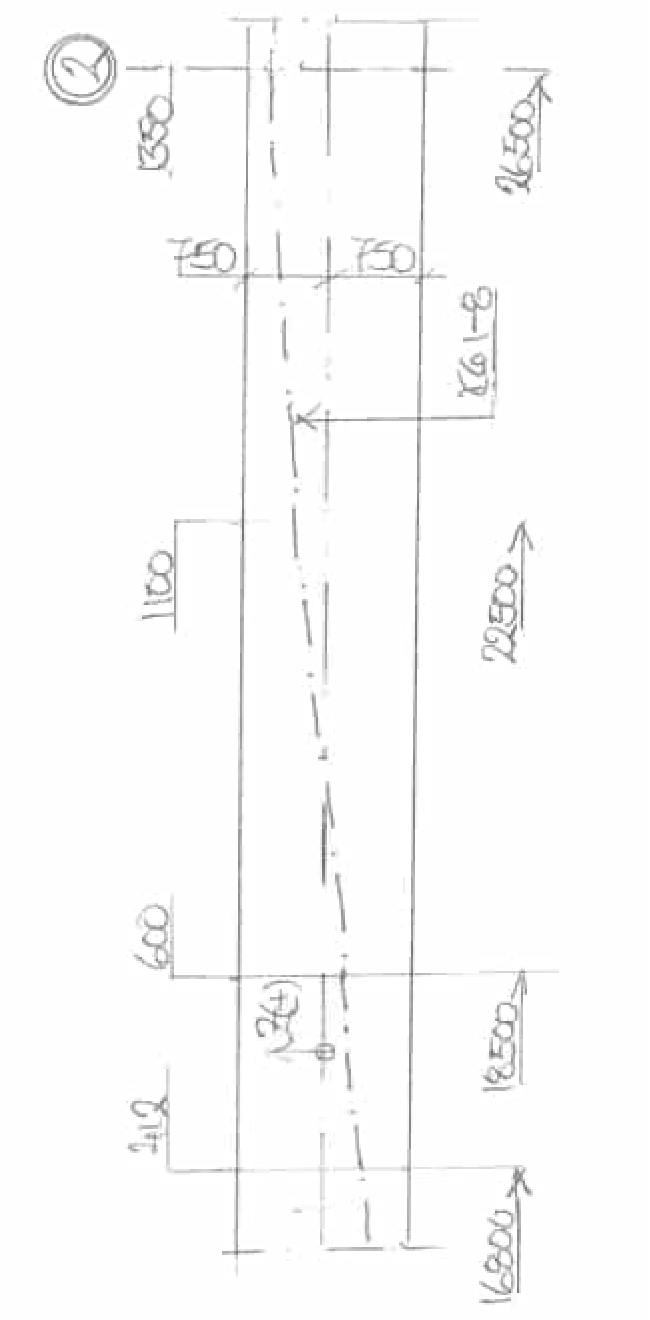
To meet the requirement for permissible stress, 3 mm theoretical locking slip is needed, see page A3:91.

Various manufacturers have requirements for the minimum possible locking slip in active anchorage corresponding to 6 mm. In system calculations, 6 mm is applied in all active anchorages on the safe side.

Cable KG 1-8:



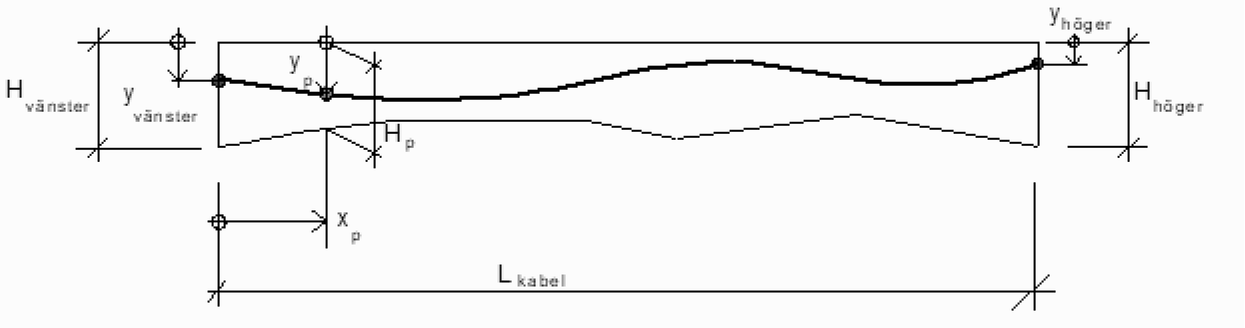
ELEVATION
Part I



ELEVATION
Part II

Object: Tendon profile (1 cable VSL 6-15)

PRINCIPLE SKETCH



INPUT

Total cable length: $L_{kabel} := 0.50\ m + 26 \cdot m + 26 \cdot m + 0.5\ m = 53\ m$

Number of definition points: $N := 15 \cdot pcs$

Friction coefficients: $\mu := 0.18$ $k := 0.005 \cdot \frac{rad}{m}$

Resistance cable: $f_{p0.1k} := 1640 \cdot MPa$

$f_{pk} := 1860 \cdot MPa$

E-modulus cable: $E_s := 195 \cdot GPa$

Tendon area: $A_s := 2250 \cdot mm^2$

Maximum permissible tensile force before locking according to SS-EN 1992-1-1 section 5.10.2.1:

$$min\left(0.8 \cdot f_{pk}, 0.9 \cdot f_{p0.1k}\right) \cdot A_s = 3321\ kN$$

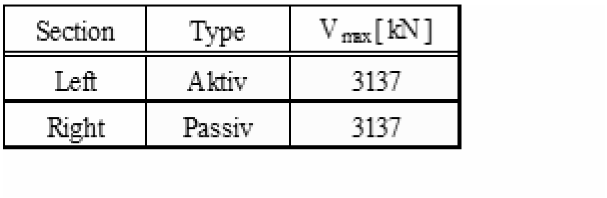
Selected prestressing force:

$$V_{ö} := 3320 \cdot kN$$

Maximum permissible tensile force after locking according to SS-EN 1992-1-1 section 5.10.3:

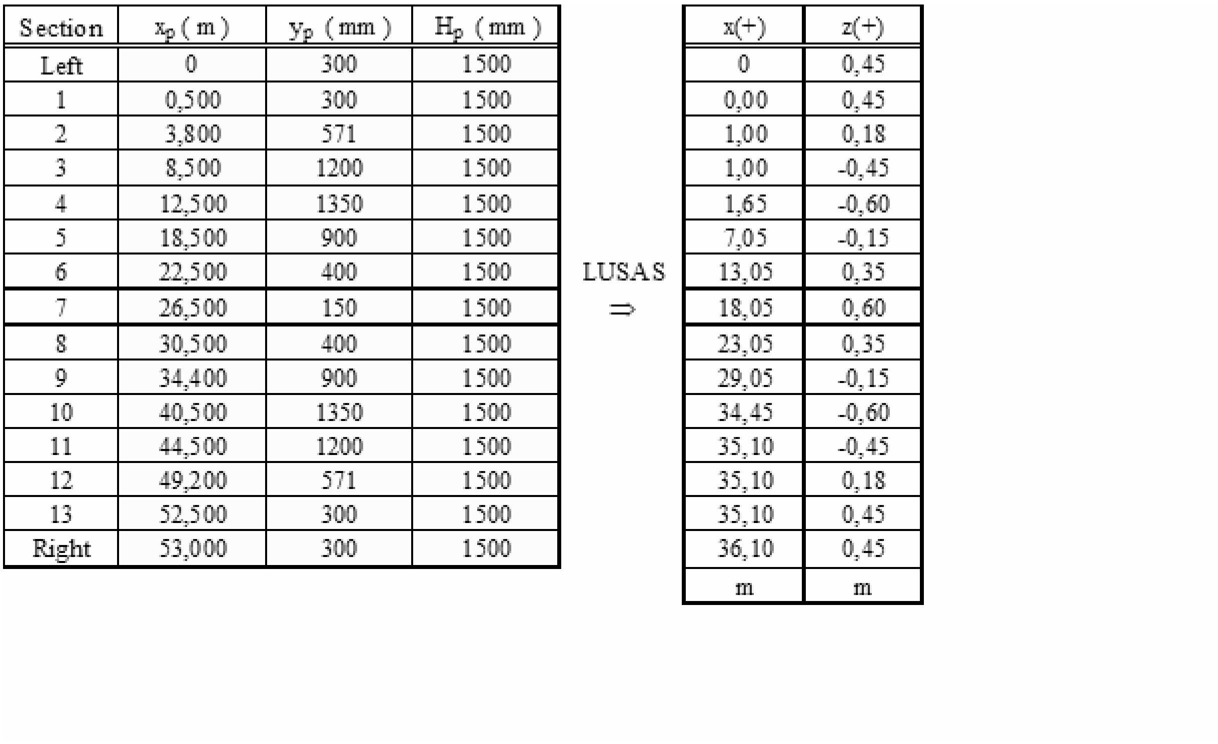
$$min\left(0.75 \cdot f_{pk}, 0.85 \cdot f_{p0.1k}\right) \cdot A_s = 3137\ kN$$

Type of anchorage ("Passiv" or "Aktiv") / chosen maximum tendon force after locking:



Section	Type	V_{max} [kN]
Left	Aktiv	3137
Right	Passiv	3137

Defined points along cable:



Section	x_p (m)	y_p (mm)	H_p (mm)
Left	0	300	1500
1	0,500	300	1500
2	3,800	571	1500
3	8,500	1200	1500
4	12,500	1350	1500
5	18,500	900	1500
6	22,500	400	1500
7	26,500	150	1500
8	30,500	400	1500
9	34,400	900	1500
10	40,500	1350	1500
11	44,500	1200	1500
12	49,200	571	1500
13	52,500	300	1500
Right	53,000	300	1500

LUSAS ⇒

x(+)	z(+)
0	0,45
0,00	0,45
1,00	0,18
1,00	-0,45
1,65	-0,60
7,05	-0,15
13,05	0,35
18,05	0,60
23,05	0,35
29,05	-0,15
34,45	-0,60
35,10	-0,45
35,10	0,18
35,10	0,45
36,10	0,45
m	m

CALCULATION

Create mathematical functions for a beam and a cable

$C := \mathrm{pspline}\left(x_p, y_p\right)$: determination of coefficients for parabolic spline functions

$y(x) := \mathrm{interp}\left(C, x_p, y_p, x\right)$: cable routing (= spline functions)

$y'(x) := \frac{d}{dx} y(x)$: slope of cable routing

$y''(x) := \frac{d^2}{dx^2} y(x)$: curvature change of cable routing

$R_{min} := \frac{1}{\max\left(y''(x)\right)}$: lowest curvature radius of cable routing

Friction loss function measured from the "left" side

$\alpha_v := \mathbf{if}\left(i > 1, \sum_{j=2}^{i} \left| y'\left(x_j\right) - y'\left(x_{j\text{-}1}\right)\right|, 0\right)$: accumulated change in angle

$\beta_v := \mu \cdot \left(\alpha_v + k \cdot x\right)$: friction loss exponent

$\eta_{vf} := e^{-\beta_v}$: friction loss before locking

$\eta_{ve} := e^{\beta_v}$: friction loss after locking

Location of maximal cable force on "left" side after locking of cable

```
$X_{mv} =$ | $x_{sk\ddot{a}r} \leftarrow 0m$  if  $Typ = "Passiv"$
           | if  $Typ = "Aktiv"$
           |     | $x_{start} \leftarrow 2m$
           |     | $x_{sk\ddot{a}r} \leftarrow \mathrm{root}\left(V_{max} - V_{\ddot{o}} \cdot \mathrm{linterp}\left(X, \eta_{vf}, x_{start}\right), x_{start}\right)$
```

Friction loss function measured from the "right" side

$\alpha_h := \mathbf{if}\left(i > 1, \sum_{j=i+1}^{n} \left| y'(x_j) - y'(x_{j-1}) \right|, 0\right)$: accumulated change in angle

$\beta_h := \mu \cdot \left(\alpha_h + k \cdot \left(L_{kabel} - x\right)\right)$: friction loss exponent

$\eta_{hf} := e^{-\beta_h}$: friction loss before locking

$\eta_{he} := e^{\beta_h}$: friction loss after locking

Location of maximal cable force on "right" side after locking of cable

```
$X_{mh} =$
    $x_{skär} \leftarrow L_{kabel}$  if  $Typ = "Passiv"$
    if  $Typ = "Aktiv"$
        $x_{start} \leftarrow L_{kabel} - 2m$
        $x_{skär} \leftarrow root(V_{max} - V_{ö} \cdot linterp(X, \eta_{hf}, x_{start}), x_{start})$
```

Location where curve of cable force "right" side intersects curve of cable force "left"

```
$X_m =$
    $x_{skär} \leftarrow L_{kabel}$  if  $Typ = "Aktiv" \wedge Typ = "Passiv"$
    $x_{skär} \leftarrow 0m$  if  $Typ = "Passiv" \wedge Typ = "Aktiv"$
    if  $Typ = "Aktiv" \wedge Typ = "Aktiv"$
        $x_{start} \leftarrow 0.5 \cdot L_{kabel}$
        $x_{skär} \leftarrow root(V_{ö} \cdot linterp(X, \eta_{vf}, x_{start}) - V_{ö} \cdot linterp(X, \eta_{hf}, x_{start}), x_{start})$
```

Determine cable force at each end of cable after locking

Cable force at "left" side :

```
$P_{ve} =$
    $V_{max} \cdot linterp(X, \eta_{hf}, 0m)$  if  $Typ = "Passiv"$
    $\frac{V_{max}}{linterp(X, \eta_{ve}, X_{mv})}$  if  $Typ = "Aktiv"$
```

Cable force at "right" side :

```
$P_{he} =$
    $V_{max} \cdot linterp(X, \eta_{vf}, L_{kabel})$  if  $Typ = "Passiv"$
    $\frac{V_{max}}{linterp(X, \eta_{he}, X_{mh})}$  if  $Typ = "Aktiv"$
```

Determine post slip / "lock sliding" at each end of cable

Left side :

$$\Delta L_v := \mathbf{if}\left(Typ = \text{“Aktiv”}, \frac{1}{A_s \cdot E_s} \cdot \int_0^{X_{mv}} \left(V_{ö} \cdot \text{linterp}\left(X, \eta_{vf}, x\right) - P_{ve} \cdot \text{linterp}\left(X, \eta_{ve}, x\right)\right) \mathrm{d}x, 0\right)$$

Right side :

$$\Delta L_h := \mathbf{if}\left(Typ = \text{“Aktiv”}, \frac{1}{A_s \cdot E_s} \cdot \int_{X_{mh}}^{L_{kabel}} \left(V_{ö} \cdot \text{linterp}\left(X, \eta_{hf}, x\right) - P_{ve} \cdot \text{linterp}\left(X, \eta_{he}, x\right)\right) \mathrm{d}x, 0\right)$$

Determine cable elongation before locking of cable

Left side:

$$L_v := \frac{1}{A_s \cdot E_s} \cdot \int_0^{X_m} \left(V_{ö} \cdot \text{linterp}\left(X, \eta_{vf}, x\right)\right) \mathrm{d}x$$

Right side :

$$L_h := \frac{1}{A_s \cdot E_s} \cdot \int_{X_m}^{L_{kabel}} \left(V_{ö} \cdot \text{linterp}\left(X, \eta_{hf}, x\right)\right) \mathrm{d}x$$

Function - determine cable force at arbitrary location along cable before locking

$$P_{\text{före}} = \begin{vmatrix} V_{ö} \cdot \text{linterp}\left(X, \eta_{vf}, x\right) & \text{if } x \le X_m \\ V_{ö} \cdot \text{linterp}\left(X, \eta_{hf}, x\right) & \text{if } x > X_m \end{vmatrix}$$

Function - determine cable force at arbitrary location along cable after locking

$$P_{efter} := \left\| \begin{array}{l} \text{if } x \le X_{mv} \\ \quad \left\| P_{ve} \cdot \text{linterp}\left(X, \eta_{ve}, x\right) \right. \\ \text{if } X_{mv} < x < X_m \\ \quad \left\| V_{ö} \cdot \text{linterp}\left(X, \eta_{vf}, x\right) \right. \\ \text{if } X_m \le x \le X_{mh} \\ \quad \left\| V_{ö} \cdot \text{linterp}\left(X, \eta_{hf}, x\right) \right. \\ \text{if } x > X_{mh} \\ \quad \left\| P_{he} \cdot \text{linterp}\left(X, \eta_{he}, x\right) \right. \end{array} \right.$$

Staking-out data for cable location in table form

Arbitrary sections :

Sections	x´ (m)	Remark
1	0	-
2	0,50	-
3	2,00	-
4	3,00	-
5	3,80	-
6	7,00	-
6	10,30	-
8	13,50	-
9	16,80	-
10	20,00	-
11	23,30	-
12	26,50	-

Cable locations :

Sections	y´ (m)	Remark.
1	0,300	Anchors
2	0,300	-
3	0,374	-
4	0,473	-
5	0,571	-
6	1,024	-
7	1,324	-
8	1,322	-
9	1,088	-
10	0,709	-
11	0,318	-
12	0,150	-

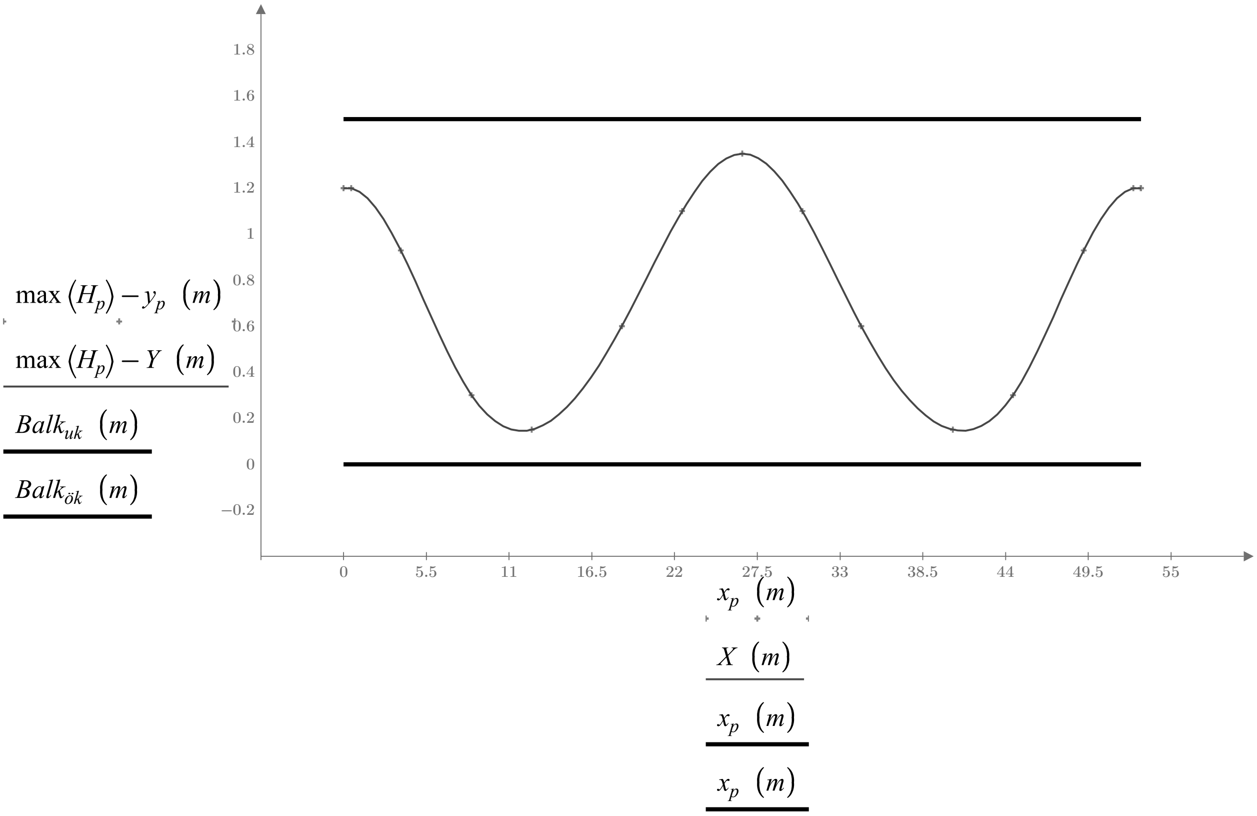
$\Rightarrow$

q_{sp} (m)
1,200
1,200
1,126
1,027
0,929
0,476
0,176
0,178
0,412
0,791
1,182
1,350

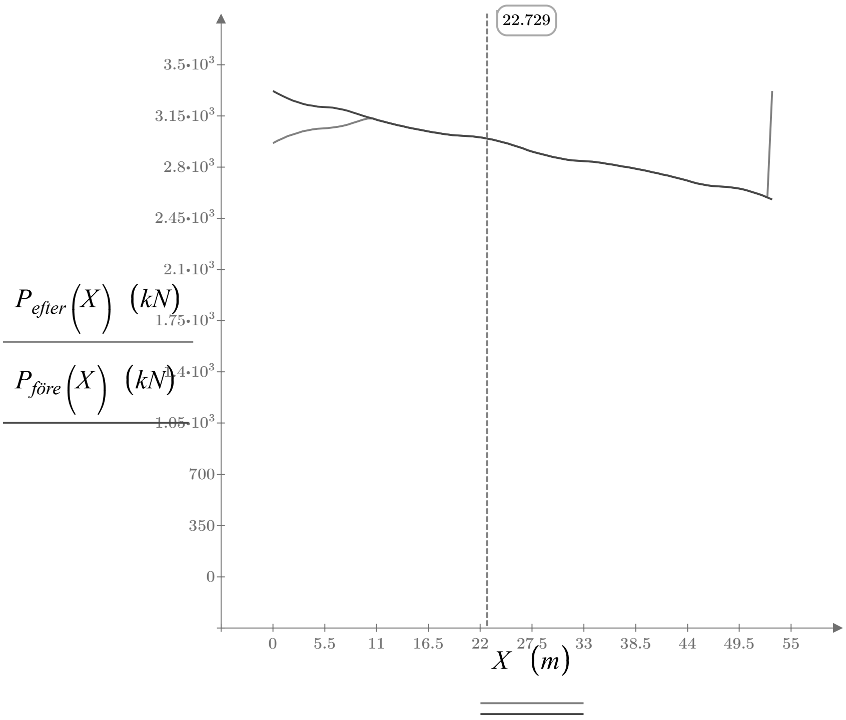
$q_{sp} = H - y'$

RESULTS

Beam and Cable routing — graphic presentation



Graphical plotting of cable forces



Minimum curvature radius

$R_{min} = 18.7\ m$

Cable elongation before locking

$L_v = 354\ mm$: left side

$L_h = 0\ mm$: right side

Post slip / "lock sliding" at each end of cable

$\Delta L_v = 4\ mm$: left side

$\Delta L_h = 0$: right side

Cable force at each end after locking

$P_{ve} = 2964\ kN$: left side

$P_{he} = 2436\ kN$: right side

Location of maximum cable force after locking

$X_{mv} = 10.294\ m$: left side

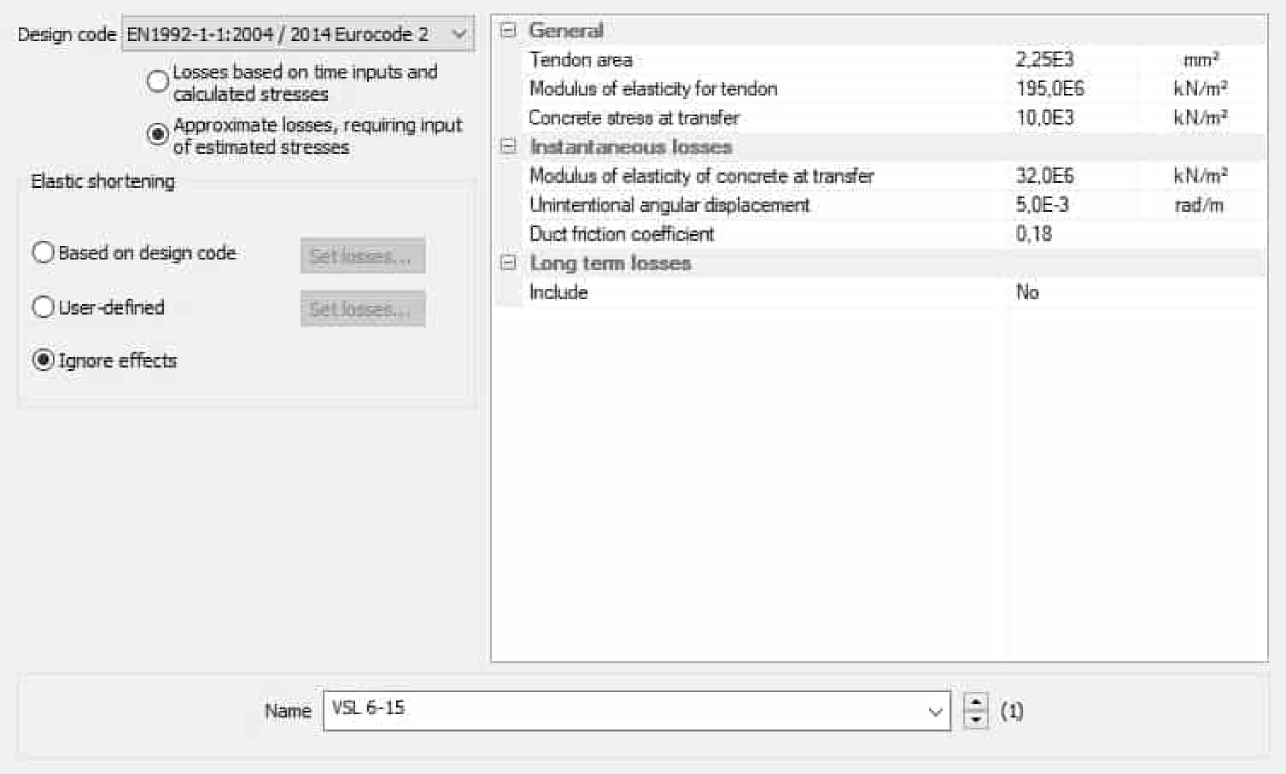
$X_{mh} = 53\ m$: right side

Location of minimum cable force after locking

$X_m = 53\ m$

3.13.4.2 Tendon properties

Calculation of "long term losses" is not done with FEM-program but separately. Hence "Include: No" in the table below.



Design code: EN1992-1-1:2004 / 2014 Eurocode 2

○ Losses based on time inputs and calculated stresses
● Approximate losses, requiring input of estimated stresses

Elastic shortening

○ Based on design code
○ User-defined
● Ignore effects

General		
Tendon area	2,25E3	mm²
Modulus of elasticity for tendon	195,0E6	kN/m²
Concrete stress at transfer	10,0E3	kN/m²
Instantaneous losses		
Modulus of elasticity of concrete at transfer	32,0E6	kN/m²
Unintentional angular displacement	5,0E-3	rad/m
Duct friction coefficient	0,18	
Long term losses		
Include	No	

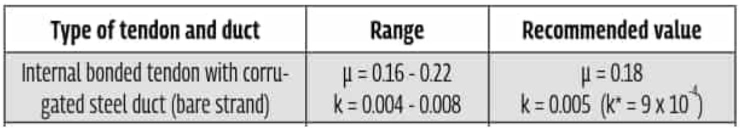
Name: VSL 6-15 (1)

- The relaxation at times t1 = 30 days and t2 = 120 years is stated on page E5:41.
- Creep at times t1 = 30 days and t2 = 120 years is stated on page E5:41.
- Shrinkage at times t1 = 30 days and t2 = 120 years is stated on page E5:41.

Friction cofficients VSL:

Calculation is performed as below.

$$P_{(x)} = P_o \cdot e^{-\mu(\alpha + k \cdot x)}$$



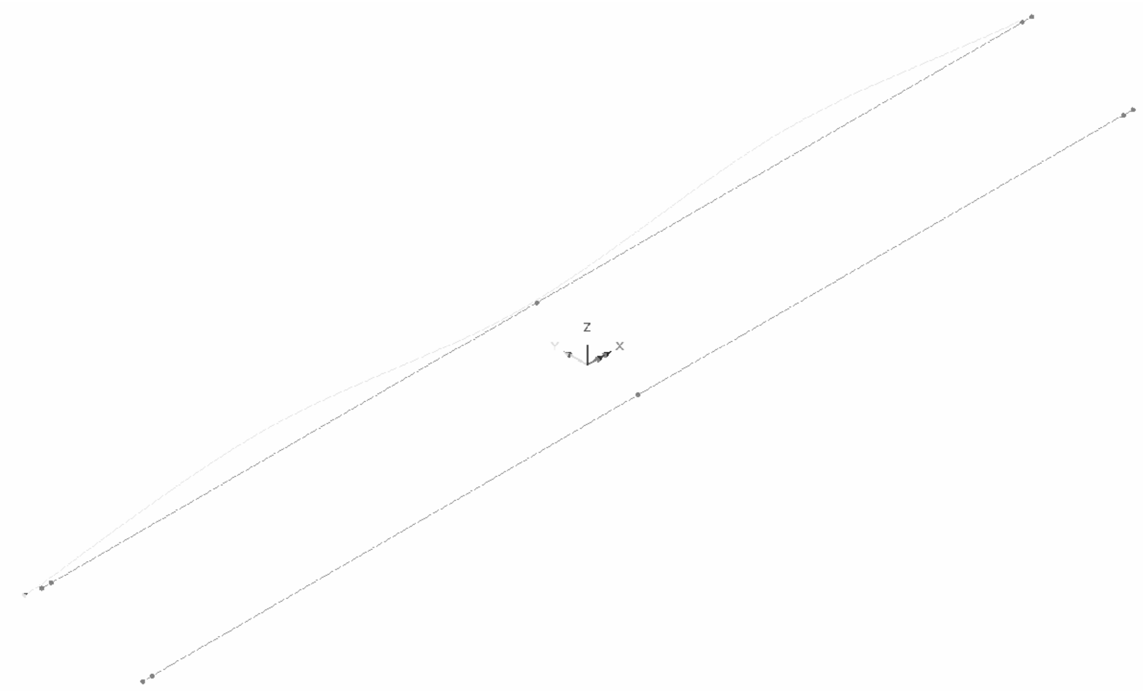
Type of tendon and duct	Range	Recommended value
Internal bonded tendon with corrugated steel duct (bare strand)	$\mu = 0.16 - 0.22$ $k = 0.004 - 0.008$	$\mu = 0.18$ $k = 0.005$ ($k^* = 9 \times 10^{-4}$)

$\mu = 0.18$

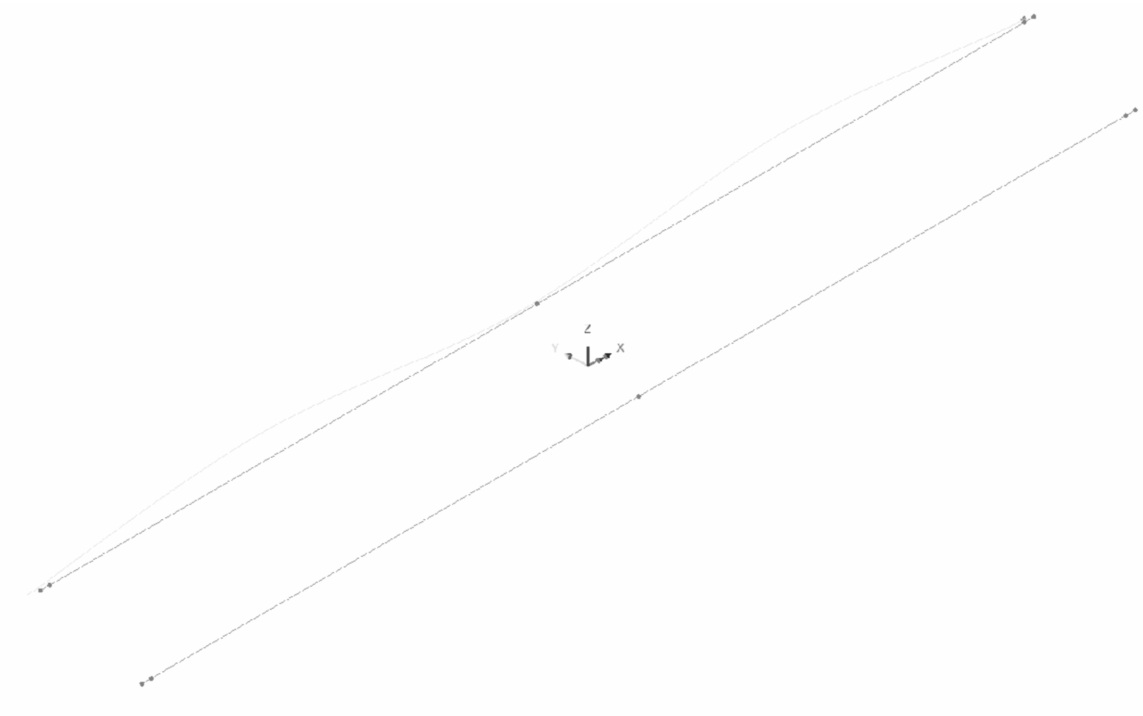
$$k = 0.005 \frac{rad}{m}$$

3.13.4.3 Tendon load case

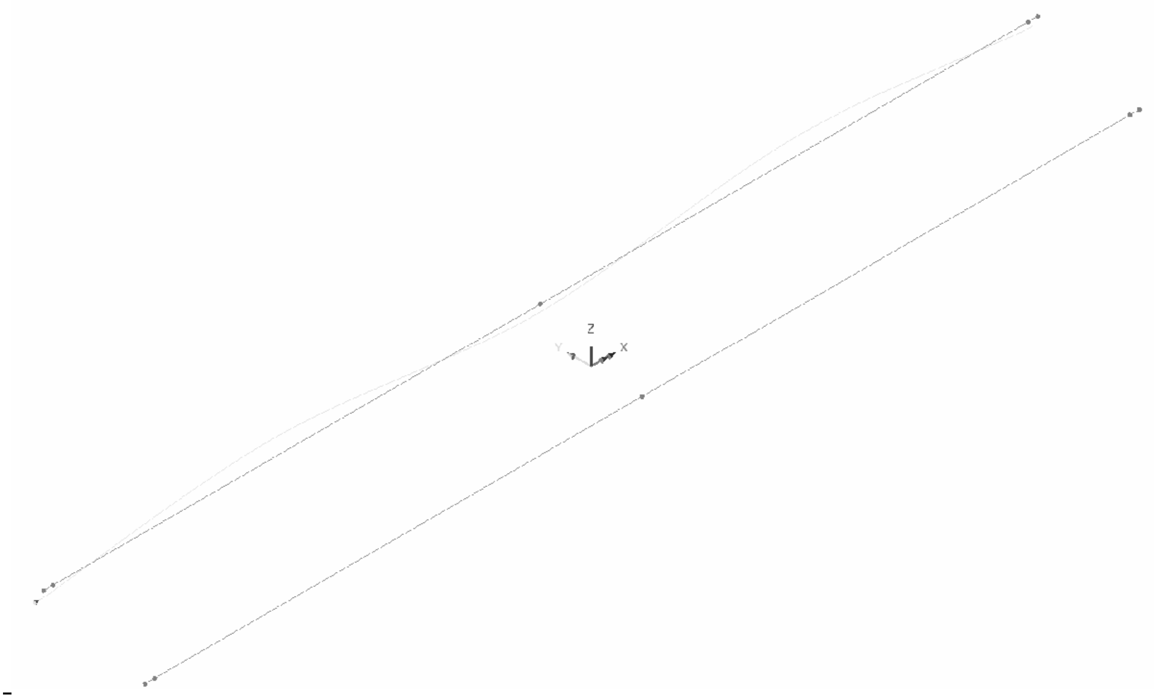
Load case LB1 – KG V1:



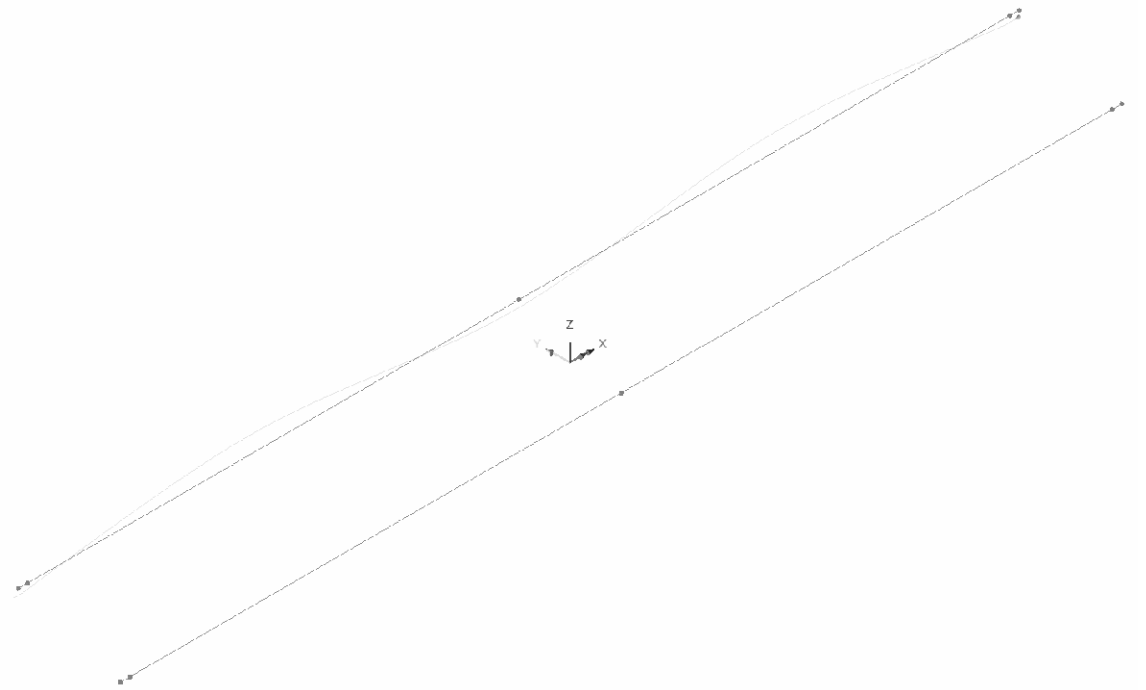
Loadcase LB1 – KG V2:



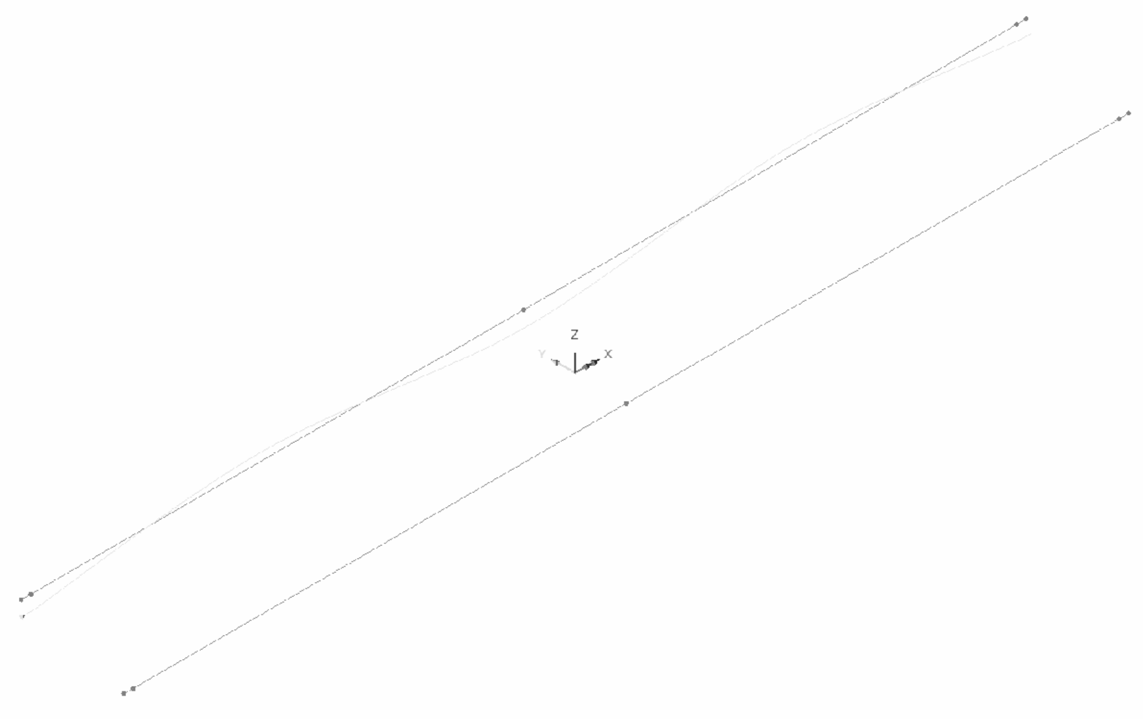
Load case LB1 – KG CV1:



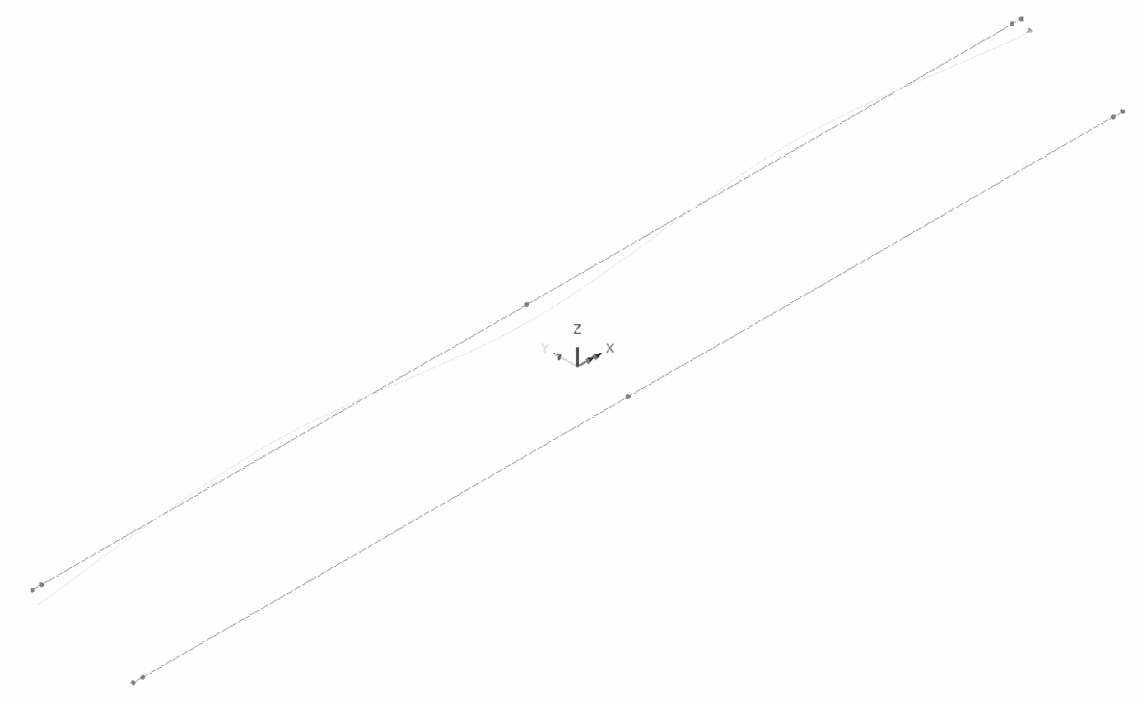
Load case LB1 – KG CV2:



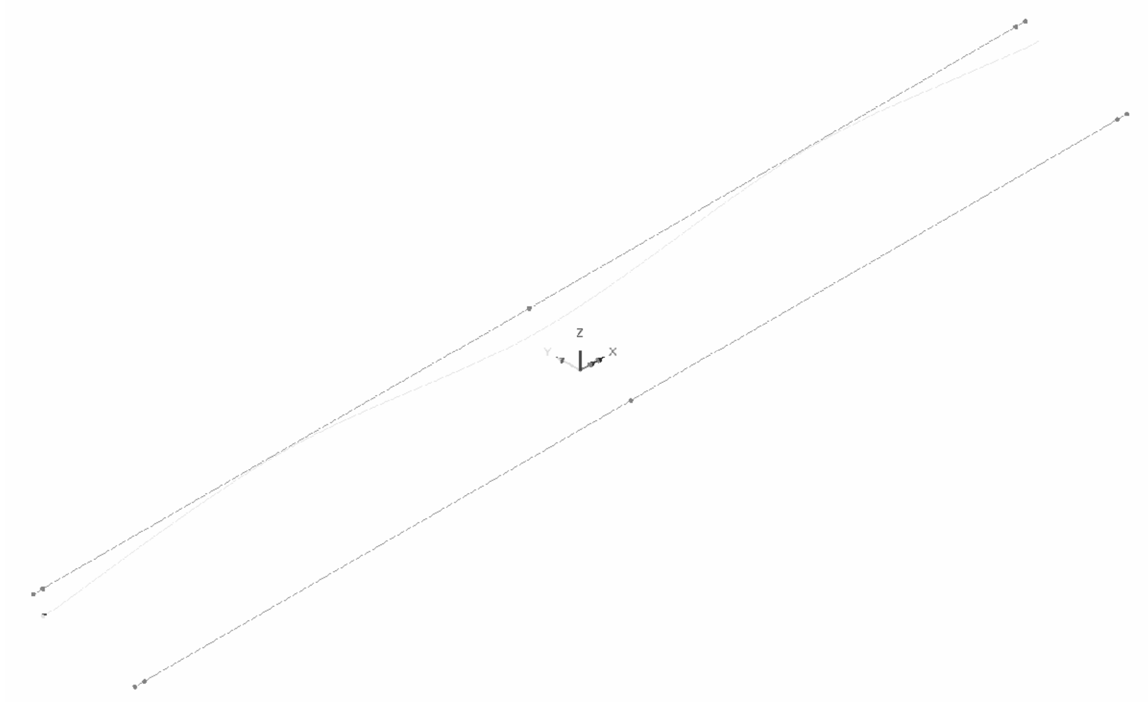
Load case LB1 – KG CH1:



Load case LB1 – KG CH2:

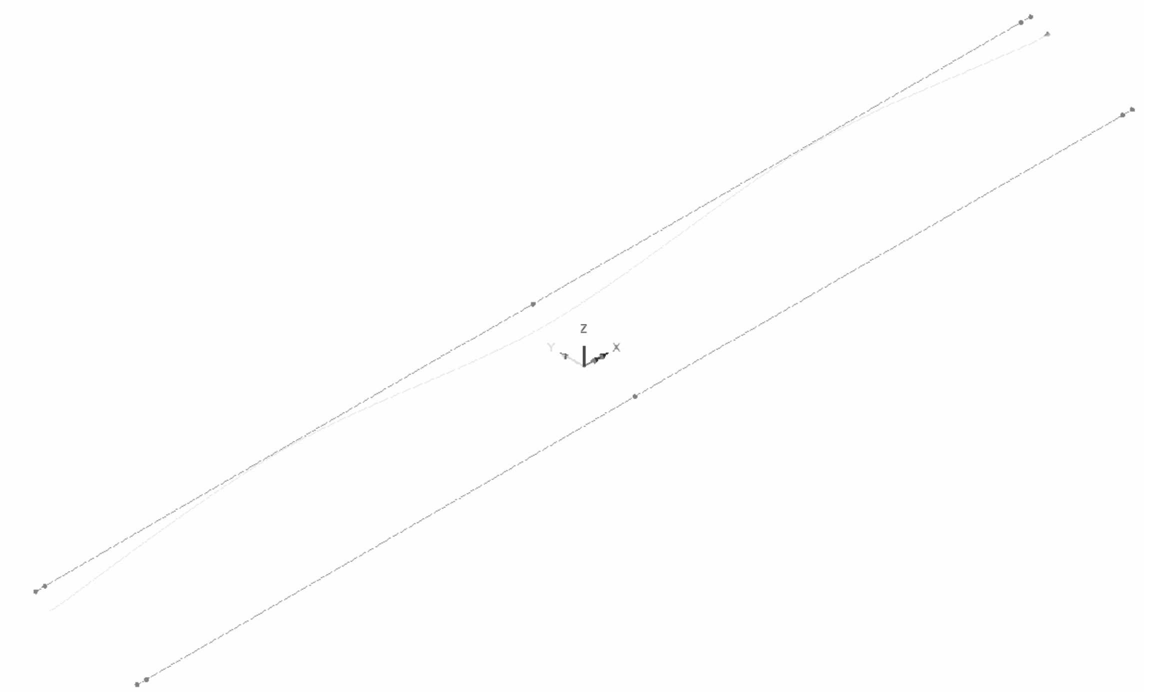


Load case LB1 – KG H1:

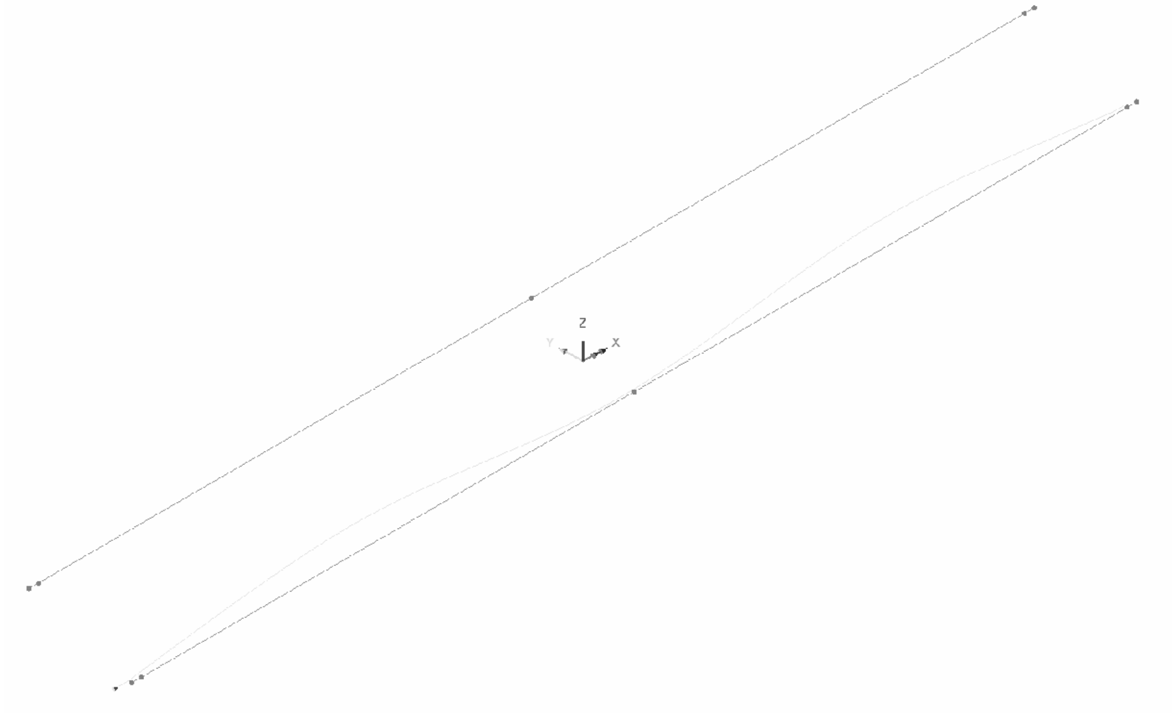


-

Load case LB1 – KG H2:

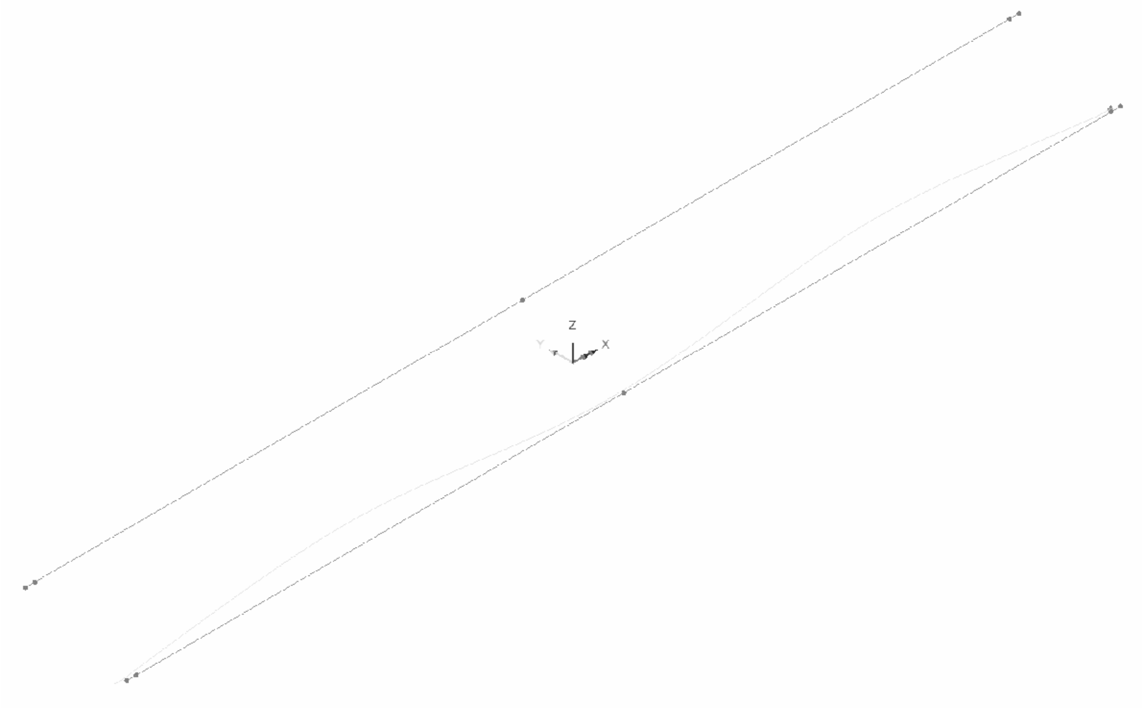


Load case LB2 – KG V1:

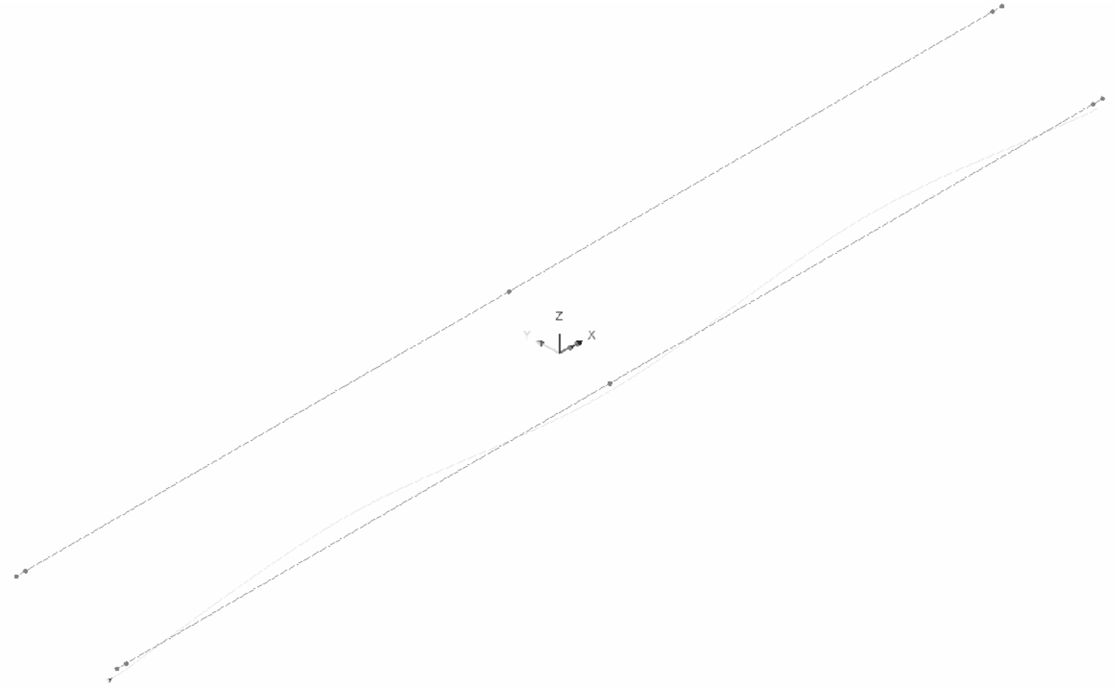


-

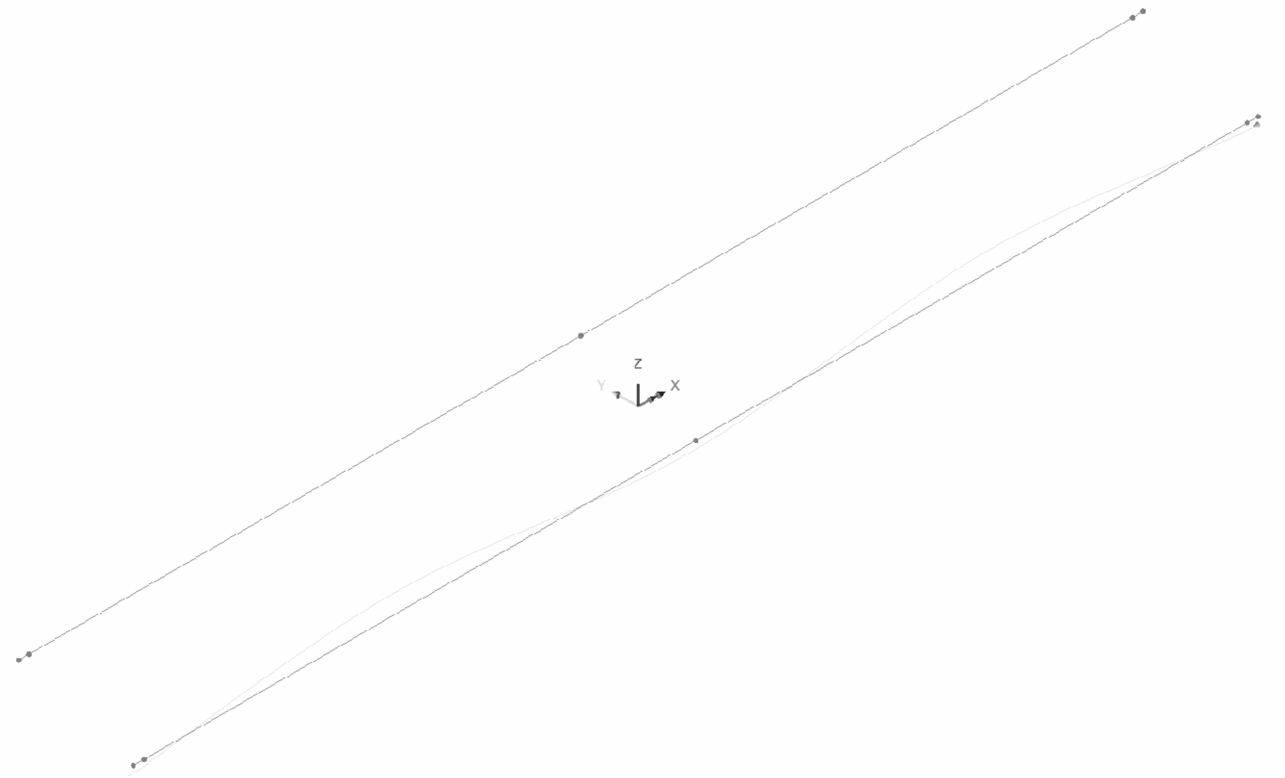
Load case LB2 – KG V2:



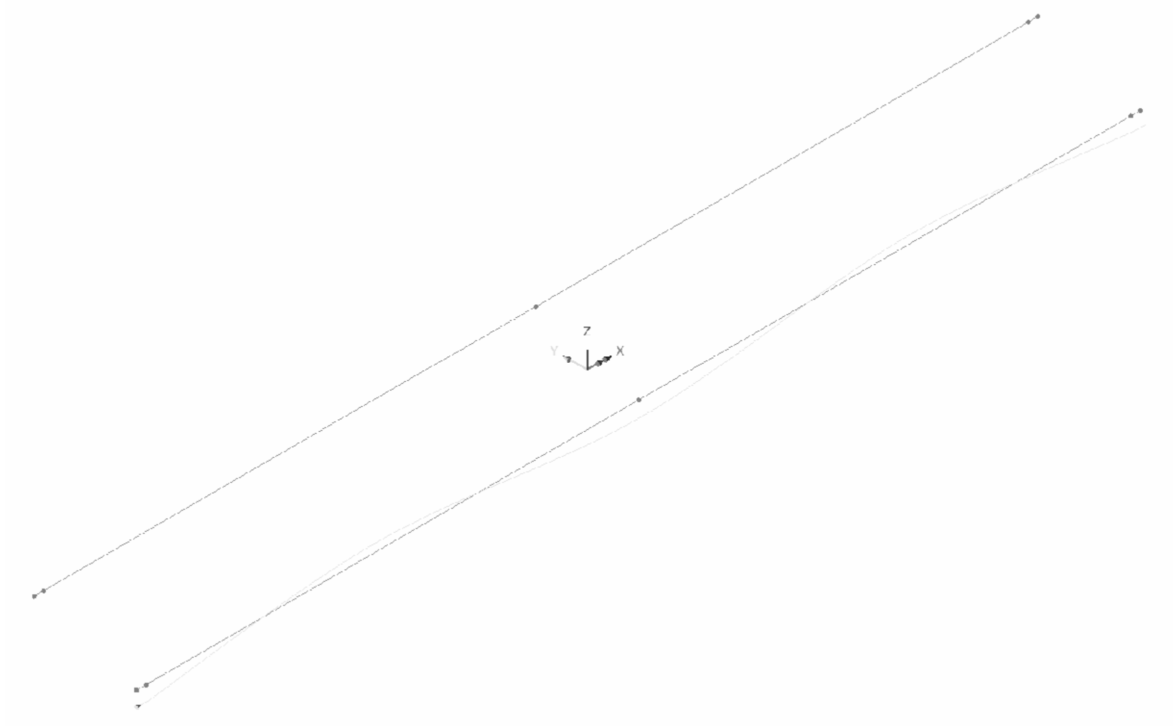
Load case LB2 – KG CV1:



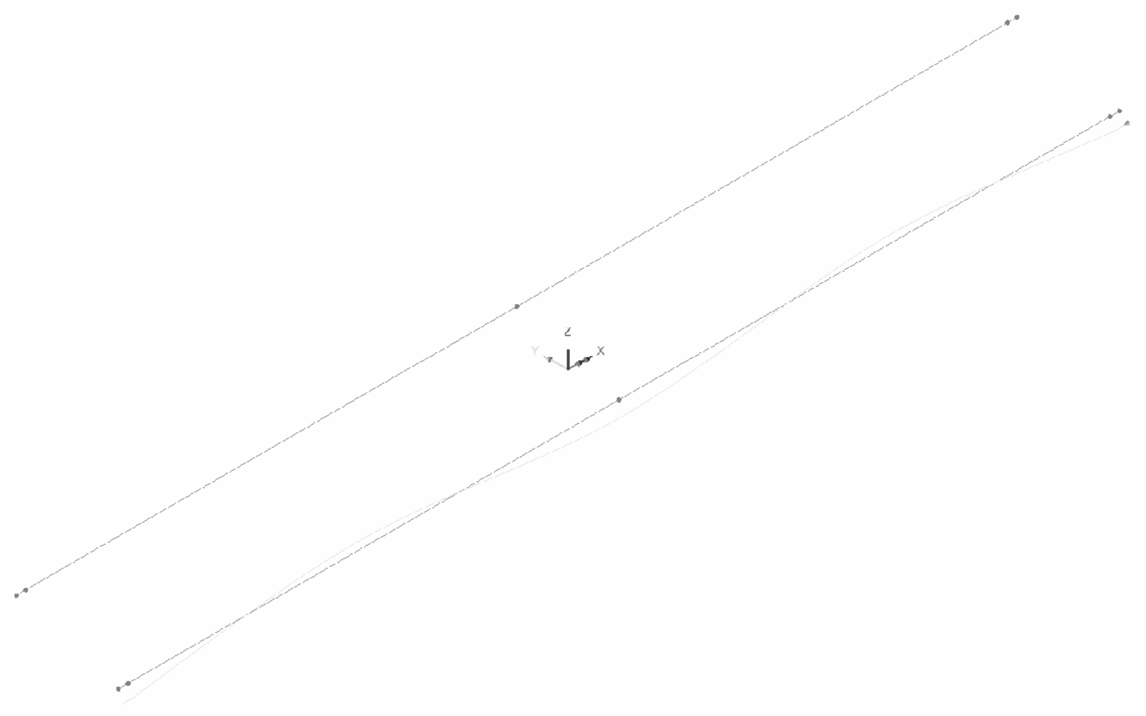
Load case LB2 – KG CV2:



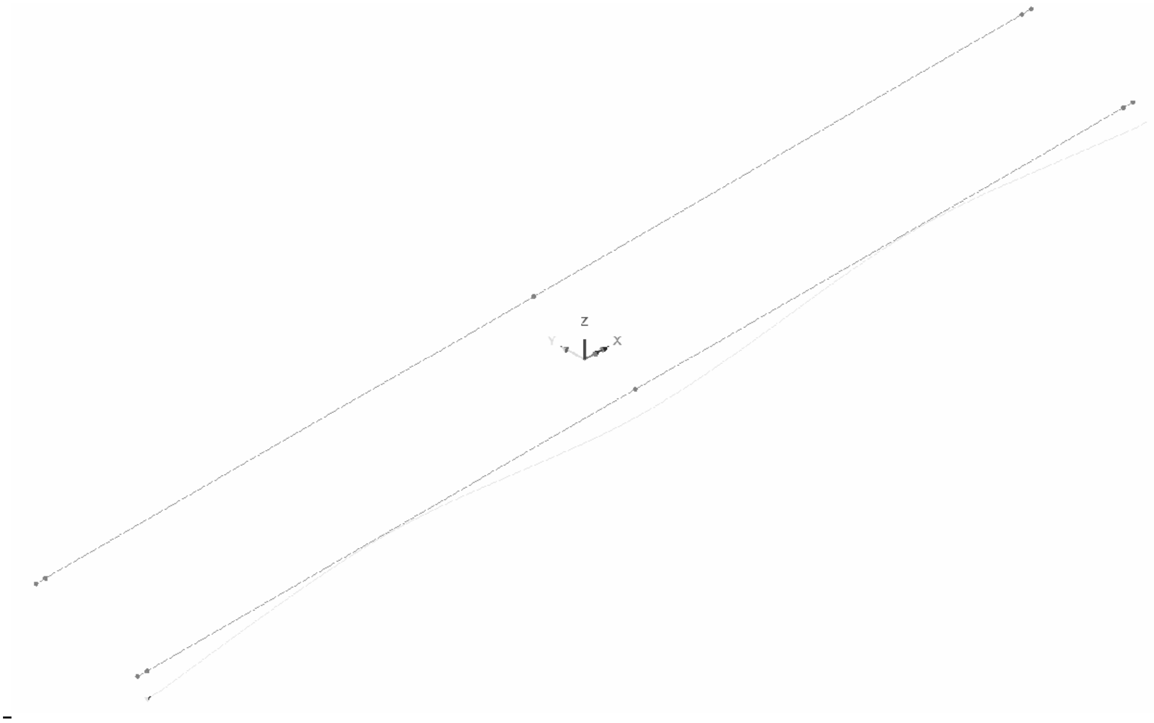
Load case LB2 – KG CH1:



Load case LB2 – KG CH2:

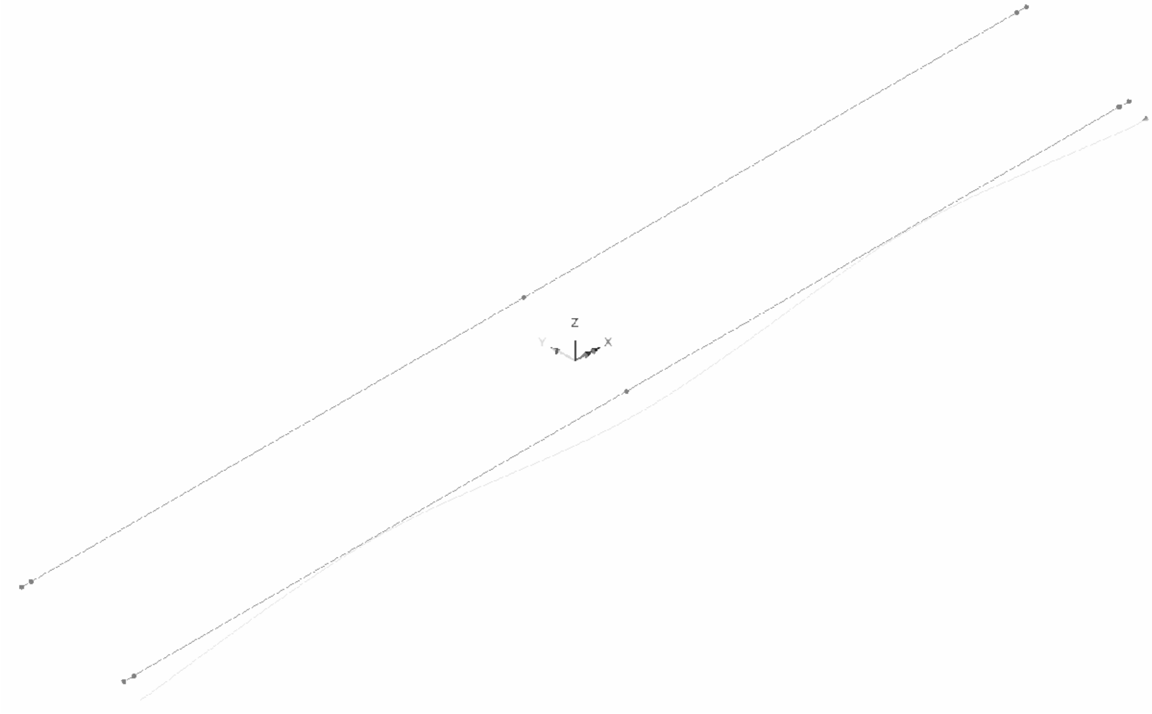


Load case LB2 – KG H1:



-

Loadc case LB2 – KG H2:



3.13.4 Load combination

Load combination basis PT-t0:

Load case	Factor
LB1 – KG V1	1.00
LB1 – KG V2	1.00
LB1 – KG CV1	1.00
LB1 – KG CV2	1.00
LB1 – KG CH1	1.00
LB1 – KG CH2	1.00
LB1 – KG H1	1.00
LB1 – KG H2	1.00
LB2 – KG V1	1.00
LB2 – KG V2	1.00
LB2 – KG CV1	1.00
LB2 – KG CV2	1.00
LB2 – KG CH1	1.00
LB2 – KG CH2	1.00
LB2 – KG H1	1.00
LB2 – KG H2	1.00

Load combination basis PT-t1:

Load case	Factor
PT – t0	0.95

Load combination basis PT-t2:

Load case	Factor
PT – t0	0.84

Envelope PT:

Load case
PT-t0
PT-t1
PT-t2

3.14 LOAD COMBINATIONS

Verification of load capacity shall be carried out for several limit states as detailed in this section.

Fatigue Limit State:
The risk of fatigue according to the partial factor method is checked using equation 6.69 provided in document SS-EN 1992-1-1.

Other Limit States:
For other limit states, section 6.4.3 of EN-1990 is applied.

3.14.1 Ultimate Limit States (ULS)

When checking the ultimate limit state, the load factors vary depending on the type of failure as detailed below:

STR: Verification of structural bearing capacity

GEO: Verification of geotechnical bearing capacity

For checking the ultimate limit state, TRVNFRA-00227 section 7.1.6.3 specifies requirements for load combinations as follows.

Design Method D2 (Set B):
Design Method D2 (Set B) according to TSFS 2018:57 Table 4.4 shall be applied for the structural bearing capacity of the construction (STR; SK 3).

Design Method is defined according to EN-1990 equations 6.10a and 6.10b as detailed below.

$$E_{Sd}^{10a} = \sum_{j\geq 1} \gamma_{G.j} \cdot G_{k,j} + \gamma_{Q.1} \cdot \psi_{0,1} \cdot Q_{k.1} + \sum_{i>1} \gamma_{Q.i} \cdot \psi_{0,i} \cdot Q_{k,i} = \psi\gamma_{ULS-A} \cdot \left(\sum_{j>1} G_{k,j} + \sum_{i>1} Q_{k,i}\right)$$

$$E_{Sd}^{10b} = \sum_{j\geq 1} \xi_j \cdot \gamma_{G.j} \cdot G_{k,j} + \gamma_{Q.1} \cdot Q_{k.1} + \sum_{i>1} \gamma_{Q.i} \cdot \psi_{0,i} \cdot Q_{k,i} = \psi\gamma_{ULS-B} \cdot \left(\sum_{j>1} G_{k,j} + \sum_{i>1} Q_{k,i}\right)$$

Equation 6.10a refers to the (ULS-A) case where the permanent loads are dominant, usually during the construction phase.

Equation 6.10b refers to the (ULS-B) case where the variable loads are dominant.
Design method 2 (set B) according to TSFS 2018:57 table 4.4 shall be applied for the structural capacity (STR; SK3).

A1 (construction loads)
All load factors are greater than set C.

A2 (geotechnical loads)

- Load coefficient earth pressure:

  $\psi\gamma_{\mathrm{ULS-A}} = \gamma_{\mathrm{d}} \cdot 1.35 \cdot \eta_{\mathrm{sup.G}} = 1.0 \cdot 0.89 \cdot 1.35 \cdot 1.1 = 1.49$ ← dimensioning

  $\psi\gamma_{\mathrm{ULS-B}} = \gamma_{\mathrm{d}} \cdot 0.89 \cdot 1.35 \cdot \eta_{\mathrm{sup.G}} = 1.0 \cdot 0.89 \cdot 1.35 \cdot 1.1 = 1.33$

- Load coefficient surcharge:

  $\psi\gamma_{\mathrm{ULS-A}} = \gamma_{\mathrm{d}} \cdot \psi_0 \cdot 1.50 = 1.0 \cdot 0.75 \cdot 1.50 = 1.13$

  $\psi\gamma_{\mathrm{ULS-B}} = \gamma_{\mathrm{d}} \cdot 1.50 = 1.0 \cdot 1.50 = 1.50$ ← dimensioning

3.14.1 Ultimate Limit States (ULS)

When checking the ultimate limit state, the load factors vary depending on the type of failure as detailed below:

STR: Verification of structural bearing capacity

GEO: Verification of geotechnical bearing capacity

For checking the ultimate limit state, TRVNFRA-00227 section 7.1.6.3 specifies requirements for load combinations as follows.

Design Method D2 (Set B):
Design Method D2 (Set B) according to TSFS 2018:57 Table 4.4 shall be applied for the structural bearing capacity of the construction (STR; SK 3).

Design Method is defined according to EN-1990 equations 6.10a and 6.10b as detailed below.

$$E_{Sd}^{10a} = \sum_{j\geq 1} \gamma_{G.j} \cdot G_{k,j} + \gamma_{Q.1} \cdot \psi_{0,1} \cdot Q_{k.1} + \sum_{i>1} \gamma_{Q.i} \cdot \psi_{0,i} \cdot Q_{k,i} = \psi\gamma_{ULS-A} \cdot (\sum_{j>1} G_{k,j} + \sum_{i>1} Q_{k,i})$$

$$E_{Sd}^{10b} = \sum_{j\geq 1} \xi_j \cdot \gamma_{G.j} \cdot G_{k,j} + \gamma_{Q.1} \cdot Q_{k.1} + \sum_{i>1} \gamma_{Q.i} \cdot \psi_{0,i} \cdot Q_{k,i} = \psi\gamma_{ULS-B} \cdot (\sum_{j>1} G_{k,j} + \sum_{i>1} Q_{k,i})$$

Equation 6.10a refers to the (ULS-A) case where the permanent loads are dominant, usually during the construction phase.

Equation 6.10b refers to the (ULS-B) case where the variable loads are dominant.
Design method 2 (set B) according to TSFS 2018:57 table 4.4 shall be applied for the structural capacity (STR; SK3).

A1 (construction loads)
All load factors are greater than set C.

A2 (geotechnical loads)

- Load coefficient earth pressure:

  $\psi\gamma_{\mathrm{ULS-A}} = \gamma_d \cdot 1.35 \cdot \eta_{\mathrm{sup.G}} = 1.0 \cdot 0.89 \cdot 1.35 \cdot 1.1 = 1.49$ ← dimensioning

  $\psi\gamma_{\mathrm{ULS-B}} = \gamma_d \cdot 0.89 \cdot 1.35 \cdot \eta_{\mathrm{sup.G}} = 1.0 \cdot 0.89 \cdot 1.35 \cdot 1.1 = 1.33$

- Load coefficient surcharge:

  $\psi\gamma_{\mathrm{ULS-A}} = \gamma_d \cdot \psi_0 \cdot 1.50 = 1.0 \cdot 0.75 \cdot 1.50 = 1.13$

  $\psi\gamma_{\mathrm{ULS-B}} = \gamma_d \cdot 1.50 = 1.0 \cdot 1.50 = 1.50$ ← dimensioning

Design method D3 (set C):

Design method D3 (set C) according to TSFS 2018:57 table 4.5 shall be applied for determining geotechnical bearing capacity (GEO; SK 2).

The design method is defined according to EN-1990 equation 6.10a and 6.10b as presented below.

$$E_{Sd}^{10a} = \sum_{j\geq 1} \gamma_{G.j} \cdot G_{k,j} + \gamma_{Q.1} \cdot \psi_{0,1} \cdot Q_{k.1} + \sum_{i>1} \gamma_{Q.i} \cdot \psi_{0,i} \cdot Q_{k,i} = \psi\gamma_{ULS-GA} \cdot (\sum_{j>1} G_{k,j} + \sum_{i>1} Q_{k,i})$$

$$E_{sd}^{10b} = \sum_{j\geq 1} \xi_j \cdot \gamma_{G.j} \cdot G_{k,j} + \gamma_{Q.1} \cdot Q_{k.1} + \sum_{i>1} \gamma_{Q.i} \cdot \psi_{0,i} \cdot Q_{k,i} = \psi\gamma_{ULS-GB} \cdot (\sum_{j>1} G_{k,j} + \sum_{i>1} Q_{k,i})$$

Equation 6.10a refers to the (ULS-A) case where the permanent loads are dominant, usually during the construction phase.

Equation 6.10b (ULS-B) refers to the case where the variable loads are dominant.

Design method 3 (set C) according to TSFS 2018:57 table 4.5 shall be applied for determining geotechnical bearing capacity (GEO).

A1 (construction loads)
All load factors are less than set B.

A2 (geotechnical loads)

- Load coefficient earth pressure: $\psi\gamma_{jord} = \gamma_d \cdot 1.1 \cdot \eta_{sup.G} = 0.91 \cdot 1.1 \cdot 1.1 = 1.10$

- Load coefficient surcharge: $\psi\gamma_{\text{över}} = \gamma_\text{d} \cdot 1.40 = 0.91 \cdot 1.40 = 1.27$

Load combination smart *ULS-PERM :*

Load case	Permanent factor	Variable factor
EGEN	1.00	1.20
BELÄGG	1.00	1.20
JORD	1.00	1.20
STOD	0	$1.2\cdot f_{STOD} = 0.40$
KRYMP	0	$1.2\cdot_{SKRYMP} = 0.40$

Load combination smart *ULS-VAR :*

(Load cases to consider : 5 / Variable loadcases : 1)

Load case	Permanent factor	Variable factor
TRAFIK	1.13	1.50
BROMS	1.13	1.50
SIDO	1.13	1.50
TEMP	$0.90f_{TEMP} = 0.70$	$1.5\cdot f_{TEMP} = 1.2$
VIND	0.45	1.50

For STR load case TEMP may be neglected, see SS-EN 1992-1-1 section 2.3.1.2(2).

Load combination smart *ULS-0 :*

Load case	Permanent factor	Variable factor
ULS-PERM	1.00	1.00
ULS-VAR	0	1.00

Load combination smart *ULS :*

Load case	Permanent factor	Variable factor
ULS-PERM	1	0
PT	1	1.35
ULS-VAR	0	1

3.14.2 Bruksgränstillstånd (SLS)

Bruksgränstillståndet är uppdelat i 3 st lastlastkombinationer beroende på dess varaktighet. Lastkombinationerna redovisas nedan.

Lastkombination	Varaktighet
SLS:K	Karakteristisk
SLS:F	Frekvent
SLS:Q	Kvasipermanent

Lastkombination SLS:K enligt EN 1990 ekv. 6.14b redovisas nedan.

$$E_{Sd} = \sum_{j\geq 1} G_{k,j} + Q_{k.1} + \sum_{i>1} \psi_{0,i} \cdot Q_{k,i} = \psi\gamma_{SLS.K} \cdot (\sum_{j>1} G_{k,j} + \sum_{i>1} Q_{k,i})$$

Lastkombination SLS:F enligt EN 1990 ekv. 6.15b redovisas nedan.

$$E_{Sd} = \sum_{j\geq 1} G_{k,j} + \psi_{1} \cdot Q_{k.1} + \sum_{i>1} \psi_{2,i} \cdot Q_{k,i} = \psi\gamma_{SLS.2} \cdot (\sum_{j>1} G_{k,j} + \sum_{i>1} Q_{k,i})$$

Lastkombination SLS:Q enligt EN 1990 ekv. 6.16b redovisas nedan.

$$E_{Sd} = \sum_{j\geq 1} G_{k,j} + \sum_{i>0} \psi_{2,i} \cdot Q_{k,i} = \psi\gamma_{SLS.Q} \cdot (\sum_{j>1} G_{k,j} + \sum_{i>1} Q_{k,i})$$

Vid dimensionering tillämpas lastkoefficienter tillhörande ekvationer 6.14a, 6.15b och 6.16b, se härledning se sida A3:137.

Nr	Last		$\psi\gamma_{SLS-K}$	$\psi\gamma_{SLS-F}$	$\psi\gamma_{SLS-Q}$
	Permanent loads				
1	Egentyngd	max	1,00	1,00	1,00
		min	1,00	1,00	1,00
2	Beläggning	max	1,10	1,10	1,10
		min	0,90	0,90	0,90
3	Överfyllnad	max	1,10	1,10	1,10
		min	0,90	0,90	0,90
4	Jordtryck	max	1,10	1,10	1,10
		min	0,90	0,90	0,90
5	Vattentryck	max	1,00	1,00	1,00
		min	1,00	1,00	1,00
6	Stödförskjutning	max	1,00	1,00	1,00
		min	1,00	1,00	1,00
7	Krympning	max	1,00	1,00	1,00
		min	1,00	1,00	1,00
8	Spännkraft	max	1,00	1,00	1,00
		min	1,00	1,00	1,00
	Variable loads				
	Lastmodell LM 1 :				
9	Boggiesystem		0.75/1.00	0/0.75	0
10	Utbredd last		0.40/1.00	0/0.40	0
11	Bromskraft		0.56/0.75	0/0.56	0
12	Sidokraft		0.56/0.75	0/0.56	0
13	Centrifugalkraft		0.56/0.75	0/0.56	0
	Lastmodell LM 2 :				
14	Enstaka axellast		0.75/1.00	0/0.75	0
	Typfordon EG A/B :				
15	Typfordon EG A/B		0.75/1.00	0/0.75	0
20	Bromskraft		0.56/0.75	0/0.56	0
22	Sidokraft		0.56/0.75	0/0.56	0
22	Centrifugalkraft		0.56/0.75	0/0.56	0
16	Temperatur		0.60/1.00	0.50/0.60	0.50
	Vindlaster:				
17	Vindlast mot bro		0.30/1.00	0/0.30	0
18	Vindlast mot trafik		0.30/1.00	0/0.30	0
19	Överlast		0.75/1.00	0/0.75	0

Load combination smart SLS-PERM :

Loadcase	Permanentfactor	Variable factor
EGEN	1.00	1.00
BELÄGG	0.90	1.20
JORD	0.90	1.20
STOD	0	$1.0 \cdot f_{STOD} = 0.33$
KRYMP	0	$1.0 \cdot f_{KRYMP} = 0.33$

Load combination smart *SLS-K-VAR* :

(Load cases to consider : 5 / Variable loadcases : 1)

Loadcase	Permanent factor	Variable factor
TRAFIK	0.75	1.00
BROMS	0.56	0.75
SIDO	0.56	0.75
TEMP	$0.60 f_{TEMP} = 0.50$	$1.0 \cdot f_{TEMP} = 0.80$
VIND	0.60	1.00

Load combination smart *SLS-F-VAR :*

Load case	Permanent factor	Variable factor
TRAFIK	0	0.75
BROMS	0	0.56
SIDO	0	0.56
TEMP	0	$0.60 f_{TEMP} = 0.50$
VIND	0	0.30

Load combination smart *SLS-K0 :*

Load case	Permanent factor	Variable factor
SLS-PERM	1	1
SLS-K-VAR	0	1

Load combination smart *SLS-K:*

Load case	Permanent factor	Variable factor
SLS-PERM	1	1
PT	1	1
SLS-K-VAR	0	1

Load combination smart *SLS-F0 :*

Load case	Permanent factor	Variable factor
SLS-PERM	1	1
SLS-F-VAR	0	1

Load combination smart *SLS-F :*

Load case	Permanent factor	Variable factor
SLS-PERM	1	1
PT	1	1
SLS-F-VAR	0	1

Load combination smart *SLS-Q0 :*

Load case	Permanent factor	Variable factor
SLS-PERM	1	1
TEMP	0	$0.50f_{TEMP} = 0.40$

Load combination smart *SLS-Q :*

Load case	Permanent factor	Variable factor
SLS-PERM	1	1
PT	1	1
TEMP	0	$0.50f_{TEMP} = 0.40$

3.14.3 Fatigue load combination

Fatigue is considered according to SS EN 1992-1-1, 6.8.4 and 6.8.6, and SS EN 1992-2, 6.8 and Appendix NN.

The risk of fatigue is checked using a simplified method, denoted as the λ-method.
Load combination according to equation SS-EN 1992-1-1 section 6.8.3 equation 6.69.

In this load combination, the traffic load is considered to consist of UTM, whereby other traffic loads are excluded.

$$E_{Sd} = \sum_{j \geq 1} G_{k,j} + P + \psi_{1,1} \cdot Q_{k,1} + \sum_{i > 1} \psi_{2,i} \cdot Q_{k,i} + Q_{fat} = \psi\gamma_{UTM} \cdot (\sum_{j \geq 1} G_{k,j} + P + \sum_{i \geq 1} Q_{k,i} + Q_{fat})$$

Fatigue is considered according to SS EN 1992-1-1, 6.8.4 and 6.8.6, and SS EN 1992-2, 6.8 and Appendix NN.

The risk of fatigue is checked using a simplified method, denoted as the λ-method.
Load combination according to equation SS-EN 1992-1-1 section 6.8.3 equation 6.69.

In this load combination, the traffic load is considered to consist of UTM, whereby other traffic loads are excluded.

Permanent loads:

Nr	Load		$\psi\gamma_{UTM}$
1	Egentyngd	max	1.00
		min	1.00
2	Beläggning	max	1.10
		min	0.90
3	Överfyllnad	max	1.10
		min	0.90
4	Jordtryck	max	1.48
		min	0.90
5	Vattentryck	max	1.00
		min	1.00
6	Stödförskjutning	max	1.00
		min	1.00
7	Krympning	max	1.00
		min	1.00
8	Spännkraft	max	1.00
		min	1.00

Variable loads:

Nr	Load	$\psi\gamma_{UTM}$
	Lastmodell LM 1 :	
9	Boggiesystem	-
10	Utbredd last	-
11	Bromskraft	-
12	Sidokraft	-
13	Centrifugalkraft	-
	Lastmodell LM 2 :	
14	Enstaka axellast	-
	Typfordon EG A/B :	
15	Typfordon EG A/B	-
16	Bromskraft	-
17	Sidokraft	-
18	Centrifugalkraft	-
19	Temperatur	0.60
	Vindlaster:	
20	Vindlast mot bro	0.30
21	Vindlast mot trafik	0.30
22	Överlast	1.01
23	UTM3	1.00

Load combination smart FAT :

(FAT-0 is identical but does not contain load case PT-t0)

Load case	Permanent factor	Variable factor
EGEN	1.00	0
BELÄGG	1.00	0
JORD	-	-
STOD	-	-
KRYMP	-	-
PT-t0	0.84	-
VIND	-	-
UTM	-	1.00
OVER	-	-
TEMP	-	-

Load cases BELÄGG, STOD and KRYMP are not fatigue loads, thus load coefficient 1.0 is applied.

Load cases pretension is not a fatigue loads, thus load coefficient lowest load value of value is assumed PT-t2 (= 0.84·PT-t0) is applied.

Load case JORD is not a fatigue load, thus load coefficient highest load coefficient is applied.

Load cases TEMP, VIND and OVER are not fatigue loads, thus load is not considered.

During verification STR, the load case TEMP can be neglected according to SS-EN 1992-1-1 section 2.3.1.2(2).