

RC closed frame bridge

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1. GENERAL / MEASUREMENT

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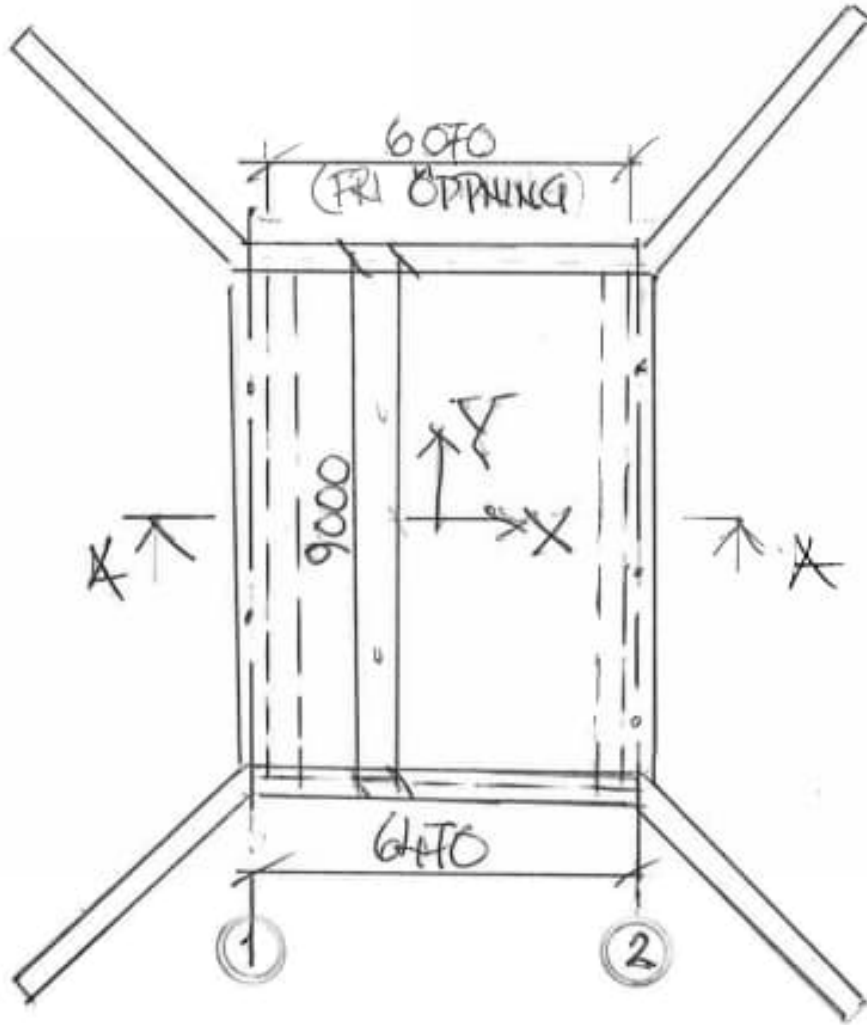
1.1 CONCRETE TYPE

Open frame constructed using reinforced concrete.

Foundation on compacted gravel.

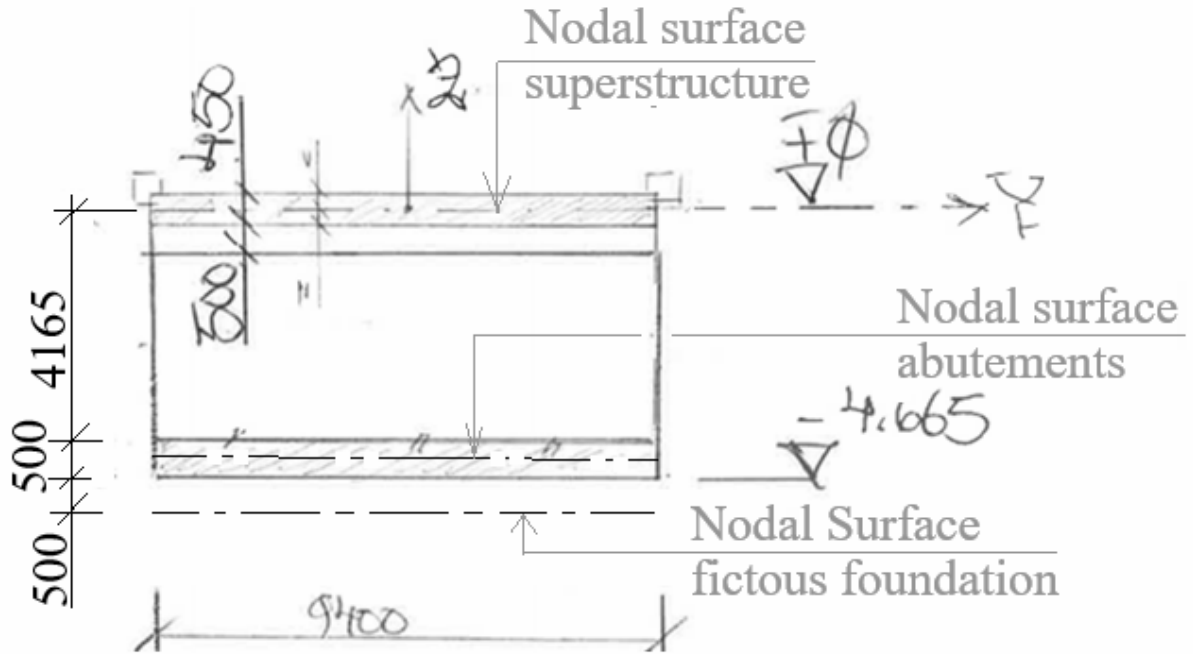
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1.2 MEASUREMENT



PLAN

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SECTION B-B

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1.3 FOUNDATION

Bottom slab is founded on 0.3 m compacted gravel on rock.

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1.4 CODE OCH TENDER DOCUMENTS

Eurocode: SS-EN 1990→ SS-EN 1999

1.5 TECHNICAL SERVICE LIFE

Technical life span 120 years (L100).

1.6 ENVIRONMENT

Pedestrian environment is assumed for the underlying pedestrical road.

Road traffic enviroment is assumed for the overlying traffic road.

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1.7 MATERIAL

Concrete : C30/37(CEM I 42.5 N, Anläggningscement klass N)

Reinforcement : B500B

Filling abutement : "Förtärkningslagermaterial" according to AMA CEB.52

Surfacing : See document "OTB/bro"

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1.8 GEOTECHNICAL CLASS

Geotechnical class GK2

1.9 SAFETY CLASS

Geotechnical resistance: safety class 2

Brigde structure : safety class 2

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1.10 CONCRETE COVER AND CRACK CRITERIA

Class identification bridge components :

Bridge components	Exposure class	Life spann	max $v_{ct_{ekv}}$	ζ
Substructure :				
▫ Wingwall to filling	XD1/XF4	L100	0.40	1.5
▫ Wingwall from filling	XD1/XF4	L100	0.40	1.5
▫ Abutement under ground	XC2/XF3	L100	0.50	1.0
▫ Abutement over ground	XC4/XF3	L100	0.50	1.2
▫ Bottom slab to foundation	XC2/XF3	L100	0.50	1.0
▫ Bottom slab remaing parts	XC2/XF3	L100	0.50	1.0
Superstructure :				
▫ Edge beam	XD3/XF4	L100	0.40	1.8
▫ Top bridge deck	XD1/XF4	L100	0.40	1.5
▫ Bottom bridge deck	XD3/XF4	L100	0.40	1.8

	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A1:11
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Design parameters reinforced concrete:

$$c_{min} = \max (c_{min.b}, c_{min.dur})$$

$$c_{nom} = c_{min} + \Delta c_{dev}$$

Bridge components	$c_{min.dur}$	$c_{min.b}$	c_{min}	Δc_{dev}	c_{nom}	$W_{k,till}$
Substructure :						
▫ Wingwall to filling	30	25	30	10	40	0.20
▫ Wingwall from filling	30	25	30	10	40	0.20
▫ Abutement under ground	15	25	25	10	35	0.40
▫ Abutement over ground	20	25	25	10	35	0.30
▫ Bottom slab to foundation	15	16	16	75 ^{4.)}	91 ^{5.)}	0.40
▫ Bottom slab remaining parts	15	25	25	10	35	0.40
Superstructure :						
▫ Edge beam	45	25	45	10	55	0.15
▫ Top bridge deck	25	25	25	10	35	0.20
▫ Bottom bridge deck	45	25	45	10	55	0.15
-	mm	mm	mm	mm	mm	mm

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2. SYSTEM ANALYSIS

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2.1 GENERAL

The bridge is built using reinforced concrete.

The bridge is designed as frame bridge.

Abutments are defined by using shell elements applied to nodal surface in abutments.

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

Entire structure is modelled using isotropic material.

Bridge foundation consists of compacted gravel.

System analysis is performed using 3D FEM-program.

Wingwalls are not modelled statically since considered inactive in vertical direction. This is due cracking and the use of only minimal reinforcement in this 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.

Foundation stiffness in vertical direction is modelled using vertical springs connection to corresponding to foundation modulus. These springs are connected to underside of bottom slab.

Friction between foundation and bottom slab in horizontal plane is modelled using a fictive rigid beam restrained against translation in X-Y plane.

The vertical stiffness between foundation and bottom slab is modelled using a rigid fictive foundation surface. Between nodal surface of bottom slab and fictive foundation joints are introduced in vertical direction (Z-plane). The chosen stiffness corresponds to stiffness of earth material.

A “super node” is positioned at centre of fictive foundation. This enables the retrieval of reaction forces.

Attachments:

Attachment	Name	Software	System
1	Input receipt	FEM	1
2	Results reactions	FEM	1
3	Results bottom slabs	FEM	1
4	Results abutments	FEM	1
5	Results bridge deck	FEM	1

	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A2:3
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2.2 SKETCH SYSTEM ANALYSIS

2.2.1 Geometry

To describe geometry FEM-program first defines POINTS.

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.

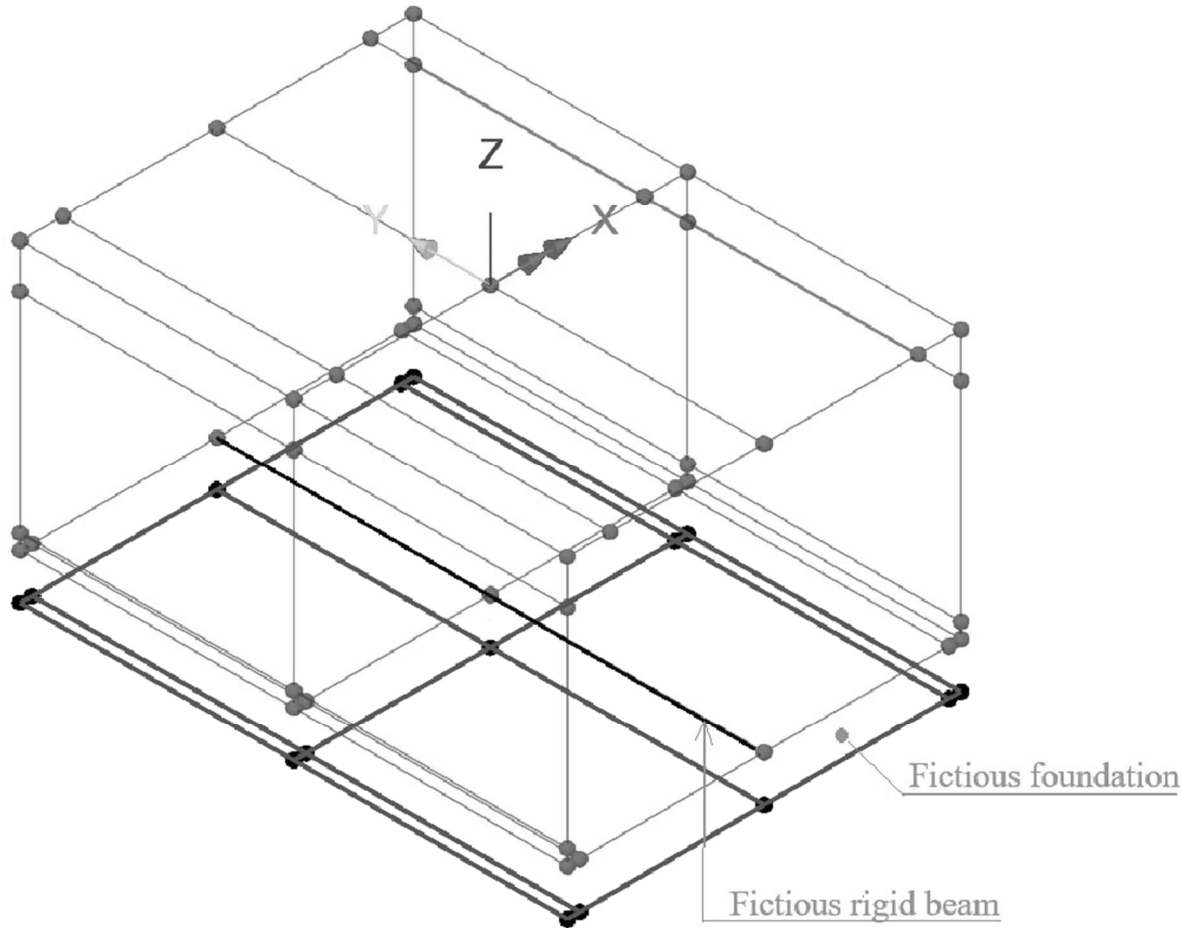
All coordinates needed to describe POINTS are found in attachment 1.

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

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

	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A2:4
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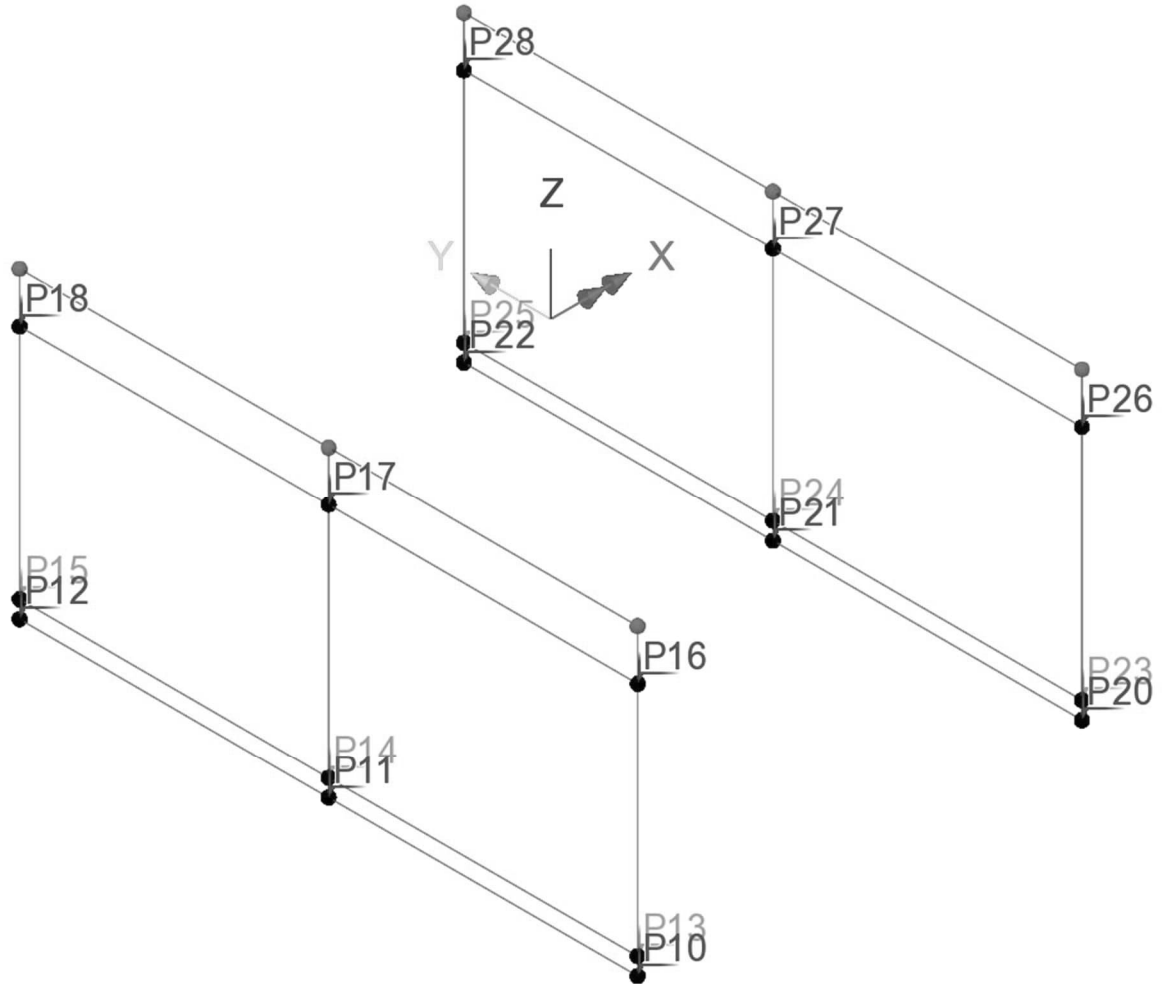
Overview :



	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A2:5
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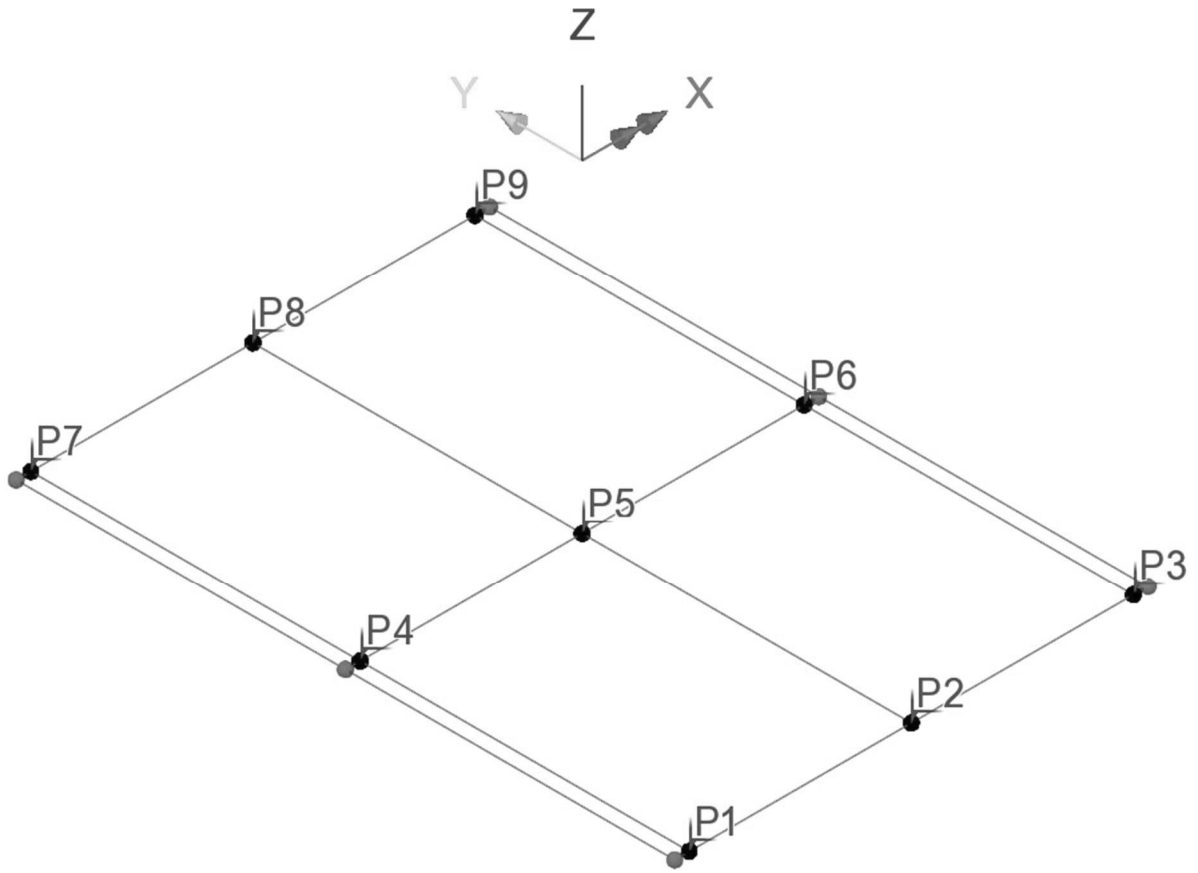
2.2.1.1 Geometri : POINTS

Abutement 1/2.:



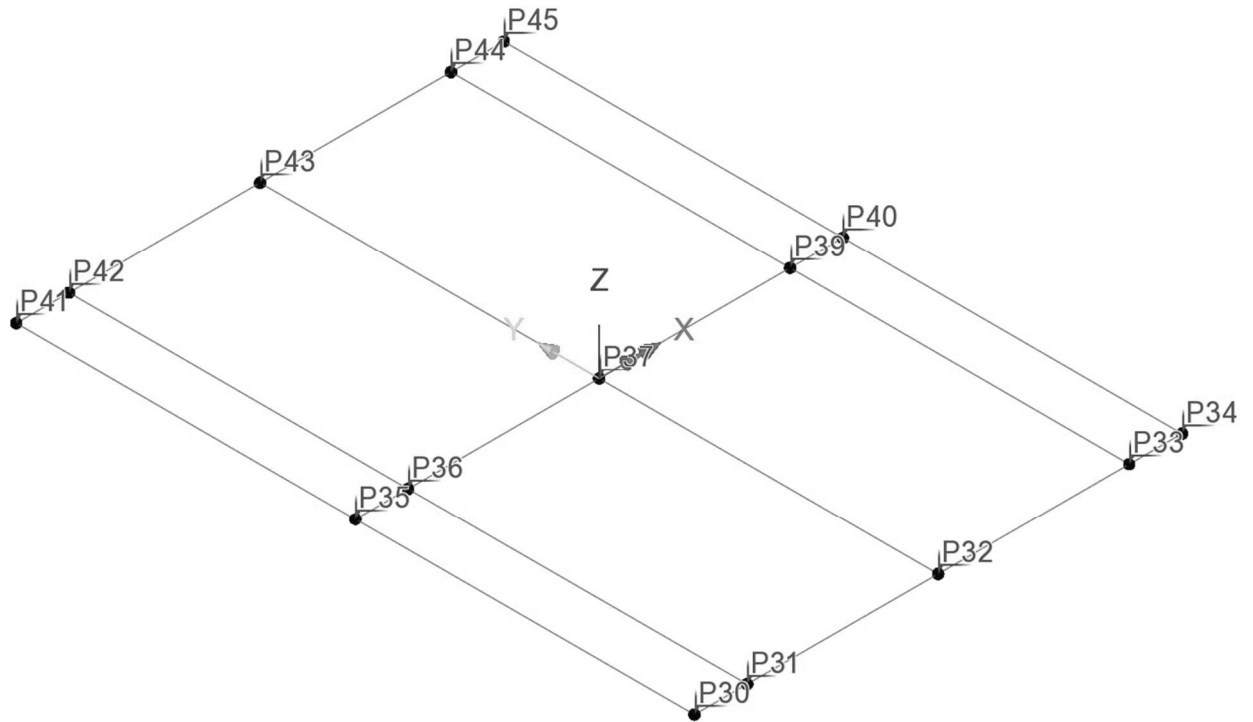
	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A2:6
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Bottom slab:



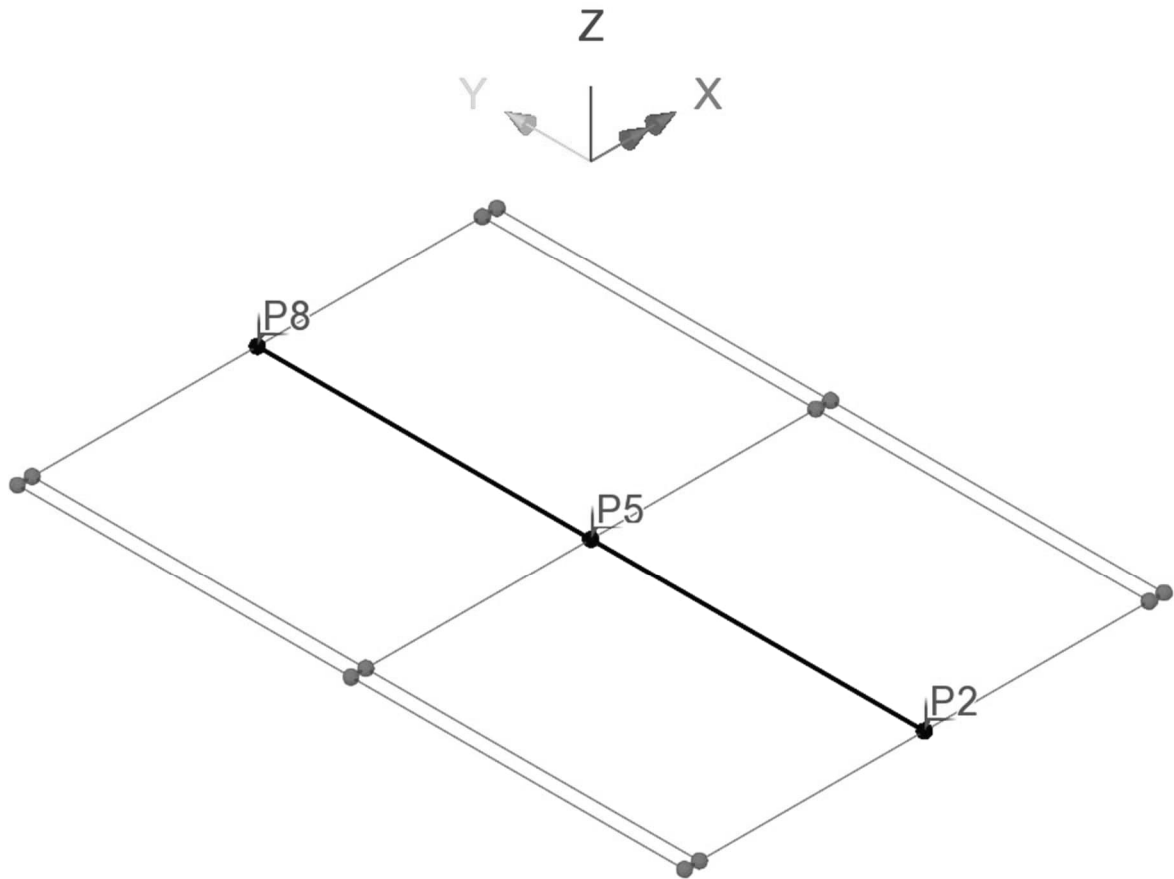
	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A2:7
		Date :	Created :

Superstructure:



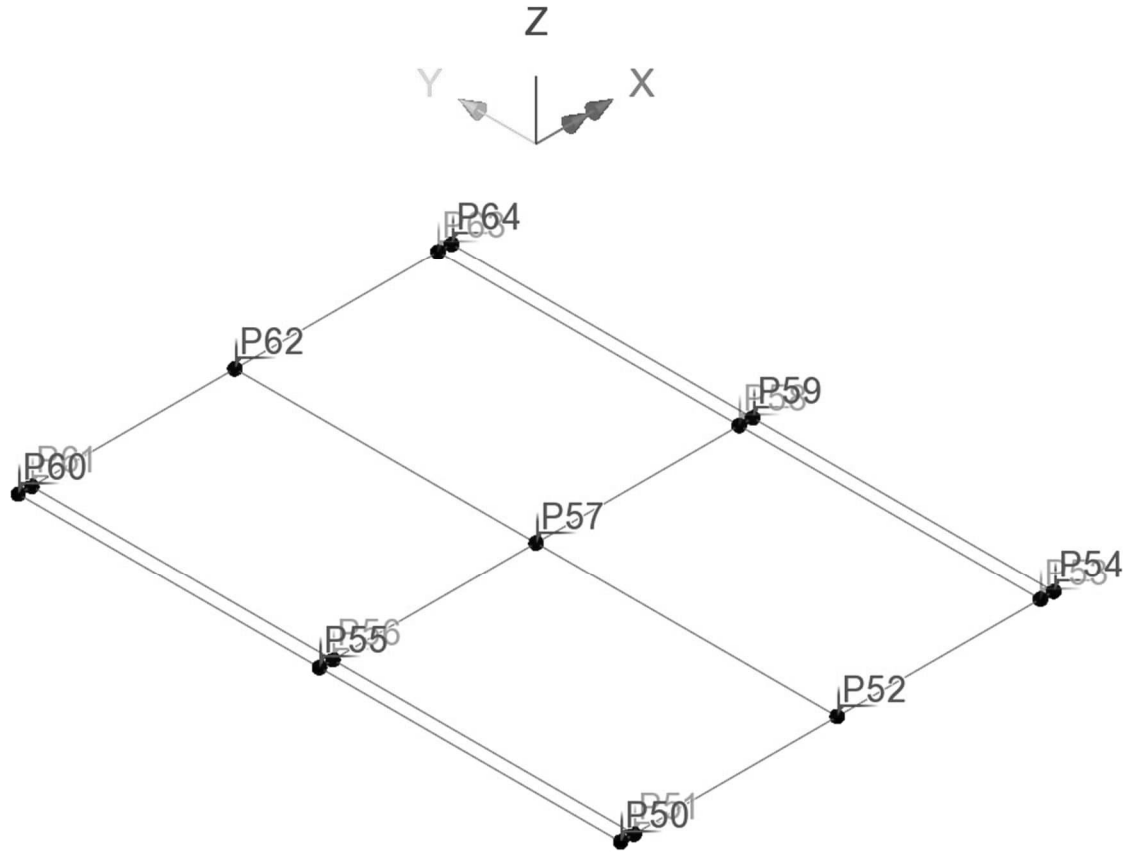
	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A2:8
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Rigid support beam:



	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A2:9
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Fictious foundation :



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2.2.1.2 Geometry: LINES

LINES are defined by POINTS, see appendix 1.

2.2.1.3 Geometry: SURFACES

SURFACES are defined by POINTS, see appendix 1.

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2.2.1.4 MESH

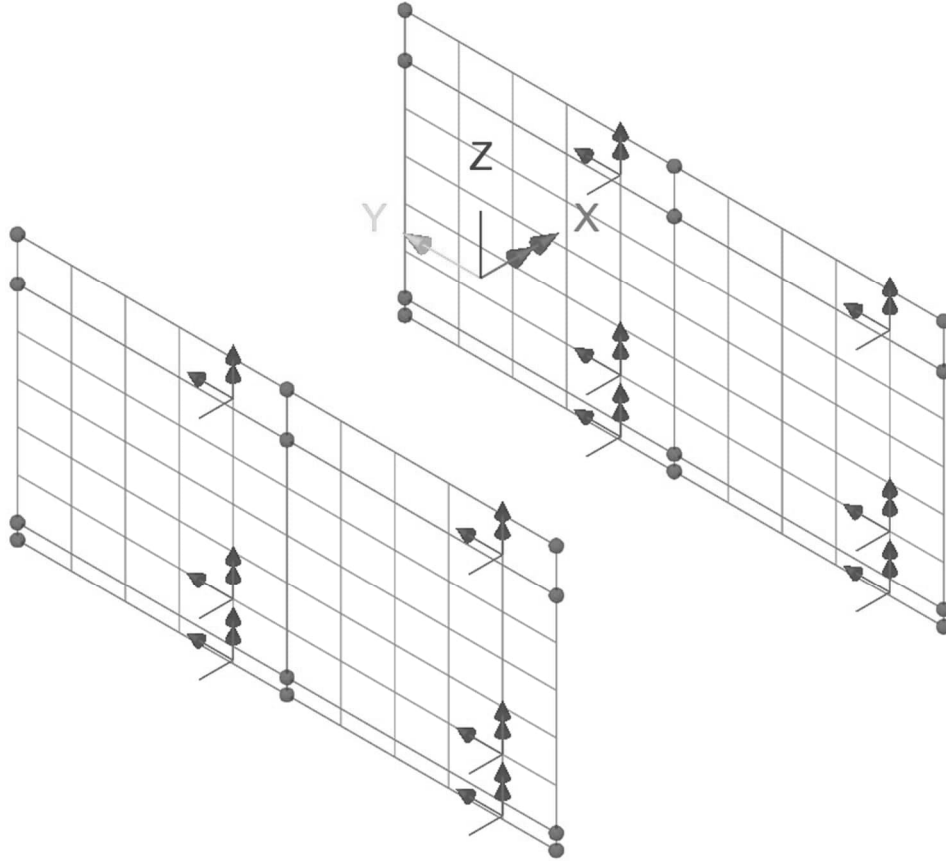
The previous defined SURFACES are attributed in order to create a MESH.

When creating a MESH automatically ELEMENTS and NODES.

Studied bridge is modelled using shell elements ("Thick shell" / QTS4).

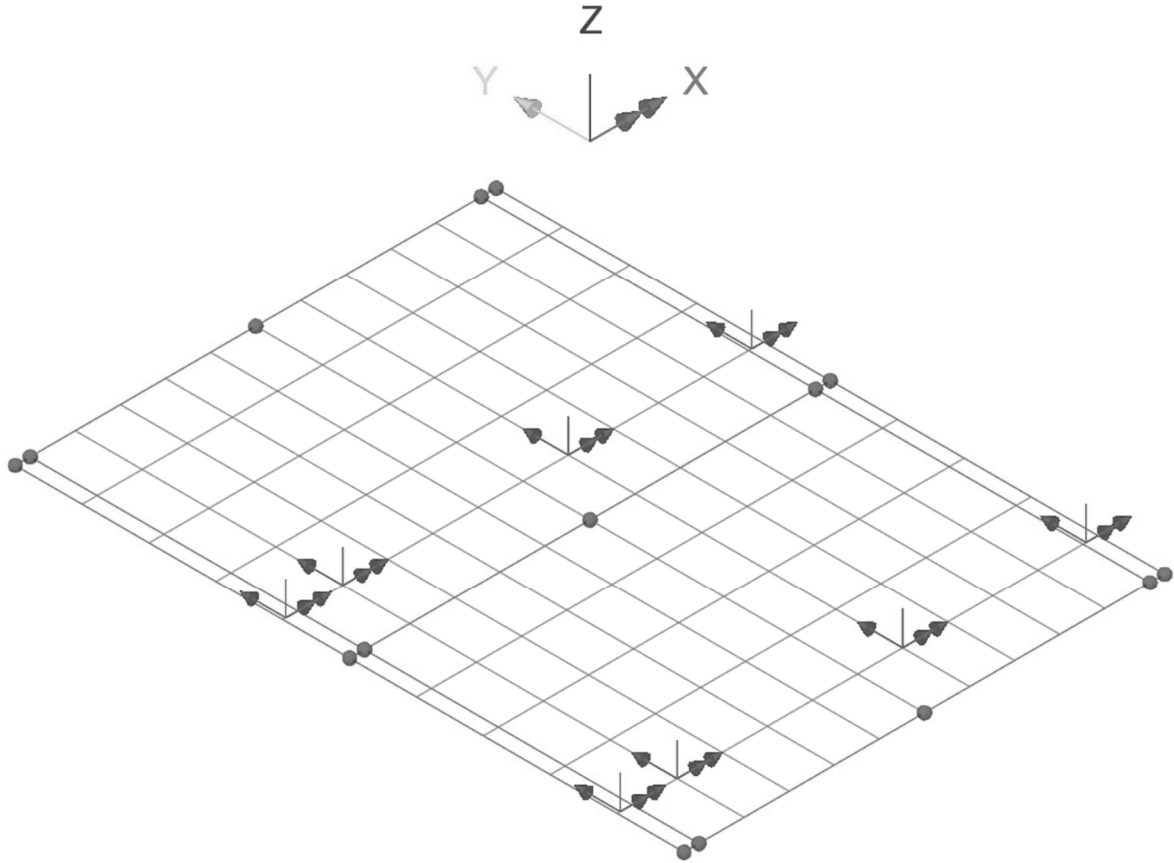
	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A2:12
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Abutments 1/2 :



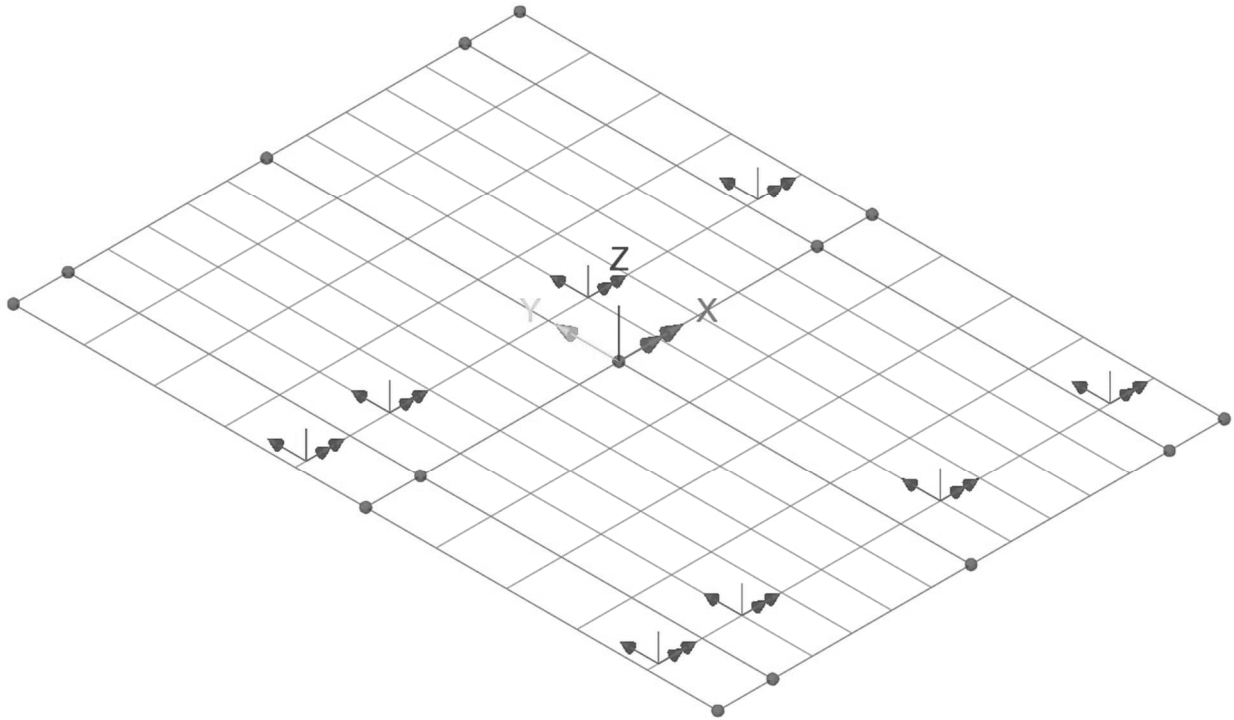
	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A2:13
		Date :	Created :

Bottom slab:



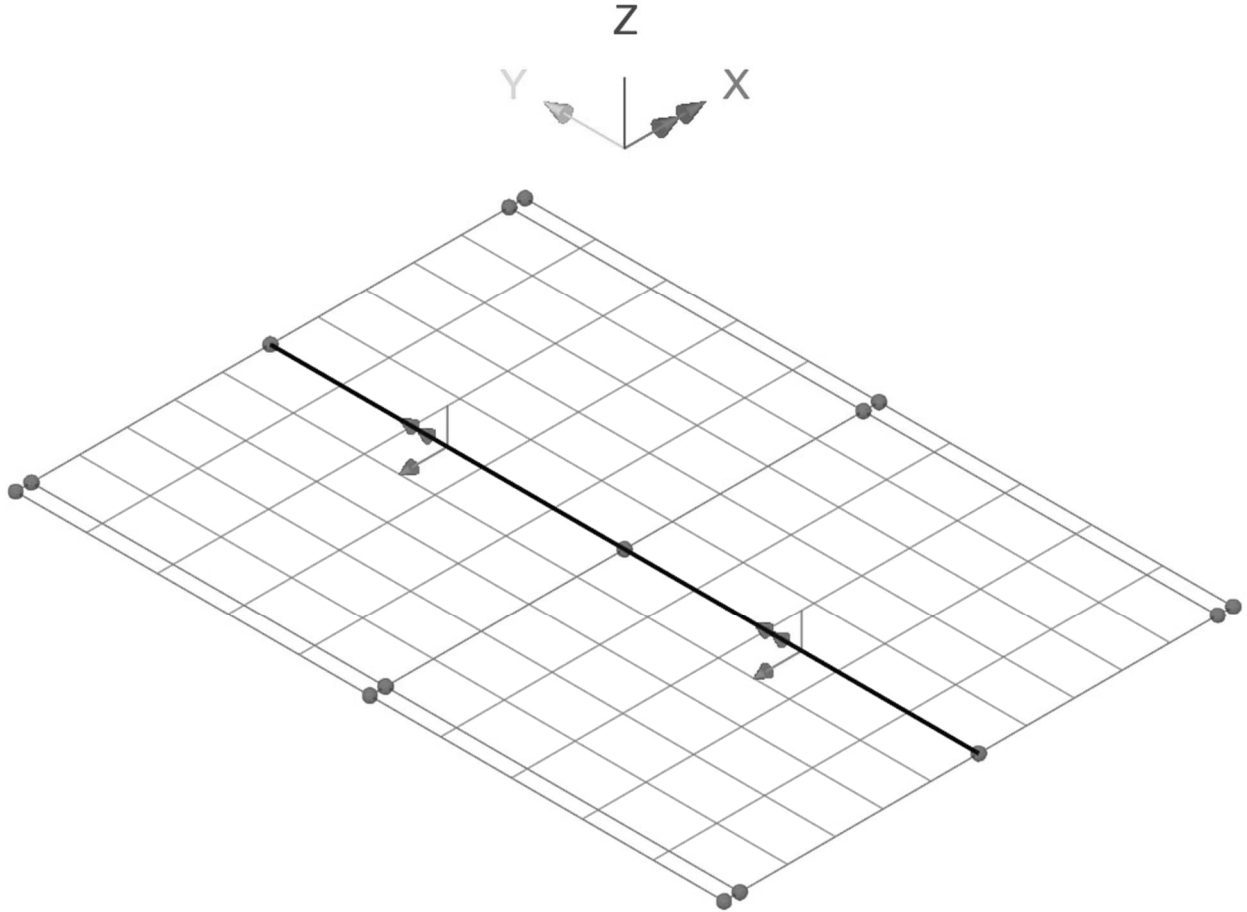
	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A2:14
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Superstructure.:



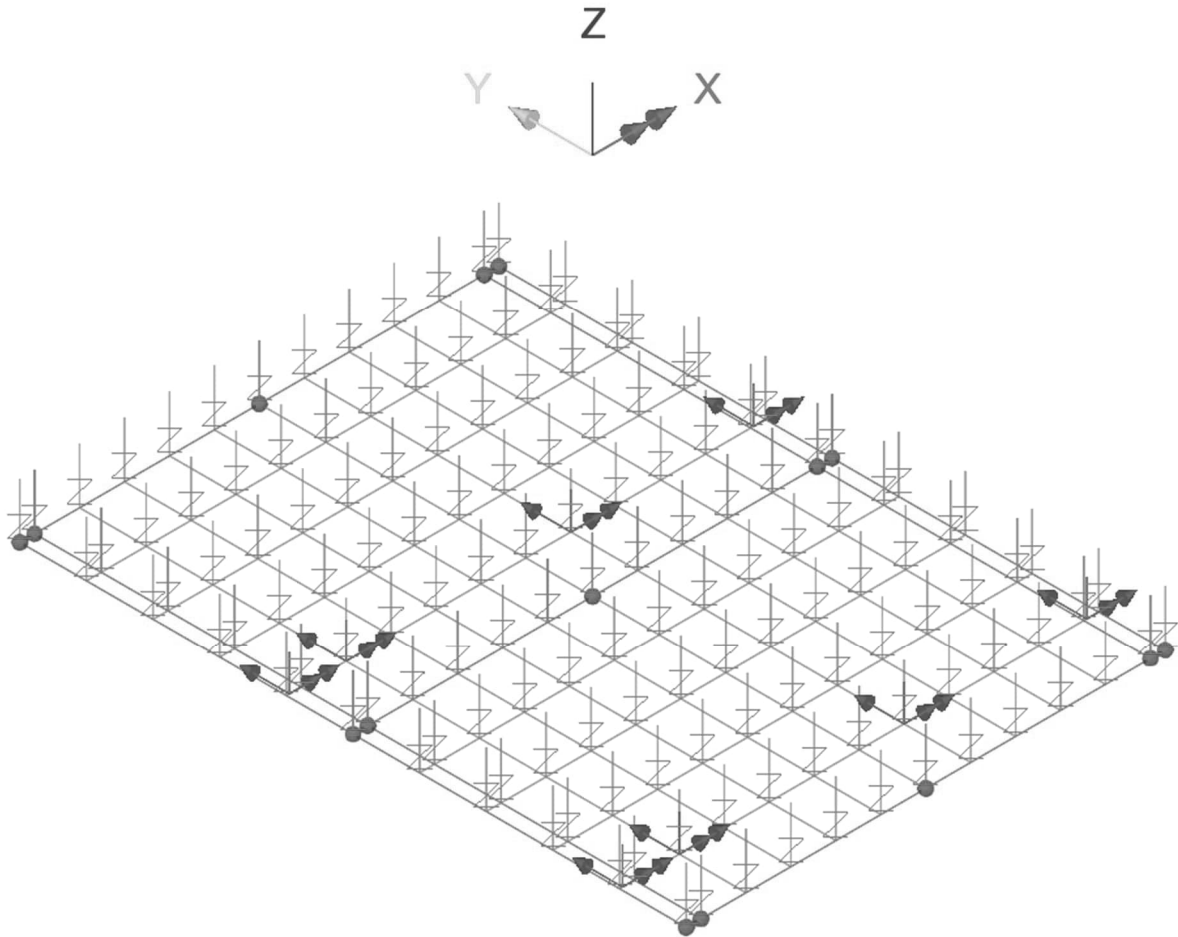
	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A2:15
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Rigid support beam.:



	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A2:16
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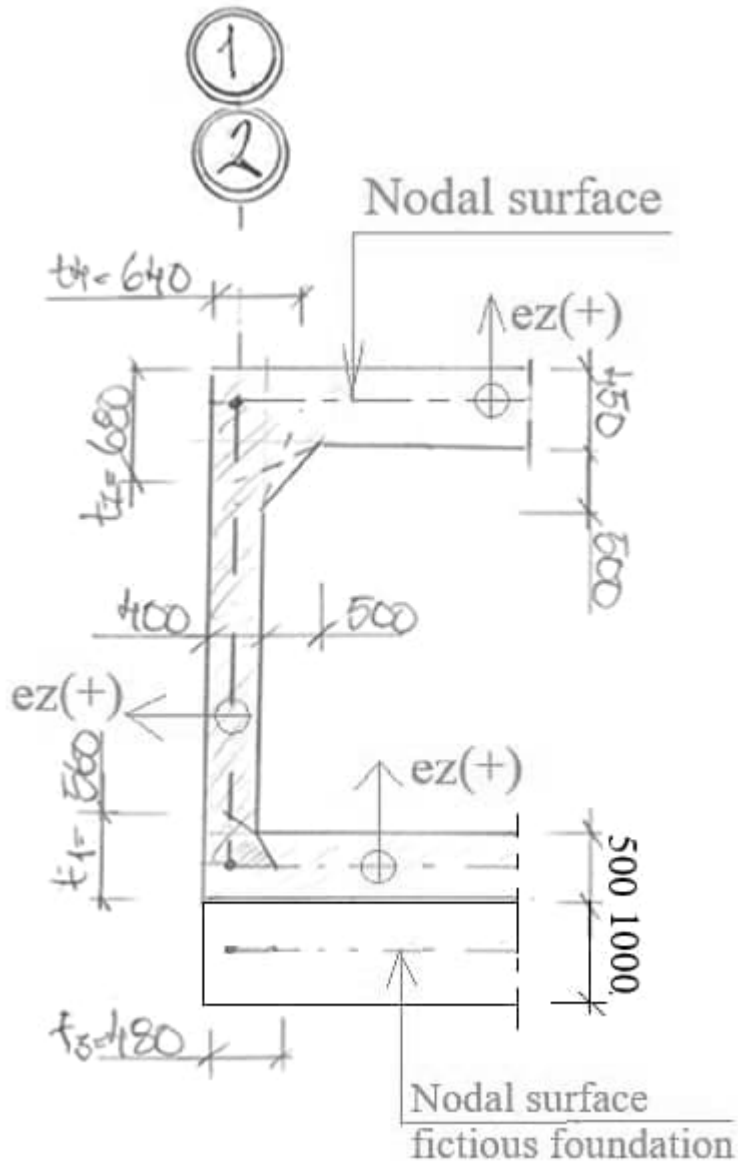
Fictious foundation :



	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A2:17
	RC closed frame bridge	Date :	Created :

2.3 CROSS SECTION PROPERTIES

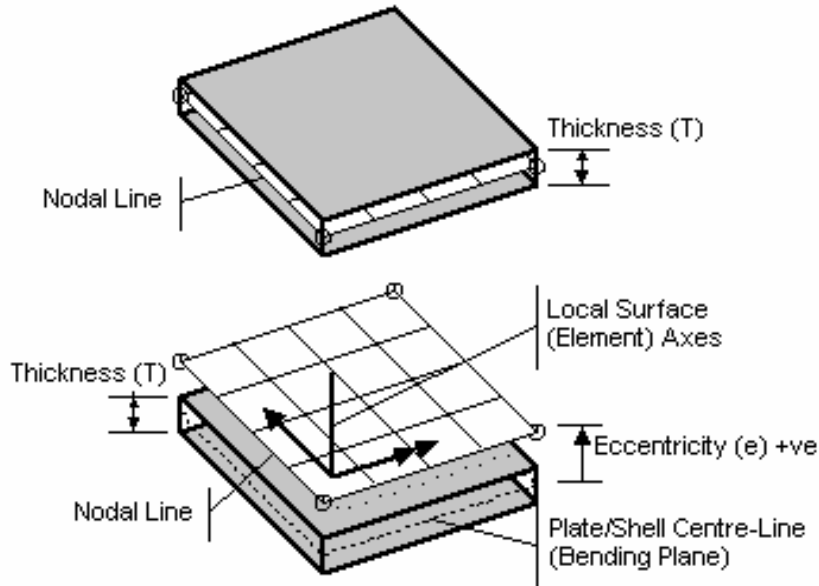
By experience stiffness increases by 1:3 at all joints as seen below.



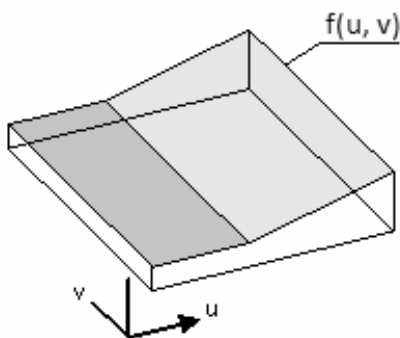
	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A2:18
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2.3.1 Shell element

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.



	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A2:19
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Surface function thickness :

Variation	Funktion(u,v)	Remark
<i>t1</i>	$0.56-0.07 \cdot u$	Bottom slab at support 1
<i>t2</i>	$0.56-0.06 \cdot u$	Bottom slab at support 2
<i>t3</i>	$0.48-0.08 \cdot u$	Bottom of abutment 1
<i>t4</i>	$0.40+0.24 \cdot u$	Bottom of abutment 2
<i>t5</i>	$0.40-0.08 \cdot u$	Top of abutment 1
<i>t6</i>	$0.40+0.24 \cdot u$	Top of abutment 2
<i>t7</i>	$0.68-0.23 \cdot u$	Superstructure at support 1
<i>t8</i>	$0.45+0.23 \cdot u$	Superstructure at support 2
-	m	-

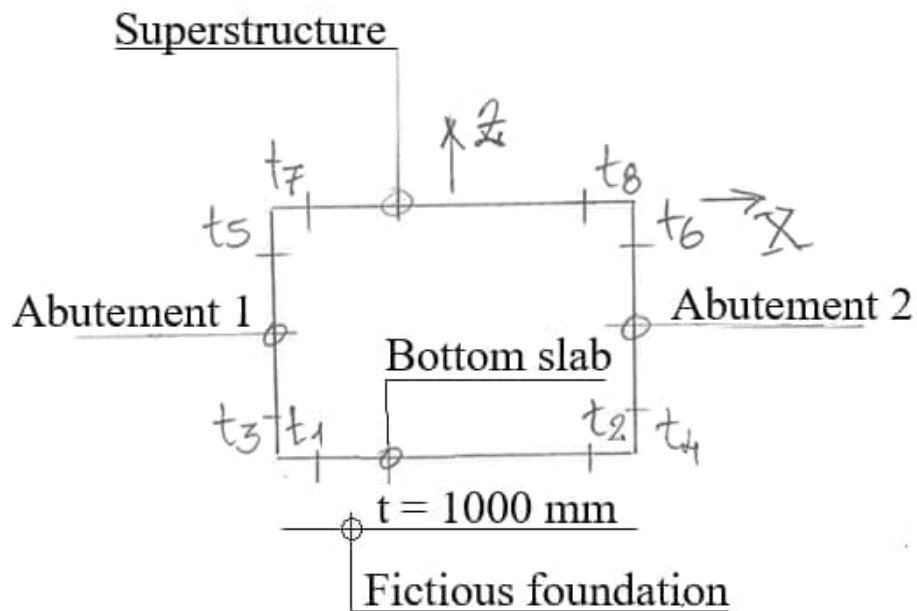
Surface function eccentricity :

Variation	Funktion(u,v)	Remark
<i>e1</i>	$-0.035+0.035 \cdot u$	Bottom slab at support 1
<i>e2</i>	$-0.035 \cdot u$	Bottom slab at support 2
<i>e3</i>	$0.04-0.04 \cdot u$	Bottom of abutment 1
<i>e4</i>	$-0.04+0.04 \cdot u$	Bottom of abutment 2
<i>e5</i>	$0.12 \cdot u$	Top of abutment 1
<i>e6</i>	$-0.12 \cdot u$	Top of abutment 2
<i>e7</i>	$0.115-0.115 \cdot u$	Superstructure at support 1
<i>e8</i>	$0.115 \cdot u$	Superstructure at support 2
-	m	-

	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A2:20
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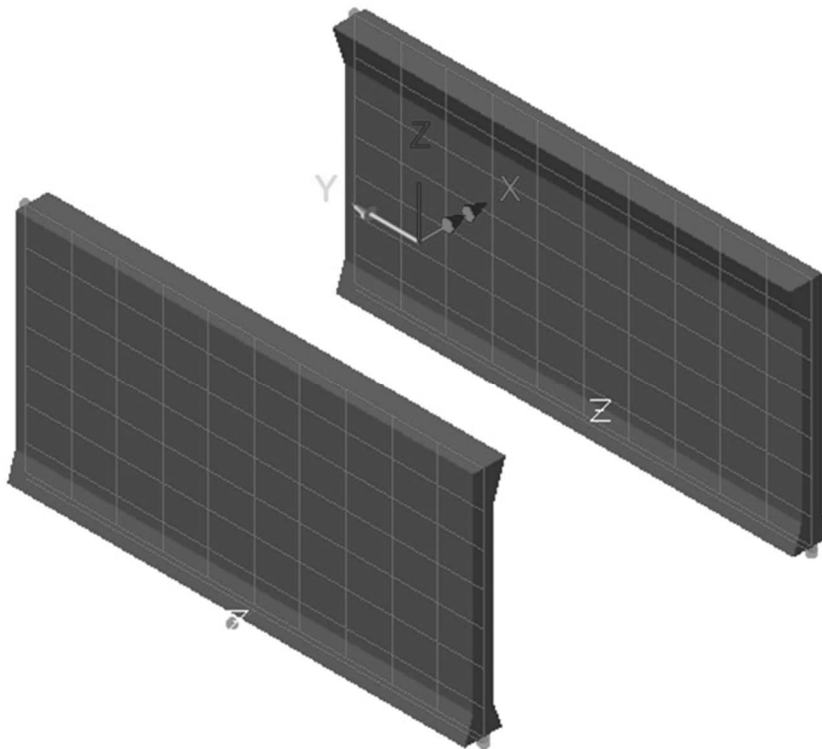
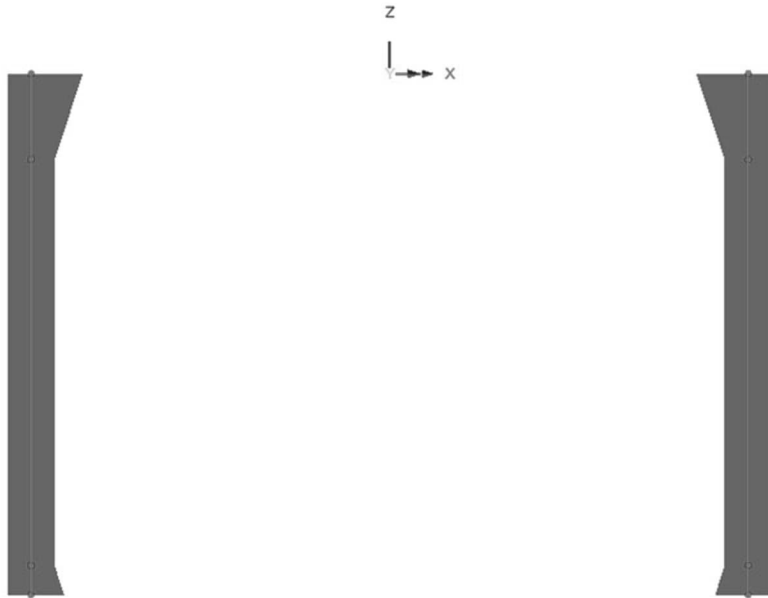
Surface geometry :

Attribute	t	ez	Remark
Bottenplatta t1	$t1$	$e1$	Bottom slab at support 1
Bottenplatta t2	$t2$	$e2$	Bottom slab at support 2
Ramben t3	$t3$	$e3$	Bottom of abutment 1
Ramben t4	$t4$	$e4$	Bottom of abutment 2
Ramben t5	$t5$	$e5$	Top of abutment 1
Ramben t6	$t6$	$e6$	Top of abutment 2
Farbana t7	$t7$	$e7$	Superstructure at support 1
Farbana t8	$t8$	$e8$	Superstructure at support 2
t = 400 mm	0.40	0	Abutment
t = 450 mm	0.45	0	Superstructure
t = 500 mm	0.50	0	Bottom slab
-	m	m	-



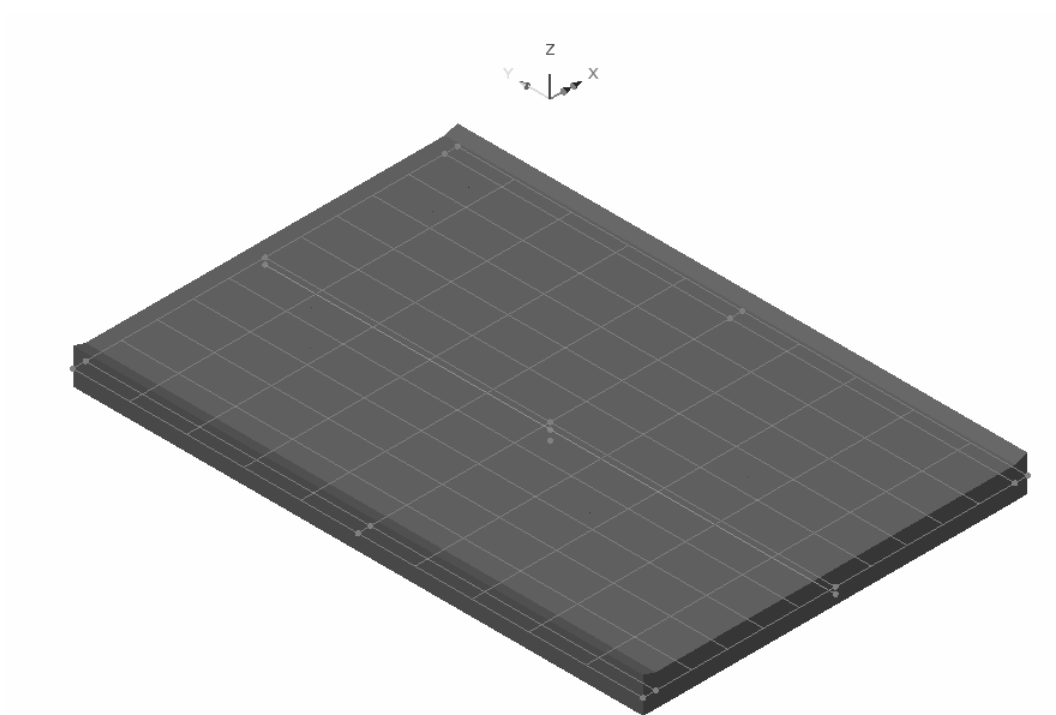
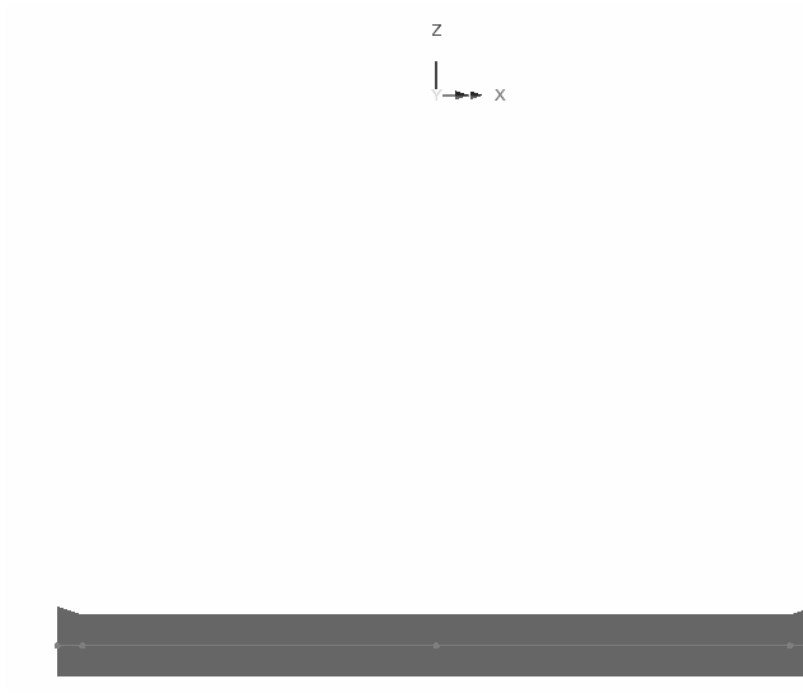
	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A2:21
		Date :	Created :

Abutments 1/2 :



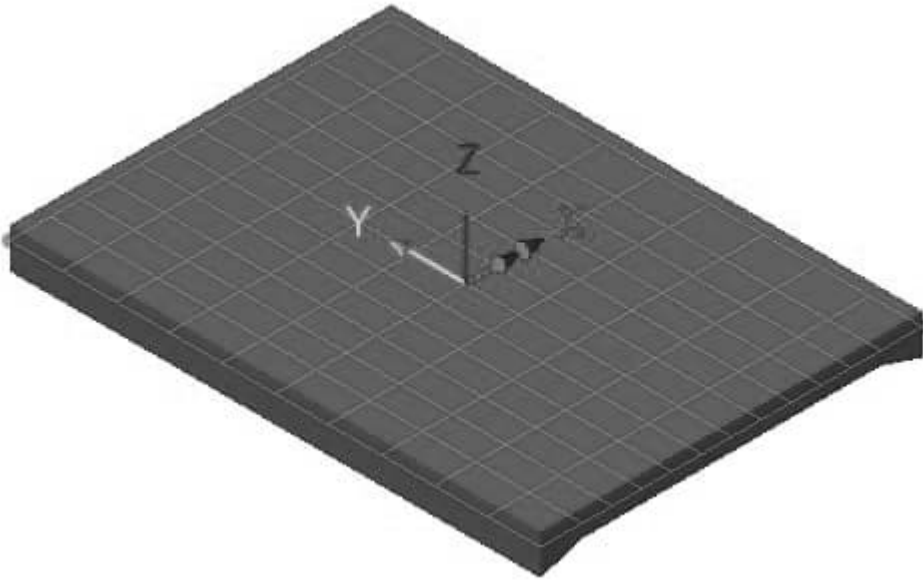
Bottom slab :

	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A2:22
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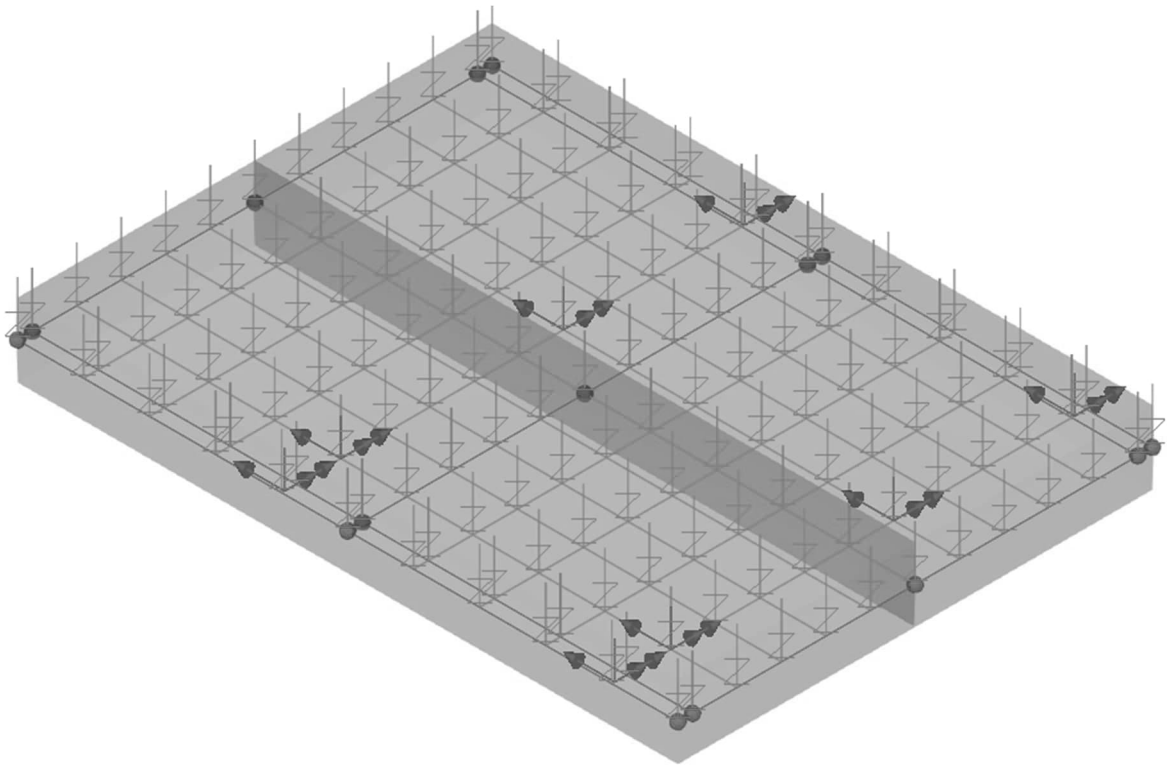


	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A2:23
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Superstructure .:



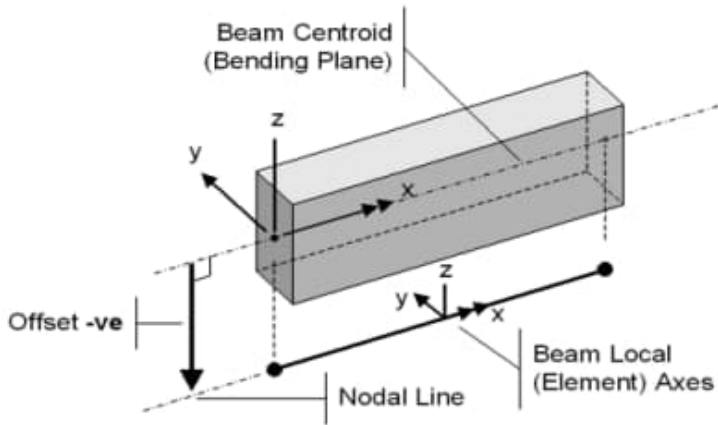
Fictitious foundation .:



	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A2:24
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2.3.2 3D-beams ("Thick beam" / BMS3)

Principal sketch of cross sections associated to beam elements ("Thick beam" BMS3) are shown below.



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A fictive “rigid support beam” is introduced at centre of bottom slab in transversal direction. The beam is rigid in all directions except axial direction (x-axis) and bending around local y-axis.

Analysis category

Definition

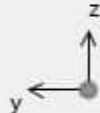
From Library
 Rotation about centroid: °
 Mirrored about axis:

Enter Properties
 Usage:

Reinforcement (only used for RC design checks)

UK Sections
 Universal Beams (BS4)
 914x305x289kg UB

100%



	Value
Cross sectional area (A)	1.0E-3
Second moment of area about y axis (Iyy)	1.0E-3
Second moment of area about z axis (Izz)	1.0E6
Product moment of area (Iyz)	0.0
Torsional constant (J)	1.0E-3
Effective shear area in y direction (Asy)	1.0E3
Effective shear area in z direction (Asz)	1.0E-3
Eccentricity in y direction (ey)	0.0
Eccentricity in z direction (ez)	0.0

Visualise... Tapering >> Section details...

Name (12)

	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A2:26
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2.4 MATERIAL

Material properties seen below are to be used.

Concrete C30/37 : $E_{cm} = 33 \text{ GPa}$

Material type	Concrete	▼
Country	Europe	▼
Standard	EN1992-1-1:2004/2014	▼
Grade	C30/37	▼
Properties		
Young's modulus	33,0E6	
Poisson's ratio	0,2	
Density	2,54842	
Thermal expansion	10,0E-6	
Name	Concrete	▼ ▲ (3)

	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A2:27
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2.5 BOUNDARY CONDITIONS

A fictive "super node" is introduced in centre of fictitious foundation. This is used to sum up all horizontal forces and vertical forces acting between foundation and bottom slab.

Structural Supports ✕

Analysis category:

		Free	Fixed	Spring	Spring stiffness
Translation in	X	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="text"/>
	Y	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="text"/>
	Z	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="text"/>
Rotation about	X	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="text"/>
	Y	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="text"/>
	Z	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Hinge rotation		<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Torsional warping		<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Pore pressure		Closed Seepage Drainage Open			Pressure
		<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Spring stiffness distribution

Stiffness

Stiffness/unit length

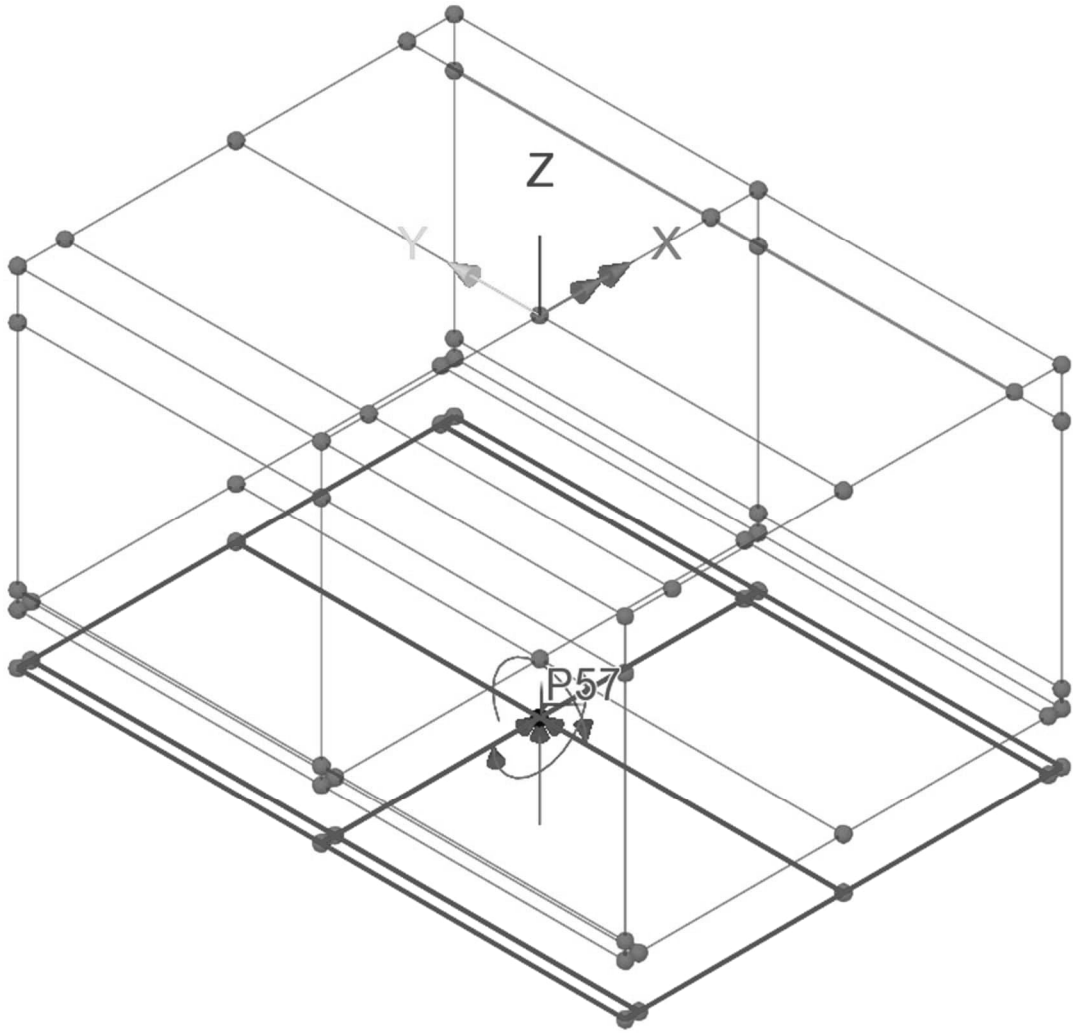
Stiffness/unit area

Name: (1)

Detail 3D

Rigid support beam / Super node

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3D Overview

	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A2:29
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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.

Typ	x-divisions	y-divisions
Element 1 x 5	1	5
Element 5 x 5	5	5

2.6.2 Balklelement (BMI21) : linear

Typ	Divisions	End release: Start	End release: End	Component
Element 5	5	None	None	Rigid support beam

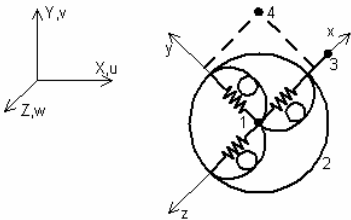
	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A2:30
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2.6.3 Joint element for beams (JSH4) : linear

Connection of super nodes to centre of rigid beams (P5) to location of super node (P57).

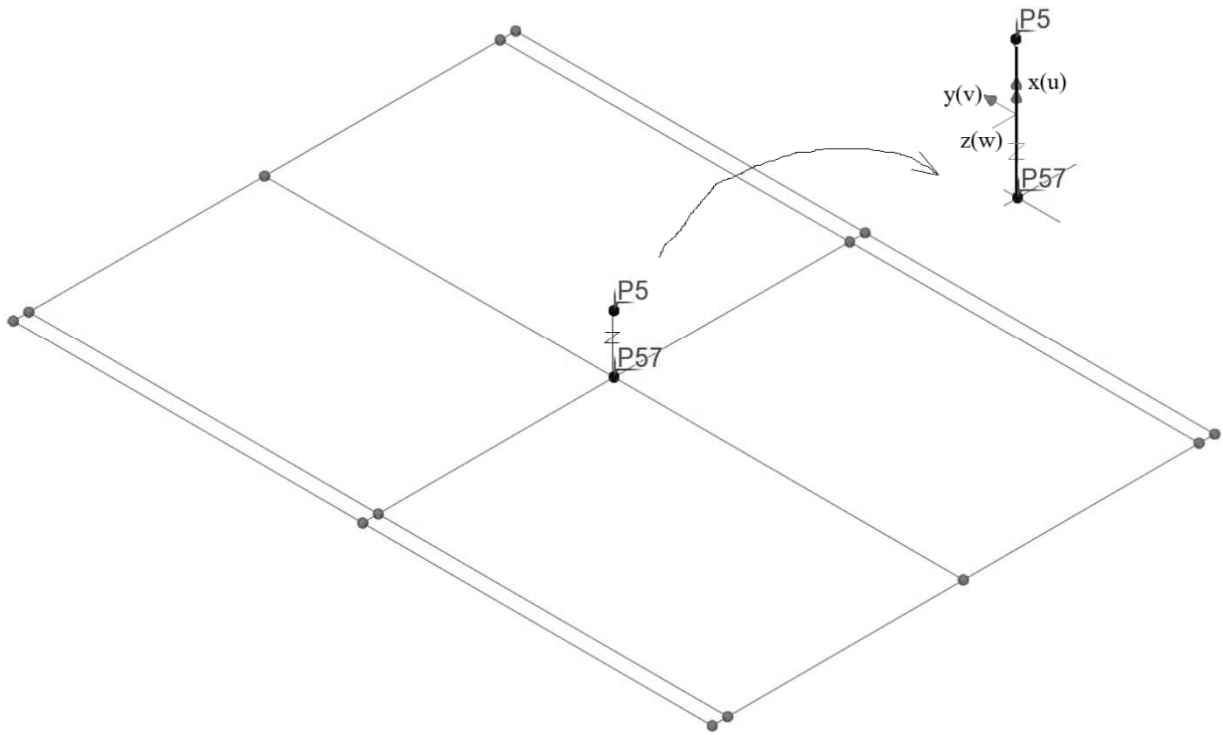
This joint is only used to transfer horizontal frictional forces to centre of foundation.

Definition of point joint element, see presentation below.

Element Name	JSH4, JL46
	
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. Use JL46 for semiloof beam end nodes.
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, θ_x , θ_y , θ_z : at nodes 1 and 2 (active nodes).
Node Coordinates	X, Y, Z: at each node.



	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A2:31
		Date :	Created :



3D Overview

	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A2:32
		Date :	Created :

Joint properties:

Spring Stiffness Only
✕

Analysis category

Assignment to

Joint type

Properties specified for each freedom

	u	v	w
Elastic spring stiffness	0,0	1,0E9	1,0E9

Name (5)

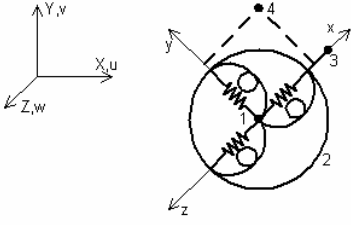
	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A2:33
		Date :	Created :

2.6.5 Joint element for surfaces (JSH4) : linear

The nodal surfaces bottom slab and fictitious foundation are connected with surface joint.

This joint can only transfer vertical forces.

Definition of surface joint element, see presentation below.

Element Name	JSH4, JL46
	
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. Use JL46 for semiloof beam end nodes.
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, θ_x , θ_y , θ_z : at nodes 1 and 2 (active nodes).
Node Coordinates	X, Y, Z: at each node.

	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A2:34
		Date :	Created :

Characteristic vertical stiffness associated to soil modulus (E_k):

$$B_k = \frac{q}{s_k} = \frac{100kPa}{0.085m} = 11725 \frac{kN}{m^3}$$

Effect of vertical stiffness due to load duration):

Used deformation modulus (E_k) corresponds to the 10-year value.

The effect of creep during loading is determined as seen below.

$$\alpha(t) = 1 + 0.2 \log(10 \cdot t) \quad :$$

$$10\text{-year value} \rightarrow \alpha(10 \text{ year}) = 1.40$$

$$\text{Short term load (variable load)} \rightarrow \alpha(0.1 \text{ year}) = 1.00$$

$$\text{Long term load (permanent load)} \rightarrow \alpha(120 \text{ year}) = 1.62$$

$$B_k(0.1 \text{ year}) = \frac{1.40}{1.00} \cdot 11725 \frac{kN}{m^3} = 16500 \frac{kN}{m^3} \quad : \text{ short term loads (variable load)}$$

$$B_k(120 \text{ år}) = \frac{1.40}{1.62} \cdot 11725 \frac{kN}{m^3} = 10100 \frac{kN}{m^3} \quad : \text{ long term loads (permanent load)}$$

	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A2:35
		Date :	Created :

Chosen joint properties:

According to older Swedish practice vertical stiffness for permanent loads was chosen so ground pressure was linear and independent of foundation stiffness.
This corresponds to $B_k \rightarrow 0 \text{ kN/m}^3$.

This praxis leads load effects in structure being on safe side.

However the global deformations will be misleading.

⇒ For this analysis $B_k = 10100 \frac{\text{kN}}{\text{m}^3}$ is chosen for both permanent and variable loads.

Spring Stiffness Only ✕

Analysis category

Assignment to

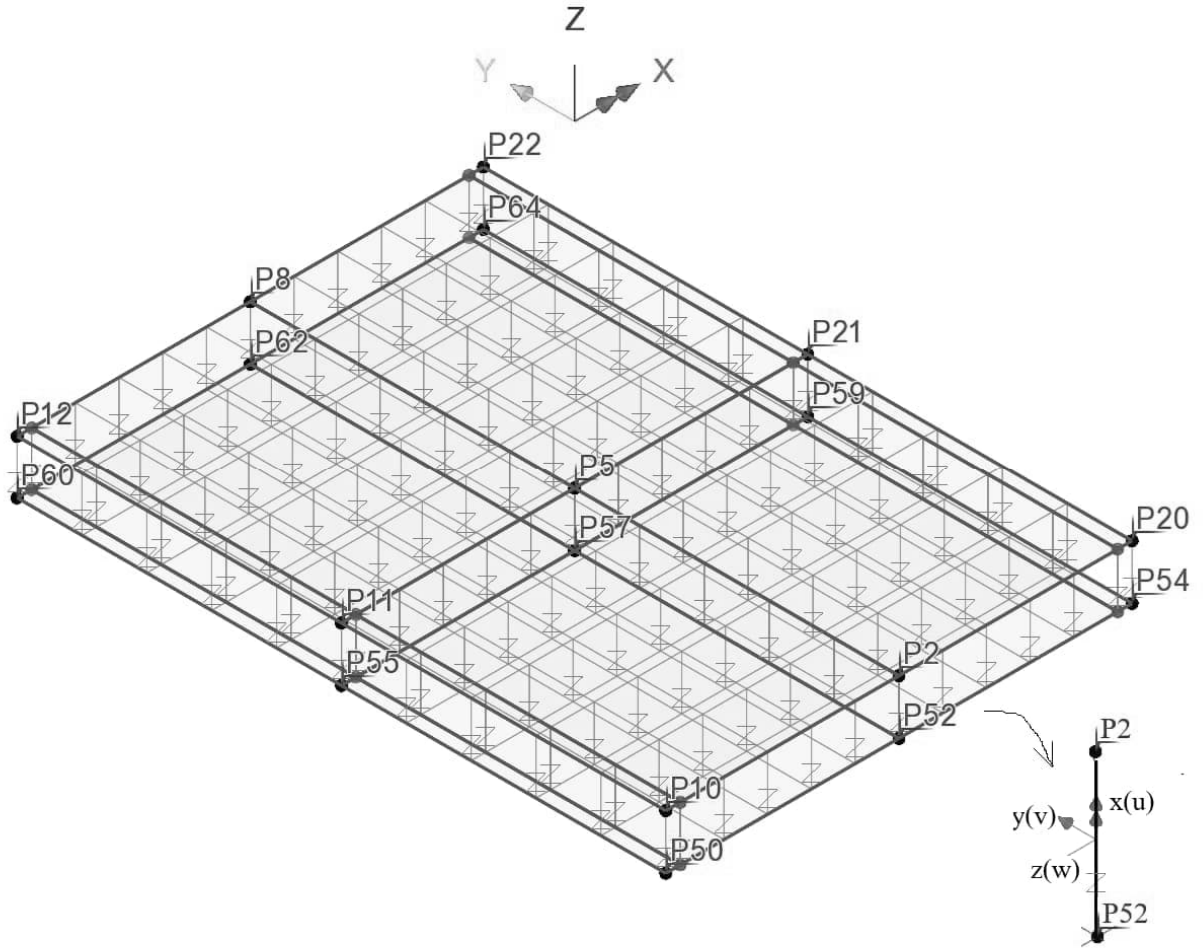
Joint type

Properties specified for each freedom

	u	v	w
Elastic spring stiffness	10,1E3	0,0	0,0

Name (4)

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A2:36
	RC closed frame bridge	Date :	Created :



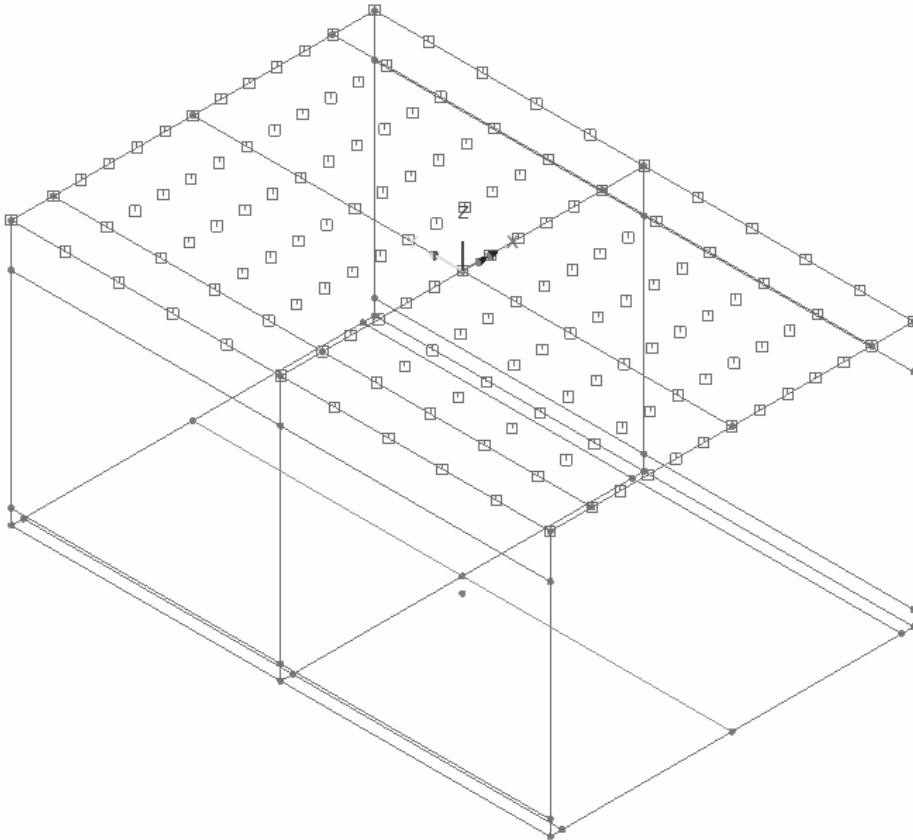
Overview 3D

	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A2:37
		Date :	Created :

2.7 SEARCH AREA

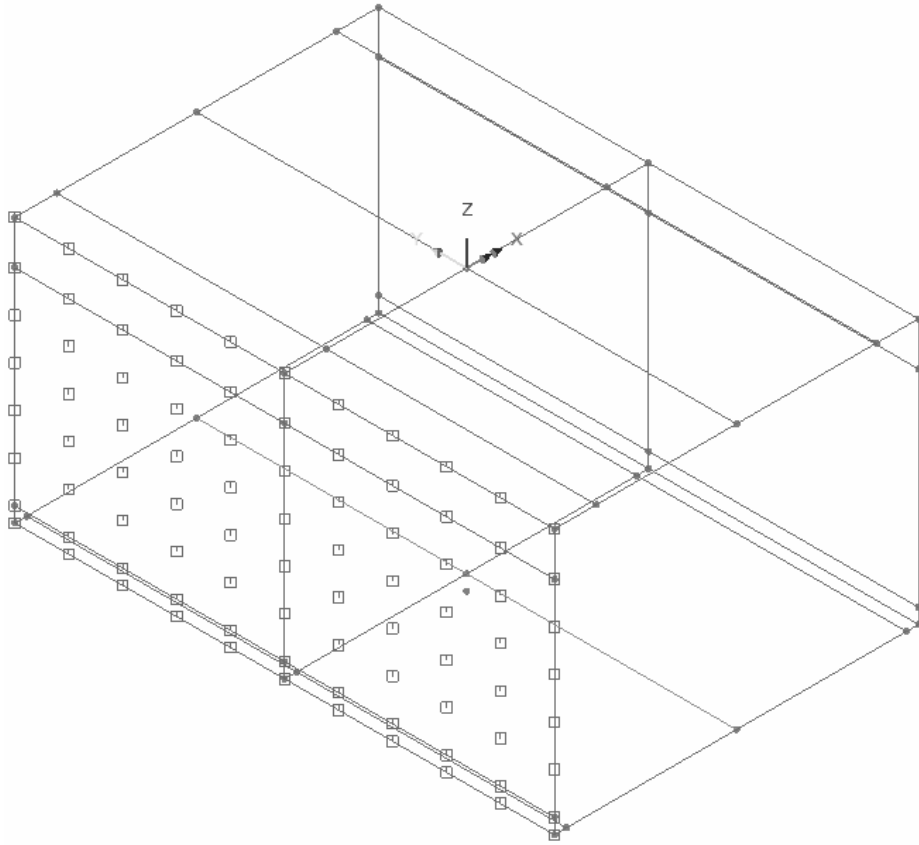
Discrete load can be applied to structure as geometrical load areas. In FEM-program load areas are termed Search Area.

2.7.1 Search area : Superstructure



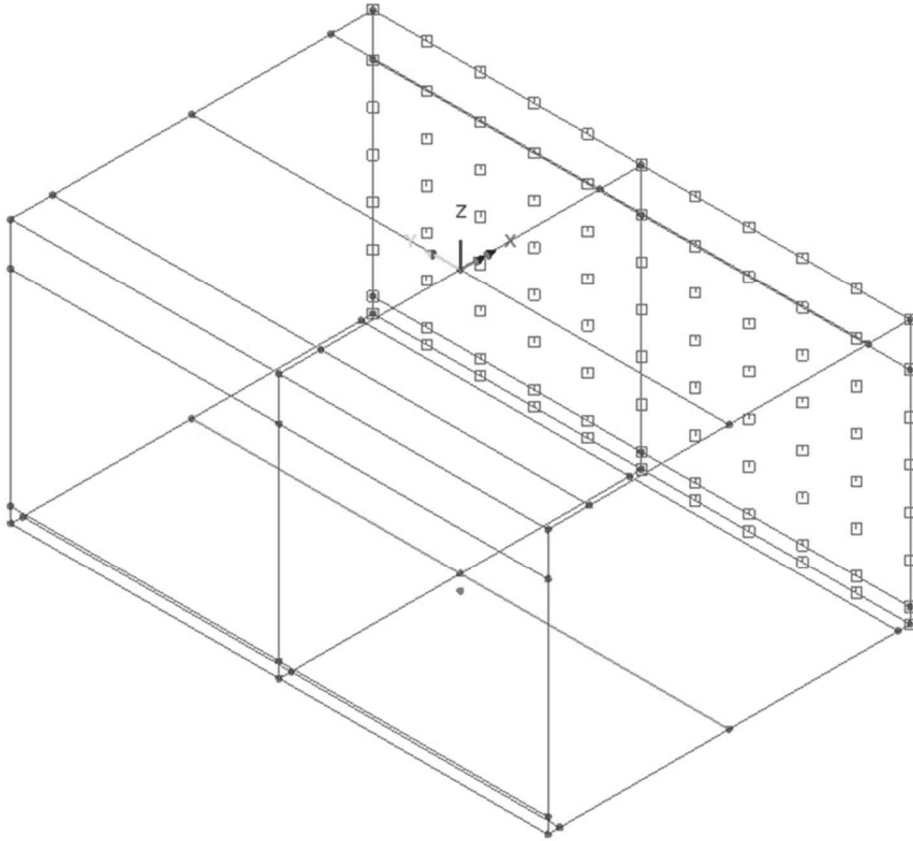
	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A2:38
		Date :	Created :

2.7.2 Search area : Abutment 1



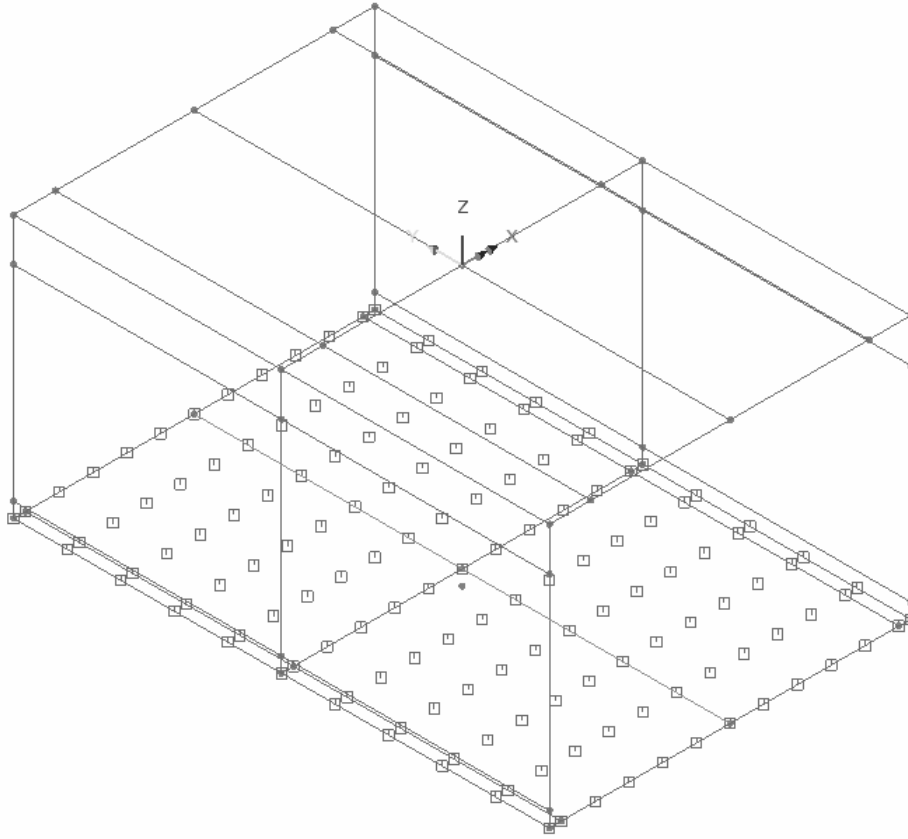
	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A2:39
		Date :	Created :

2.7.3 Search area : Abutment 2



	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A2:40
		Date :	Created :

2.7.4 Search area : Bottom slab



	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A3:1
		Date :	Created :

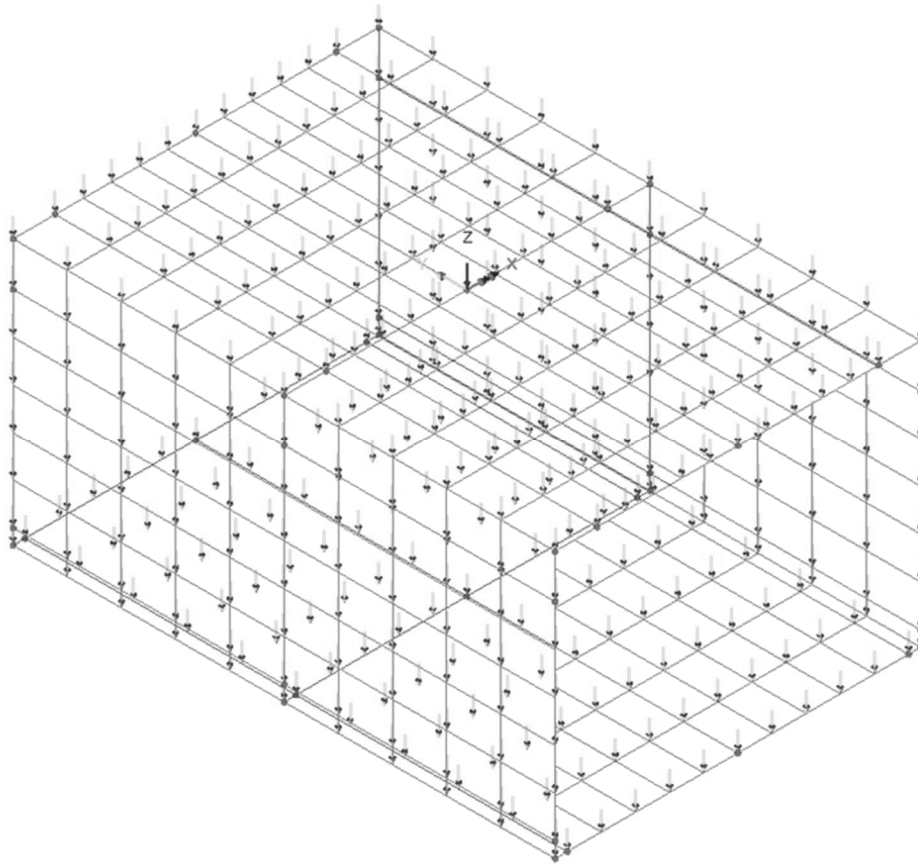
3. LOADS

3.1	DEAD WEIGHT	page 3:2-4
3.2	SURFACING	page 3:4-5
3.3	EARTH PRESSURE	page 3:6-12
3.4	SUPPORT SETTLEMENT	page 3:13
3.5	CREEP	page 3:14
3.6	SHRINKAGE	page 3:15-16
3.7	TRAFFIC LOAD	page 3:17-32
3.8	BRAKING LOAD	page 3:33-38
3.9	LATERAL LOAD	page 3:39-42
3.10	WIND LOAD	page 3:43-48
3.11	SURCHARGE	page 3:49-58
3.12	TEMPERATURE	page 3:59-72
3.13	LOAD COMBINATIONS	page 3:73-85

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:2
	RC closed frame bridge	Date :	Created :

3.1 DEAD WEIGHT

$$\gamma_c = 25 \cdot \frac{kN}{m^3} \quad : \text{concrete}$$



Overview 3D

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:3
	RC closed frame bridge	Date :	Created :

Loadcase : EGEN

Structural loading : Body force

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

Component	Value
Linear acceleration in X	0.0
Linear acceleration in Y	0.0
Linear acceleration in Z	-10.0
Angular velocity about X axis	0.0
Angular velocity about Y axis	0.0
Angular velocity about Z axis	0.0
Angular acceleration about X axis	0.0
Angular acceleration about Y axis	0.0
Angular acceleration about Z axis	0.0

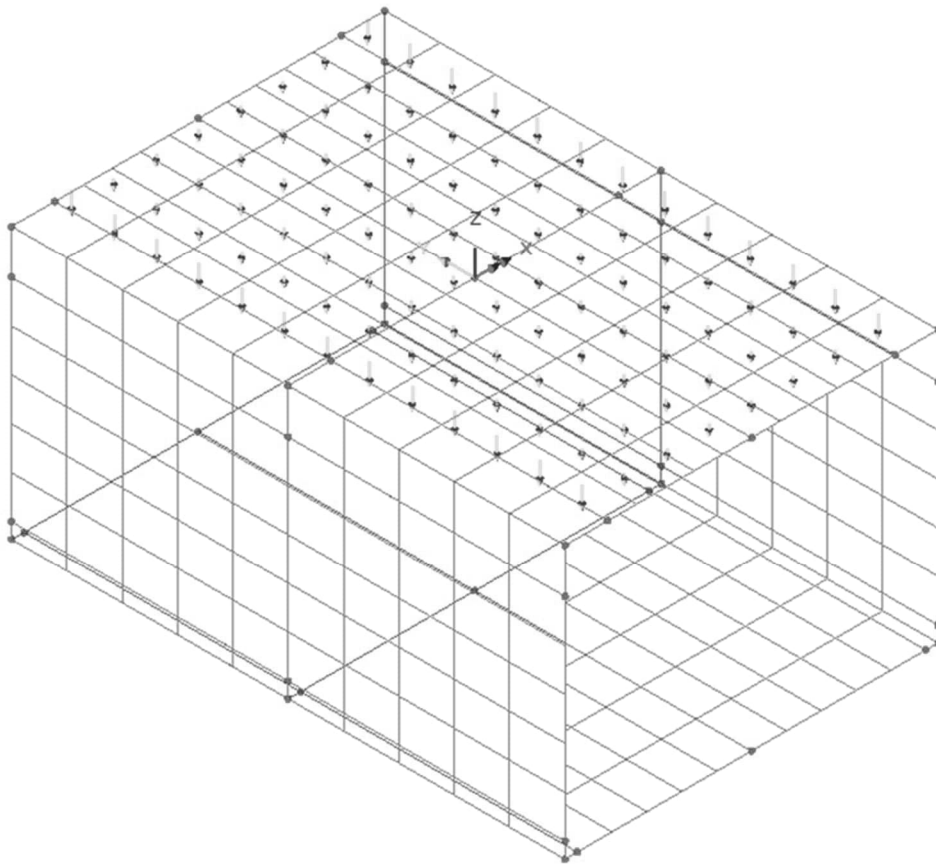
Name (1415)

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:4
	RC closed frame bridge	Date :	Created :

3.2 SURFACING

Surfacing load is seen below:

$$q_{belagg} = \gamma_{belaggning} \cdot t + q_{matta} = 22 \frac{kN}{m^3} \cdot 0.105m + 0.11kPa = 2.6kPa$$



View 3D

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:5
	RC closed frame bridge	Date :	Created :

Loadcase : BELAGG

Structural loading : Discrete 4 node patch load

Surface load (q_z) : -2.6kPa

Search Area : Farbana

Loads outside search area : Include full load

Patch type

8 node patch
 4 node patch
 Multi-node patch
 Straight line
 Curve

Load direction

X
 Z
 Y
 XYZ
 Patch x
 Patch y
 Surface normal

Projection vector

Project in load direction
 Project for prestress

X component

Y component

Z component

Patch load divisions

Use default

Number of divisions in

Number of divisions in y

	X	Y	Z	Load
1	-3.435	-4.5	1.0	-2.6
2	3.435	-4.5	1.0	-2.6
3	3.435	4.5	1.0	-2.6
4	-3.435	4.5	1.0	-2.6

Name (1)

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:6
	RC closed frame bridge	Date :	Created :

3.3 EARTH PRESSURE

Earth pressure is determined for “förstärkningslager material”.

$$\gamma_{m,\phi} = 1.30 \quad :$$

$$\gamma_{m,E} = 1.30$$

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

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

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

$$\rightarrow \varphi_d = \arctan\left(\frac{\tan\varphi_k}{\gamma_m}\right) = \arctan\left(\frac{\tan 45^\circ}{1.0}\right) = 45^\circ \quad : \text{ design method D2}$$

$$\rightarrow \varphi_d = \arctan\left(\frac{\tan\varphi_k}{\gamma_m}\right) = \arctan\left(\frac{\tan 45^\circ}{1.3}\right) = 38^\circ \quad : \text{ design method D3}$$

Earth pressure coefficients are seen below.

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

$$K_a = \tan^2\left(45^\circ - \frac{\varphi_d}{2}\right)$$

$$K_p = \tan^2\left(45^\circ + \frac{\varphi_d}{2}\right)$$

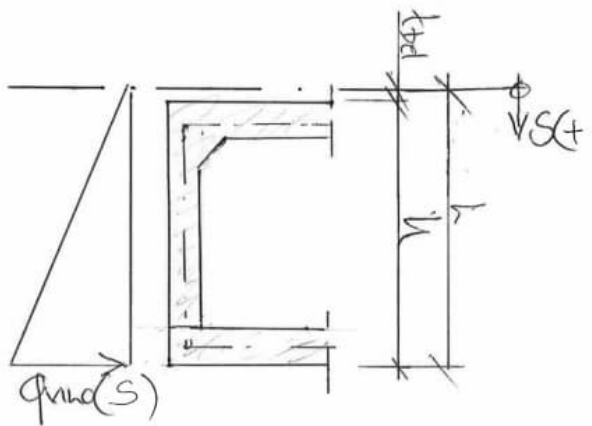
φ_d	K_a	K_o	K_p	Method
38°	0.24	0.38	4.20	D3
45°	0.17	0.29	5.82	D2

Bridge design is conducted using method D3.

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:7
	RC closed frame bridge	Date :	Created :

$$L = 4.665m + \frac{0.45m}{2} + 0.11m = 5.0m$$

$$q_{vilo}(s) = K_0 \cdot \gamma \cdot s = 0.38 \cdot 22 \frac{kN}{m^3} \cdot s(+) = s(+) \cdot 8.58kPa$$



	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:8
	RC closed frame bridge	Date :	Created :

3.3.1 Load against support 1

$q_{vilo} (0m) = 0kPa$: top of surfacing

$q_{vilo} (5.0m) = 5.0m \cdot 8.6 \frac{kN}{m^3} = 43kPa$: bottom of foundation slab

Loadcase : JORD 1

Structural loading : Discrete 4 node patch load

Surface load (q_x) : 0 kPa → +43 kPa

Search Area : Ramben 1

Loads outside search area : Include full load

Patch type

8 node patch
 4 node patch
 Multi-node patch
 Straight line
 Curve

Load direction

X Z
 Y XYZ
 Patch x
 Patch y
 Surface normal

Projection vector

Project in load direction
 Project for prestress

X component
Y component
Z component

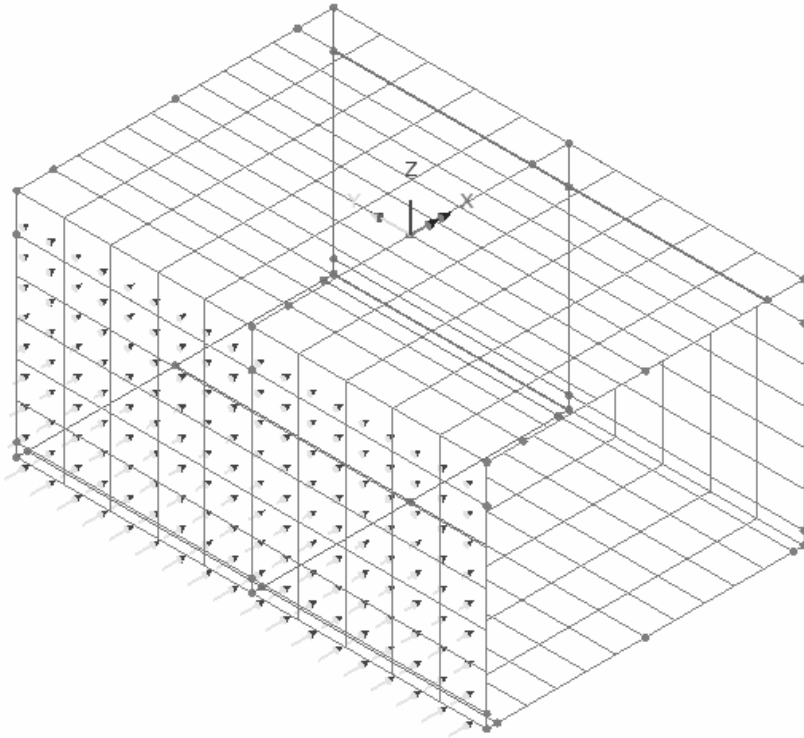
Patch load divisions

Use default
Number of divisions in
Number of divisions in y

	X	Y	Z	Load
1	-8.0	-4.5	-4.665	43.0
2	-8.0	-4.5	0.335	0.0
3	-8.0	4.5	0.335	0.0
4	-8.0	4.5	-4.665	43.0

Name (3)

	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A3:9
		Date :	Created :



Overview 3D

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:10
	RC closed frame bridge	Date :	Created :

3.3.2 Last against support 2

$q_{vilo}(0m) = 0kPa$: top of surfacing

$q_{vilo}(5.0m) = 5.0m \cdot 8.6 \frac{kN}{m^3} = 43kPa$: bottom of foundation slab

Loadcase : JORD 2

Structural loading : Discrete 4 node patch load

Surface load (q_x) : 0 kPa \rightarrow -43 kPa

Search Area : Ramben 2

Loads outside search area : Include full load

Patch type

8 node patch
 4 node patch
 Multi-node patch
 Straight line
 Curve

Load direction

X Z
 Y XYZ
 Patch x
 Patch y
 Surface normal

Projection vector

Project in load direction
 Project for prestress

X component
Y component
Z component

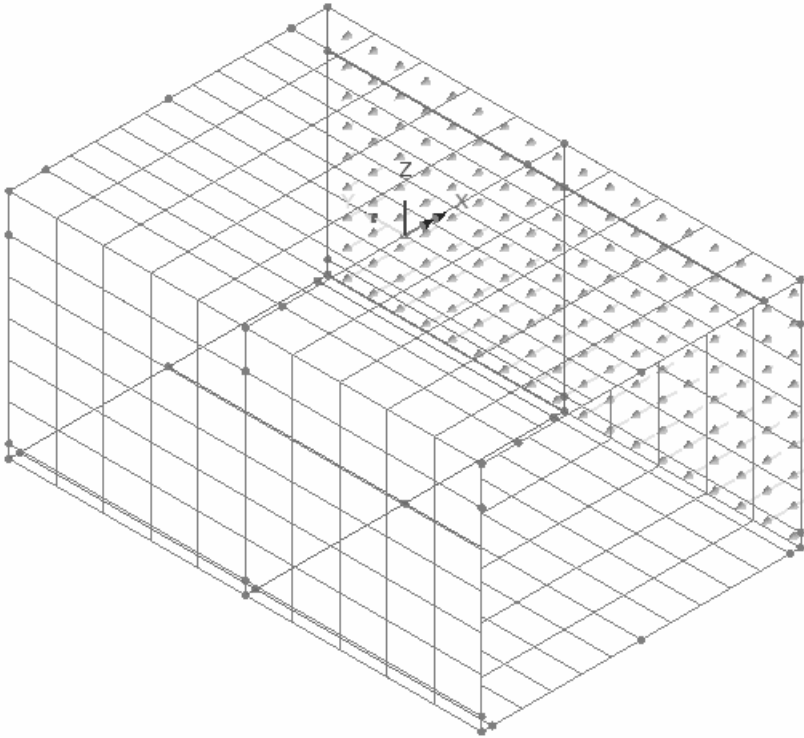
Patch load divisions

Use default
Number of divisions in
Number of divisions in y

	X	Y	Z	Load
1	8.0	-4.5	-4.665	-43.0
2	8.0	-4.5	0.335	0.0
3	8.0	4.5	0.335	0.0
4	8.0	4.5	-4.665	-43.0

Name (4)

	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A3:11
		Date :	Created :



Overview 3D

	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A3:12
		Date :	Created :

3.3.3 Load combinations

Load combinations of existing load cases.

Load combination basic JORD :

Load case	Factor
JORD 1	1
JORD 2	1

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:13
	RC closed frame bridge	Date :	Created :

3.4 SUPPORT SETTLEMENT

Since bridge has one common bottom no forces arises due to settlement. Only translation of structures occurs.

This load case is not considered in the static model for this reason.

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:14
	RC closed frame bridge	Date :	Created :

3.5 CREEP

Total creep is determined according to SS-EN 1992-1-1 §3.1.4 for RH 80% at time t_1 .

Time for first loading (= time when formwork was removed) is termed t_0 .

$$t_0 = 5 \text{ days}$$

$$t_1 = 120 \text{ years}$$

Bridge consists of parts with different thicknesses as seen below.

Creep is determine using Mathcad program PROG A001.

For $t = 0.45 \text{ m} \rightarrow \phi(t_1, t_0) = 2.02$ see page A3:17.

However creep value $\phi(t_1, t_0) = 2.0$ is chosen on safe side for all components.

The effect of stiffness due to creep see SS-EN 1992-1-1 5.8.7.

Load	ϕ
Permanent	2.0
Variable excluding temperature	0
Temperature	0.3*

* = According to Swedish practice.

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

Instead of adjusting E-modulus load coefficients are adjusted as seen below.

$$f_{KRYMP} = \frac{1}{1 + \phi_{ef}} = \frac{1}{1 + 2.0} = 0.33$$

$$f_{STÖD} = \frac{1}{1 + \phi_{ef}} = \frac{1}{1 + 2.0} = 0.33$$

$$f_{TEMP} = \frac{1}{1 + \phi_{ef}} = \frac{1}{1 + 0.3} = 0.77$$

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:15
	RC closed frame bridge	Date :	Created :

3.6 SHRINKAGE

Total shrinkage according to SS-EN 1992-1-1 §3.1.4 and KBB section B.3.1.5 for RH 80%.

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

$$t_s = 0 \text{ days}$$

$$t_1 = 120 \text{ years}$$

Total shrinkage $\varepsilon_{cs}(t_1) = 0.024\%$ is assumed for superstructure.

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).

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:16
	RC closed frame bridge	Date :	Created :

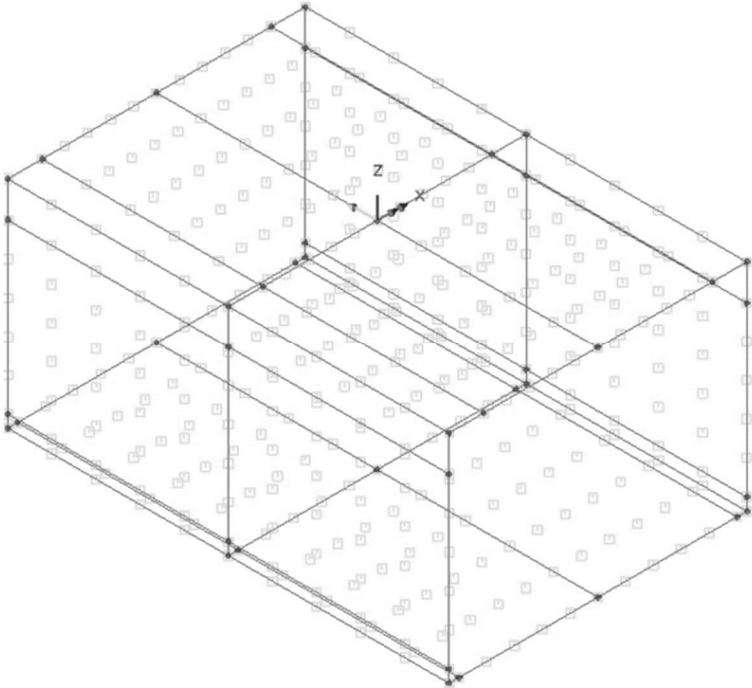
Loadcase : KRYMP

Structural loading : Temperature

Definition : Nodal

Initial temperature : 0 °C

Final temperature : -25 °C



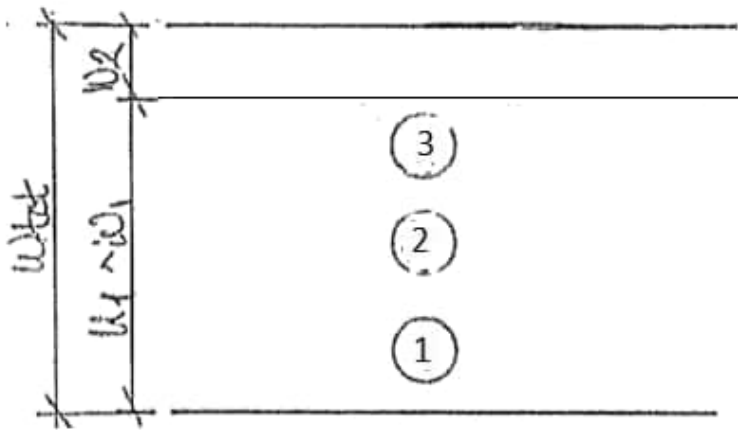
	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:17
	RC closed frame bridge	Date :	Created :

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 : $w_{tot} = 9.0m$

Number of traffic lanes : $n_1 = \text{Integer} \left[\frac{w_{tot}}{3.0m} \right] = 3 \text{ st}$

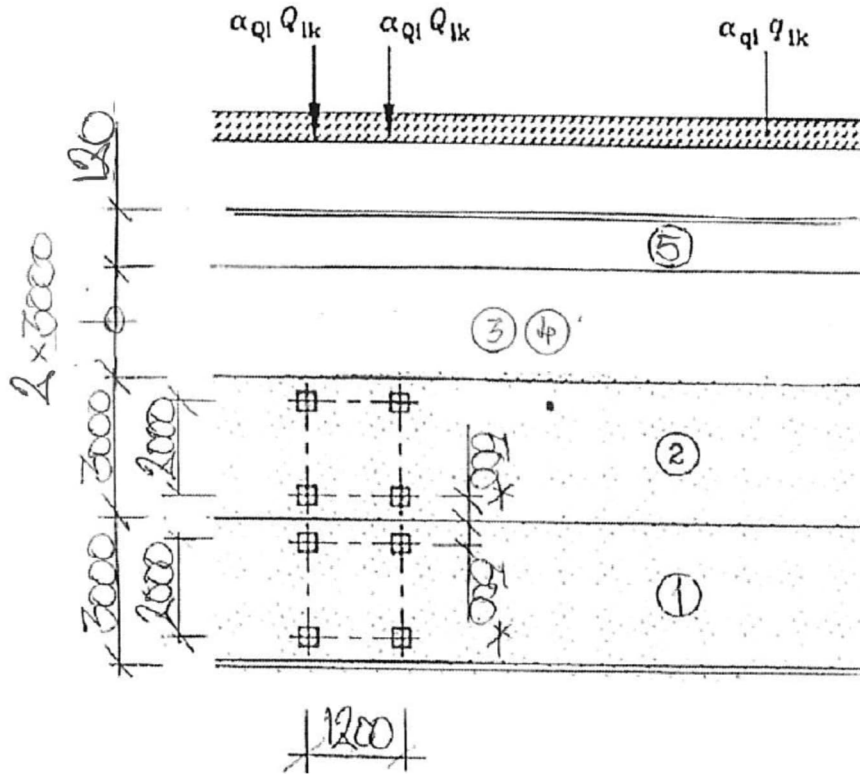
Full traffic width : $w_1 = 3.0m$

Remaining width : $w_2 = 0m$

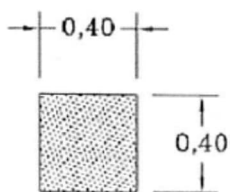
	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:18
	RC closed frame bridge	Date :	Created :

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.



	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:19
	RC closed frame bridge	Date :	Created :

Axellaster :

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
3-9	100	0	0	No load
-	kN	-	kN	-

Utbredda laster :

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
2-9	2.5	1.0	2.5
-	kPa	-	kPa

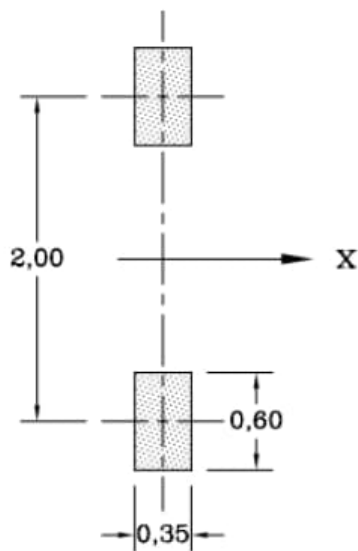
Remark

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

	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A3:20
		Date :	Created :

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

$Q_k = 400 \text{ kN}$: characteristic value

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

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:21
	RC closed frame bridge	Date :	Created :

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.

Evaluation is performed with wheelbase distance 1.7 m and 2.3 m.

$\epsilon_{\text{dyn}} = 25 \%$: dynamic factor*

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

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

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

Remark

Evaluation see Vehicle Load Optimisation (VLO), see section 3.7.5.

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:22
	RC closed frame bridge	Date :	Created :

a) \downarrow
A

b) $\downarrow \geq 10 \downarrow$
0,88 B

c) $\downarrow \geq 13 \downarrow$
B

d) $\downarrow \geq 18 \downarrow$
1,0 B

e) $\downarrow 10 \downarrow \geq 10 \downarrow$
1,7 B

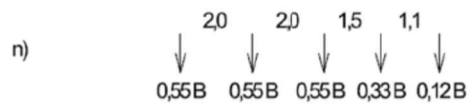
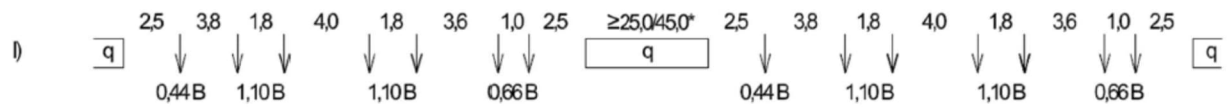
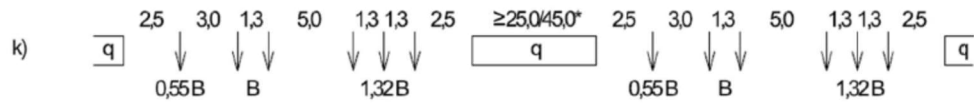
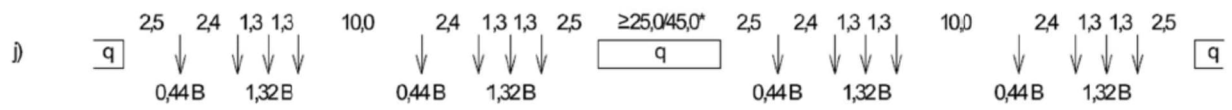
f) $\downarrow 13 \downarrow \geq 13 \downarrow$
1,32 B

g) \overline{q} 25 \downarrow 24 \downarrow 13 \downarrow 13 \downarrow 25 ≥ 50 \overline{q} 25 \downarrow 24 \downarrow 13 \downarrow 13 \downarrow 25 \overline{q}
0,44 B 1,32 B 0,44 B 1,32 B

h) \overline{q} 25 \downarrow 30 \downarrow 13 \downarrow ≥ 50 \downarrow 13 \downarrow 13 \downarrow 25 \overline{q}
0,55 B B 1,32 B

i) \overline{q} 25 \downarrow 38 \downarrow 18 \downarrow ≥ 40 \downarrow 18 \downarrow 36 \downarrow 10 \downarrow 25 \overline{q}
0,44 B 1,0 B 1,0 B 0,66 B

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:23
	RC closed frame bridge	Date :	Created :

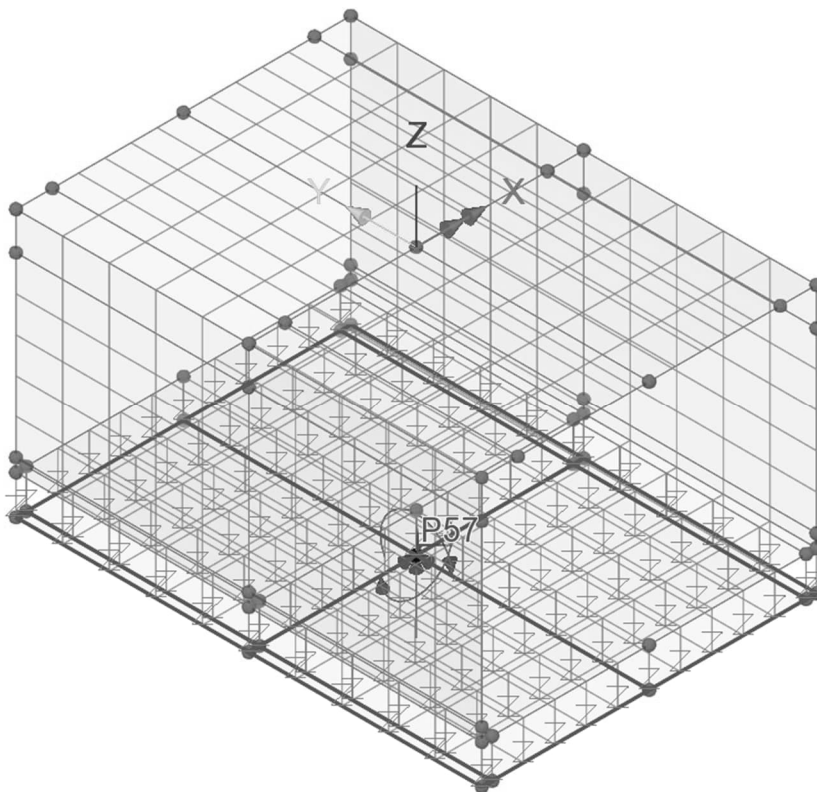
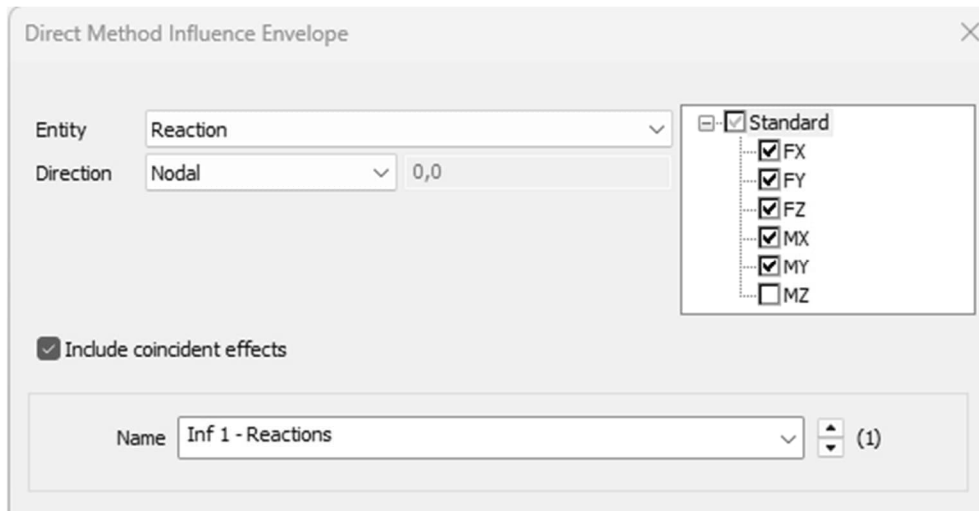


	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:24
	RC closed frame bridge	Date :	Created :

3.7.5 Vehicle Load Optimization (VLO)

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

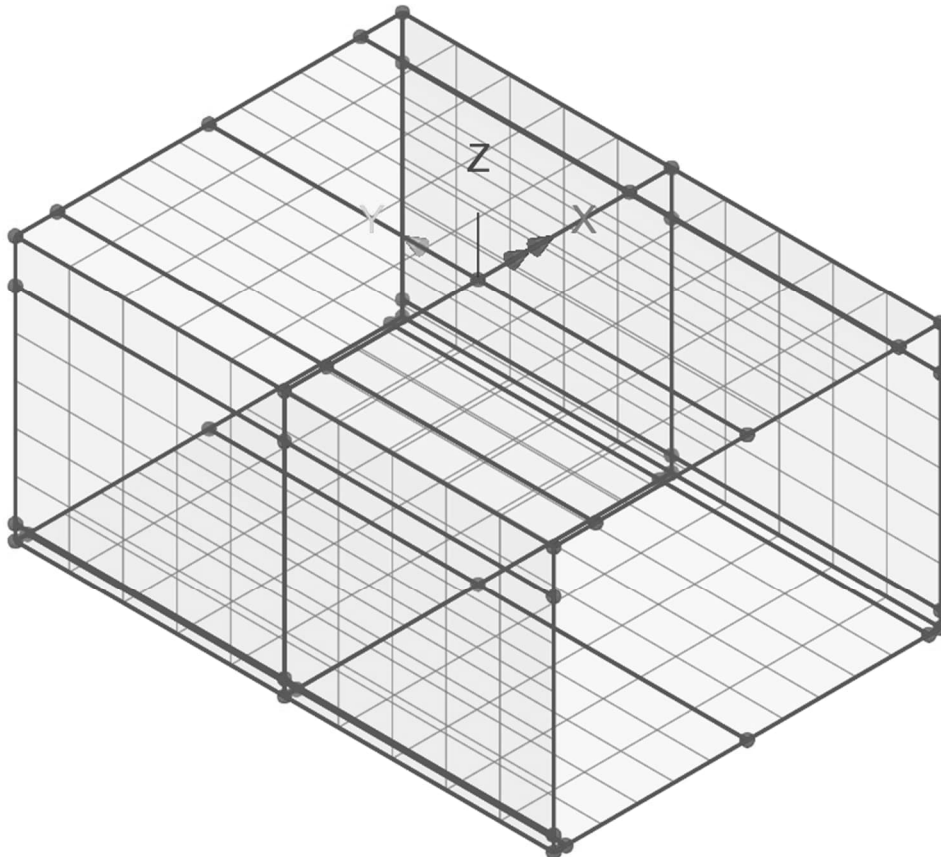
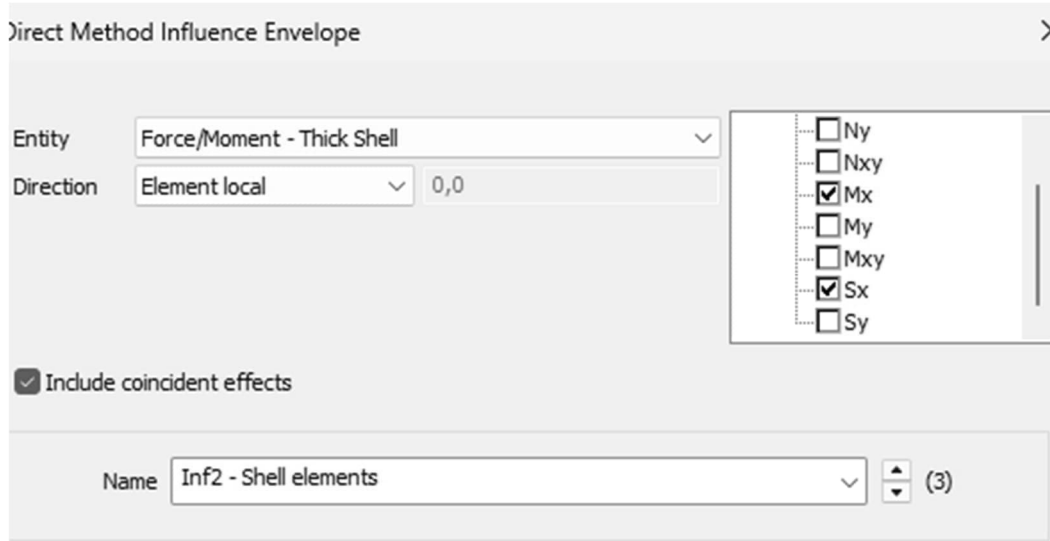
Inf1 – Reactions :



Overview 3D

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:25
	RC closed frame bridge	Date :	Created :

*Inf2 – Thick shells :
(Abutements & bridge deck)*



Overview 3D

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:26
	RC closed frame bridge	Date :	Created :

Influence surfaces.:

Search area: Superstructure

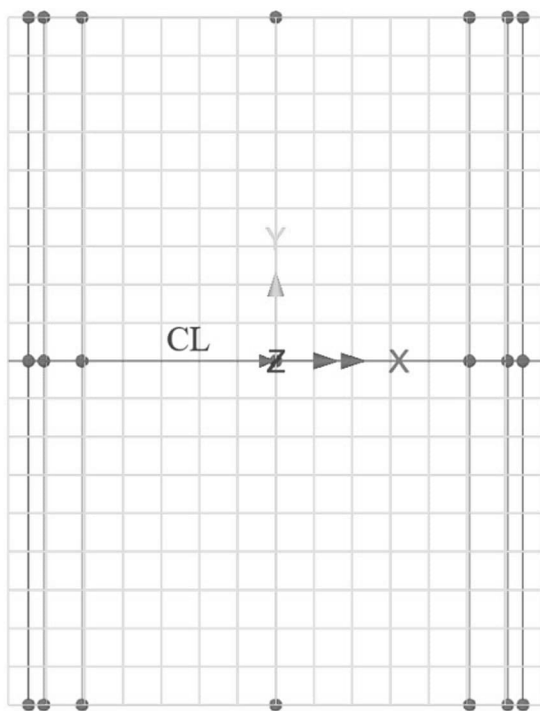
Definition type: Grid

Centerline (path): L122

Transverse width: 9.0 m

Longitudinal spacing: 0.5 m

Transversal spacing: 0.5 m



PLAN

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:27
	RC closed frame bridge	Date :	Created :

Vehicle load optimisation options:

Loading options

Country: Sweden Optional code settings...

Design code: EN1991-2 Sweden 2011 Optional loading parameters...

Solution process

View onerous effects table Set influence surfaces...

Create loading patterns Define carriageways...

All chosen influences
 Most onerous

Create envelopes

By design case
 By influence and design case

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:28
	RC closed frame bridge	Date :	Created :

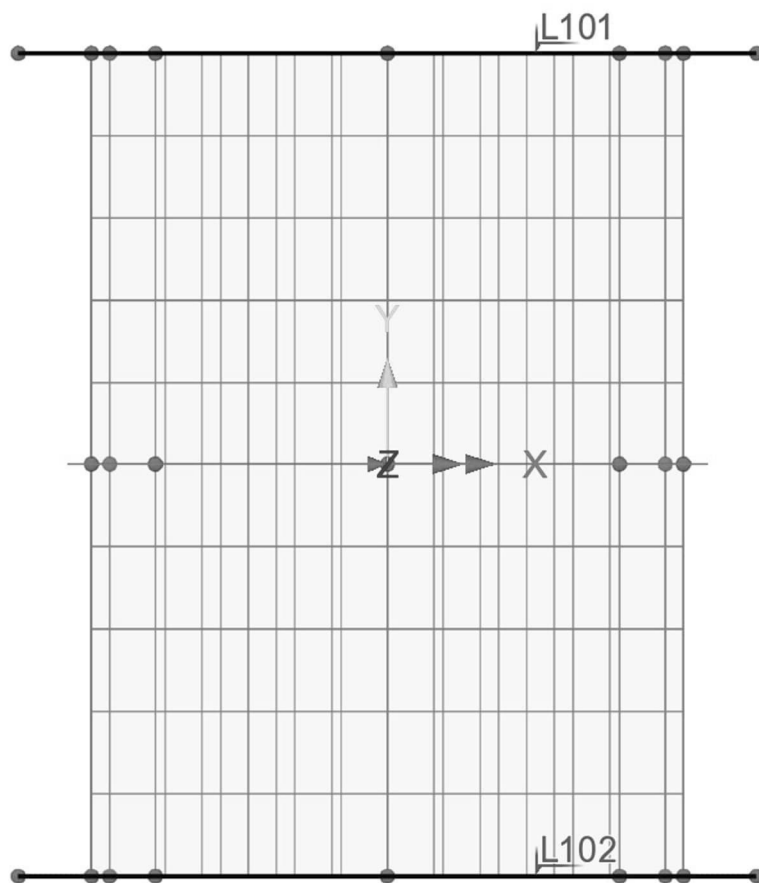
Vehicle longitudinal incremental movement: 0.25 m

Vehicle transverse incremental movement: 1.0 m

Vehicle direction: both

Definition of carriageway (kerbs): L101 & L102

Influence surfaces: Include all (positive & negative)



	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:29
	RC closed frame bridge	Date :	Created :

3.7.5.1 Envelope : LM 1

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

The screenshot shows the 'EN1991-2 Sweden 2011' configuration window. On the left, under 'Representative values required', the 'Characteristic' option is selected. On the right, under 'Load groups to include', 'Group 1a - LM1' is selected. The 'Dynamic amplification (additional)' is set to 20%. The 'Vehicle(s)' field contains 'SV1800200low'. The 'Include associated LM1' checkbox is checked. The 'Output for each load group' checkbox is unchecked.

3.7.5.2 Envelope : LM 2

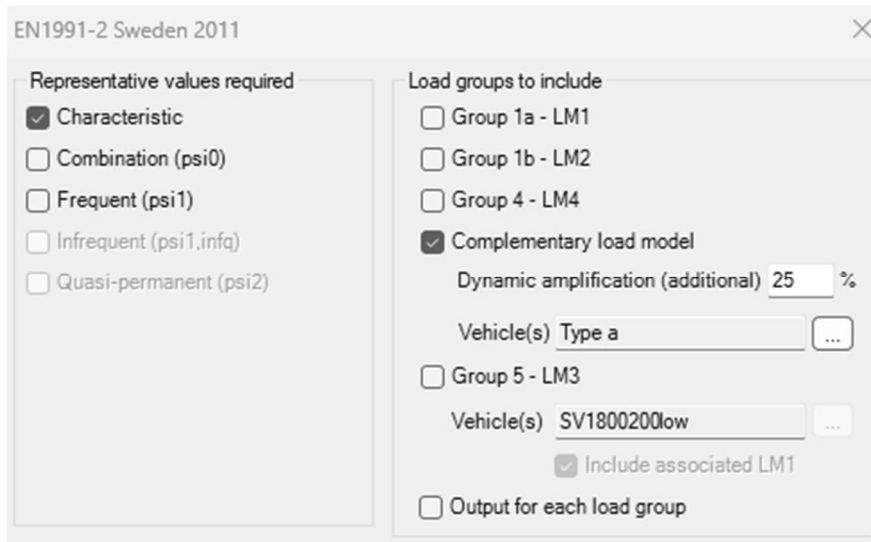
Load model 2 (LM2) defined in SS-EN 1991-2 section 4.3.3.

The screenshot shows the 'EN1991-2 Sweden 2011' configuration window. On the left, under 'Representative values required', the 'Characteristic' option is selected. On the right, under 'Load groups to include', 'Group 1b - LM2' is selected. The 'Dynamic amplification (additional)' is set to 20%. The 'Vehicle(s)' field contains 'SV1800200low'. The 'Include associated LM1' checkbox is checked. The 'Output for each load group' checkbox is checked.

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:30
	RC closed frame bridge	Date :	Created :

3.7.5.3 Envelope : EG A

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

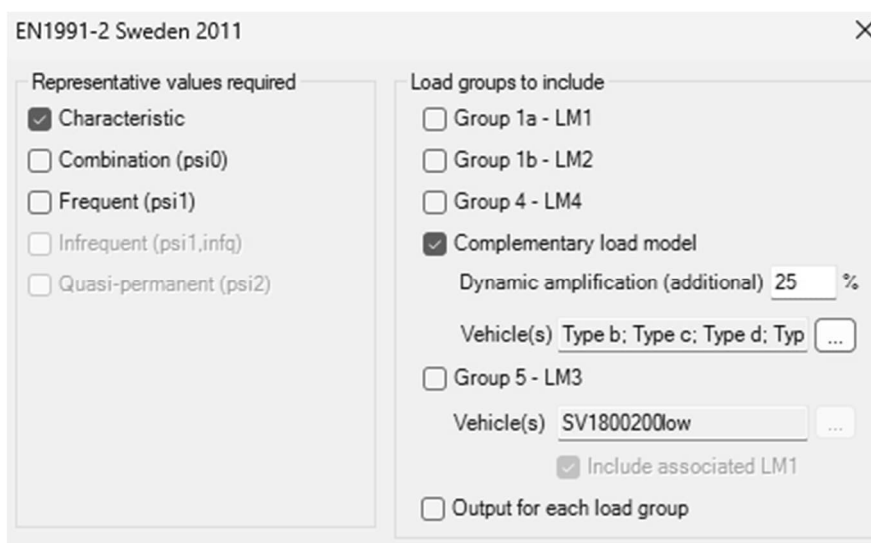


Dynamic amplification (additional): 25 %

Vehicle selection: Type a

3.7.5.4 Envelope : EG B

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



Dynamic amplification (additional): 25 %

Vehicle selection: Type b → n

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:31
	RC closed frame bridge	Date :	Created :

3.7.5.5 Combined traffic load

There are a total 3 different traffic loads termed LM 1, LM2, EG A and EG B.

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

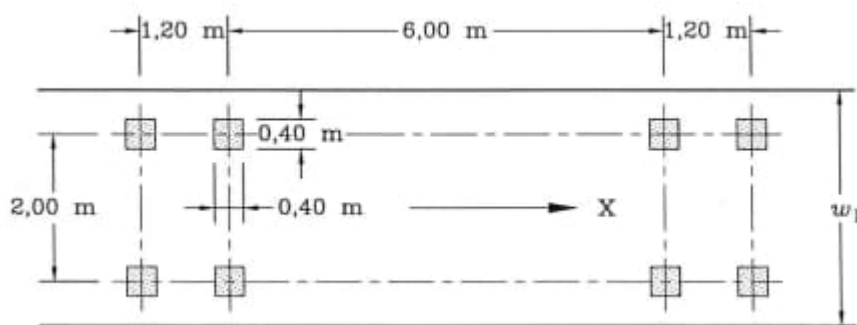
Envelope TRAFFIC :

Envelope
LM 1
LM 2
EG A
EG B

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:32
	RC closed frame bridge	Date :	Created :

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.



$Q_k = 120 \text{ kN}$: characteristic value including nation adaptation factors.

Representative values required <input checked="" type="checkbox"/> Characteristic <input type="checkbox"/> Combination (psi0) <input type="checkbox"/> Frequent (psi1) <input type="checkbox"/> Infrequent (psi1,infq) <input type="checkbox"/> Quasi-permanent (psi2)	Load groups to include <input type="checkbox"/> Group 1a - LM1 <input type="checkbox"/> Group 4 - LM4 <input type="checkbox"/> Complementary load model Dynamic amplification (additional) 20 % Vehicle(s) None ... <input checked="" type="checkbox"/> Group 5 Vehicle(s) UTM3 ... <input type="checkbox"/> Include associated LM1
--	--

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:33
	RC closed frame bridge	Date :	Created :

3.8 BRAKING LOAD

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

Load acts at level of surfacing.

$$L = 0.2\text{m} + 6.47\text{m} + 0.2\text{m} = 6.87\text{ m}$$

Load model LM 1 :

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

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

$$Q_{broms} = 0.6 \cdot (2 \cdot 270\text{kN}) + 0.1 \cdot 7.2\text{kPa} \cdot 3.0\text{m} \cdot 6.87\text{m} = 324\text{kN} + 15\text{kN} = 339\text{kN}$$

Load model EG B = 300 kN (see : TRVFS 2011:12 chapter 6 §3) :

Type m is considered critical.

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

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

$$Q_{broms} = 0.35 \cdot (1 + 1.32) \cdot B = 0.35 \cdot (1 + 1.32) \cdot 300\text{kN} = 244\text{kN}$$

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:34
	RC closed frame bridge	Date :	Created :

3.8.1 Load definition

Load is applied to static model as line load at centre of bridge with distribution width $0.5w_{tot}$ chosen on safe side.

$$p_x = \frac{Q_{broms}}{0.5w_{tot}} = \frac{339kN}{0.5 \cdot 9.0m} = 75 \frac{kN}{m}$$

$$m_y = p_x \cdot \left(\frac{0.45m}{2} + t_{bel} \right) = 75 \frac{kN}{m} \cdot \left(\frac{0.45m}{2} + 0.11m \right) = 25 \frac{kNm}{m}$$

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:35
	RC closed frame bridge	Date :	Created :

Load case : BROMS 1+

Structural loading : Global distributed

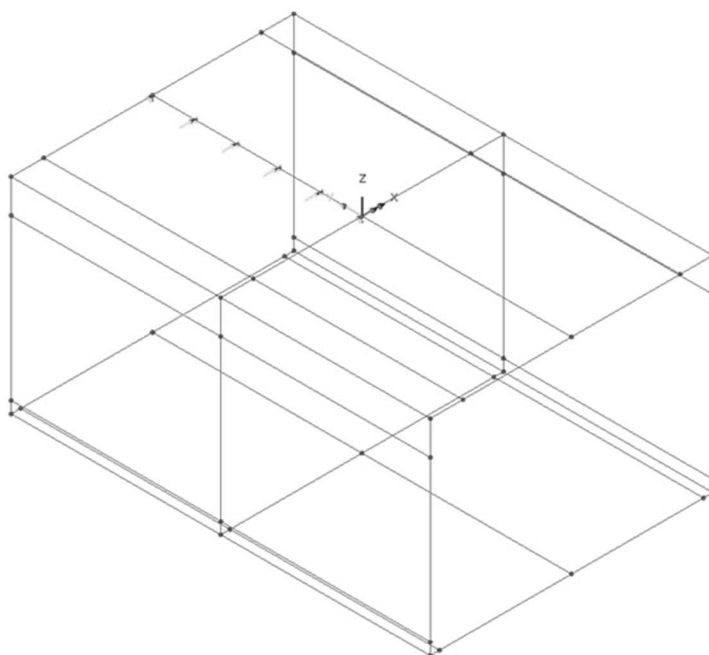
Line load (p_x) : 75 kN/m

Line load (m_y) : 25 kNm/m

Total
 Per unit length
 Per unit area

Component	Value
X Direction	75.0
Y Direction	0.0
Z Direction	0.0
Moment about X axis	0.0
Moment about Y axis	25.0
Moment about Z axis	0.0

Name (10)



	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A3:36
		Date :	Created :

Loadcase : BROMS 2+

Structural loading : Global distributed

Line load (p_x) : 75 kN/m

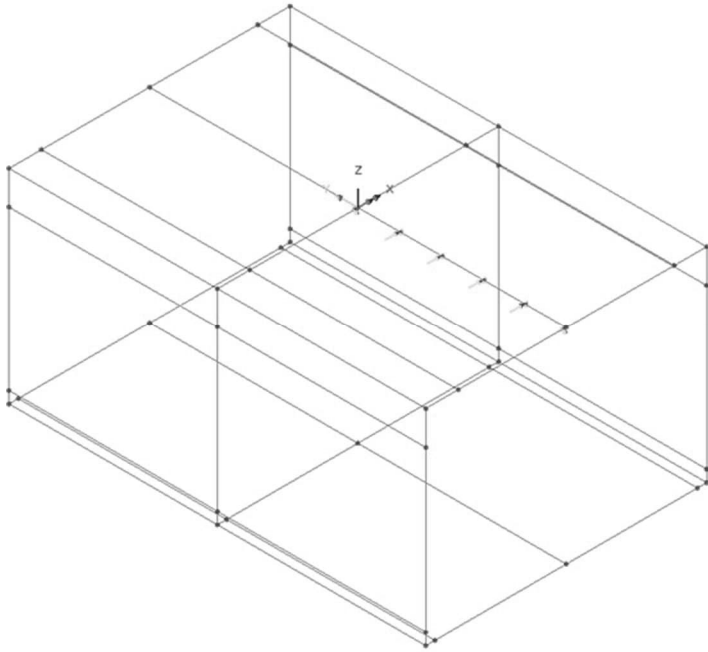
Line load (m_y) : 25 kNm/m

Total
 Per unit length
 Per unit area

Component	Value
X Direction	75.0
Y Direction	0.0
Z Direction	0.0
Moment about X axis	0.0
Moment about Y axis	25.0
Moment about Z axis	0.0

Name (11)

	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A3:37
		Date :	Created :



	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A3:38
		Date :	Created :

3.8.2 Load combination

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-

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:39
	RC closed frame bridge	Date :	Created :

3.9 LATERAL FORCE

Lateral force is defined by SS-EN 1991-2 §4.4.2.

The load is orthogonal to braking force and acts due to skewed braking.

Load model LM 1 :

$$Q_{tk} = 0.25Q_{lk} = 0.25 \cdot 339kN = 85kN \quad : \text{skewed braking}$$

Load model EG B = 300 kN (see TRVFS 2011:12 chapter 6 §3):

$$Q_{tk} = 0.25Q_{lk} = 0.25 \cdot 185N = 46kN \quad : \text{skewed braking}$$

Remark

Lateral force associated to LM 1 will be applied to all traffic loads on safe side.

$$\rightarrow Q_{sido} = 85kN$$

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:40
	RC closed frame bridge	Date :	Created :

3.9.1 Definition of load

Load is applied to static model as line load acting along centreline of superstructure. A distribution width of $0.5L_{spann}$ is used on safe side.

$$p_y = \frac{Q_{sido}}{0.5L_{spann}} = \frac{85kN}{0.5 \cdot 6.47m} = 26 \frac{kN}{m}$$

$$m_x = -p_y \cdot \left(\frac{0.45m}{2} + t_{bel} \right) = -26 \frac{kN}{m} \cdot \left(\frac{0.45m}{2} + 0.11m \right) = -8 \frac{kNm}{m}$$

	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A3:41
		Date :	Created :

Loadcase.: SIDO+

Structural loading : Global distributed

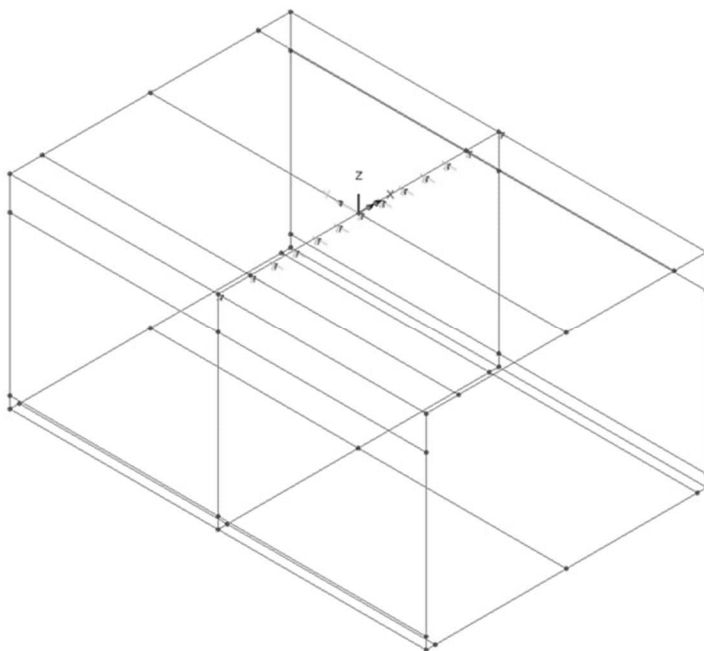
Line load (p_y) : 26 kN/m

Line load (m_x) : -8 kNm/m

Total
 Per unit length
 Per unit area

Component	Value
X Direction	0.0
Y Direction	26.0
Z Direction	0.0
Moment about X axis	-8.0
Moment about Y axis	0.0
Moment about Z axis	0.0

Name (12)



	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A3:42
		Date :	Created :

3.9.2 Load combination

Basic load cases :

Load case	Load	Factor
SIDO-	SIDO+	-1

Envelope SIDO :

Load case
SIDO+
SIDO-

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:43
	RC closed frame bridge	Date :	Created :

3.10 WIND LOAD

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

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

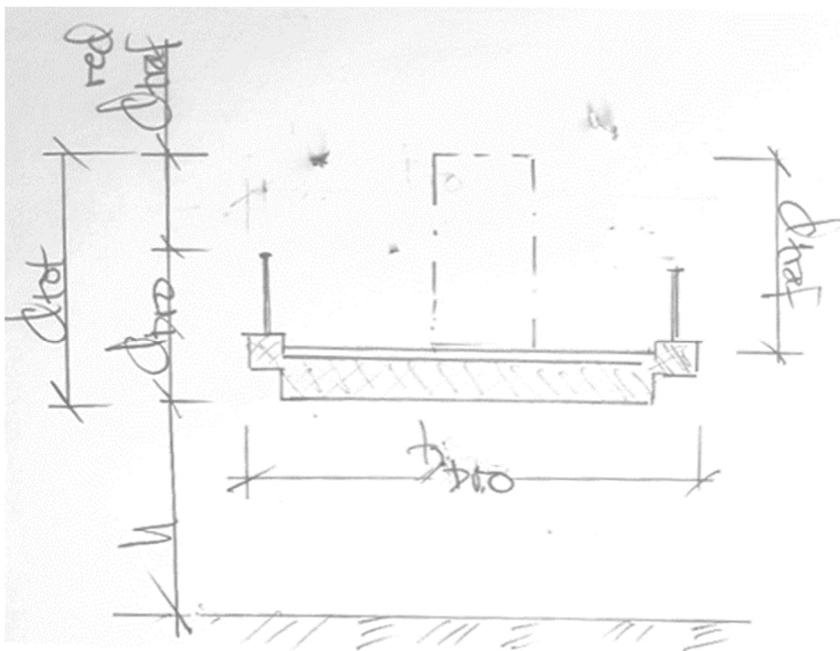
$$\psi_k = 1.00$$

$$\psi_0 = 0.30$$

$$\psi_1 = 0.20$$

$$\psi_2 = 0$$

Load intensity:



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

h = 3 m but 4 m is applied on safe side

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:44
	RC closed frame bridge	Date :	Created :

$$q_p \left(h = 4m; \text{Type II}; v_b = 23 \frac{m}{s} \right) = 0.54 kPa \quad : \text{TRVFS 2011:12 attachment 4 table 4.2}$$

$$q_b = \frac{1}{2} \cdot \rho \cdot v_b^2 = \frac{1}{2} \cdot 1.25 \frac{kg}{m^3} \cdot \left(23 \frac{m}{s} \right)^2 = 0.33 \frac{kN}{m^2} \quad : \text{SS-EN 1991-1-4 chapter 4.5}$$

$$c_e = \frac{q_p}{q_b} = \frac{0.54 kPa}{0.33 kPa} = 1.64 \quad : \text{SS-EN 1991-1-4 chapter 4.5}$$

$$d_{bro} = 0.45m + 0.17m + 0.12m + 1.10m = 1.84m \quad : \text{construction height}$$

$$d_{traf}^{red} = 2.0m - (0.12m + 1.10m) = 0.78m \quad : \text{construction height above railing}$$

$$d_{tot} = 1.84 + 0.78m = 2.6m$$

$$\rightarrow \frac{b_{bro}}{d_{tot}} = \frac{9.0m}{2.6m} = 3.5$$

$$c_{f.x} \left(\frac{b_{bro}}{d_{tot}} = 3.5 \right) = 1.35 \quad : \text{SS-EN 1991-1-4 sketch 8.3}$$

$$C = c_e \cdot c_{f.x} = 1.64 \cdot 1.35 = 2.2$$

Wind load structure :

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

$$p_{vind}^{bro} = \frac{F_w}{L} = \frac{1}{2} \cdot \rho \cdot v_b^2 \cdot C \cdot \frac{A_{ref.x}^{bro}}{L} = \frac{1}{2} \cdot 1.25 \frac{kg}{m^3} \cdot \left(23 \frac{m}{s} \right)^2 \cdot 2.2 \cdot 1.84m = 1.3 \frac{kN}{m}$$

Wind load traffic (above railing) :

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

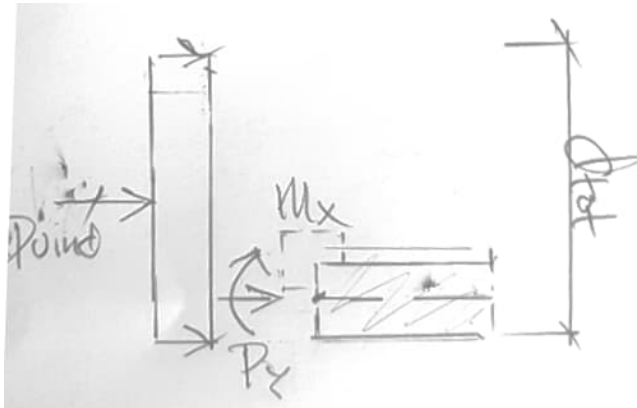
$$p_{vind}^{traf} = \frac{F_w}{L} = \frac{1}{2} \cdot \rho \cdot v_b^2 \cdot C \cdot \frac{A_{ref.x}^{traf}}{L} = \frac{1}{2} \cdot 1.25 \frac{kg}{m^3} \cdot \left(23 \frac{m}{s} \right)^2 \cdot 2.2 \cdot 0.78m = 0.6 \frac{kN}{m}$$

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:45
	RC closed frame bridge	Date :	Created :

3.10.1 Definition of load

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

$$p_{vind} = p_{vind}^{bro} + p_{vind}^{trafik} = 1.3 \frac{kN}{m} + 0.6 \frac{kN}{m} = 1.9 \frac{kN}{m}$$



$$p_y = 1.9 \frac{kN}{m}$$

→

$$m_x = -p_y \cdot \frac{d_{tot} - 0.45m}{2} = -1.9 \frac{kN}{m} \cdot \frac{2.6m - 0.45m}{2} = -2.0 \frac{kNm}{m}$$

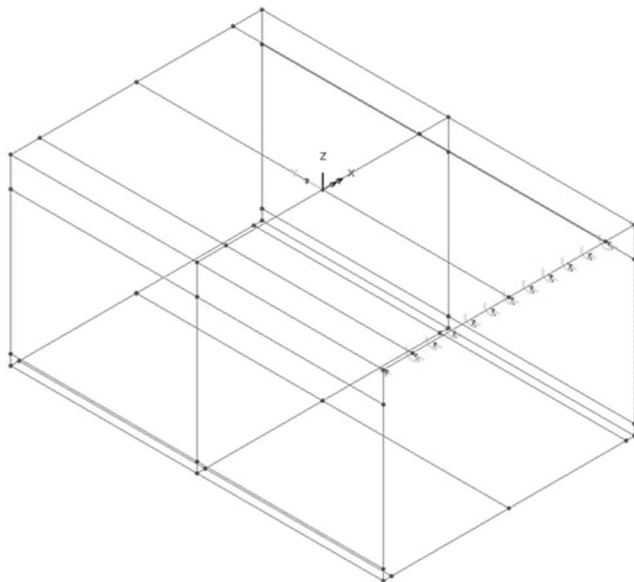
	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A3:46
		Date :	Created :

Load : VIND+

Structural loading : Global distributed

Line load in Y direction (p_y) : $+1.9 \frac{kN}{m}$

Line moment about X axis (m_x) : $-2.0 \frac{kNm}{m}$



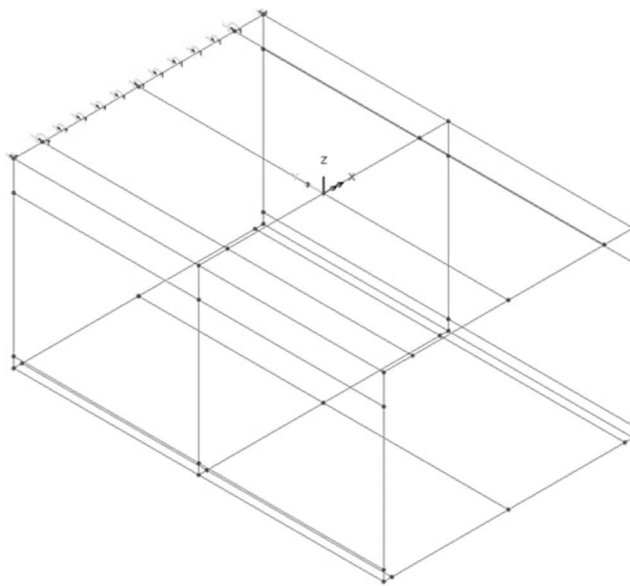
	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A3:47
		Date :	Created :

Load : VIND-

Structural loading : Global distributed

Line load in Y direction (p_y) : $-1.9 \frac{kN}{m}$

Line moment about X axis (m_x) : $2.0 \frac{kNm}{m}$



	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A3:48
		Date :	Created :

3.10.2 Load combination

Envelope VIND:

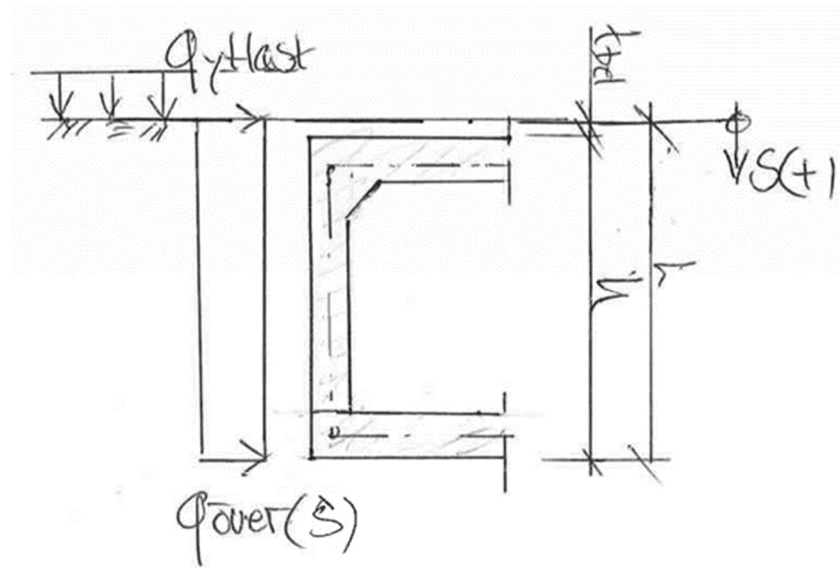
Load case
VIND+
VIND-

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:49
	RC closed frame bridge	Date :	Created :

3.11 SURCHARGE

Vertical surcharge is 20 kPa within road width 6 m. Remaining road has a vertical surcharge of 10 kPa.

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



$$q_{\text{ytlast}}^{b=6.0m} = 0.39 \cdot 20kPa = 8kPa$$

$$q_{\text{ytlast}}^{\text{övrigt}} = 0.39 \cdot 10kPa = 4kPa$$

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:50
	RC closed frame bridge	Date :	Created :

3.11.1 Load abutment 1

Surcharge is composed of three various surface loads as seen below.

OVER 1-1 : load width 9.0 m and $q_{ytlast} = 4kPa$

OVER 1-21 : load width 6.0 m and $q_{ytlast} = 4kPa$

OVER 1-22 : load width 6.0 m and $q_{ytlast} = 4kPa$

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:51
	RC closed frame bridge	Date :	Created :

Loadcase : OVER 1-1

Structural loading : Discrete 4 node patch load

Surface load (q_x) : 4 kPa

Search Area : Ramben 1

Loads outside search area : Include full load

Patch type
 8 node patch 4 node patch Multi-node patch Straight line Curve

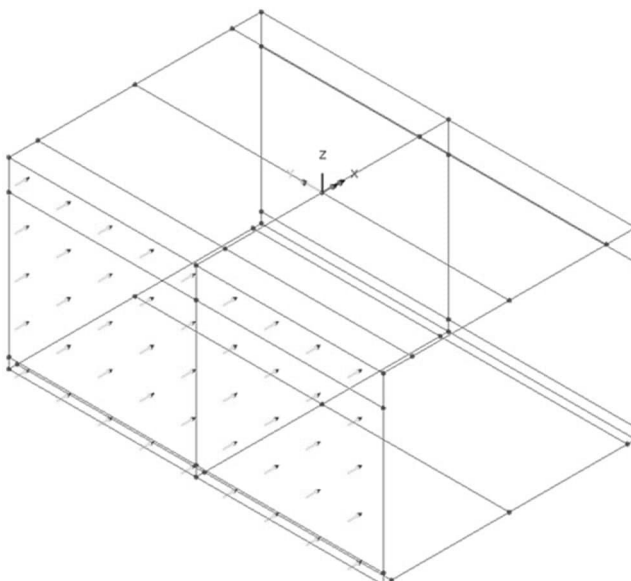
Load direction
 X Z
 Y XYZ
 Patch x
 Patch y
 Surface normal

Projection vector
 Project in load direction
 Project for prestress
 X component
 Y component
 Z component

Patch load divisions
 Use default
 Number of divisions in
 Number of divisions in y

	X	Y	Z	Load
1	-8.0	-4.5	-4.665	4.0
2	-8.0	-4.5	0.335	4.0
3	-8.0	4.5	0.335	4.0
4	-8.0	4.5	-4.665	4.0

Name (13)



	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:52
	RC closed frame bridge	Date :	Created :

Loadcase : OVER 1-21

Structural loading : Discrete 4 node patch load

Surface load (q_x) : 4 kPa

Search Area : Ramben 1

Loads outside search area : Include full load

Patch type

8 node patch
 4 node patch
 Multi-node patch
 Straight line
 Curve

Load direction

X Z
 Y XYZ
 Patch x
 Patch y
 Surface normal

Projection vector

Project in load direction
 Project for prestress

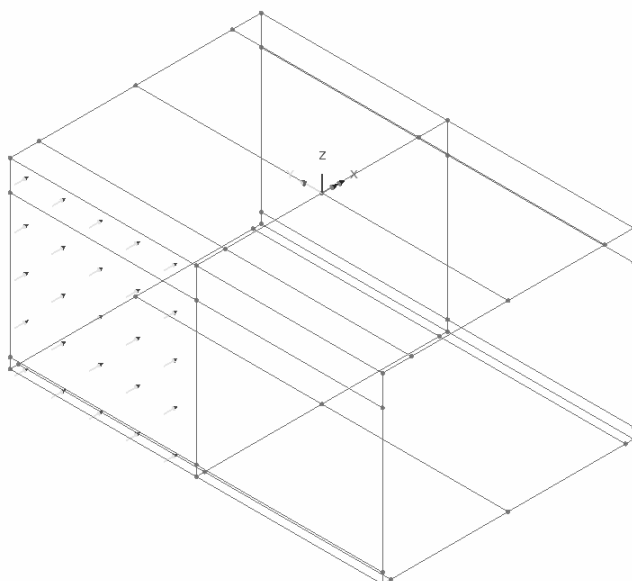
X component
Y component
Z component

Patch load divisions

Use default
Number of divisions in
Number of divisions in y

	X	Y	Z	Load
1	-8.0	-1.5	-4.665	4.0
2	-8.0	-1.5	0.335	4.0
3	-8.0	4.5	0.335	4.0
4	-8.0	4.5	-4.665	4.0

Name (15)



	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:53
	RC closed frame bridge	Date :	Created :

Loadcase : OVER 1-22

Structural loading : Discrete 4 node patch load

Surface load (q_x) : 4 kPa

Search Area : Ramben 1

Loads outside search area : Include full load

Patch type
 8 node patch 4 node patch Multi-node patch Straight line Curve

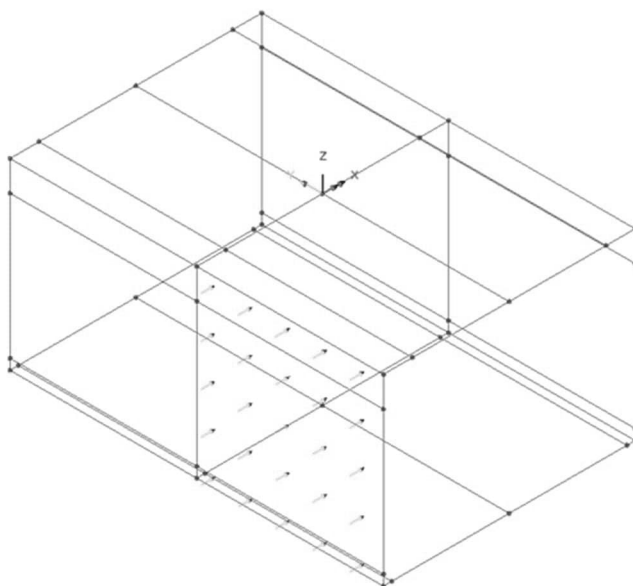
Load direction
 X Z
 Y XYZ
 Patch x
 Patch y
 Surface normal

Projection vector
 Project in load direction
 Project for prestress
 X component: 0.0
 Y component: 0.0
 Z component: 1.0

Patch load divisions
 Use default
 Number of divisions in: 0
 Number of divisions in y: 0

	X	Y	Z	Load
1	-8.0	-4.5	-4.665	4.0
2	-8.0	-4.5	0.335	4.0
3	-8.0	1.5	0.335	4.0
4	-8.0	1.5	-4.665	4.0

Name: OVER 1-22 (16)



	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A3:54
		Date :	Created :

3.11.2 Load abutment 2

Surcharge is composed of three various surface loads as seen below.

OVER 2-1 : load width 9.0 m and $q_{ytlast} = 4kPa$

OVER 2-21 : load width 6.0 m and $q_{ytlast} = 4kPa$

OVER 2-22 : load width 6.0 m and $q_{ytlast} = 4kPa$

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:55
	RC closed frame bridge	Date :	Created :

Loadcase : OVER 2-1

Structural loading : Discrete 4 node patch load

Surface load (q_x) : -4 kPa

Search Area : Ramben 2

Loads outside search area : Include full load

Patch type
 8 node patch 4 node patch Multi-node patch Straight line Curve

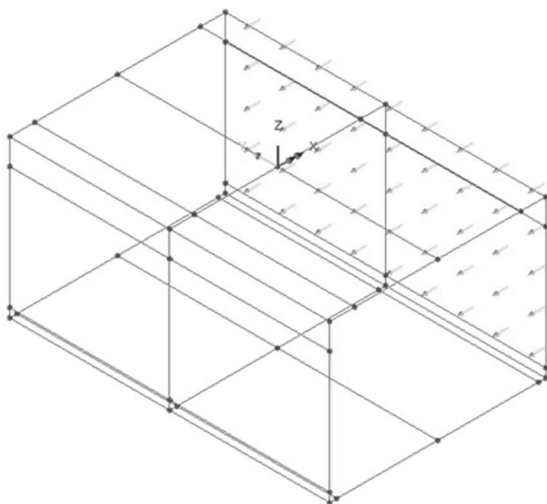
Load direction
 X Z
 Y XYZ
 Patch x
 Patch y
 Surface normal

Projection vector
 Project in load direction
 Project for prestress
X component
Y component
Z component

Patch load divisions
 Use default
Number of divisions in
Number of divisions in y

	X	Y	Z	Load
1	8.0	-4.5	-4.665	-4.0
2	8.0	-4.5	0.335	-4.0
3	8.0	4.5	0.335	-4.0
4	8.0	4.5	-4.665	-4.0

Name (14)



	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:56
	RC closed frame bridge	Date :	Created :

Loadcase : OVER 2-21

Structural loading : Discrete 4 node patch load

Surface load (q_x) : -4 kPa

Search Area : Ramben 2

Loads outside search area : Include full load

Patch type
 8 node patch 4 node patch Multi-node patch Straight line Curve

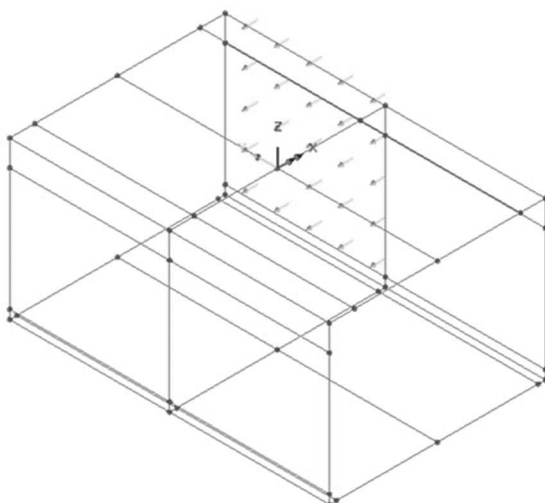
Load direction
 X Z
 Y XYZ
 Patch x
 Patch y
 Surface normal

Projection vector
 Project in load direction
 Project for prestress
X component: 0.0
Y component: 0.0
Z component: 1.0

Patch load divisions
 Use default
Number of divisions in: 0
Number of divisions in y: 0

	X	Y	Z	Load
1	8.0	-1.5	-4.665	-4.0
2	8.0	-1.5	0.335	-4.0
3	8.0	4.5	0.335	-4.0
4	8.0	4.5	-4.665	-4.0

Name: OVER 2-21 (17)



	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:57
	RC closed frame bridge	Date :	Created :

Loadcase : OVER 2-22

Structural loading : Discrete 4 node patch load

Surface load (q_x) : -4 kPa

Search Area : Ramben 2

Loads outside search area : Include full load

Patch type

8 node patch
 4 node patch
 Multi-node patch
 Straight line
 Curve

Load direction

X Z
 Y XYZ
 Patch x
 Patch y
 Surface normal

Projection vector

Project in load direction
 Project for prestress

X component
Y component
Z component

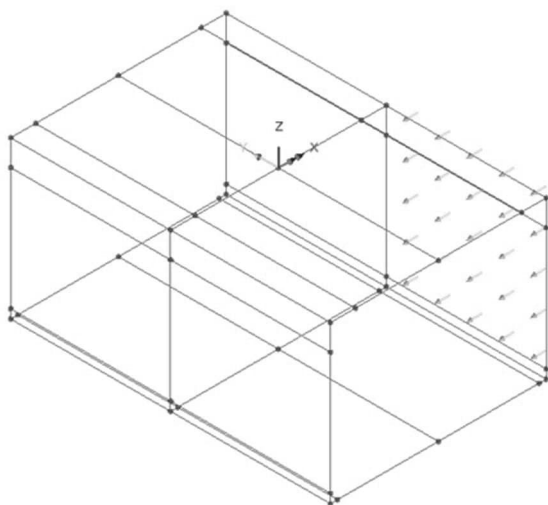
Patch load divisions

Use default

Number of divisions in
Number of divisions in y

	X	Y	Z	Load
1	8.0	-4.5	-4.665	-4.0
2	8.0	-4.5	0.335	-4.0
3	8.0	1.5	0.335	-4.0
4	8.0	1.5	-4.665	-4.0

Name (18)



	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A3:58
		Date :	Created :

3.11.3 Load combination

Envelope OVER 1-2 :

Load case
OVER 1-21
OVER 1-22

Envelope OVER 2-2 :

Load case
OVER 2-21
OVER 2-22

Load combination smart OVER :

Load case	Permanent factor	Variable factor
OVER 1-1	0	1
OVER 1-2	0	1
OVER 2-1	0	1
OVER 2-2	0	1

Smart load combination OVER :

Load case	Permanent factor	Variable factor
OVER-1	0	1.00
OVER-2	0	1.00

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:59
	RC closed frame bridge	Date :	Created :

3.12 TEMPERATURE

Temperature effect bridges according to TRVK Bro 11 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, $T_{\text{mont}} = +10^{\circ} \text{C}$: EN 1991-1-5A.1(3)

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

Concrete slab \Rightarrow typ 3

Location : Karlstad

$T_{\text{max}} = +34^{\circ} \text{C}$: BFS 2013:10 EKS 9 Tabell C-11

$T_{\text{min}} = -37^{\circ} \text{C}$: BFS 2010:3 EKS 6 Tabell C-11

Duration coefficients :

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

$$\psi_0 = 0.60$$

$$\psi_1 = 0.60$$

$$\psi_2 = 0.50$$

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:60
	RC closed frame bridge	Date :	Created :

3.12.1 Even temperature over entire bridge (JTEMP)

Even temperature over entire bridge according to EN 1991-1-5 section 6.1.3.3. This temperature change is seasonal.

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

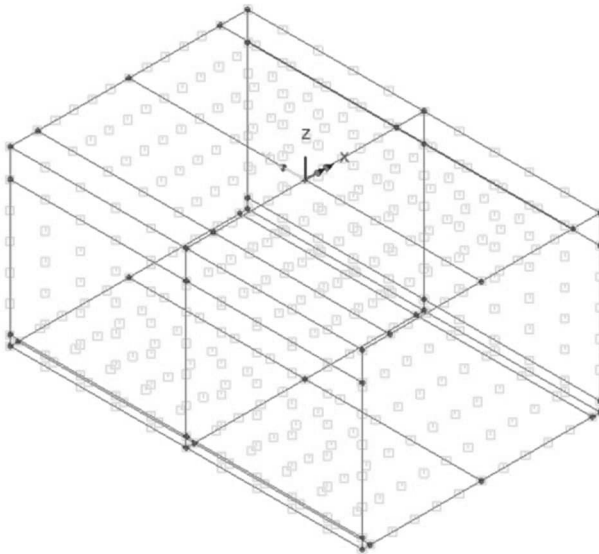
$$T_e(T) = \text{linterp}\left[(-50 \ 0 \ 30 \ 50)^T \cdot ^\circ\text{C}, (-42 \ 7 \ 32 \ 52)^T \cdot ^\circ\text{C}, T\right]$$

$$T_{e.max} = T_e(T_{max}) = 36^\circ\text{C}$$

$$T_{e.min} = T_e(T_{min}) = -29^\circ\text{C}$$

$$T^+ = T_{e.max} - T_0 = +36^\circ\text{C} - 10^\circ\text{C} = +26^\circ\text{C}$$

$$T^- = T_{e.min} - T_0 = -29^\circ\text{C} - 10^\circ\text{C} = -39^\circ\text{C}$$



	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A3:61
		Date :	Created :

Load : JTEMP+

Structural loading : Temperature

Final temperature : +26C

Initial temperature : ±0 C

Loadcase : JTEMP+

Load : JTEMP-

Structural loading : Temperature

Final temperature : -39C

Initial temperature : ±0 C

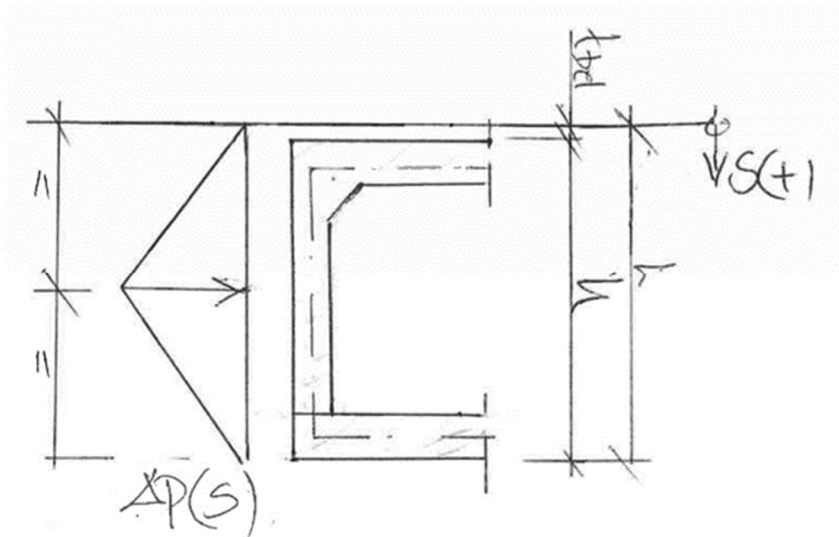
Loadcase : JTEMP-

..

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:62
	RC closed frame bridge	Date :	Created :

3.12.2 Increased earth pressure due to movement (DELTA P)

$$\rightarrow \delta = (T^+ - T^-) \cdot \alpha \cdot \frac{L_{bro}}{2} = (26^\circ\text{C} + 39^\circ\text{C}) \cdot 1.2 \cdot 10^{-5} \cdot \frac{6870\text{mm}}{2} = 2.7\text{mm}$$



$$h = 4890\text{mm}$$

$$t_{bel} = 110\text{mm}$$

$$\rightarrow L = 5000\text{mm}$$

$$\Delta q(s) = c \cdot \gamma \cdot s \cdot \frac{\delta}{h} = 600 \cdot 22 \frac{\text{kN}}{\text{m}^3} \cdot s \cdot \frac{2.7\text{mm}}{4890\text{mm}}$$

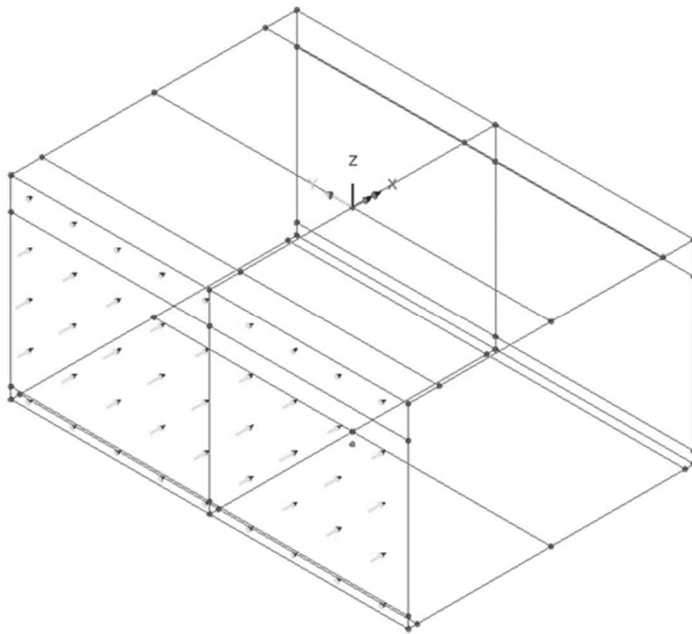
$$\Delta q_{max} = 600 \cdot 22 \frac{\text{kN}}{\text{m}^3} \cdot \frac{5000\text{mm}}{2} \cdot \frac{2.7\text{mm}}{4890\text{mm}} = 18\text{kPa}$$

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:63
	RC closed frame bridge	Date :	Created :

3.12.2.1 Load abutment 1

Discrete patch load : DELTA P-1

Search Area : Ramben 1



Patch type

8 node patch
 4 node patch
 Multi-node patch
 Straight line
 Curve

Load direction

X
 Z
 Y
 XYZ
 Patch x
 Patch y
 Surface normal

Projection vector

Project in load direction
 Project for prestress

X component: 0.0
Y component: 0.0
Z component: 1.0

Patch load divisions

Use default
Number of divisions in x: 0
Number of divisions in y: 0

	X	Y	Z	Load
1	-8.0	-4.5	-4.665	0.0
2	-8.0	-4.5	-2.165	18.0
3	-8.0	-4.5	0.335	0.0
4	-8.0	0.0	0.335	0.0
5	-8.0	4.5	0.335	0.0
6	-8.0	4.5	-2.165	18.0
7	-8.0	4.5	-4.665	0.0

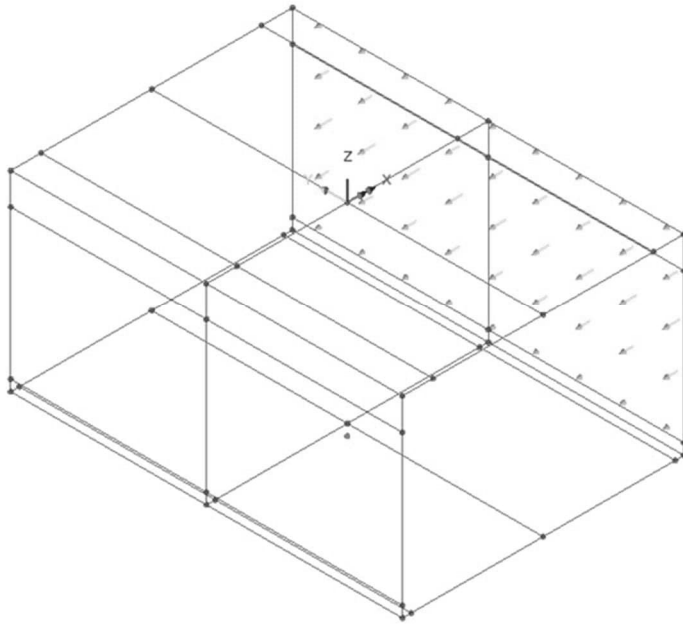
Name: DELTA P-1 (27)

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:64
	RC closed frame bridge	Date :	Created :

3.12.2.2 Load abutment 2

Discrete patch load : DELTA P-2

Search Area : Ramben 2



Patch type

8 node patch
 4 node patch
 Multi-node patch
 Straight line
 Curve

Load direction

X
 Z
 Y
 XYZ
 Patch x
 Patch y
 Surface normal

Projection vector

Project in load direction
 Project for prestress

X component: 0.0
Y component: 0.0
Z component: 1.0

Patch load divisions

Use default
Number of divisions in: 0
Number of divisions in y: 0

	X	Y	Z	Load	^
1	8.0	-4.5	-4.665	0.0	
2	8.0	-4.5	-2.165	-18.0	
3	8.0	-4.5	0.335	0.0	
4	8.0	0.0	0.335	0.0	
5	8.0	4.5	0.335	0.0	
6	8.0	4.5	-2.165	-18.0	
7	8.0	4.5	-4.665	0.0	

Name: DELTA P-2 (28)

	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A3:65
		Date :	Created :

3.12.2.3 Load combination

Load combination basic DELTA P.:

Loadcase	Factor
DELTA P-1	1
DELTA P-2	1

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:66
	RC closed frame bridge	Date :	Created :

3.12.3 Uneven temperature of entire cross section (OJTEMP)

Linear temperature difference over cross section is determined by EN 1991-1-5 § 6.1.4.1 with a surfacing thickness 110 mm and type 3.

$$k_{1.sur} = 0.70$$

$$k_{2.sur} = 1.00$$

$$\Delta T_{max} = +15^{\circ}\text{C} \cdot k_{1.sur} = +15^{\circ}\text{C} \cdot 0.70 = 11^{\circ}\text{C} \quad : \text{ top level hotter}$$

$$\Delta T_{min} = -8^{\circ}\text{C} \cdot k_{2.sur} = -8^{\circ}\text{C} \cdot 1.00 = -8^{\circ}\text{C} \quad : \text{ bottom level hotter}$$

Remark

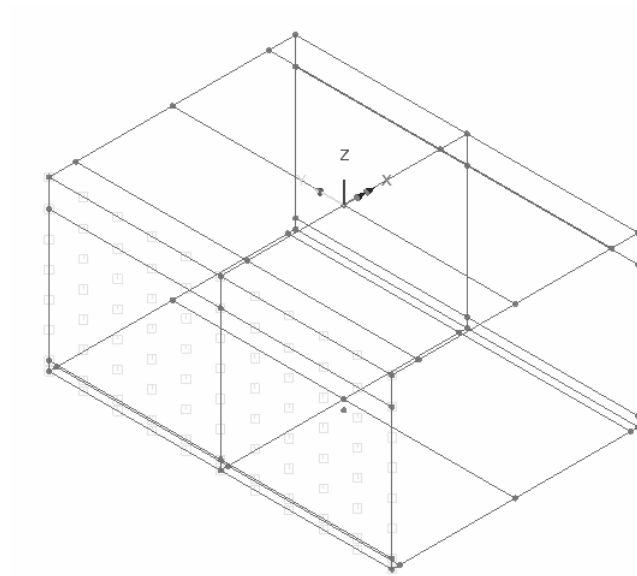
Uneven temperature is given with temperature gradient $\frac{\delta T}{\delta Z}$ inside software.

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:67
	RC closed frame bridge	Date :	Created :

3.12.3.1 Uneven temperature *Bottom slab*

$$\left| \frac{\delta T^{max}}{\delta Z} \right| = \left| \frac{11^{\circ}\text{C}}{0.50\text{m}} \right| = 22 \frac{^{\circ}\text{C}}{\text{m}} \quad : \text{maximal temperature gradient on side from filling}$$

$$\left| \frac{\delta T^{min}}{\delta Z} \right| = \left| \frac{-8^{\circ}\text{C}}{0.50\text{m}} \right| = 16 \frac{^{\circ}\text{C}}{\text{m}} \quad : \text{minimal temperature gradient on side towards filling}$$



Loadcase : OJTEMP 1 -MAX

Structural loading : Temperature

Definition : Element

Final Z temperature gradient : +22 °C/m

Loadcase : OJTEMP 1 -MIN

Structural loading : Temperature

Definition : Element

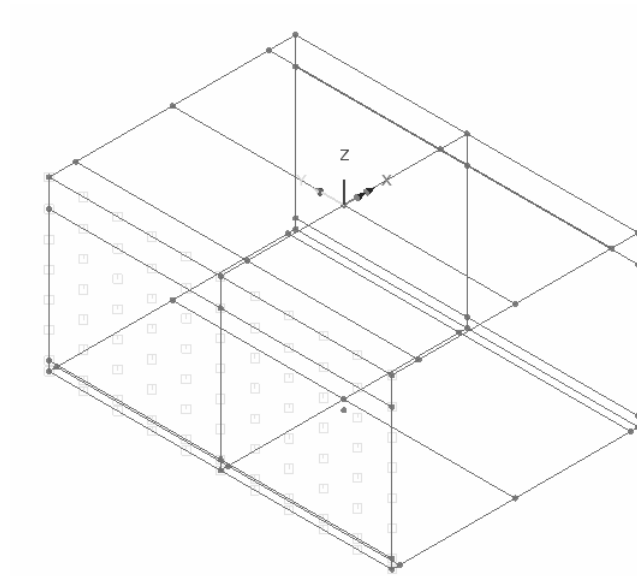
Final Z temperature gradient : -16 °C/m

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:68
	RC closed frame bridge	Date :	Created :

3.12.3.2 Uneven temperature *abutment 1*

$$\left| \frac{\delta T^{max}}{\delta Z} \right| = \left| \frac{11^{\circ}\text{C}}{0.40\text{m}} \right| = 28 \frac{^{\circ}\text{C}}{\text{m}} \quad : \text{maximal temperature gradient on side from filling}$$

$$\left| \frac{\delta T^{min}}{\delta Z} \right| = \left| \frac{-8^{\circ}\text{C}}{0.40\text{m}} \right| = 20 \frac{^{\circ}\text{C}}{\text{m}} \quad : \text{minimal temperature gradient on side towards filling}$$



Loadcase : OJTEMP 2 -MAX

Structural loading : Temperature

Definition : Element

Final Z temperature gradient : +28 °C/m

Loadcase : OJTEMP 2 -MIN

Structural loading : Temperature

Definition : Element

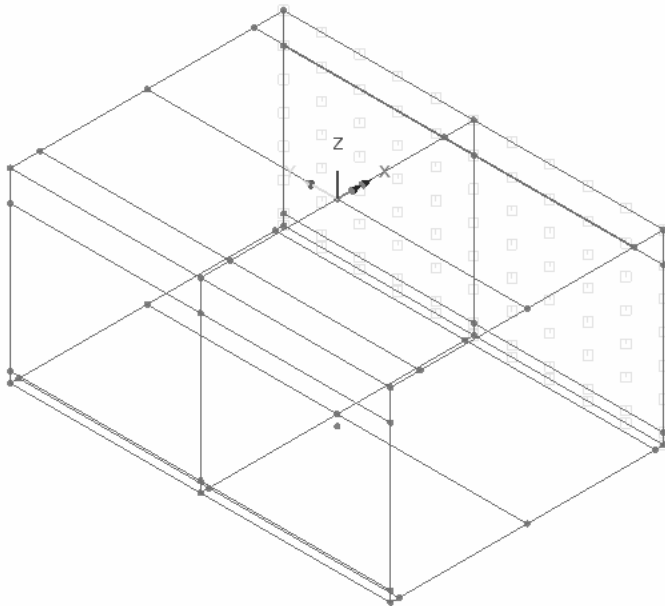
Final Z temperature gradient : -20 °C/m

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:69
	RC closed frame bridge	Date :	Created :

3.12.3.3 Uneven temperature *abutment 2*

$$\left| \frac{\delta T^{max}}{\delta Z} \right| = \left| \frac{11^{\circ}\text{C}}{0.40\text{m}} \right| = 28 \frac{^{\circ}\text{C}}{\text{m}} \quad : \text{maximal temperature gradient on side from filling}$$

$$\left| \frac{\delta T^{min}}{\delta Z} \right| = \left| \frac{-8^{\circ}\text{C}}{0.40\text{m}} \right| = 20 \frac{^{\circ}\text{C}}{\text{m}} \quad : \text{minimal temperature gradient on side towards filling}$$



Loadcase : OJTEMP.3.-MAX

Structural loading : Temperature

Definition : Element

Final Z temperature gradient : +20 °C/m

Loadcase : OJTEMP.3.-MIN

Structural loading : Temperature

Definition : Element

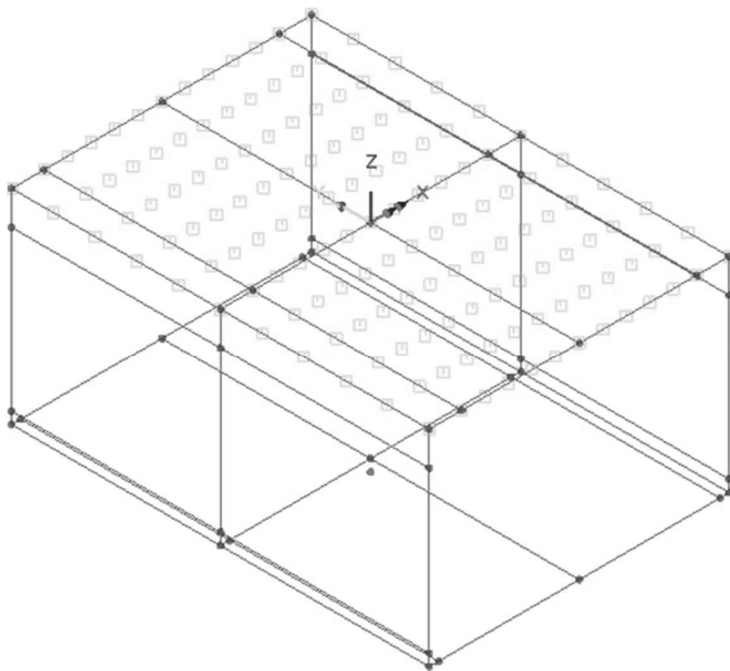
Final Z temperature gradient : -28 °C/m

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:70
	RC closed frame bridge	Date :	Created :

3.12.3.4 Uneven temperature *superstructure*

$$\left| \frac{\delta T^{max}}{\delta Z} \right| = \left| \frac{11^{\circ}\text{C}}{0.45\text{m}} \right| = 24 \frac{^{\circ}\text{C}}{\text{m}} \quad : \text{maximal temperature gradient acting at top side}$$

$$\left| \frac{\delta T^{min}}{\delta Z} \right| = \left| \frac{-8^{\circ}\text{C}}{0.45\text{m}} \right| = 18 \frac{^{\circ}\text{C}}{\text{m}} \quad : \text{minimal temperature gradient acting at bottom side}$$



Loadcase : OJTEMP 4 -MAX

Structural loading : Temperature

Definition : Element

Final Z temperature gradient : +24 °C/m

Loadcase : OJTEMP 4 -MIN

Structural loading : Temperature

Definition : Element

Final Z temperature gradient : -18 °C/m

	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A3:71
		Date :	Created :

3.12.3.4 Load combination

Load combination smart OJTEMP:

Load case	Permanent factor	Variable factor
OJTEMP 1-MAX	0	1
OJTEMP 1-MIN	0	1
OJTEMP 2-MAX	0	1
OJTEMP 2-MIN	0	1
OJTEMP 3-MAX	0	1
OJTEMP 3-MIN	0	1
OJTEMP 4-MAX	0	1
OJTEMP 4-MIN	0	1

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:72
	RC closed frame bridge	Date :	Created :

3.12.4 Simultaneous even and uneven temperature change

Simultaneous even and uneven temperature change according to 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 basic JTEMP MAX :

Load case	Factor
JTEMP+	1
DELTA P	1

Load combination basic JTEMP MIN :

Load case	Factor
JTEMP-	1

Envelope JTEMP :

Load case
JTEMP MAX
JTEMP MIN

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

	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A3:73
		Date :	Created :

3.13 LOAD COMBINATIONS

Verification of resistance is to be performed at different states as seen below.

Design is to be performed using method of partial coefficients according to EN-1990.

Resistance must be verified for both ultimate and service state.

Verification of ultimate state used various load coefficients depending on type of resistance break as seen below.

EQU : verification of overturning of foundation

STR/GEO : verification of structural and geotechnical resistance

Design is to be performed using a “simplified method” for load coefficients. How chosen coefficients are determined is shown in Mathcad program PROG L2.002. All formulas and part results are shown.

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:74
	RC closed frame bridge	Date :	Created :

3.13.1 Ultimate state (ULS)

This load combination is the main normal load situation where the variable loads are dominant.

KBB section B.3.3.1 has requirements on load combination seen listed below:

- Design method D2 is to be used for STR according to SS-EN 1990 section A.2.3.1(5).

Design value according to table A2.4(B) is used for both geotechnical and structural loads.

A1 (structure load) + A1 (geotechnical load, $\psi\gamma = 1.35$ & $\gamma_M = 1.00 \rightarrow 0.29$)

- Design method D3 is to be used for GEO see SS-EN 1990 section A.2.3.1(5).

Design value according to table A2.4(C) is to be used for both geotechnical loads while table A2.4(B) for structural loads.

A1 (structural load) + A2 (geotechnical load, $\psi\gamma = 1.00$ & $\gamma_M = 1.30 \rightarrow 0.38$)

In order to limit the number of load combinations design values table A2.4(B) are used also for geotechnical evaluation of GEO. Fictive load coefficients seen below are used for the geotechnical loads.

Verification of geotechnical loads :

$$K_o(D2) = 1 - \sin(\varphi_d) = 1 - \sin 45^\circ = 0.29$$

$$K_o(D3) = 1 - \sin(\varphi_d) = 1 - \sin 38^\circ = 0.38$$

Earthpressure $\rightarrow 1.35^{1.)} \cdot K_o(D2) = 0.39 > 1.00 \cdot K_o(D3) = 0.38$ dvs OK !

Surcharge $\rightarrow 1.70^{2.)} \cdot K_o(D2) = 0.49 \equiv 1.30 \cdot K_o(D3) = 0.49$ dvs OK !

1.) Load coefficient $\psi\gamma_{ULS-B} = 1.35$ is used instead of 1.20

2.) Load coefficient $\psi\gamma_{ULS-B} = 1.70$ is used instead of 1.50

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:75
	RC closed frame bridge	Date :	Created :

Design method D2

(Used for both STR & GEO)

For design method D2 (setting B) there are two expressions of equation 6.10a & 6.10b according to SS-EN 1990.

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

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

Equation 6.10a is used when permanent loads are dominant. This situation arises during construction stage but is not considered critical for operational stage.

Equation 6.10b is used when variable loads are dominant. This situation arises during operational stage. This is the situation used in static model.

	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A3:76
		Date :	Created :

Simplified method for design method D2

Design is performed using the "simplified method" where load coefficients associated to equation 6.10a is termed ULS-A while ULS-B is used for equation 6.10b.

On the safe side the same load coefficient is used for traffic lane loads as for axis loads.

	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A3:77
		Date :	Created :

Nr	Last	$\Psi\gamma_{ULS-A}$	$\Psi\gamma_{ULS-B}$	$\Psi\gamma_{ULS-B}$	
<u>Permanent loads</u>					
1	Egentyngd	max	1,35	1,20	1,20
		min	1,00	1,00	1,00
2	Beläggning	max	1,35	1,20	1,20
		min	1,00	1,00	1,00
3	Överfyllnad	max	1,35	1,20	1,20
		min	1,00	1,00	1,00
4	Jordtryck	max	1,35	1,20	1,35
		min	1,00	1,00	1,00
5	Vattentryck	max	1,35	1,20	1,20
		min	1,00	1,00	1,00
6	Stödförskjutning ¹⁾	max	1,35	1,20	1,20
		min	1,00	1,00	1,00
7	Krympning ²⁾	max	1,35	1,20	1,20
		min	1,00	1,00	1,00
8	Spännkraft	max	1,35	1,35	1,35
		min	1,00	1,00	1,00
⇒					
<u>Variable loads</u>					
Lastmodell LM 1 :					
9	Boggiesystem	1.13/0.84	1.13/1.50	1.13/1.50	
10	Utbredd last	0.60/0.24	0.60/1.50	0.60/1.50	
11	Bromskraft	0.84/1.13	1.13/1.50	1.13/1.50	
12	Sidokraft	0.84/1.13	1.13/1.50	1.13/1.50	
13	Centrifugalkraft	0.84/1.13	1.13/1.50	1.13/1.50	
Lastmodell LM 2 :					
14	Enstaka axellast	0	0/1.50	0/1.50	
Typfordon EG A/B :					
15	Typfordon EG A/B	1.13/0.84	1.13/1.50	1.13/1.50	
20	Bromskraft	0.84/1.13	1.13/1.50	1.13/1.50	
21	Sidokraft	0.84/1.13	1.13/1.50	1.13/1.50	
22	Centrifugalkraft	0.84/1.13	1.13/1.50	1.13/1.50	
16	Temperatur ³⁾	0.90	0.90/1.50	0.90/1.50	
Vindlaster:					
17	Vindlast mot bro	0.45	0.45/1.50	0.45/1.50	
18	Vindlast mot trafik	0.45	0.45/1.50	0.45/1.50	
19	Överlast	1.13	1.13/1.50	1.13/1.70	

	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A3:78
		Date :	Created :

Load combination smart ULS-PERM :

Load case	Permanent factor	Variable factor
EGEN	1.00	0.20
BELÄGG	1.00	0.20
JORD	1.00	0.20
STOD	0	$1.2 \cdot f_{STOD} = 0.40$
KRYMP	0	$1.2 \cdot s_{KRYMP} = 0.40$

Load combination smart ULS-VAR :

(Load cases to consider : 6 / Variable loadcases : 1)

Load case	Permanent factor	Variable factor
VÄGTRAFIK	1.13	0.37
BROMS	1.13	0.37
SIDO	1.13	0.37
TEMP	0.90	0.60
VIND	0.45	1.05
OVER	1.13	0.57

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

Load combination smart ULS :

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

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:79
	RC closed frame bridge	Date :	Created :

3.13.2 Service state (SLS)

Service state is divided into three different load combinations dependant on duration of loads, as seen below.

Load combination	Duration
SLS:K	Characteristic
SLS:F	Frequent
SLS:Q	Quasi-permanent

Load combination SLS:K see EN 1990 equation 6.14b:

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

Load combination SLS:F see EN 1990 equation 6.15b:

$$E_{Sd} = \sum_{j \geq 1} G_{k,j} + \psi_1 \cdot Q_{k,1} + \sum_{i > 1} \psi_{2,i} \cdot Q_{k,i} = \psi \gamma_{SLS,2} \cdot \left(\sum_{j \geq 1} G_{k,j} + \sum_{i > 1} Q_{k,i} \right)$$

Load combination SLS:Q see EN 1990 equation 6.16b:

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

Design will be performed using "simplified method" with load coefficients derived from equations see above.

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:80
	RC closed frame bridge	Date :	Created :

Simplified method (see separate derivation)

Nr	Last		$\Psi\gamma_{SLS-K}$	$\Psi\gamma_{SLS-F}$	$\Psi\gamma_{SLS-Q}$
	<u>Permanent loads</u>				
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
	<u>Variable loads</u>				
	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

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:81
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Load combination smart SLS-PERM.:

Loadcase	Permanent factor	Variable factor
EGEN	1.00	0
BELÄGG	0.90	0.20
JORD	0.90	0.20
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 : 6 / Variable loadcases : 1)

Loadcase	Permanent factor	Variable factor
VÄGTRAFIK	0.75	0.25
BROMS	0.56	0.19
SIDO	0.56	0.19
TEMP	0.60	0.40
VIND	0.60	0.40
OVER	0.75	0.25

Load combination smart SLS-F-VAR.:

Load case	Permanent factor	Variable factor
VÄGTRAFIK	0	0.75
BROMS	0	0.56
SIDO	0	0.56
TEMP	0	0.60
VIND	0	0.30
OVER	0	0.75

	Part A - CALCULATION ASSUMPTIONS RC closed frame bridge	Status :	Page: A3:82
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Load combination smart SLS-K:

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

Load combination smart SLS-F:

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

Load combination smart SLS-Q:

Load case	Permanent factor	Variable factor
SLS-PERM	1	0
TEMP	0	0.50

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:83
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3.13.3 Fatigue

Risk of fatigue is performed using simplified method, termed λ -method.

Load combination according to SS-EN 1992-1-1 section 6.8.3 equation 6.69 :

(In this load combination traffic is assumed to be UTM3 thus all other traffic loads are not applied)

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

According to SS-EN 1992-2 attachment NN 2.1 this method assumes verification of ULM3 according to SS-EN 1991-2 section 4.6.4 :

Load combination UTM results in a expression that complies with frequent load combination in service state (SLS:F):

$$E_{Sd} \approx \psi \gamma_{SLS.F} \cdot \left(\sum_{j \geq 1} G_{k,j} + P + \sum_{i \geq 1} Q_{k,j} \right) + Q_{ULM3} = \psi \gamma_{UTM} \cdot \left(\sum_{j \geq 1} G_{k,j} + P + \sum_{i \geq 1} Q_{k,i} + Q_{ULM3} \right)$$

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Simplified method (see separate derivation)

Nr	Last	ψ/γ_{UTM}
	<u>Permanent loads</u>	
1	Egentyngd	max 1,00 min 1,00
2	Beläggning	max 1,00 min 1,00
3	Överfyllnad	max 1,00 min 1,00
4	Jordtryck	max 1,00 min 1,00
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
	<u>Variable loads</u>	
	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	-
20	Bromskraft	-
22	Sidokraft	-
22	Centrifugalkraft	-
16	Temperatur	0.60 ^{a.)}
	Vindlaster:	
17	Vindlast mot bro	0.30 ^{a.)}
18	Vindlast mot trafik	0.30 ^{a.)}
19	Överlast	0.75 ^{a.)}
23	ULM3	1.00

^{a.)} Loads are not consider as fatigue loads when analysing stress width range.

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Load combination smart FAT.:

Loadcase	Permanent factor	Variable factor
EGEN	1.00	0
BELÄGG	1.00	0
JORD	1.00	0
STOD	-	-
KRYMP	-	-
STOD	-	-
KRYMP	-	-
UTM	-	1.00
OVER	-	-
TEMP	-	-

Load cases STOD (settlement), KRYMP (shrinkage) and OVER (surcharge) are not used since not considered to be fatigue loads.

For verification STR the load case TEMP (temperature) may be neglected according to SS-EN 1992-1-1 section 2.3.1.2(2).