Dynamic analysis: Pretensioned beam bridge

High speed dynamic analysis is performed using method of interactive modal dynamics. Method allows the definition of a constant moving load across a pre-specified path (track) and obtains the results for a specified range of travelling speeds.

1. Generate static model.
2. Perform *eigenvalue* analysis in frequency range 0 → 35 Hz.
3. Determine *participation factors.*
4. Determine *mass participation factors.*
5. Determine *sum mass participation factors.*
6. Define discrete point load Unit Axle load (P = 1 kN).
7. Define HSLM- A1 using *vehicle configuration.*
8. Perform *moving dynamic load generation* for Unit Axle
9. Perform *modal force calculation* for Unit load.
10. Chose location for results.
11. Perform dynamic *moving load analysis* for vehicule HSLM – A1

CONTENTS

1. GENERAL / MEASUREMENT

1.1 CONSTRUCTION TYPE

Bridge is a pretenstioned bridge with 3 spans. End supports have movable bearings in longitudinal direction. Intermediate supports have fixed bearings. Foundation is piled.

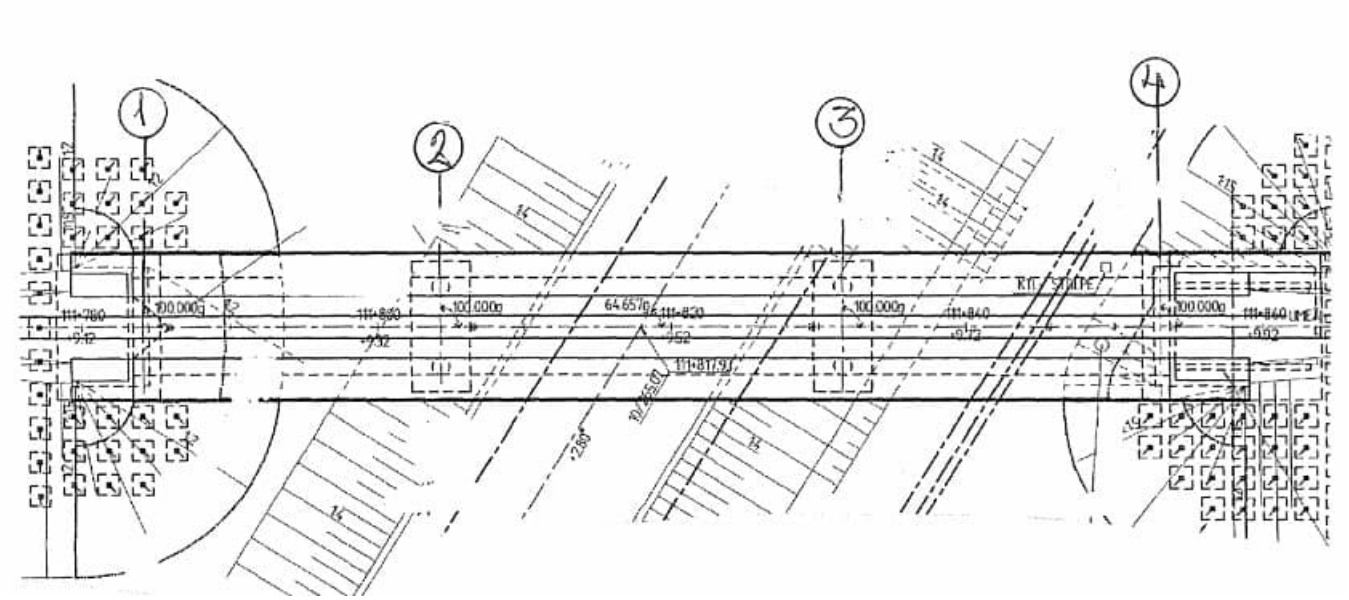
1.2 DAMPNING

L = 70 m $\Rightarrow \zeta = 1.0\ \%$

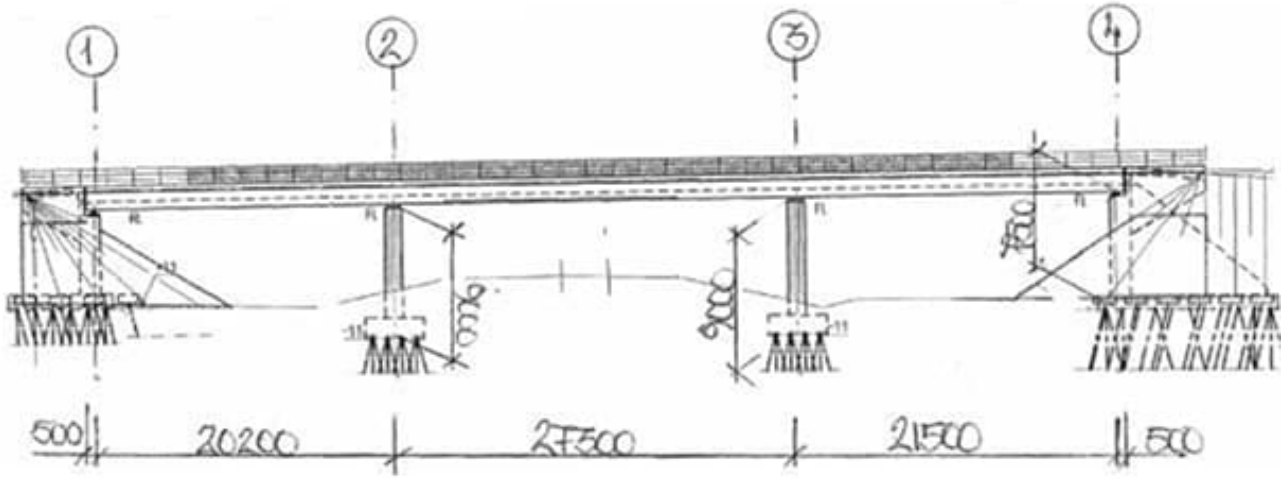
1.3 MATERIAL

C35/45 $\Rightarrow E_{ck} = 34$ GPa

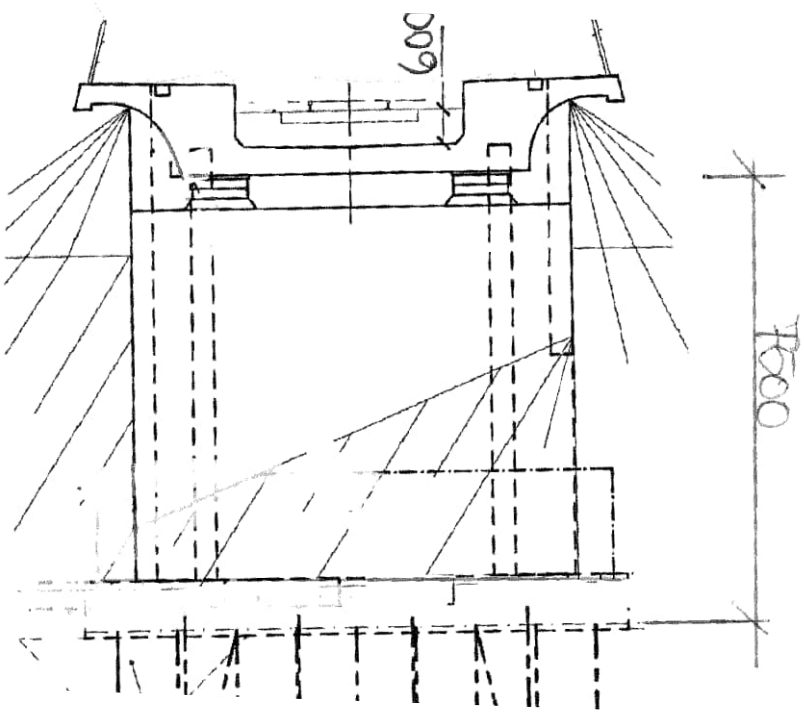
1.4 MEASUREMENTS



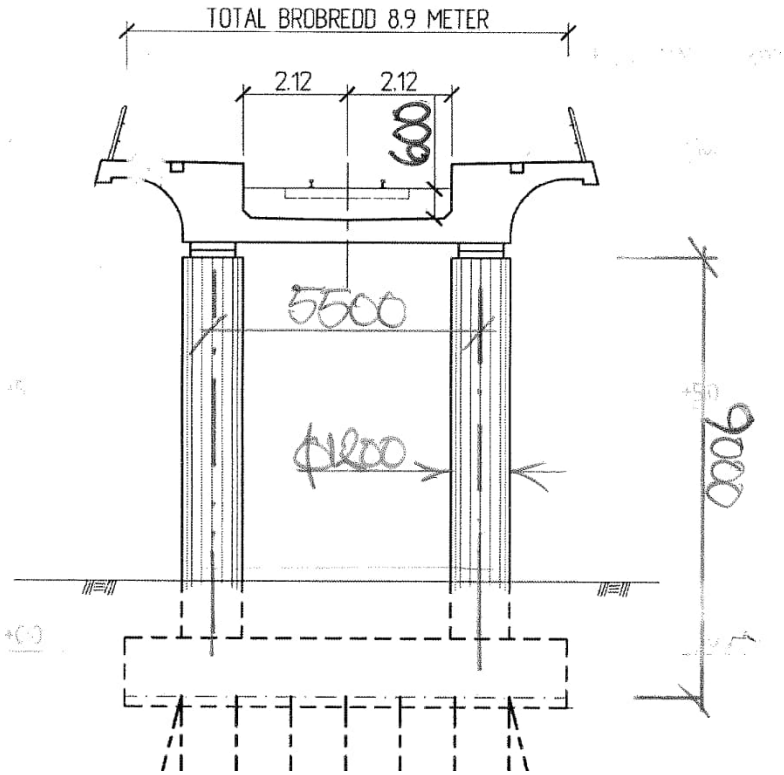
PLAN



ELEVATION



Cross section
End supports.



Cross section
Intermediate supports.

1.5 FOUNDATION

All support are founded on concrete piles (SP3).

1.6 CODE OCH TENDER 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

2. SYSTEM ANALYSIS

2.1 GENERAL

The bridge is a prestressed trough girder bridge. The superstructure is modeled using an equivalent single girder bridge.

To achieve this, the same calculation model has been applied. The analysis assumes that modeling is done with 3D beam elements. Additionally, the following assumptions have been made:

The conducted dynamic analysis is based on the following assumptions:

- No vibration modes resulting from translations in the transverse direction are of interest. This assumption seems reasonable due to the significant flexural stiffness of the superstructure in the transverse direction, as well as the direction of the main load. Thus, the superstructure is constrained against translation in the transverse direction (Y-direction).
- No vibration modes due to rotation of the superstructure are of interest. This assumption seems reasonable because the centerline of the track coincides with the centroid of the gross cross-section, meaning that no torsional moments occur. Thus, rotation in the longitudinal direction (X-direction) is constrained.
- Linear elastic analysis concerning geometry, material, and boundary conditions.
- Modal superposition is applied.

The analysis assumes that the load is applied to the structure through shell elements. In this case, 4-node shell elements of the "thick shells" type are used. To achieve this, fictive shell elements with reduced geometry and stiffness are introduced.

The foundation at the intermediate supports is modeled as a fictive supernode. These properties correspond to the equivalent stiffness of pile foundations.

Columns at the intermediate supports are connected to the superstructure and the supernode with rigid links (joint element JSH4).

Bearings at the intermediate supports are modeled by introducing "end releases" corresponding to the properties of the respective bearings.

The crosssection material properties of superstructure so desnsity includes weight of ballast.

Appendices:

Appendix	Name
1	Input receipt
2	Results

2.2 SKETCH SYSTEM ANALYSIS

To describe geometry first POINTS are defined.

Beam elements are defined by applying attributes to LINES.

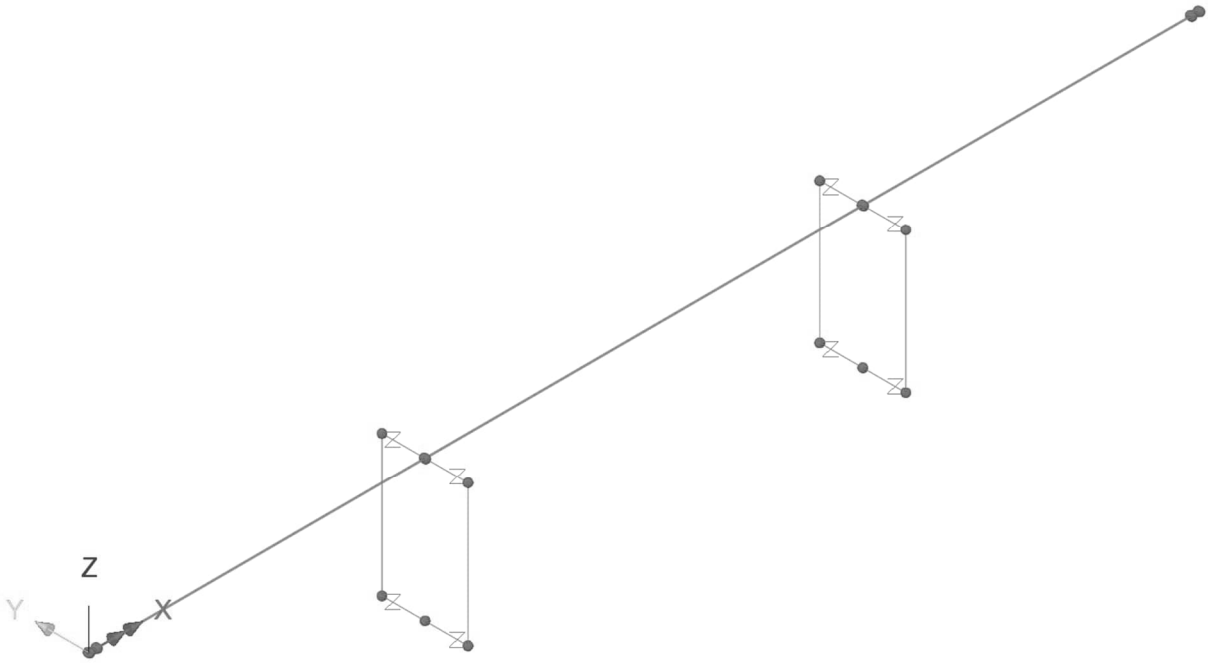
Shell elements are defined by applying attributes to SURFACES.

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

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

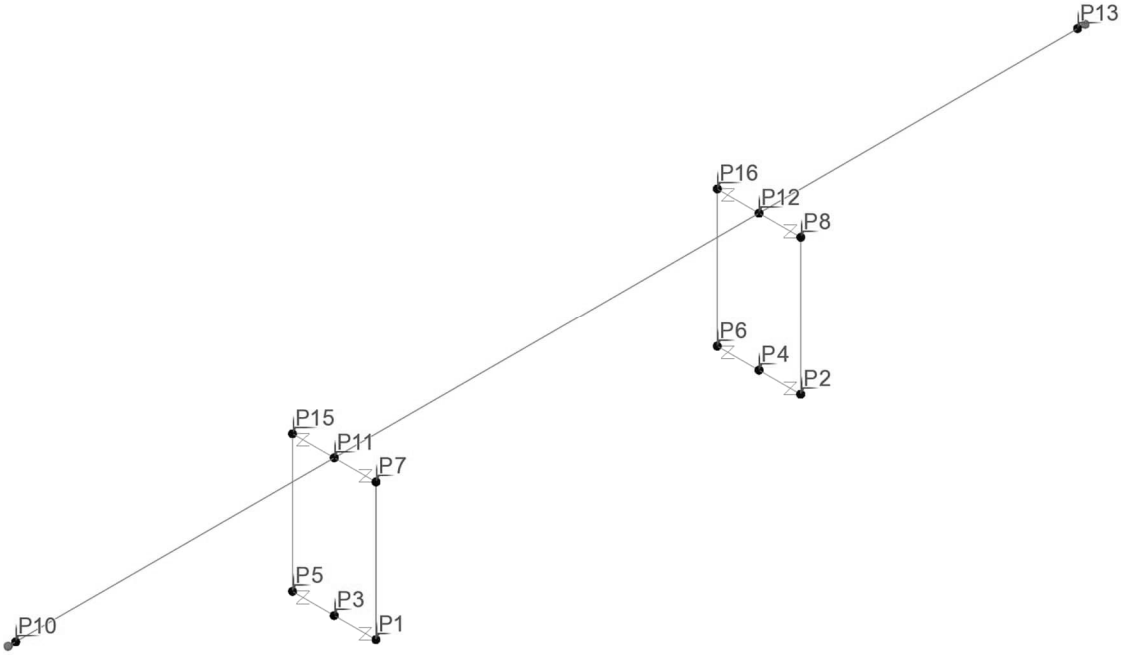
All POINTS needed to describe LINES are found in appendix 1.

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

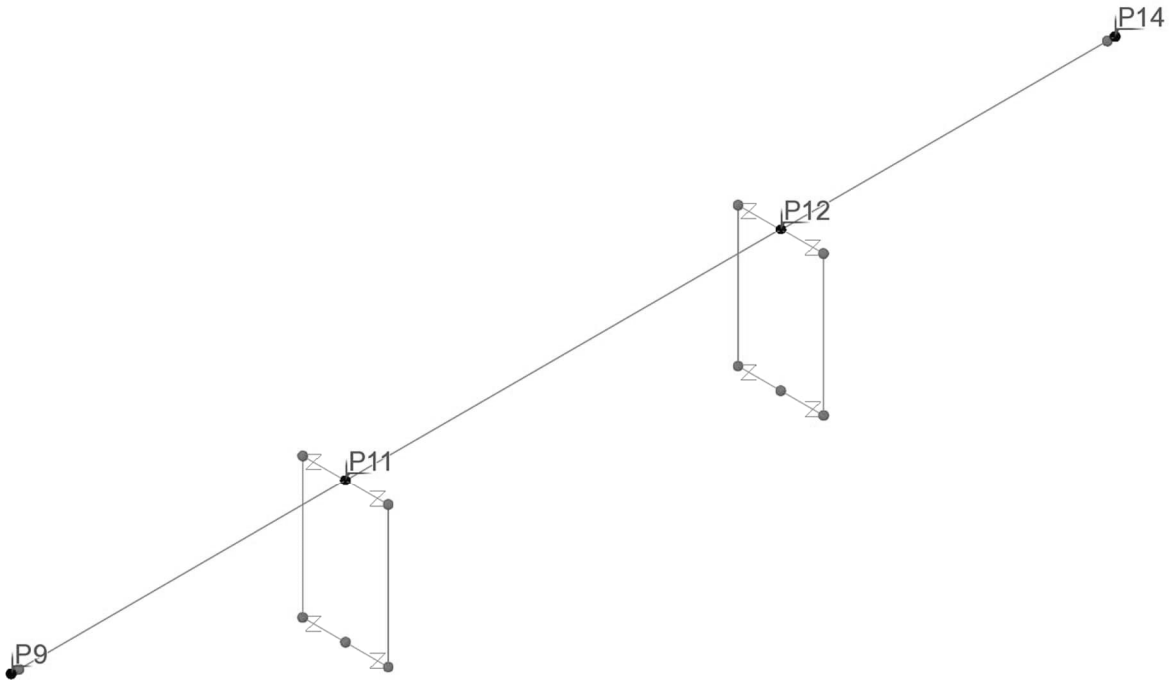


Overview 3D
Geometry

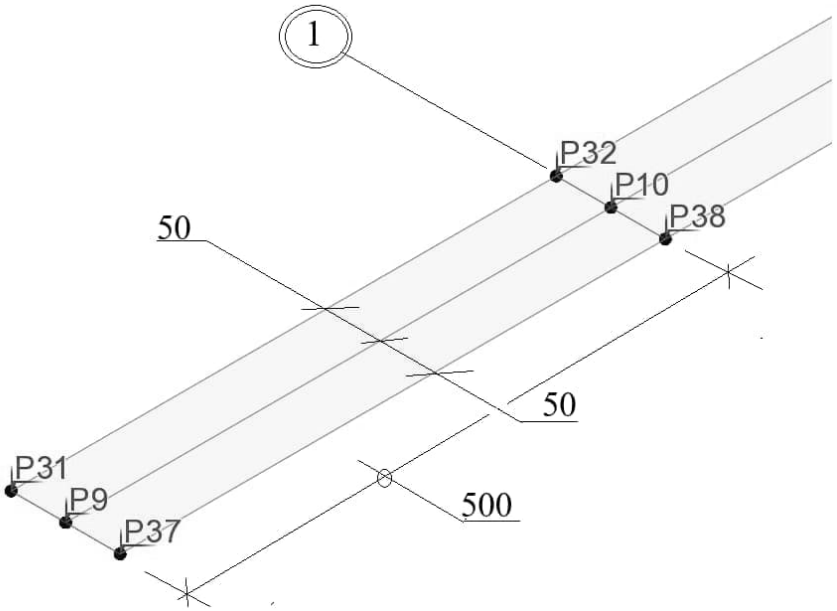
2.2.1 Geometry : POINTS



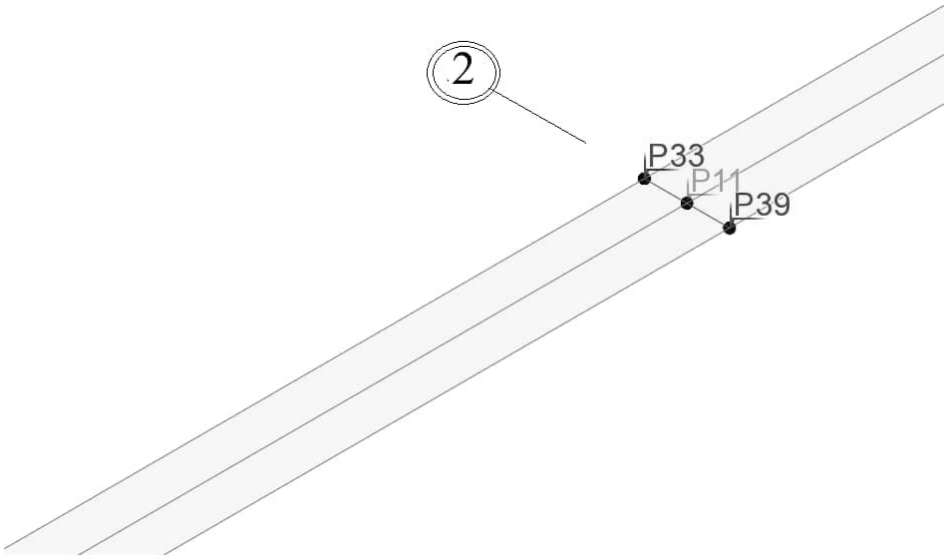
Supports 1-4



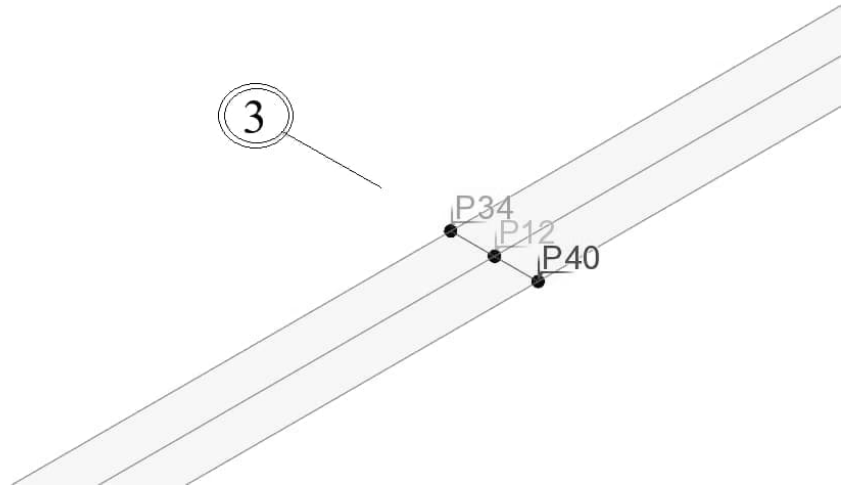
Superstructure



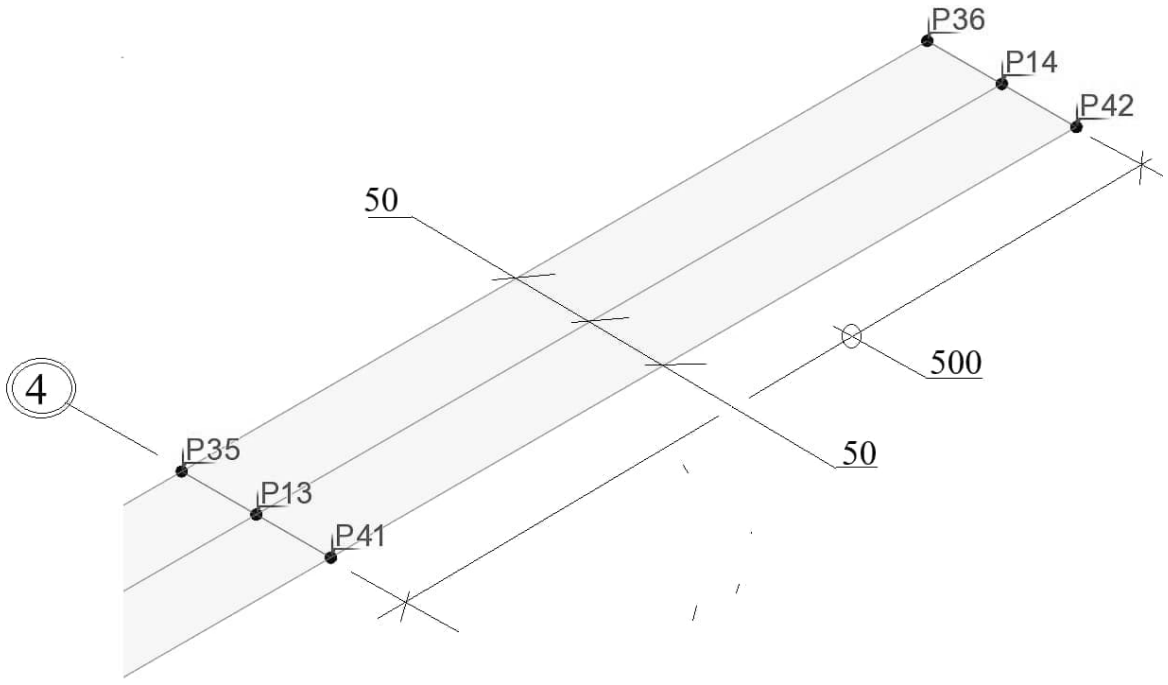
Fictive deck: detail 1
(End support 1)



Fictive deck: detail 2
(Span 1)

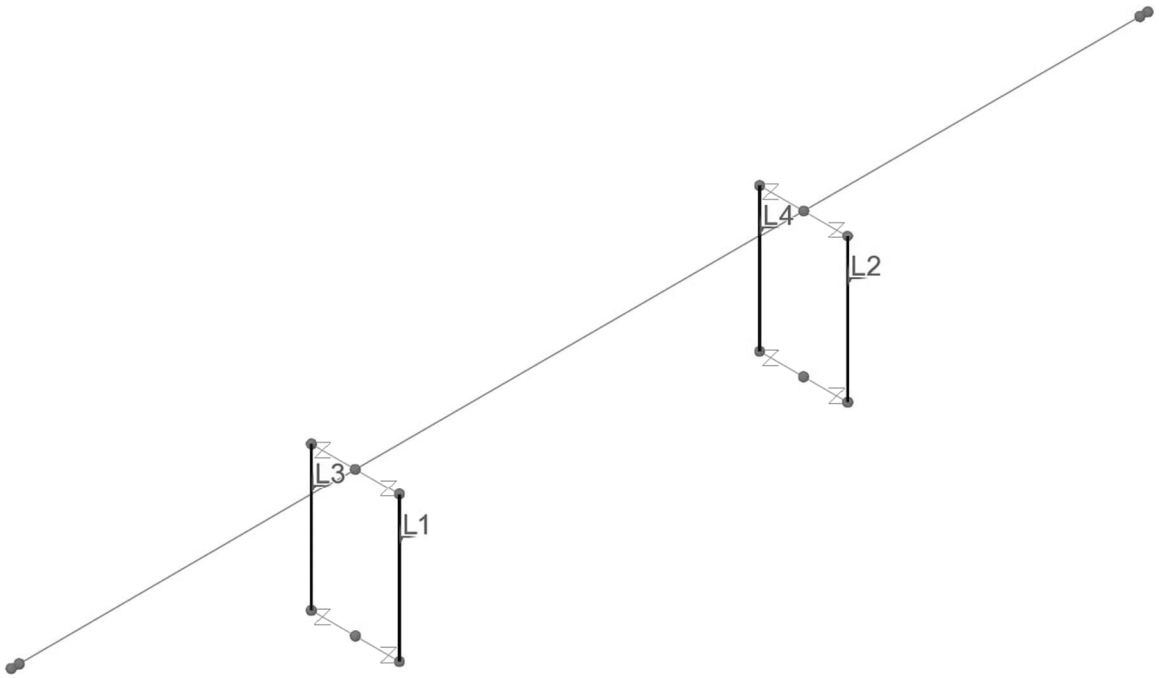


Fictive deck: detail 3
(Span 2

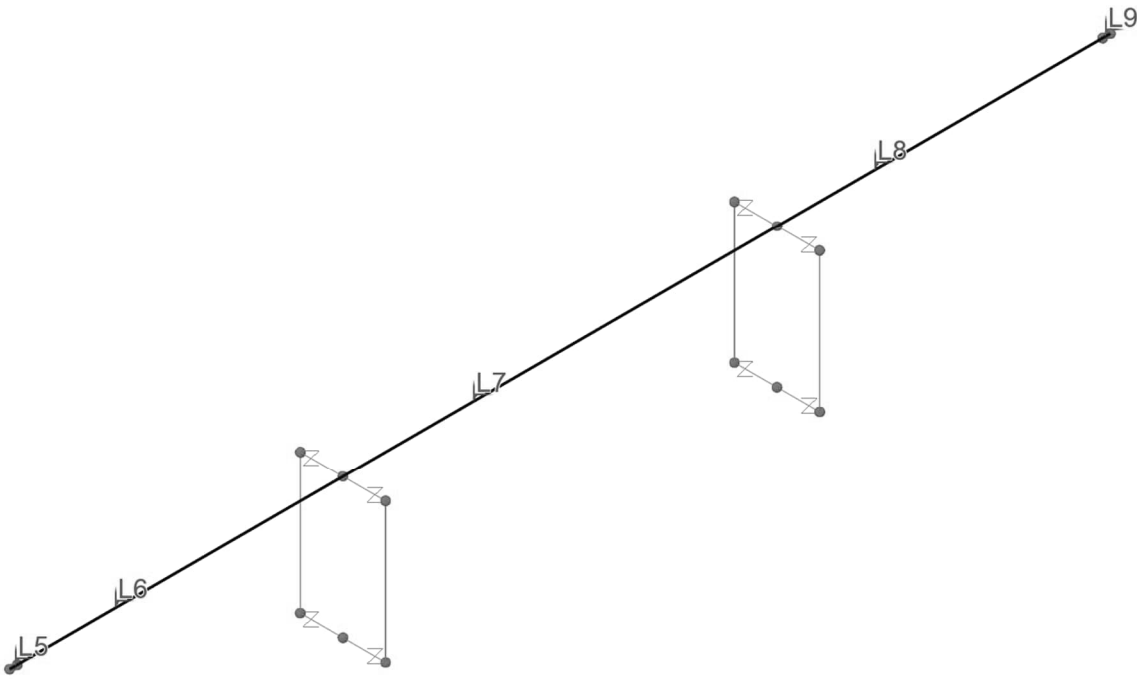


Fictive deck: detail 5
(End support 4)

2.2.2 Geometry : LINES



Supports 2 & 3



Superstructure

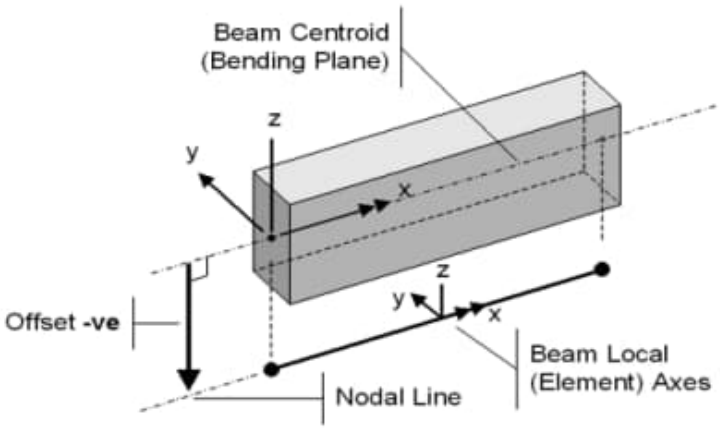
2.2.3 Geometri : SURFACES

Surfaces are only utilized to define fictitious shell elements with a width of 0.1 meters. These elements are specified in the input receipt (refer to Appendix 1).

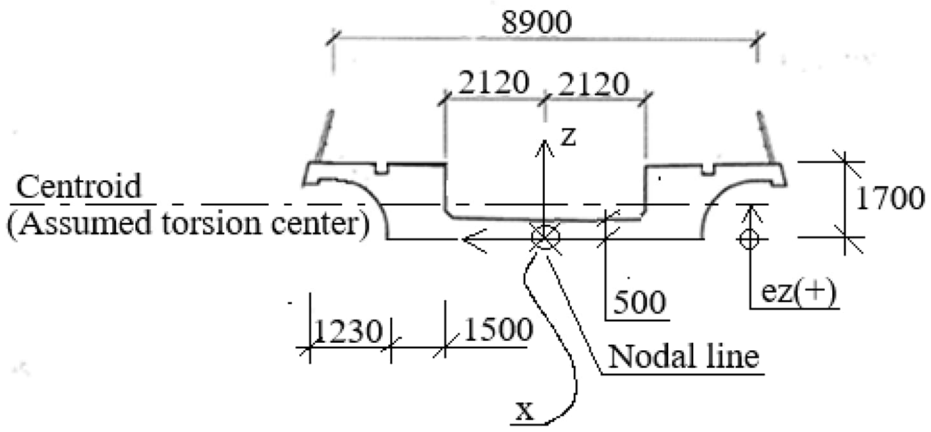
2.3 CROSS SECTION PROPERTIES

2.3.1 3D-beams

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

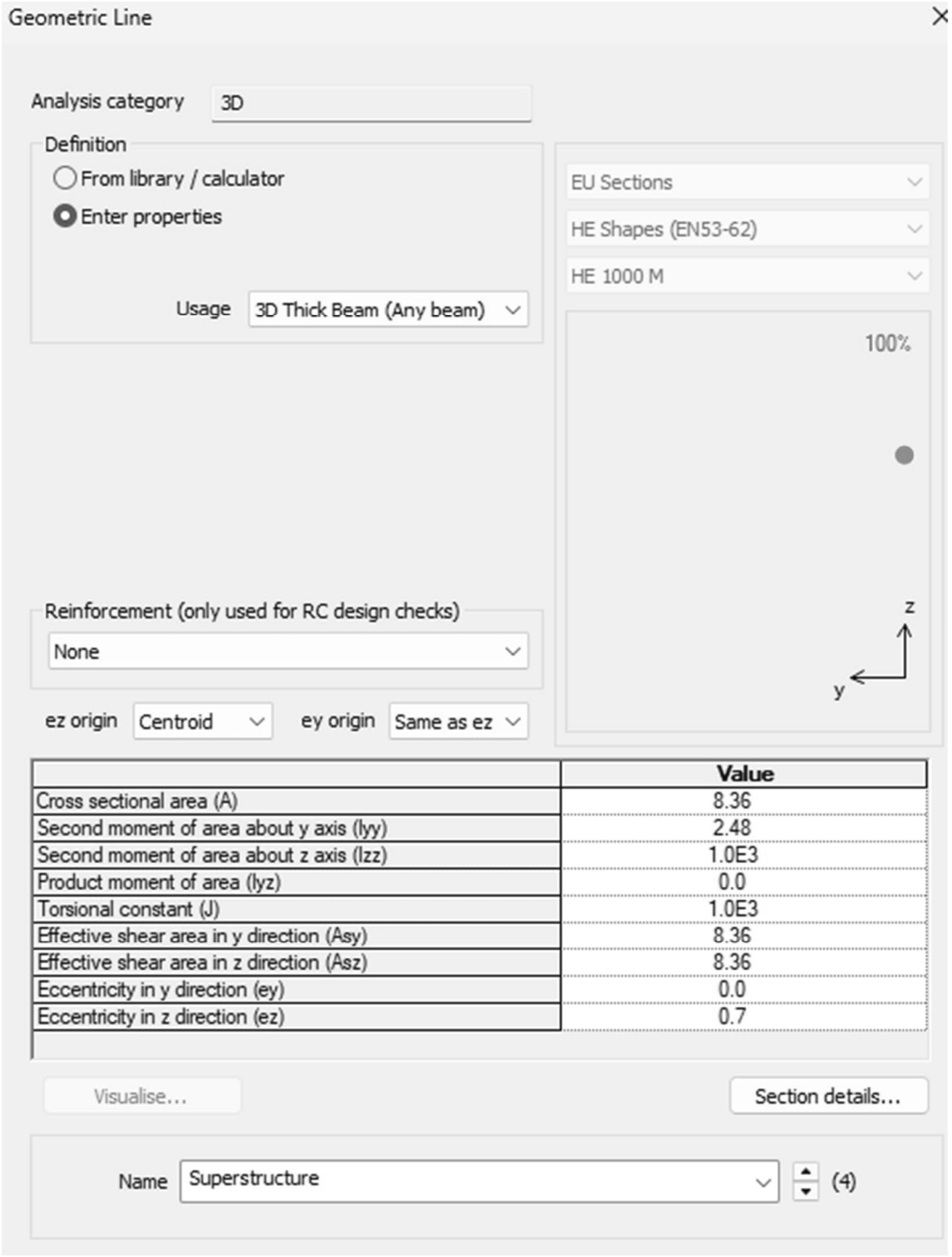


2.3.1.1 Superstructure



Determination of equivalent crossection properties according to separate calculation, see summary below.

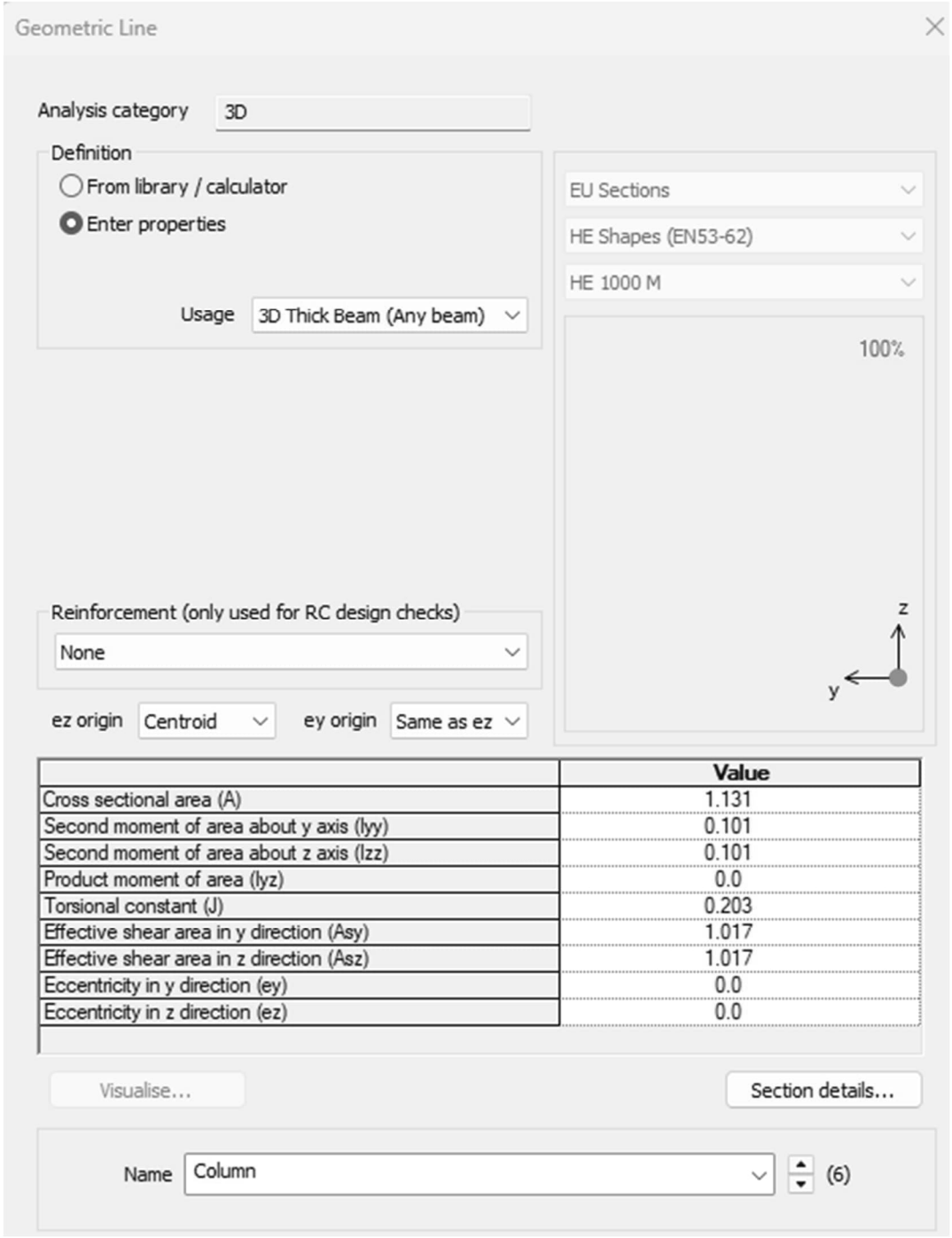
Cross section properties	Value
A	8.36 m^2
I_{yy}	2.48 m^4
I_{zz}	10^3 m^4
J	10^3 m^4
A_{sz}	8.36 m^2
A_{sy}	8.36 m^2
e_z	0.70 m


Geometric Line
Analysis category
3D
Definition
From library / calculator
Enter properties
Usage
3D Thick Beam (Any beam)
EU Sections
HE Shapes (EN53-62)
HE 1000 M
100%
z
y
Reinforcement (only used for RC design checks)
None
ez origin
Centroid
ey origin
Same as ez
Value
Cross sectional area (A) 8.36
Second moment of area about y axis (Iyy) 2.48
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) 8.36
Effective shear area in z direction (Asz) 8.36
Eccentricity in y direction (ey) 0.0
Eccentricity in z direction (ez) 0.7
Visualise...
Section details...
Name
Superstructure
(4)

2.3.1.2 Columns (ϕ1200)

Determination of ecrossection properties according to separate calculation, see summary below.

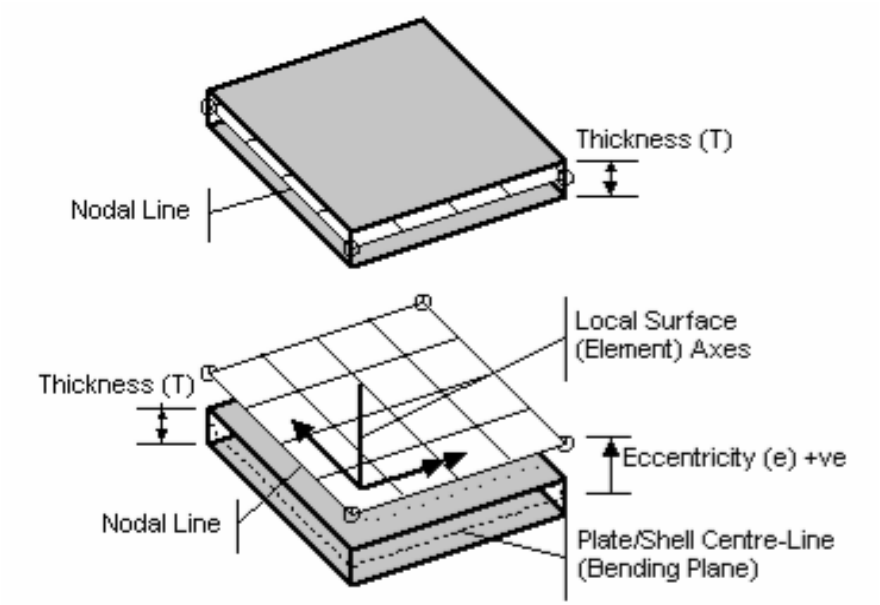
Cross section properties	Value
A	1.131 m^2
I_{yy}	0.101 m^4
I_{zz}	0.101 m^4
J	0.203 m^4
A_{sz}	1.017 m^2
A_{sy}	1.017 m^2
e_z	0 m

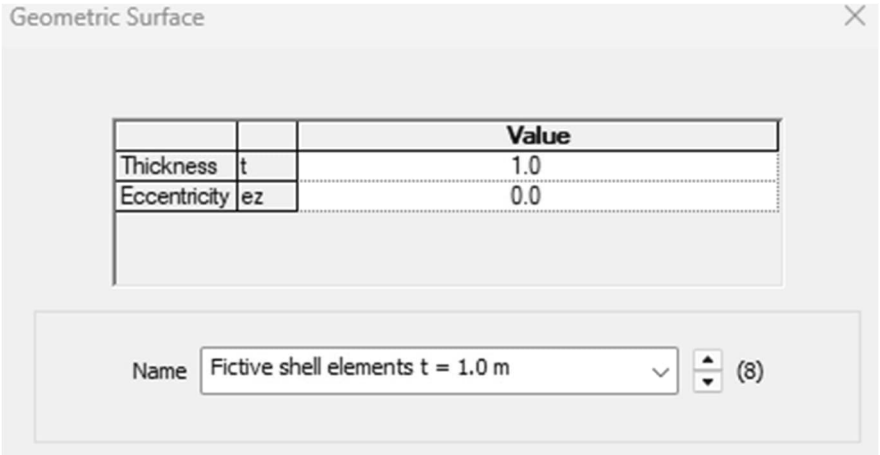

Geometric Line
Analysis category
3D
Definition
From library / calculator
Enter properties
Usage
3D Thick Beam (Any beam)
EU Sections
HE Shapes (EN53-62)
HE 1000 M
100%
z
y
Reinforcement (only used for RC design checks)
None
ez origin
Centroid
ey origin
Same as ez
Value
Cross sectional area (A) 1.131
Second moment of area about y axis (Iyy) 0.101
Second moment of area about z axis (Izz) 0.101
Product moment of area (Iyz) 0.0
Torsional constant (J) 0.203
Effective shear area in y direction (Asy) 1.017
Effective shear area in z direction (Asz) 1.017
Eccentricity in y direction (ey) 0.0
Eccentricity in z direction (ez) 0.0
Visualise...
Section details...
Name
Column
(6)

2.3.2 Shell elements

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

Fictitious shell element are used to apply loads from dynamic loads on a structure. The scale elements have a fictitious total width of 0.10 m and a height of 1.0 m. The effect of the fictitious scale elements is considered negligible in the longitudinal direction.



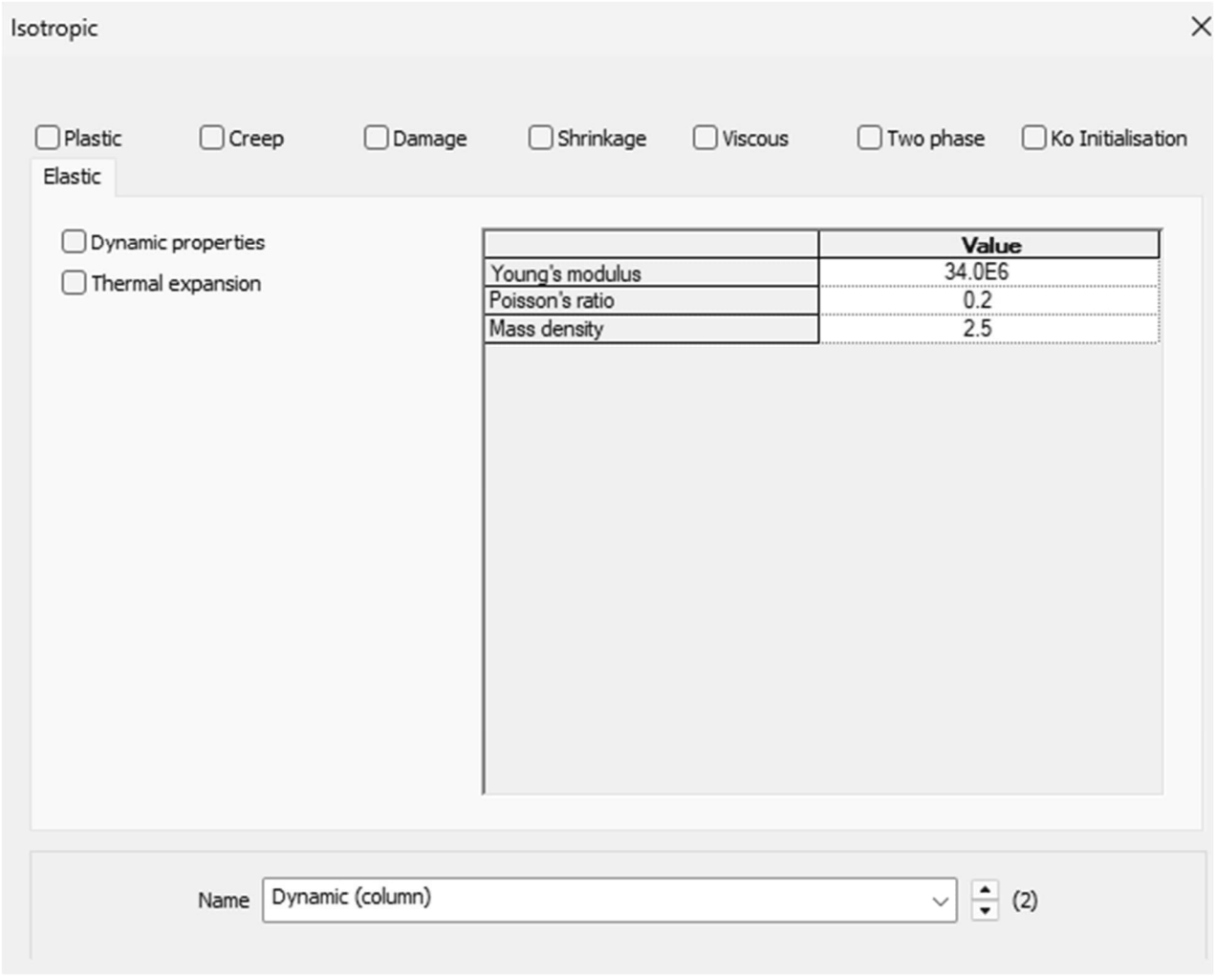


2.4 MATERIAL

2.4.1 Concrete material properties

Concrete C35/45 : E_{cm} = 34 GPa

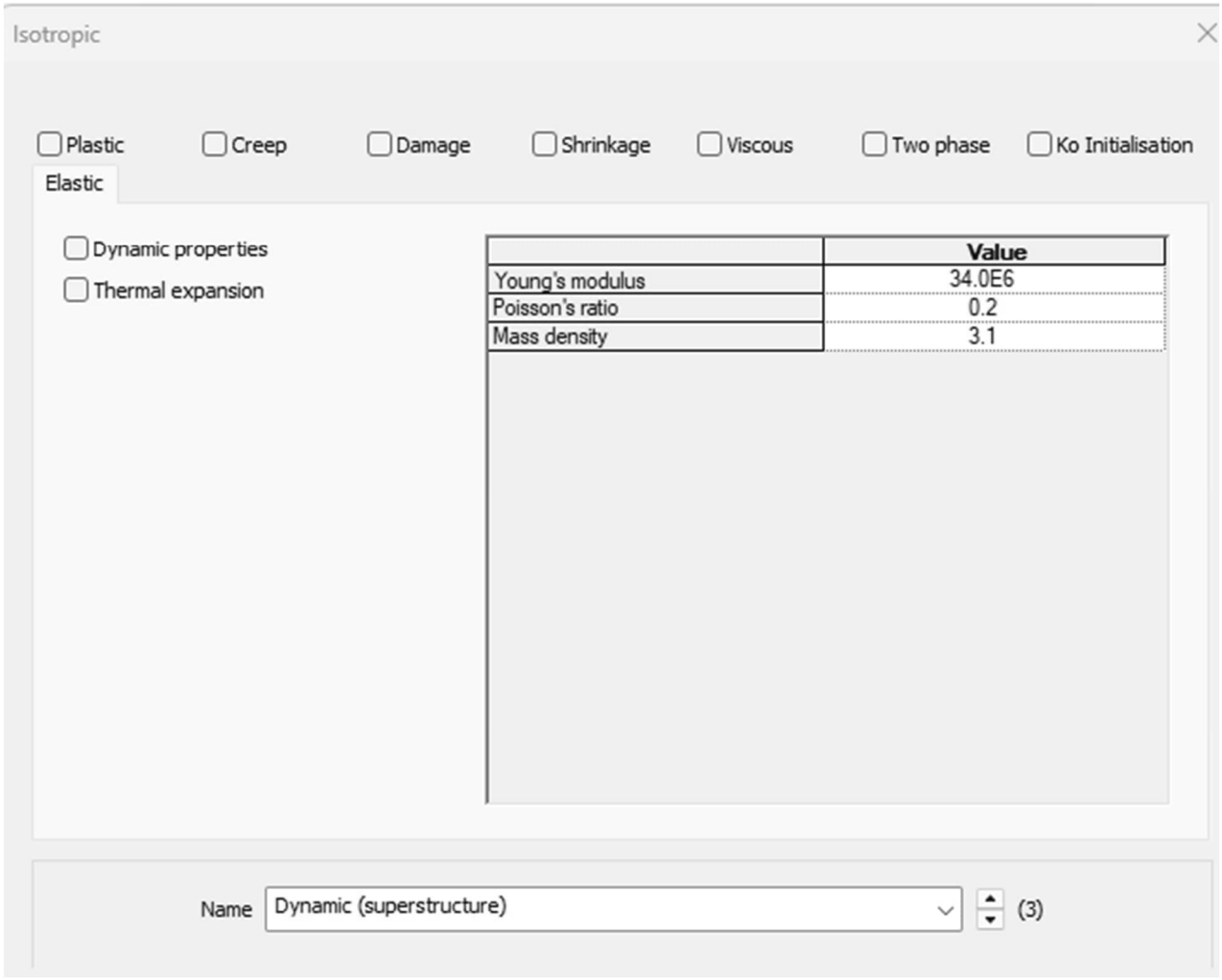
2.4.1.1 Substructure



2.4.1.2 Superstructure

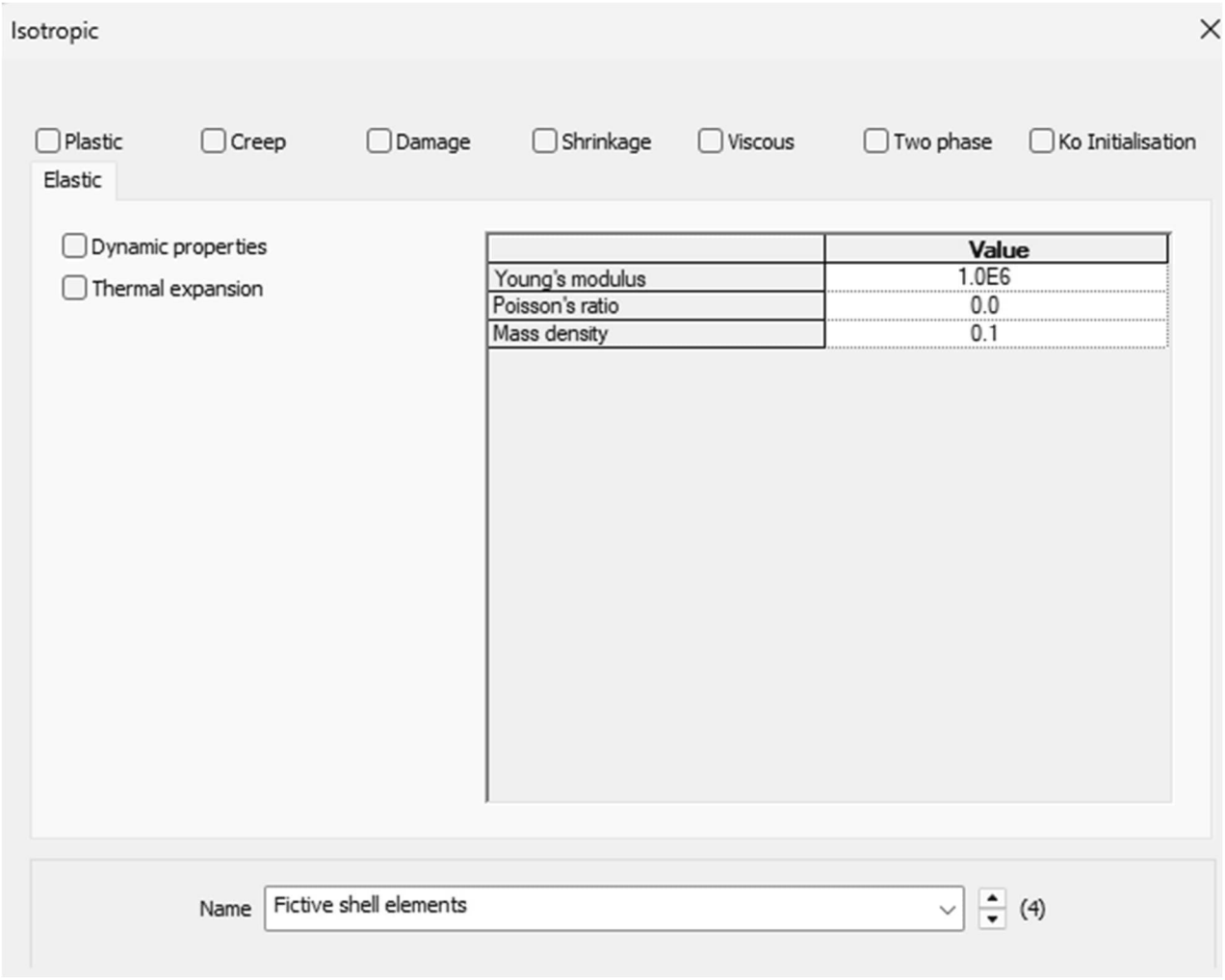
Mass density is adapted to include 0.6 m ballast over width 4.24 m, below is used equivalent mass density.

$$\gamma'_c = \frac{8.36m^2 \cdot 25\frac{kN}{m^3} + 0.6m \cdot 4.24m \cdot 20\frac{kN}{m^3}}{8.36m^2} = 31\frac{kN}{m^3} \therefore 3.1\frac{tons}{m^3}$$



2.4.2 Fictive shell element

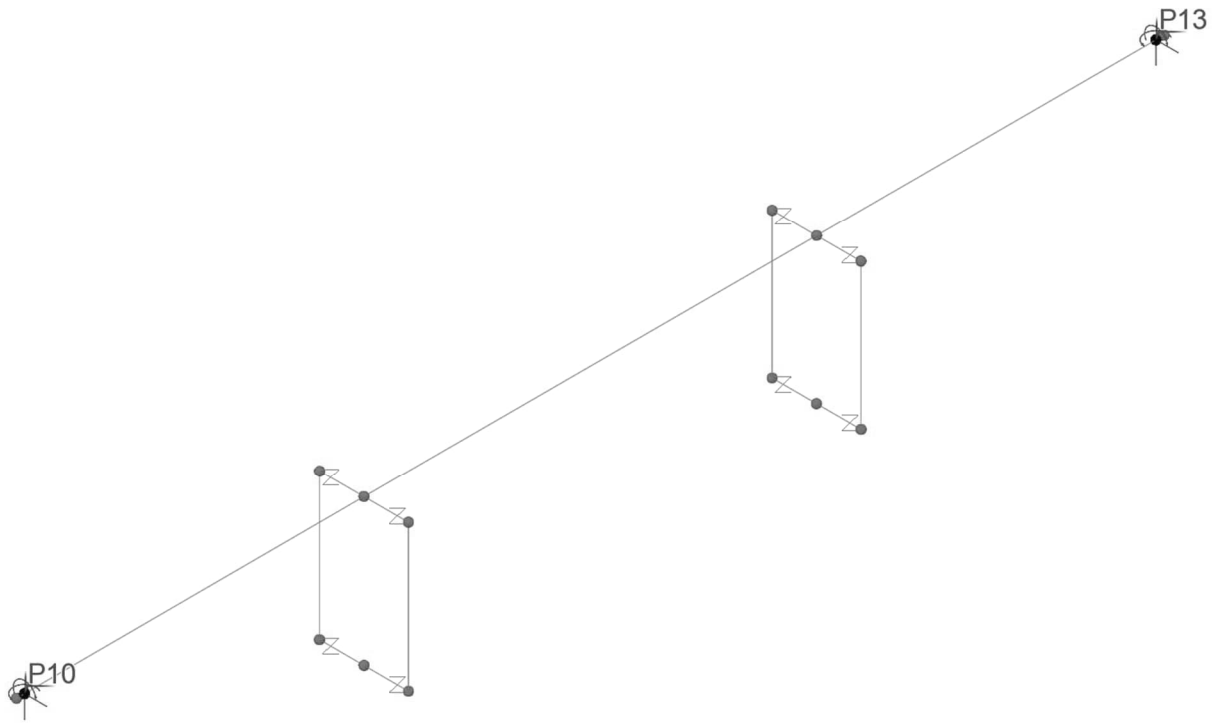
The ficitive shellelement (B x H: 0.1 m x 1.0 m) is modeled with negligable stiffness (= E_{cm} /34) and weightless (0.1 tons/m^3).



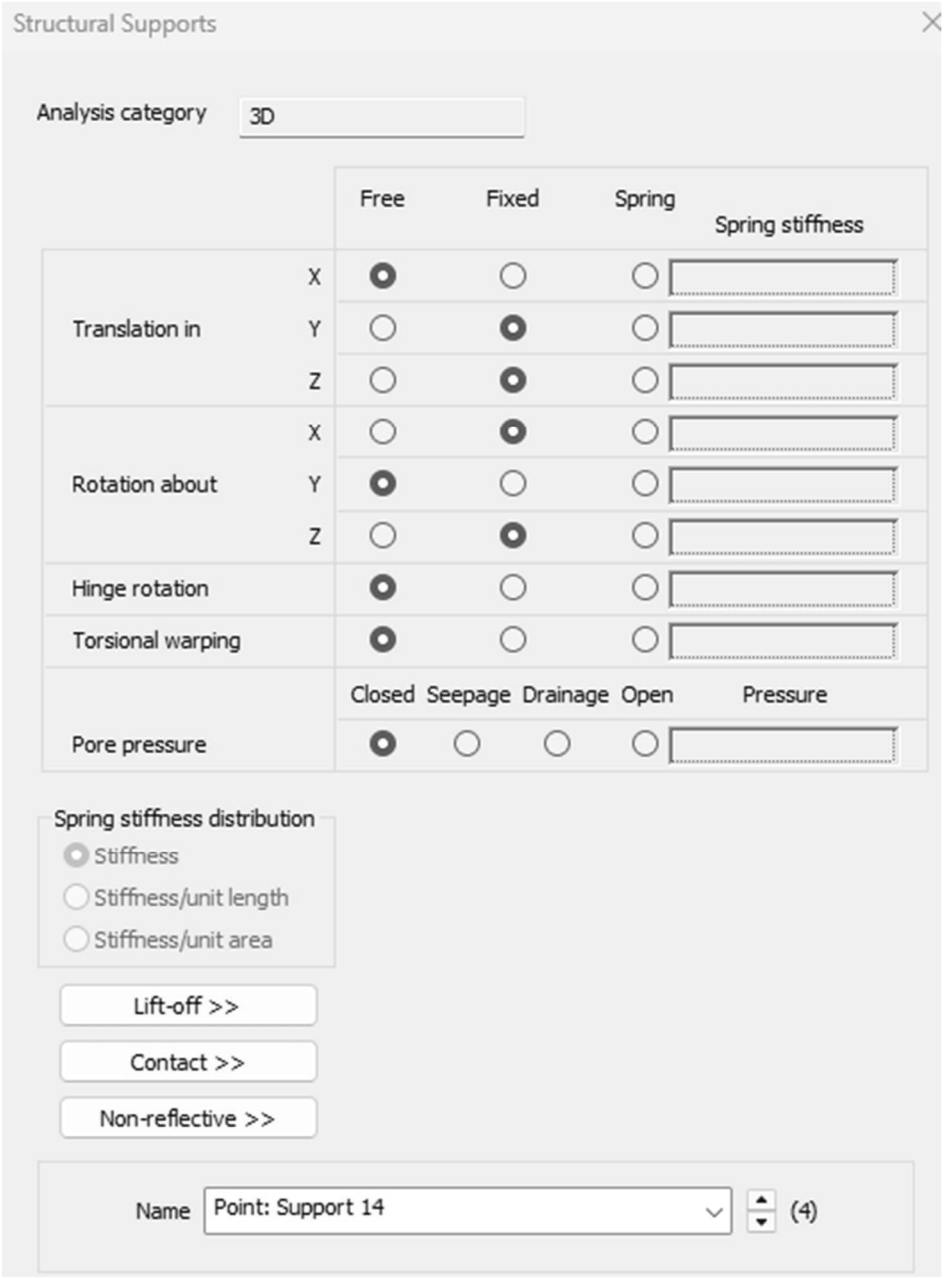
2.5 BOUNDARY CONDITIONS

2.5.1 End supports

End supports have bearings that permit movement in longitudinal direction (X-direction) and free rotation in longitudinal direction (rotation Y-direction).



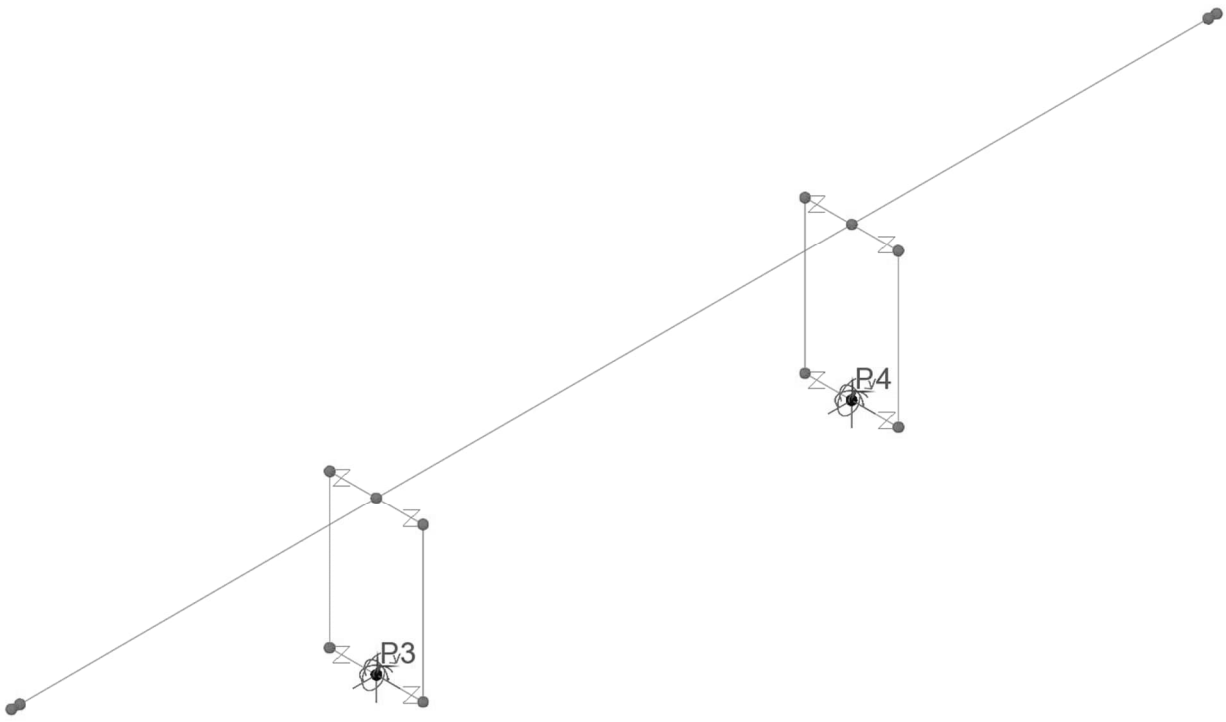
3D overview


Structural Supports
Analysis category
3D
Free
Fixed
Spring
Spring stiffness
Translation in
X
Y
Z
Rotation about
X
Y
Z
Hinge rotation
Torsional warping
Closed
Seepage
Drainage
Open
Pressure
Pore pressure
Spring stiffness distribution
Stiffness
Stiffness/unit length
Stiffness/unit area
Lift-off >>
Contact >>
Non-reflective >>
Name
Point: Support 14
(4)

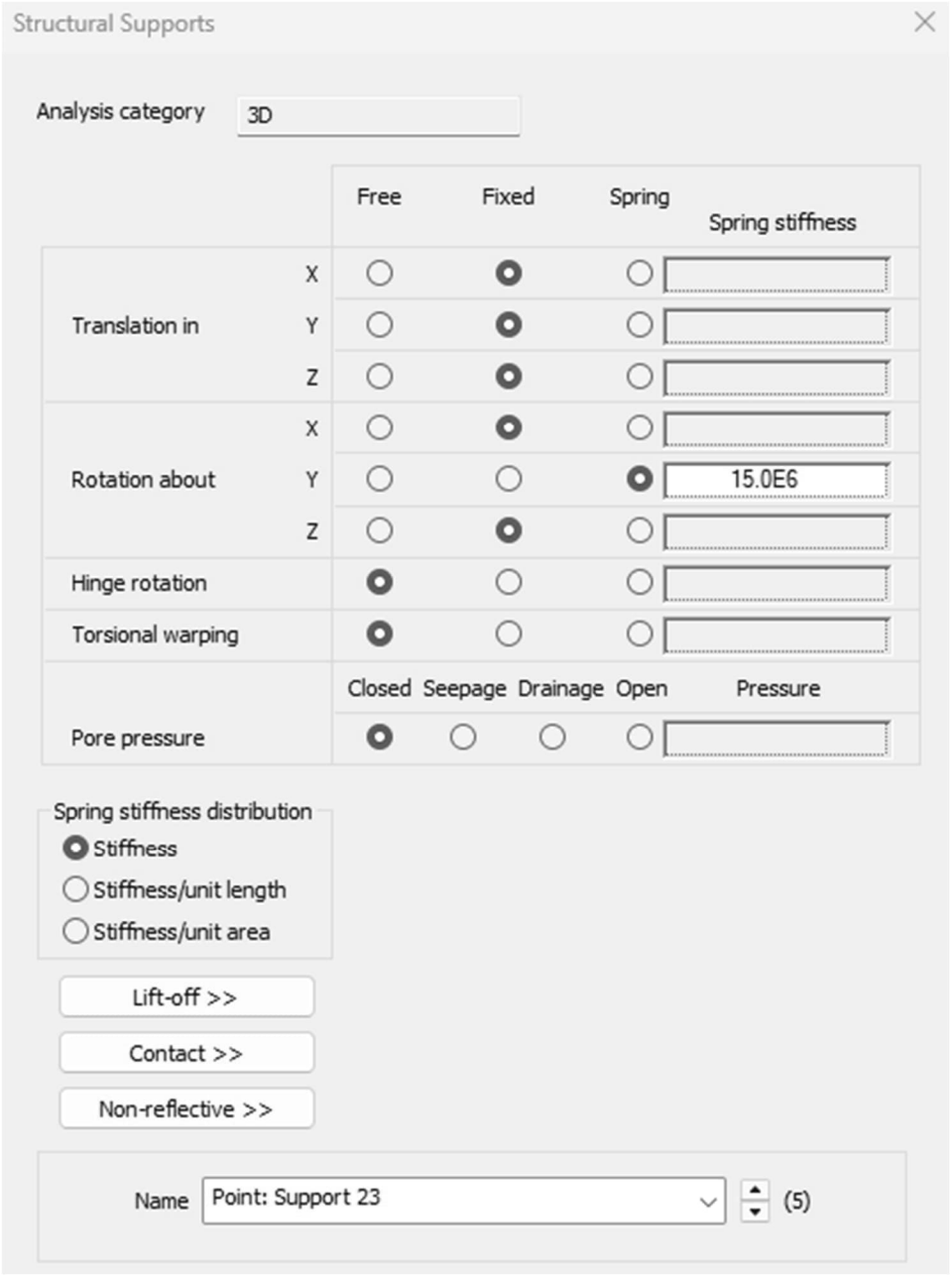
2.5.2 Intermediate supports

Below are stiffnesses in piled foundation. The stiffnesses are determined separately.

Stiffness	Value
$C_{\Delta, x}$	Fixed
$C_{\Delta, y}$	Fixed
$C_{\Delta, z}$	Fixed
$C_{\varphi, x\text{-}x}$	Fixed
$C_{\varphi, y\text{-}y}$	$15 \cdot 10^6$ kNm/rad
$C_{\varphi, z\text{-}z}$	Fixed

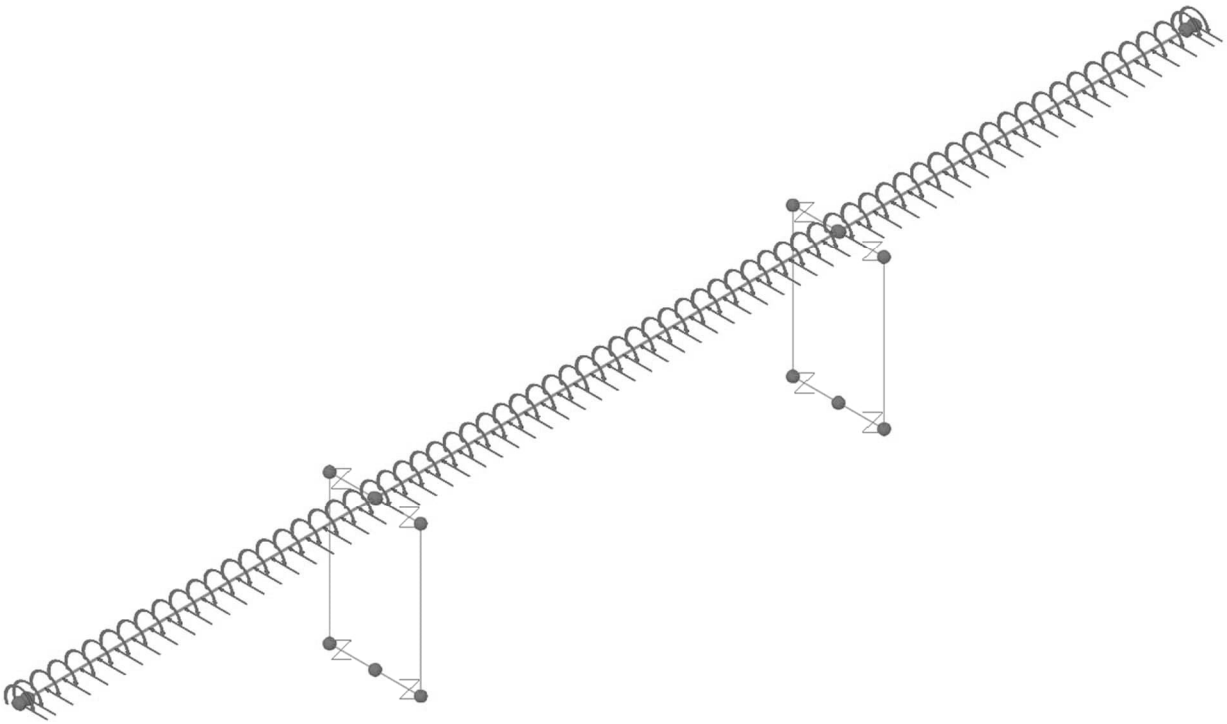


3D overview

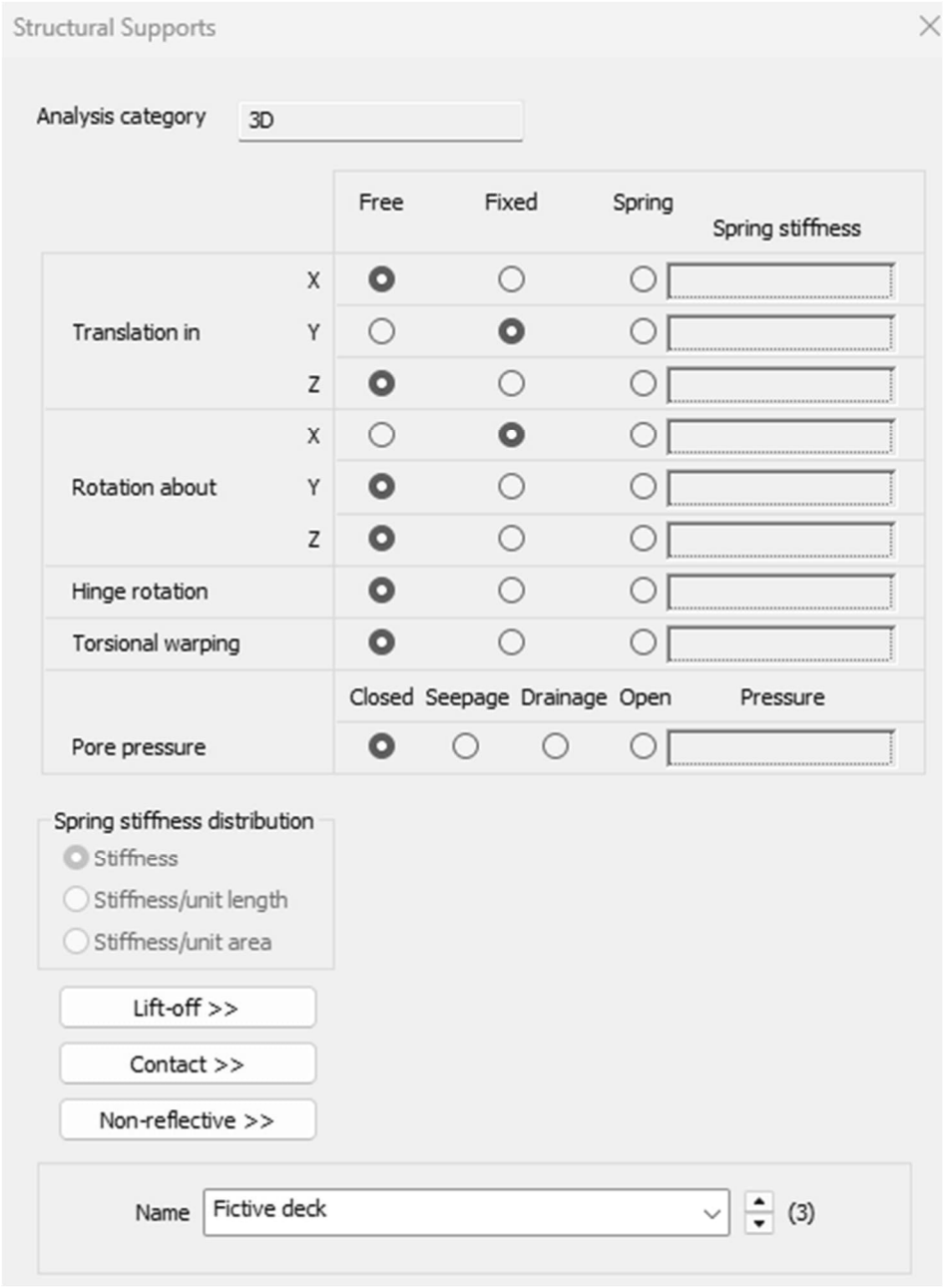

Structural Supports
Analysis category
3D
Free
Fixed
Spring
Spring stiffness
Translation in
X
Y
Z
Rotation about
X
Y
Z
15.0E6
Hinge rotation
Torsional warping
Closed
Seepage
Drainage
Open
Pressure
Pore pressure
Spring stiffness distribution
Stiffness
Stiffness/unit length
Stiffness/unit area
Lift-off >>
Contact >>
Non-reflective >>
Name
Point: Support 23
(5)

2.5.3 Boundary conditions fictive deck

Below are boundary conditions applied to fictive deck (B x H = 0.1 m x 1.0 m) to prevent translation in transverse direction (Y-direction) and rotation (around X-axle).



3D overview

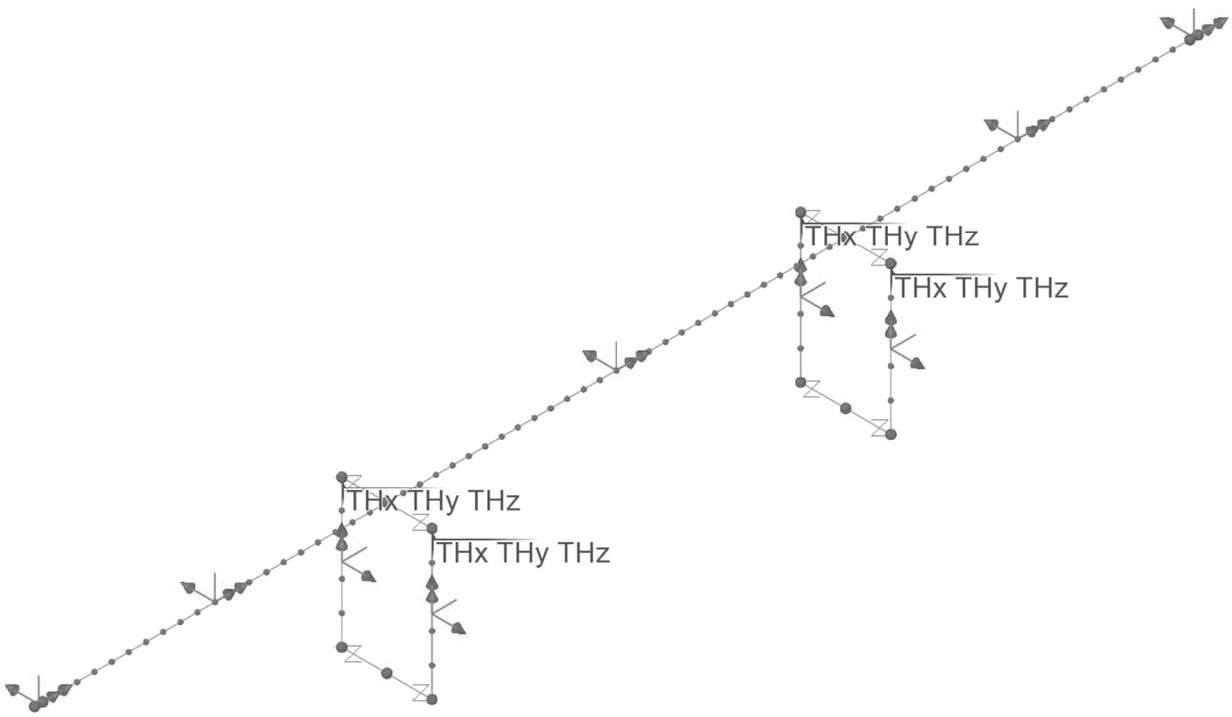

Structural Supports
Analysis category
3D
Free
Fixed
Spring
Spring stiffness
Translation in
X
Y
Z
Rotation about
X
Y
Z
Hinge rotation
Torsional warping
Closed
Seepage
Drainage
Open
Pressure
Pore pressure
Spring stiffness distribution
Stiffness
Stiffness/unit length
Stiffness/unit area
Lift-off >>
Contact >>
Non-reflective >>
Name
Fictive deck
(3)

2.6 MESH

2.6.1 Beam element (BMI21) : linear

Studied bridge uses beam elements (" Beam element" / BMI21) for support beam.

Type	Divisions	End release: Start	End release: End	Structure
Element 1	1	None	None	Superstructure
Element 2	2	None	None	Superstucture
Element 20	20	None	None	Supertructure
Element 28	28	None	None	Superstructure
Element 5	5	None	Pinned	Columns

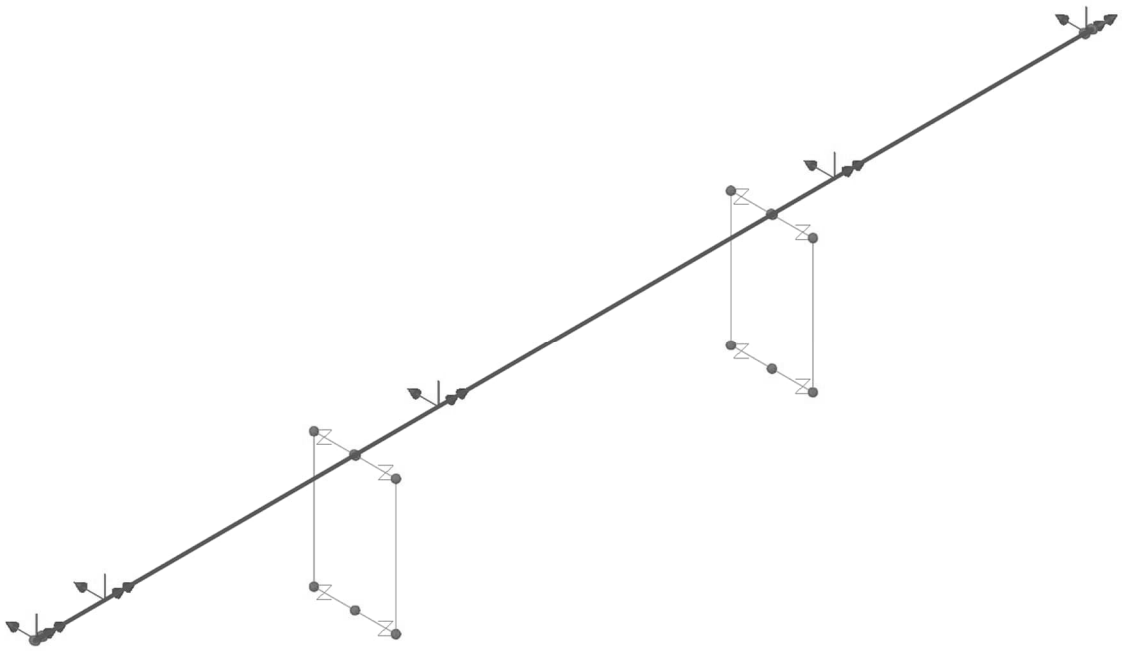


3D overview

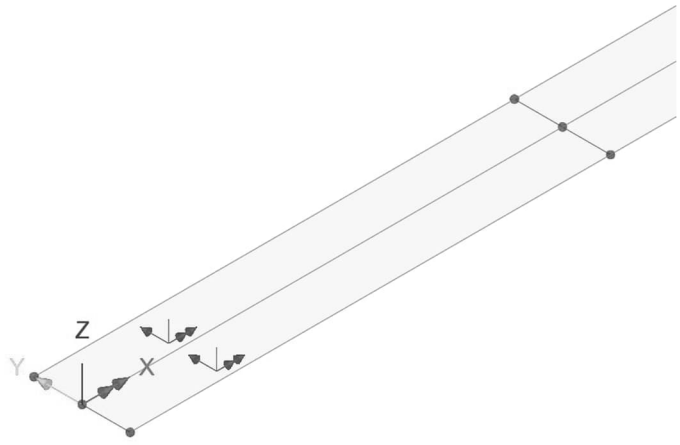
2.6.2 Shell element (QTS4): linear

Fictive deck is modelled using shell elements. There are to surfaces symmetrical on either side of centerline of superstructure thus there is 2 elements in y-direction.

Type	x-divisions	y-divisions
Element 1 x 1	1	1
Element 20 x 1	20	1
Element 28 x 1	28	1



3D overview

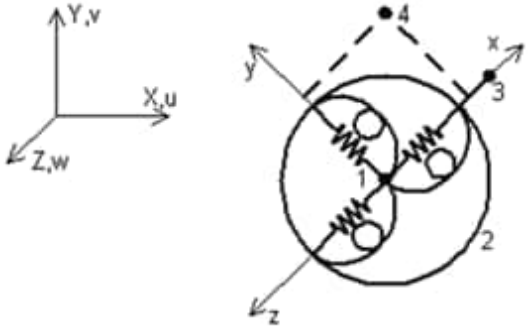


Detail 1

2.6.3 Joint element for beams (JSH4) : columns

Connection used to connect columns to superstructure and supernodes.

Element Name	**JSH4**



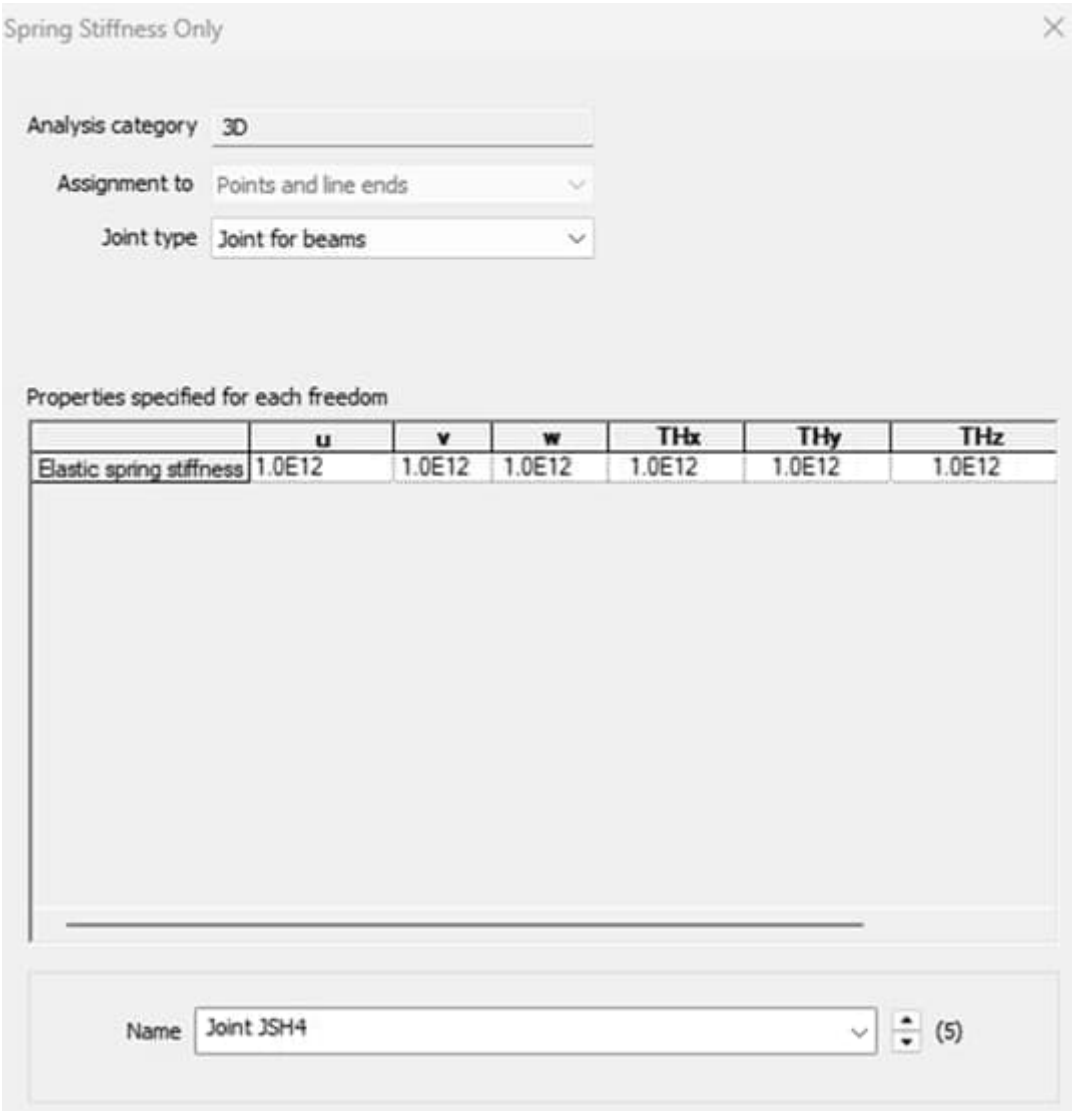
Element Group	Joints
Element Subgroup	3D Joints
Element Description	3D joint elements which connects two nodes by six springs in the local x, y and z-directions.
Number Of Nodes	4. The 3rd and 4th nodes are used to define the local x-axis and local xy-plane respectively.
Freedoms	U, V, W, θx, θy, θz: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

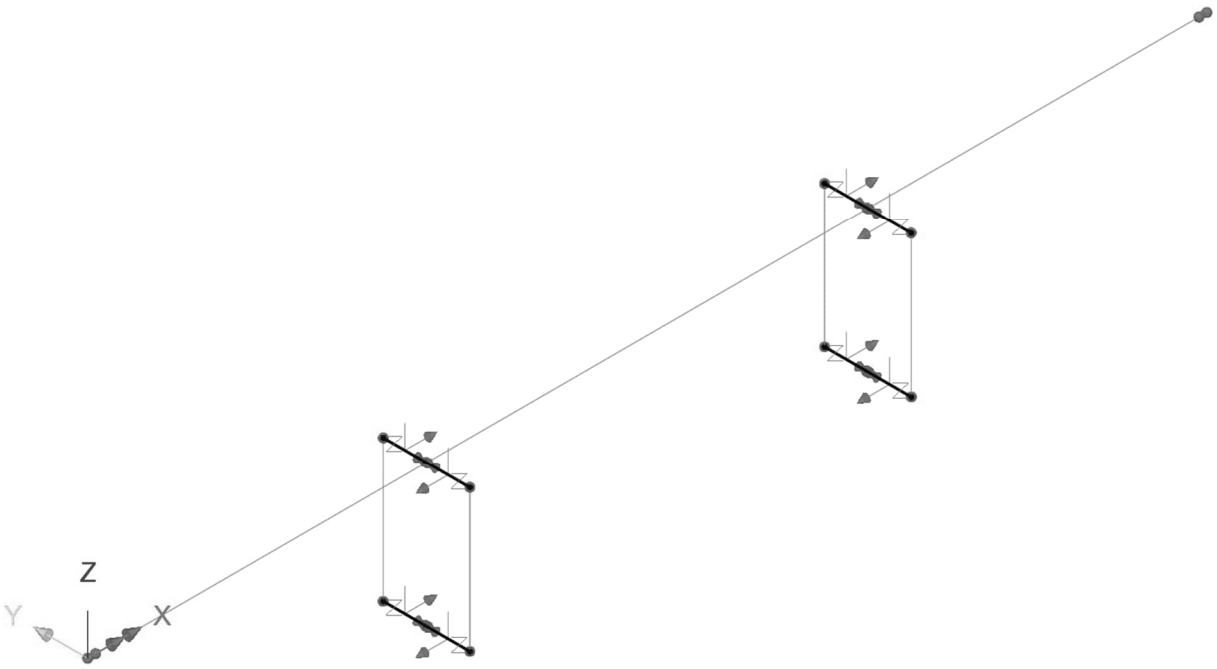
Geometric Properties

ez	Eccentricity measured from the joint xy-plane to the nodal line.
dy	Parametric distance factor (between 0.0 and 1.0), which defines the position of the shear spring for the local y direction between nodes 1 and 2. It is measured from node 1 (dy=0) along the local x direction.
dz	Parametric distance factor (between 0.0 and 1.0), which defines the position of the shear spring for the local z direction between nodes 1 and 2. It is measured from node 1 (dz=0) along the local x direction.

Joint material:

The joint is rigid $\rightarrow$ u = v = w = 10^{12} kN/m & THx = THy = THz = 10^{12} kNm/rad.

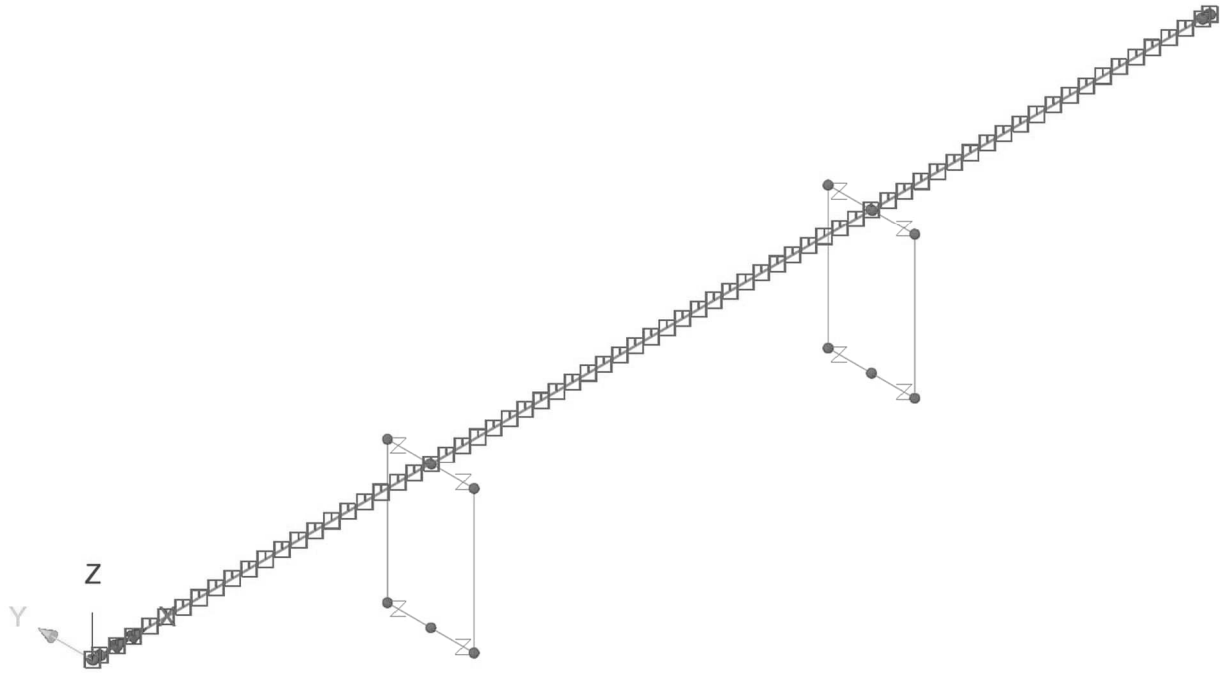




3D overview

2.7 SEARCH AREA

Discrete load can be applied to structure as geometrical load area, termed Search Area.



3D overview
Search Area : Fictive deck

3. LOADS

3.1 DEAD WEIGHT

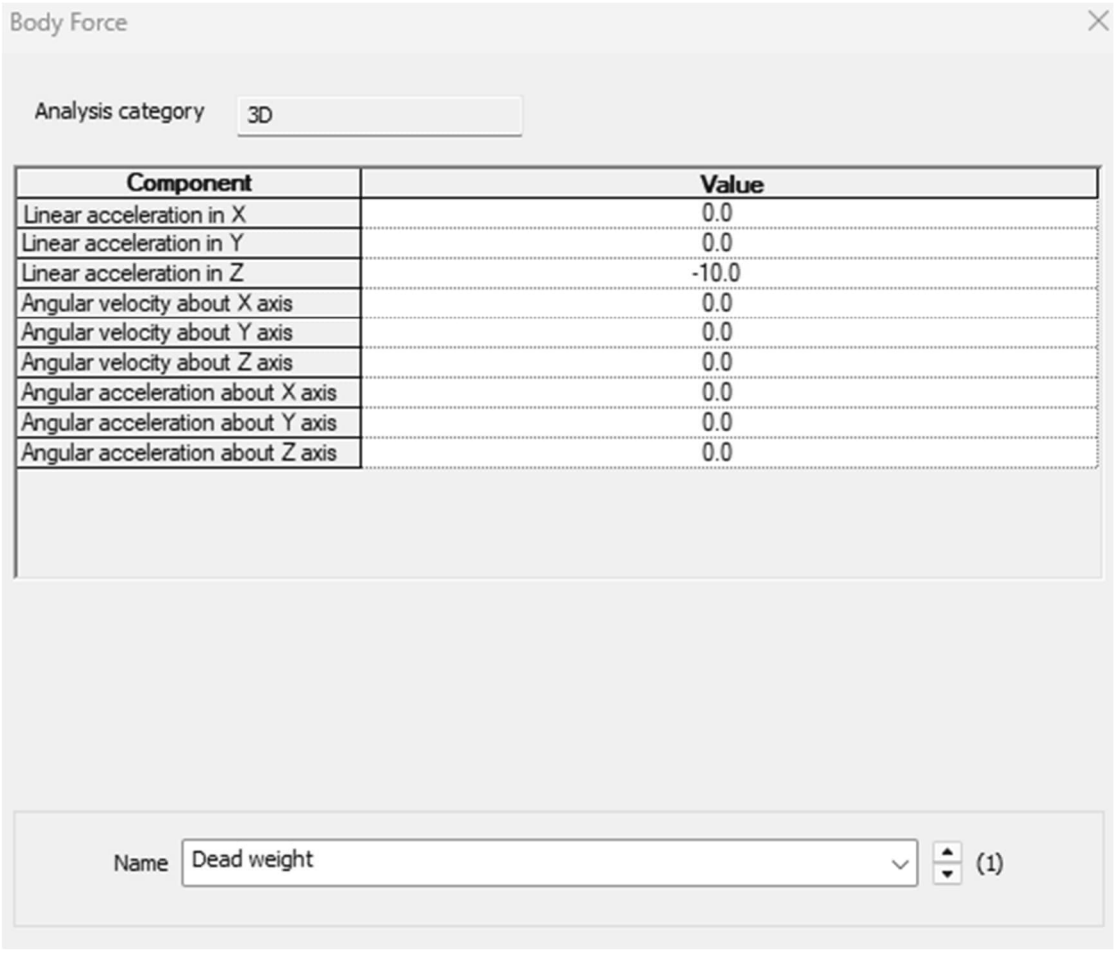
$\gamma_c = 25 \cdot \frac{kN}{m^3}$: columns

$\gamma_c = 31 \cdot \frac{kN}{m^3}$: superstructure

Loadcase : Dead weight

Structural loading : Body force

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



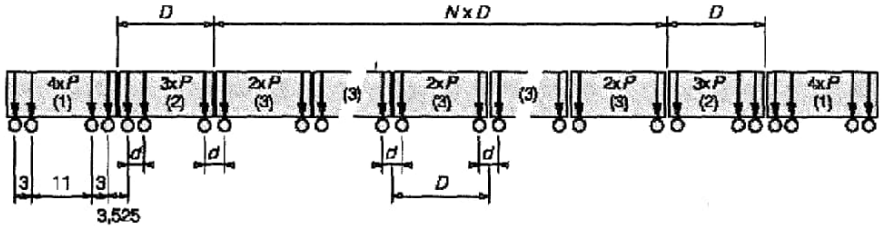
3.2 BALLAST

Ballast with thickness 0.6 m is included into load case deadweight.

$\gamma_{ballast} = 20\ kN/m^3$

3.3 TRAIN LOAD

Train load HSLM A1- A10 according to SS-EN 1992-2 tabell 1.



(1) Motorvagn (första och sista motorvagn är identiska)

(2) Vagnar anslutande till motorvagn

(3) Mellanliggande vagnar

Figur 1 Fördelning av laster för HSLM-A (SS-EN 1991-2)

Tabell 1 Lastmodeller för HSLM-A (SS-EN 1991-2)

Lastmodell	Antal mellanliggande vagnar (N)	Vagnlängd (D) m	Hjulavstånd inom boogie (d) m	Axellast (P) kN
A1	18	18	2,0	170
A2	17	19	3,5	200
A3	16	20	2,0	180
A4	15	21	3,0	190
A5	14	22	2,0	170
A6	13	23	2,0	180
A7	13	24	2,0	190
A8	12	25	2,5	190
A9	11	26	2,0	210
A10	11	27	2,0	210

3.3.1 Speeds

Speed in interval 140 – 300 km/h (39 – 83 m/s) are considered with interwall 4.4 m/s.

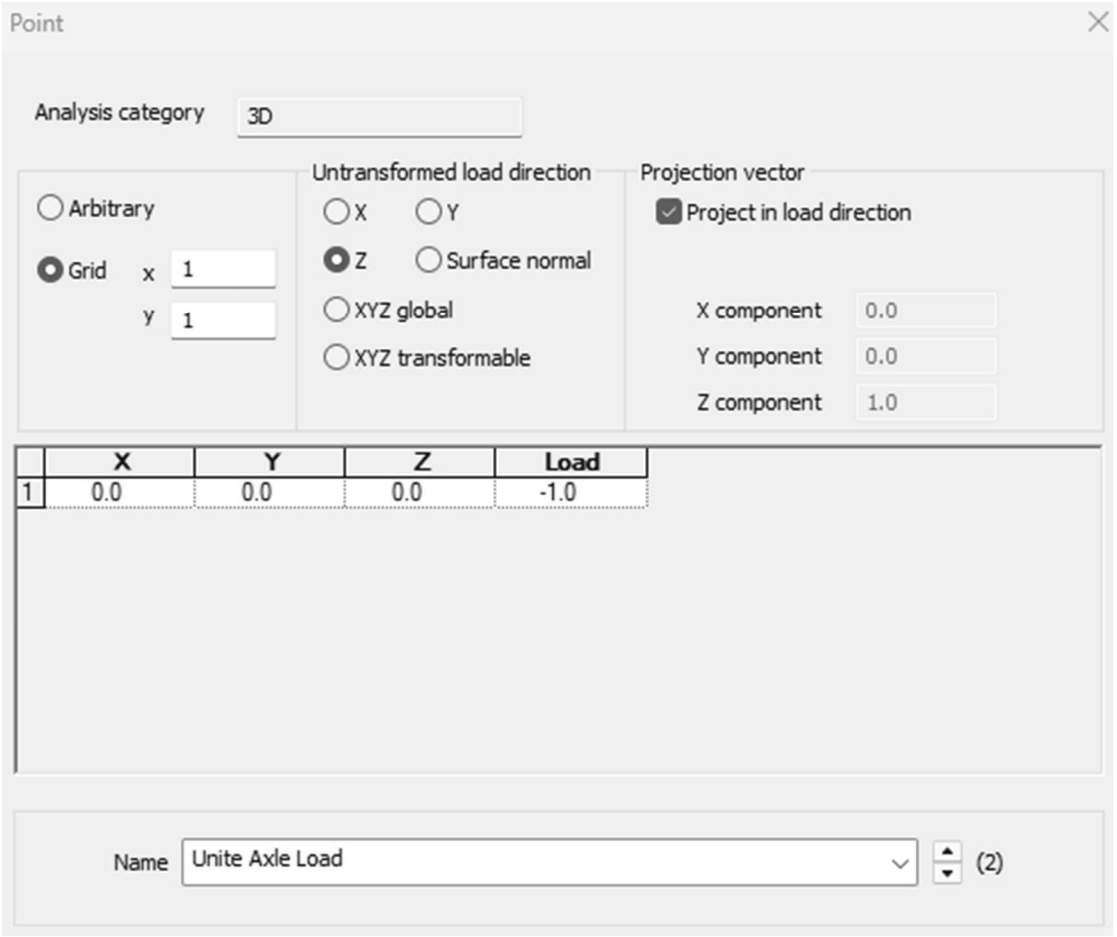
3.3.2 Dampening

Δ_{damp} = 1.5 % : dampening

3.3.3 Distance between rails (including unit load)

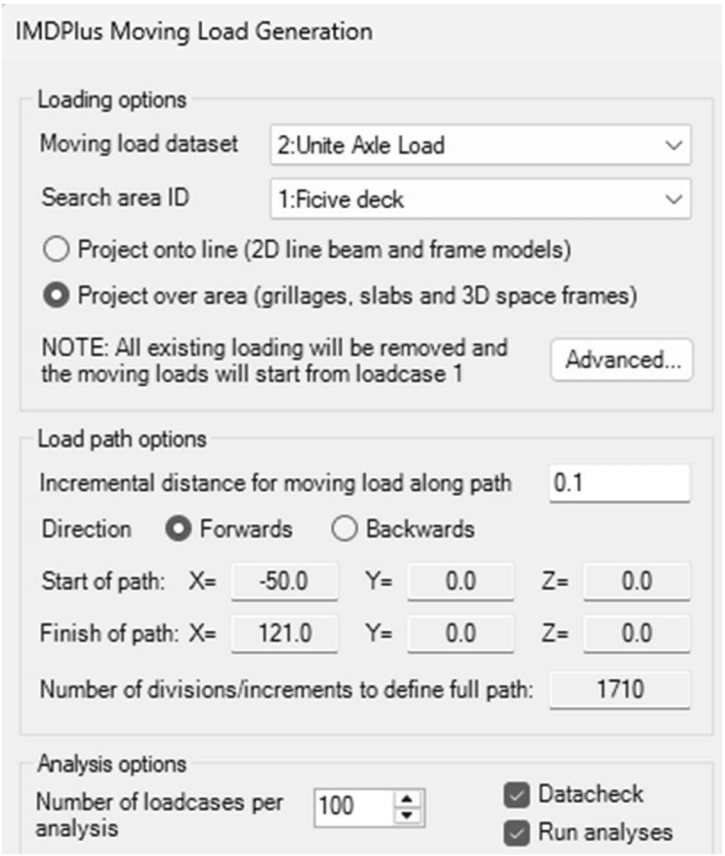
Distance between rails (r = 1425 mm) is not considered. The since no analysis of superstructure is performed in transversal direction, thus the unit load is not split into two point loads. The unit load a centre of fictive deck with narrow width (0.1 m).

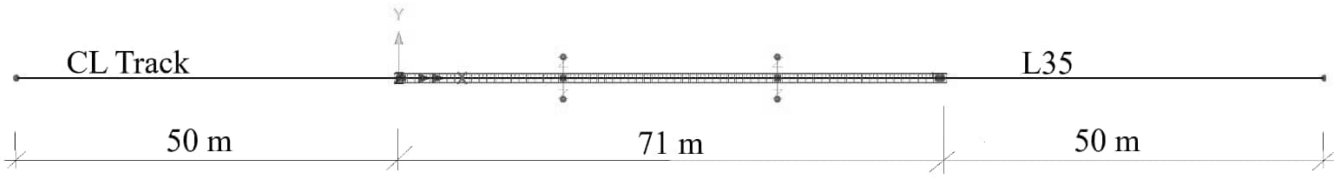
Definition of unit load Axle load (P = 1 kN) :



3.2.4 Track

Track length centre of bridge ± 85.5 m with stepping length 0.1 m.



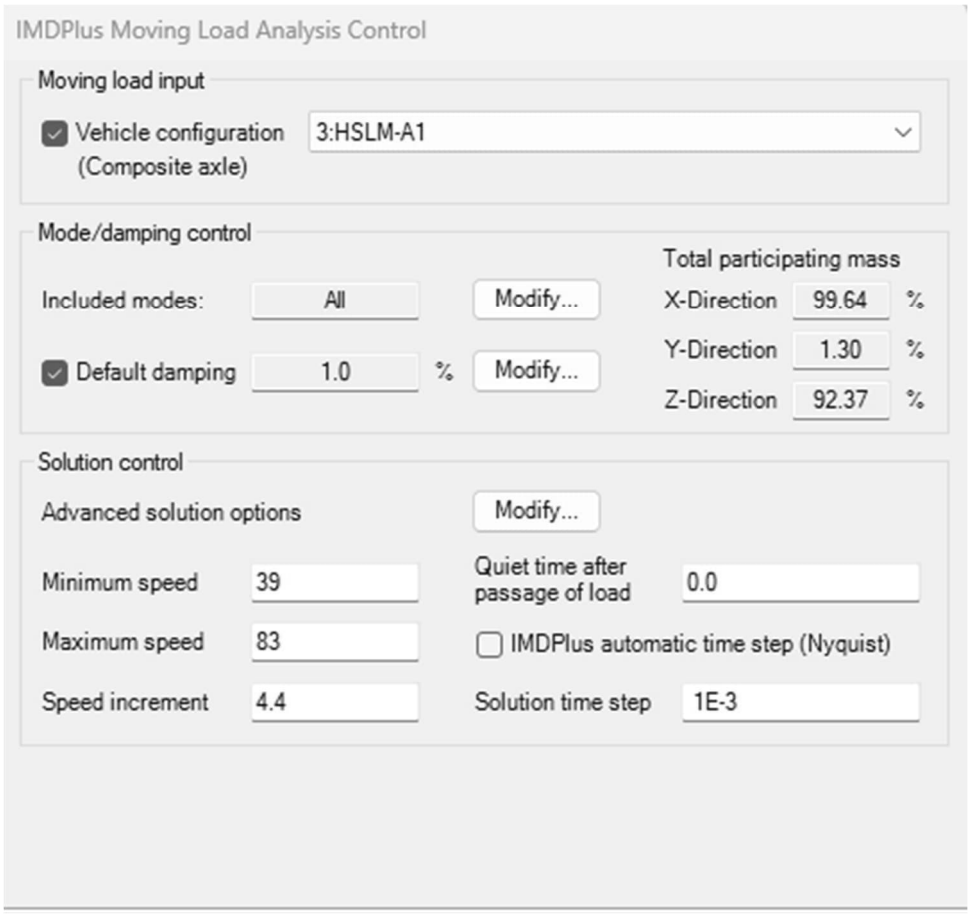


PLAN

3.2.5 Train load HSLM - A1

s	P	Train vehicle
0	170	Locomotive 1
-3.000	170	-"-
-14.000	170	-"-
-17.000	170	-"-
-20.525	170	Locomotive 1
-22.525	170	-"-
-35.7625	170	-"-
-37.7625	170	Carriage 1
-53.7625	170	-"-
-55.7625	170	Carriage 2
-71.7625	170	-"-
-73.7625	170	Carriage 3
-89.7625	170	-"-
-91.7625	170	Carriage 4
-107.763	170	-"-
-109.763	170	Carriage 5
-125.763	170	-"-
-127.763	170	Carriage 6
-143.763	170	-"-
-145.763	170	Carriage 7
-161.763	170	-"-
-163.763	170	Carriage 8
-179.763	170	-"-
-181.763	170	Carriage 9
-197.763	170	-"-
-199.763	170	Carriage 10
-215.763	170	-"-
-217.763	170	Carriage 11
-233.763	170	-"-
-235.763	170	Carriage 12
-251.763	170	-"-
-253.763	170	Carriage 13
-269.763	170	-"-
m	kN	-

s	P	Train vehicle
-271.763	170	Carriage 14
-287.763	170	-"-
-289.763	170	Carriage 15
-305.763	170	-"-
-307.763	170	Carriage 16
-323.763	170	-"-
-325.763	170	Carriage 17
-341.763	170	-"-
-343.763	170	Carriage 18
-359.763	170	-"-
-361.763	170	Locomotive 3
-375	170	-"-
-377	170	-"-
-380.525	170	Locomotive 4
-383.525	170	-"-
-394.525	170	-"-
-397.525	170	-"-
m	kN	-


IMDPlus Moving Load Analysis Control
Moving load input
Vehicle configuration (Composite axle)
3:HSLM-A1
Mode/damping control
Included modes:
All
Modify...
Default damping
1.0
%
Modify...
Total participating mass
X-Direction
99.64
%
Y-Direction
1.30
%
Z-Direction
92.37
%
Solution control
Advanced solution options
Modify...
Minimum speed
39
Maximum speed
83
Speed increment
4.4
Quiet time after passage of load
0.0
IMDPlus automatic time step (Nyquist)
Solution time step
1E-3

3.2.6 Train load HSLM A2-A10.

Only train load HSLM A1 is considered in this illustration.

4. RESULTS

4.1 WORKFLOW

Workflow for dynamic analysis:

1. Generate static model.
2. Perform *eigenvalue* analysis in frequency range $0 \rightarrow 35$ Hz.
3. Determine *participation factors.*
4. Determine *mass participation factors.*
5. Determine *sum mass participation factors.*
6. Define discrete point load Unit Axle load (P = 1 kN).
7. Define HSLM- A1 using *vehicle configuration.*
8. Perform *moving dynamic load generation* for Unit Axle
9. Perform *modal force calculation* for Unit load.
10. Chose location for results. Centre of deck is chosen (0 m; 0 m; 5.75 m).
11. Perform dynamic *moving load analysis* for vehicule HSLM – A1

4.2 VERIFICATION ACCELERATION

Largest vertical acceleration (Z-direction) is $|A_z|$ = 0.42 mm and occurs at train speed v = 83 m/s at nodes 17 & 298 , see appendix 2 page 8.

4.3 VERIFICATION DEFORMATION

Largest vertical deformation (Z-direction) is $|\Delta_z|$ = 0.7 mm and occurs at train speed v = 83 m/s at nodes 17 & 298, see appendix 2 page 9.

4.4 VERIFICATION BENDING MOMENT

Largest hogging moment in longitudinal direction (X-direction) is |My| = 1200 kNm/m and occurs at train speed v = 83 m/s at nodes 17 & 298, see appendix 2 page 10.

Title: Input receipt

Model Units: kN,m,t,s,C
Report Units: kN,m,t,s,C

Model Title: System 001
Model File: System 001

Clarification of definitions.

In the report, the letter “T” is used to describe a range. The letter is an abbreviation of “to”.

See example of assignment below.

Assignment to Lines:
105T110;114T119

This expression means that the assignment occurs to the lines L105 → L110 and L114 → L119.

Assignment to Surfaces:
3T17;19T24
This expression means that the assignment occurs to the surfaces S3 → S17 and S19 → S24.

Table of Contents

1. Points

Point	X coordinate	Y coordinate	Z coordinate
1	21.5	-2.8	-9.0
2	49.5	-2.8	-9.0
3	21.5	0.0	-9.0
4	49.5	0.0	-9.0
5	21.5	2.8	-9.0
6	49.5	2.8	-9.0
7	21.5	-2.8	0.0
8	49.5	-2.8	0.0
9	0.0	0.0	0.0
10	0.5	0.0	0.0
11	21.5	0.0	0.0
12	49.5	0.0	0.0
13	70.5	0.0	0.0
14	71.0	0.0	0.0
15	21.5	2.8	0.0
16	49.5	2.8	0.0
19	-50.0	0.0	0.0
20	121.0	0.0	0.0
31	0.0	0.1	0.0
32	0.5	0.1	0.0
33	21.5	0.1	0.0
34	49.5	0.1	0.0
35	70.5	0.1	0.0
36	71.0	0.1	0.0
37	0.0	-0.1	0.0
38	0.5	-0.1	0.0
39	21.5	-0.1	0.0
40	49.5	-0.1	0.0
41	70.5	-0.1	0.0
42	71.0	-0.1	0.0
-	m	m	m

2. Lines

Line	Points	Line	Points
1	1,7	2	2,8
3	5,15	4	6,16
5	9,10	6	10,11
7	11,12	8	12,13
9	13,14	58	9,31
59	32,10	60	31,32
61	33,11	62	32,33
63	34,12	64	33,34
65	35,13	66	34,35
67	36,14	68	35,36
69	9,37	70	38,10
71	37,38	72	39,11
73	38,39	74	40,12
75	39,40	76	41,13
77	40,41	78	42,14
79	41,42		

3. Surfaces

Surface	Lines	Surface	Lines
1	5,59,60,58	2	6,61,62,59
3	7,63,64,61	4	8,65,66,63
5	9,67,68,65	6	71,70,5,69
7	73,72,6,70	8	75,74,7,72
9	77,76,8,74	10	79,78,9,76

4. MESH: Line

Attribute: 2 Title: Element 20
Sub Type = Line Mesh **Element Type = BMI21**

Mesh spacing	Nr. of elements	Start node end releases:	End node end releases:
Uniform	20	None	None

Assignment to Lines: **Beta angle = 0.0**
6;8;62;66;73;77

Attribute: 3 Title: Element 28
Sub Type = Line Mesh **Element Type = BMI21**

Mesh spacing	Nr. of elements	Start node end releases:	End node end releases:
Uniform	28	None	None

Assignment to Lines: **Beta angle = 0.0**
7;64;75

Attribute: 4 Title: Element 1
Sub Type = Line Mesh **Element Type = BMI21**

Mesh spacing	Nr. of elements	Start node end releases:	End node end releases:
Uniform	1	None	None

Assignment to Lines: **Beta angle = 0.0**
5;9;60;68;71;79

Attribute: 5 Title: Element 5
Sub Type = Line Mesh **Element Type = BMI21**

Mesh spacing	Nr. of elements	Start node end releases:	End node end releases:
Uniform	5	None	THX THY THZ

Assignment to Lines: **Beta angle = 0.0**
1T4

5. MESH: Joint

Attribute: 11 **Title: JSH4**
Sub Type = Point Mesh **Element Type = JSH4**

Property	Symbol	Value
Element defined by name	DefinedByName	false
Single feature joint	isSingleFtrJnt	false

Assignment to Points: **Beta angle = 0.0, Interface secondary Point 3, Mesh from primary to secondary**
1;2;5T8;15;16

6. MESH:Surface

Attribute: 7 **Title: Element 20 x 1**
Sub Type = Surface Mesh **Element Type = QTS4**

Property	Symbol	Value
Element size	size	0.0
Number of divisions in x	xDivisions	20
Number of divisions in y	yDivisions	1
Transition mesh	transition	true
Allow irregular mesh	allowIrregular	true
Element defined by name	DefinedByName	false
Single feature joint	isSingleFtrJnt	false

Assignment to Surfaces:
2;4;7;9

Attribute: 8 **Title: Element 1 x 1**
Sub Type = Surface Mesh **Element Type = QTS4**

Property	Symbol	Value
Element size	size	0.0
Number of divisions in x	xDivisions	1
Number of divisions in y	yDivisions	1
Transition mesh	transition	true
Allow irregular mesh	allowIrregular	true
Element defined by name	DefinedByName	false
Single feature joint	isSingleFtrJnt	false

Assignment to Surfaces:
1;5;6;10

Attribute: 9 **Title: Element 28 x 1**
Sub Type = Surface Mesh **Element Type = QTS4**

Property	Symbol	Value
Element size	size	0.0
Number of divisions in x	xDivisions	28
Number of divisions in y	yDivisions	1
Transition mesh	transition	true
Allow irregular mesh	allowIrregular	true
Element defined by name	DefinedByName	false
Single feature joint	isSingleFtrJnt	false

Assignment to Surfaces:
3;8

7. Geometric: Line

Attribute: 4

Title: Superstructure

Sub Type = Line Geometric
Assigned in: Analysis 1

Property	Symbol	Value
Cross sectional area	A	8.4
Second moment of area about y axis	Iyy	2.5
Second moment of area about z axis	Izz	1000.0
Product moment of area	Iyz	0.0
Torsional constant	J	1000.0
Eccentricity in local z direction, relative to specified origin	ez0	0.7
Eccentricity in local y direction, relative to specified origin	ey0	0.0
Eccentricity in local z direction, relative to beam centroid	ez	0.7
Eccentricity in local y direction, relative to beam centroid	ey	0.0
Wagner constant 1st moment of square radius about y (Iyr)	Iyr	0.0
Wagner constant 1st moment of square radius about z (Izr)	Izr	0.0
Wagner constant 4th moment of area about origin (Irr)	Irr	0.0
Wagner constant 2nd moment of warping about origin (Iwr)	Iwr	0.0
Effective shear area in local z direction	Asz	8.4
Effective shear area in local y direction	Asy	8.4
Radius of gyration about y axis	ky	0.5
Radius of gyration about z axis	kz	10.9
y axis extreme fibre, top	yt	0.0
y axis extreme fibre, bottom	yb	0.0
z axis extreme fibre, top	zt	0.0
z axis extreme fibre, bottom	zb	0.0
Shape code identifier	Type	-1
Element type	elementType	"3D Thick Beam"
Reinforcement	reinforcement	None

Assignment to Lines:
5T9;60T68I2;71T79I2

Attribute: 6

Title: Column

Sub Type = Line Geometric

Assigned in: Analysis 1

Property	Symbol	Value
Cross sectional area	A	1.1
Second moment of area about y axis	Iyy	0.1
Second moment of area about z axis	Izz	0.1
Product moment of area	Iyz	0.0
Torsional constant	J	0.2
Eccentricity in local z direction, relative to specified origin	ez0	0.0
Eccentricity in local y direction, relative to specified origin	ey0	0.0
Eccentricity in local z direction, relative to beam centroid	ez	0.0
Eccentricity in local y direction, relative to beam centroid	ey	0.0
Wagner constant 1st moment of square radius about y (Iyr)	Iyr	0.0
Wagner constant 1st moment of square radius about z (Izr)	Izr	0.0
Wagner constant 4th moment of area about origin (Irr)	Irr	0.0
Wagner constant 2nd moment of warping about origin (Iwr)	Iwr	0.0
Effective shear area in local z direction	Asz	1.0
Effective shear area in local y direction	Asy	1.0
Radius of gyration about y axis	ky	0.3
Radius of gyration about z axis	kz	0.3
y axis extreme fibre, top	yt	0.0
y axis extreme fibre, bottom	yb	0.0
z axis extreme fibre, top	zt	0.0
z axis extreme fibre, bottom	zb	0.0
Shape code identifier	Type	-1
Element type	elementType	"3D Thick Beam"
Reinforcement	reinforcement	None

Assignment to Lines:
1T4

8. Geometric: Surface

Attribute: 8

Title: Fictive shell elements t = 1.0 m Sub Type = Surface

Geometric Assigned in: Analysis 1

Property	Symbol	Value
Thickness	t	1.0
Eccentricity in local z direction, relative to beam centroid	ez	0.0

Assignment to Surfaces:

1T10

9. Isotropic material

Attribute: 2

Title: Dynamic (column)

Sub Type = Isotropic Material

Assigned in: Analysis 1

Property	Symbol	Value
Young's modulus	E	34000000.0
Poisson's ratio	nu	0.2
Density	rho	2.5

Assignment to Lines:

1T4

Attribute: 3

Title: Dynamic (superstructure)

Sub Type = Isotropic Material

Assigned in: Analysis 1

Property	Symbol	Value
Young's modulus	E	34000000.0
Poisson's ratio	nu	0.2
Density	rho	3.1

Assignment to Lines:

5T9;60T68I2;71T79I2

Attribute: 4

Title: Fictive shell elements

Sub Type = Isotropic Material

Assigned in: Analysis 1

Property	Symbol	Value
Young's modulus	E	1000000.0
Poisson's ratio	nu	0.0
Density	rho	0.1

Assignment to Surfaces:

1T10

10. Joint material

Attribute: 5 Title: Joint JSH4
Sub Type = Joint Material, Spring Stiffness Only
Assigned in: Analysis 1

	u	v	w	THx	THy	THz
Number of degrees	6	6	6	6	6	6
Joint type	JointType	"3D beams and/or	"3D beams and/or	"3D beams and/or	"3D beams and/or	"3D beams and/or
Assignment type	Assignment	"Point"	"Point"	"Point"	"Point"	"Point"
Elastic spring	K[0]	1000000000000.0	1000000000000.0	1000000000000.0	1000000000000.0	1000000000000.0
Elastic spring	K[1]	1000000000000.0	1000000000000.0	1000000000000.0	1000000000000.0	1000000000000.0
Elastic spring	K[2]	1000000000000.0	1000000000000.0	1000000000000.0	1000000000000.0	1000000000000.0
Elastic spring	K[3]	1000000000000.0	1000000000000.0	1000000000000.0	1000000000000.0	1000000000000.0
Elastic spring	K[4]	1000000000000.0	1000000000000.0	1000000000000.0	1000000000000.0	1000000000000.0
Elastic spring	K[5]	1000000000000.0	1000000000000.0	1000000000000.0	1000000000000.0	1000000000000.0

Assignment to Points:

1;2;5T8;15;16

11. Support

Attribute: 4

Title: Point: Support 14

Sub Type = Structural Support
Assigned in: Analysis 1

Property	Symbol	Value
Translation in X	U	"F"
Translation in Y	V	"R"
Translation in Z	W	"R"
Rotation about X	THX	"R"
Rotation about Y	THY	"F"
Rotation about Z	THZ	"R"
Torsional warping	Torsion	"F"
Moment about hinge	L1	"F"
Pore pressure	pore	"C"

Assignment to Points:
10;13

Attribute: 5

Title: Point: Support 23

Sub Type = Structural Support
Assigned in: Analysis 1

Property	Symbol	Value
Translation in X	U	"R"
Translation in Y	V	"R"
Translation in Z	W	"R"
Rotation about X	THX	"R"
Rotation about Y	THY	"S"
Rotation about Z	THZ	"R"
Torsional warping	Torsion	"F"
Moment about hinge	L1	"F"
Pore pressure	pore	"C"
Spring stiffness distribution	springType	"Total"
Stiffness in rotation about Y	THYstiff	15000000.0

Assignment to Points:
3;4

12. Search Area

Attribute: 1

Title: Ficive deck

Sub Type = Search Area
Assignment to Surfaces: 1T10

13. Body load

Attribute: 1

Title: Dead weight

Sub Type = Body Force Load

Property	Symbol	Value
Linear acceleration in X	AccX	0.0
Linear acceleration in Y	AccY	0.0
Linear acceleration in Z	AccZ	-10.0
Angular velocity about X axis	AngVelX	0.0
Angular velocity about Y axis	AngVelY	0.0
Angular velocity about Z axis	AngVelZ	0.0
Angular acceleration about X axis	AngAccX	0.0
Angular acceleration about Y axis	AngAccY	0.0
Angular acceleration about Z axis	AngAccZ	0.0
Linear acceleration In X fluid phase	lnFlAccX	0.0
Linear acceleration In Y fluid phase	lnFlAccY	0.0
Linear acceleration In Z fluid phase	lnFlAccZ	-10.0

Assignment to Lines:

1T9;60T68I2;71T79I2

14. Discrete point load

Symbol	Property
dirType	Load direction
pDir	Projection vector
nGridX	X Grid size
nGridY	Y Grid size
pos	Coordinates
P	Load

Attribute: 2 Title: Unite Axle Load
Sub Type = Discrete Point Load

dirType	pDir_x	pDir_y	pDir_z	nGridX	nGridY
Z	0.0	0.0	1.0	0	0
pos_x	**pos_y**	**pos_z**	**Pz**		
0.0	0.0	0.0	-1.05		

Search area=Fictive deck
Moving status = Include Full Load

Path discrete longitudinal axes (null)
Assignment to Line: 35

Patch transformation = None Load transformation = None
Search area=Fictive deck

15. Load groups: HSLM-A1

Load groups : HLML-A1

s	P	s	P
0	170	-271.763	170
-3.000	170	-287.763	170
-14.000	170	-289.763	170
-17.000	170	-305.763	170
-20.525	170	-307.763	170
-22.525	170	-323.763	170
-35.7625	170	-325.763	170
-37.7625	170	-341.763	170
-53.7625	170	-343.763	170
-55.7625	170	-359.763	170
-71.7625	170	-361.763	170
-73.7625	170	-375.000	170
-89.7625	170	-377.000	170
-91.7625	170	-380.525	170
-107.763	170	-383.525	170
-109.763	170	-394.525	170
-125.763	170	-397.525	170
-127.763	170		
-143.763	170		
-145.763	170		
-161.763	170		
-163.763	170		
-179.763	170		
-181.763	170		
-197.763	170		
-199.763	170		
-215.763	170		
-217.763	170		
-233.763	170		
-235.763	170		
-251.763	170		
-253.763	170		
-269.763	170		

16. IMD Analysis

Type: IMD analysis

Load groups : HSLM-A1
Track: Line 35
Speed : 39, 83
Speed intervall: 4.4
Dampening: 0.010
Influence attributes :
Inf 1 - Deformation
Inf 2 – Acceleration
Inf 3 – Forces

Title: Results

Model Units: kN,m,t,s,C
Report Units: kN,m,t,s,C

Model Title: System 001
Model File: System 001

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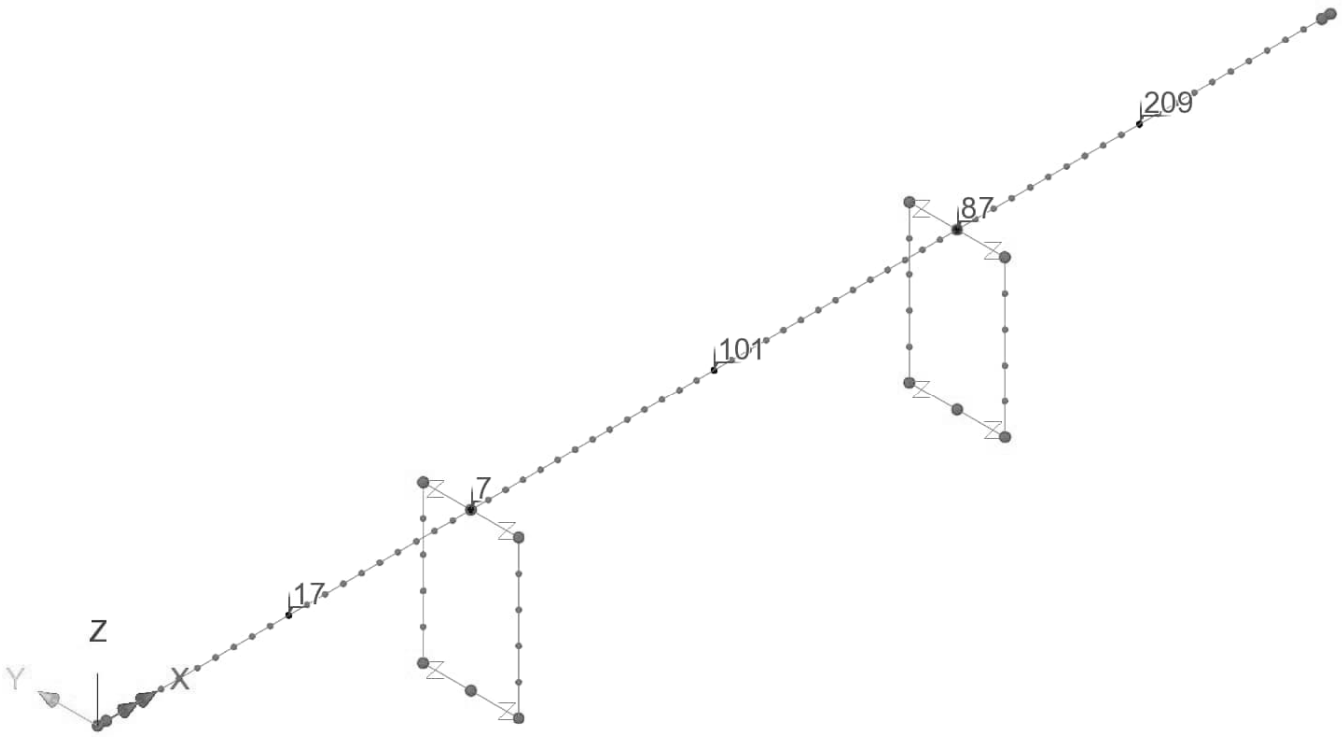
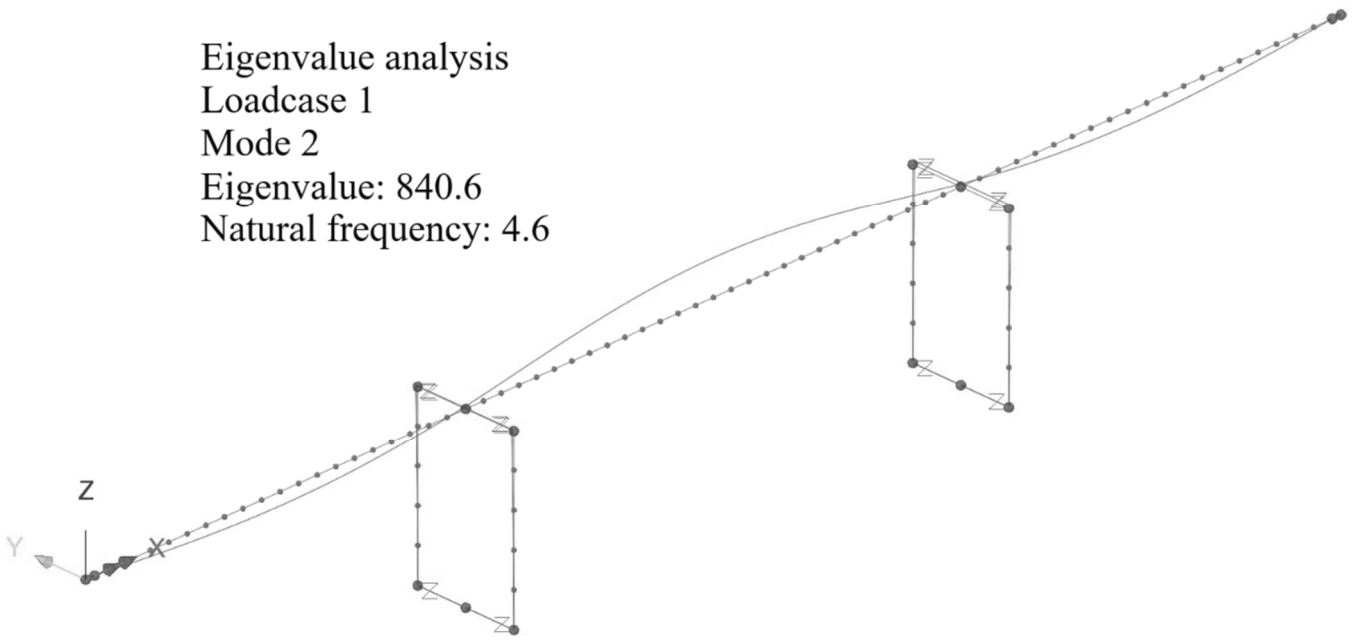
1. Result nodes

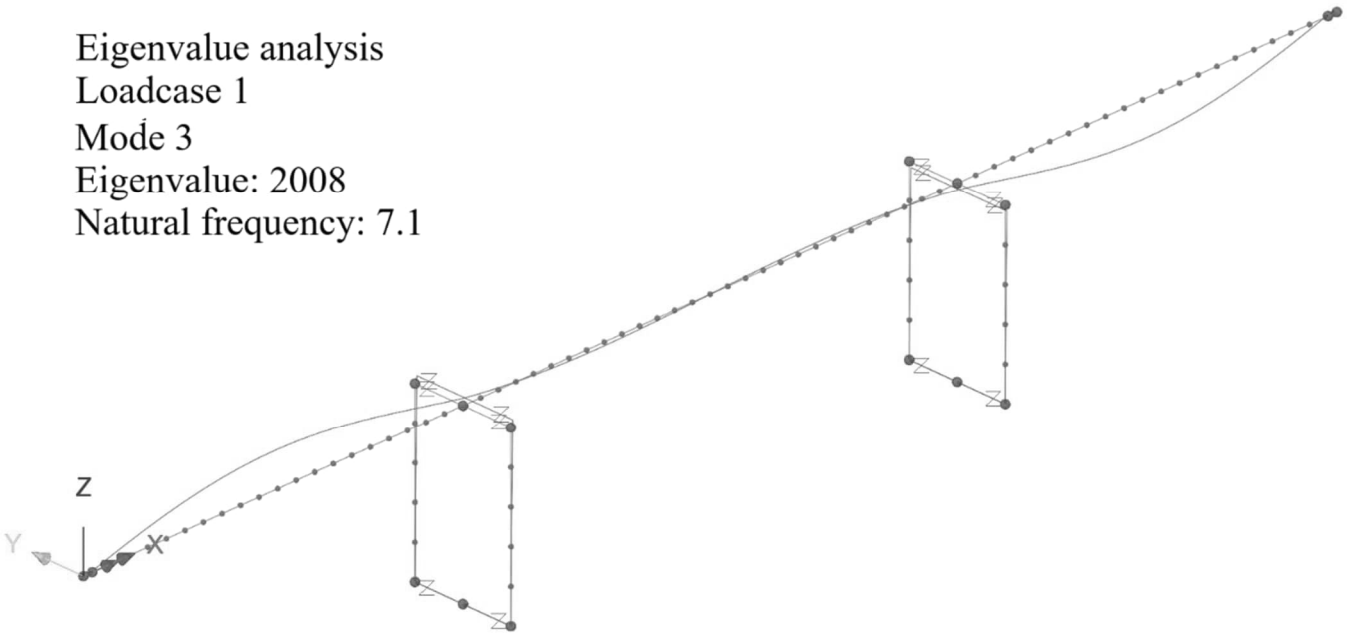


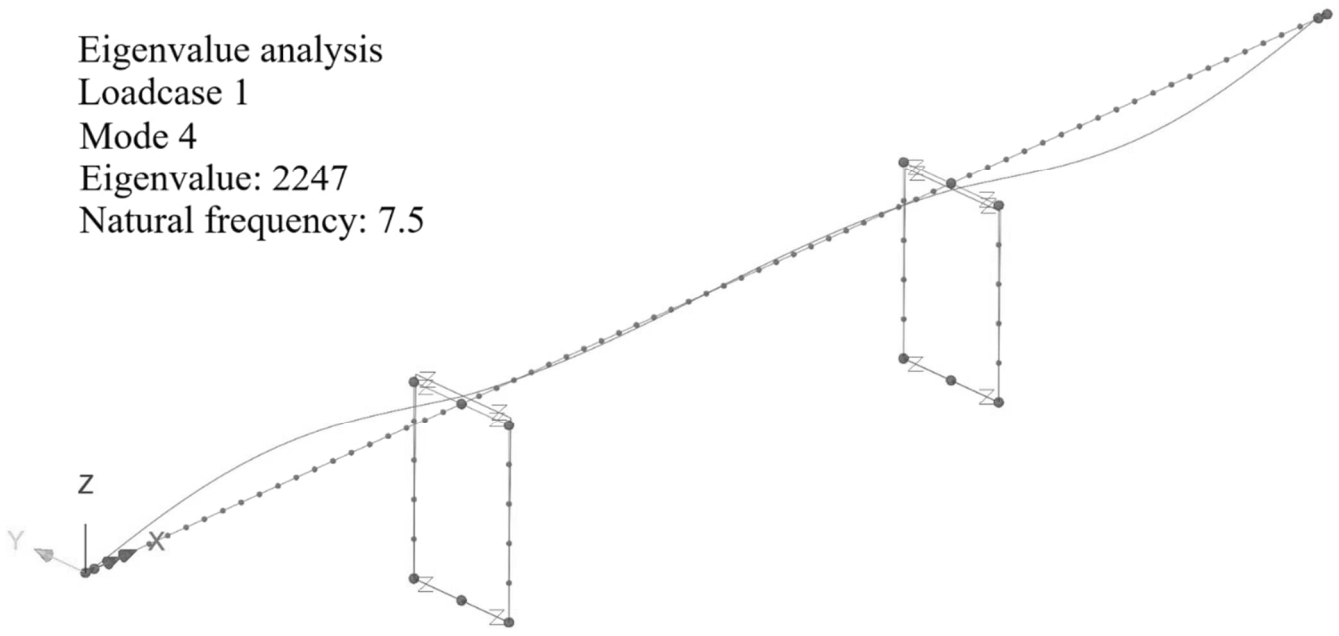
Node	X	Y	Z
17	11.0	0	0
7	21.5	0	0
101	35.5	0	0
87	49.5	0	0
209	60.0	0	0
-	m	m	m

2. Eigenvalues

Nr	Mode	Eigenvalue	Frequency
1	1	9	0.5
2	2	841	4.6
3	3	2008	7.1
4	4	2247	7.5
5	5	6687	13.0
6	6	14261	19.0
7	7	17931	21.3
8	8	21364	23.3
9	9	29004	27.1
10	10	35202	29.9
11	11	35274	29.9
12	12	38216	31.1




Eigenvalue analysis
Loadcase 1
Mode 3
Eigenvalue: 2008
Natural frequency: 7.1
Z
Y
X


Eigenvalue analysis
Loadcase 1
Mode 4
Eigenvalue: 2247
Natural frequency: 7.5
Z
Y
X

3. Participation factors

Mode	P.Factor X	P.Factor Y	P.Factor Z	Frequency
1	-74.7	0.0	0.0	0.5
2	0.0	0.0	18.9	4.6
3	0.1	0.0	0.0	7.1
4	0.0	0.0	67.1	7.5
5	0.0	0.0	0.0	13.0
6	0.0	0.0	-12.5	19.0
7	0.1	0.0	0.0	21.3
8	0.0	0.0	0.1	23.3
9	0.0	0.0	13.6	27.1
10	5.2	0.0	0.0	29.9
11	0.0	0.0	0.9	29.9
12	0.0	0.0	0.0	31.1

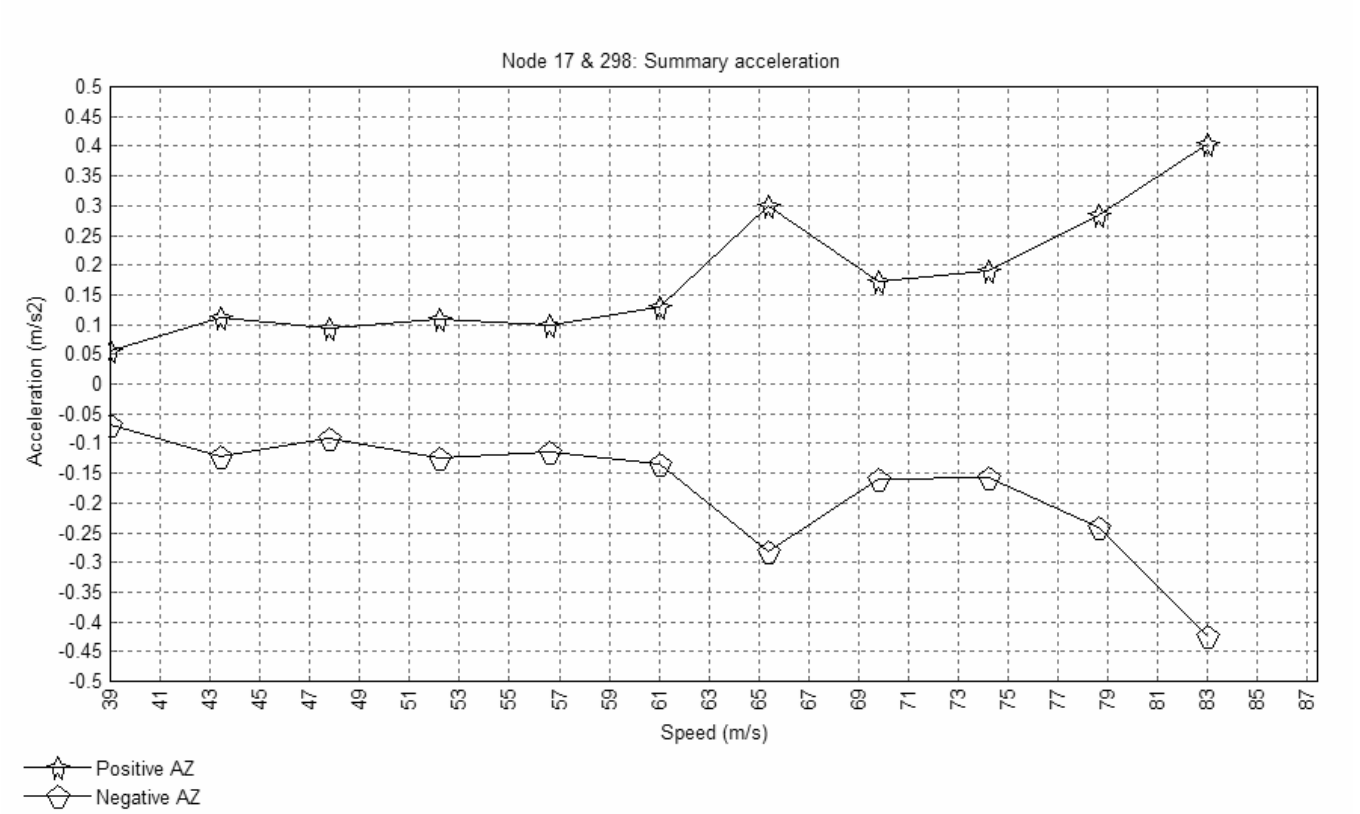
4. Mass participation factors

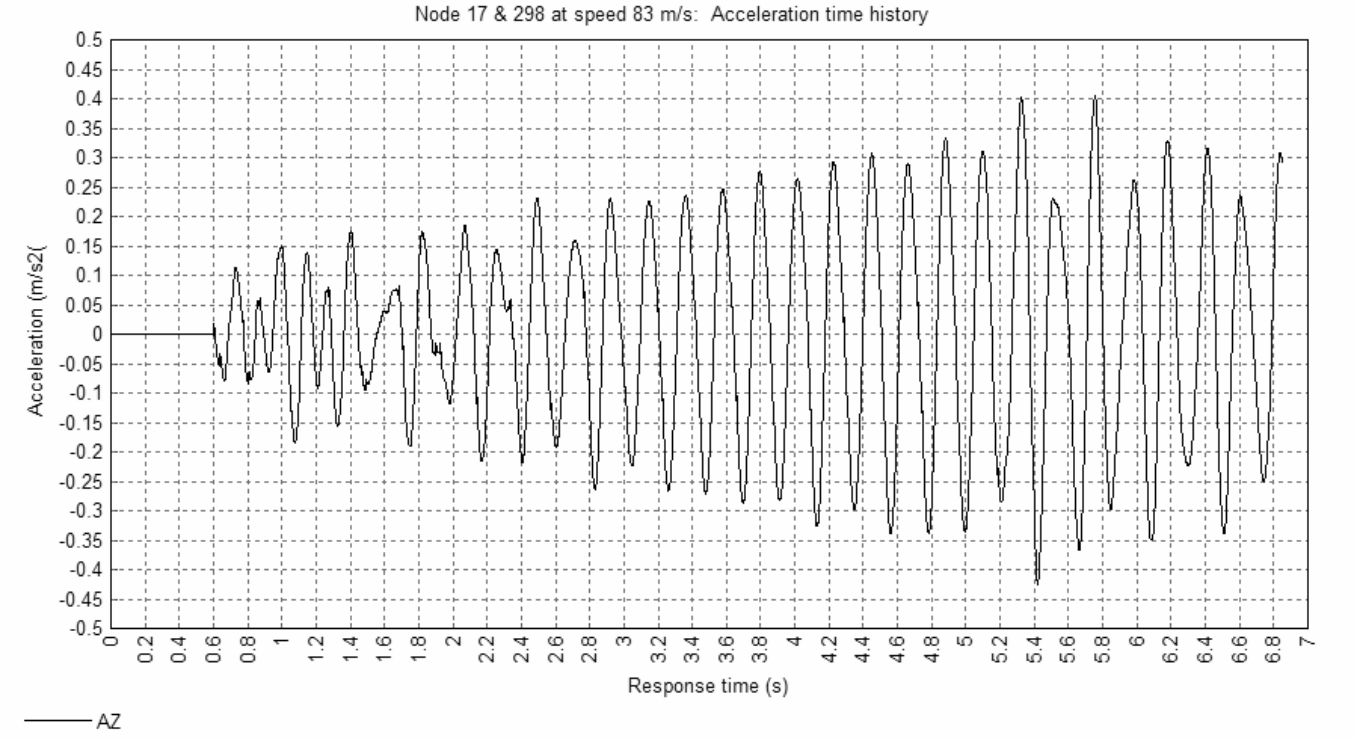
Mode	Mass PF X	Mass PF Y	Mass PF Z	Frequency
1	1.0	0.0	0.0	0.5
2	0.0	0.0	0.1	4.6
3	0.0	0.0	0.0	7.1
4	0.0	0.0	0.8	7.5
5	0.0	0.0	0.0	13.0
6	0.0	0.0	0.0	19.0
7	0.0	0.0	0.0	21.3
8	0.0	0.0	0.0	23.3
9	0.0	0.0	0.0	27.1
10	0.0	0.0	0.0	29.9
11	0.0	0.0	0.0	29.9
12	0.0	0.0	0.0	31.1

5. Sum mass participation factors

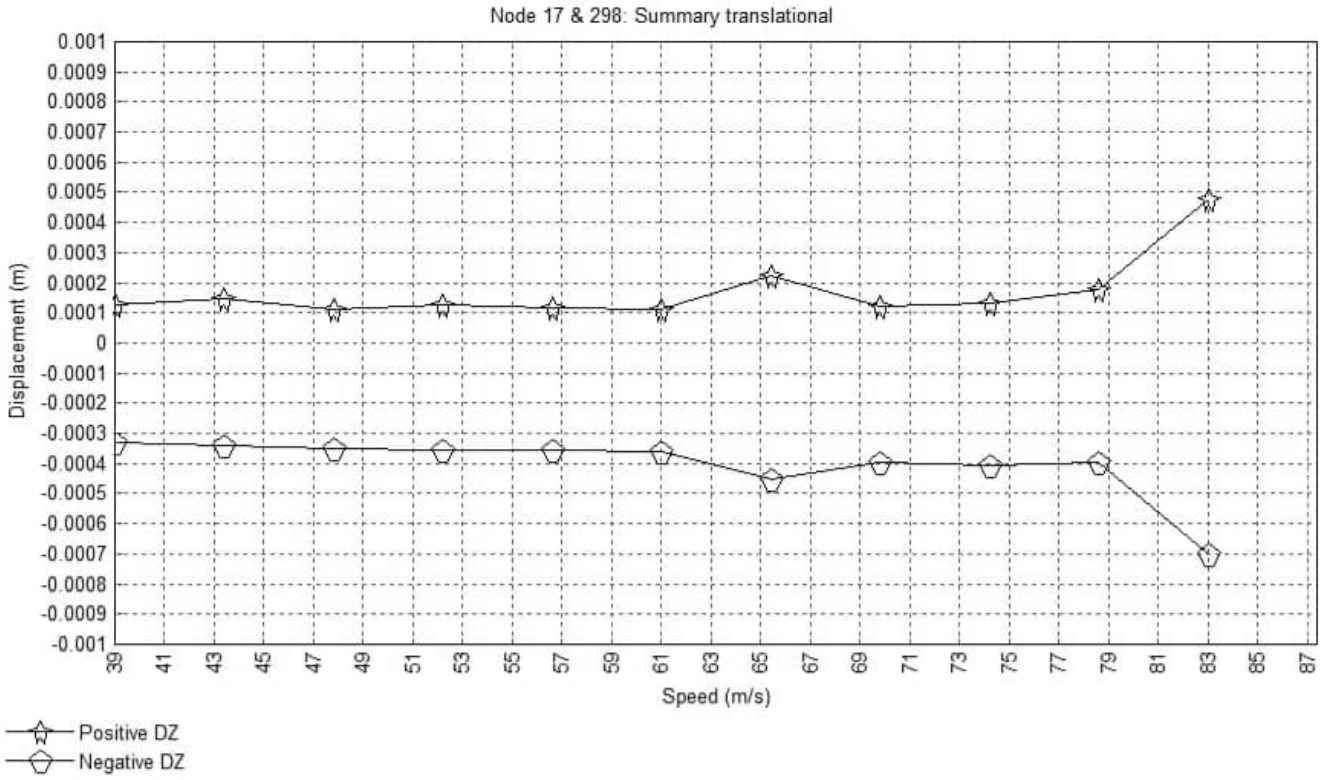
Mode	Sum Mass X	Sum Mass Y	Sum Mass Z	Frequency
1	0.99	0.00	0.00	0.5
2	0.99	0.00	0.06	4.6
3	0.99	0.00	0.06	7.1
4	0.99	0.00	0.86	7.5
5	0.99	0.00	0.86	13.0
6	0.99	0.00	0.89	19.0
7	0.99	0.00	0.89	21.3
8	0.99	0.00	0.89	23.3
9	0.99	0.00	0.92	27.1
10	1.00	0.00	0.92	29.9
11	1.00	0.00	0.92	29.9
12	1.00	0.00	0.92	31.1

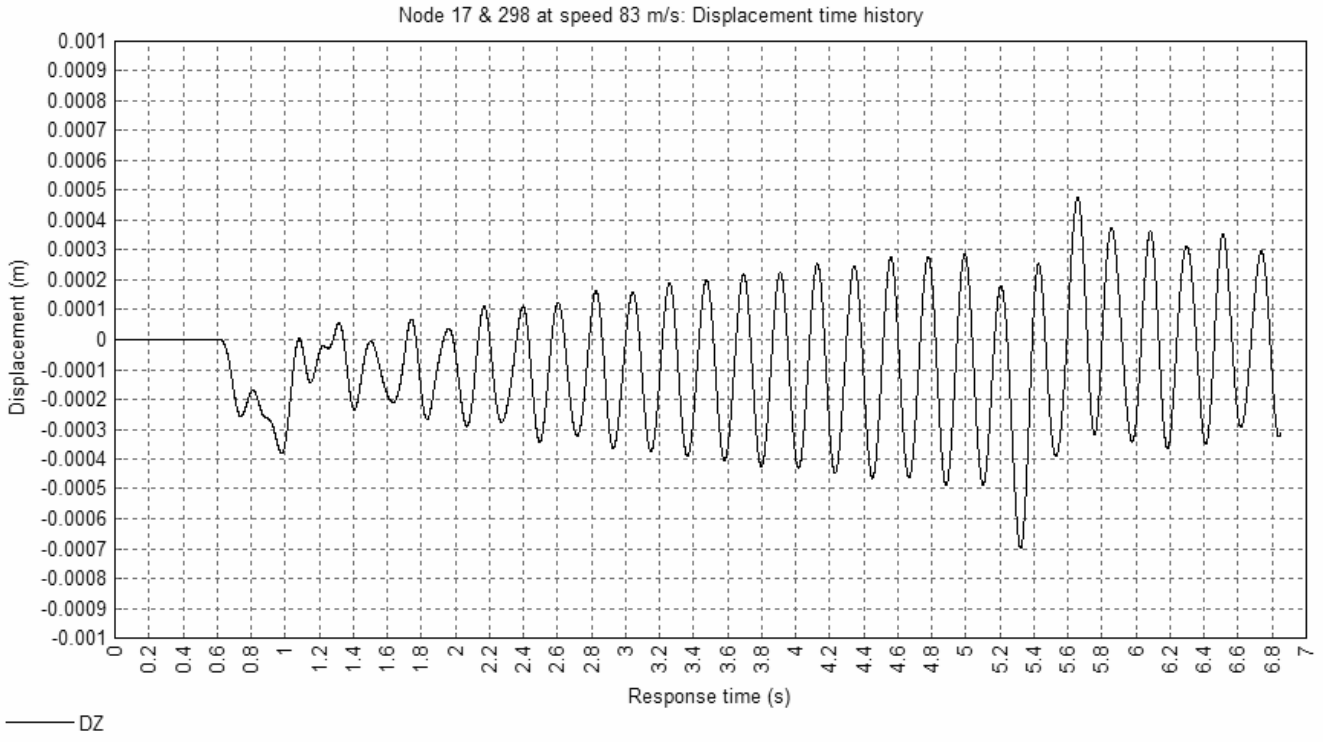
6. Acceleration (Z-direction)





7. Deformation (Z-direction)





8. Design moment (My)