

Composite steel curved quadruple I-girder bridge

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4.	System 001 : Results bracings

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1. GENERAL / MEASUREMENT

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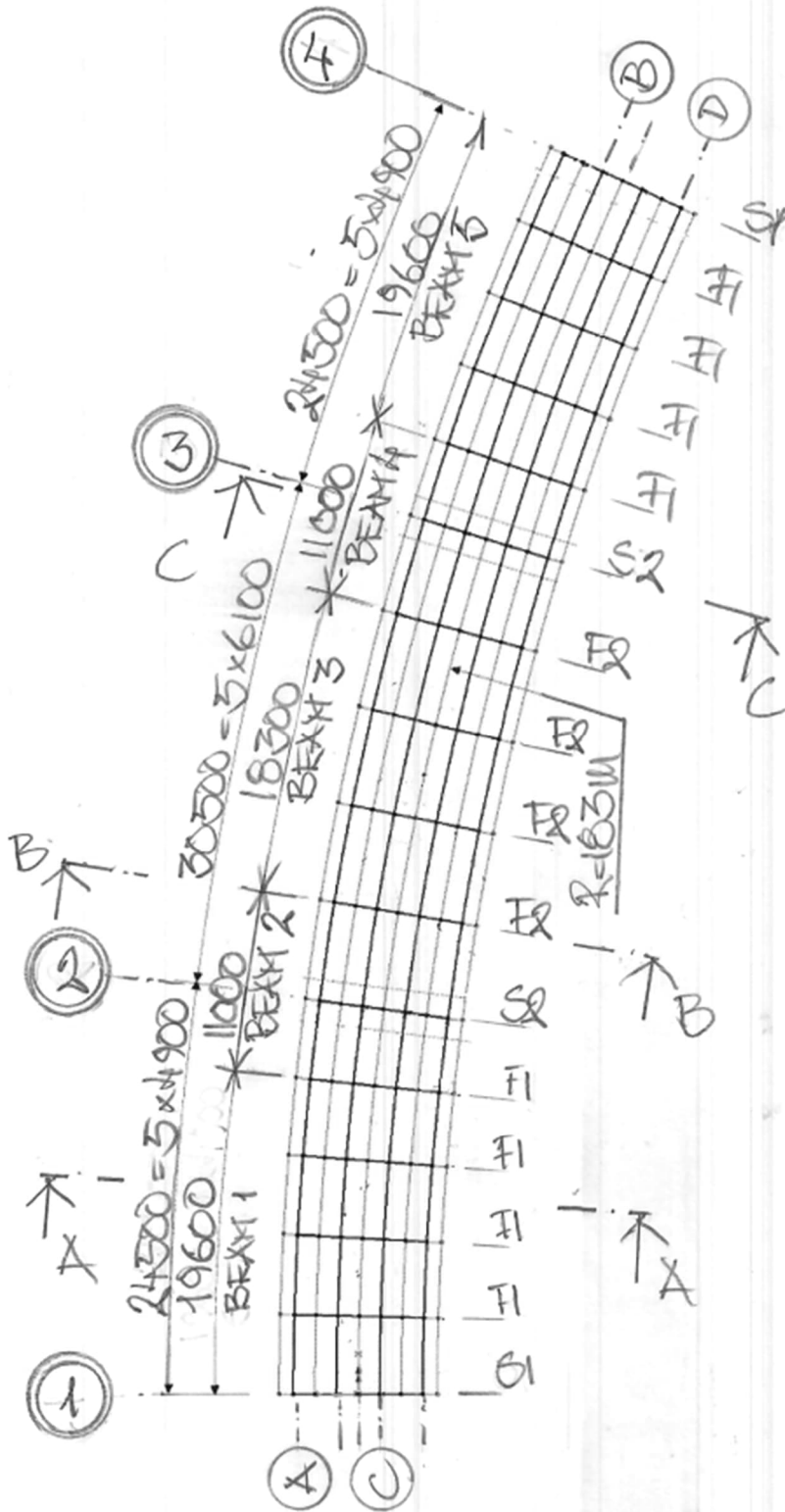
1.1 CONSTRUCTION TYPE

Composite steel girders.

Superstructure is modelled using girders modeled as shells (web) and flanges (beam) with deck as shells.

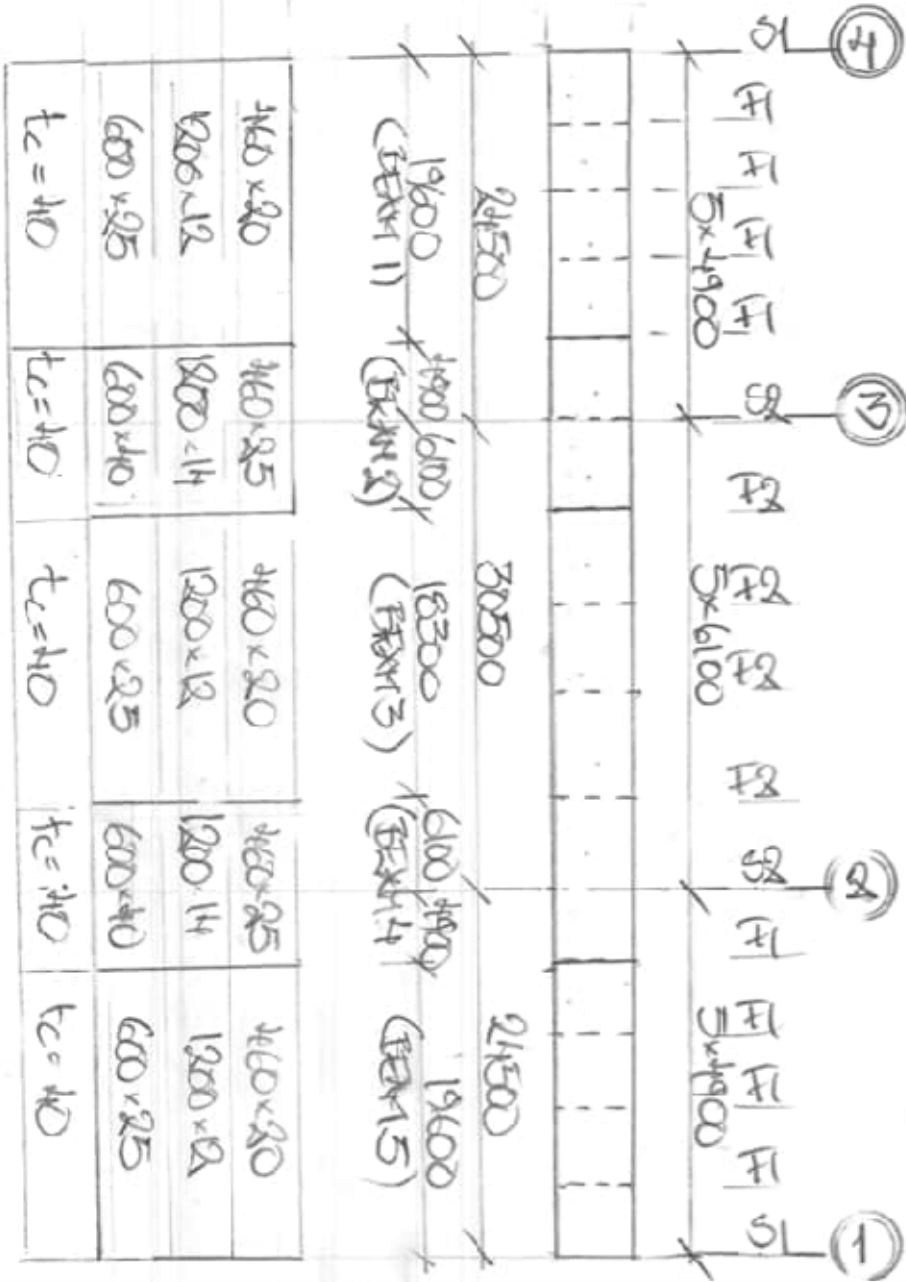
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1.2 MEASUREMENT



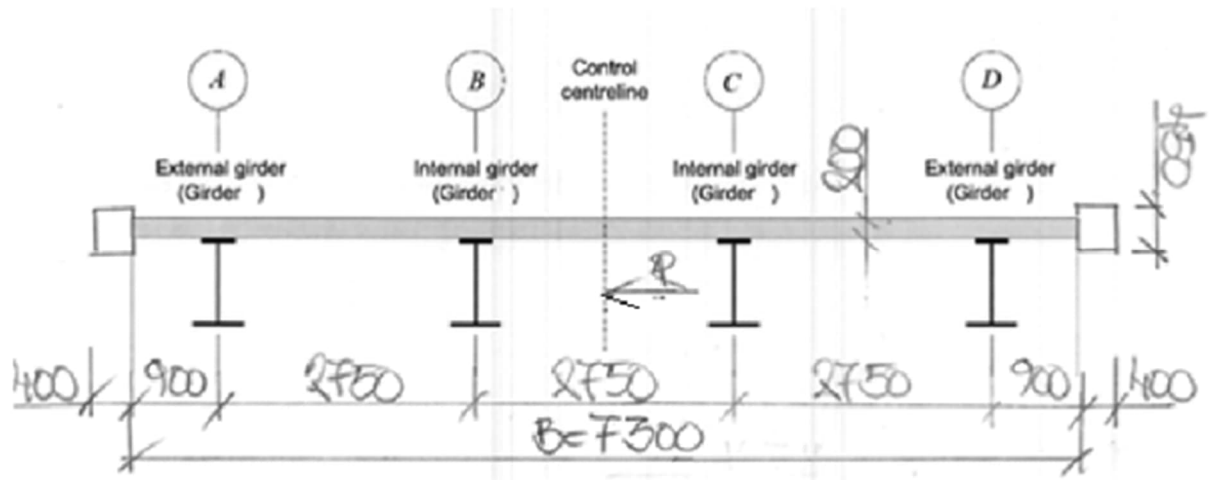
PLAN

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A1:4
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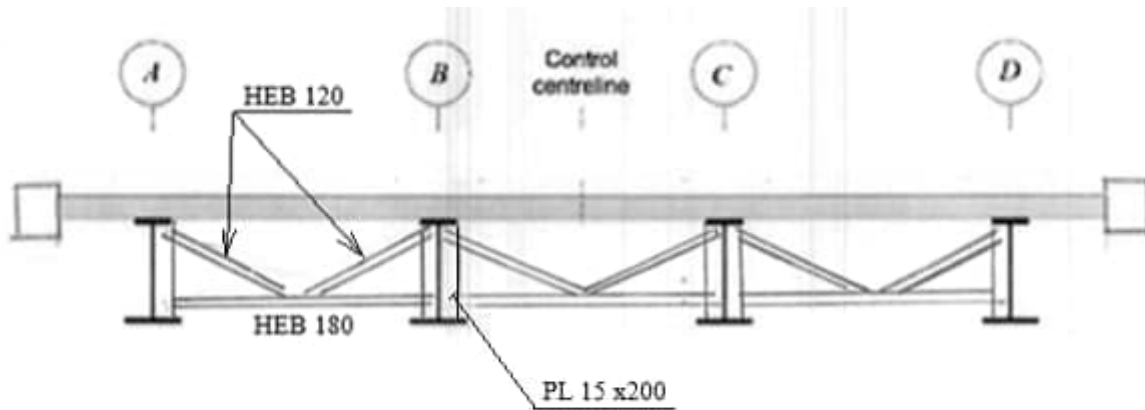
ELEVATION GIRDERS
BEAM 1-5

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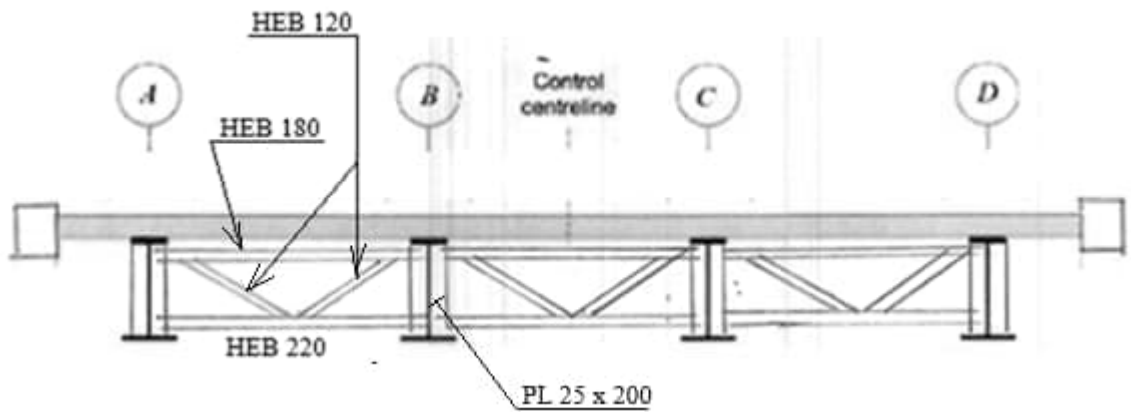


SECTION A-A
Concrete deck

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SECTION B-B
Bracing F2 (F1)



SECTION C-C
Bracing S2 (S1)

-

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1.4 CODE DOCUMENTS

Documents	Version	Name
SS-EN 1990-1997	-	Svensk Standard Eurokod 1-7
TRVINFRA-00226	2.0	KRAV, Bro och broliknande konstruktion, Allmänna krav
TRVINFRA-00227	2.0	KRAV, Bro och broliknande konstruktion, Byggande
TRVINFRA-00228	2.0	KRAV, Bro och broliknande konstruktion, Brounderhåll
TRVINFRA-00331	2.0	KRAV, Bro och broliknande konstruktion, Bärighetsberäkning
TSFS 2018:57		Transportstyrelsens föreskrifter och allmänna råd om tillämpning av eurokoder

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1.5 TECHNICAL SERVICE LIFE

Technical life span 120 years (L100).

1.6 MATERIAL

Concrete : C35/45 (CEM I 42.5 ”Anläggningscement klass N”)

Reinforcement : B500B

Steel : S355 or S460 (SS-EN 1993-1-1 tabell 3.1)

Surfacing : Type “2aIA” with thickness 110 mm.

1.7 SAFETY CLASS

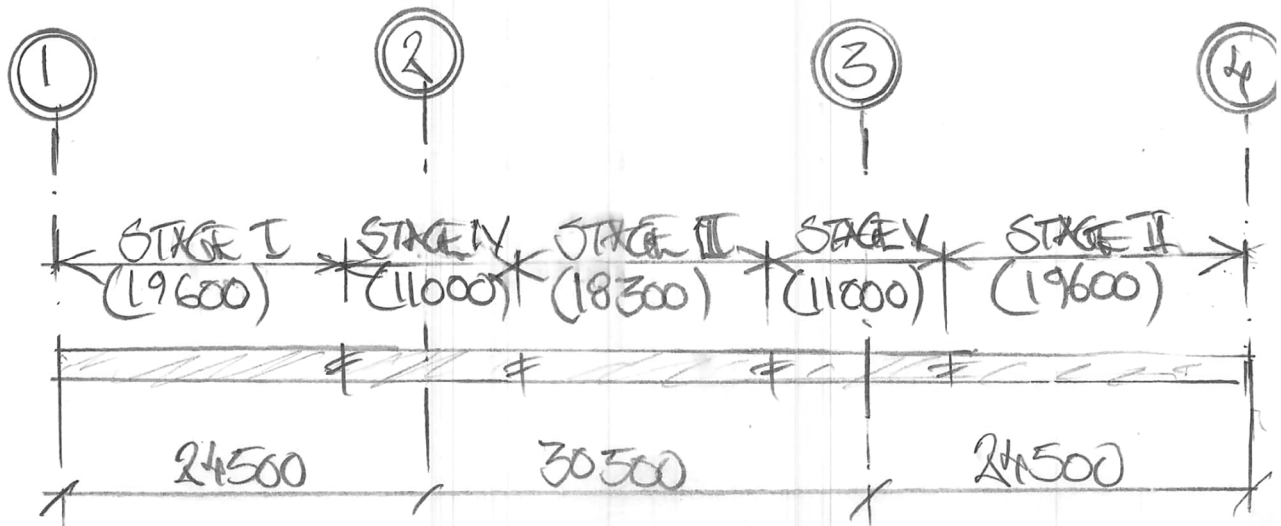
Geotechnical resistance: SK 2

Bridge structure : SK 3

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A1:9
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1.8 CASTING STAGE

Concrete deck is cast in 5 casting stages seen below.



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2. SYSTEM ANALYSIS

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2.2	SKETCH SYSTEM ANALYSIS	page 2:8-22
2.3	MESH	page 2:23-27
2.4	CROSS SECTION PROPERTIES	page 2:28-49
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2.7	MATERIAL	page 2:57-66
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2.9	SEARCH AREA	page 2:69
2.10	SLICE RESULTANTS BEAMS/SHELLS	page 2:70-74
2.11	FLANGE WIDTH	page 2:75

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2.1 GENERAL

The bridge is a curved steel composite bridge. The bridge has three spans with a total of 4 girders.

Full interaction between main beams and concrete roadway is assumed.

Edge beams are not considered to contribute any stiffness, however, as a load.

A local coordinate system orientated radial to centre line ($R = 183$ m).

Static model offers the possibility of staged expansion in the same static calculation. A total of 8 different static systems are used. These are designated Stage I, II, III, IV, V, O:P, O:V and O:TEMP.

The geometric model is the same for these, however, they may have different boundary conditions, material properties, cross-sectional constants and loads. In addition, individual structural parts can also be activated/deactivated.

Statically model also has a function called *Steel Composite Designer* that determines cross-sectional constants are used in system analysis.

Static model also has a function called *Steel Composite Designer* that can retrieve results from system analysis determine load capacity according to SS-EN 1994 and associated utilization ratios.

When determining load effects, the influence of the cracking of the roadway is considered by ignoring the stiffness of the tensile concrete. Only the effect of reinforcement is considered.

Cracking is considered to occur when $\sigma_{SLS-K} > 2f_{ctm}$ according to SS-EN 1994 sections 5.4.2.3 and 1.5.2.12.

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

Web of girders are defined by shell element vertical nodal surfaces in superstructure.

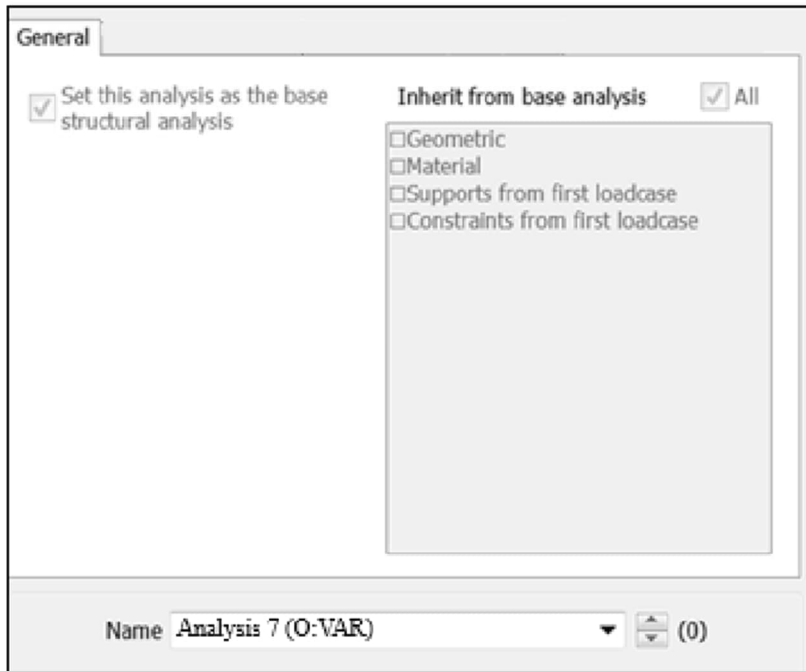
Flanges of girder are defined using beam elements applied to nodal line in superstructure.

Stiffeners and bracings are defined using beam elements applied to nodal line in superstructure.

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:3
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There is a total of 8 analysis.

Analysis 7 is introduced as the “Base Analysis”. It is based on this static system that changes to statics are carried out. It is also this system that is used for traffic load evaluation/VLO.

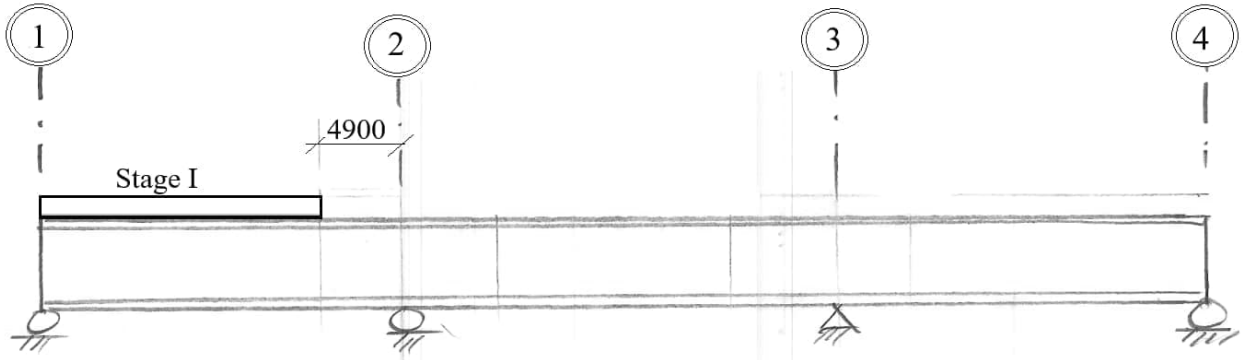


Analysis performed within static model SYSTEM 001

(* = Base analysis)

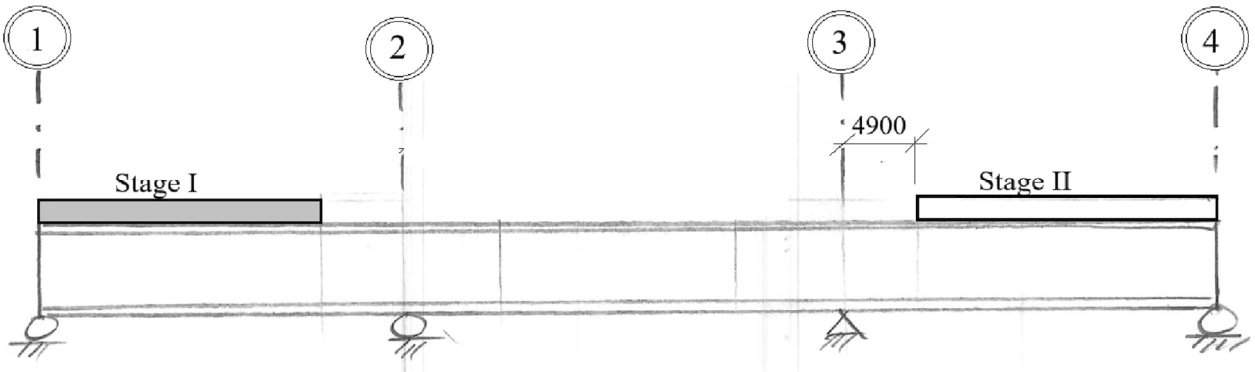
Analysis Nr.	Names	Stage	Casting stage
1	C1	Construction	I
2	C2	Construction	II
3	C3	Construction	III
4	C4	Construction	IV
5	C5	Construction	V
6	O: PERM	Operational	-
7*	O: VAR	Operational	-
8	O: TEMP	Operational	-

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:4
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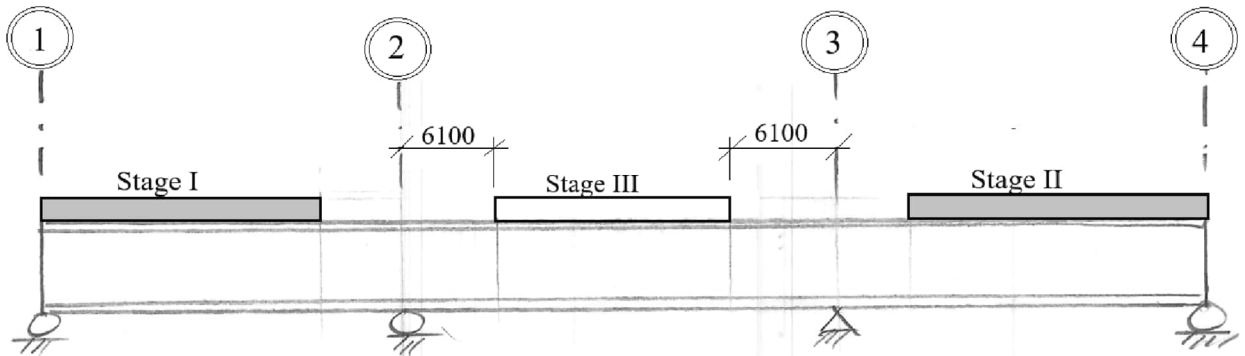
Analysis 1 (C1): Stage I

Construction stage: Wet concrete stage I



Analysis 2 (C2): Stage II

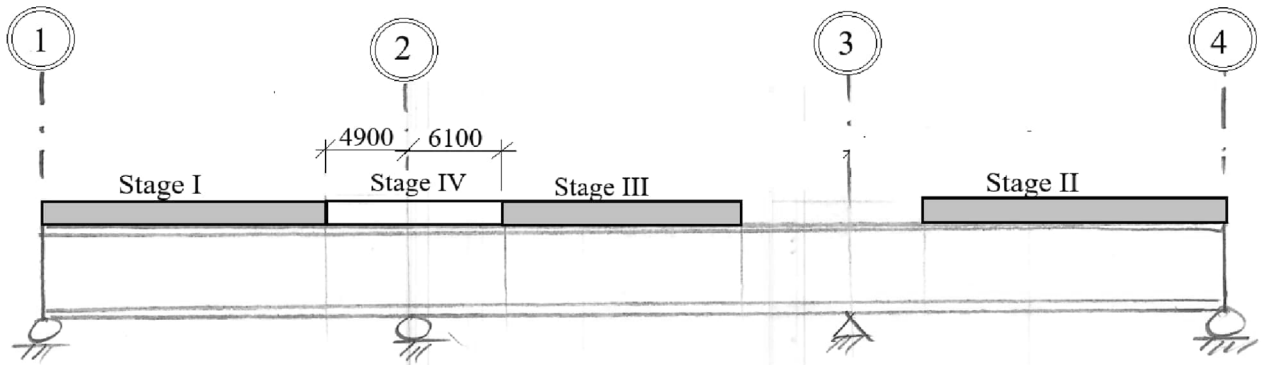
Construction stage: Wet concrete stage II



Analysis 3 (C3): Stage III

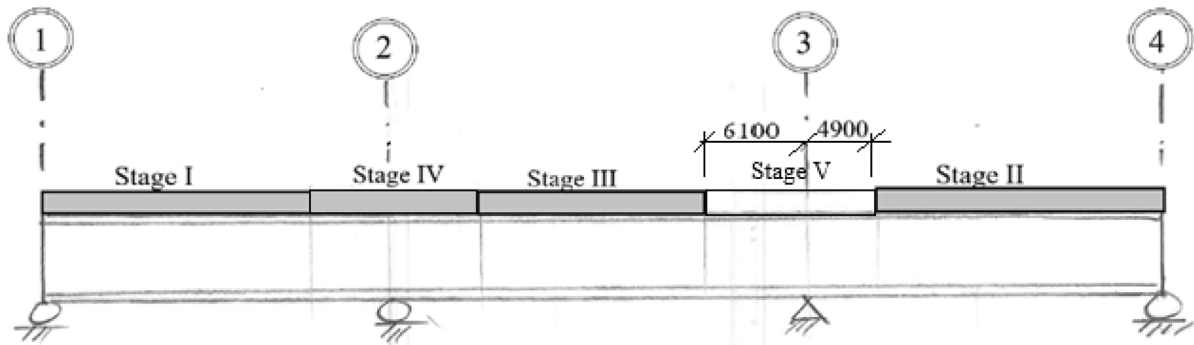
Construction stage: Wet concrete stage III

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Analysis 4 (C4): Stage IV

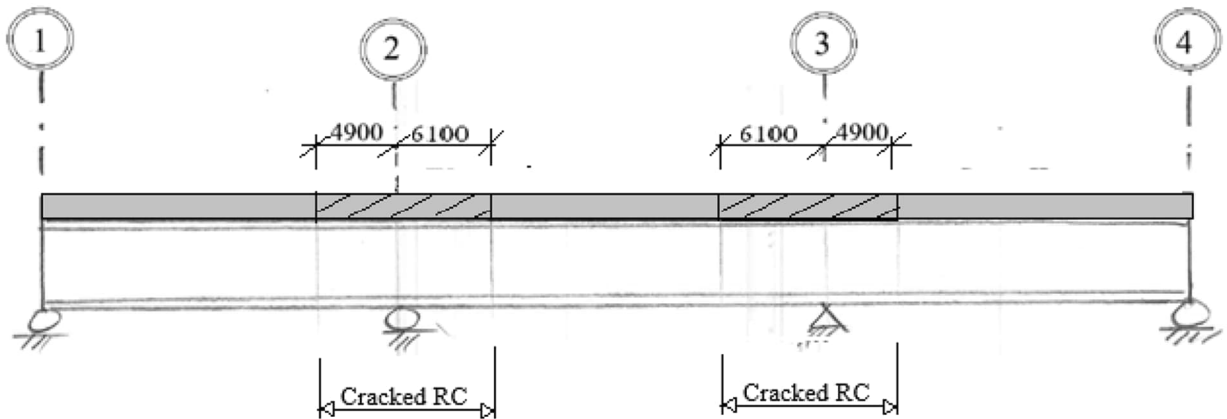
Construction stage: Wet concrete stage IV



Analysis 5 (C5): Stage V

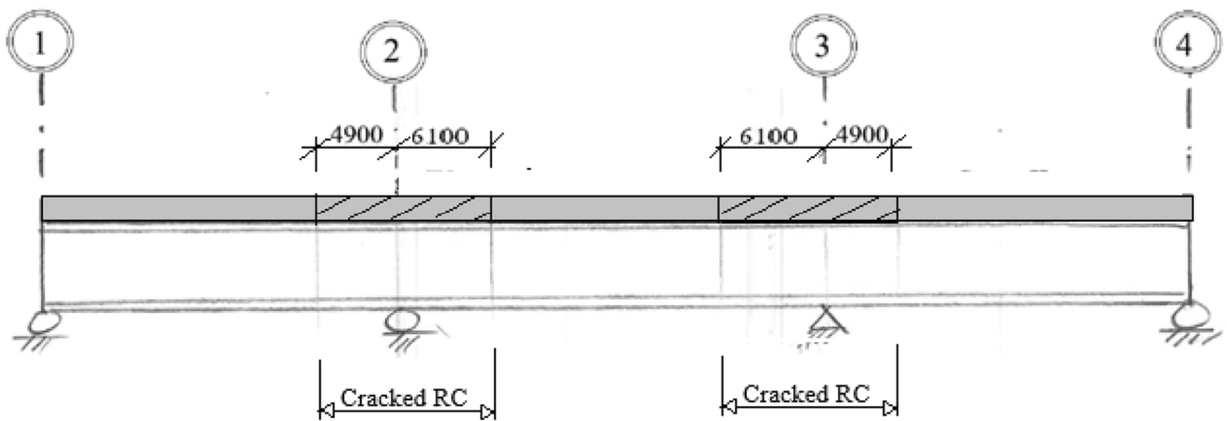
Construction stage: Wet concrete stage V

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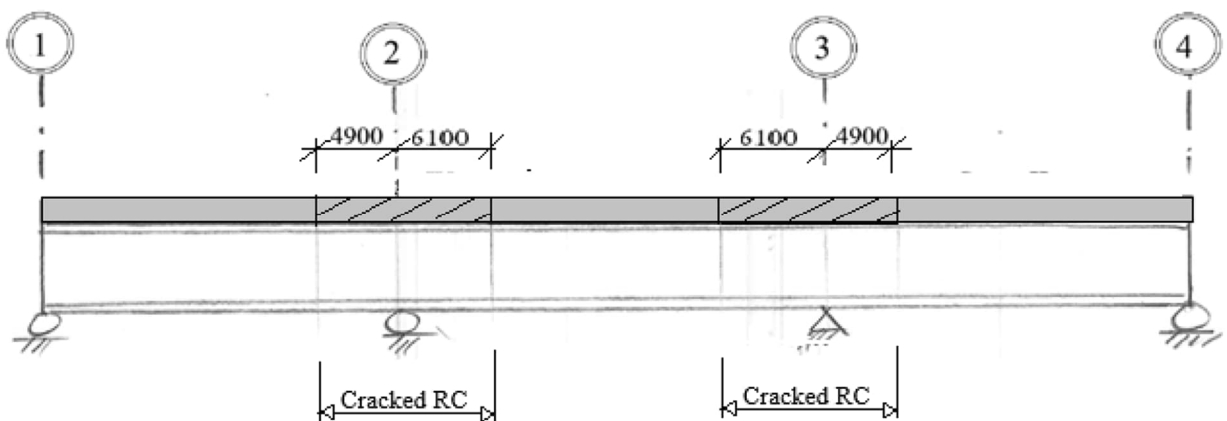
Analysis 6 (O:PERM)

Operation bridge: Cracking locally around support 2 & 3



Analysis 7 (O:VAR)

Operation bridge: Cracking locally around support 2 & 3



Analysis 8 (O:TEMP)

Operation bridge: Cracking locally around support 2 & 3

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:7
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Summary appendices

Appendix	Name
1	Input receipt
2	Results reactions
3	Results longitudinal beams
4	Results bridge deck

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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.

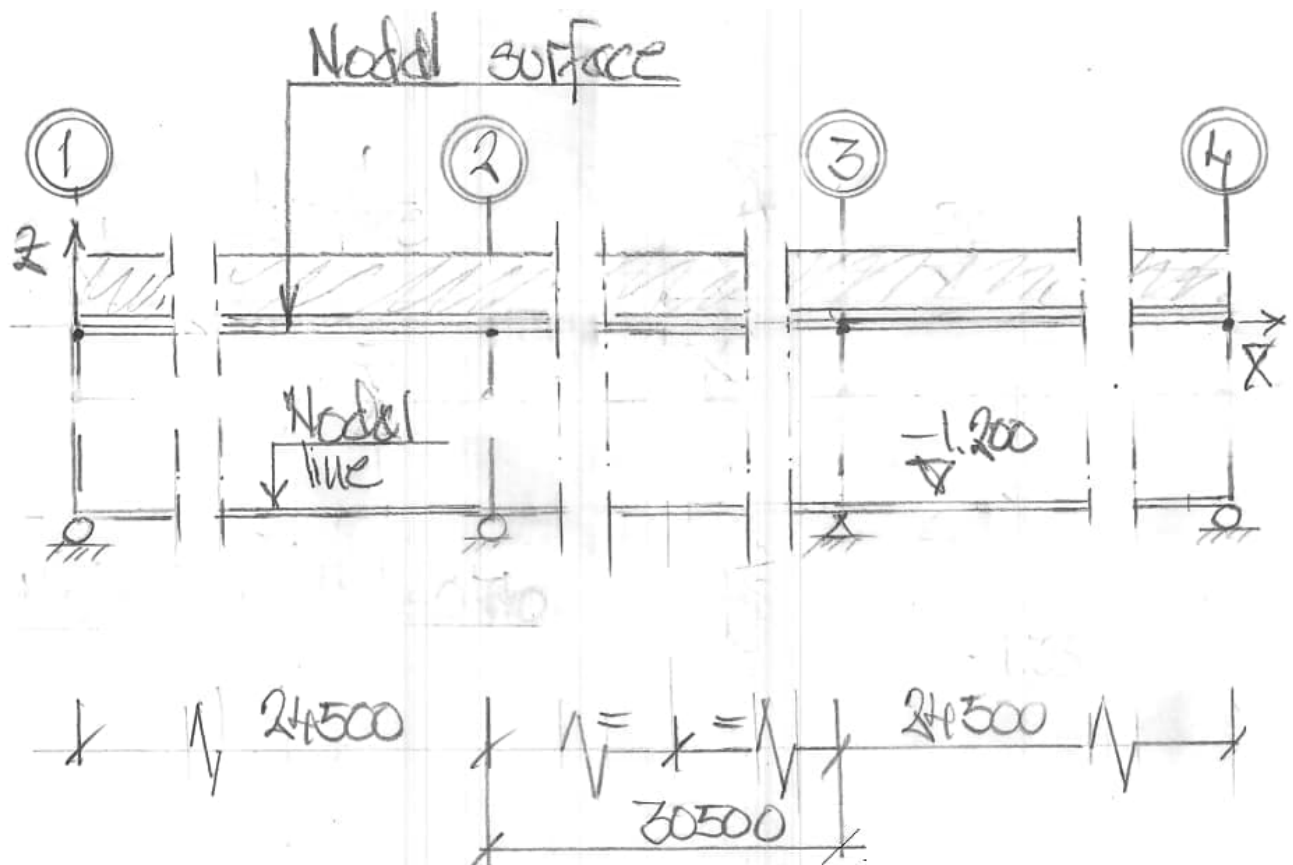
Attached pictures are retrieved from graphical sketches generated by STACTIC MODELL of POINTS, LINES and SURFACES.

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.

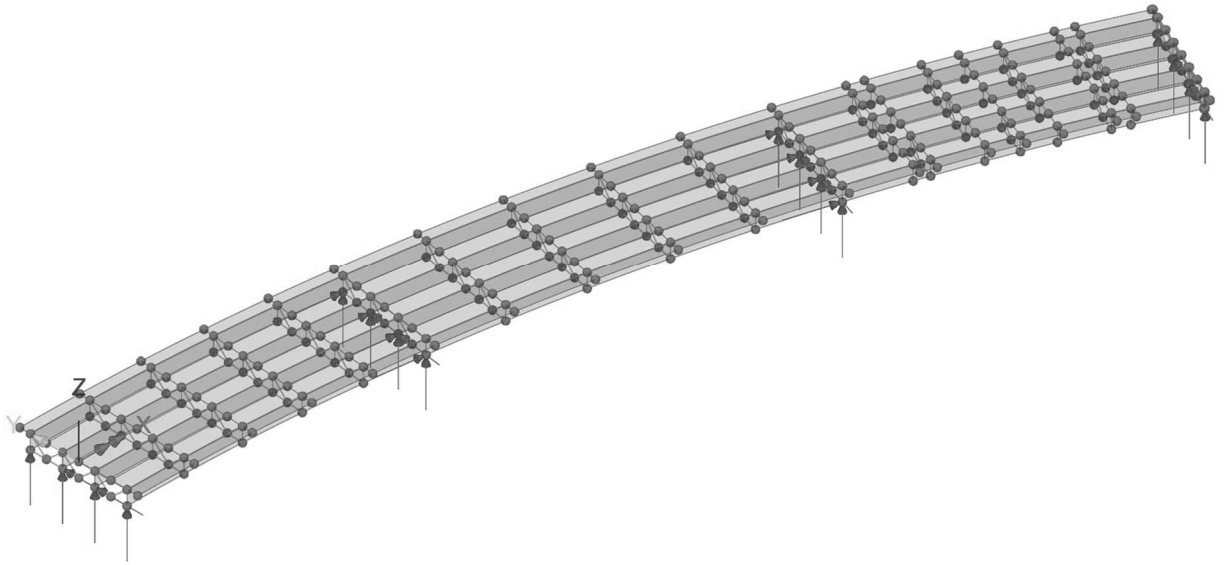
Superstructure is modelled using Nodal Line and Nodal Surfaces as seen in sketch below



ELEVATION

Principal sketch girders.

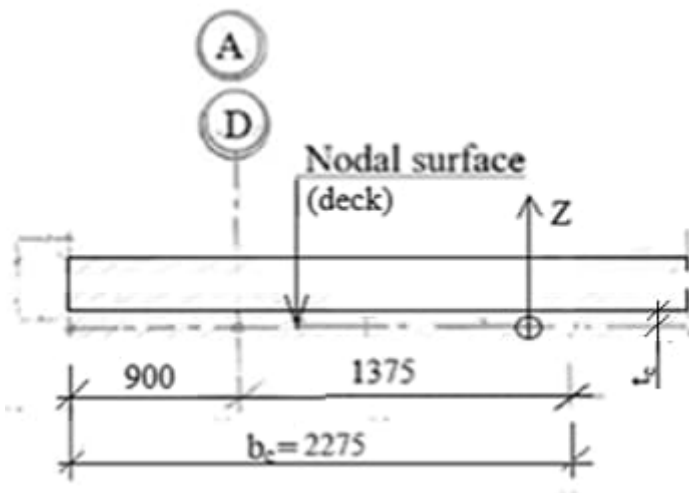
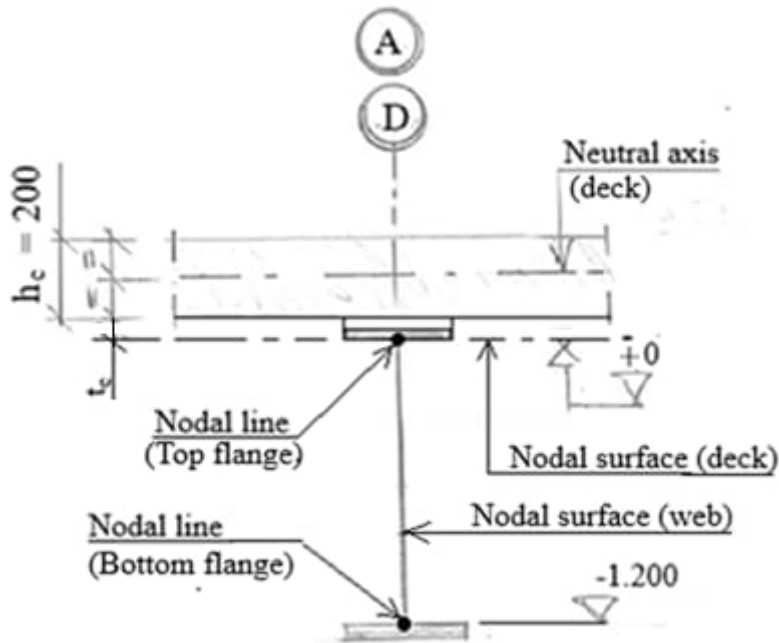
	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:9
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3D sketch
Overview

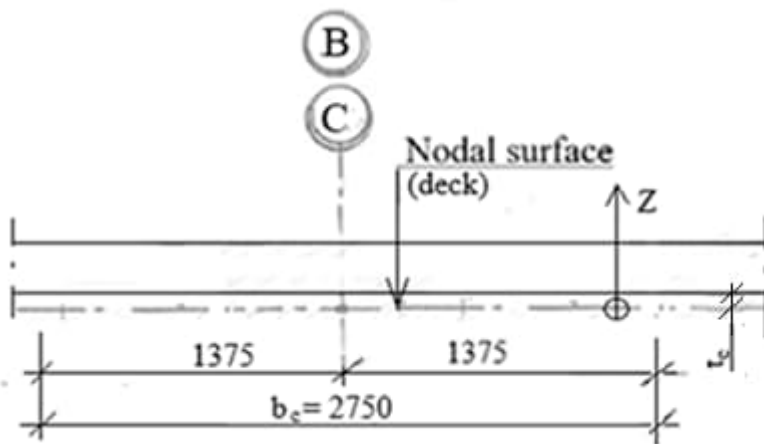
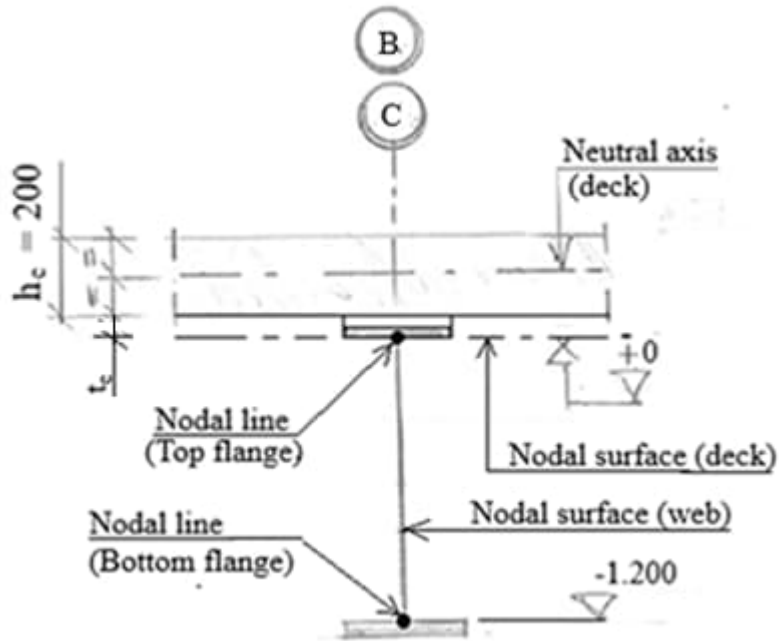
	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A2:10
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External beams:



	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A2:11
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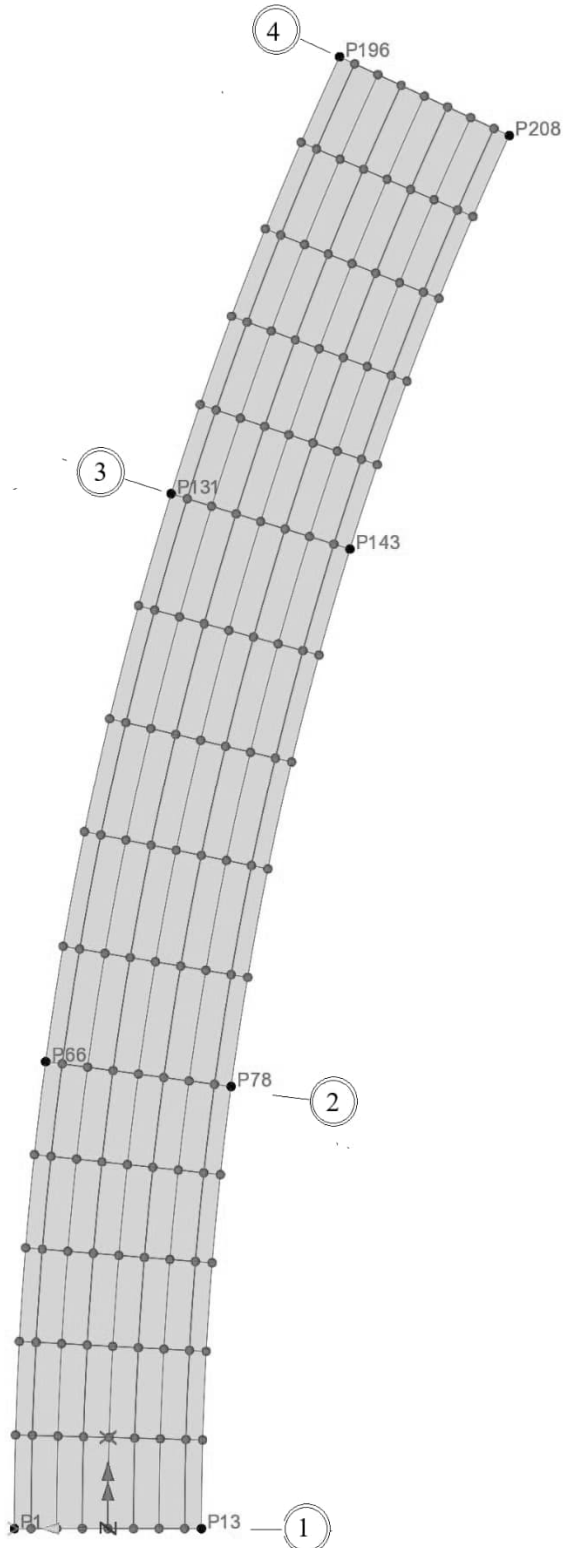
Internal beams:



	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:12
		Date :	Created :

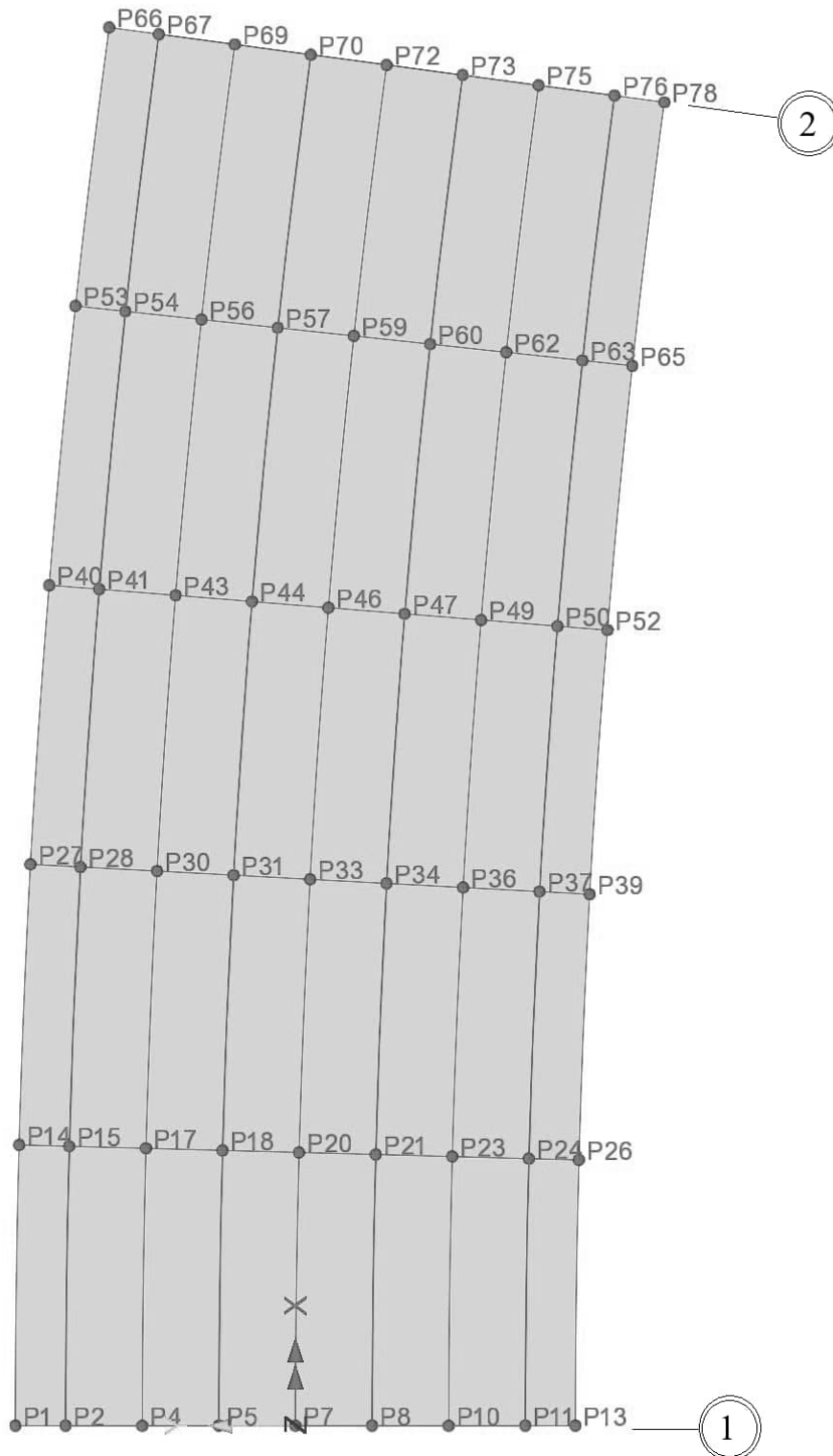
2.2.1 Geometry : POINTS

2.2.1.1 Deck



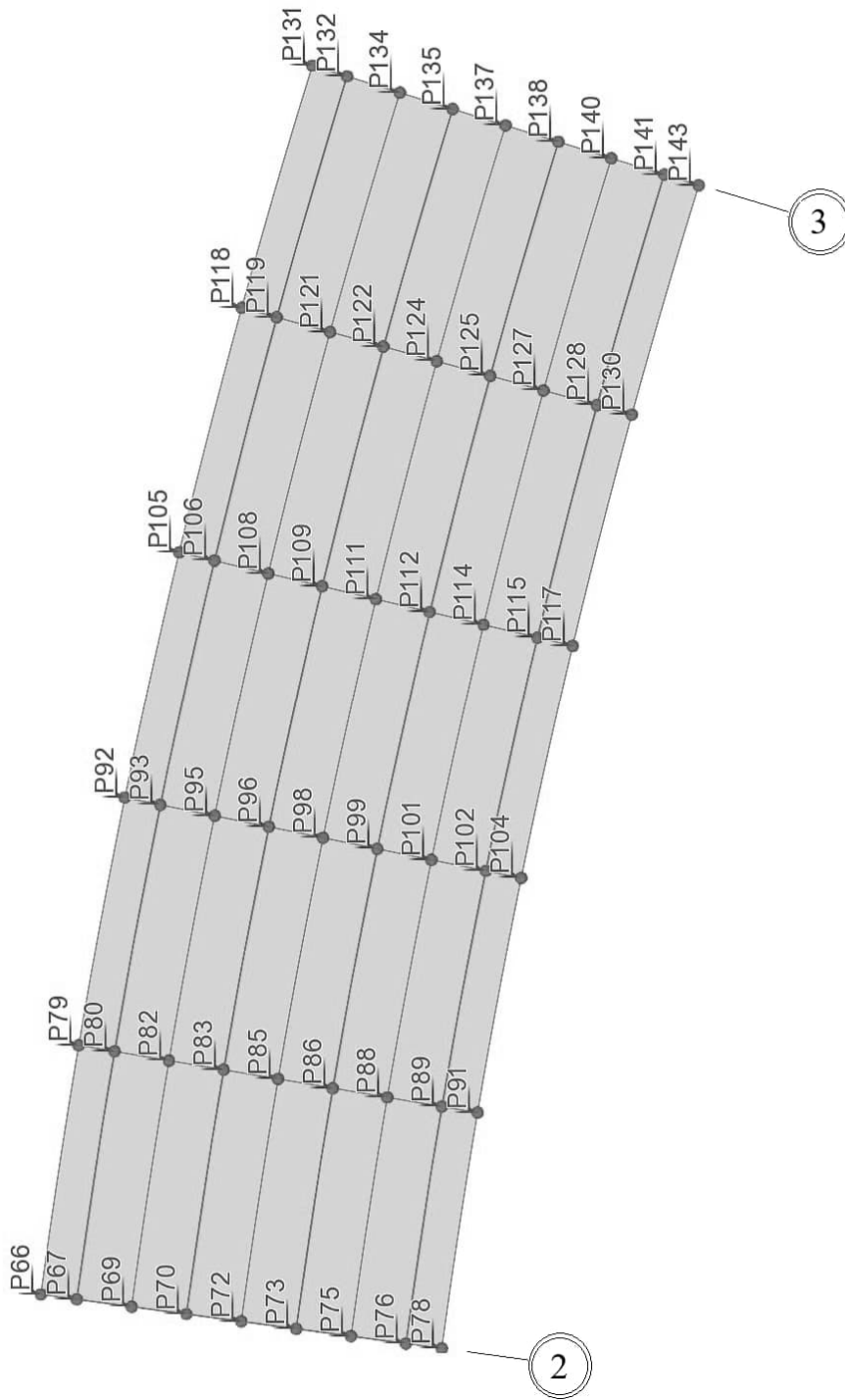
2D Overview

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A2:13
	Composite steel girder bridge	Date :	Created :



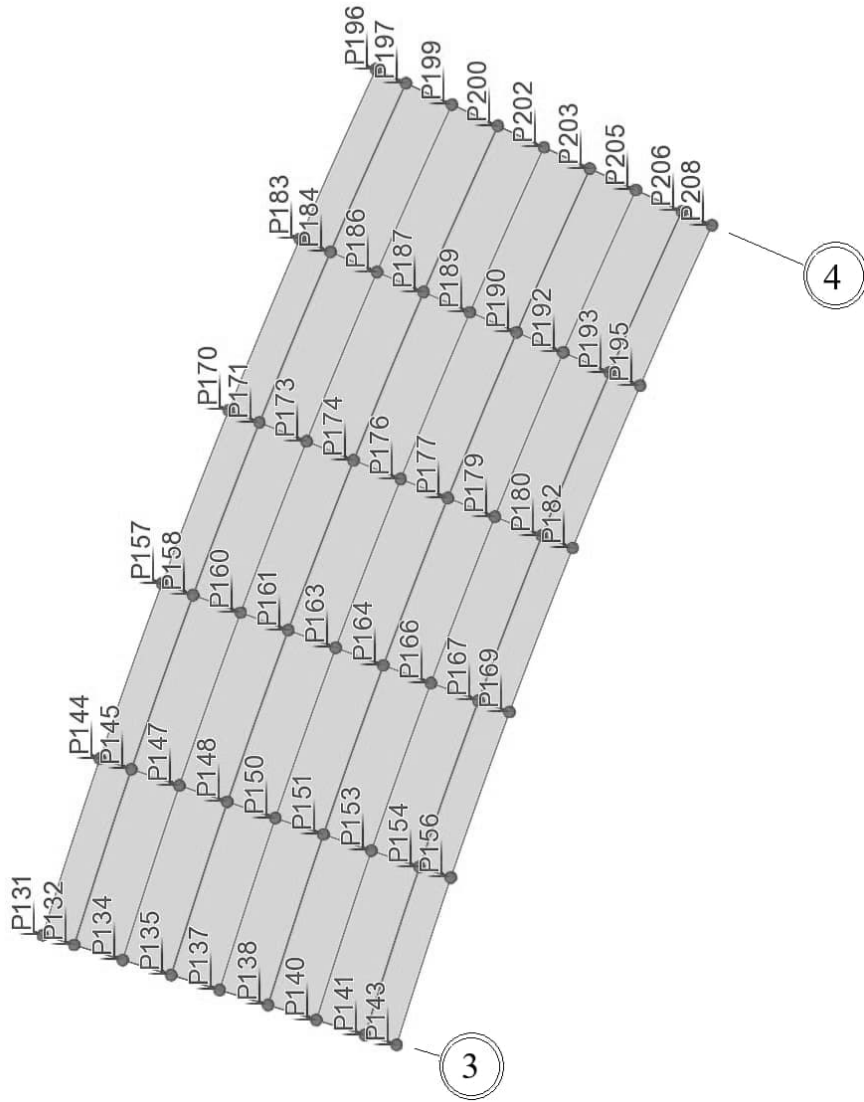
Span 1

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A2:14
	Composite steel girder bridge	Date :	Created :



Span 2

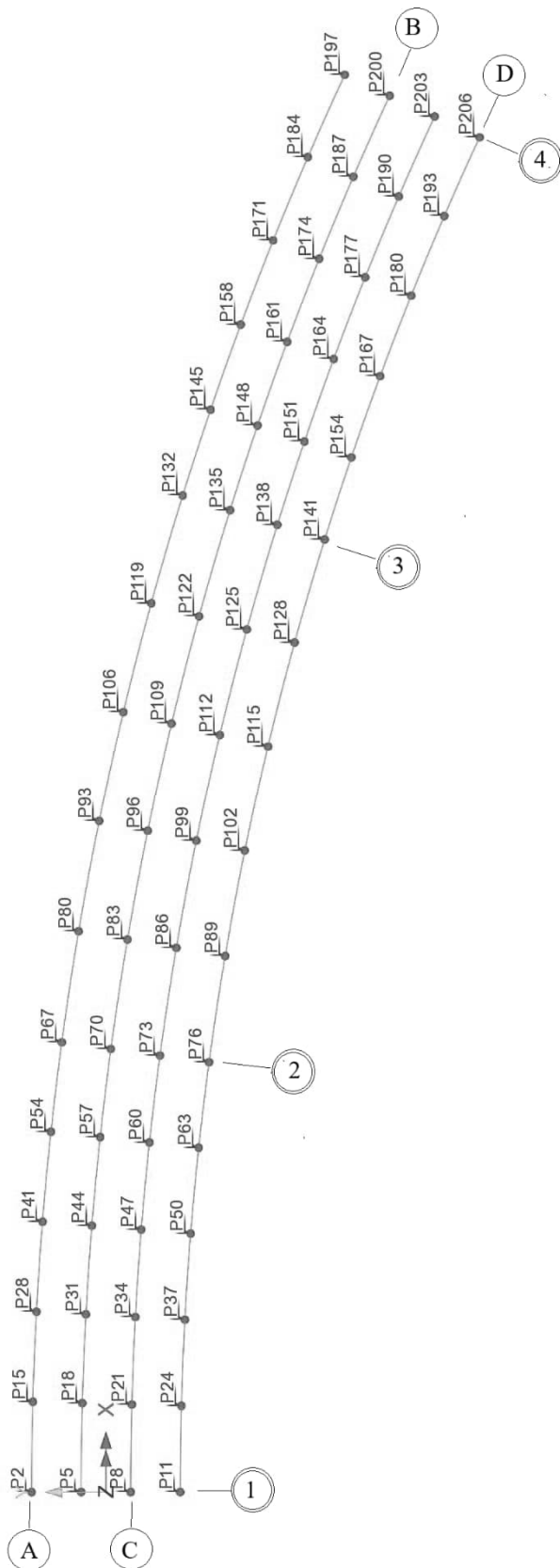
	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:15
		Date :	Created :



Span 3

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A2:16
	Composite steel girder bridge	Date :	Created :

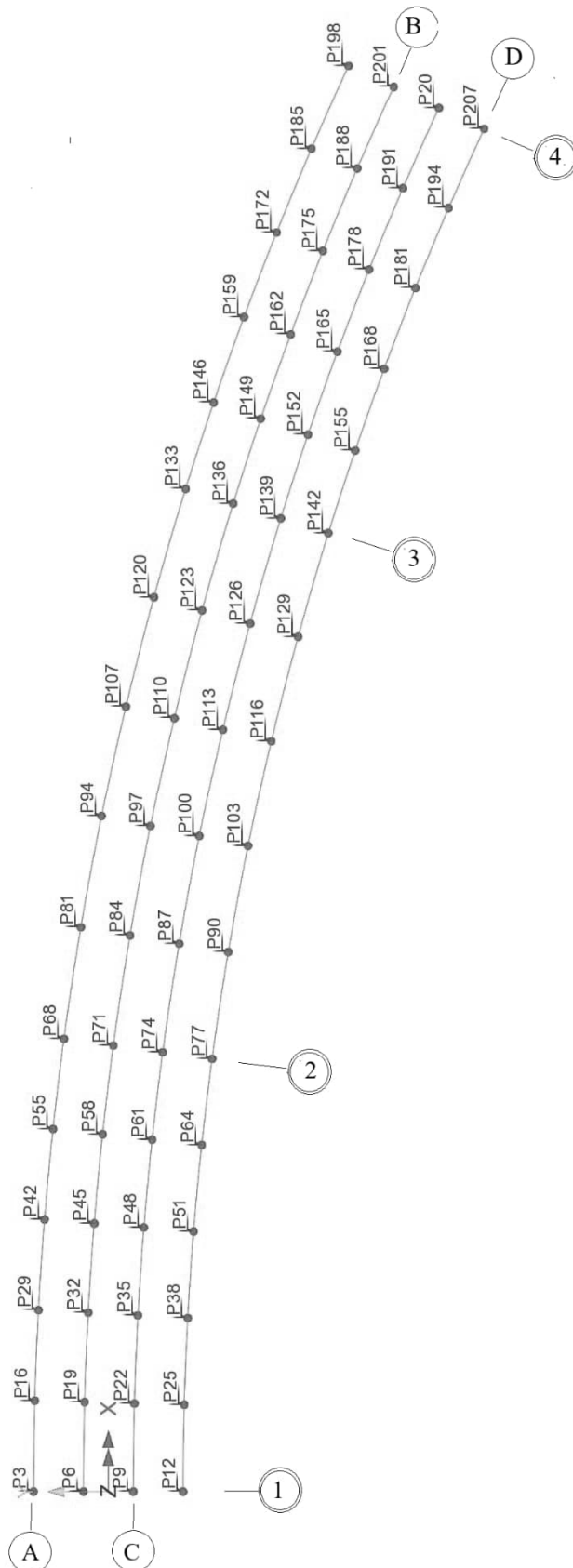
2.2.1.2 Girder: top flange



2D Overview

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A2:17
	Composite steel girder bridge	Date :	Created :

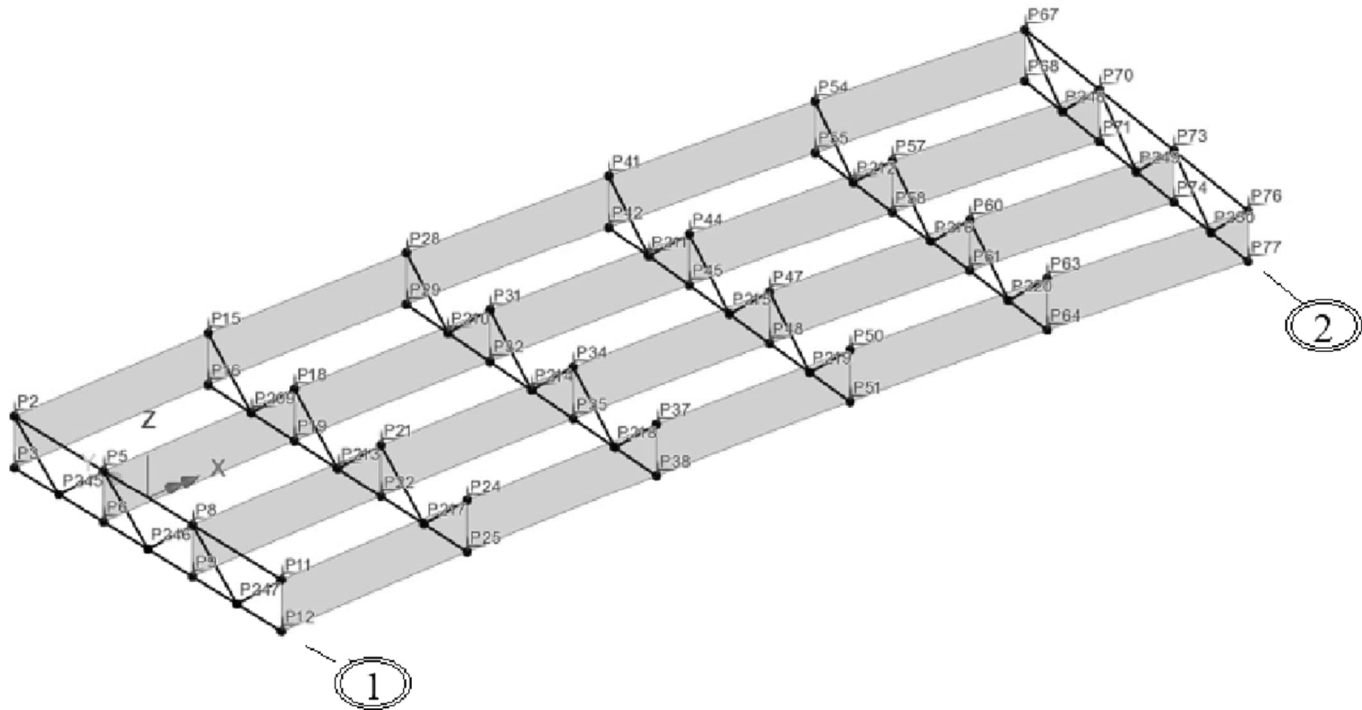
2.2.1.3 Girder: bottom flange



2D Overview

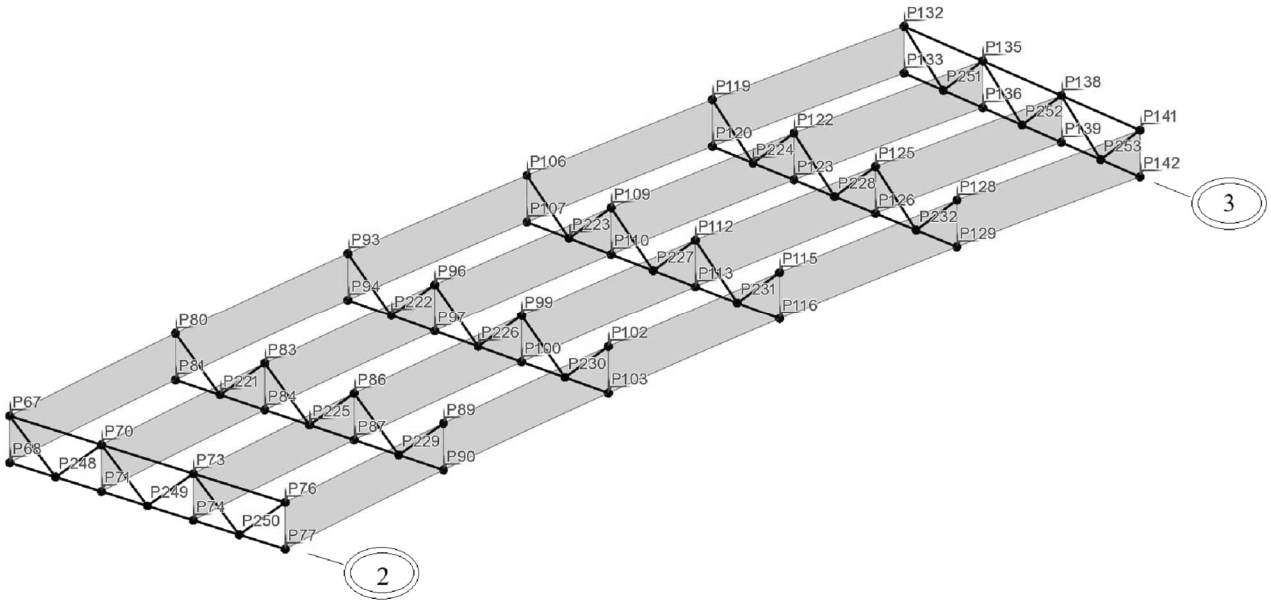
	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:18
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2.2.1.4 Bracings & web

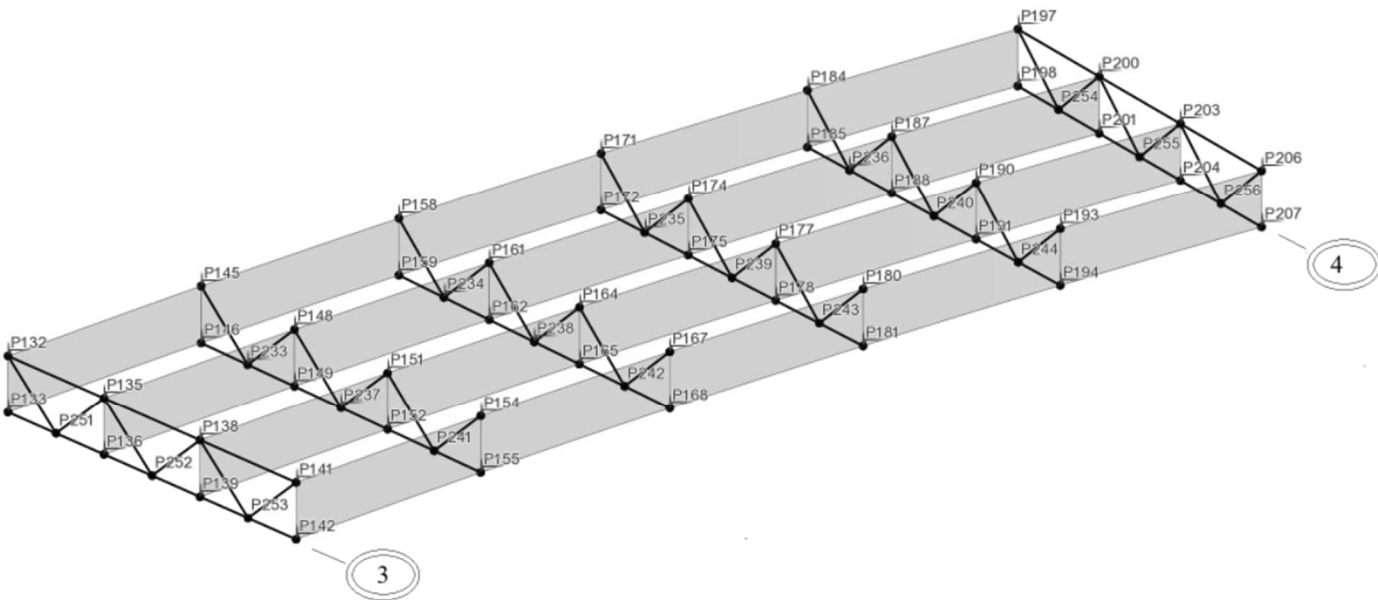


Span 1

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A2:19
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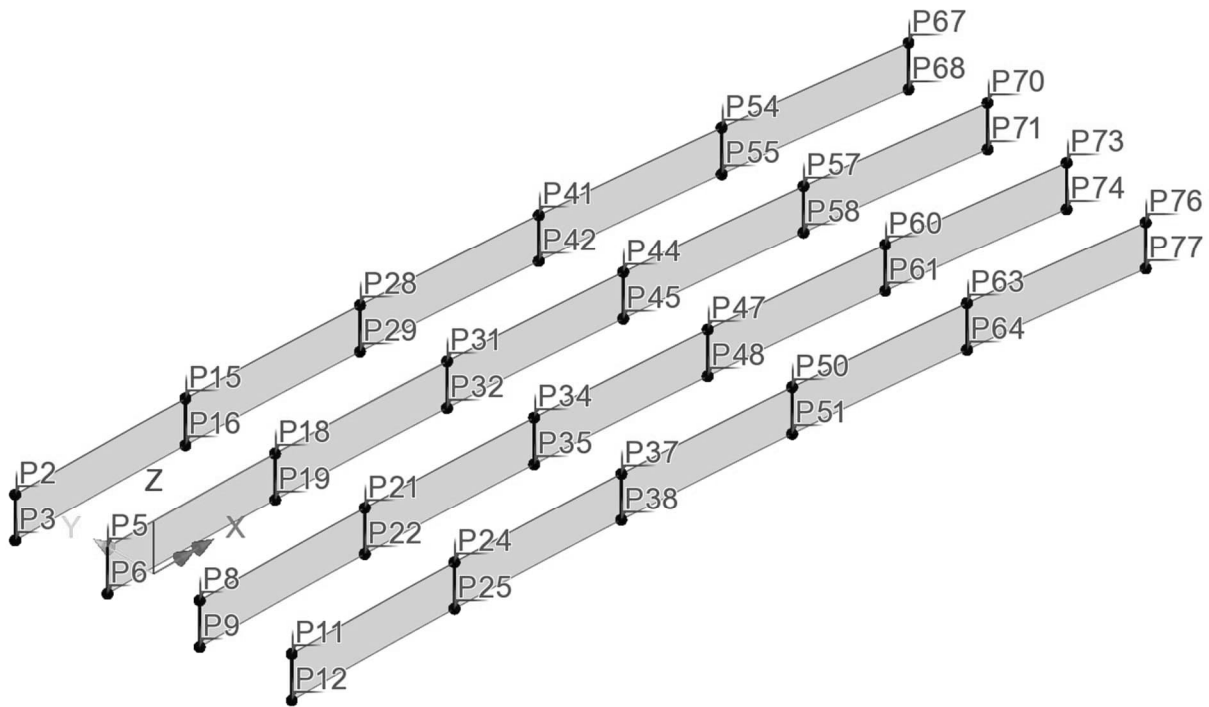
Span 2



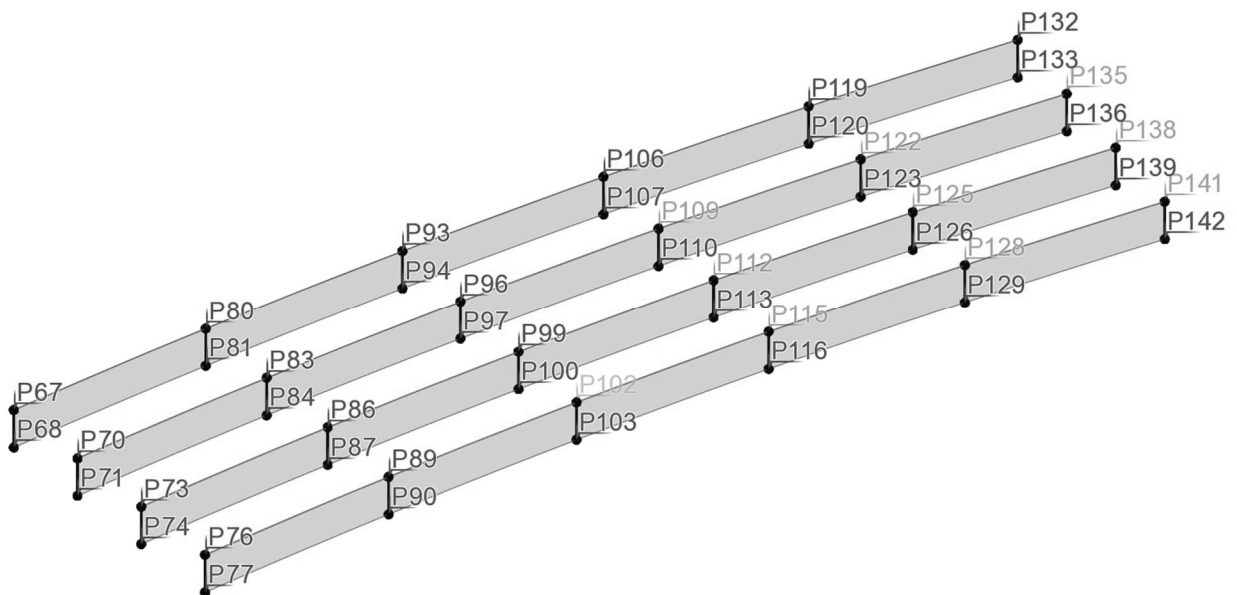
Span 3

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:20
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2.2.1.5 Stiffeners

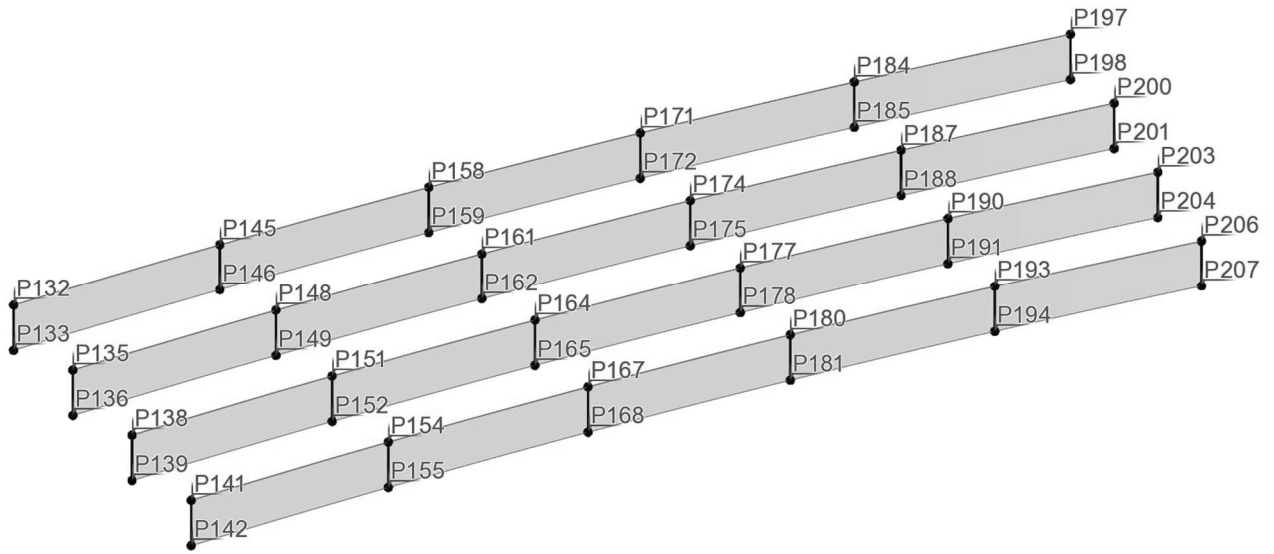


Span 1



Span 2

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:21
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Span 3

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:22
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2.2.2 Geometry: LINES

LINES are defined by POINTS, see appendix 1.

2.2.3 Geometry : SURFACES

SURFACES are defined by LINES, see appendix 1.

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:23
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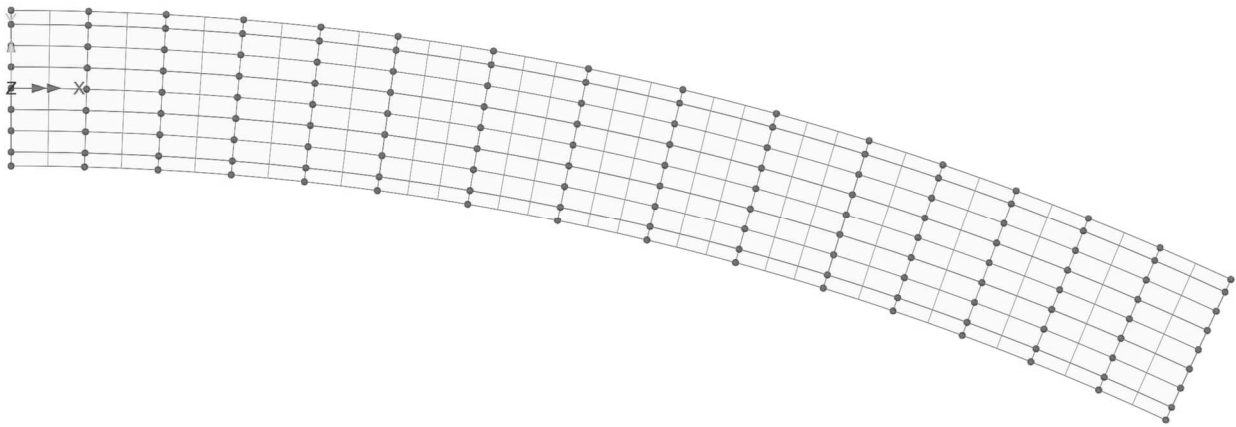
2.3 MESH

2.3.1 MESH: Shell element (QTS8)

Shell elements are used is webs and deck.

Type	x-divisions	y-divisions	Element size	Part
Thick shell	Auto	Auto	Max 2.10	Deck & Web
-	-	-	m	-

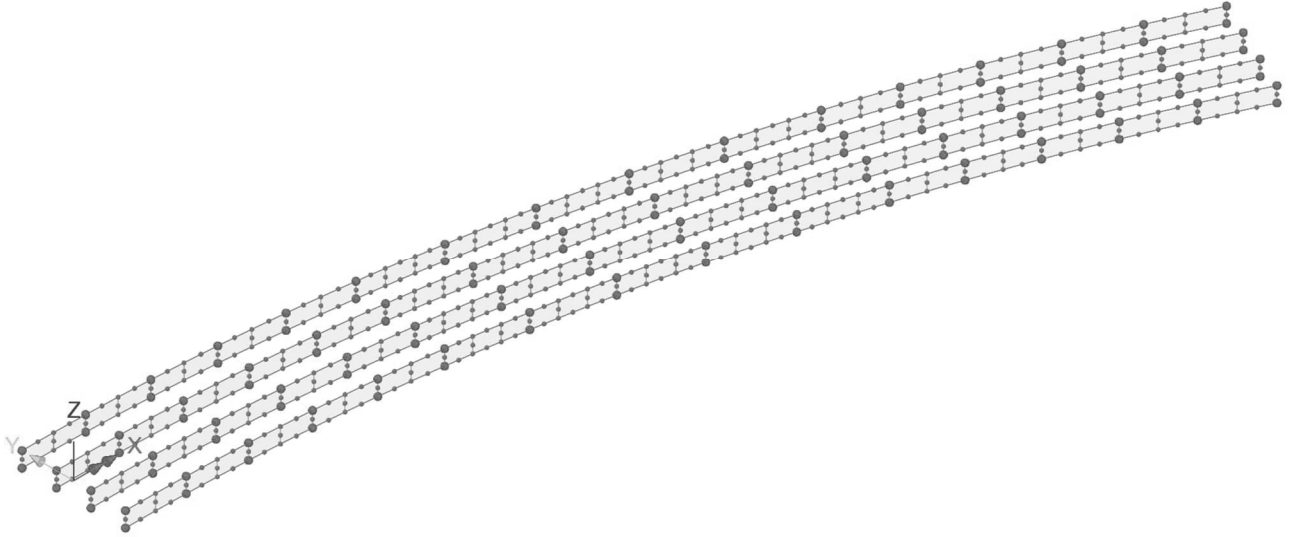
Deck:



2D Overview

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:24
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Webs:



3D Overview

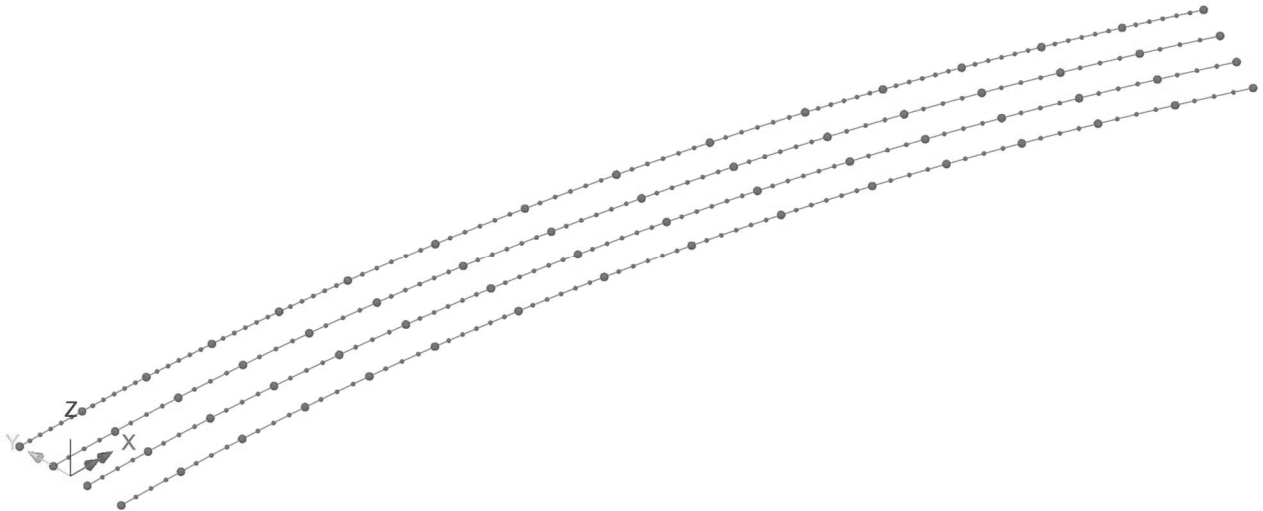
	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:25
		Date :	Created :

2.3.2 MESH: 3D-beam element (BMI31)

Beam elements are used for flanges and bracings, se table below.

Type	Divisions	Element size	End release: Start	End release: End	Part
Thick beam	1	Auto	None	None	Bracings
Thick beam	Auto	Max 2.1	None	None	Flanges & Stiffners
	2	-	-	-	-

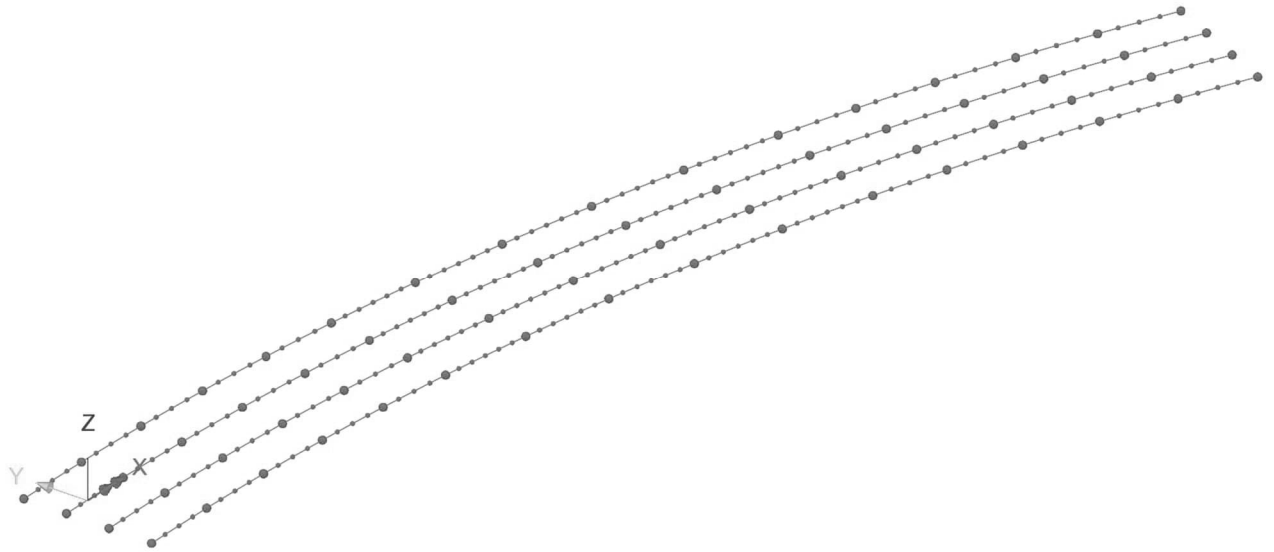
Top flanges:



3D Overview

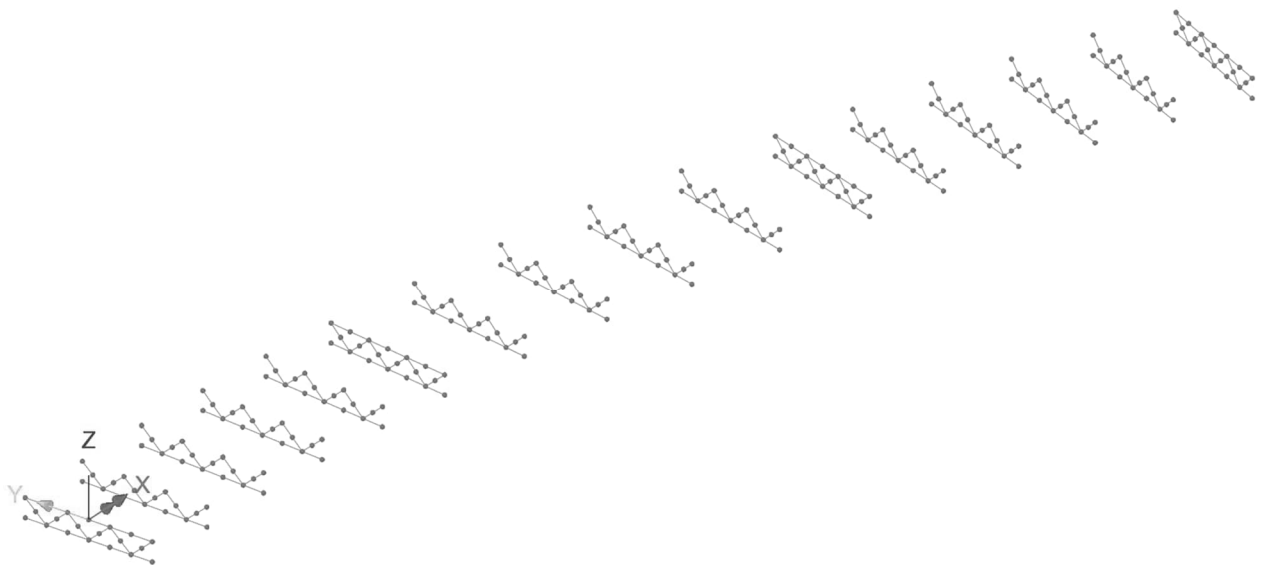
	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:26
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Bottom flanges:



3D Overview

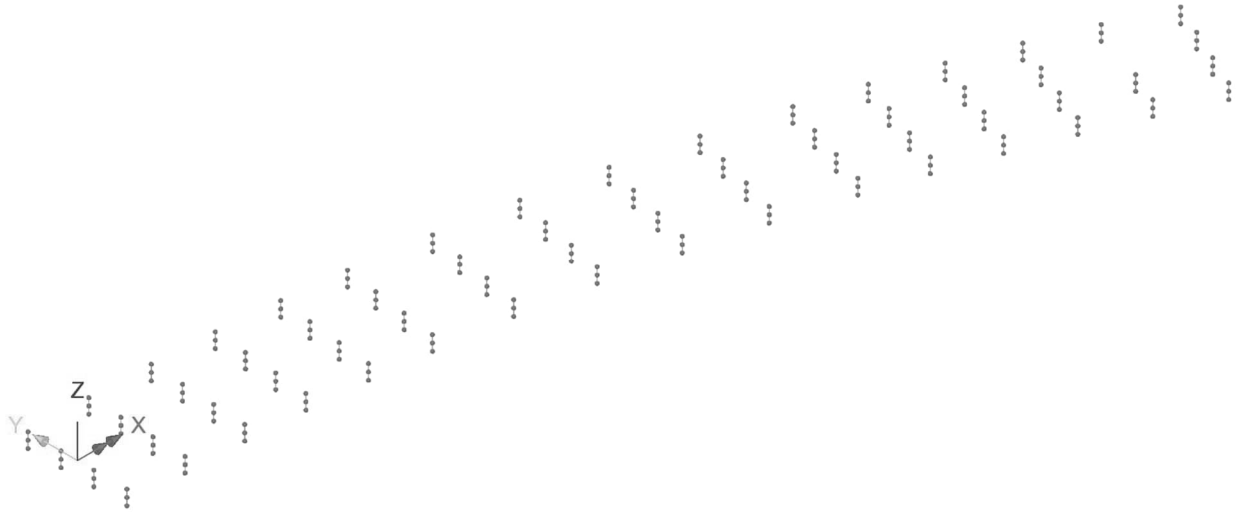
Bracings:



3D Overview

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:27
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Stiffeners:



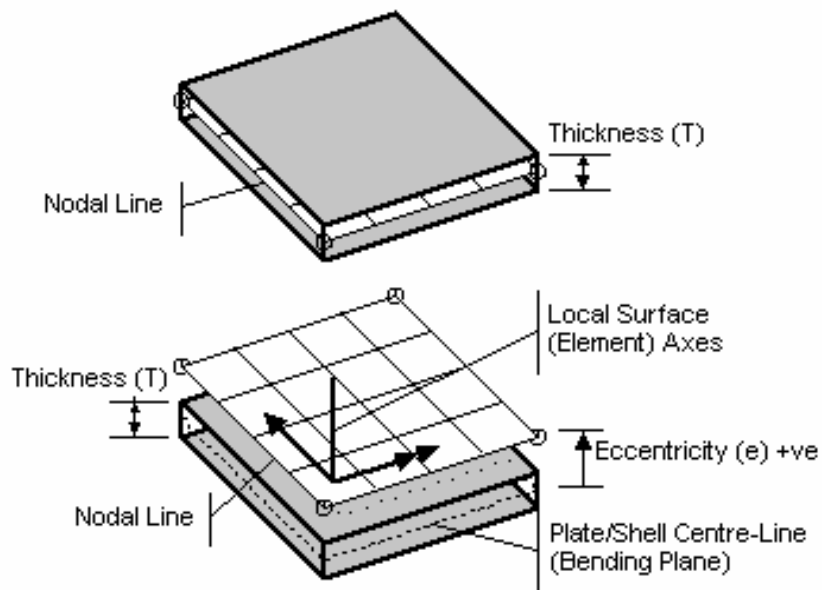
3D Overview

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A2:28
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2.4 CROSS SECTION PROPERTIES

2.4.1 Shell elements

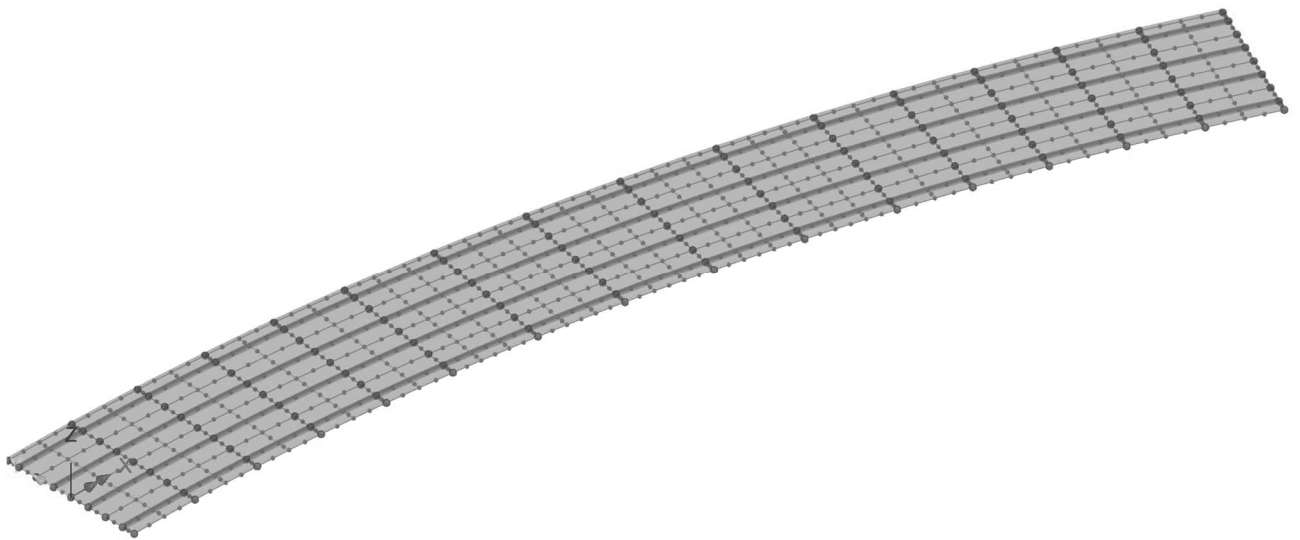
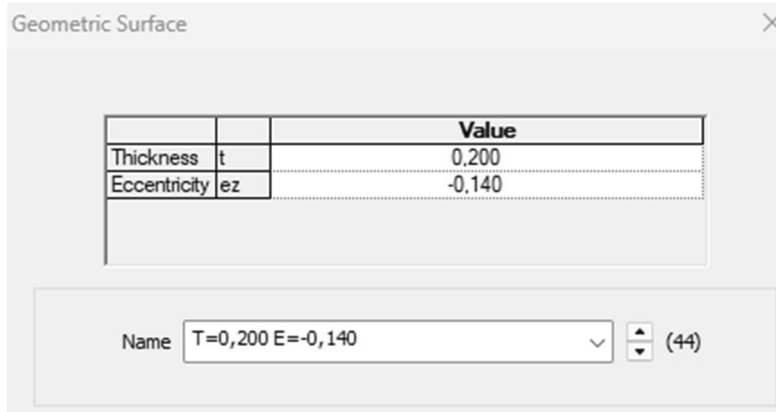
Web and deck are defined as shell elements. Principle figures of geometry is seen below.



	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:29
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Deck :

Deck is given geometric properties seen below.

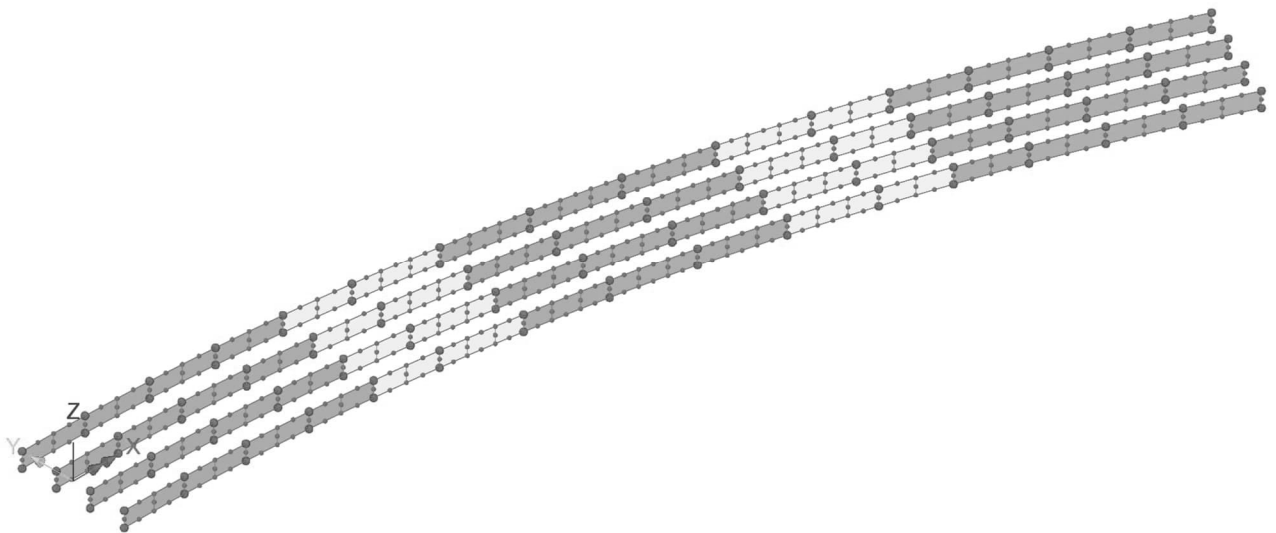
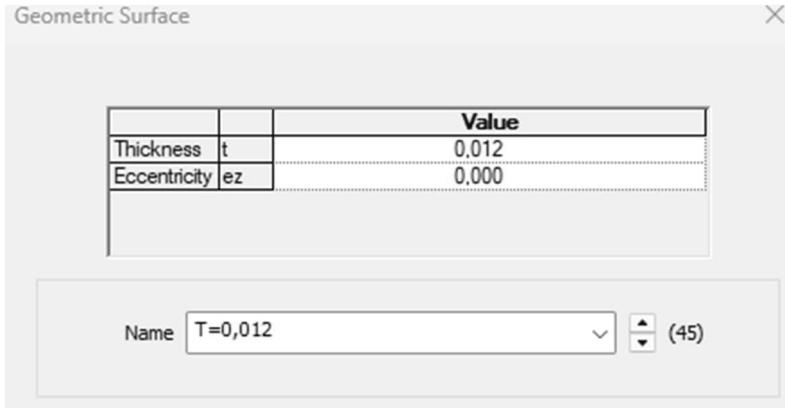


3D Overview

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:30
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Web (BEAM 1, BEAM 3 & BEAM 5):

Deck is given geometric properties seen below.

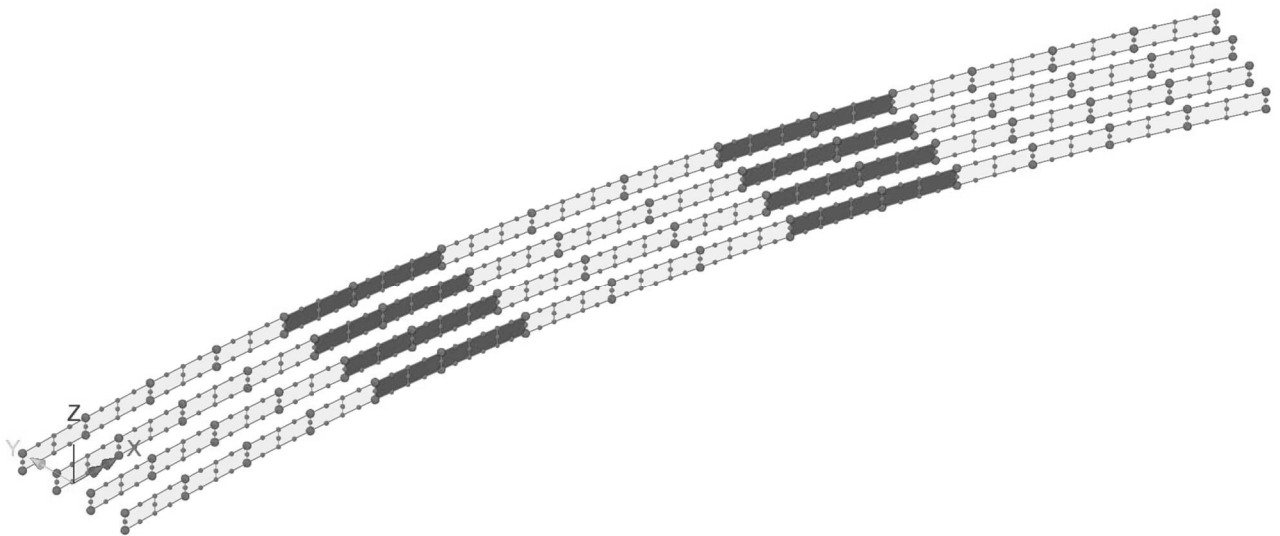
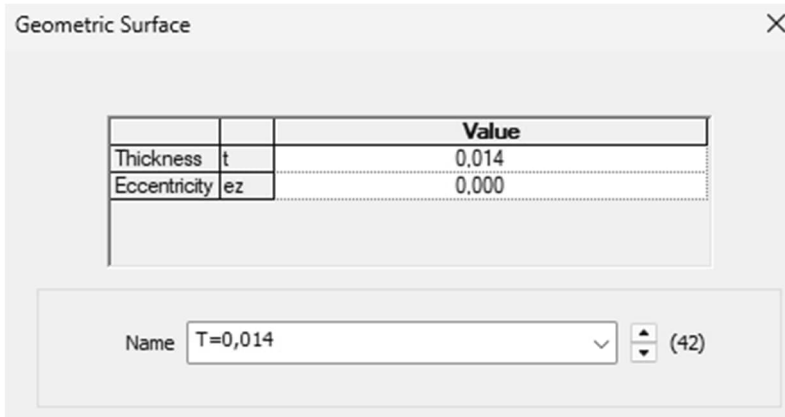


3D Overview

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:31
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Web (BEAM 2 & BEAM 4):

Deck is given geometric properties seen below.



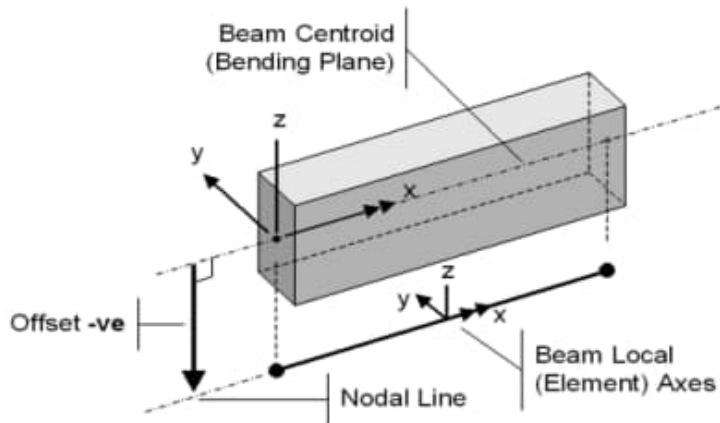
3D Overview

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:32
		Date :	Created :

2.4.2 3D-beam elements

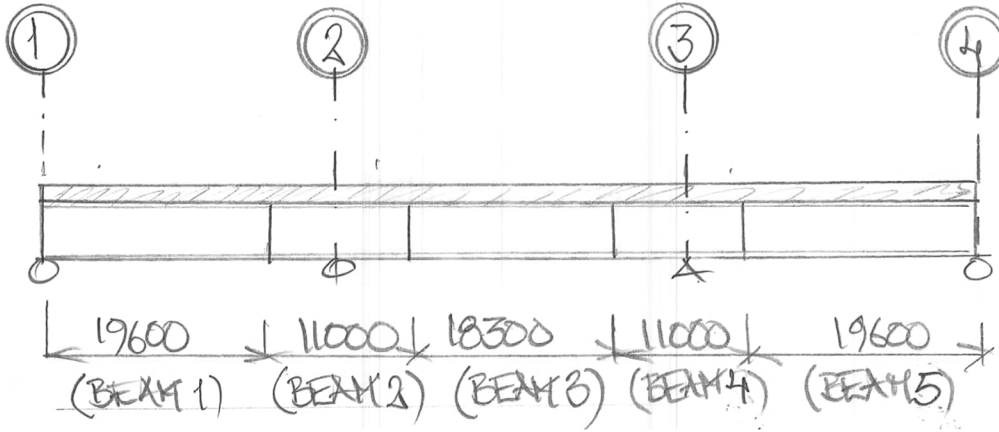
Flanges and bracing are as beam elements.

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



	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:33
		Date :	Created :

2.4.2.1 Flanges steel girders



	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:34
		Date :	Created :

Top flange (BEAM 1, BEAM 3 & BEAM 5):

Flange is given geometric properties seen below.

Geometric Line

Analysis category: 3D

Definition:
 From library / calculator
 Enter properties

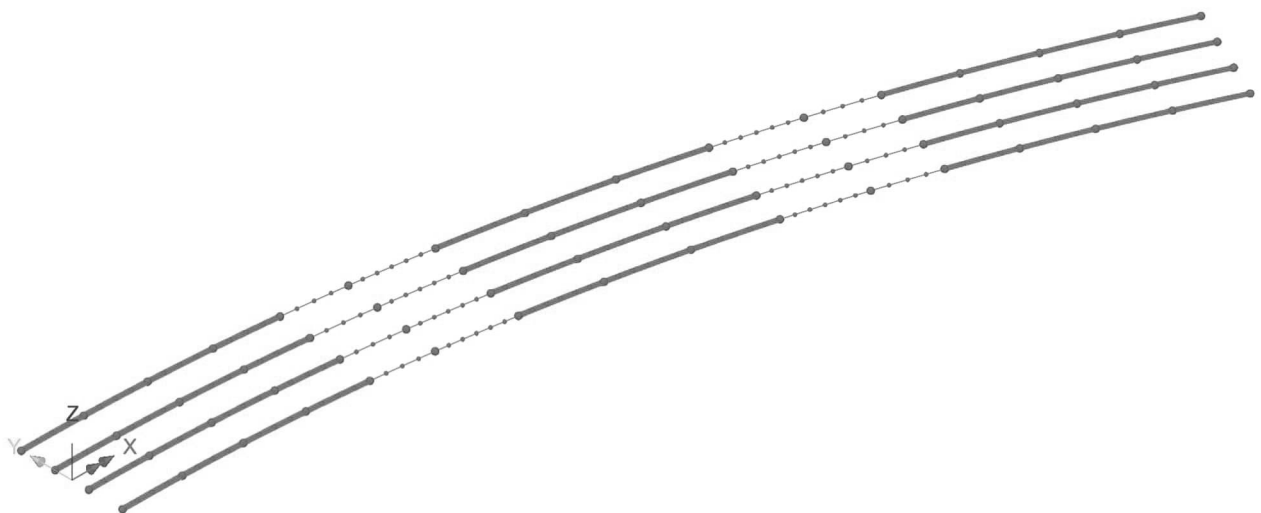
Rotation about centroid: 0 ° Mirrored about axis: None

Reinforcement (only used for RC design checks): None

ez origin: Centroid ey origin: Same as ez

Parametric Sections: [v]
 Rectangular Sections: [v]
 1:RSS D=0,020 B=0,460 EZ=-0,010 [v]

	Value
Cross sectional area (A)	0.009
Second moment of area about y axis (Iyy)	0.307E-6
Second moment of area about z axis (Izz)	0.162E-3
Product moment of area (Iyz)	0.000
Torsional constant (J)	1.193E-6
Effective shear area in y direction (Asy)	0.008
Effective shear area in z direction (Asz)	0.008
Eccentricity in y direction (ey)	0.000
Eccentricity in z direction (ez)	-0.010



3D Overview

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:35
		Date :	Created :

Top flange (BEAM 2 & BEAM 4):

Flange is given geometric properties seen below.

Geometric Line

Analysis category: 3D

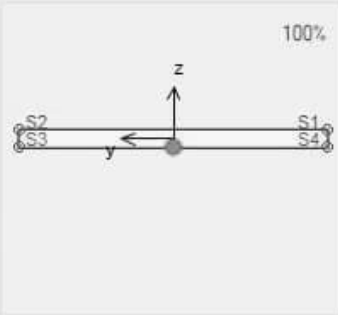
Definition:
 From library / calculator
 Enter properties

Rotation about centroid: 0 ° Mirrored about axis: None

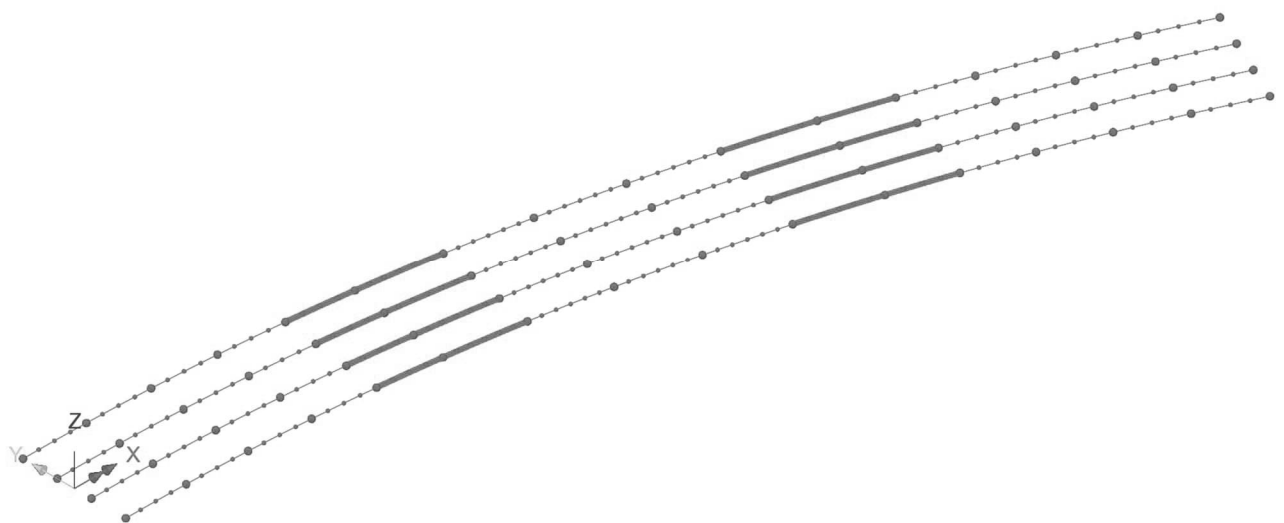
Reinforcement (only used for RC design checks): None

ez origin: Centroid ey origin: Same as ez

Parametric Sections: 3:RSS D=0,025 B=0,460 EZ=-0,013



	Value
Cross sectional area (A)	0,012
Second moment of area about y axis (Iyy)	0,599E-6
Second moment of area about z axis (Izz)	0,203E-3
Product moment of area (Iyz)	0,000
Torsional constant (J)	2,314E-6
Effective shear area in y direction (Asy)	0,010
Effective shear area in z direction (Asz)	0,010
Eccentricity in y direction (ey)	0,000
Eccentricity in z direction (ez)	-0,013



3D Overview

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:36
		Date :	Created :

Bottom flange (BEAM 1, BEAM 3 & BEAM 5):

Flange is given geometric properties seen below.

Geometric Line

Analysis category: 3D

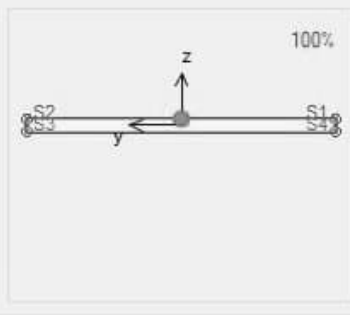
Definition:
 From library / calculator
 Enter properties

Rotation about centroid: 0 °
 Mirrored about axis: None

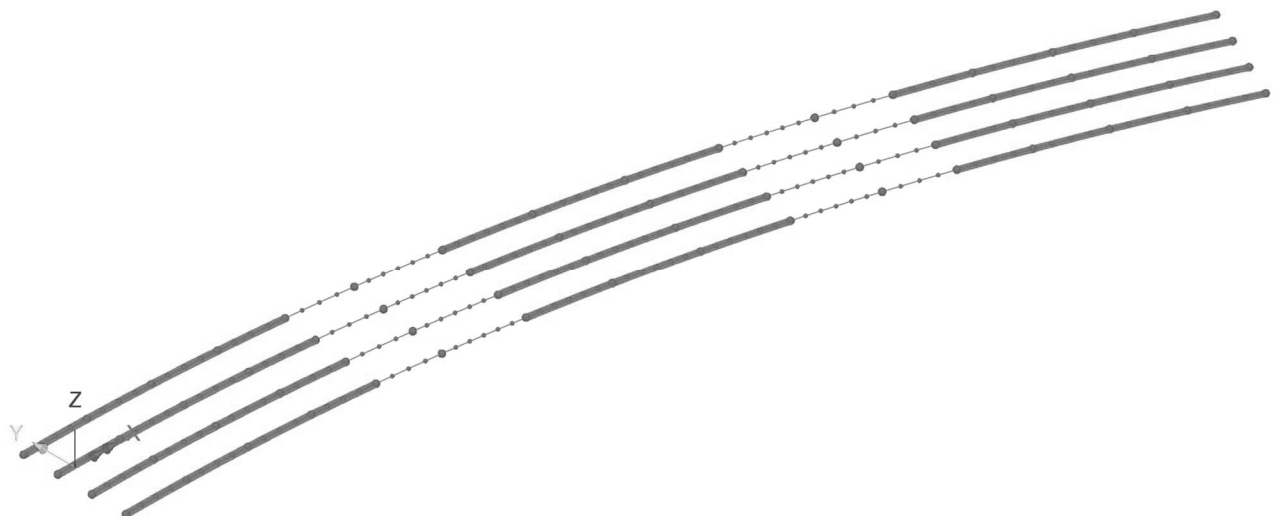
Reinforcement (only used for RC design checks):
 None

ez origin: Centroid
 ey origin: Same as ez

Parametric Sections: 2:RSS D=0,025 B=0,600 EZ=0,013 (f)



	Value
Gross sectional area (A)	0,015
Second moment of area about y axis (Iyy)	0,781E-6
Second moment of area about z axis (Izz)	0,450E-3
Product moment of area (Iyz)	0,000
Torsional constant (J)	3,043E-6
Effective shear area in y direction (Asy)	0,013
Effective shear area in z direction (Asz)	0,013
Eccentricity in y direction (ey)	0,000
Eccentricity in z direction (ez)	0,013



3D Overview

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A2:37
	Composite steel girder bridge	Date :	Created :

Bottom flange (BEAM 2 & BEAM 4):

Flange is given geometric properties seen below.

Geometric Line

Analysis category: 3D

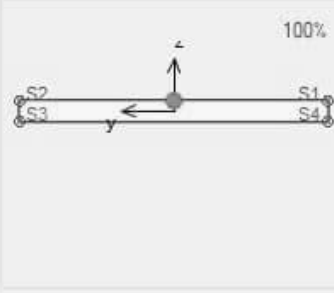
Definition: From library / calculator Enter properties

Rotation about centroid: 0° Mirrored about axis: None

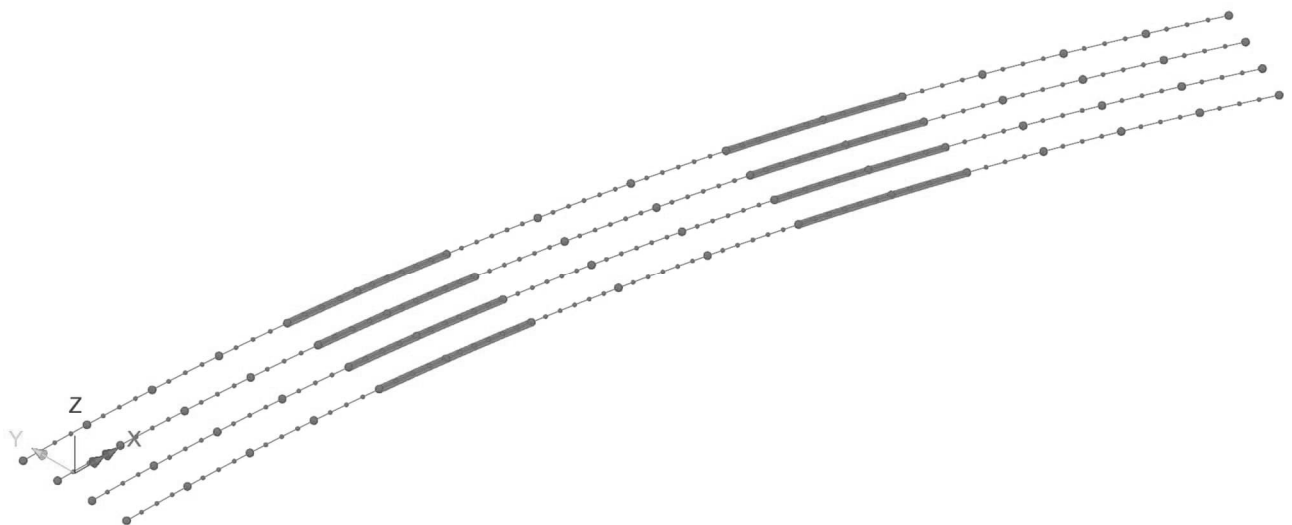
Reinforcement (only used for RC design checks): None

ez origin: Centroid ey origin: Same as ez

Parametric Sections: 4:RSS D=0,040 B=0,600 EZ=0,020 (f)



	Value
Cross sectional area (A)	0,024
Second moment of area about y axis (Iyy)	3,200E-6
Second moment of area about z axis (Izz)	0,001
Product moment of area (Iyz)	0,000
Torsional constant (J)	0,012E-3
Effective shear area in y direction (Asy)	0,020
Effective shear area in z direction (Asz)	0,020
Eccentricity in y direction (ey)	0,000
Eccentricity in z direction (ez)	0,020

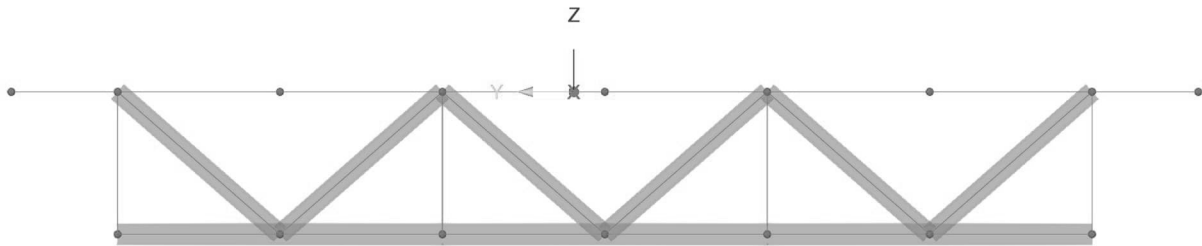


3D Overview

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:38
		Date :	Created :

2.4.2.2 Intermediate bracing: type F

Each bracing consist of 2 part and are identical at all supports (F1 & F2)



Typ F

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A2:39
	Composite steel girder bridge	Date :	Created :

Bracings intermediate (F1 & F2)- horizontal beam (HEB 180):

Beam is given geometric properties seen below.

Geometric Line

Analysis category: 3D

Definition

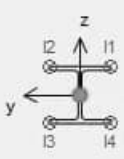
From library / calculator
 Enter properties

Rotation about centroid: 0 ° Mirrored about axis: None

Reinforcement (only used for RC design checks): None

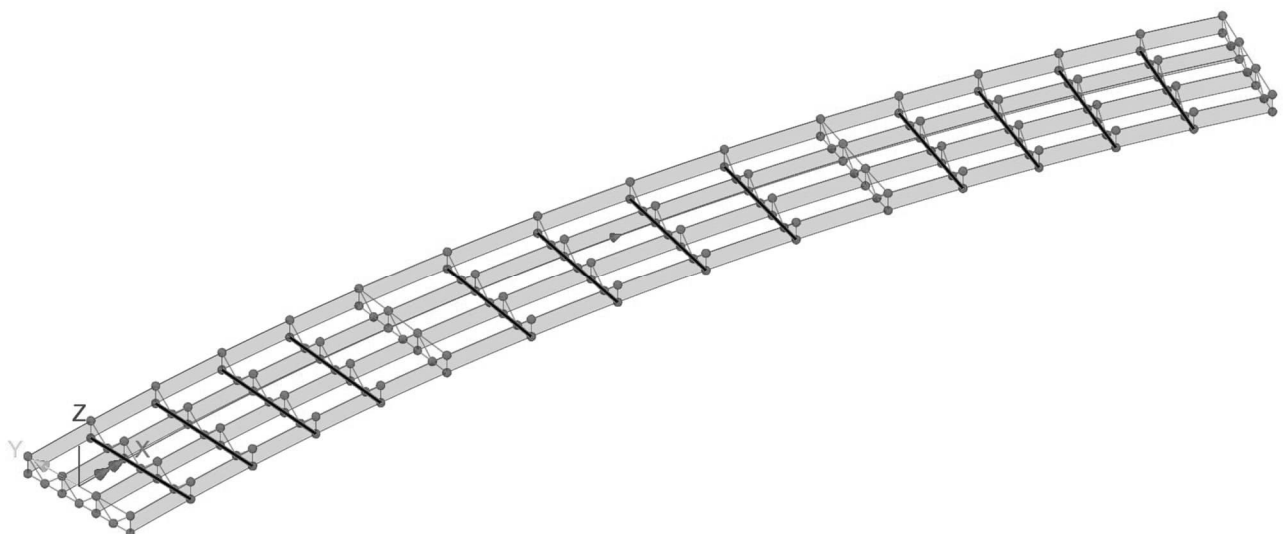
ez origin: Centroid ey origin: Same as ez

EU Sections: HE Shapes (EN53-62) HE 180 B



	Value
Cross sectional area (A)	0,004
Second moment of area about y axis (Iyy)	0,020E-3
Second moment of area about z axis (Izz)	7,300E-6
Product moment of area (Iyz)	0,000
Torsional constant (J)	0,081E-6
Effective shear area in y direction (Asy)	0,002
Effective shear area in z direction (Asz)	0,001
Eccentricity in y direction (ey)	0,000
Eccentricity in z direction (ez)	0,000

Name: Typ F: Horizontal beam (43)



3D Overview

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A2:40
	Composite steel girder bridge	Date :	Created :

Bracings intermediate (F1 & F2)- inclined beam (HEB 120):

Beam is given geometric properties seen below.

Geometric Line

Analysis category: 3D

Definition: From library / calculator Enter properties

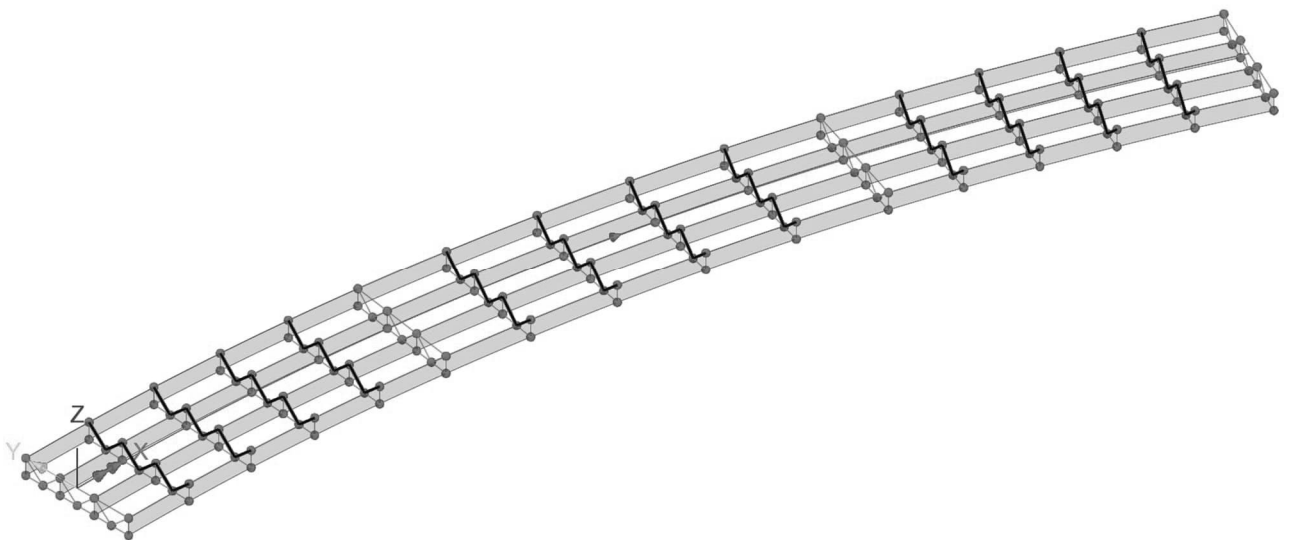
Rotation about centroid: 0 ° Mirrored about axis: None

EU Sections: HE Shapes (EN53-62) HE 120 B

ez origin: Centroid ey origin: Same as ez

	Value
Cross sectional area (A)	0,003
Second moment of area about y axis (Iyy)	8,644E-6
Second moment of area about z axis (Izz)	3,175E-6
Product moment of area (Iyz)	0,000
Torsional constant (J)	0,141E-6
Effective shear area in y direction (Asy)	0,002
Effective shear area in z direction (Asz)	0,001
Eccentricity in y direction (ey)	0,000
Eccentricity in z direction (ez)	0,000

Name: Typ F: Inclined beam (51)

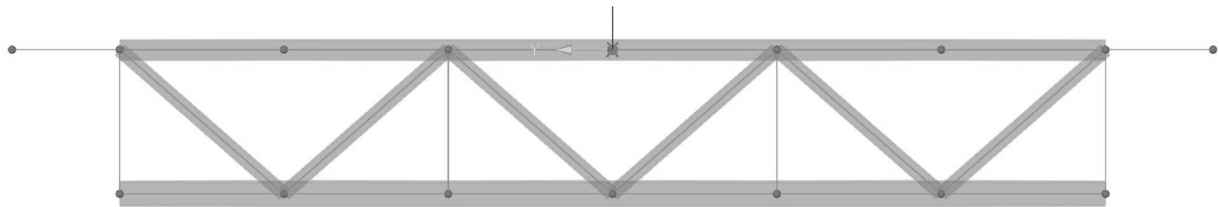


3D Overview

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:41
		Date :	Created :

2.4.2.4 Support bracing: type S

Each bracing consists of 3 part and are identical at all supports (S1 & S2)



Typ S

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A2:42
	Composite steel girder bridge	Date :	Created :

Bracings supports (S1 & S2)- horizontal beam bottom (HEB 220):

Beam is given geometric properties seen below.

Geometric Line

Analysis category 3D

Definition

From library / calculator

Enter properties

Rotation about centroid 0 ° Mirrored about axis None

EU Sections

HE Shapes (EN53-62)

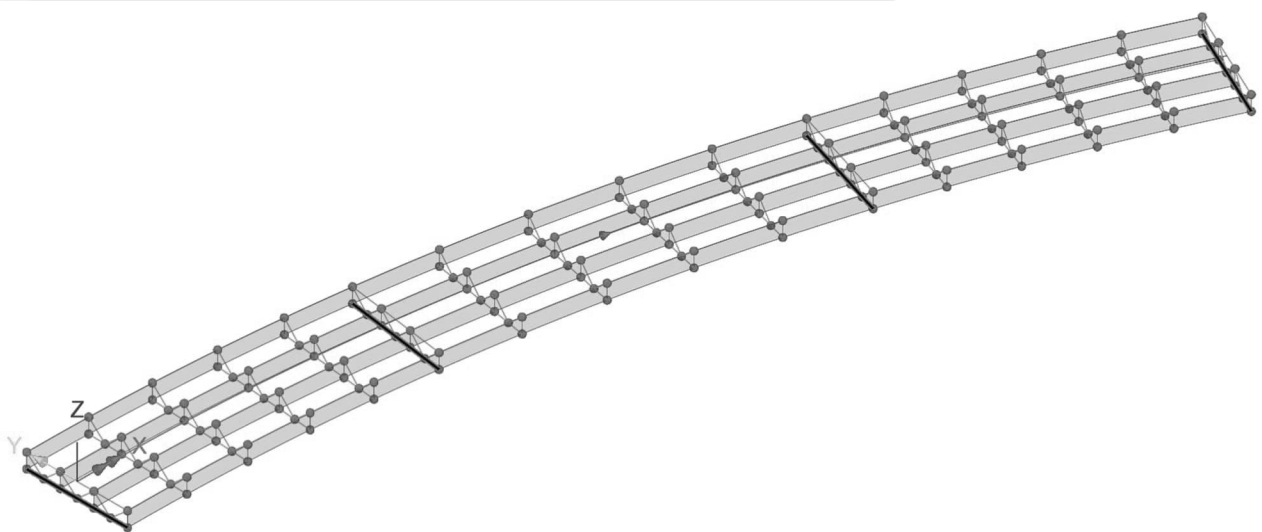
HE 220 B

100%

ez origin Centroid ey origin Same as ez

	Value
Cross sectional area (A)	0.009
Second moment of area about y axis (Iyy)	0.081E-3
Second moment of area about z axis (Izz)	0.028E-3
Product moment of area (Iyz)	0.000
Torsional constant (J)	0.781E-6
Effective shear area in y direction (Asy)	0.006
Effective shear area in z direction (Asz)	0.002
Eccentricity in y direction (ey)	0.000
Eccentricity in z direction (ez)	0.000

Name Typ S: Horizontal beam bottom (45)



3D Overview

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A2:43
	Composite steel girder bridge	Date :	Created :

Bracings supports (S1 & S2)- horizontal beam top (HEB 180):

Beam is given geometric properties seen below.

Geometric Line

Analysis category 3D

Definition

From library / calculator

Enter properties

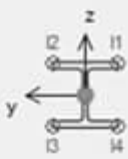
Rotation about centroid 0 = Mirrored about axis None

EU Sections

HE Shapes (EN53-62)

HE 180 B

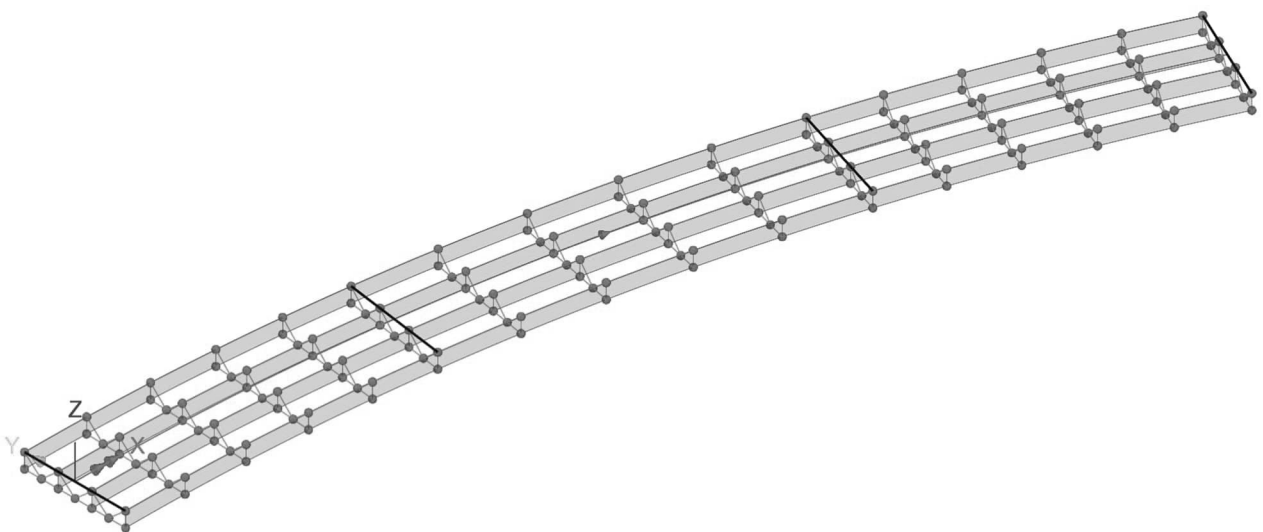
100%



	Value
Cross sectional area (A)	0,007
Second moment of area about y axis (I _{yy})	0,038E-3
Second moment of area about z axis (I _{zz})	0,014E-3
Product moment of area (I _{yz})	0,000
Torsional constant (J)	0,428E-6
Effective shear area in y direction (A _{sy})	0,005
Effective shear area in z direction (A _{sz})	0,001
Eccentricity in y direction (e _y)	0,000
Eccentricity in z direction (e _z)	0,000

ez origin Centroid ey origin Same as ez

Name Typ S: Horizontal beam top (46)



3D Overview

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A2:44
	Composite steel girder bridge	Date :	Created :

Bracings supports (S1 & S2)- inclined beam (HEB 120):

Beam is given geometric properties seen below.

Geometric Line

Analysis category: 3D

Definition:
 From library / calculator
 Enter properties

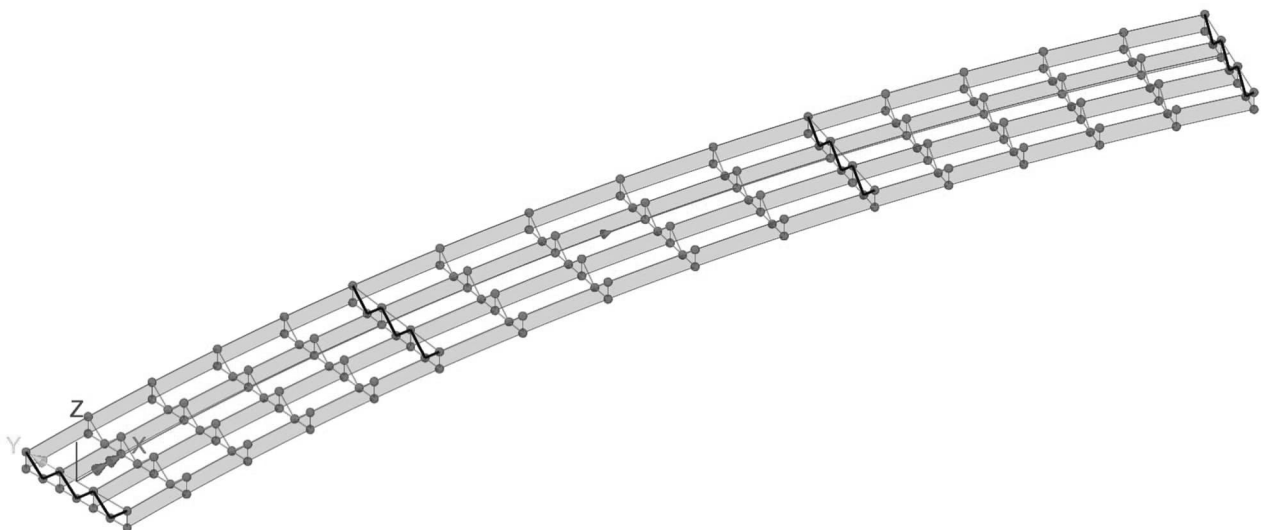
Rotation about centroid: 0 °
 Mirrored about axis: None

EU Sections: HE Shapes (EN53-62)
 HE 120 B

ez origin: Centroid
 ey origin: Same as ez

	Value
Cross sectional area (A)	0,003
Second moment of area about y axis (Iyy)	8,644E-6
Second moment of area about z axis (Izz)	3,175E-6
Product moment of area (Iyz)	0,000
Torsional constant (J)	0,141E-6
Effective shear area in y direction (Asy)	0,002
Effective shear area in z direction (Asz)	0,001
Eccentricity in y direction (ey)	0,000
Eccentricity in z direction (ez)	0,000

Name: Type S: Inclined beam (47)

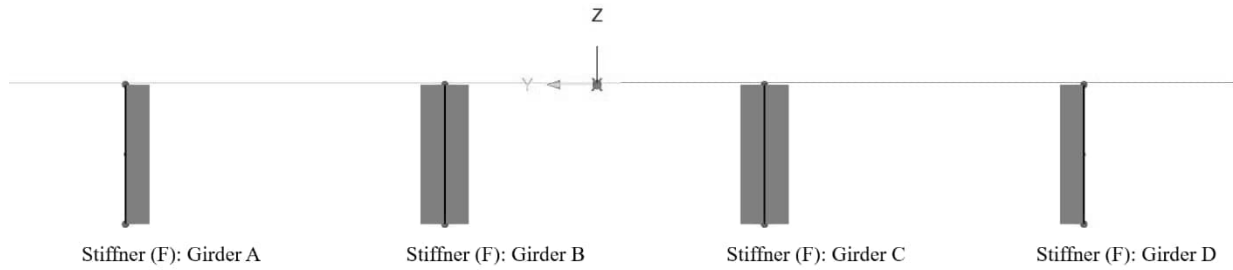


3D Overview

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:45
		Date :	Created :

2.4.2.5 Stiffeners (F)

At locations of every bracing type F, stiffeners seen below are applied.



	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A2:46
	Composite steel girder bridge	Date :	Created :

Stiffener(F) – Girder A:

A beam (PL 15 x 200) is placed eccentrically (e_y) as seen below.

$$e_y = 0.5 \cdot (b + t_w) = 0.5 \cdot (200 \text{ mm} + 14 \text{ mm}) = +107 \text{ mm}.$$

Geometric Line ✕

Analysis category:

Definition:
 From library / calculator
 Enter properties

Rotation about centroid: ° Mirrored about axis:

Parametric Sections:
Rectangular Sections:
11:PL 15 x 200 (RSS D=0,015 B=0,2)

100%

Reinforcement (only used for RC design checks):

ez origin: ey origin:

	Value
Cross sectional area (A)	0,003
Second moment of area about y axis (I _{yy})	0,056E-6
Second moment of area about z axis (I _{zz})	0,010E-3
Product moment of area (I _{yz})	0,000
Torsional constant (J)	0,214E-6
Effective shear area in y direction (A _{sy})	0,003
Effective shear area in z direction (A _{sz})	0,003
Eccentricity in y direction (e _y)	0,107
Eccentricity in z direction (e _z)	0,000

Name: (49)

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:47
		Date :	Created :

Stiffener(F) – Girders B & C:

Equivalent compounded section is used as seen below. Consists of 2 identical beams (PL 15 x 200) placed eccentrically (e_y) as seen below.

$$e_y = \pm 0.5 \cdot (b + t_w) = \pm 0.5 \cdot (200 \text{ mm} + 14 \text{ mm}) = \pm 107 \text{ mm.}$$

Compound Section ✕

Analysis category: Specify material for each row
Reference material:

	Section	Horizontal Alignment			Vertical Alignment			Material
		This sect	Align to	Other sect	This sect	Align to	Other sect	
1	PL 15 x 200 (RSS D=0.01)	Centroid	Coords	-0,107	Centroid	Coords	0,000	
2	PL 15 x 200 (RSS D=0.01)	Centroid	Coords	0,107	Centroid	Coords	0,000	

100%

Calculated properties

A

Iyy

Izz

Iyz

J

Asz

Asy

Name: (50)

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A2:48
	Composite steel girder bridge	Date :	Created :

Stiffener(F) – Girders D:

A beam (PL 15 x 200) is placed eccentrically (e_y) as seen below.

$$e_y = -0.5 \cdot (b + t_w) = -0.5 \cdot (200 \text{ mm} + 14 \text{ mm}) = -107 \text{ mm.}$$

Geometric Line ✕

Analysis category

Definition
 From library / calculator
 Enter properties

Rotation about centroid ° Mirrored about axis

Reinforcement (only used for RC design checks)

ez origin ey origin

Parametric Sections

Rectangular Sections

11:PL 15 x 200 (RSS D=0,015 B=0,2)

100%

	Value
Cross sectional area (A)	0,003
Second moment of area about y axis (Iyy)	0,056E-6
Second moment of area about z axis (Izz)	0,010E-3
Product moment of area (Iyz)	0,000
Torsional constant (J)	0,214E-6
Effective shear area in y direction (Asy)	0,003
Effective shear area in z direction (Asz)	0,003
Eccentricity in y direction (ey)	-0,107
Eccentricity in z direction (ez)	0,000

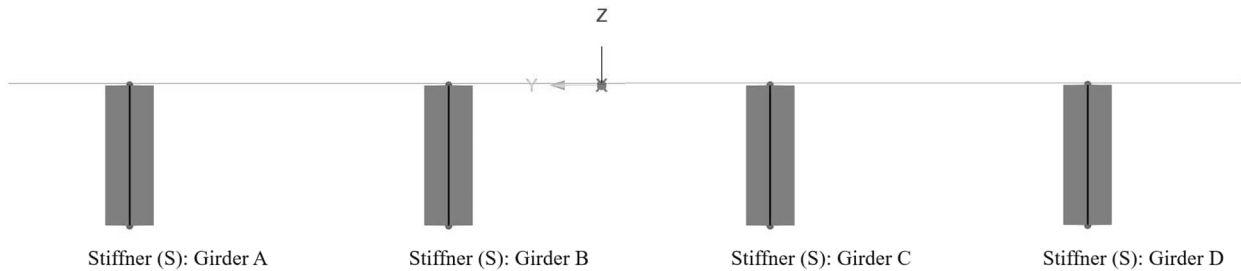
Name (51)

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:49
		Date :	Created :

2.4.2.6 Stiffeners (S)

At locations of every bracing type S, identical stiffeners used. These consists of 2 identical beams (PL 25 x 200) placed eccentrically (e_y) as seen below.

$$e_y = \pm 0.5 \cdot (b + t_w) = \pm 0.5 \cdot (200 \text{ mm} + 14 \text{ mm}) = \pm 107 \text{ mm.}$$



Compound Section ✕

Analysis category: Specify material for each row
Reference material:

	Section	Horizontal Alignment			Vertical Alignment			Material
		This sect	Align to	Other sect	This sect	Align to	Other sect	
1	PL 25 x 200 (RSS D=0,02)	Centroid	Coords	-0,107	Centroid	Coords	0,000	
2	PL 25 x 200 (RSS D=0,02)	Centroid	Coords	0,107	Centroid	Coords	0,000	

100%

Calculated properties

A: 0,010

Iyy: 0,521E-6

Izz: 0,148E-3

Iyz: 0,000

J: 1,919E-6

Asz: 0,008

Asy: 0,008

Name: (48)

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:50
		Date :	Created :

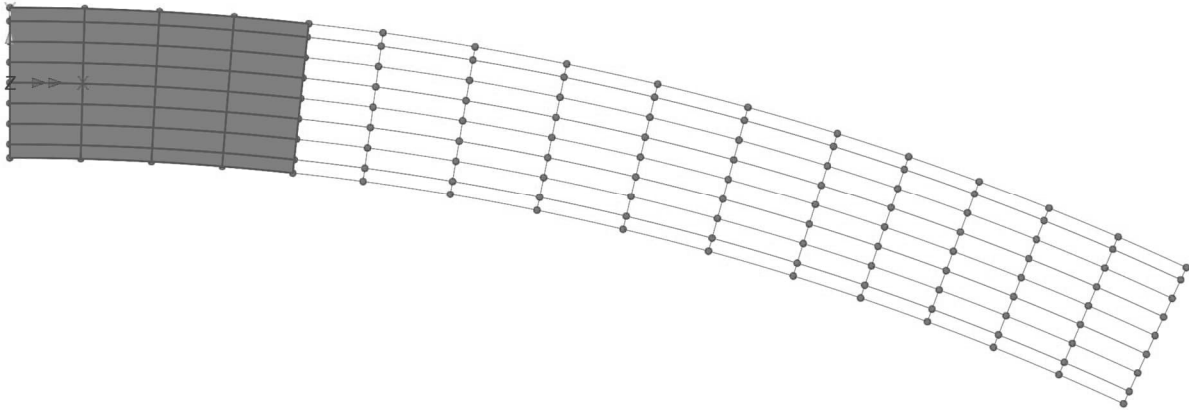
2.5 CASTING STAGES

There are a total of 5 construction and 2 operational stages. In the different phases the roadway is activated/deactivated. Changes are made in relation to system 7 (Base Analysis).

This is handled by applying “Deactivate” in the applicable phases. When applied to a static system, allocation must be made for each individual load case.

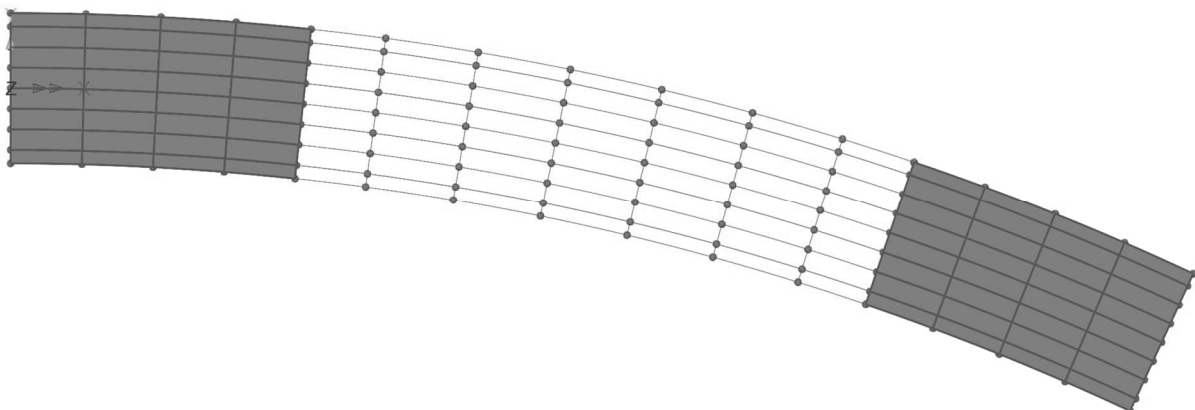
2.5.1 Analysis 1 (Stage I)

Deactivate : Stage II-V



2.5.2 Analysis 2 (Stage II)

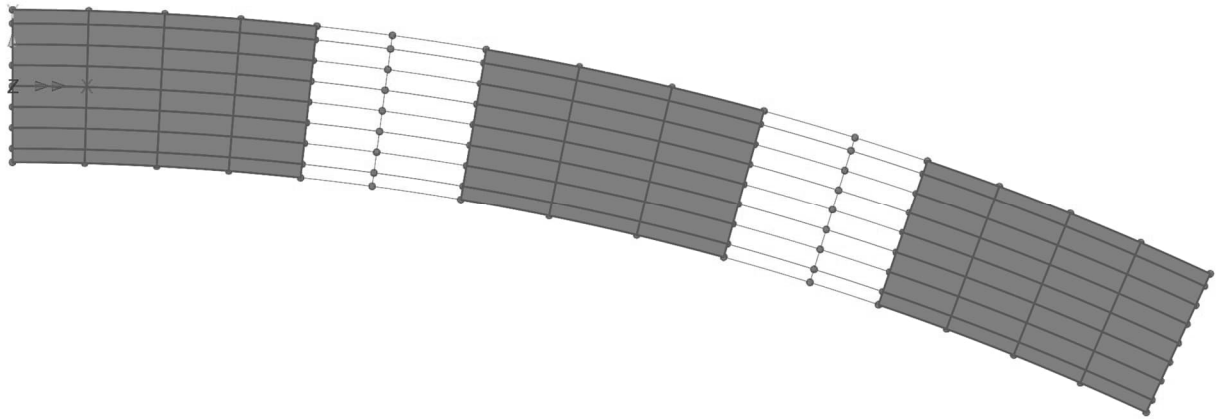
Deactivate : Stage III-V



	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:51
		Date :	Created :

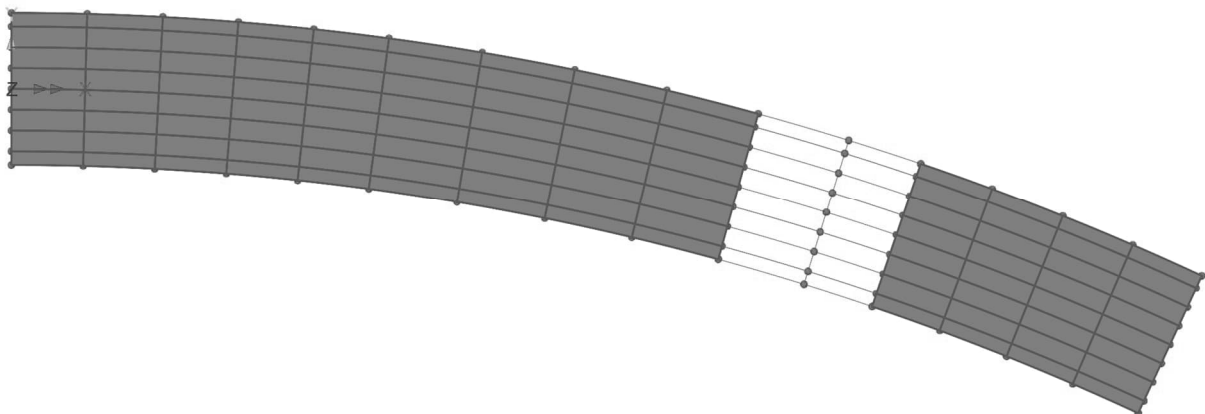
2.5.3 Analysis 3 (Stage III)

Deactivate : Stage IV-V



2.5.4 Analysis 4 (Stage 4)

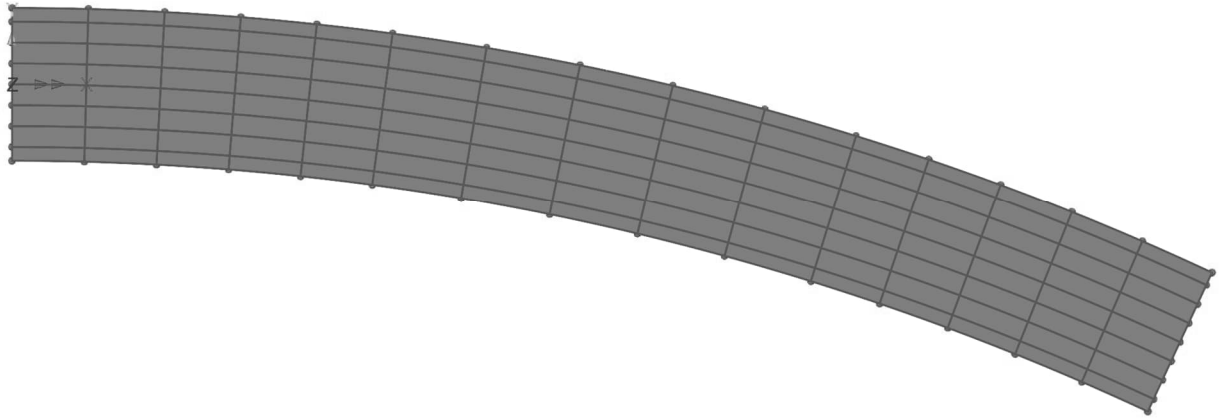
Deactivate : Stage V



	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:52
		Date :	Created :

2.5.5 *Analysis 5 (Stage 5)*

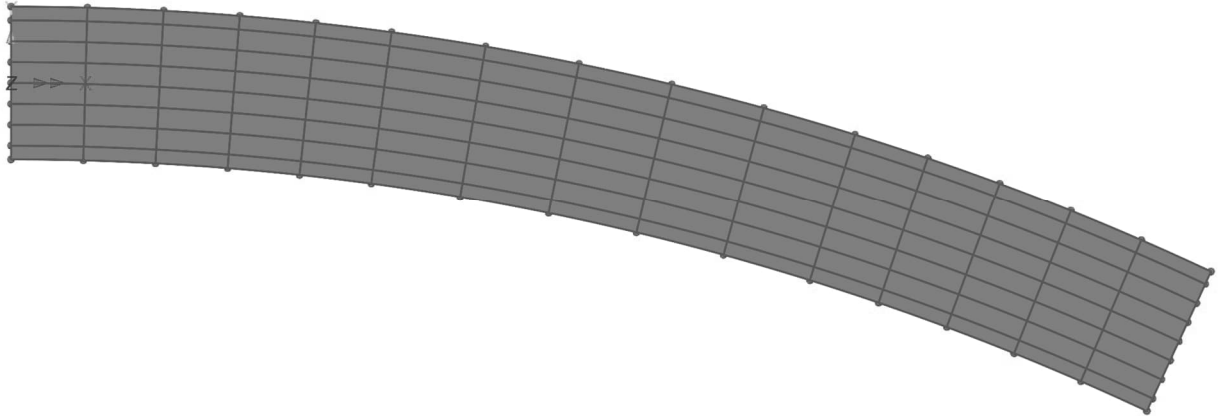
Deactivate : None



	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:53
		Date :	Created :

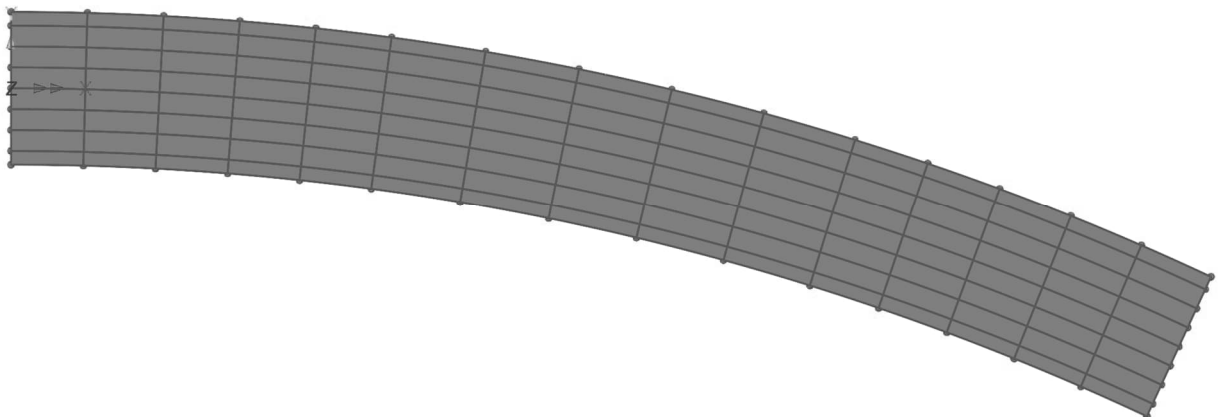
2.5.6 Analysis 6 (O:PERM)

Deactivate : None



2.5.7 Analysis 7 (O:VAR)

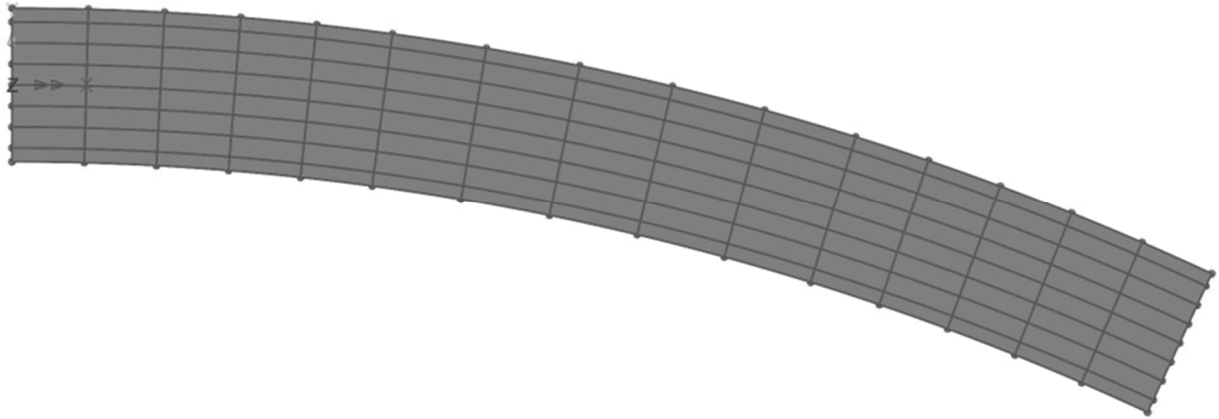
Deactivate : None



	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:54
		Date :	Created :

2.5.8 Analysis 8 (O:TEMP)

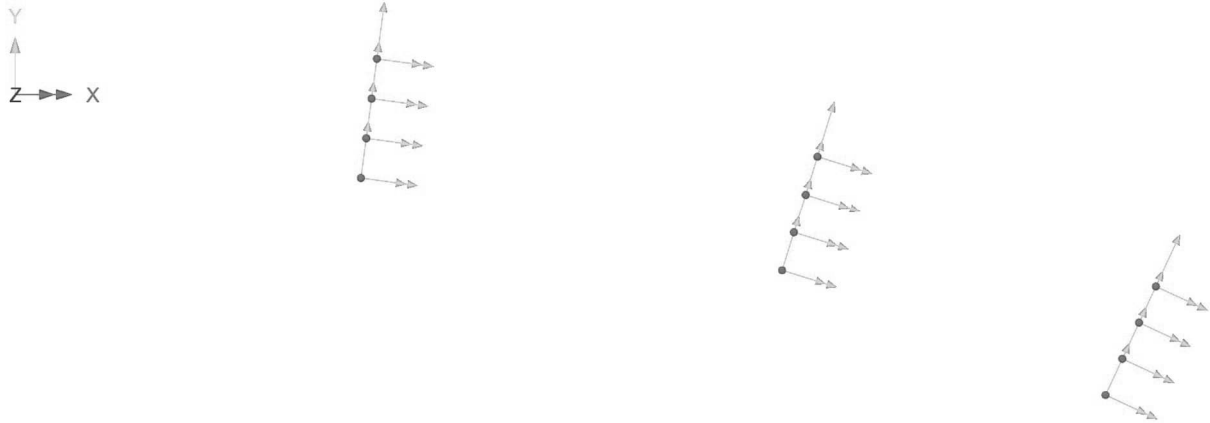
Deactivate : None



	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:55
		Date :	Created :

2.6 LOCAL COORDINATE SYTEM

When assigning loads and boundary conditions, local coordinate systems are used at each support line as described below.



2D Overview

Coordinate system at support 1:
Global coordinate system

Coordinate system at support 2:

Local Coordinate ✕

Coordinates type

Cartesian
 Cylindrical
 Spherical
 Surface

Rotate
 Scale
 Matrix

Angle

About axis

X-axis
 Y-axis
 Z-axis

Origin

X

Y

Z

Local coordinate generated from selection

No Local coordinate attributes created from selection Use

Name (1)

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A2:56
	Composite steel girder bridge	Date :	Created :

Coordinate system at support 3:

Local Coordinate ✕

Coordinates type

Cartesian
 Cylindrical
 Spherical
 Surface

Rotate
 Scale
 Matrix

Angle

-17,220

About axis

X-axis
 Y-axis
 Z-axis

Origin

X

Y

Z

Local coordinate generated from selection

No Local coordinate attributes created from selection Use

Name (2)

Coordinate system at support 4:

Local Coordinate ✕

Coordinates type

Cartesian
 Cylindrical
 Spherical
 Surface

Rotate
 Scale
 Matrix

Angle

-24,891

About axis

X-axis
 Y-axis
 Z-axis

Origin

X

Y

Z

Local coordinate generated from selection

No Local coordinate attributes created from selection Use

Name (3)

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:57
		Date :	Created :

2.7 MATERIAL

2.7.1 Steel

Steel : $E_s = 210 \text{ GPa}$

Material Library
✕

Material type

Country

Standard

Grade

Properties

Young's modulus

Poisson's ratio

Density

Thermal expansion

Name

⬆️ ⬆️ (2)

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:58
		Date :	Created :

2.7.2 Concrete

In total, there are 7 stages, of which 5 are construction and 2 are operational stages. Considering this, the material properties of concrete deck vary.

Used concrete C35/45: $E_{cm} = 34.0 \text{ GPa}$

There several types of concrete as seen in table below. In system analysis to determine load effects only types 3, 5 & 7 are considered.

Type	E	Stage	ϕ	ψ_L	Cross section	Load
1	0 ^{1.)}	Constructional	-	-	Wet	Permanent loads
2	34.0 ^{2.)}	Constructional	0	1.0 ^{3.)}	Uncracked	Permanent loads
3	11.3	Operational	2.0	1.0 ^{3.)}	Uncracked	Permanent loads excl. shrinkage
4	11.3	Operational	2.0	1.0 ^{3.)}	Uncracked	Shrinkage
5	34.0	Operational	0	1.0 ^{3.)}	Uncracked	Variable loads excl. temperature
6	26.2	Operational	0.3	1.0 ^{3.)}	Uncracked	Variable excl. temperature
7	0 ^{1.)}	Operational	-	1.0 ^{3.)}	Cracked	All loads
-	GPa	-	-	-	-	-

Footnote:

- 1.) Instead, a negligible stiffness is used $E_{cm}/1000$. The effect of reinforcement is not considered when determining load effects in system analysis.
- 2.) Loads associated to permanent load will also act during operational stage, thus Young's modulus associated to type 3 is used during system analysis.
- 3.) Used on safe side in example.

Remark

The effect of rebars and types 4 & 6 will only be considered when applying loads and determining resistance according SS-EN 1994-1.

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:59
		Date :	Created :

2.7.2.1 Material : Wet & cracked concrete

The isotropic concrete has negligible stiffness ($E_{cm}/1000$), corresponding to material properties associated to concrete type 1 & 7.

$$E = E_{cm} / 1000 = 34 \cdot 10^6 \text{ kPa} / 1000 = 34 \cdot 10^3 \text{ kPa}$$

Isotropic ✕

Plastic
 Creep
 Damage
 Shrinkage
 Viscous
 Two phase
 Ko Initialisation

Elastic

Dynamic properties
 Thermal expansion

	Value
Young's modulus	34,0E3
Poisson's ratio	0,2
Mass density	2,5
Coefficient of thermal expansion	10,0E-6

Name (6)

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:60
		Date :	Created :

2.7.2.2 Material : Uncracked concrete - permanent loads

The isotropic concrete material properties associated to concrete type 2 & 3.

$$E = E_{cm} / (1 + \nu_L \cdot \phi) = 34 \cdot 10^6 \text{ kPa} / (1 + 1.0 \cdot 2.0) = 11.3 \cdot 10^6 \text{ kPa}$$

Isotropic
✕

Plastic
 Creep
 Damage
 Shrinkage
 Viscous
 Two phase
 Ko Initialisation

Elastic

Dynamic properties
 Thermal expansion

	Value
Young's modulus	11,3E6
Poisson's ratio	0,2
Mass density	2,5
Coefficient of thermal expansion	10,0E-6

Name
(4)

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:61
		Date :	Created :

2.7.2.3 Material : Uncracked concrete - variable loads excl. temperature

The isotropic concrete material properties associated to concrete type 5.

$$E = E_{cm} / (1 + \psi_L \cdot \phi) = 34 \cdot 10^6 \text{ kPa} / (1 + 0) = 34.0 \cdot 10^6 \text{ kPa}$$

Isotropic ✕

Plastic
 Creep
 Damage
 Shrinkage
 Viscous
 Two phase
 Ko Initialisation

Elastic

Dynamic properties
 Thermal expansion

	Value
Young's modulus	34,0E6
Poisson's ratio	0,2
Mass density	2,5
Coefficient of thermal expansion	10,0E-6

Name (5)

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:62
		Date :	Created :

2.7.2.4 Material : Uncracked concrete - temperature

The isotropic concrete material properties associated to concrete type 6.

$$E = E_{cm} / (1 + \psi_L \cdot \phi) = 34 \cdot 10^6 \text{ kPa} / (1 + 1.0 \cdot 0.3) = 26.2 \cdot 10^6 \text{ kPa}$$

Isotropic ✕

Plastic
 Creep
 Damage
 Shrinkage
 Viscous
 Two phase
 Ko Initialisation

Elastic

Dynamic properties
 Thermal expansion

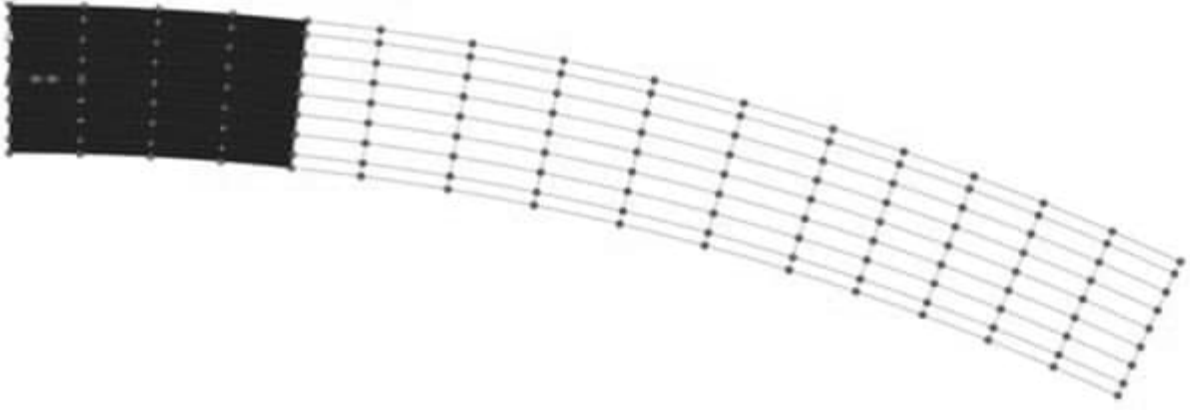
	Value
Young's modulus	26,2E6
Poisson's ratio	0,2
Mass density	2,5
Coefficient of thermal expansion	10,0E-6

Name (7)

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:63
		Date :	Created :

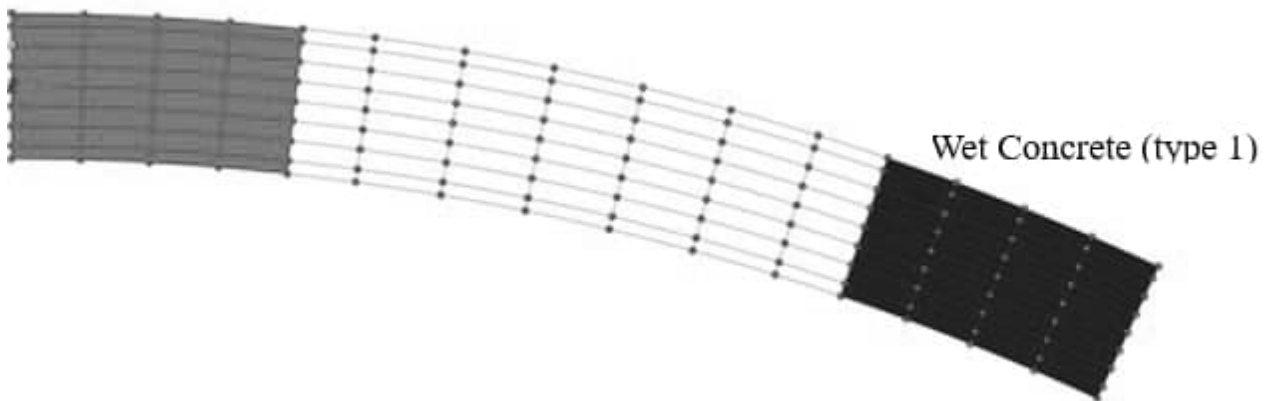
2.7.2.5 *Analysis 1 (Stage I)*

Wet Concrete (type 1)



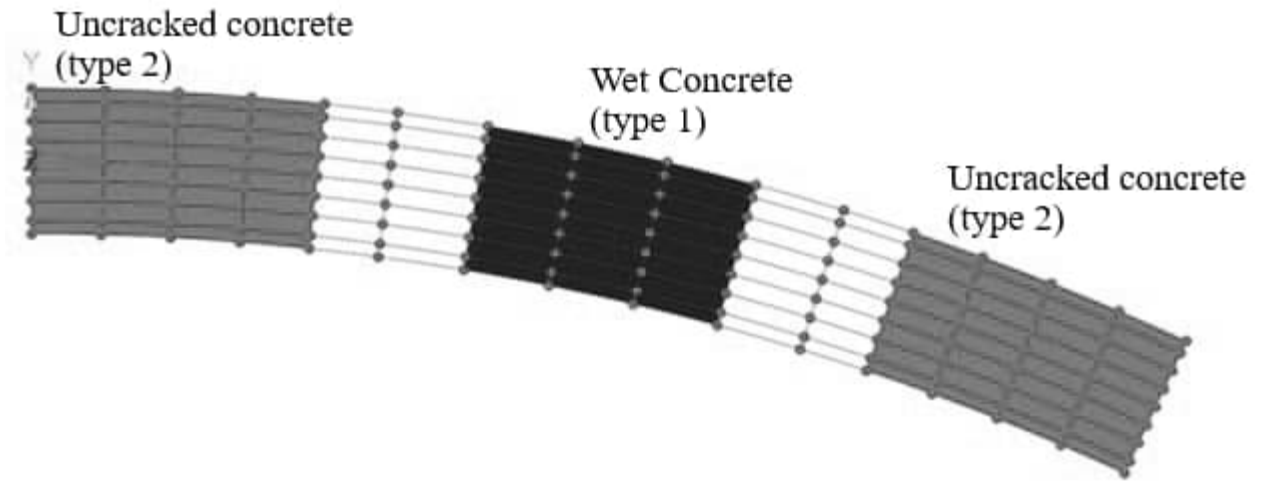
2.7.2.6 *Analysis 2 (Stage II)*

Uncracked concrete
(type 2)

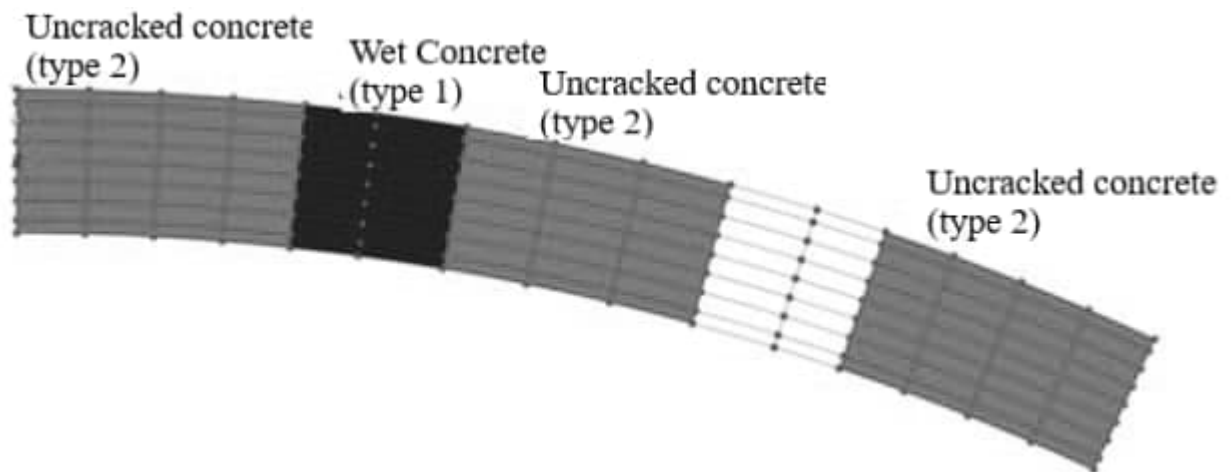


	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:64
		Date :	Created :

2.7.2.7 *Analysis 3 (Stage III)*

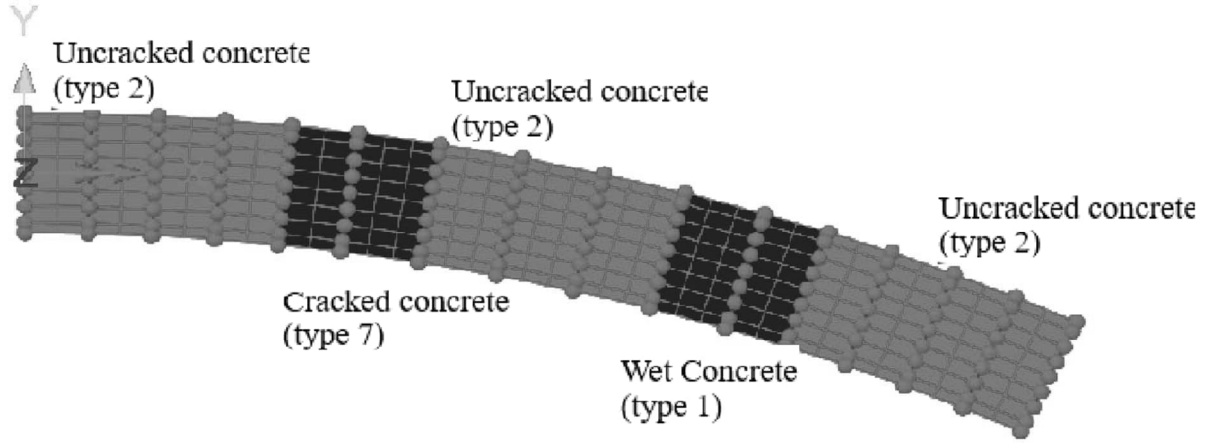


2.7.2.8 *Analysis 4 (Stage IV)*

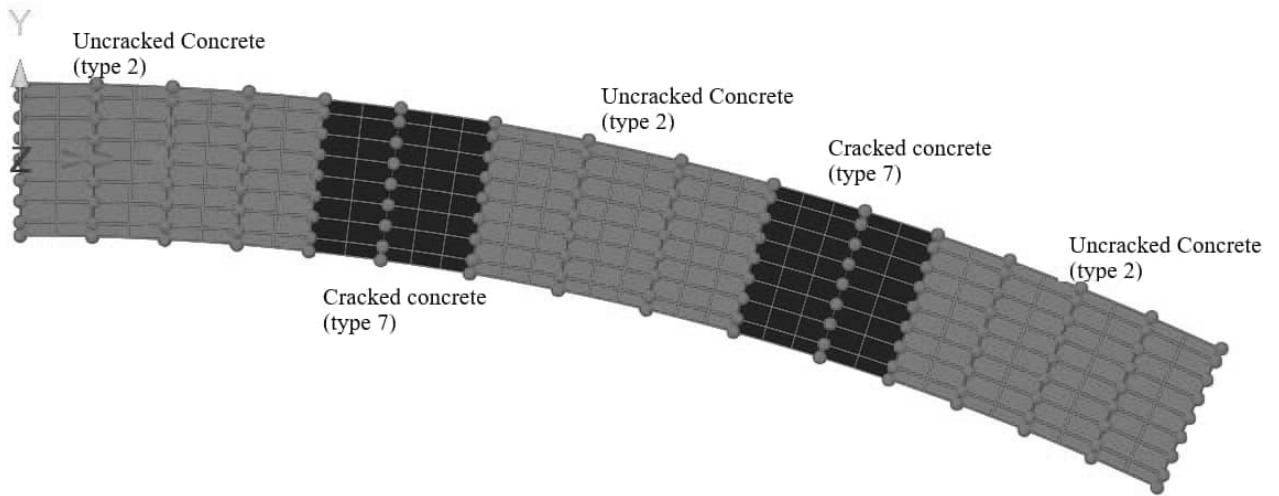


	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A2:65
	Composite steel girder bridge	Date :	Created :

2.7.2.9 *Analysis 5 (Stage V)*

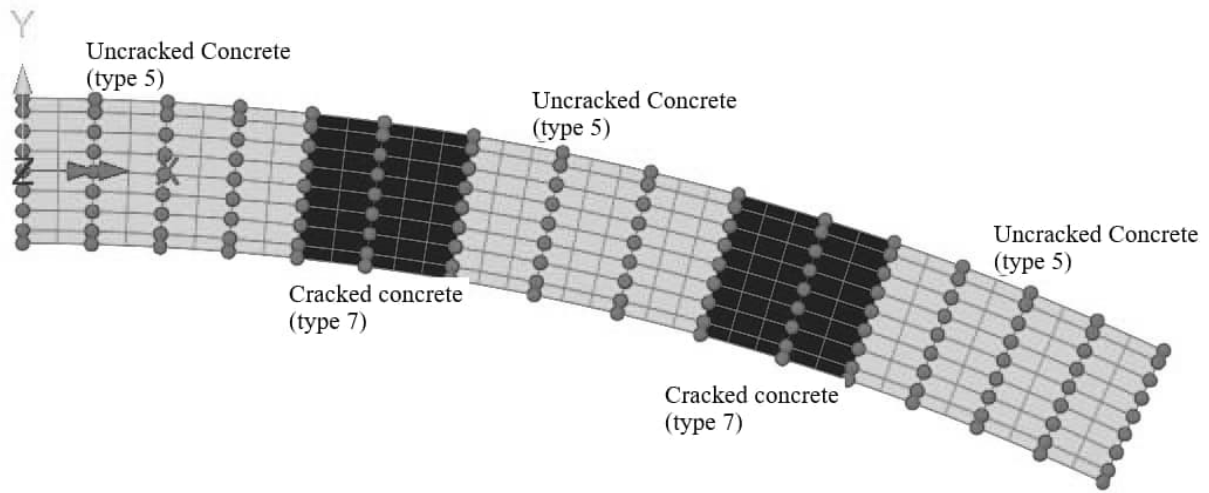


2.7.2.10 *Analysis 6 (O:PERM)*

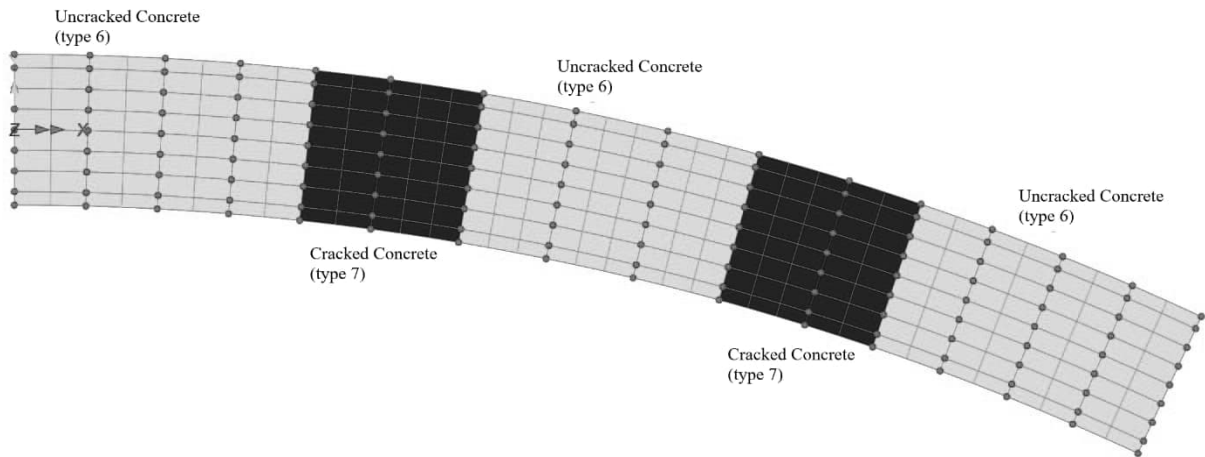


	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:66
		Date :	Created :

2.7.2.11 *Analysis 7 (O:VAR)*



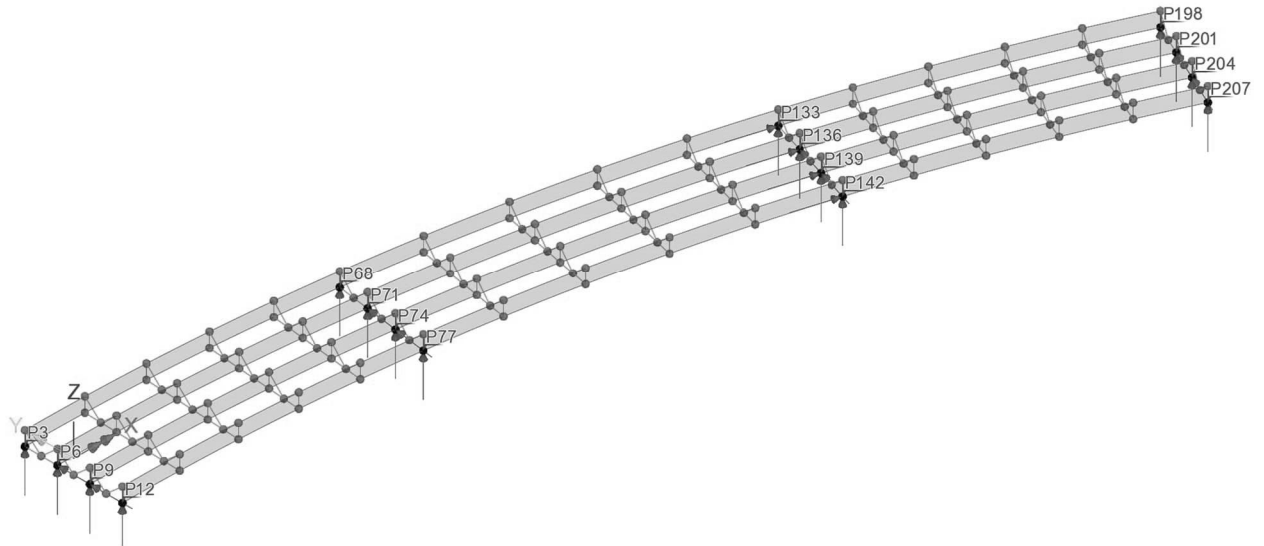
2.7.2.11 *Analysis 8 (O:TEMP)*



	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:67
		Date :	Created :

2.8 BOUNDARY CONDITIONS

At every support 4 bearings are defined as seen below. Support 3 is fixed in longitudinal direction.



Overview 3D

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:68
		Date :	Created :

2.8.1 Bearings support 1

Girders				
	Girder number	Longitudinal support	Transverse support	Vertical support
▶	1:A	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
	2:B	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
	3:C	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
	4:D	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>

2.8.2 Bearings support 2

Girders				
	Girder number	Longitudinal support	Transverse support	Vertical support
▶	1:A	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
	2:B	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
	3:C	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
	4:D	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>

2.8.3 Bearings support 3

Girders				
	Girder number	Longitudinal support	Transverse support	Vertical support
▶	1:A	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
	2:B	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
	3:C	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
	4:D	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>

2.8.4 Bearings support 4

Girders				
	Girder number	Longitudinal support	Transverse support	Vertical support
▶	1:A	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
	2:B	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
	3:C	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
	4:D	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>

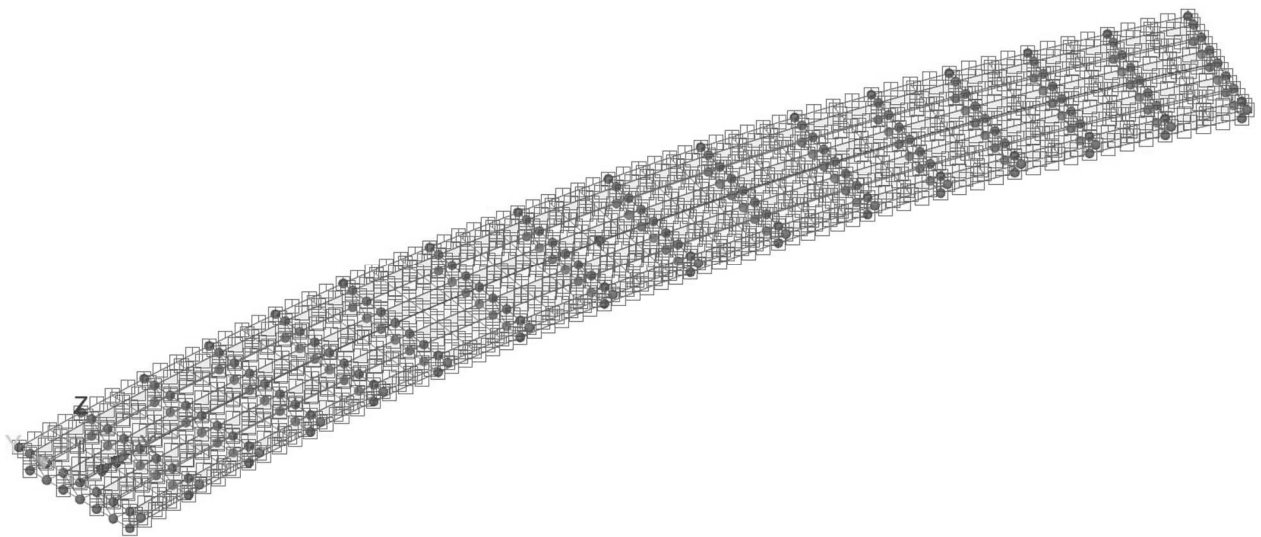
	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:69
		Date :	Created :

2.9 SEARCH AREA

Discrete load can be applied to structure as geometrical load areas. In static model load areas are termed *Search Area*.

Deck:

-



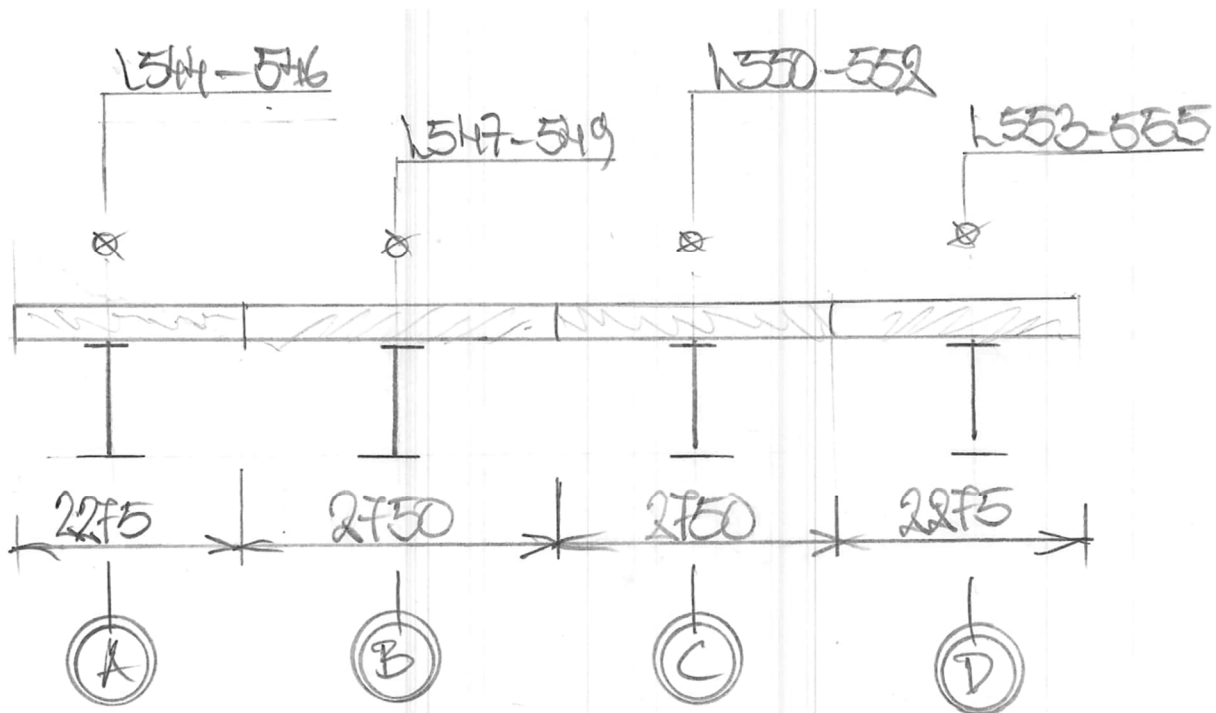
	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:70
		Date :	Created :

2.10 SLICE RESULTANTS BEAMS/SHELLS

Equivalent section forces will be determined at 4 sub-points for each main beam. This is done by studying load effects in the Nodal surface and Nodal line for the respective girder.

STACTIC MODELL has a script called "Slice Resultant Beams/Shells" to handle this, see the presentation below.

Grider	Path line	Width (b _c)	Extent
A	L544, L545, L546	2.275	Group "Girder A"
B	L547, L548, L549	2.750	Group "Girder B"
C	L550, L551, L552	2.750	Group "Girder C"
D	L553, L554, L555	2.275	Group "Girder D"
-	-	m	-



	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:71
		Date :	Created :

2.10.1 Slice beam: Girder A

Span 1: 25.052 m = 4 x 6.263 m;

Span 2: 31.184 m = 4 x 7.796 m

Span 3: 25.052 m = 4 x 6.263 m

Slice Resultants Beams/Shells ✕

Slice path

Selected lines

Slice locations

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

Include additional slices at points along path

Distance from reference origin to start of path (chainage)

Slice Options

Moments about Neutral axis Slice path

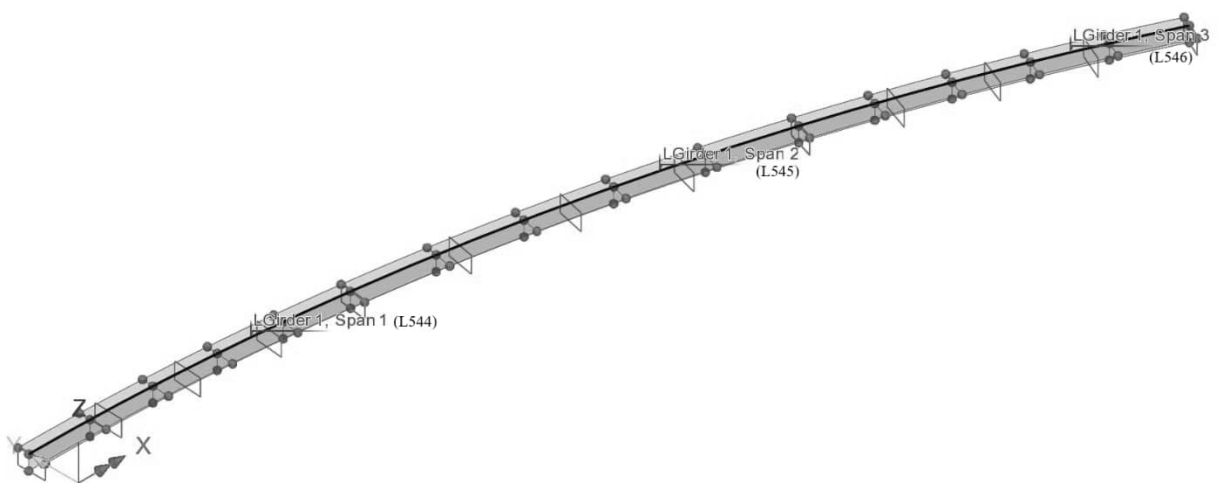
Slice width Include whole elements only

Smooth corners on path

Extent ▼

Rotation about x

Name ▼ ▲ (3)



OVERVIEW

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:72
		Date :	Created :

2.10.2 Slice beam: Girder B

Span 1: 24.684 m = 4 x 6.171 m

Span 2: 30.728 m = 4 x 7.682 m

Span 3: 24.484 m = 4 x 6.171 m

Slice Resultants Beams/Shells ✕

Slice path

Selected lines

Slice locations

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

Include additional slices at points along path

Distance from reference origin to start of path (chainage)

Slice Options

Moments about Neutral axis Slice path

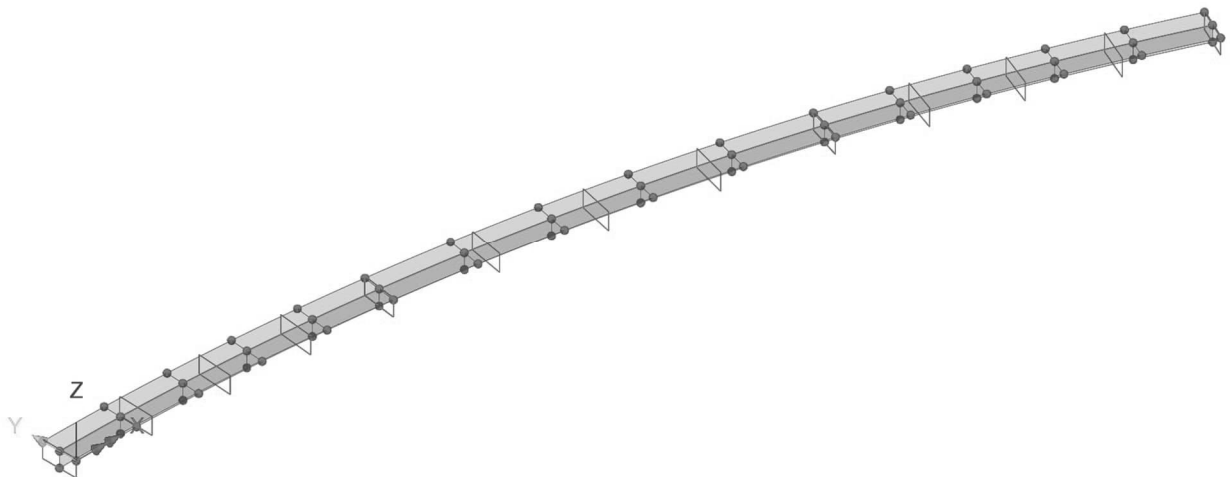
Slice width Include whole elements only

Smooth corners on path

Extent

Rotation about x

Name (1)



OVERVIEW

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:73
		Date :	Created :

2.10.3 Slice beam: Girder C

Span 1: 24.316 m = 4 x 6.079 m

Span 2: 30.268 m = 4 x 7.567 m

Span 3: 24.316 m = 4 x 6.079 m

Slice Resultants Beams/Shells ✕

Slice path

Selected lines

Slice locations

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

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

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

Constant spacing e.g. 1.25

Include additional slices at points along path

Distance from reference origin to start of path (chainage)

Slice Options

Moments about Neutral axis Slice path

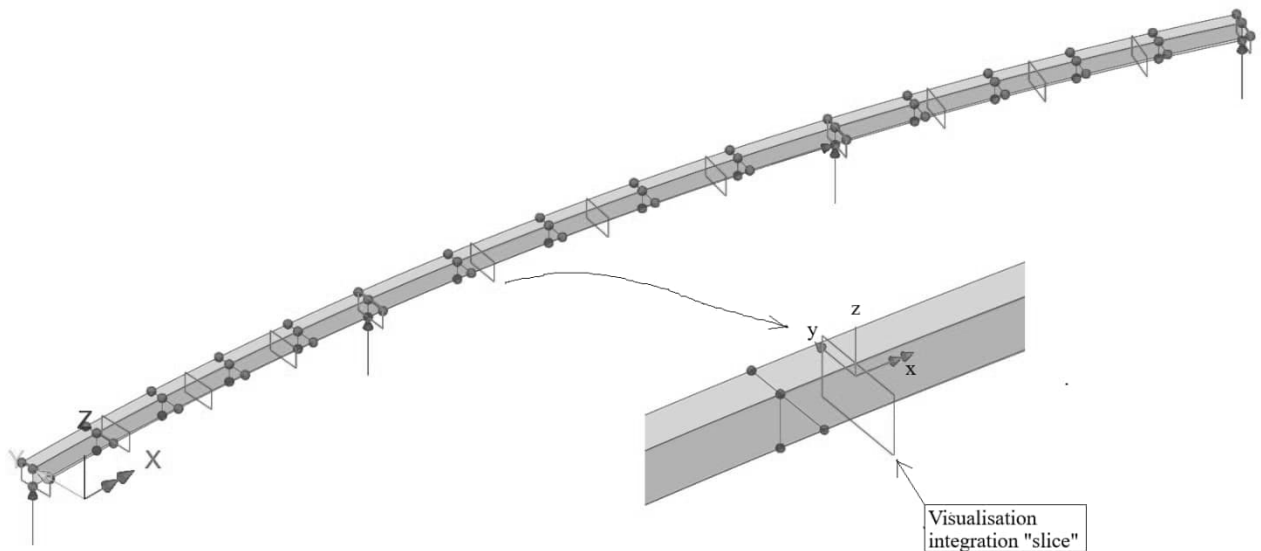
Slice width Include whole elements only

Smooth corners on path

Extent

Rotation about x

Name (new)



OVERVIEW

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:74
		Date :	Created :

2.10.4 Slice beam: Girder D

Span 1: 23.948 m = 4 x 5.987 m

Span 2: 29.812 m = 4 x 7.453 m

Span 3: 23.948 m = 4 x 5.987 m

Slice Resultants Beams/Shells ✕

Slice path

Selected lines Update

Slice locations

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

Include additional slices at points along path

Distance from reference origin to start of path (chainage)

Slice Options

Moments about Neutral axis Slice path

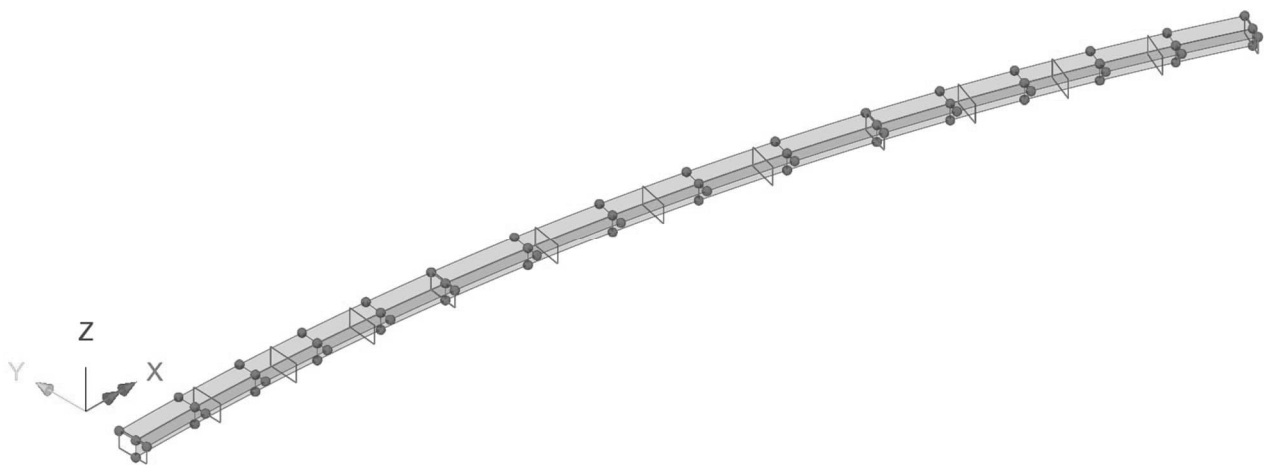
Slice width Include whole elements only

Smooth corners on path

Extent

Rotation about x

Name (4)



OVERVIEW

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A2:75
		Date :	Created :

2.11 FLANGE WIDTH

Flange width is determined by SS-EN 1992-1-1 section 5.3.2.1.

No reduction cross section is considered ($\therefore b_{ef} \equiv b$).

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A3:1
		Date :	Created :

3. LOADS

3.1	DEAD WEIGHT	page 3:2-10
3.2	SURFACING	page 3:11
3.3	CREEP	page 3:12
3.4	SHRINKAGE	page 3:13-16
3.5	TEMPERATURE	page 3:17-23
3.6	TRAFFIC LOAD	page 3:24-36
3.7	LOAD COMBINATIONS	page 3:37-48

This worked example is only intended to illustrate software, thus the number of loads are simplified, thus only dead weight, surfacing, creep, shrinkage and traffic load is considered. (The effect of formwork is not considered in this example.)

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A3:2
		Date :	Created :

3.1 DEAD WEIGHT

The dead weight is either steel structure or concrete deck. Densities below are applied.

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

$$\gamma_s = 77 \cdot \frac{kN}{m^3} \quad : \text{steel}$$

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:3
	Composite steel girder bridge	Date :	Created :

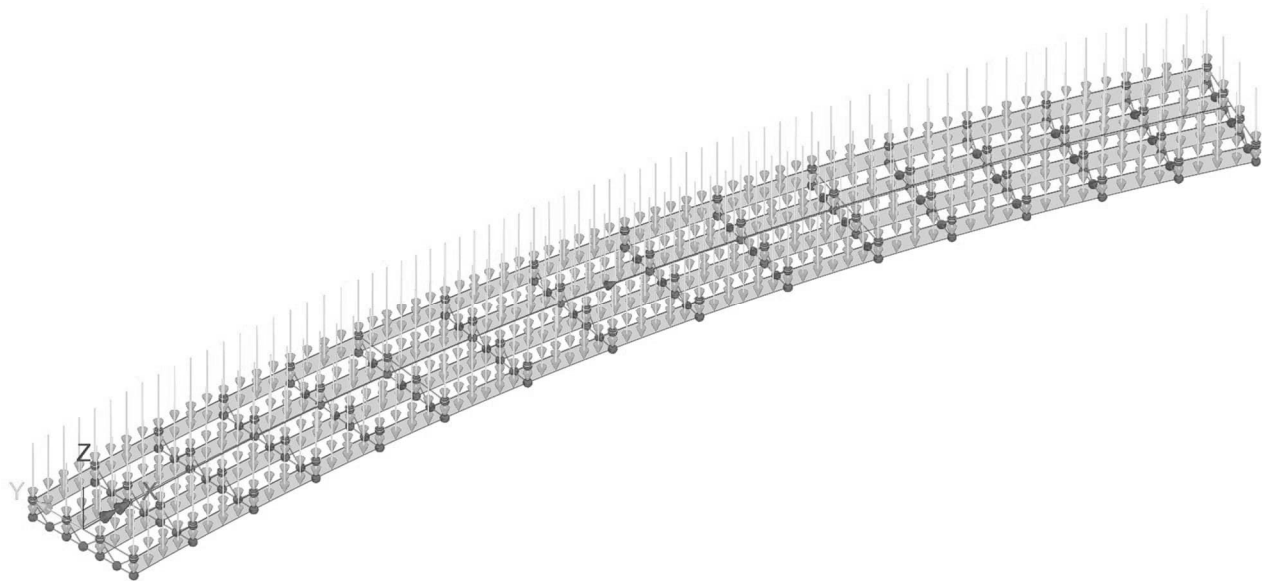
3.1.1 Steel structure (DEAD 1:1)

Load case : DEAD 1:1

Analysis: Analysis 1 (STAGE I)

Structural loading : Body force

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



Overview 3D

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A3:4
		Date :	Created :

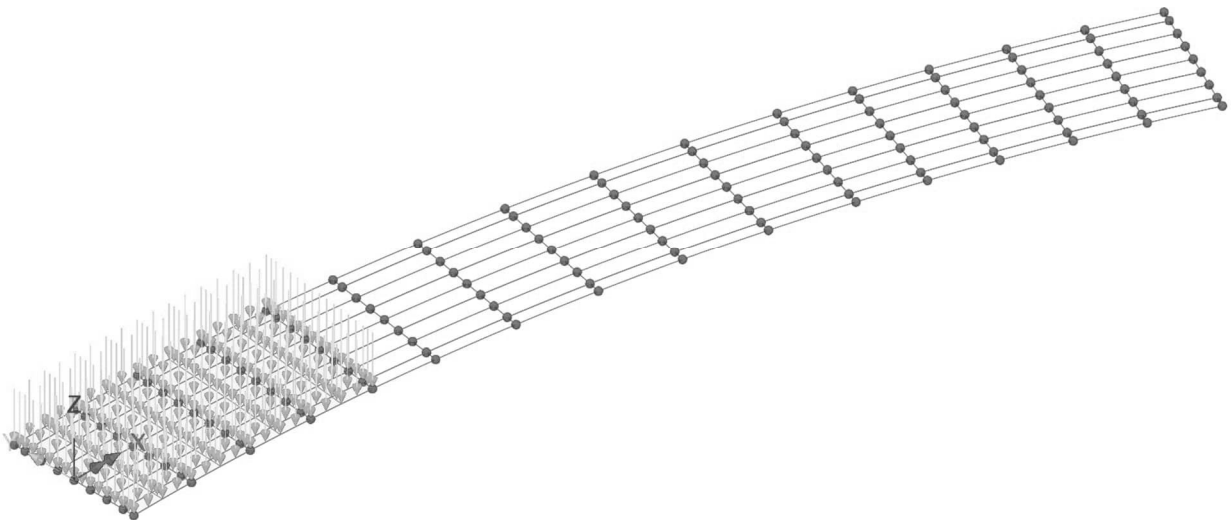
3.1.2 Concrete stage I (DEAD 2:1)

Load case : DEAD 2:1

Analysis: Analysis 1 (STAGE I)

Structural loading : Body force

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



	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:5
	Composite steel girder bridge	Date :	Created :

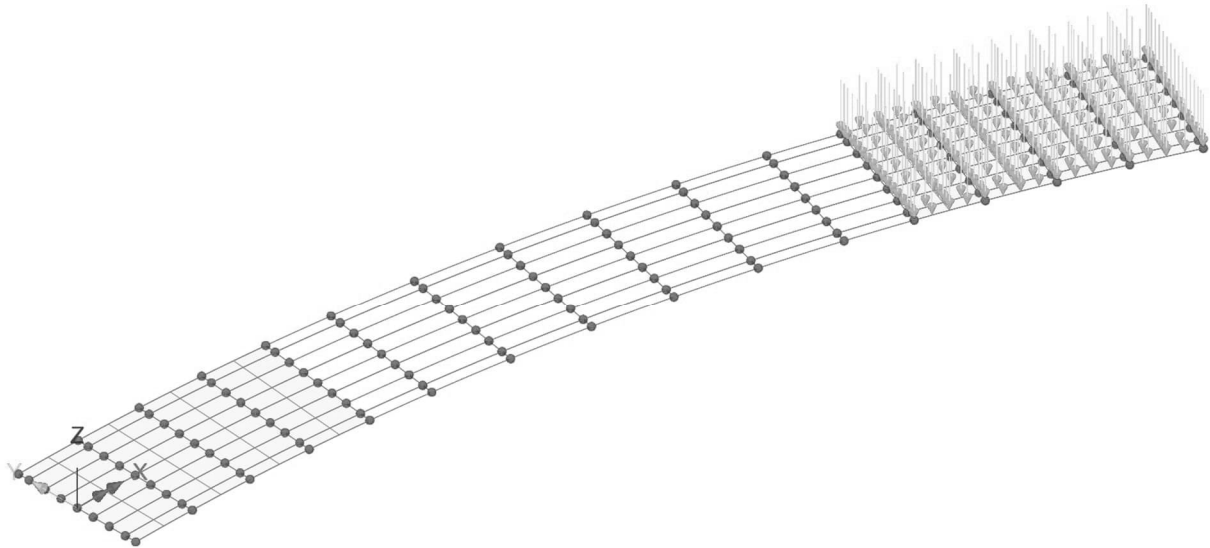
3.1.3 Concrete stage II (DEAD 2:2)

Load case : DEAD 2:2

Analysis: Analysis 2 (STAGE II)

Structural loading: Body force

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



	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:6
	Composite steel girder bridge	Date :	Created :

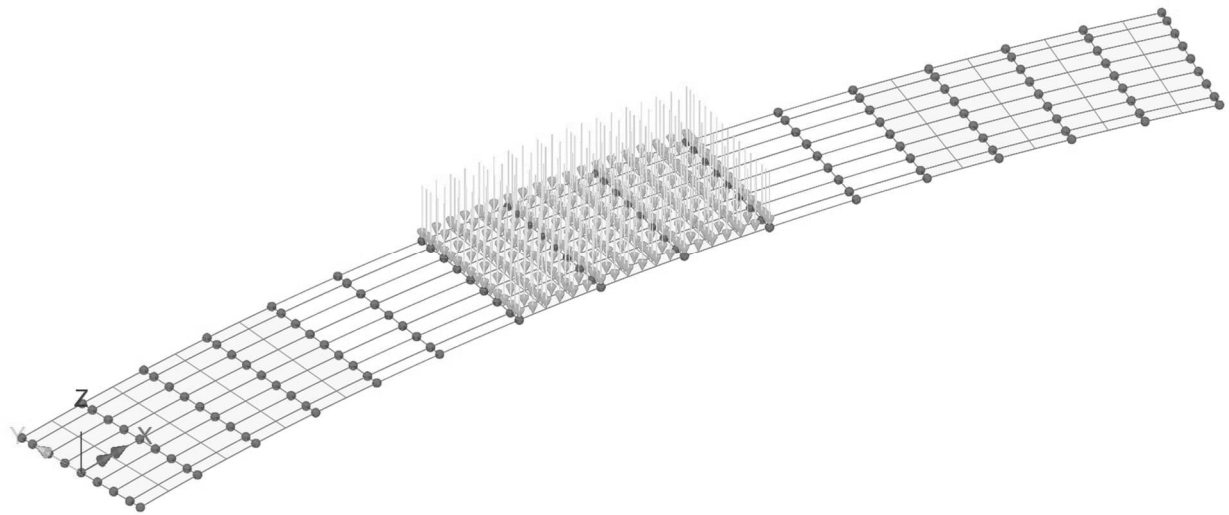
3.1.4 Concrete stage III (DEAD 2:3)

Load case : DEAD 2:3

Analysis: Analysis 3 (STAGE III)

Structural loading: Body force

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



	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:7
	Composite steel girder bridge	Date :	Created :

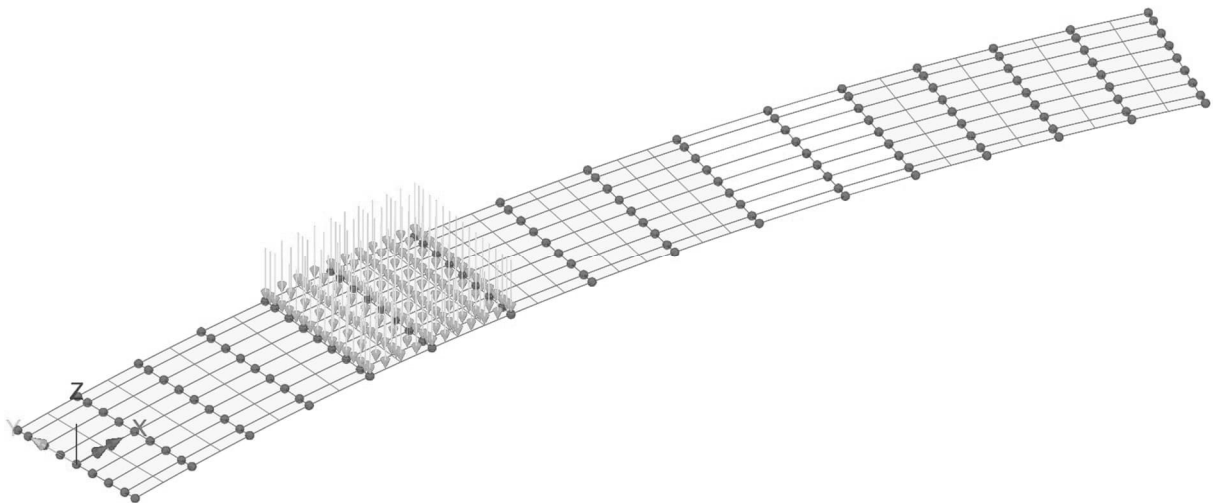
3.1.5 Concrete stage IV (DEAD 2:4)

Load case.: DEAD 2:4

Analysis: Analysis 4 (STAGE IV)

Structural loading: Body force

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



	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A3:8
		Date :	Created :

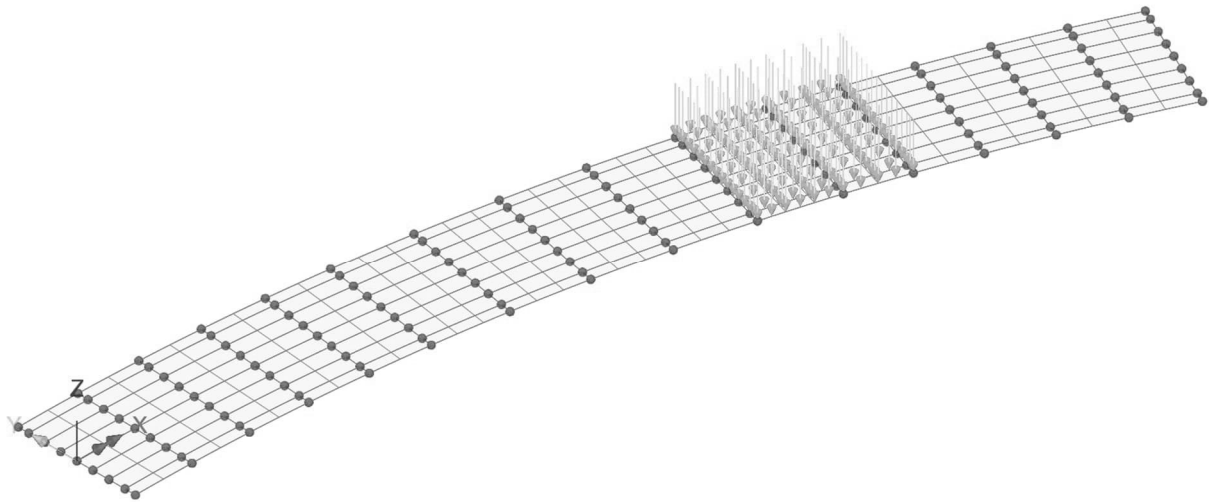
3.1.6 Concrete stage V (DEAD 2:5)

Load case : DEAD 2:5

Analysis: Analysis 5 (STAGE V)

Structural loading: Body force

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



	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:9
	Composite steel girder bridge	Date :	Created :

3.1.7 Edge beams including railing (DEAD 3)

Along each edge beam a line load is introduced. The load includes weight of edge beam and railing. The edge beam is assumed to be cast after completion stage I-V, thus analysis 6.

$$p_{railing} = 0.7 \frac{kN}{m} \quad : \text{weight railing}$$

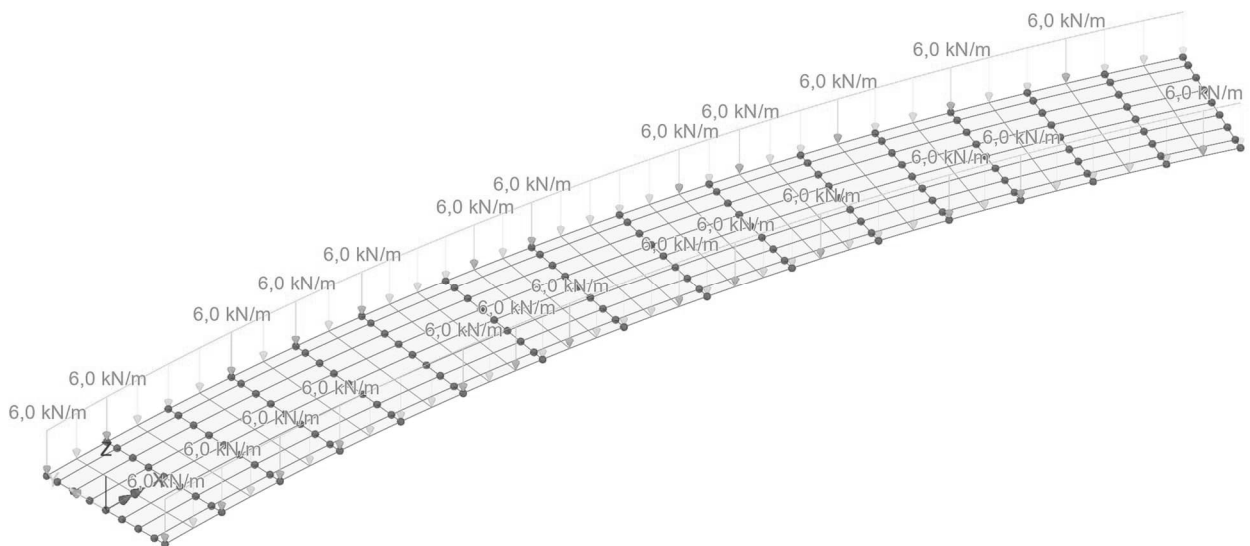
$$\rightarrow p_z = p_{railing} + p_{EB} = 0.7 \frac{kN}{m} + 0.40m \cdot 0.45m \cdot 25 \frac{kN}{m^3} = -6 \frac{kN}{m}$$

Load case : DEAD 3

Analysis: Analysis 6 (O:PERM)

Structural loading : Global distributed

Line load per unit length in Z direction: $-6 \frac{kN}{m}$



Overview 3D

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A3:10
		Date :	Created :

3.1.8 Load combination deadweight (DEAD)

Basic load combination DEAD:

Loadcase	Factor
DEAD 1:1	1.00
DEAD 2:1	1.00
DEAD 2:2	1.00
DEAD 2:3	1.00
DEAD 2:4	1.00
DEAD 2:5	1.00
DEAD 3	1.00

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:12
	Composite steel girder bridge	Date :	Created :

3.3 CREEP

Total creep is determined according to SS-EN 1992-1-1 §3.1.4 and TRVINFRA-00227 section 7.1.6.4 for RH 80% at time t_1 .

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

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

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

On safe side $\phi(t_1, t_0) = 2.0$ is applied.

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

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

Load cases	φ
Permanent	2.0
Variable excluding temperature	0
Temperature	0.3*

* = According to Swedish work practice

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

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

$$f_{shrinkage} = \frac{1}{1 + \varphi_{ef}} = \frac{1}{1 + 2.0} = 0.33$$

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

Note:

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

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:13
	Composite steel girder bridge	Date :	Created :

3.4 SHRINKAGE

Load applied to Analysis : *Analysis 6*

Total shrinkage according to SS-EN 1992-1-1 §3.1.4 and TRVINFRA-00227 section 7.1.6.4 for RH 80% at time t_1 .

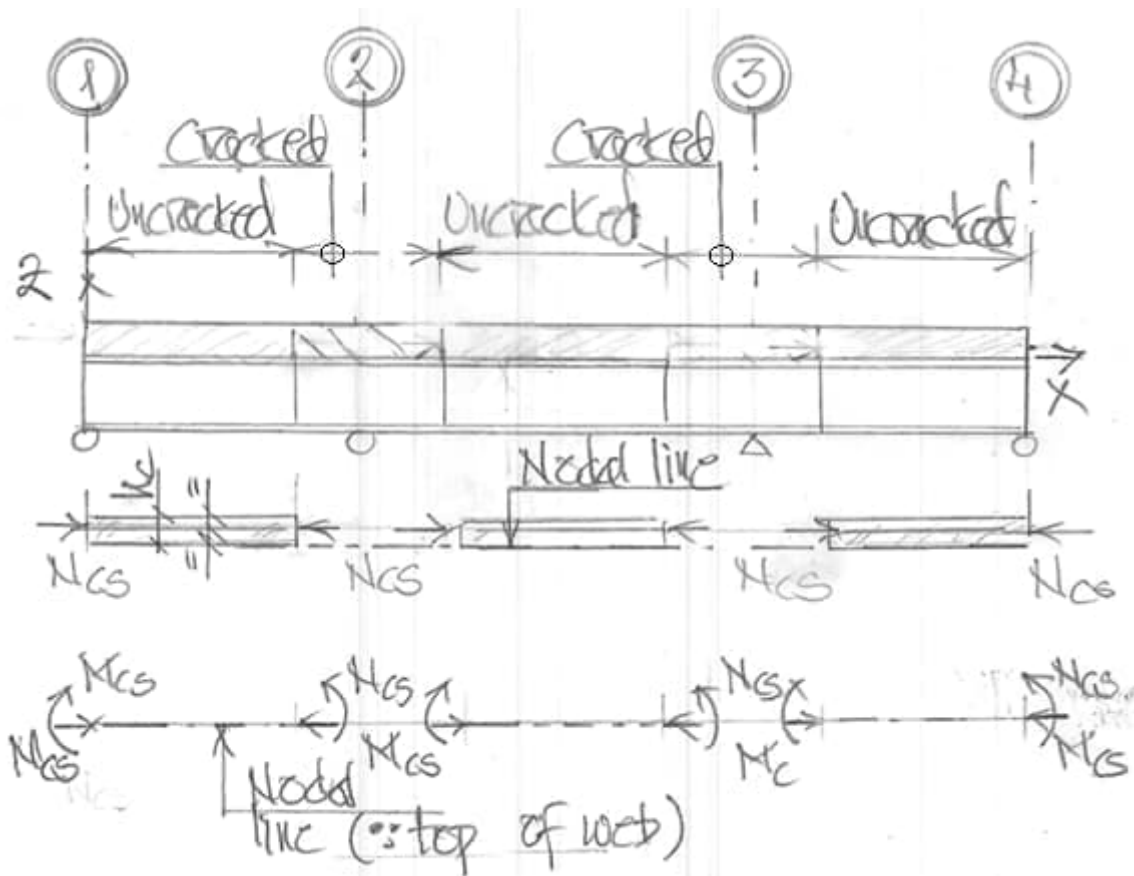
Determination of load effect from shrinkage should consider the reduced concrete stiffness from creep.

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

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

On safe side $\epsilon_{cs}(t_1) = 0.025\%$ is applied.

Shrinkage corresponds to movement due to an imaginary temperature load $\therefore T = -25^\circ\text{C}$ but a normal force (N_{cs}) is instead inserted at centre of deck at location of uncracked concrete. These force arises due to prevented movement by steel girder.



	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:14
	Composite steel girder bridge	Date :	Created :

Uncracked concrete (girder A & D):

$$N_{cs.1} = \varepsilon_{cs} \cdot \frac{E_{cm}}{1 + \psi_L \cdot \phi_{t1}} \cdot h_c \cdot b_c = 0.25 \cdot 10^{-3} \cdot \frac{34 \cdot 10^6 kPa}{1 + 0.55 \cdot 2.0} \cdot 0.20m \cdot 2.275m = 1842kN$$

$$M_{cs.1} = N_{cs.1} \cdot (t_c + 0.5h_c) = 1842kN \cdot (0.040 m + 0.5 \cdot 0.20m) = 258kNm$$

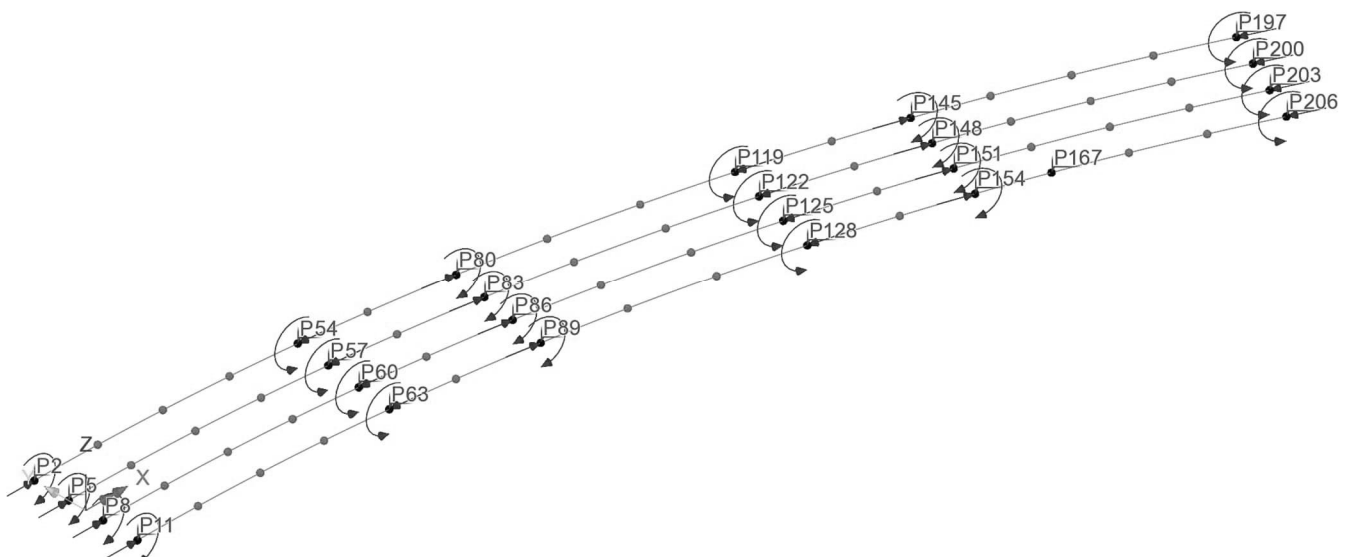
Uncracked concrete (girder B & C):

$$N_{cs.2} = \varepsilon_{cs} \cdot \frac{E_{cm}}{1 + \psi_L \cdot \phi_{t1}} \cdot h_c \cdot b_c = 0.25 \cdot 10^{-3} \cdot \frac{34 \cdot 10^6 kPa}{1 + 0.55 \cdot 2.0} \cdot 0.20m \cdot 2.750m = 2228kN$$

$$M_{cs.2} = N_{cs.2} \cdot (t_c + 0.5h_c) = 2228kN \cdot (0.040 m + 0.5 \cdot 0.20m) = 312kNm$$

Cracked concrete :

$$N_{cs} = 0kN$$



3D Overview

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A3:15
		Date :	Created :

Load : Ncs:1+

Analysis : Analysis 6 (O:PERM)

Structural loading : Internal beam point

Point load in X direction (P_x) : 1842 kN

Point moment around Y direction (M_y) : 258 kNm

Distance along local element (parametric) : 0

Load direction : Element local

Load position : About nodal line

Points: P2, P11, P80, P89, P145 & P154

Load case : SHRINKAGE

Load : Ncs:1-

Analysis : Analysis 6 (O:PERM)

Structural loading : Internal beam point

Point load in X direction (P_x) : -1842 kN

Point moment around Y direction (M_y) : -258 kNm

Distance along local element (parametric) : 1.0

Load direction : Element local

Load position : About nodal line

Points: P54, P63, P119, P128, P197 & P206

Load case : SHRINKAGE

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A3:16
		Date :	Created :

Load : Ncs:2+

Analysis : Analysis 6 (O:PERM)

Structural loading : Internal beam point

Point load in X direction (P_x) : 2228 kN

Point moment around Y direction (M_y) : 312 kNm

Distance along local element (parametric) : 0

Load direction : Element local

Load position : About nodal line

Points: P5, P8, P83, P86, P148 & P151

Load case : SHRINKAGE

Load : Ncs:2-

Analysis : Analysis 6 (O:PERM)

Structural loading : Internal beam point

Point load in X direction (P_x) : -2228 kN

Point moment around Y direction (M_y) : -312 kNm

Distance along local element (parametric) : 1.0

Load direction : Element local

Load position : About nodal line

Points: P57, P60, P122, P125, P200 & P203

Load case : SHRINKAGE

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:17
	Composite steel girder bridge	Date :	Created :

3.5 TEMPERATURE

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

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

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

Casting temperature, $T_{\text{mont}} = +10^{\circ} \text{C}$: EN 1991-1-5A.1(3)

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

Concrete slab \Rightarrow typ 2

Location : Skellefteå

$T_{\text{max}} = +34^{\circ}\text{C}$: TSFS chapter 8 sketch 8.1

$T_{\text{min}} = -42^{\circ}\text{C}$: TSFS chapter 8 sketch 8.2

Duration coefficients :

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

$$\psi_0 = 0.60$$

$$\psi_1 = 0.60$$

$$\psi_2 = 0.50$$

System superstructure:

Analysis 8 is used (see page A2:6).

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:18
	Composite steel girder bridge	Date :	Created :

3.5.1 Even temperature over entire bridge

Even temperature over entire bridge according to EN 1991-1-5 section 6.1.3.3. This temperature variation is seasonal and mainly gives rise to translation relative centre of movement located at support 3 where bearings are fixed.

Function according to SS-EN 1991-1-5 sketch 6.1 (bridge type 2):

$$T_e(T) = \text{linterp}\left[(-50 \ 0 \ 30 \ 50)^T \cdot ^\circ\text{C}, (-46 \ 5 \ 34 \ 54)^T \cdot ^\circ\text{C}, T\right]$$

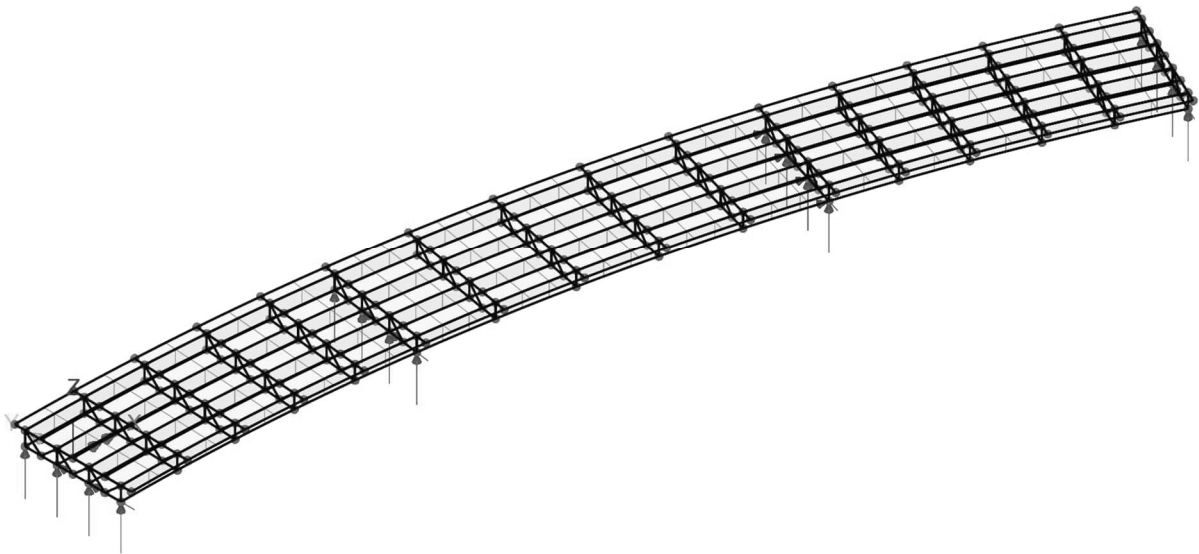
$$T_{e,\max} = T_e(T_{\max}) = 38 \text{ } ^\circ\text{C}$$

$$T_{e,\min} = T_e(T_{\min}) = -38 \text{ } ^\circ\text{C}$$

$$T^+ = T_{e,\max} - T_0 = +38^\circ\text{C} - 10^\circ\text{C} = +28^\circ\text{C}$$

$$T^- = T_{e,\min} - T_0 = -38^\circ\text{C} - 10^\circ\text{C} = -48^\circ\text{C}$$

Since temperature only gives rise to movement it is not added to this design report.



	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:19
	Composite steel girder bridge	Date :	Created :

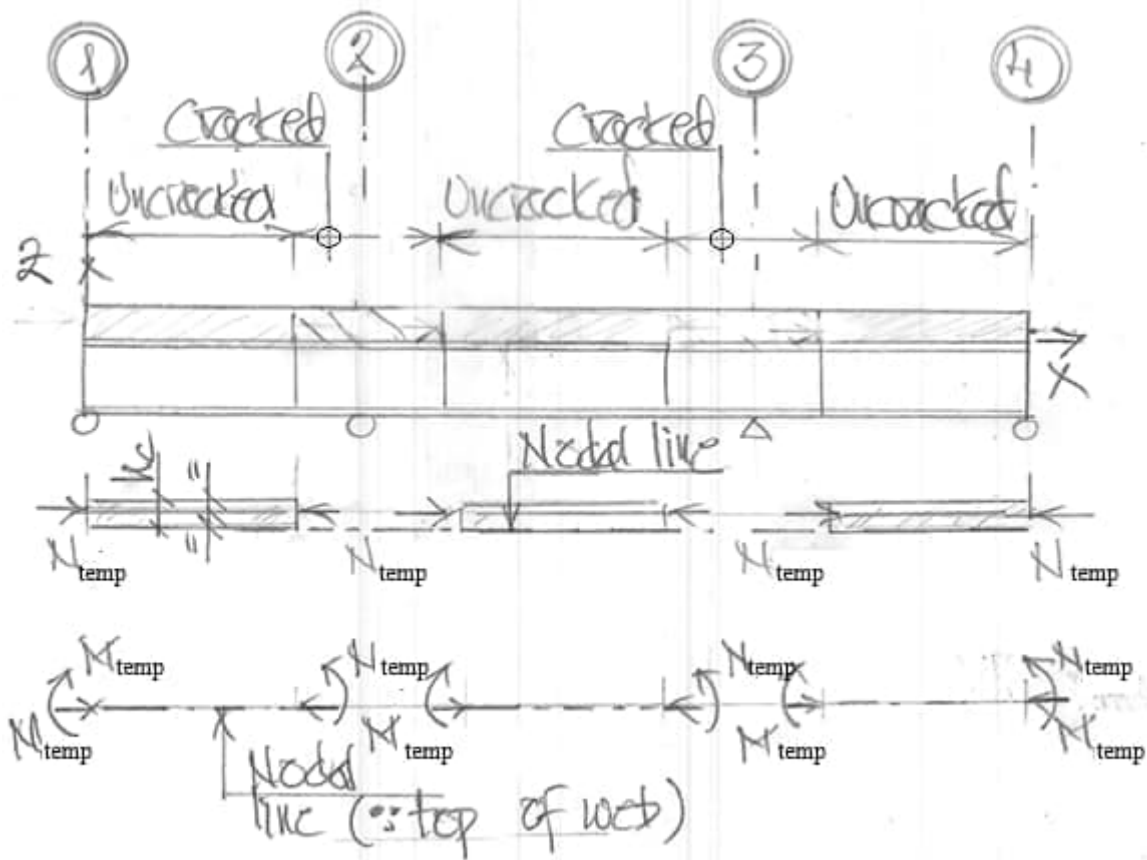
3.5.2 Uneven temperature between parts of cross section (UTEMP)

The linear temperature difference across the cross-section is determined according to the simplified procedure in EN 1991-1-5, clause 6.1.4.2 (method 2). Bridge superstructure type 2 (composite)

$\Delta T_{\max} = +10^{\circ}\text{C}$: top surface warmer

$\Delta T_{\min} = -10^{\circ}\text{C}$: bottom surface warmer

The effect of temperature is disregarded in cracked areas while it is considered in uncracked areas as seen in stech below.



	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:20
	Composite steel girder bridge	Date :	Created :

Uncracked concrete (girder A & D):

$$N_{temp.1} = \pm \alpha \cdot \frac{E_{cm}}{1 + \psi_L \cdot \phi_{t1}} \cdot \Delta T \cdot h_c \cdot b_c = \pm 10^{-5} \cdot \frac{34 \cdot 10^6 kPa}{1 + 1.0 \cdot 0.3} \cdot 10^\circ C \cdot 0.20m \cdot 2.275m \dots$$

$$= \pm 1190kN$$

$$M_{temp.1} = N_{temp.1} \cdot (t_c + 0.5h_c) = \pm 1190kN \cdot (0.040 m + 0.5 \cdot 0.20m) = \pm 167kNm$$

Uncracked concrete (girder B & C):

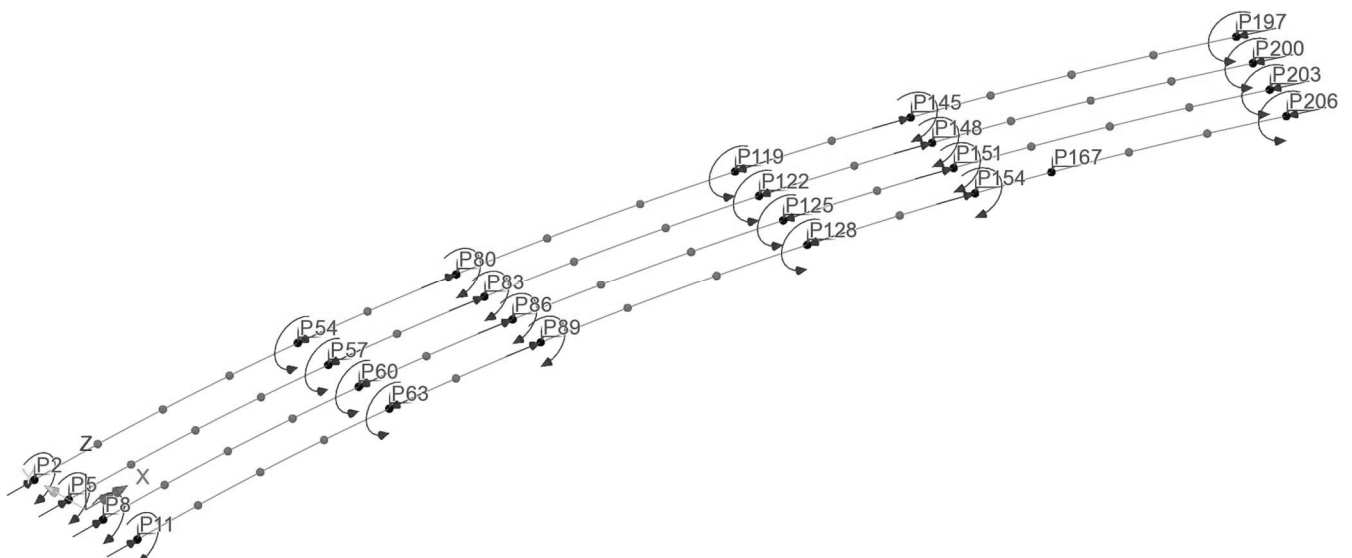
$$N_{temp.2} = \pm \alpha \cdot \frac{E_{cm}}{1 + \psi_L \cdot \phi_{t1}} \cdot \Delta T \cdot h_c \cdot b_c = \pm 10^{-5} \cdot \frac{34 \cdot 10^6 kPa}{1 + 1.0 \cdot 0.3} \cdot 10^\circ C \cdot 0.20m \cdot 2.750m \dots$$

$$= \pm 1438kN$$

$$M_{temp.2} = N_{temp.1} \cdot (t_c + 0.5h_c) = \pm 1438kN \cdot (0.040 m + 0.5 \cdot 0.20m) = \pm 201kNm$$

Cracked concrete :

$$N_{temp} = 0kN$$



3D Overview

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:21
	Composite steel girder bridge	Date :	Created :

Load : Ntemp:1+

Analysis : Analysis 8 (O:TEMP)

Structural loading : Internal beam point

Point load in X direction (P_x) : 1190 kN

Point moment around Y direction (M_y) : 167 kNm

Distance along local element (parametric) : 0

Load direction : Element local

Load position : About nodal line

Points: P2, P11, P80, P89, P145 & P154

Load case : UTEMP+

Load : Ntemp:1-

Analysis : Analysis 8 (O:TEMP)

Structural loading : Internal beam point

Point load in X direction (P_x) : -1190 kN

Point moment around Y direction (M_y) : -167 kNm

Distance along local element (parametric) : 1.0

Load direction : Element local

Load position : About nodal line

Points: P54, P63, P119, P128, P197 & P206

Load case : UTEMP+

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A3:22
		Date :	Created :

Load : Ntemp:2+

Analysis : Analysis 8 (O:TEMP)

Structural loading : Internal beam point

Point load in X direction (P_x) : 1438 kN

Point moment around Y direction (M_y) : 201 kNm

Distance along local element (parametric) : 0

Load direction : Element local

Load position : About nodal line

Points: P5, P8, P83, P86, P148 & P151

Load case : UTEMP+

Load : Ntemp:2-

Analysis : Analysis 8 (O:TEMP)

Structural loading : Internal beam point

Point load in X direction (P_x) : -1438 kN

Point moment around Y direction (M_y) : -201 kNm

Distance along local element (parametric) : 1.0

Load direction : Element local

Load position : About nodal line

Points: P57, P60, P122, P125, P200 & P203

Load case : UTEMP+

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A3:23
		Date :	Created :

3.5.3 Uneven temperature across the cross section

The linear temperature difference across the cross-section is determined according to EN 1991-1-5 § 6.1.4.1 for a deck thickness of 100 mm and type 2 (composite bridge).

$$k_{1,sur} = 1.00$$

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

$$\Delta T_{max} = +15^{\circ}C \cdot k_{1,sur} = +15^{\circ}C \quad : \text{top surface warmer}$$

$$\Delta T_{min} = -18^{\circ}C \cdot k_{2,sur} = -18^{\circ}C \quad : \text{bottom surface warmer}$$

Remark

The described uneven temperature across the cross-section is considered to produce a lower load effect than between parts of cross section (UTEMP). For this read the load is not added to design report.

3.5.4 Combination of uniform and uneven temperature

Combination is done according to SS-EN 1991-1-5 section 6.1.5.

For design, however, the safe side is applied, which gives the load combination as shown below.

3.5.4 Kombination av jämn och ojämn temperatur

Kombinering sker enligt SS-EN 1991-1-5 avsnitt 6.1.5.

During design, however $\omega_M = 1.0$ and $\omega_N = 1.0$ are applied on safe side.

Smart Load combination UTEMP:

Load case	Permanent factor	Variable factor
UTEMP+	0	+1.00
UTEMP-	0	-1.00

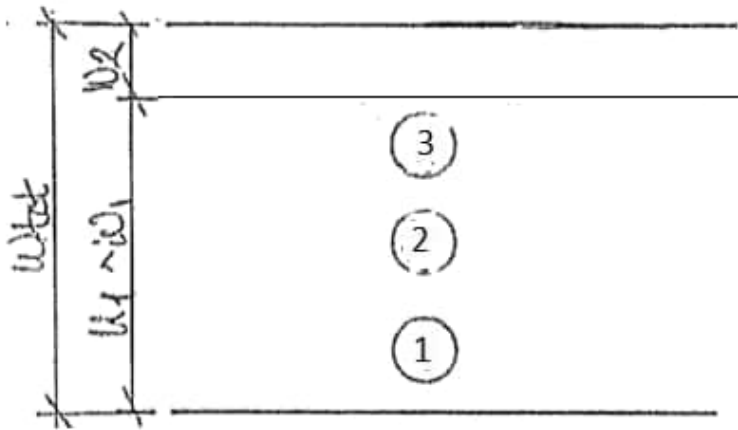
	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:24
	Composite steel girder bridge	Date :	Created :

3.6 TRAFFIC

Load applied to Analysis : Analysis 7 (O:VAR)

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

3.6.1 Traffic lane division



Total traffic width : $w_{tot} = 10.05 \text{ m}$

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

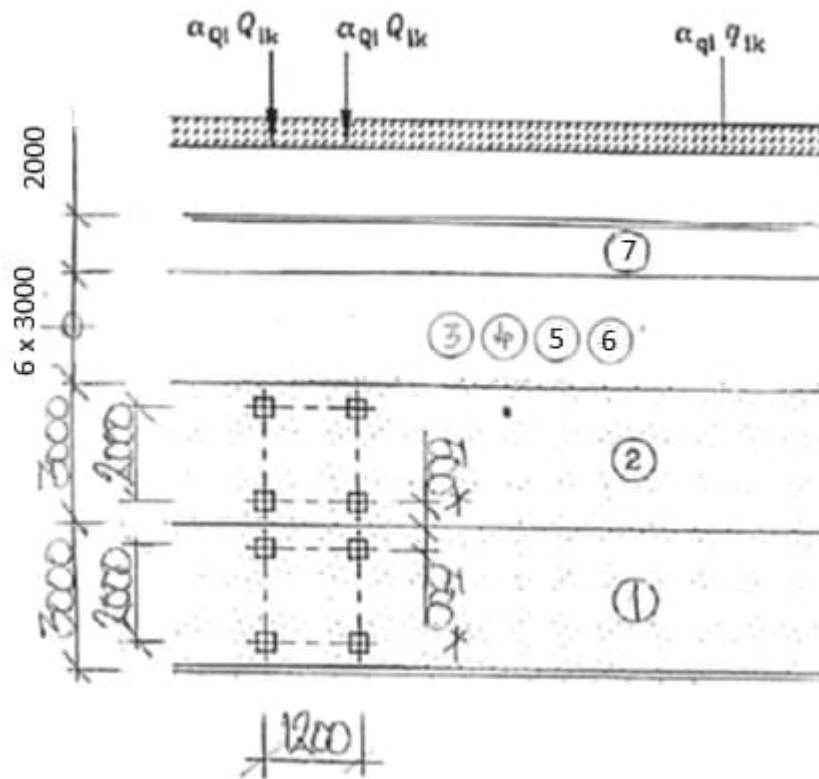
Full traffic width : $w_1 = 3.0\text{m}$

Remaining width : $w_2 = 1.05\text{m}$

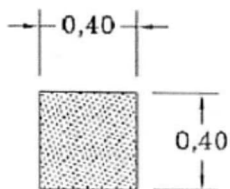
	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:25
	Composite steel girder bridge	Date :	Created :

3.6.2 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 Composite steel girder bridge	Status :	Page: A3:26
		Date :	Created :

Axle loads:

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

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

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

Surface loads:

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

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

Traffic lane	q_k	α_q	q'_k
1	9.0	0.8	7.2
2-3	2.5	1.0	2.5
-	kPa	-	kPa

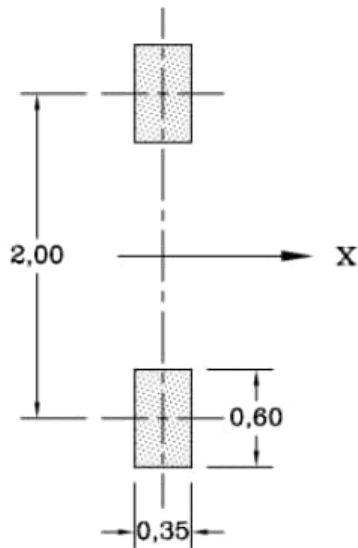
Remark

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

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:27
	Composite steel girder bridge	Date :	Created :

3.6.3 Load model 2 (LM 2)

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



$$\beta_{\varrho} = \alpha_{\varrho} = 0.90$$

: 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

Tire pressure

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

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:28
	Composite steel girder bridge	Date :	Created :

3.6.4 Vehicle Load Optimization (VLO)

3.6.4.1 Influence components

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

Inf1 – Beam & shells :

Direct Method Influence Envelope

Entity: ▾

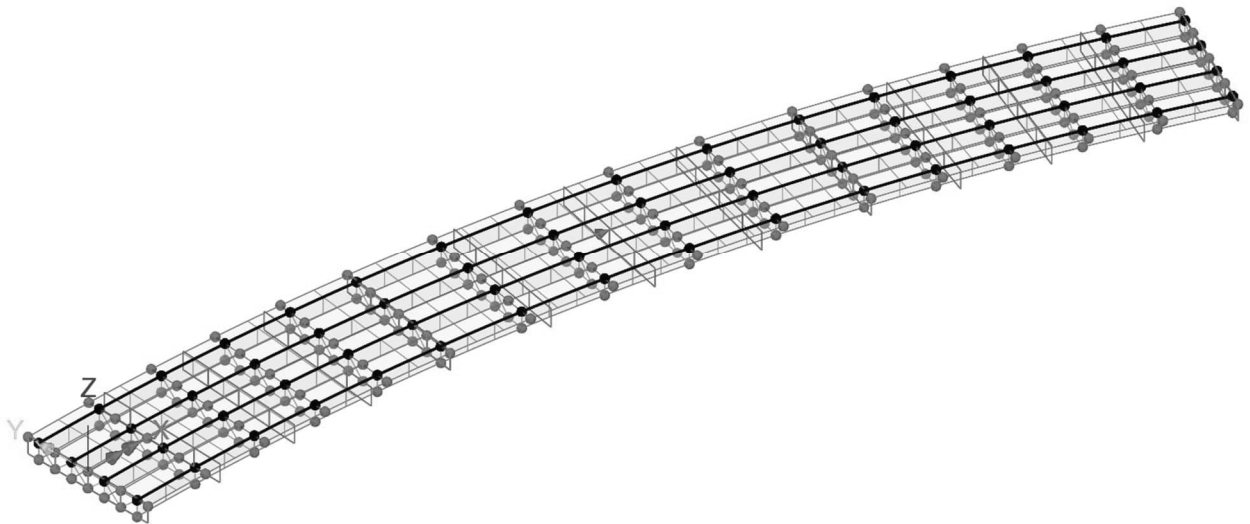
Direction: ▾ 0,0

Standard

- Fx
- Fy
- Fz
- Mx
- My
- Mz

Include coincident effects

Name: ▾ (1)



Overview 3D

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:29
	Composite steel girder bridge	Date :	Created :

Inf2 - Reactions :

Direct Method Influence Envelope

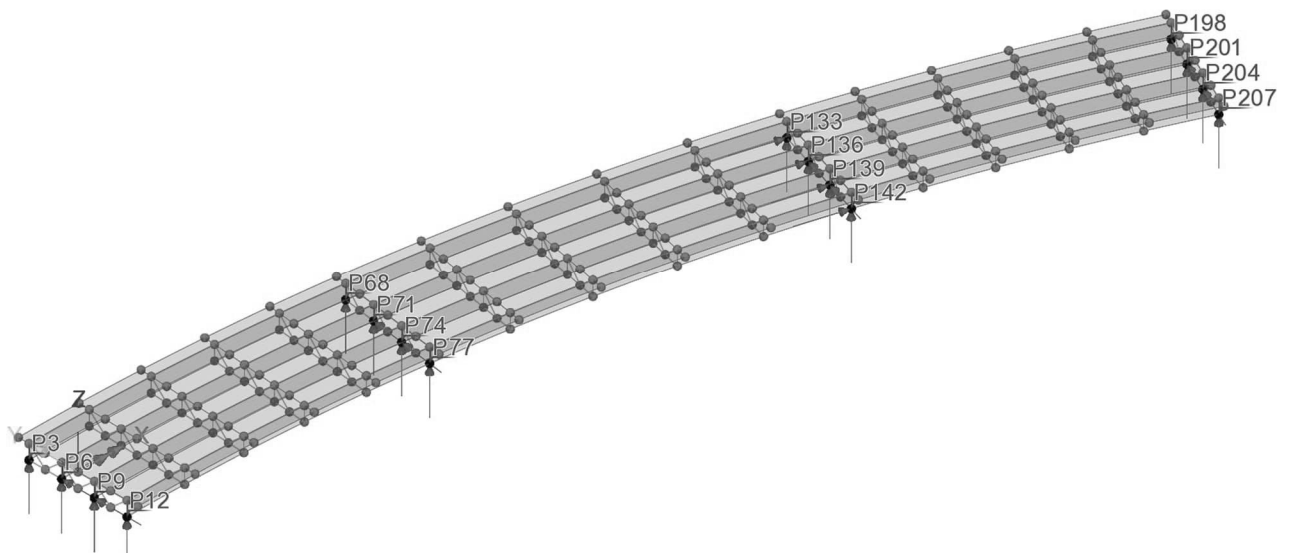
Entity: Reaction

Direction: Nodal 0,000

Standard
 FX
 FY
 FZ
 MX
 MY
 MZ

Include coincident effects

Name: Inf2 - Reaction (2)



Overview 3D

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A3:30
		Date :	Created :

Inf3 - Deck :

Direct Method Influence Envelope

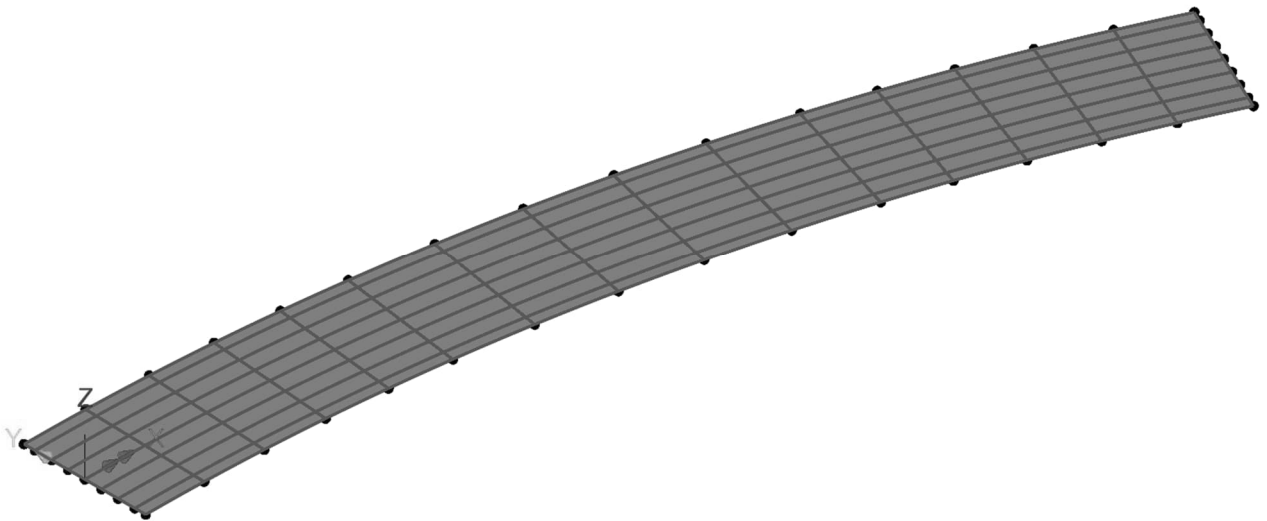
Entity: Force/Moment - Thick Shell

Direction: Element local 0,000

- Ny
- Nxy
- Mx
- My
- Mxy
- Sx
- Sy

Include coincident effects

Name: Inf3 - Deck (3)



Overview 3D

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A3:31
		Date :	Created :

3.6.4.2 Influence surface analysis

A influence surface is generated for every node grid. Below are the used settings.

Influence surfaces :

Search area: Superstructure

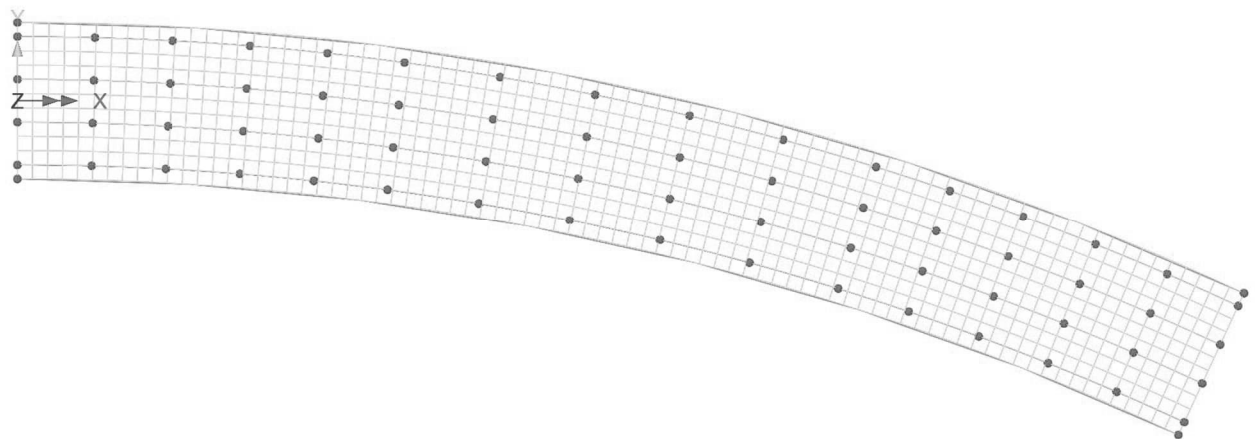
Definition type: Grid

Path: Centerline X

Transverse width: 10.05 m

Longitudinal spacing (ΔL_x) : 1.0 m

Transversal spacing: (ΔL_y) : 1.0 m



PLAN

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:32
	Composite steel girder bridge	Date :	Created :

3.6.4.3 Traffic load analysis (VLO)

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

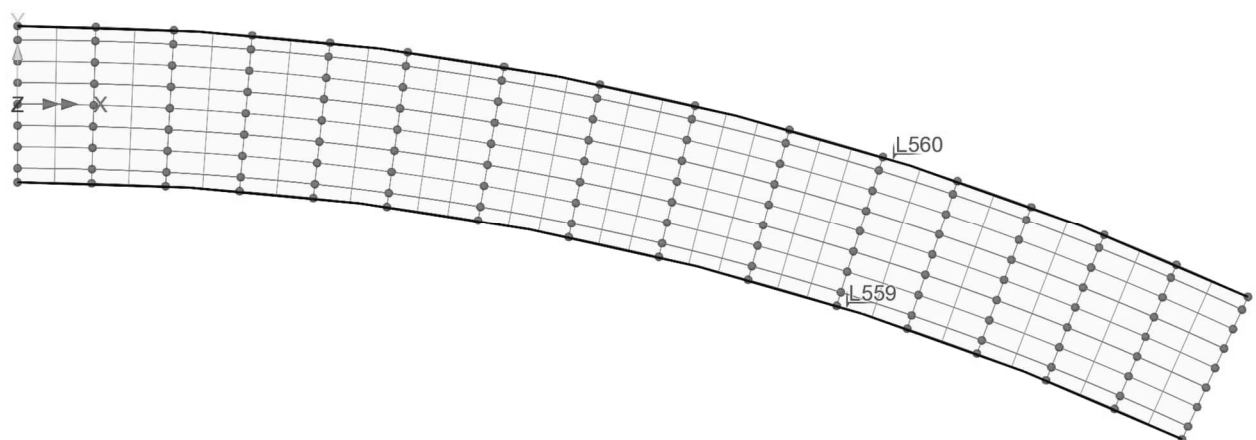
Vehicle longitudinal incremental movement: 0.25 m

Vehicle transverse incremental movement: 0.50 m

Vehicle direction: both

Definition of carriageway (kerbs): L559 & L560

Influence surfaces: Include all (positive & negative)



PLAN

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:33
	Composite steel girder bridge	Date :	Created :

3.6.4.4 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' dialog box. 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 is set to 'None'. Other options like 'Group 1b - LM2', 'Group 4 - LM4', and 'Group 5 - LM3' are unselected.

3.6.4.5 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' dialog box. 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 is set to 'None'. Other options like 'Group 1a - LM1', 'Group 4 - LM4', and 'Group 5 - LM3' are unselected.

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A3:34
		Date :	Created :

3.6.4.6 Combined traffic load (TRAFFIC)

There are a total 2 different traffic loads termed LM 1 and LM 2.

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

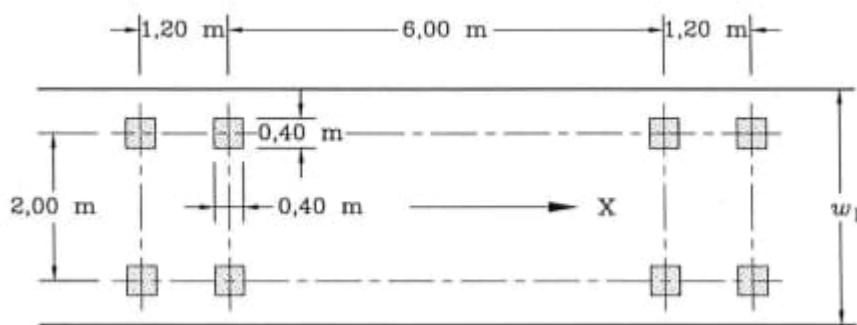
Envelope..TRAFFIC.:

Envelope
LM 1
LM 2

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:35
	Composite steel girder bridge	Date :	Created :

3.6.4.7 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.

The load definition:

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

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: A3:36
	Composite steel girder bridge	Date :	Created :

Point ✕

Analysis category

Arbitrary

Grid x
y

Untransformed load direction

X Y

Z Surface normal

XYZ global

XYZ transformable

Projection vector

Project in load direction

X component

Y component

Z component

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

Name ▼ | ▲ (new)

	Part A - CALCULATION ASSUMPTIONS Composite steel girder bridge	Status :	Page: A3:37
		Date :	Created :

3.7 LOAD COMBINATIONS

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

Fatigue Limit State:

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

Other Limit States:

For other limit states, section 6.4.3 of EN-1990 is applied.

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

Fatigue Limit State:

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

Other Limit States:

For other limit states, section 6.4.3 of EN-1990 is applied.

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:38
	Composite steel girder bridge	Date :	Created :

3.7.1 Ultimate Limit States (ULS)

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

STR: Verification of structural bearing capacity

GEO: Verification of geotechnical bearing capacity

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

Design Method D2 (Set B):

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

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

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

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

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

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

Design method 2 (set B) according to TSFS 2018:57 table 4.4 shall be applied for the structural capacity (STR; SK3).

A1 (construction loads)

All load factors are greater than set C.

A2 (geotechnical loads)

- Load coefficient earth pressure:

$$\psi \gamma_{ULS-A} = \gamma_d \cdot 1.35 \cdot \eta_{sup,G} = 1.0 \cdot 0.89 \cdot 1.35 \cdot 1.1 = 1.49 \quad \leftarrow \text{dimensioning}$$

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

- Load coefficient surcharge:

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

$$\psi \gamma_{ULS-B} = \gamma_d \cdot 1.50 = 1.0 \cdot 1.50 = 1.50 \quad \leftarrow \text{dimensioning}$$

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:39
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Design method D3 (set C) according to TSFS 2018:57 table 4.5 shall be applied for determining geotechnical bearing capacity (GEO; SK 2).

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

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

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

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

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

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

A1 (construction loads)

All load factors are less than set B.

A2 (geotechnical loads)

- Load coefficient earth pressure: $\psi \gamma_{jord} = \gamma_d \cdot 1.1 \cdot \eta_{sup.G} = 0.91 \cdot 1.1 \cdot 1.1 = 1.10$
- Load coefficient surcharge: $\psi \gamma_{\text{över}} = \gamma_d \cdot 1.40 = 0.91 \cdot 1.40 = 1.27$

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Simplified Design Method ULS:

To limit the number of load combinations, design method D2 (STR) is also applied for checking geotechnical bearing capacity (GEO). This is done by adjusting load coefficients associated with the geotechnical loads.

When applying the geotechnical loads, the earth pressure coefficient corresponding to D2 is applied.

Permanent loads:

Nr	Load		$\Psi\gamma_{ULS-A}$	$\Psi\gamma_{ULS-B}$
1	Dead weight	max	1.35	1.20
		min	1.00	1.00
2	Surfacing	max	1.45	1.35
		min	0.90	0.90
3	Filling	max	1.45	1.35
		min	0.90	0.90
4	Earth pressure	max	1.49	1.35
		min	0.90	0.90
5	Water pressure	max	1.35	1.10
		min	1.00	1.00
6	Support settlement	max	1.35	1.20
		min	1.00	1.00
7	Shrinkage	max	1.35	1.20
		min	1.00	1.00

Remark

Equation ULS-B is considered dominant; thus ULS-A is not considered.

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Variable loads:

Nr	Load	$\Psi\gamma_{ULS-A}$	$\Psi\gamma_{ULS-B}$
	Load model LM 1 :		
9	Tandem axel	1.13	1.03/1.50
10	Surface load	0.60	0.60/1.50
11	Braking force	0.84	0.84/1.13
12	Lateral force	0.84	0.84/1.13
13	Centrifugal force	0.84	0.84/1.13
	Load model LM 2 :		
14	Single axel	0	0/1.50
	Complementary load EG A/B :		
15	Vehicle EG A/B	1.13	1.13/1.50
16	Braking force	0.84	0.84/1.13
17	Lateral force	0.84	0.84/1.13
18	Centrifugal force	0.84	0.84/1.13
19	Temperature	0.90	0.90/1.50
	Wind load:		
20	Wind against bridge	0.45	0.45/1.50
21	Wind against vehicles	0.45	0.45/1.50
22	Surcharge	1.13	1.13/1.50

Remark

Equation ULS-B is considered dominant; thus ULS-A is not considered.

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Load combination smart ULS-PERM :

Load case	Permanent factor	Variable factor
DEAD	1.00	0.20
SURF	0.90	0.45
SHRINKAGE	0	1.20

Load combination smart ULS-VAR :

(Load cases to consider : 2 / Variable load cases : 1)

Load case	Permanent factor	Variable factor
TRAFIK	1.03	0.47
TEMP	0.90	0.60

Load combination smart ULS :

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

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3.14.2 Service limit state (SLS)

The service limit state is divided into 3 load combinations based on their duration. The load combinations are presented below.

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

Load Combination SLS:K according to EN 1990 equation 6.14b is presented below.

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

Load Combination SLS:F according to EN 1990 equation 6.15b is presented below.

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

Load Combination SLS:Q according to EN 1990 equation 6.16b is presented below.

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

When designing, load coefficients according to equations 6.14a, 6.15b, and 6.16b are applied.

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Permanent loads:

Nr	Load		$\Psi\gamma_{SLS-K}$	$\Psi\gamma_{SLS-F}$	$\Psi\gamma_{SLS-Q}$
1	Dead weight	max	1.00	1.00	1.00
		min	1.00	1.00	1.00
2	Surfacing	max	1.10	1.10	1.00
		min	0.90	0.90	1.00
3	Filling	max	1.10	1.10	1.00
		min	0.90	0.90	1.00
4	Earth pressure	max	1.35	1.35	1.35
		min	0.90	0.90	1.00
5	Water pressure	max	1.00	1.00	1,00
		min	1.00	1.00	1.00
6	Support settlement	max	1.00	1.00	1.00
		min	1.00	1.00	1.00
7	Shrinkage	max	1.00	1.00	1.00
		min	1.00	1.00	1.00

Variable loads:

Nr	Load	$\Psi\gamma_{SLS-K}$	$\Psi\gamma_{SLS-F}$	$\Psi\gamma_{SLS-Q}$
	Load model LM 1 :			
9	Tandem axel	0.75/1.00	0/0.75	0
10	Surface load	0.40/1.00	0/0.40	0
11	Braking force	0.56/0.75	0/0.56	0
12	Lateral force	0.56/0.75	0/0.56	0
13	Centrifugal force	0.56/0.75	0/0.56	0
	Load model LM 2 :			
14	Single axel	0.75/1.00	0/0.75	0
	Complementary load EG A/B :			
15	Vehicle EG A/B	0.75/1.00	0/0.75	0
16	Braking force	0.56/0.75	0/0.56	0
17	Lateral force	0.56/0.75	0/0.56	0
18	Centrifugal force	0.56/0.75	0/0.56	0
19	Temperature	0.60/1.00	0.50/0.60	0.50
	Wind load:			
20	Wind against bridge	0.30/1.00	0/0.30	0
21	Wind against vehicles	0.30/1.00	0/0.30	0
22	Surcharge	0.75/1.35	0/0.75	0

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Load combination smart SLS-PERM :

Load case	Permanent factor	Variable factor
DEAD	1.00	0
SURF	0.90	0.20
SHRINKAGE	0	1.00

Load combination smart SLS-K-VAR :

(Load cases to consider : 2 / Variable load cases : 1)

Load case	Permanent factor	Variable factor
TRAFIK	0.75	0.25
TEMP	0.60	0.40

Load combination smart SLS-F-VAR :

Load case	Permanent factor	Variable factor
TRAFIK	0	0.75
TEMP	0	0.60

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
DEAD	1.00	0
SURF	0.90	0.20
SHRINKAGE	0	1.00
TEMP	0	0.50

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3.14.4 Fatigue load combination

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

The risk of fatigue is checked using a simplified method, denoted as the λ -method.

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

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

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

Permanent loads:

Nr	Load		$\psi \gamma_{UTM}$
1	Dead weight	max	1.00
		min	1.00
2	Surfacing	max	1.10
		min	0.90
3	Filling	max	1.10
		min	0.90
4	Earth pressure	max	1.48
		min	0.90
5	Water pressure	max	1.00
		min	1.00
6	Support settlement	max	1.00
		min	1.00
7	Shrinkage	max	1.00
		min	1.00

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Variable loads:

Nr	Load	$\Psi\gamma_{UTM}$
	Load model LM 1 :	
9	Tandem axel	-
10	Surface load	-
11	Braking force	-
12	Lateral force	-
13	Centrifugal force	-
	Load model LM 2 :	
14	Single axel	-
	Complementary load EG A/B :	
15	Vehicle EG A/B	-
16	Braking force	-
17	Lateral force	-
18	Centrifugal force	-
19	Temperature	0.60
	Wind load:	
20	Wind against bridge	0.30
21	Wind against vehicles	0.30
22	Surcharge	1.01
23	UTM3	1.00

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Load combination smart FAT.:

Load case	Permanent factor	Variable factor
DEAD	1.00	0
SURF	1.00	0
SHRINKAGE	-	-
UTM 3	-	1.00
TEMP	-	-

Load cases DEAD, SURF and SHRINKAGE are not fatigue loads, thus load coefficient 1.0 is applied.

Load case TEMP is not a fatigue loads, thus load is not considered.