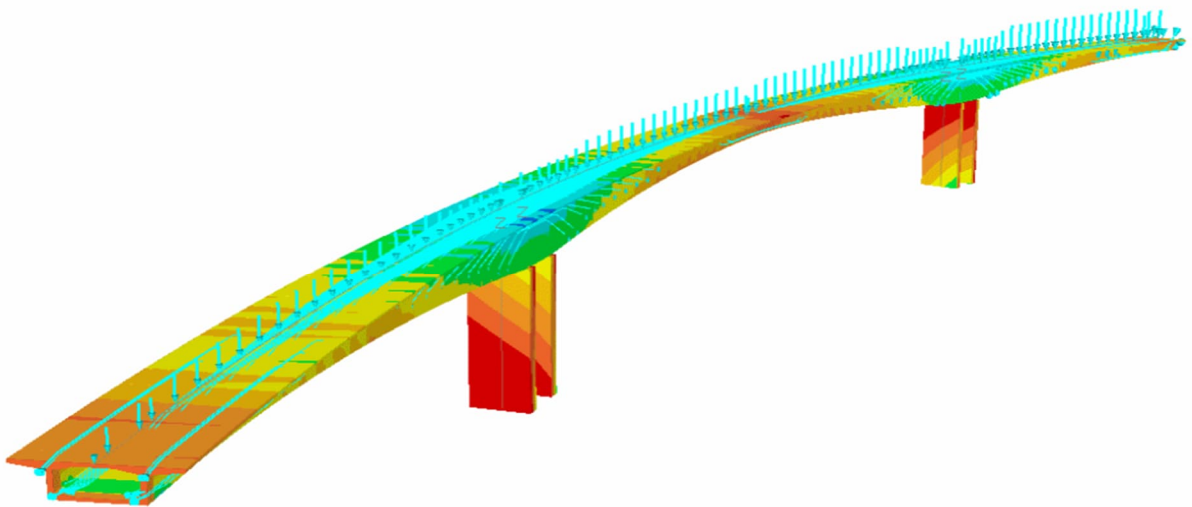


Pretensioned curved tapered box bridge (FCM)

Principle workflow:

1. **Analysis 1** is transient (day 0 → 120 years) considering prestress, dead weight, relaxation, creep and and shrinkage during alla stages of construction.
This analysis is transient with regard to material and active parts of structure during construction. In total there are 7 different construction stages.
2. **Analysis 2** is none transient and only linear. This is analysis is used for all loads acting after completed construction.
3. Results from **Analysis 1 & 2** are combined to ULS & SLS.



CONTENTS

Part	Pages	Date	Rev. Date	Rev.
A. CALCULATION ASSUMPTIONS				
1. GENERAL & MEASUREMENTS	1: 1 - 1: 15			
2. STATIC SYSTEM	2: 1 - 2: 44			
3. LOADS	3: 1 - 3: 82			

Appendix
1. System 001 : Input receipt

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A1:1
		Date :	Created :

1. GENERAL / MEASUREMENT

1.1	CONSTRUCTION TYPE	page 1:2
1.2	MEASUREMENTS	page 1:3-6
1.3	FOUNDATION	page 1:7
1.4	CODE OCH TENDER DOCUMENTS	page 1:7
1.5	TECHNICAL SERVICE LIFE	page 1:7
1.6	ENVIRONMENT	page 1:8
1.7	MATERIAL	page 1:8
1.8	GEOTECHNICAL CLASS	page 1:8
1.9	SAFETY CLASS	page 1:8
1.10	CONCRETE COVER AND CRACK CRITERIA	page 1:8-10
1.11	CONSTRUCTION CS	page 1:11-15

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A1:2
		Date :	Created :

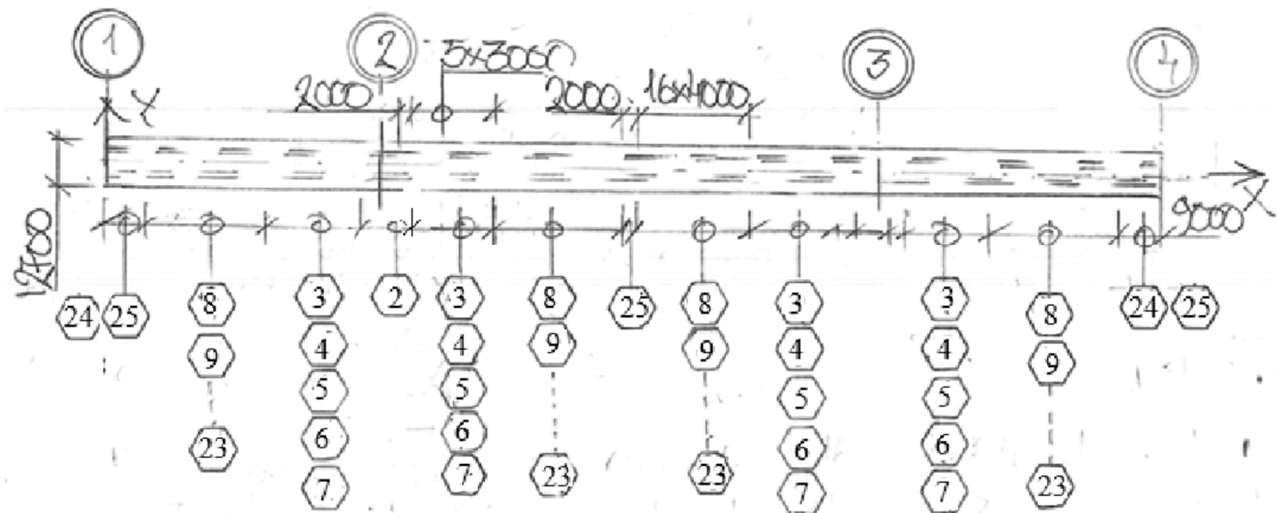
1.1 CONSTRUCTION TYPE

The bridge is a pretensioned single box bridge constructed using a free cantilever method (FCM).

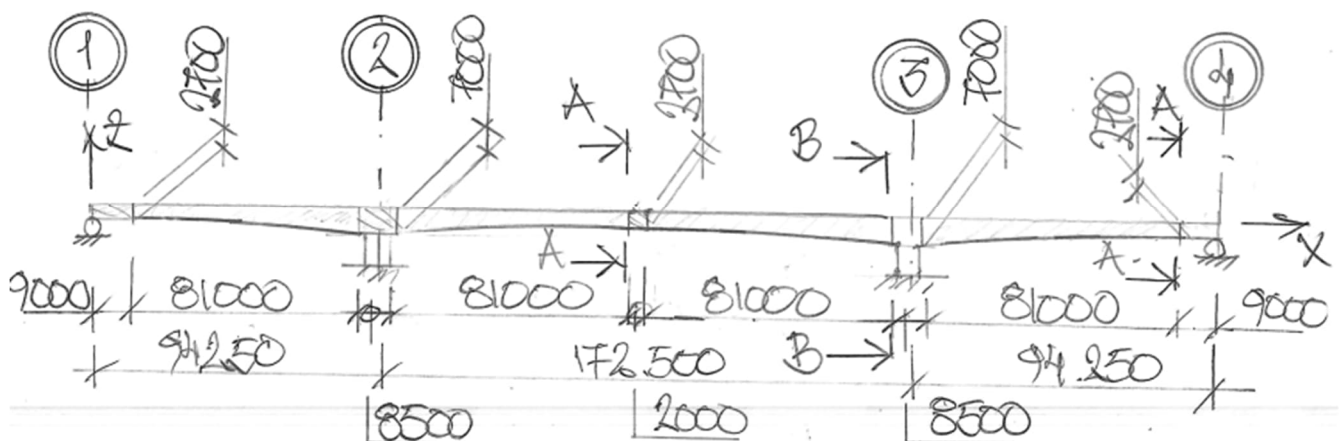
In total 52 casting stages ($\therefore = 2 \times \text{CS: } 1 \rightarrow 26$) is assumed.

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A1:3
		Date :	Created :

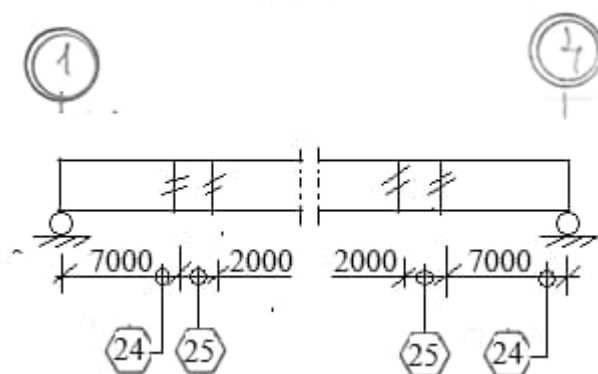
1.2 MEASUREMENT



PLAN



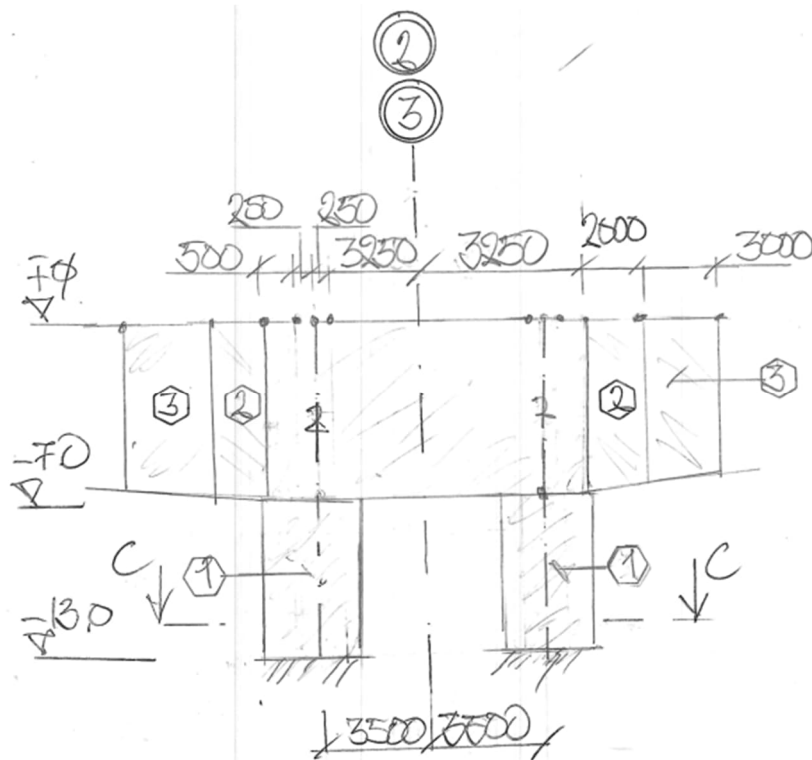
ELEVATION



DETAIL 1

Longitudinal view at support 1 & 4.

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A1:4
		Date :	Created :



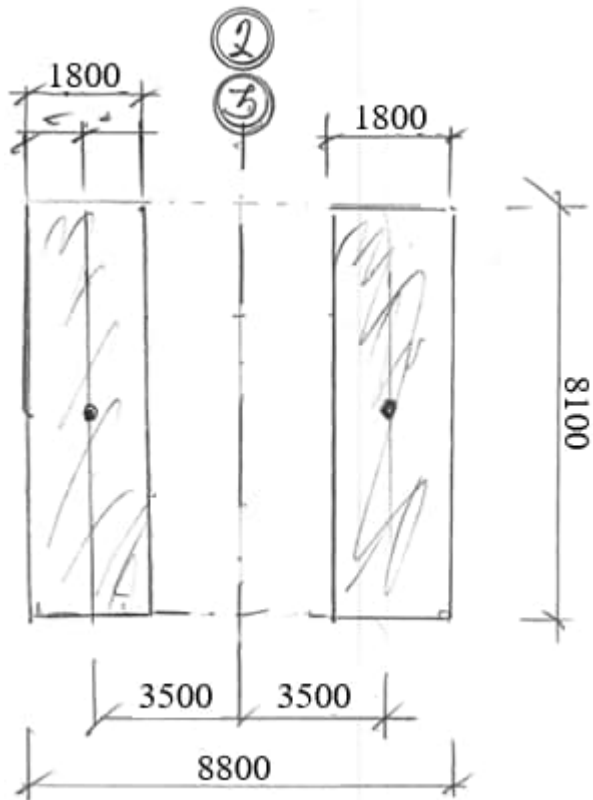
DETAIL 2

Longitudinal view at support 2 & 3.



SECTION A-A

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A1:6
		Date :	Created :



SECTION C-C

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A1:7
		Date :	Created :

1.3 FOUNDATION

Bottom slabs are assumed resting on rock.

1.4 CODE OCH TENDER DOCUMENTS

- "Bro och broliknande konstruktion allmänna krav" (TRVINFRA-00226 v5)
- "Bro och broliknande konstruktion byggande" (TRVINFRA-0027 v6)
- "TSFS 2018:57 med ändringar tom TSFS 2022:50"
- "AMA Anläggning 23"
- "TRV ändringar och tillägg till AMA 23" (TDOK 2023:0125 v3)
- "Geokonstruktion dimensionering och utformning" (TRVINFRA-00230 v2)
- Document SS-EN 1990 to SS-EN 1999, see TRVINFRA section A.1.2.3.2

1.5 TECHNICAL SERVICE LIFE

Technical life span 120 years (L100).

1.6 ENVIRONMENT

Road traffic environment ("vägmiljö") is assumed for the overlying traffic road since salt is used at winter, see TB section B1.

1.7 MATERIAL

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

Reinforcement : B500B

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

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

Surfacing : See document RKFM

Pretension: VSL system or equivalent

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A1:8
		Date :	Created :

1.8 GEOTECHNICAL CLASS

Geotechnical class GK2

1.9 SAFETY CLASS

Geotechnical resistance: SK 2

Bridge structure : SK 3

1.10 CONCRETE COVER AND CRACK CRITERIA

Class identification bridge components :

Bridge components	Exposure class ^{1.)}	Life spann	max v _{ctekv} ^{2.)}	ζ ^{3.)}
Substructure incl. linkplate:				
▫ Wingwall towards filling	XD1/XF4	L100	0.45	1.5
▫ Wingwall from filling	XD1/XF4	L100	0.45	1.5
▫ Abutement below ground	XC2/XF3	L100	0.50	1.0
▫ Abutement in air	XC4/XF3	L100	0.50	1.2
▫ Bottom slab in general	XC2/XF3	L100	0.50	1.0
▫ Bottom slab underside	XC2/XF3	L100	0.50	1.0
▫ Link slab in general	XD3/XF2	L100	0.40	1.8
▫ Link slab underside	XD3/XF2	L100	0.40	1.8
Superstructure:				
▫ Edge beam	XD3/XF4	L100	0.40	1.8
▫ Bridge deck	XD1/XF4	L100	0.40	1.5
▫ End shield towards filling	XD1/XF4	L100	0.40	1.5
▫ End shield from filling	XC2/XF3	L100	0.50	1.0

Footnote:

1.) TRVINFRA-00227 section 5.3.2.3

2.) TSFS table 12.1

3.) TSFS table 12.3

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A1:9
		Date :	Created :

Design parameters low corrosion sensitive reinforcement (rebars):

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

$c_{min,b}$: minimum cover with regard to adhesion requirements

Δc_{dev} : execution tolerance

$c_{min} = \max(c_{min,b}; c_{min,dur}; 10mm)$: SS-EN 1992-1-1 eq. 4.2

$c_{nom} = c_{min} + \Delta c_{dev}$: SS-EN 1992-1-1 eq. 4.1, noted as BM on the drawing

Construction part	$c_{min,dur}$ ^{1.)}	$c_{min,b}$ ^{2.)}	c_{min}	c_{dev} ^{3.)}	c_{nom}	$w_{k,till}$ ^{4.)}
Substructure incl. linkplate:						
▫ Wingwall towards filling	30	20	30	10	40	0.20
▫ Wingwall from filling	30	20	30	10	40	0.20
▫ Abutement below ground	20	20	20	10	30	0.40
▫ Abutement in air	25	20	25	10	35	0.30
▫ Bottom slab in general	20	20	20	10	30	0.40
▫ Bottom slab underside	20	20	20	10	30	0.40
▫ Link slab in general	45	20	45	10	55	0.15
▫ Link slab underside	45	20	45	10	60 ^{5.)}	0.15
Superstructure:						
▫ Edge beam	45	20	45	10	55	0.15
▫ Bridge deck	25	20	25	10	35	0.20
▫ End shield towards filling	25	20	25	10	35	0.20
▫ End shield from filling	25	20	25	10	35	0.40

Footnotes:

1.) TSFS table 12.1

2.) SS-EN 1992-1-1 section 4.4.1.2 table 4.2

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

4.) TSFS table 12.2

5.) TSFS chapter 12 paragraph 3§ $k_1 = c_{min} + 15$ mm when casting against building foil.

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A1:10
		Date :	Created :

Design parameters high corrosion sensitive reinforcement (pretension):

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

$c_{min,b}$: minimum cover with regard to adhesion requirements

Δc_{dev} : execution tolerance

$c_{min} = \max(c_{min,b}; c_{min,dur}; 10mm)$: SS-EN 1992-1-1 eq. 4.2

$c_{nom} = c_{min} + \Delta c_{dev}$: SS-EN 1992-1-1 eq. 4.1, noted as BM on the drawing

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

Footnotes:

1.) TSFS table 12.1

2.) SS-EN 1992-1-1 section 4.4.1.2 (3) specifies pretension tube $\phi 90$

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

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

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A1:11
		Date :	Created :

1.11 CONSTRUCTION STAGES

The construction of bridge is performed using free cantilever method (FCM).

A total of 7 stages with construction time seen below.

It is assumed that concrete is activated structurally after 60 days for piers (∴ CS 1), 15 days after upper part of piers (∴ CS 2) and 5 days for remining construction stages (∴ CS 3 → CS 26).

Construction time is 60 days for piers (∴ CS 1), 10 days after upper part of piers (∴ CS 2) and 6 days for remining construction stages (∴ CS 3 → CS 26).



CS 1 (∴ Costruction Stage 1)

Time: 0 day → 60 day



C3 2

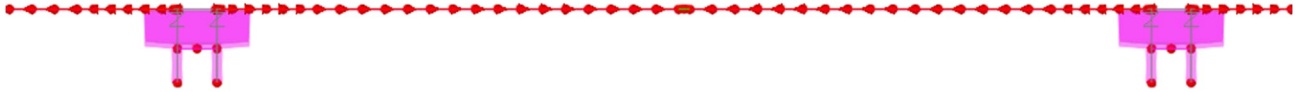
Time: 61 day → 66 day



CS 3

Time: 67 day → 72 day

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A1:12
		Date :	Created :



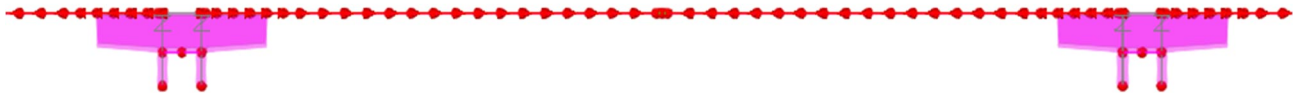
CS 4

Time: 73 day → 78 day



CS 5

Time: 79 day → 84 day



CS 6

Time: 85 day → 90 day



CS 7

Time: 91 day → 96 day



CS 8

Time: 97 day → 102 day

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A1:13
		Date :	Created :



CS 9

Time: 103 day → 108 day



CS 10

Time: 109 day → 115 day



CS 11

Time: 116 day → 120 day



CS 12

Time: 121 day → 126 day



CS 13

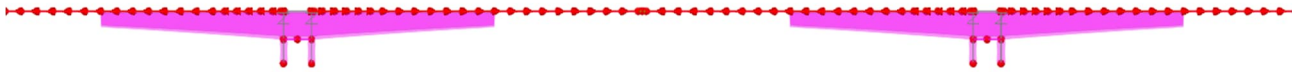
Time: 127 day → 132 day



CS 14

Time: 133 day → 138 day

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A1:14
		Date :	Created :



CS 15

Time: 139 day → 144 day



CS 16

Time: 145 day → 150 day



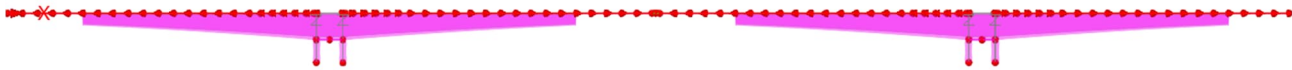
CS 17

Time: 151 day → 156 day



CS 18

Time: 157 day → 162 day



CS 19

Time: 163 day → 168 day



CS 20

Time: 169 day → 174 day



CS 21

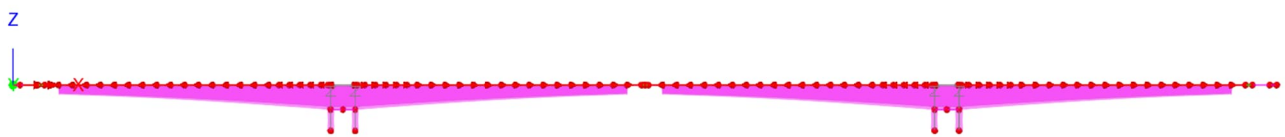
Time: 175 day → 180 day

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A1:15
		Date :	Created :



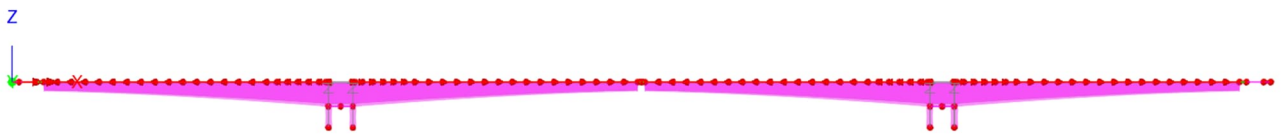
CS 22

Time: 181 day → 186 day



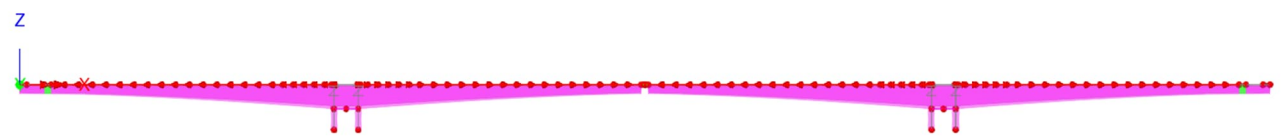
CS 23

Time: 187 day → 192 day



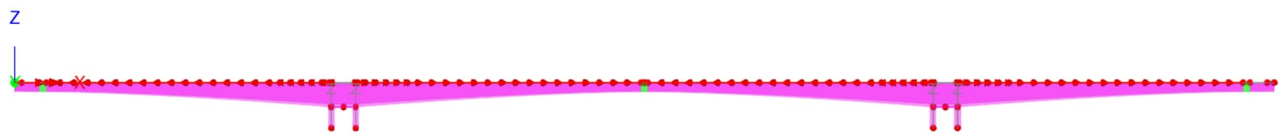
CS 24

Time: 193 day → 194 day



CS 25

Time: 195 day → 196 day



CS 26

Time: 197 day → 206 day

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:1
		Date :	Created :

2. SYSTEM ANALYSIS

2.1	GENERAL	page 2:2-7
2.2	SKETCH SYSTEM ANALYSIS	page 2:8-13
2.3	CROSS SECTION PROPERTIES	page 2:14-29
2.4	MATERIAL	page 2:30
2.5	BOUNDARY CONDITIONS	page 2:31-33
2.6	MESH	page 2:34-37
2.7	SEARCH AREA	page 2:38
2.8	STRUCTURE ACTIVATION	page 2:39-44

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:2
		Date :	Created :

2.1 GENERAL

The pretensioned single box bridge constructed using a free cantilever method (FCM). The construction during 52 stages.

Entire structure is modelled with 3D-beam elements (BM21) a location of nodal lines.

Entire structure is modelled using isotropic material.

In system analysis gross cross section may be used for longitudinal beams in superstructure, see SS-EN 1992-1-1 section 5.3.2.1 (4).

The effect of creep and shrinkage is considered by applying times of construction stages.

During the 25 stages of construction a method of activation is applied.

In the model the static effect of edge beam is not considered according to technical practice since edge beams generally need replacement.

When determining the long-term effect of creep, shrinkage and relaxation 120 years is considered ($\therefore$ 43 800 days).

Superstructure has varying height from $H = 2.70$ m ($\therefore$ section 1) to $H = 7.00$ m ($\therefore$ section 2) long a distance of 81 m. This creates difficulty when interpolating torsional rigidity (J) since does not vary as H . To circumvent this issue no interpolation is made over a longer distance than 4 m. This results in several lines (21 lines) along the total distance of 81 m instead of only one.

When construction using free cantilever method (FCM) where end span ($L = 94.25$ m) is longer than 50 % of midspan length ($L = 172.5$ m) there is a need to introduce temporary supports at near end support at casting stage 24.

Connection between piers superstructure is rigid. Constraints are modelled using rigid link (joint element JSH4). Since nodal line of superstructure is located at top of deck a fictive “hinge” is added to rigid link at level of centroid.

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:3
		Date :	Created :

Several different static models are applied depending on casting stage. The base analysis is the static linear model with entire structure active (= Analysis 2). During the casting stages part of superstructure are deactivated as seen in table below.

Stage	LC CS 1	LC CS 2	LC CS 3	LC CS 4	LC CS 5	LC CS 6	LC CS 7	Analysis
1	Active	Active	Active	Active	Active	Active	Active	1
2	Deactive	Active	Active	Active	Active	Active	Active	1
3	Deactive	Deactive	Active	Active	Active	Active	Active	1
4	Deactive	Deactive	Deactive	Active	Active	Active	Active	1
5	Deactive	Deactive	Deactive	Deactive	Active	Active	Active	1
6	Deactive	Deactive	Deactive	Deactive	Deactive	Active	Active	1
7	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1
8	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1
9	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1
10	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1
11	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1
12	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1
13	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1
14	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1
15	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1
16	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1
17	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1
18	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1
19	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1
20	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1
21	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1
22	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1
23	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1
24	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1
25	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1

Table of construction stages

LC CS 1→ CS 7.

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:4
		Date :	Created :

Stage	LC CS 8	LC CS 9	LC CS 10	LC CS 11	LC CS 12	LC CS 13	LC CS 14	Analysis
1	Active	Active	Active	Active	Active	Active	Active	1
2	Active	Active	Active	Active	Active	Active	Active	1
3	Active	Active	Active	Active	Active	Active	Active	1
4	Active	Active	Active	Active	Active	Active	Active	1
5	Active	Active	Active	Active	Active	Active	Active	1
6	Active	Active	Active	Active	Active	Active	Active	1
7	Active	Active	Active	Active	Active	Active	Active	1
8	Active	Active	Active	Active	Active	Active	Active	1
9	Deactive	Active	Active	Active	Active	Active	Active	1
10	Deactive	Deactive	Active	Active	Active	Active	Active	1
11	Deactive	Deactive	Deactive	Active	Active	Active	Active	1
12	Deactive	Deactive	Deactive	Deactive	Active	Active	Active	1
13	Deactive	Deactive	Deactive	Deactive	Deactive	Active	Active	1
14	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Active	1
15	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1
16	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1
17	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1
18	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1
19	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1
20	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1
21	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1
22	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1
23	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1
24	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1
25	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1

Table of construction stages

LC CS 8→ CS 14.

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:5
		Date :	Created :

Stage	LC CS 16	LC CS 9	LC CS 17	LC CS 18	LC CS 19	LC CS 20	LC CS 21	Analysis
1	Active	Active	Active	Active	Active	Active	Active	1
2	Active	Active	Active	Active	Active	Active	Active	1
3	Active	Active	Active	Active	Active	Active	Active	1
4	Active	Active	Active	Active	Active	Active	Active	1
5	Active	Active	Active	Active	Active	Active	Active	1
6	Active	Active	Active	Active	Active	Active	Active	1
7	Active	Active	Active	Active	Active	Active	Active	1
8	Active	Active	Active	Active	Active	Active	Active	1
9	Active	Active	Active	Active	Active	Active	Active	1
10	Active	Active	Active	Active	Active	Active	Active	1
11	Active	Active	Active	Active	Active	Active	Active	1
12	Active	Active	Active	Active	Active	Active	Active	1
13	Active	Active	Active	Active	Active	Active	Active	1
14	Active	Active	Active	Active	Active	Active	Active	1
15	Active	Active	Active	Active	Active	Active	Active	1
16	Active	Active	Active	Active	Active	Active	Active	1
17	Deactive	Active	Active	Active	Active	Active	Active	1
18	Deactive	Deactive	Active	Active	Active	Active	Active	1
19	Deactive	Deactive	Deactive	Active	Active	Active	Active	1
20	Deactive	Deactive	Deactive	Deactive	Active	Active	Active	1
21	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Active	1
22	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1
23	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1
24	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1
25	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	Deactive	1

Table of construction stages

LC CS 15→ CS 21.

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:6
		Date :	Created :

Stage	LC CS 22	LC CS 23	LC CS 24	LC CS 25	LC CS 26	LC Longterm	Analysis
1	Active	Active	Active	Active	Active	Active	1
2	Active	Active	Active	Active	Active	Active	1
3	Active	Active	Active	Active	Active	Active	1
4	Active	Active	Active	Active	Active	Active	1
5	Active	Active	Active	Active	Active	Active	1
6	Active	Active	Active	Active	Active	Active	1
7	Active	Active	Active	Active	Active	Active	1
8	Active	Active	Active	Active	Active	Active	1
9	Active	Active	Active	Active	Active	Active	1
10	Active	Active	Active	Active	Active	Active	1
11	Active	Active	Active	Active	Active	Active	1
12	Active	Active	Active	Active	Active	Active	1
13	Active	Active	Active	Active	Active	Active	1
14	Active	Active	Active	Active	Active	Active	1
15	Active	Active	Active	Active	Active	Active	1
16	Active	Active	Active	Active	Active	Active	1
17	Active	Active	Active	Active	Active	Active	1
18	Active	Active	Active	Active	Active	Active	1
19	Active	Active	Active	Active	Active	Active	1
20	Active	Active	Active	Active	Active	Active	1
21	Active	Active	Active	Active	Active	Active	1
22	Active	Active	Active	Active	Active	Active	1
23	Deactive	Active	Active	Active	Active	Active	1
24	Deactive	Deactive	Active	Active	Active	Active	1
25	Deactive	Deactive	Deactive	Active	Active	Active	1

Table of construction stages

LC CS 22→ CS 25 (& LC Longterm).

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:7
		Date :	Created :

Stage	Surfacing	Variable loads	Analysis
1	Active	Active	2*
2	Active	Active	2*
3	Active	Active	2*
4	Active	Active	2*
5	Active	Active	2*
6	Active	Active	2*
7	Active	Active	2*
8	Active	Active	2*
9	Active	Active	2*
10	Active	Active	2*
11	Active	Active	2*
12	Active	Active	2*
13	Active	Active	2*
14	Active	Active	2*
15	Active	Active	2*
16	Active	Active	2*
17	Active	Active	2*
18	Active	Active	2*
19	Active	Active	2*
20	Active	Active	2*
21	Active	Active	2*
22	Active	Active	2*
23	Active	Active	2*
24	Active	Active	2*
25	Active	Active	2*

Table of operation stages
(* = Base analysis)

Appendices:

Appendix	Name
1	Input receipt
2	Results reactions
3	Results piers
4	Results superstructure

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:8
		Date :	Created :

2.2 SKETCH SYSTEM ANALYSIS

2.2.1 Geometry

To describe geometry first POINTS are defined.

Beam elements are defined by applying attributes to LINES.

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

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

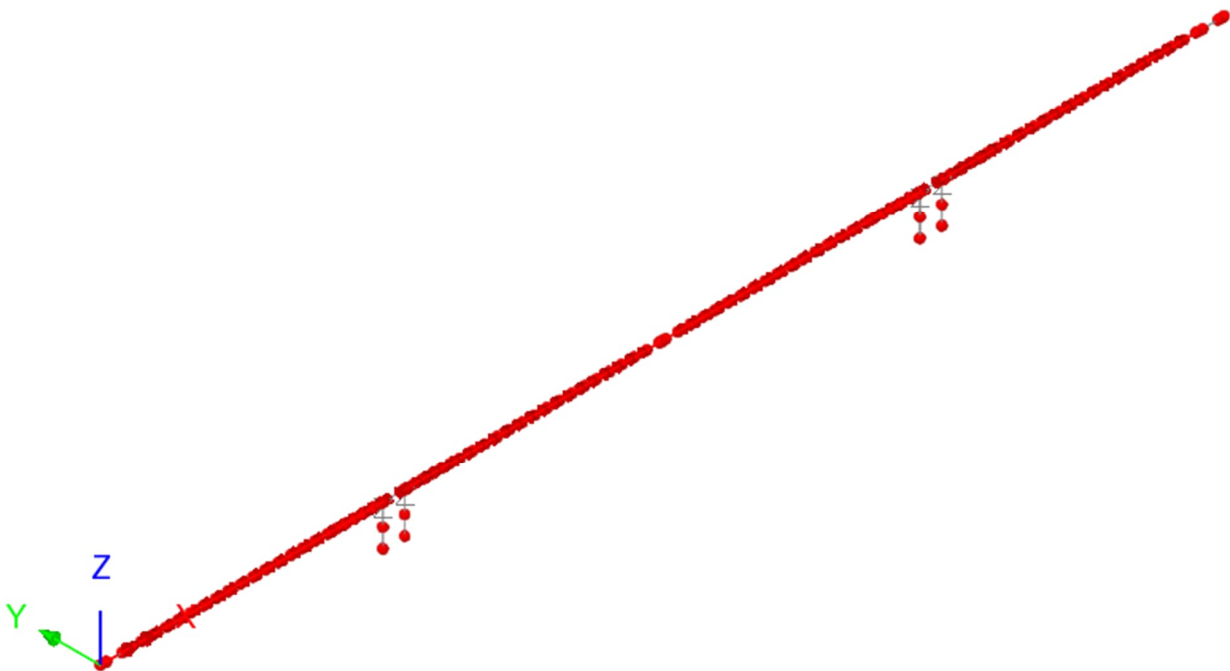
All POINTS needed to describe LINES are found in Appendix 1.

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:9
		Date :	Created :

Overview :



ELVEVATION

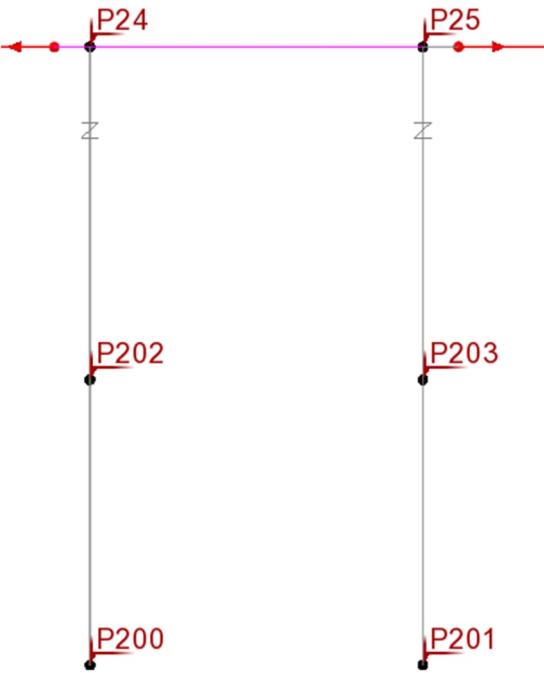


3D VIEW

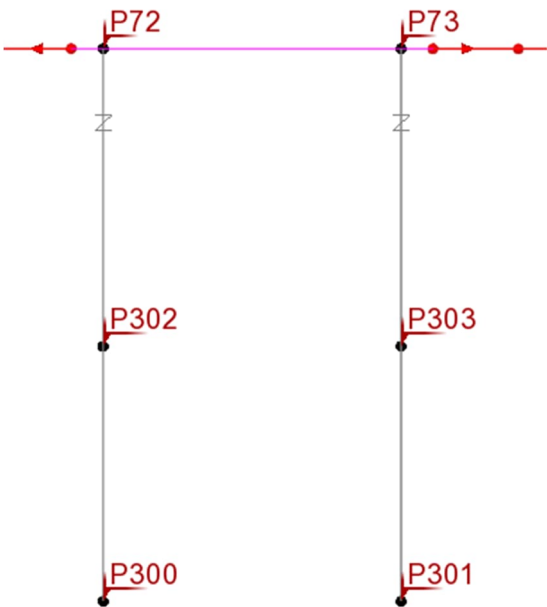
	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:10
		Date :	Created :

2.2.1.1 Geometry : POINTS

Pier – support 2 :



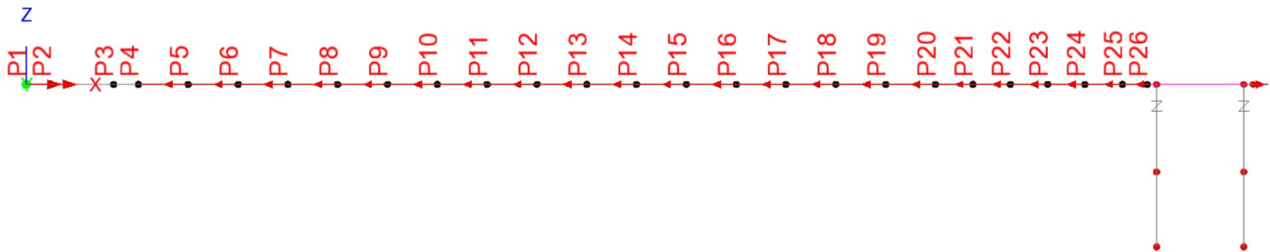
Pier – support 3 :



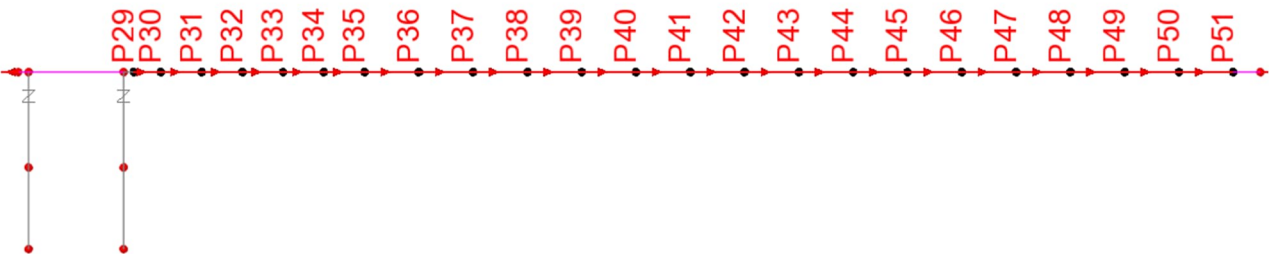
Remark
See direction local coordinate system.

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:11
		Date :	Created :

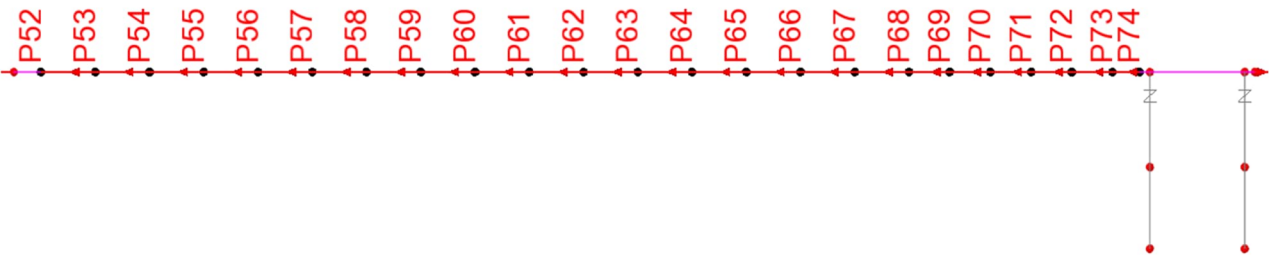
Superstructure :



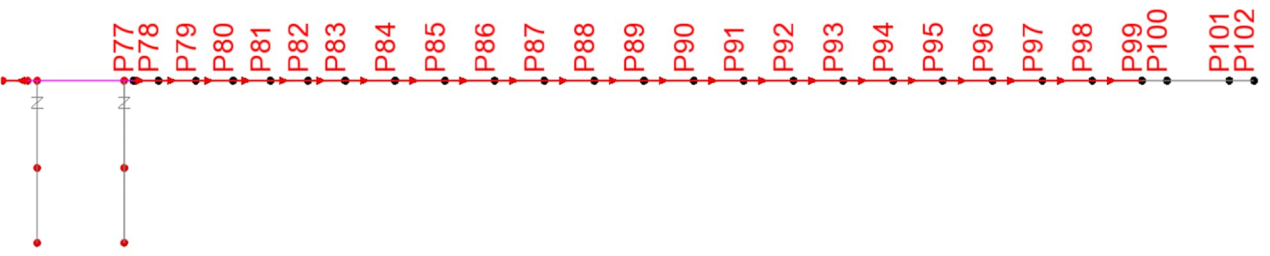
ELEVATION
Span 1-2



ELEVATION
Span 2-3: left



ELEVATION
Span 2-3: right

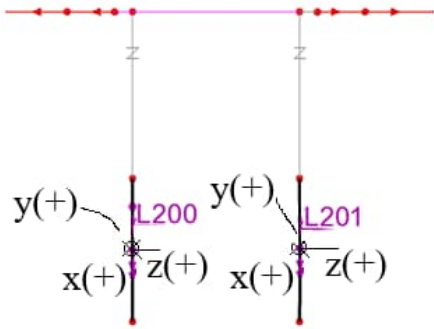


ELEVATION
Span 3-4

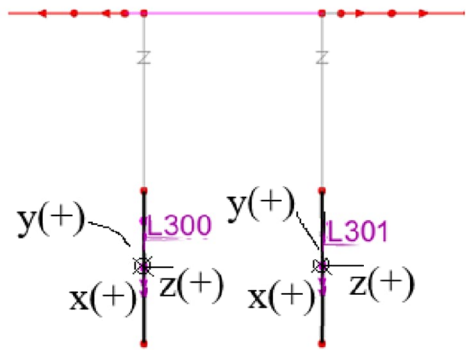
	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:12
		Date :	Created :

2.2.1.2 Geometry : LINES

Pier – support 2 :

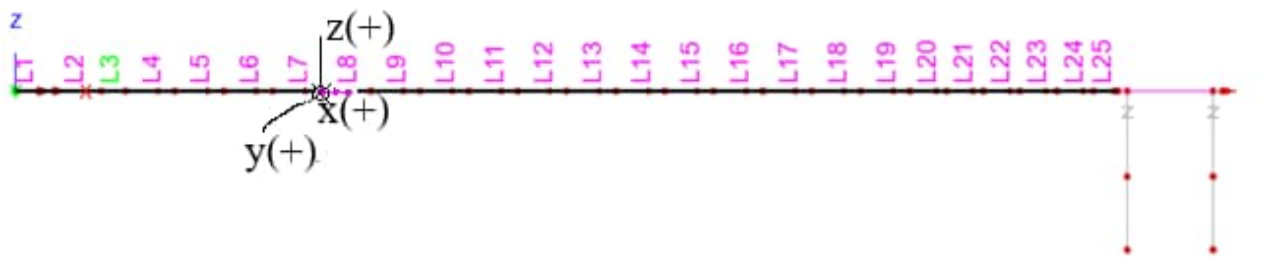


Pier – support 3 :

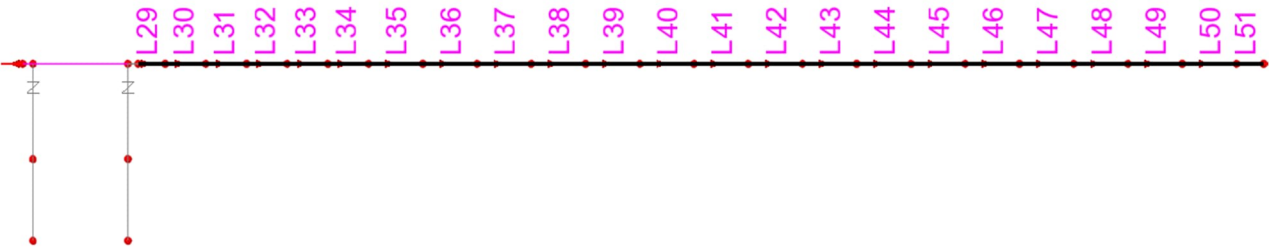


	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:13
		Date :	Created :

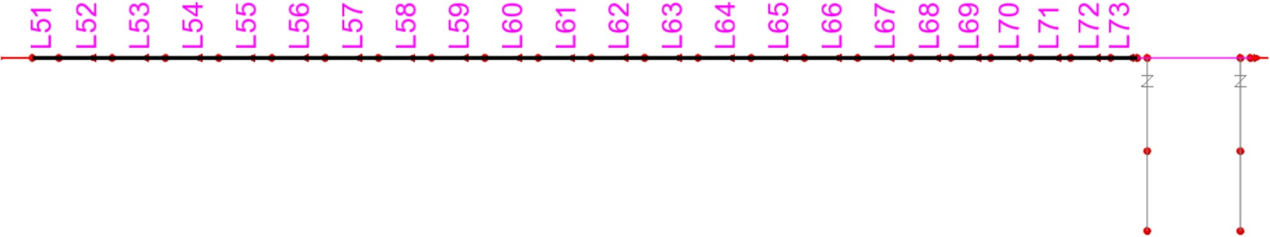
Superstructure :



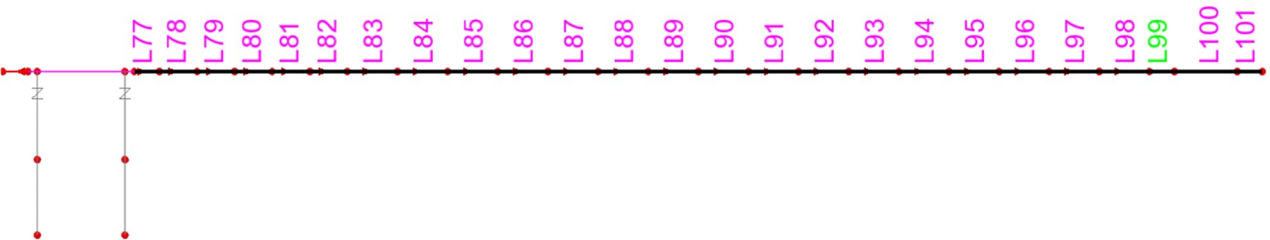
ELEVATION
Span 1-2



ELEVATION
Span 2-3: left



ELEVATION
Span 2-3: right



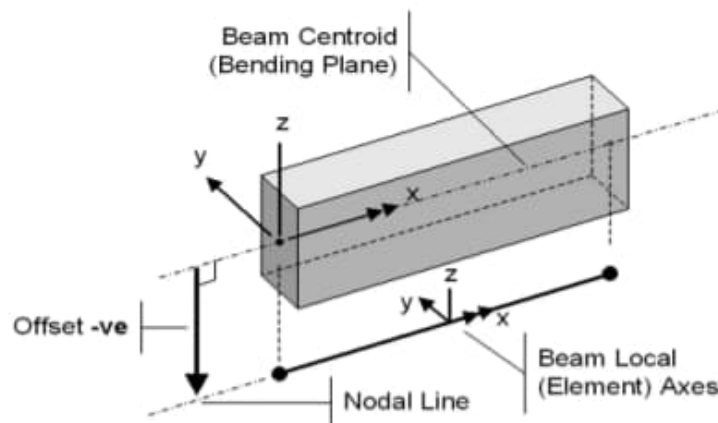
ELEVATION
Span 3-4

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:14
		Date :	Created :

2.3 CROSS SECTION PROPERTIES

The structure only contain 3D-beams ("Thick beam" / BMS3).

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

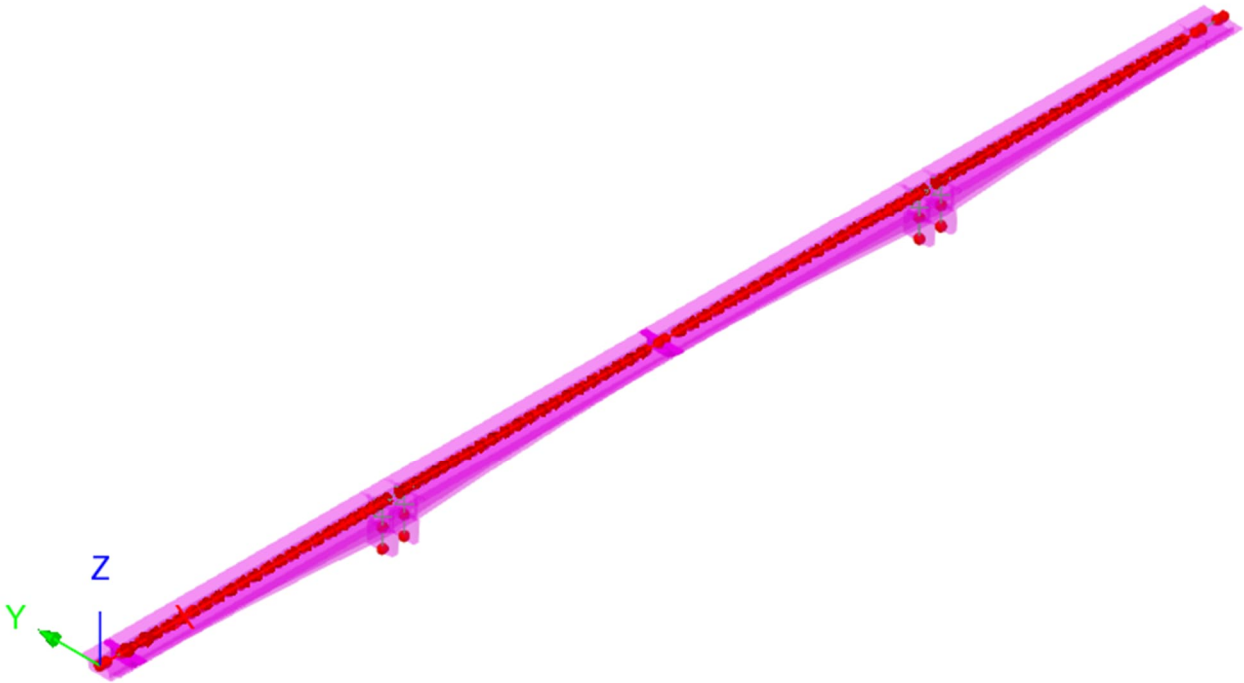


Principal sketch
3D-element



Overview 2D
Graphic visualization

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:15
		Date :	Created :



Overview 3D
Graphic visualization

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:16
		Date :	Created :

2.3.1 Definition cross sections

2.3.1.1 Section 1 (superstructure - H = 2.20 m)

The geometry seen below is used to calculate cross section properties.

Input measurements (see page A1:4):

Box Section Property Calculator

Type

☐ Simple section
☐ Exclude void

☒ Complex section

Cell details

Number of cells

1

B

Box section dimensions

H

2.7

Hm

0.0

Wb

3.55

Tb

0.26

Wt

3.55

Tt

0.25

w

Tw

Cantilever slab dimensions

Wc

2.8

Tc1

0.6

Tc2

0.25

Number of extra points

Top slab

1

Bottom slab

1

Cantilever slab

1

Web interior face

0

Web exterior face

0

Extra points locations

Point	Offset (O)	Height (H)
P1	3.1	0.575
P2	3.1	0.51
t1	1.35	0.25
b1	1.85	0.26
c1	1.05	0.25

Calculated properties

A

8.48575

Ixx

9.06781

Iyy

88.7979

Ixy

0.0

J

19.9567

Asy

1.68201

Asx

5.09604

yt

1.05553

yb

1.64447

Clear inputs

Section details...

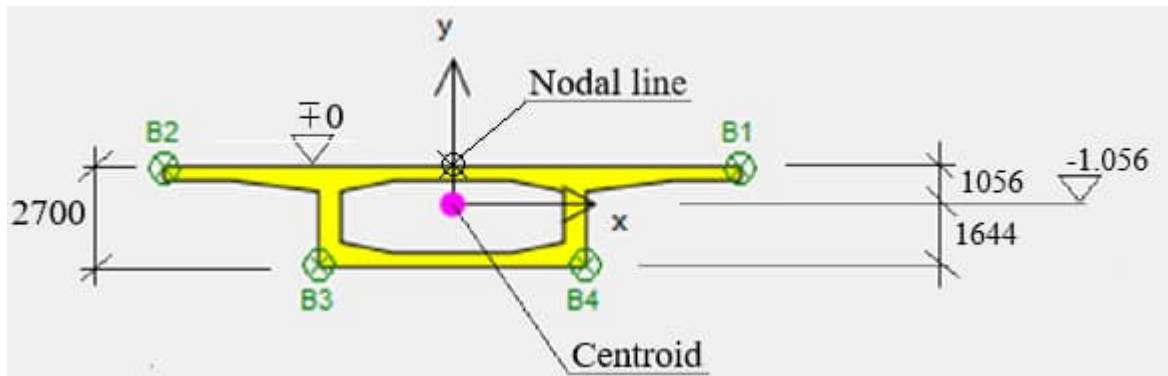
Name

Section 1

(2)

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:17
		Date :	Created :

Results section properties:



Cross section properties

Section Details

Calculated properties

		Value
Cross sectional area	A	8.48575
Second moment of area about x axis	I _{xx}	9.06781
Second moment of area about y axis	I _{yy}	88.7979
Product moment of area	I _{xy}	0.0
Torsional constant	J	19.9567
Effective shear area in x direction	A _{sx}	5.09604
Effective shear area in y direction	A _{sy}	1.68201
Radius of gyration about x axis	k _x	1.03373
Radius of gyration about y axis	k _y	3.23487
Warping torsional constant about shear centre	C _w	24.3584
Shear centre x distance from centroid	x _o	0.0
Shear centre y distance from centroid	y _o	-0.379164
Monosymmetry constant about x	betax	3.37534
Monosymmetry constant about y	betay	0.0
Wagner constant 1st moment of square radius about x	I _{xr}	23.7322
Wagner constant 1st moment of square radius about y	I _{yr}	29.6565E-12
Wagner constant 4th moment of area about origin	I _{lr}	1.73493E3
Wagner constant 2nd moment of warping about origin	I _{wr}	-72.8571E-6
Plastic section modulus about x axis	Z _{px}	7.46032
Plastic section modulus about y axis	Z _{py}	24.7124
Plastic torsional section modulus	Z _{pt}	15.7484
Plastic neutral axis, distance from centroid along x axis	x _p	0.0
Plastic neutral axis, distance from centroid along y axis	y _p	0.629717

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:18
		Date :	Created :

2.3.1.2 Section 2 (superstructure - H = 7.0 m)

The geometry seen below is used to calculate cross section properties.

Input measurements (see page A1:5):

Box Section Property Calculator

Type

☐ Simple section

☒ Complex section

☐ Exclude void

Cell details

Number of cells

1

B

Box section dimensions

H

7.0

Hm

0.0

Wb

3.55

Tb

0.85

Wt

3.55

Tt

0.25

W

Tw

Cantilever slab dimensions

Wc

2.8

Tc1

0.6

Tc2

0.25

Number of extra points

Top slab

1

Bottom slab

1

Cantilever slab

1

Web interior face

0

Web exterior face

0

Extra points locations

Point	Offset (O)	Height (H)
P1	3.1	0.575
P2	3.1	1.1
t1	1.35	0.25
b1	1.85	0.85
c1	1.05	0.25

Calculated properties

A

16.0137

Ixx

122.487

Iyy

143.366

Ixy

0.0

J

136.128

Asy

5.64658

Asx

7.24063

yt

3.70889

yb

3.29111

Clear inputs

Section details...

Name

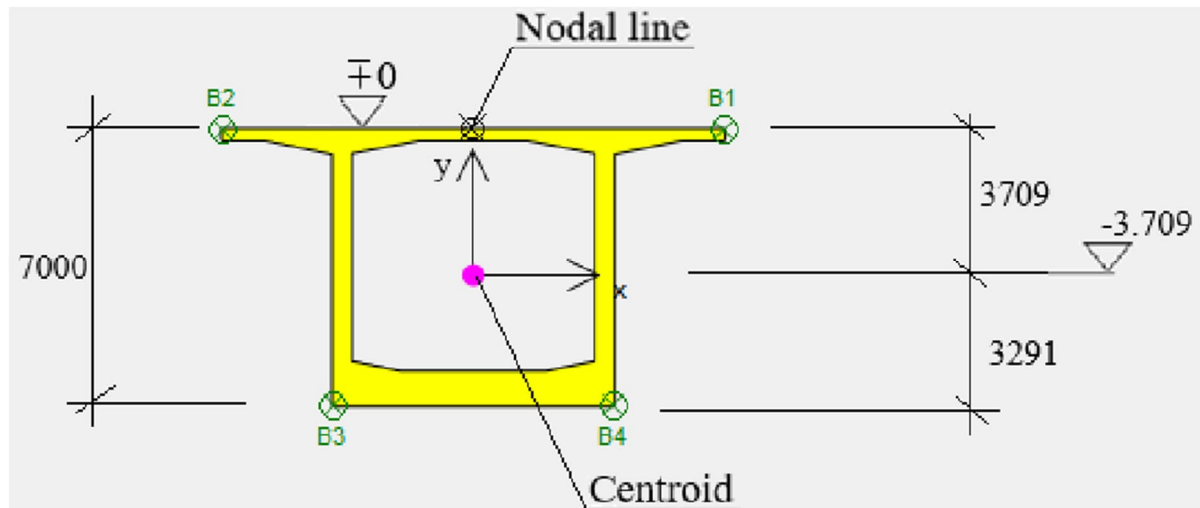
Section 2

(3)

File : A2 System analysis
Datum : 2026-06-27
Tid : 10:55

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:19
		Date :	Created :

Results section properties:



Cross section properties

Section Details		
Calculated properties		
		Value
Cross sectional area	A	16.0137
Second moment of area about x axis	Ixx	122.487
Second moment of area about y axis	Iyy	143.366
Product moment of area	Ixy	0.0
Torsional constant	J	136.128
Effective shear area in x direction	Asx	7.24063
Effective shear area in y direction	Asy	5.64658
Radius of gyration about x axis	kx	2.76565
Radius of gyration about y axis	ky	2.99211
Warping torsional constant about shear centre	Cw	81.4629
Shear centre x distance from centroid	xo	0.0
Shear centre y distance from centroid	yo	-0.823051
Monosymmetry constant about x	betax	3.42725
Monosymmetry constant about y	betay	0.0
Wagner constant 1st moment of square radius about x	lxr	218.172
Wagner constant 1st moment of square radius about y	lyr	-0.112437E-9
Wagner constant 4th moment of area about origin	lrr	5.5589E3
Wagner constant 2nd moment of warping about origin	lwr	-3.72957E-3
Plastic section modulus about x axis	Zpx	41.1095
Plastic section modulus about y axis	Zpy	43.2501
Plastic torsional section modulus	Zpt	50.2356
Plastic neutral axis, distance from centroid along x axis	xp	0.0
Plastic neutral axis, distance from centroid along y axis	yp	-0.597325

Location shear centre (SC) from top of deck $\rightarrow 3.71 \text{ m} + y_o = 2.89 \text{ m}$

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:20
		Date :	Created :

2.3.1.3 Section 3 (rectangular: B x H = 6000 x 1000)

The geometry seen below is used to calculate cross section properties.

Input measurements (see page A1:6):

Rectangular Sections

Type

Rectangular Solid

Dimensional data

D

1.8

B

8.1

Calculated properties

A

14.58

Ixx

3.9366

Iyy

79.7161

Ixy

0.0

J

13.5421

Asy

12.1552

Asx

12.1503

Section details...

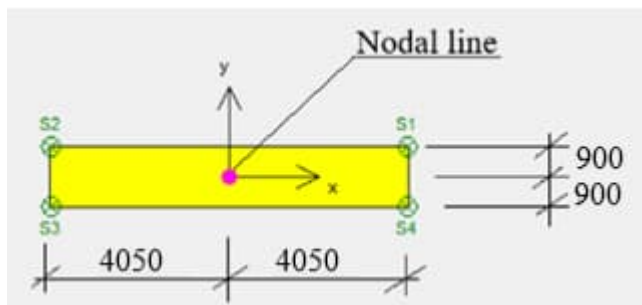
Name

Section 3

(1)

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:21
		Date :	Created :

Cross section properties



Cross section properties

Section Details

Calculated properties

		Value
Cross sectional area	A	14.58
Second moment of area about x axis	Ixx	3.9366
Second moment of area about y axis	Iyy	79.7161
Product moment of area	Ixy	0.0
Torsional constant	J	13.5421
Effective shear area in x direction	Asx	12.1503
Effective shear area in y direction	Asy	12.1552
Radius of gyration about x axis	kx	0.519615
Radius of gyration about y axis	ky	2.33827
Warping torsional constant about shear centre	Cw	17.5045
Shear centre x distance from centroid	xo	0.0
Shear centre y distance from centroid	yo	0.0
Monosymmetry constant about x	betax	0.0
Monosymmetry constant about y	betay	0.0
Wagner constant 1st moment of square radius about x	Ixr	-4.16539E-15
Wagner constant 1st moment of square radius about y	Iyr	0.233966E-12
Wagner constant 4th moment of area about origin	Irr	829.486
Wagner constant 2nd moment of warping about origin	Iwr	-35.1142E-12
Plastic section modulus about x axis	Zpx	6.561
Plastic section modulus about y axis	Zpy	29.5245
Plastic torsional section modulus	Zpt	16.5698
Plastic neutral axis, distance from centroid along x axis	xp	0.0
Plastic neutral axis, distance from centroid along y axis	yp	0.0

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:22
		Date :	Created :

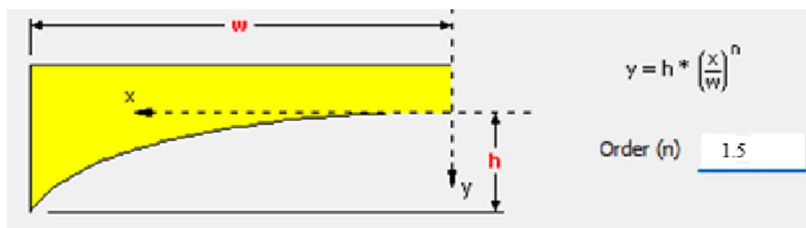
2.3.2 Superstructure: span left side pier 2

Beam is tapered with section varying with function seen below from section 1 → section 2.



ELEVATION

Function:



Multiple varying section:

Analysis category 3D
☒ Specify shape interpolation
☐ Symmetric section

Distance interpretation
☐ Scaled to fit each line individually
☒ Along reference path Pier 1, Taper Zone 1

	Section	Shape Interpolation	Distance
1	At Pier (CBoxSingleCell D=7 Wt=3.55 Wb=3.55	Start	0.0
2	midspan (CBoxSingleCell D=2.7 Wt=3.55 Wb=3	Function (n=1.5)	81.0

ez origin Centroid
Interpolation of properties Enhanced approximation

ey origin Same as ez

Align all to section 2
Vertical Top to top
Horizontal Centre to centre

1

2

1

2

Section 1-1

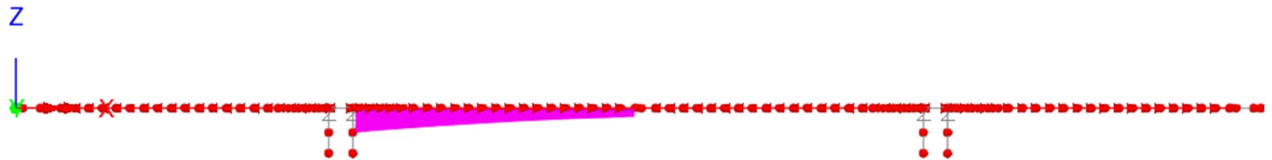
Section 2-2

Name Multiple Section Pier 2:L (5)

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:23
		Date :	Created :

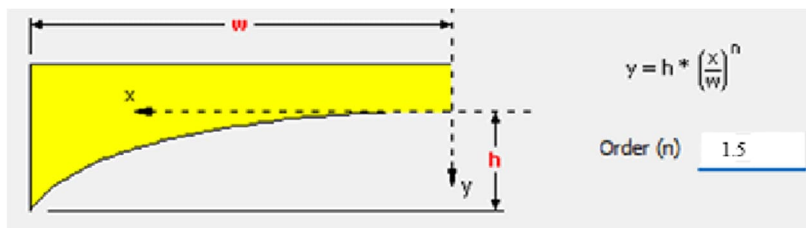
2.3.2 Superstructure: span right side pier 2

Beam is tapered with section varying with function seen below from section 1 → section 2.



ELEVATION

Function:



Multiple varying section:

Analysis category 3D

☒ Specify shape interpolation
☐ Symmetric section

Distance interpretation
☐ Scaled to fit each line individually
☒ Along reference path Pier 1, Taper Zone 2

	Section	Shape Interpolation	Distance
1	At Pier (CBoxSingleCell D=7 Wt=3.55 Wb=3.55	Start	0.0
2	midspan (CBoxSingleCell D=2.7 Wt=3.55 Wb=3	Function (n=1.5)	81.0

Edit...
Insert
Delete
Flip

ez origin Centroid
Interpolation of properties Enhanced approximation

ey origin Same as ez

Align all to section
2

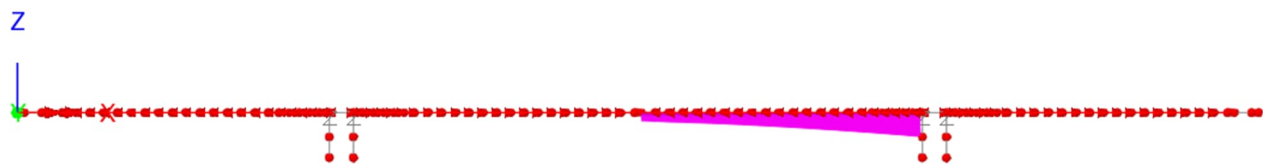
Vertical Top to top
Horizontal Centre to centre

Name Multiple Section Pier 2:R (6)

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:24
		Date :	Created :

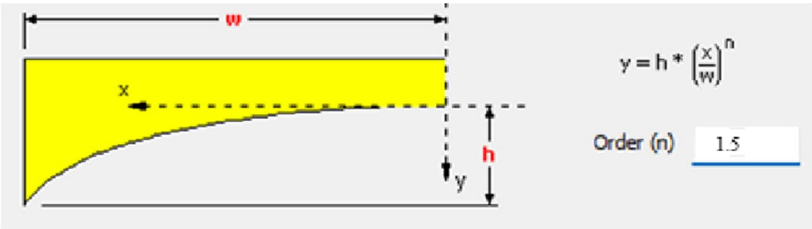
2.3.3 Superstructure: span left side pier 3

Beam is tapered with section varying with function seen below from section 1 → section 2.

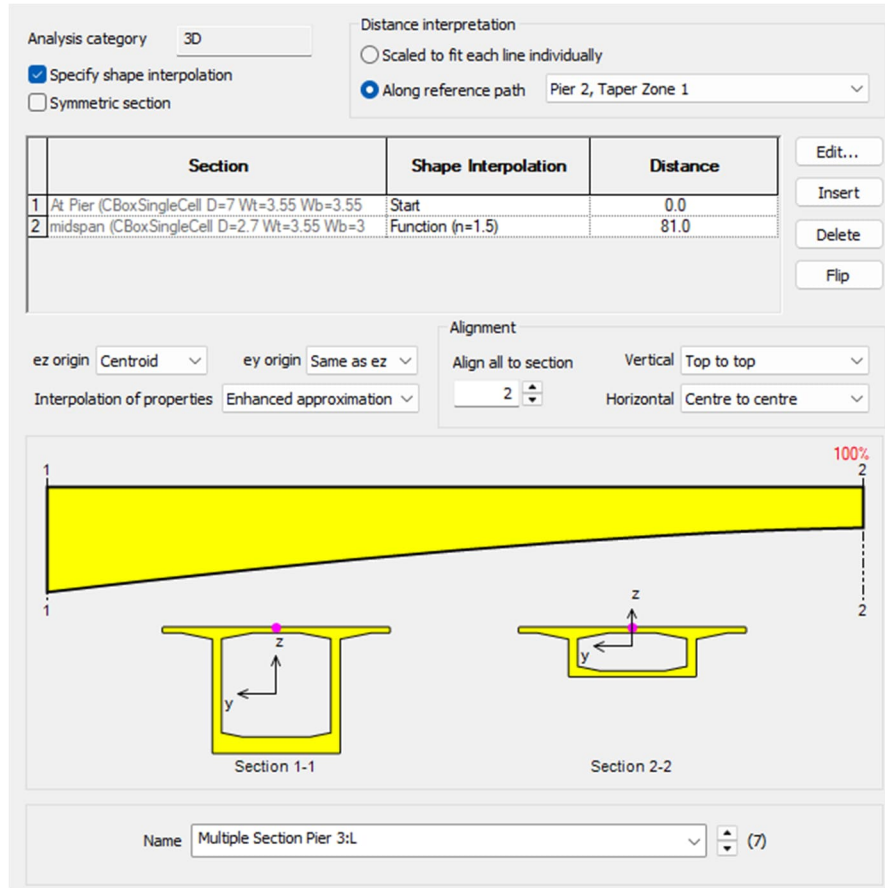


ELEVATION

Function:



Multiple varying section:



	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:25
		Date :	Created :

2.3.4 Superstructure: span right side pier 3

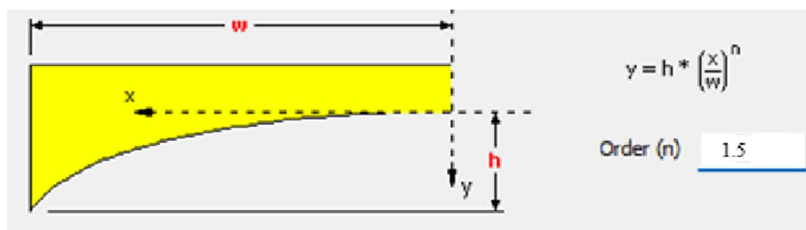
Beam is tapered with section varying with function seen below from section 1 → section 2.

Z



ELEVATION

Function:



Multiple varying section:

Analysis category 3D

☒ Specify shape interpolation
☐ Symmetric section

Distance interpretation
☐ Scaled to fit each line individually
☒ Along reference path Pier 2, Taper Zone 2

	Section	Shape Interpolation	Distance
1	At Pier (CBoxSingleCell D=7 Wt=3.55 Wb=3.55)	Start	0.0
2	midspan (CBoxSingleCell D=2.7 Wt=3.55 Wb=3)	Function (n=1.5)	81.0

Edit...
Insert
Delete
Flip

ez origin Centroid
Interpolation of properties Enhanced approximation

ey origin Same as ez

Alignment
Align all to section 2
Vertical Top to top
Horizontal Centre to centre

Section 1-1

Section 2-2

Name Multiple Section Pier 3:R (8)

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:26
		Date :	Created :

2.3.5 Superstructure: on top of pier

Analysis category3D

Definition

From library / calculator

Enter properties

Rotation about centroid0°

Mirrored about axisNone

Reinforcement (only used for RC design checks)

None

ez originCentroid

ey originSame as ez

Parametric Sections

Box Sections

3:Section 2 (CBoxSingleCell D=7 Wt=

100%

B2

B1

B3

B4

z

y

	Value
Cross sectional area (A)	16.0137
Second moment of area about y axis (Iyy)	122.487
Second moment of area about z axis (Izz)	143.366
Product moment of area (Iyz)	0.0
Torsional constant (J)	136.128
Effective shear area in y direction (Asy)	7.24063
Effective shear area in z direction (Asz)	5.64658
Eccentricity in y direction (ey)	0.0
Eccentricity in z direction (ez)	3.72

Visualise...

Section details...

Name

Section 2 at top of piers

(2)

ELEVATION

File : A2 System analysis
Datum : 2026-06-27
Tid : 10:55

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:28
		Date :	Created :

2.3.7 Superstructure: constant height endspan

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

Box Sections

2:Section 1 (CBoxSingleCell D=2.7 W1

	Value
Cross sectional area (A)	8.48575
Second moment of area about y axis (Iyy)	9.06781
Second moment of area about z axis (Izz)	88.7979
Product moment of area (Iyz)	0.0
Torsional constant (J)	19.9567
Effective shear area in y direction (Asy)	5.09604
Effective shear area in z direction (Asz)	1.68201
Eccentricity in y direction (ey)	0.0
Eccentricity in z direction (ez)	1.05553

Visualise...

Section details...

Name
Constant endspan

(10)



ELEVATION

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:30
		Date :	Created :

2.4 MATERIAL

Material properties seen below are to be used. Relative humidity (RH) 80 % is used to determine creep and shrinkage. according to SS-EN 1992-1-1.

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

Material Library

Material type Concrete
Country Europe
Standard EN1992-1-1:2004/2014
Grade Advanced define

Advanced Define
Characteristic cylinder strength 35.0E3
Aggregate type Quartzite

Prestress parameters
Cement type Class N (normal hardening)
Internal perimeter factor 0.5
Relative humidity (%) 70.0
☒ Auto calculate notional size for beams and surfaces
☐ Enter notional size for any feature

Properties
Young's modulus 34.0771E6
Poisson's ratio 0.2
Density 2.54842
Thermal expansion 10.0E-6

Name Concrete (4)



ELEVATION

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:31
		Date :	Created :

2.5
 BOUNDARY CONDITIONS

2.5.1
 Mid supports

At points P200, P201, P300 & P301 boundary condition seen below is applied.

Analysis category

3D

		Free	Fixed	Spring	Spring stiffness
Translation in	X	☐	☒	☐	
	Y	☐	☒	☐	
	Z	☐	☒	☐	
Rotation about	X	☐	☒	☐	
	Y	☐	☒	☐	
	Z	☐	☒	☐	
Hinge rotation		☒	☐	☐	
Torsional warping		☒	☐	☐	
Pore pressure		Closed	Seepage	Drainage	Open
		☒	☐	☐	☐

Spring stiffness distribution

☒ Stiffness
 ☐ Stiffness/unit length
 ☐ Stiffness/unit area

Lift-off >>
 Contact >>
 Non-reflective >>

Name

Mid support

(1)



ELEVATION

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:32
		Date :	Created :

2.5.2 End supports

At points P1 & P102 boundary condition seen below is applied.

Analysis category 3D

		Free	Fixed	Spring	Spring stiffness
Translation in	X	☒	☐	☐	
	Y	☐	☒	☐	
	Z	☐	☒	☐	
Rotation about	X	☐	☒	☐	
	Y	☒	☐	☐	
	Z	☒	☐	☐	
Hinge rotation		☒	☐	☐	
Torsional warping		☒	☐	☐	
Pore pressure		Closed	Seepage	Drainage	Open
		☒	☐	☐	☐

Spring stiffness distribution
☒ Stiffness
☐ Stiffness/unit length
☐ Stiffness/unit area

Lift-off >>
Contact >>
Non-reflective >>

Name End support (5)



ELEVATION

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:33
		Date :	Created :

2.5.

3 Temporary supports

During casting stage 24 there is a need of temporary supports at points 31 & P100.

Analysis category

		Free	Fixed	Spring	Spring stiffness	
Translation in	X	☐	☒	☐		
	Y	☐	☒	☐		
	Z	☐	☒	☐		
Rotation about	X	☒	☐	☐		
	Y	☒	☐	☐		
	Z	☒	☐	☐		
Hinge rotation		☒	☐	☐		
Torsional warping		☒	☐	☐		
Pore pressure		Closed	Seepage	Drainage	Open	Pressure
		☒	☐	☐	☐	

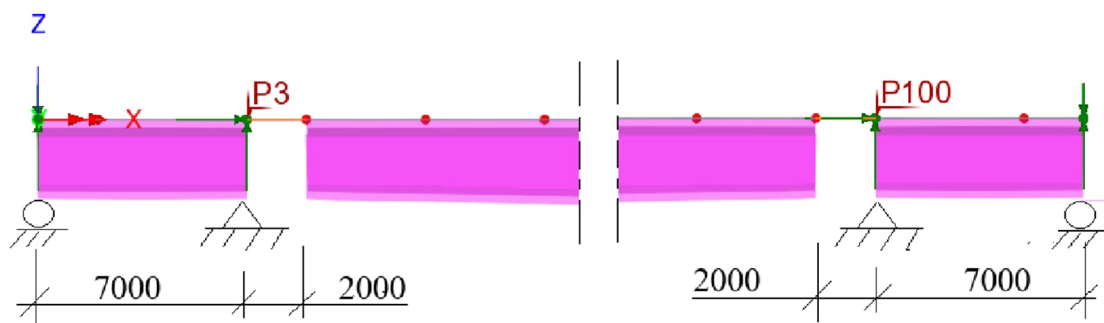
Spring stiffness distribution

☒ Stiffness

☐ Stiffness/unit length

☐ Stiffness/unit area

Name (2)



Remark

This support is “removed” in casting stage 25 by adding fictive support using with free movement in all directions. The boundary condition is termed “Removal temporary support”.

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:34
		Date :	Created :

2.6 MESH

2.6.1 Line elements

Linear beams elements (BM21) are with various subdivisions as seen below.

Typ	Divisions	End release: Start	End release: End
Element 1	1	None	None



ELEVATION

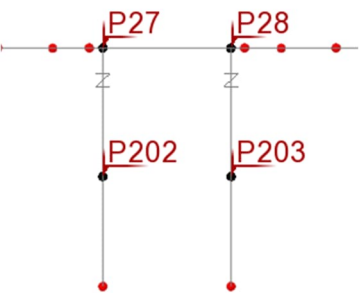
	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:35
		Date :	Created :

2.6.2 Point elements

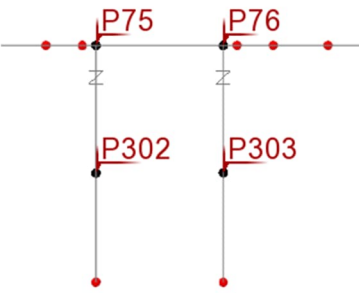
Point elements are used to tie superstructure with piers (∴ support 2 & 3) acting as “rigid links”.

FEM-elements:

Rigid joint element (JSH4) are used to tie superstructure with piers. “Primary node” is located at top of superstructure, while “secondary node” is located at top of pier, se sketches below.



ELEVATION
Support 2



ELEVATION
Support 3

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:36
		Date :	Created :

Material properties (JSH4):

“Rigid link” is modelled using rigid springs as seen in table below.

Analysis category: 3D

Assignment to: Points and line ends

Joint type: Joint for beams

Properties specified for each freedom

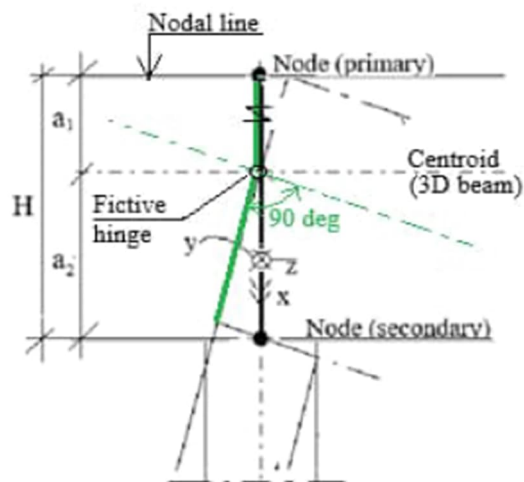
	u	v	w	THx	THy	THz
Elastic spring stiffness	1E12	1E12	1E12	1E12	1E12	1E12

Name: Joint Material (3)

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:37
		Date :	Created :

Geometric properties:

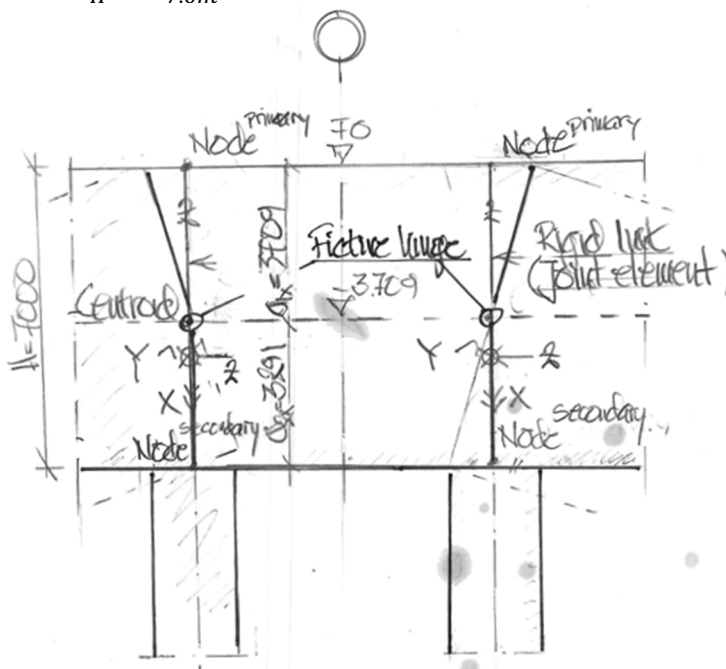
The superstructure has nodal line located at top of deck instead of a level centroid fictive “hinge” is added at level of centroid, see sketch below.



Prometric distance to fictive “hinge” from primary node:

$$\eta_y = \frac{a_{1y}}{H} = \frac{2.89m}{7.0m} = 0.41 \quad : \text{transversal direction (shear centre)}$$

$$\eta_z = \frac{a_{1x}}{H} = \frac{3.71m}{7.0m} = 0.53 \quad : \text{longitudinal direction (centroid)}$$



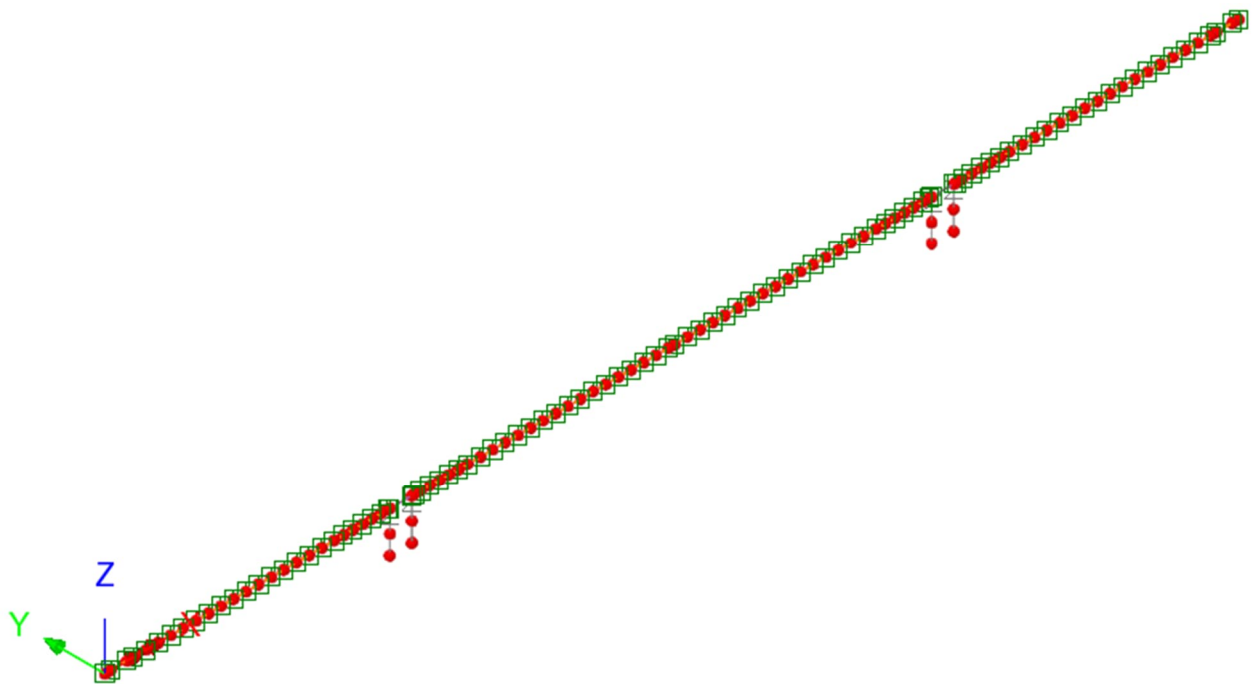
ELEVATION

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:38
		Date :	Created :

2.7 SEARCH AREA

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

Search area : “Superstructure”



Overview

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:39
		Date :	Created :

2.8 STUCTURE ACTIVATION

All part are active unless deactivated.

When it comes to deactivation there are several types. For FCM deactivated mesh is expected to follow movement of at connecting active mesh but (no stress will occur since stiffness zero). This deactivation is called “*follow active mesh*” and is used for all casting stages except castings stages 25 at end spans. At these locations deactivation “*closing part*” is used between two previously constructed parts that are active.



Stage 1: (Analysis 1)

Entire superstructure is assigned as “DEACTIVE” (stage 2-26).



Stage 2: (Analysis 1)

Marked stage 2 is assigned as “ACTIVE”.



Stage 3: (Analysis 1)

Marked stage 3 is assigned as “ACTIVE”.



Stage 4: (Analysis 1)

Marked stage 4 is assigned as “ACTIVE”.

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:40
		Date :	Created :

Z



Stage 5: (Analysis 1)

Marked stage 5 is assigned as “ACTIVE”.

Z



Stage 6: (Analysis 1)

Marked stage 6 is assigned as “ACTIVE”.

Z



Stage 7: (Analysis 1)

Marked stage 7 is assigned as “ACTIVE”.

Z



Stage 8: (Analysis 1)

Marked stage 8 is assigned as “ACTIVE”.

Z



Stage 9: (Analysis 1)

Marked stage 9 is assigned as “ACTIVE

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:41
		Date :	Created :



Stage 10: (Analysis 1)
Marked stage 10 is assigned as “ACTIVE



Stage 11: (Analysis 1)
Marked stage 11 is assigned as “ACTIVE



Stage 12: (Analysis 1)
Marked stage 12 is assigned as “ACTIVE



Stage 13: (Analysis 1)
Marked stage 13 is assigned as “ACTIVE



Stage 14: (Analysis 1)
Marked stage 14 is assigned as “ACTIVE

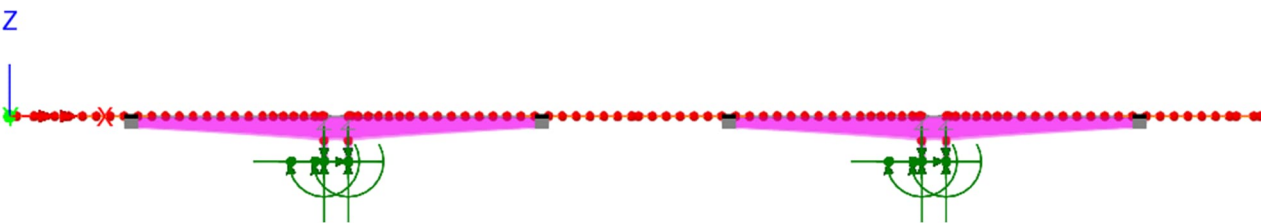
	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:42
		Date :	Created :



Stage 15: (Analysis 1)
Marked stage 15 is assigned as “ACTIVE



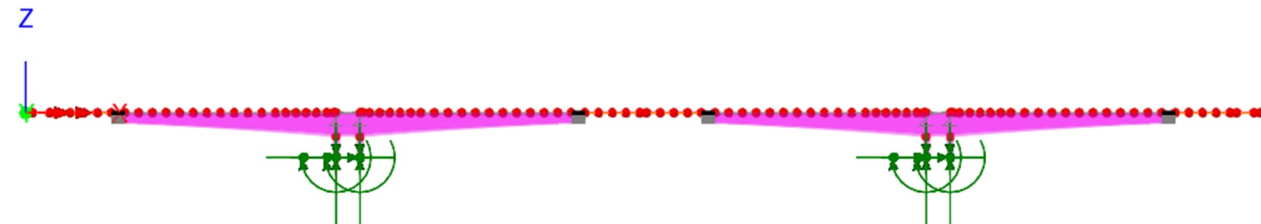
Stage 16: (Analysis 1)
Marked stage 16 is assigned as “ACTIVE



Stage 17: (Analysis 1)
Marked stage 17 is assigned as “ACTIVE



Stage 18: (Analysis 1)
Marked stage 18 is assigned as “ACTIVE



Stage 19: (Analysis 1)
Marked stage 19 is assigned as “ACTIVE

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:43
		Date :	Created :

Z



Stage 20: (Analysis 1)

Marked stage 20 is assigned as “ACTIVE

Z



Stage 21: (Analysis 1)

Marked stage 21 is assigned as “ACTIVE

Z



Stage 22: (Analysis 1)

Marked stage 22 is assigned as “ACTIVE

Z



Stage 23: (Analysis 1)

Marked stage 23 is assigned as “ACTIVE

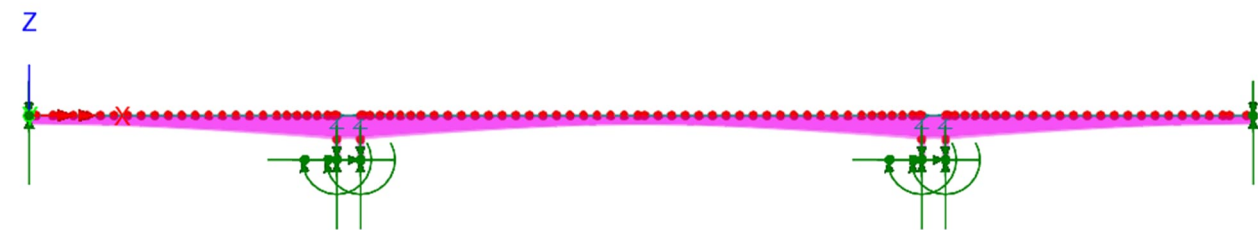
Z



Stage 24: (Analysis 1)

Marked stage 24 is assigned as “ACTIVE. Also supports “End support” & “Temporary support” is added.

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A2:44
		Date :	Created :



Stage 25 (Analysis 1)
Same as stage 25 but after removal “Temporary support”.



During operation (Analysis 2)
Entire superstructure is active including all permanent supports, same as stage 25.

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:1
		Date :	Created :

3. LOADS

3.1	DEAD WEIGHT	page 3:2-12
3.2	SURFACING	page 3:13
3.3	TIME MANAGMENT	page 3:14
3.4	CREEP	page 3:15
3.5	SHRINKAGE	page 3:15
3.6	TRAFFIC LOAD	page 3:16-32
3.7	PRESTRESS	page 3:33-70
3.8	LOAD COMBINATIONS	page 3:71-82

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:2
		Date :	Created :

3.1 DEAD WEIGHT

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

: concrete

3.1.1 Body loads

Load: Dead weight 1

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

Load case : Stage 1 → until end analysis 1

Load: Dead weight 1



ELEVATION

Load case : Stage 2 → until end analysis 1

Load: Dead weight 1



ELEVATION

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:3
		Date :	Created :

Load case : Stage 3→ until end analysis 1

Load: Dead weight 1



ELEVATION

Load case : Stage 4→ until end analysis 1

Load: Dead weight 1



ELEVATION

Load case : Stage 5→ until end analysis 1

Load: Dead weight 1



ELEVATION

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:4
		Date :	Created :

Load case : Stage 6→ until end analysis 1

Load: Dead weight 1



ELEVATION

Load case : Stage 7→ until end analysis 1

Load: Dead weight 1



ELEVATION

Load case : Stage 7→ until end analysis 1

Load: Dead weight 1



ELEVATION

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:5
		Date :	Created :

Load case : Stage 8 → until end analysis 1

Load: Dead weight 1



ELEVATION

Load case : Stage 9 → until end analysis 1

Load: Dead weight 1



ELEVATION

Load case : Stage 10 → until end analysis 1

Load: Dead weight 1



ELEVATION

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:6
		Date :	Created :

Load case : Stage 8 → until end analysis 1

Load: Dead weight 1



ELEVATION

Load case : Stage 9 → until end analysis 1

Load: Dead weight 1



ELEVATION

Load case : Stage 10→ until end analysis 1

Load: Dead weight 1



ELEVATION

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:7
		Date :	Created :

Load case : Stage 11→ until end analysis 1

Load: Dead weight 1



ELEVATION

Load case : Stage 12→ until end analysis 1

Load: Dead weight 1



ELEVATION

Load case : Stage 13→ until end analysis 1

Load: Dead weight 1



ELEVATION

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:8
		Date :	Created :

Load case : Stage 14→ until end analysis 1

Load: Dead weight 1



ELEVATION

Load case : Stage 15→ until end analysis 1

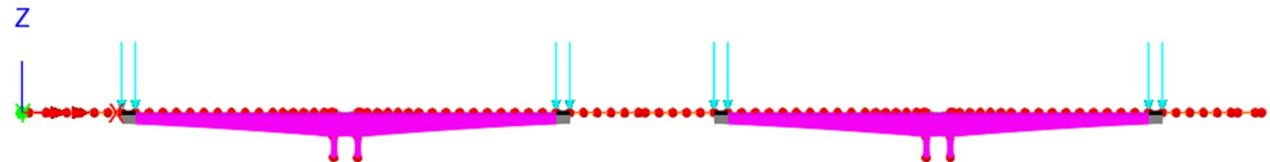
Load: Dead weight 1



ELEVATION

Load case : Stage 16→ until end analysis 1

Load: Dead weight 1



ELEVATION

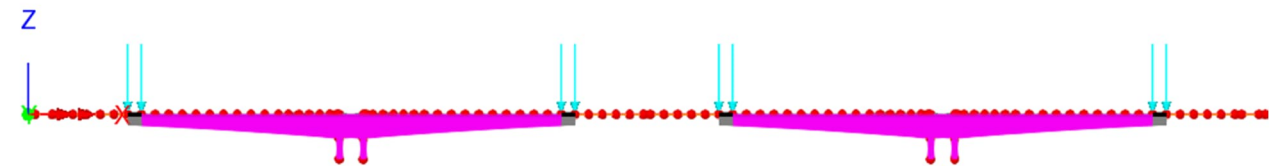
	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:9
		Date :	Created :

Load case : Stage 17→ until end analysis 1

Load: Dead weight 1

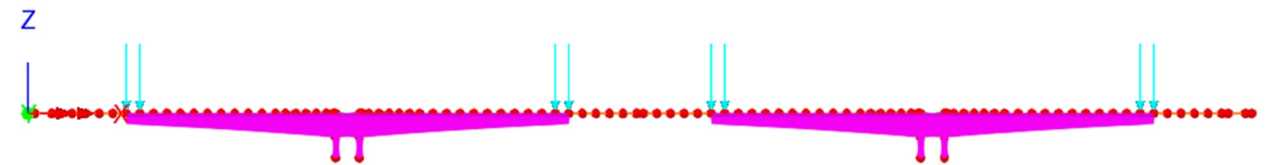


ELEVATION



Load case : Stage 18→ until end analysis 1

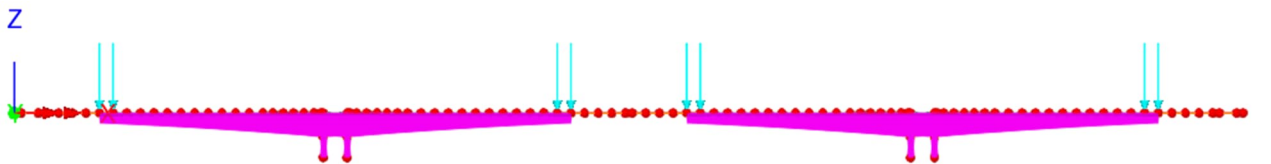
Load: Dead weight 1



ELEVATION

Load case : Stage 19→ until end analysis 1

Load: Dead weight 1

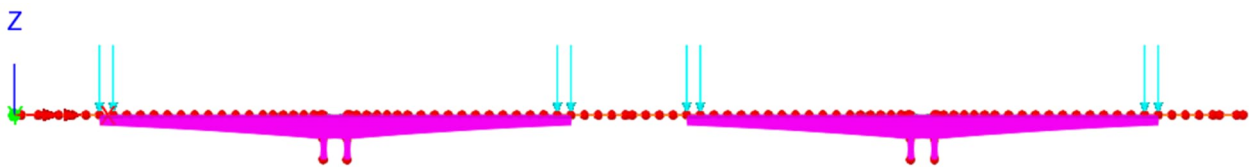


ELEVATION

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:10
		Date :	Created :

Load case : Stage 20→ until end analysis 1

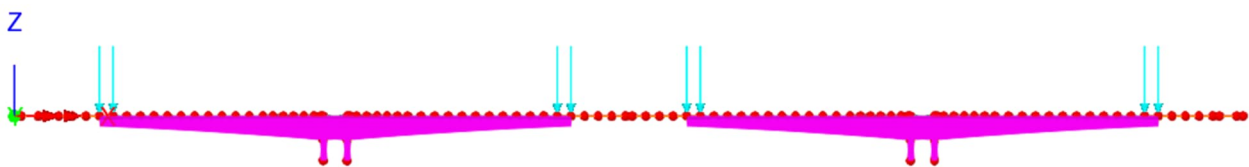
Load: Dead weight 1



ELEVATION

Load case : Stage 21→ until end analysis 1

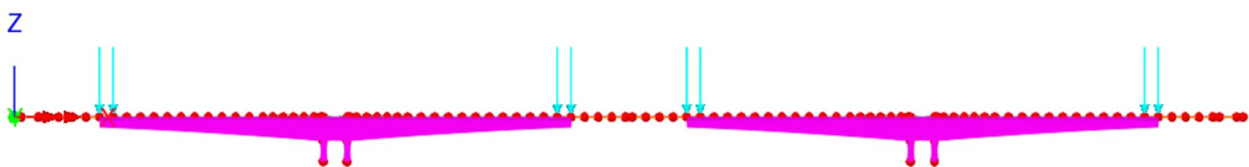
Load: Dead weight 1



ELEVATION

Load case : Stage 22→ until end analysis 1

Load: Dead weight 1

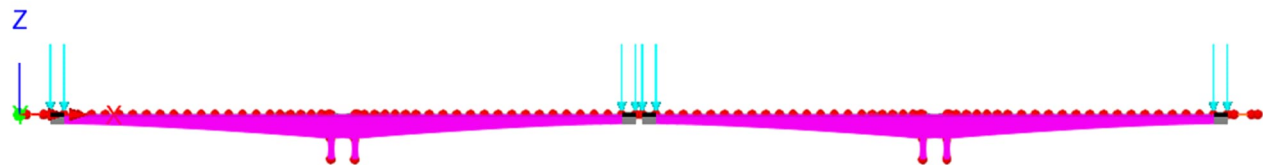


ELEVATION

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:11
		Date :	Created :

Load case : Stage 23→ until end analysis 1

Load: Dead weight 1



ELEVATION

Load case : Stage 24→ until end analysis 1

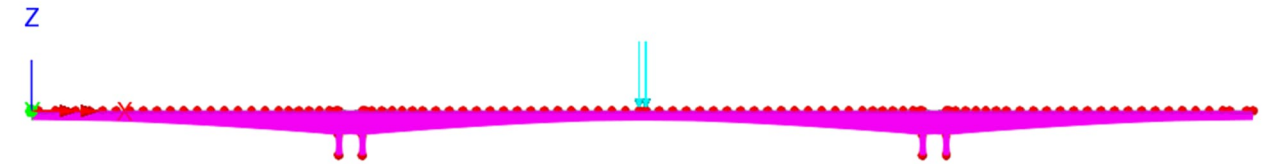
Load: Dead weight 1



ELEVATION

Load case : Stage 25→ until end analysis 1

Load: Dead weight 1



ELEVATION

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:12
		Date :	Created :

3.1.2
Edge beams including railing

Along each edge bream a line load is introduced. The load includes weight of both edge beams and railings.

$$p_{r\ddot{a}cke} = 0.7 \frac{kN}{m}$$
: weight railing

$$\rightarrow p_z = 2p_{r\ddot{a}cke} + 2p_{KB} = 2 \cdot 0.7 \frac{kN}{m} + 2 \cdot 0.45m \cdot 0.45m \cdot 25 \frac{kN}{m^3} = -12 \frac{kN}{m}$$

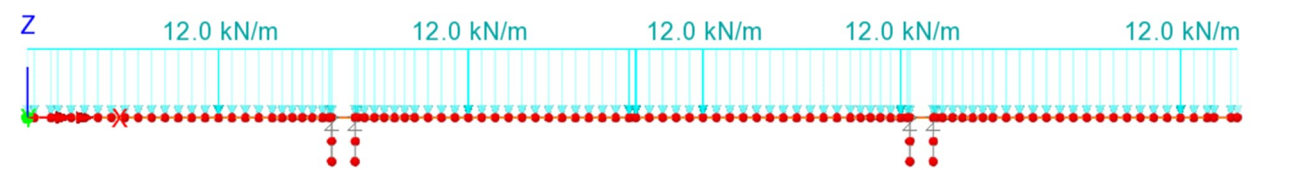
Load: Dead weight 2

Structural loading : Global distributed

Line load per unit length in Z direction: $-12 \frac{kN}{m}$

Load case : Stage 25→ until end analysis 1

Load: Dead weight 2



ELEVATION

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:13
		Date :	Created :

3.2 SURFACING

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

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

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

$$q_{matta} = 0.11 kPa \quad : \text{waterproofing}$$

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

$$\rightarrow p_z = B \cdot q_{belägg} = 12.7m \cdot 2.2 kPa = -29 \frac{kN}{m}$$

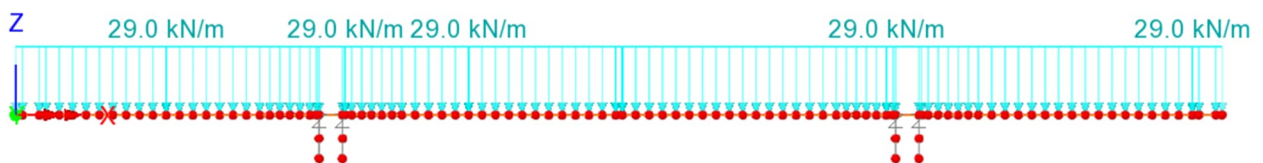
Load : Surfacing

Structural loading : Global distributed

Surface load per unit length in Z direction: $-29 \frac{kN}{m}$

Load case : Stage 25 → until end analysis 1

Load: Surfacing



ELEVATION

Remark

Load is also applied to Analysis 2 (LC Surfacing).

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:14
		Date :	Created :

.3 TIME MANAGEMENT

The effect of creep, shrinkage and relaxation is determined by assuming construction times see below.

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

$$t_1 = 120 \text{ years} \therefore 43800 \text{ days}$$

Only “Analysis 1 “ use time dependent nonlinear analysis with regard to material. Below time table used for this analysis.

“Age at placement” : time after casting until concrete is assumed statically active

“Age at shrinkage” : time after casting until concrete is assumed statically active

“Stage duration” : length between casting stages

	Loadcase	Age at Placement	Age at shrinkage	Stage Duration	Response Time
+	CS 1	5	5	10	10
+	CS 2	5	5	10	20
+	CS 3	5	5	10	30
+	CS 4	5	5	10	40
+	CS 5	5	5	10	50
+	CS 6	5	5	10	60
+	CS 7	5	5	10	70
+	CS 8	5	5	10	80
+	CS 9	5	5	10	90
+	CS 10	5	5	10	100
+	CS 11	5	5	10	110
+	CS 12	5	5	10	120
+	CS 13	5	5	10	130
+	CS 14	5	5	10	140
+	CS 15	5	5	10	150
+	CS 16	5	5	10	160
+	CS 17	5	5	10	170
+	CS 18	5	5	10	180
+	CS 19	5	5	10	190
+	CS 20	5	5	10	200
+	CS 21	5	5	10	210
+	CS 22	5	5	10	220
+	CS 23	5	5	10	230
+	CS 24	5	5	0	230
+	CS 25	5	5	0	230
	Prestress (CS 25)	-	-	0	230
	Longterm	-	-	43800	44030
	Prestress (longterm)	-	-	0	44030

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:15
		Date :	Created :

3.4 CREEP

Creep is determined according to SS-EN 1992-1-1 §3.1.4.

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

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

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

In this analysis only used to determine pretension loss over time.

3.5 SHRINKAGE

Shrinkage is determined according to SS-EN 1992-1-1 §3.1.4.

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

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

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

In this analysis only used to determine pretension loss over time.

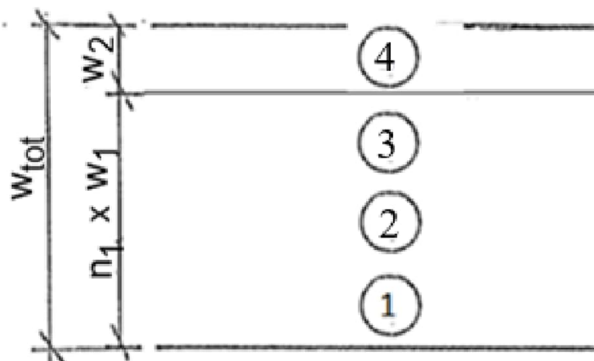
	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:16
		Date :	Created :

3.6 TRAFFIC

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

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

3.6.1 Traffic lane division



Total traffic width : $w_{tot} = 0.1 \text{ m} + 12.7 \text{ m} + 0.1 \text{ m} = 12.9 \text{ m}$

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

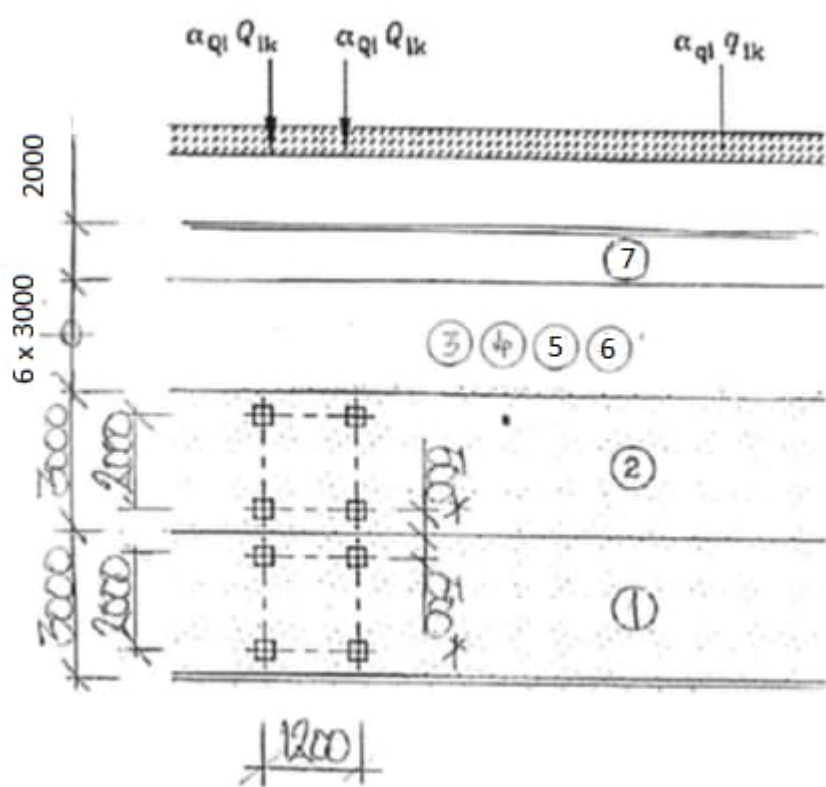
Full traffic width : $w_1 = 3.0\text{m}$

Remaining width : $w_2 = 0.9\text{m}$

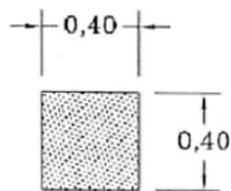
	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:17
		Date :	Created :

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 Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:18
		Date :	Created :

Axellaster :

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

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

Traffic lane	Q_k	α_Q	Q'_k	Remark
1	300	0,9	270	LM1- 2 x 270 kN
2	200	0,9	180	LM1- 2 x 180 kN
3-4	100	0	0	No load
-	kN	-	kN	-

Utbredda laster :

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

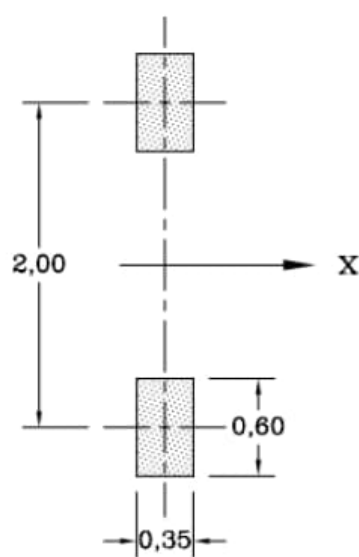
$q'_k = \alpha_q \cdot q_k$: characteristic value including national adaptation factor

Traffic lane	q_k	α_q	q'_k
1	9.0	0.8	7.2
2-4	2.5	1.0	2.5
-	kPa	-	kPa

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:19
		Date :	Created :

3.6.3 Load model 2 (LM 2)

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



- $\beta_Q = \alpha_Q = 0.90$: national adaptation factor
- $Q_k = 400\text{ kN}$: characteristic value
- $Q'_k = \beta_k \cdot Q_k = 360\text{ kN}$: characteristic value including national adaptation factor

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

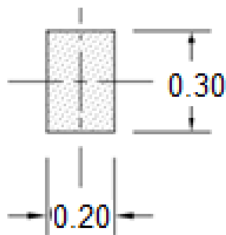
	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:20
		Date :	Created :

3.6.4 Load model EG A/B

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

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

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



Wheel pressure

$\varepsilon_{\text{dyn}} = 25 \%$: dynamic factor ^{1.)}

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

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

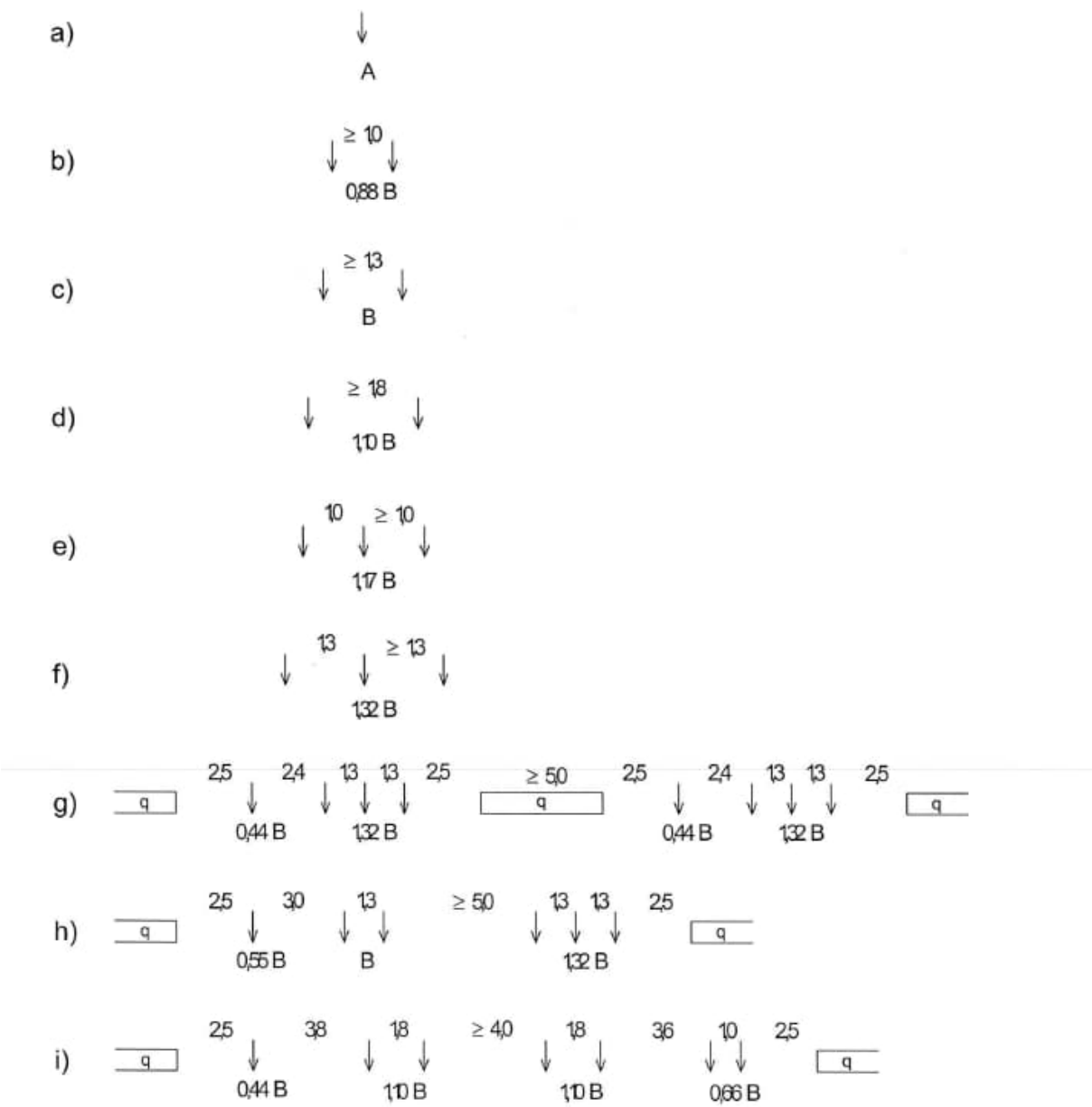
$p = 5 \frac{\text{kN}}{\text{m}}$: surface load

Footnote:

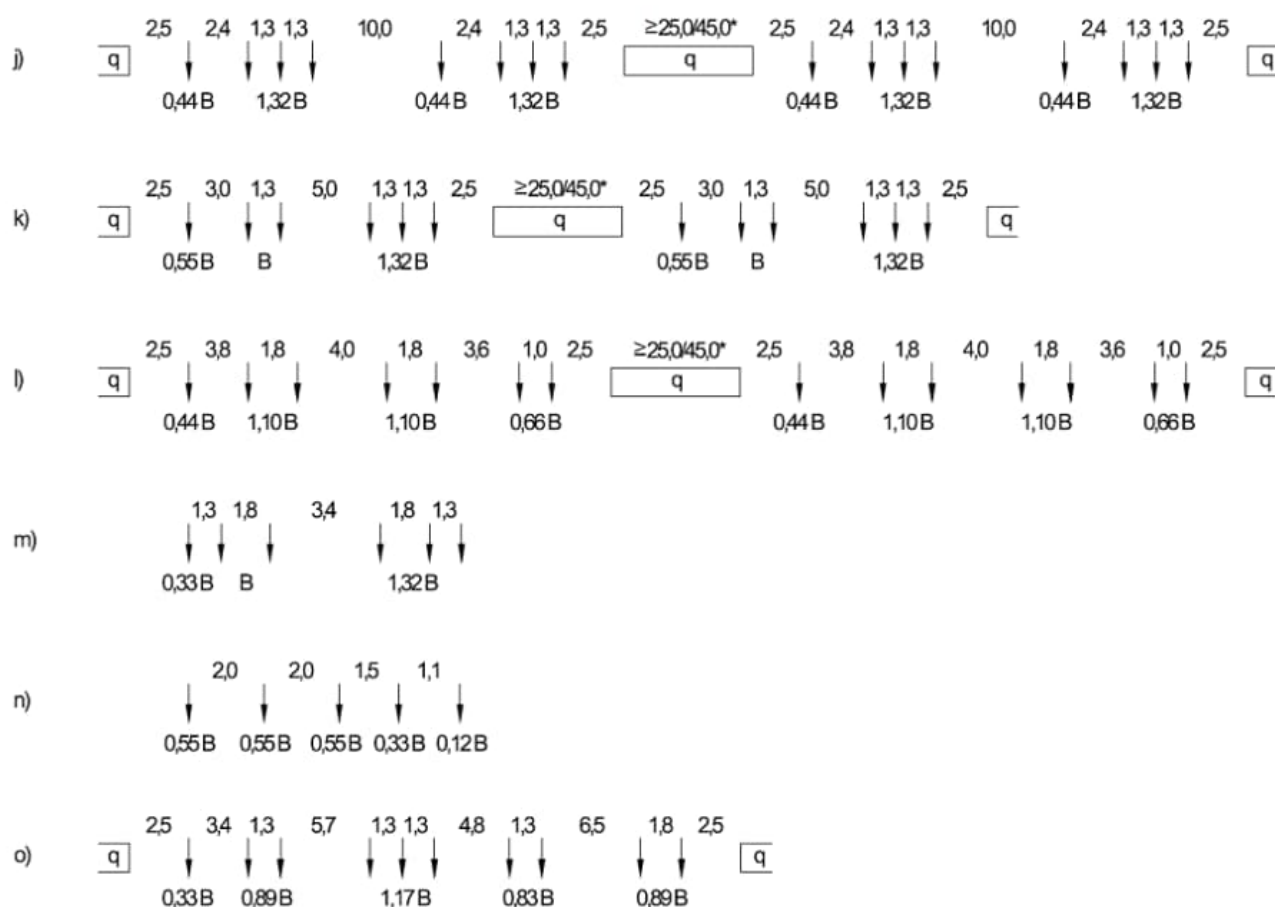
^{1.)} TRVINFRA-00227 table 7.1-5 section 4.2.1(1) states apply 25 % ..

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:21
		Date :	Created :

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



	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:22
		Date :	Created :



Note:

Evaluation is carried out with the script Vehicle Load Optimization (VLO), see sections 3.5.3 and 3.5.4.

Since there is no motorway, * = 45 m is applied according to TRVINFRA-00331 section 8.3.2.2.1 for vehicle types j, k, and l.

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:23
		Date :	Created :

3.6.5 Vehicle Load Optimization (VLO)

Influence surfaces are created using *Method Influence Envelope* for indicated components.

Influence	Components	Entity	Method
Inf1 - Beam	Fx, Fy, Fz, Mx, My	Forces 3D-beam	<i>Influence Envelope</i>
Inf2 - Reaction	FX, FY, FZ, MX, MY	Reaction	<i>Influence Envelope</i>

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:26
		Date :	Created :

3.6.5.2 Influence surface analysis

Influence surfaces :

Search area: Superstructure

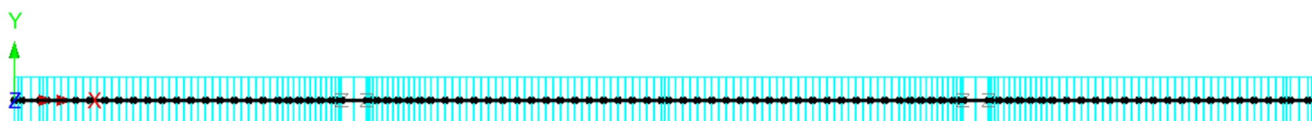
Definition type: Nodes in seach areas

Path: Centerline X

Transverse width: 12.9 m

Longitudinal spacing: - (not used since type not grid)

Transversal spacing: - (not used since type not grid)



PLAN

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:27
		Date :	Created :

3.6.5.3 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

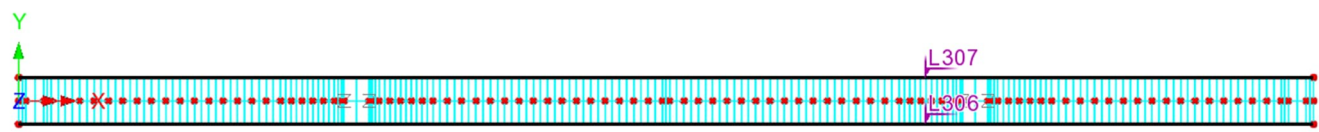
Vehicle longitudinal incremental movement: 0.25 m

Vehicle transverse incremental movement: 0.25 m

Vehicle direction: both

Definition of carriageway (kerbs): L306 & L307

Influence surfaces: Include all (positive & negative)



PLAN

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:28
		Date :	Created :

3.6.5.4 Envelope : LM 1

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

Representative values required	Load groups to include
☒ Characteristic	☒ Group 1a - LM1
☐ Combination (psi0)	☐ Group 4 - LM4
☐ Frequent (psi1)	☐ Complementary load model
☐ Infrequent (psi1,infq)	Dynamic amplification (additional) 20 %
☐ Quasi-permanent (psi2)	Vehicle(s) None ...
	☐ Group 5 - LM3
	Vehicle(s) None ...
	☐ Include associated LM1

3.6.5.5 Envelope : LM 2

Load model 2 (LM2) defined in SS-EN 1991-2 section 4.3.3. The load is defined in Group 5 vehicle) since Group 1b is not defined in present version of software.

Representative values required	Load groups to include
☒ Characteristic	☐ Group 1a - LM1
☐ Combination (psi0)	☐ Group 4 - LM4
☐ Frequent (psi1)	☐ Complementary load model
☐ Infrequent (psi1,infq)	Dynamic amplification (additional) 20 %
☐ Quasi-permanent (psi2)	Vehicle(s) None ...
	☒ Group 5
	Vehicle(s) LM2 ...
	☐ Include associated LM1

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:29
		Date :	Created :

3.6.5.6 Envelope : EG A

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

The screenshot shows the 'EN1991-2 Sweden 2011 - USER' dialog box. On the left, under 'Representative values required', the 'Characteristic' checkbox is checked, while 'Combination (psi0)', 'Frequent (psi1)', 'Infrequent (psi1,infq)', and 'Quasi-permanent (psi2)' are unchecked. On the right, under 'Load groups to include', 'Group 1a - LM1', 'Group 4 - LM4', and 'Group 5 - LM3' are unchecked, while 'Complementary load model' is checked. Below this, 'Dynamic amplification (additional)' is set to 25%. The 'Vehicle(s)' field is set to 'Type a'. At the bottom, 'Include associated LM1' is checked.

Dynamic amplification (additional): 25 %

Vehicle selection: Type a

3.6.5.7 Envelope : EG B

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

The screenshot shows the 'EN1991-2 Sweden 2011 - USER' dialog box for EG B. On the left, under 'Representative values required', the 'Characteristic' checkbox is checked, while 'Combination (psi0)', 'Frequent (psi1)', 'Infrequent (psi1,infq)', and 'Quasi-permanent (psi2)' are unchecked. On the right, under 'Load groups to include', 'Group 1a - LM1', 'Group 4 - LM4', and 'Group 5 - LM3' are unchecked, while 'Complementary load model' is checked. Below this, 'Dynamic amplification (additional)' is set to 25%. The 'Vehicle(s)' field is set to 'Type b; Type c; Type d; Typ'. At the bottom, 'Include associated LM1' is unchecked.

Dynamic amplification (additional): 25 %

Vehicle selection: Type b → o

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:30
		Date :	Created :

3.6.5.8 Combined traffic load (TRAFIK)

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

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

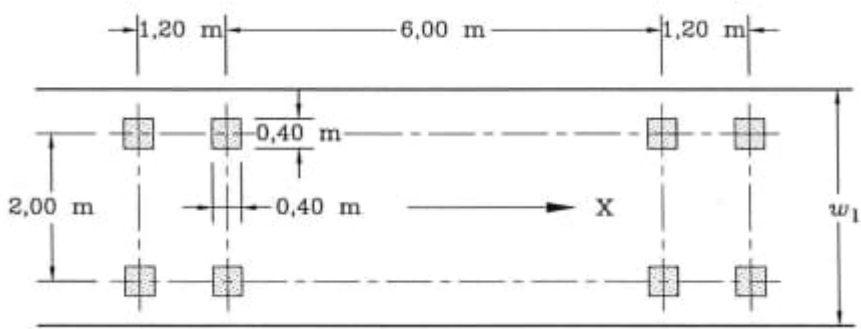
Envelope...TRAFIK :

Envelope
LM 1
LM 2
EG A
EG B

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:31
		Date :	Created :

3.6.5.9 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.

Traffic category:
TRVINFRA-0027 table 7.1-5(h) gives traffic category 3

Reference values for the number of heavy vehicles:
According to SS-EN 1991-2 section 4.6.1 table 4.5(n), Category 3 is obtained

→ $N_{obs} = 125,000 \text{ vehicles/year}$

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:32
		Date :	Created :

The load definition:

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

Representative values required	Load groups to include
☒ Characteristic	☐ Group 1a - LM1
☐ Combination (psi0)	☐ Group 4 - LM4
☐ Frequent (psi1)	☐ Complementary load model
☐ Infrequent (psi1,infq)	Dynamic amplification (additional) 20 %
☐ Quasi-permanent (psi2)	Vehicle(s) None ...
	☒ Group 5
	Vehicle(s) UTM3 ...
	☐ Include associated LM1

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:33
	Pretensioned curved tapered box bridge (FCM)	Date :	Created :

3.7 PRESTESS

Analysis of pre tensioned cable is studied at times : t_0 (5 days) until t_2 (120 years).

3.7.1 General

Properties chosen system see below.

Material :

$$f_{p0.1k} = 1675MPa$$

$$f_{pk} = 1860MPa$$

$$E_{sk} = 195GPa$$

$$\mu = 0.18$$

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

Casting tube :

80 mm / 86 mm

Slip during locking:

6 mm

Permissible curvature :

$$R_{\min} = 5.7m$$

Cabel area :

$$A_p = 4106mm^2$$

Anchor plate :

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

Ultimate load :

$$F_u = 4106mm^2 \cdot 1860MPa = 7637kN$$

Permissible stress before locking :

See SS-EN 1992-1-1 section 5.10.2.1

$$\sigma_{p,max}^{before} = \min(0.8f_{pk}; 0.9f_{p0.1k}) = \min(1488MPa; 1507MPa) = 1488MPa$$

Permissible stress after locking.:

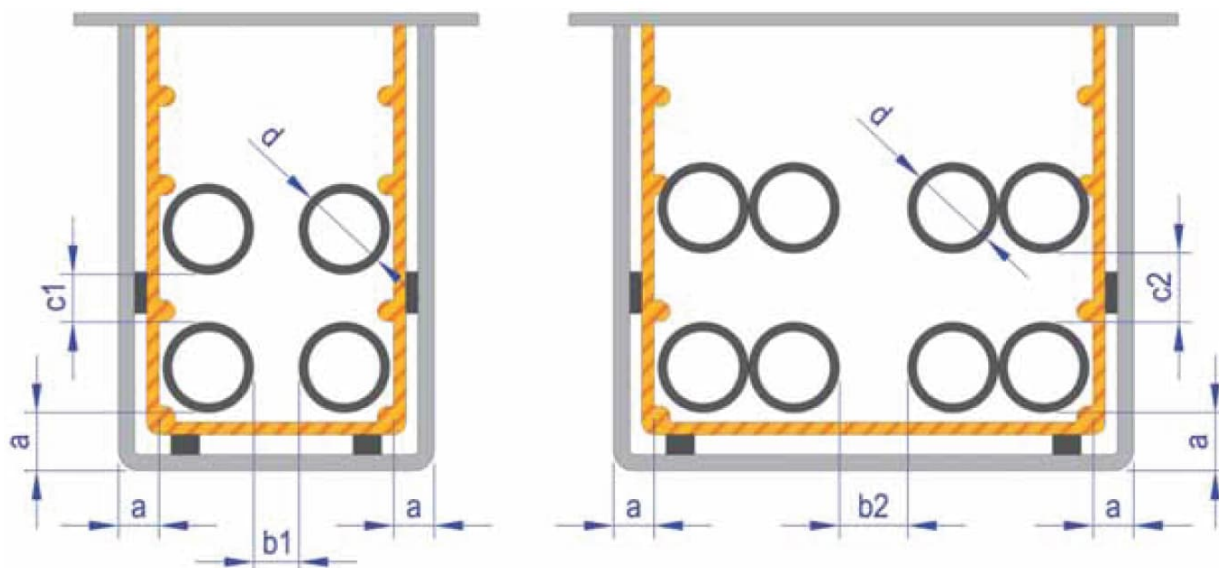
See SS-EN 1992-1-1 section 5.10.3

$$\sigma_{p,max}^{after} = \min(0.75f_{pk}; 0.85f_{p0.1k}) = \min(1395MPa; 1423MPa) = 1395MPa$$

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:34
		Date :	Created :

3.7.2 Execution

Recommended measurements :



$d = 90 \text{ mm}$

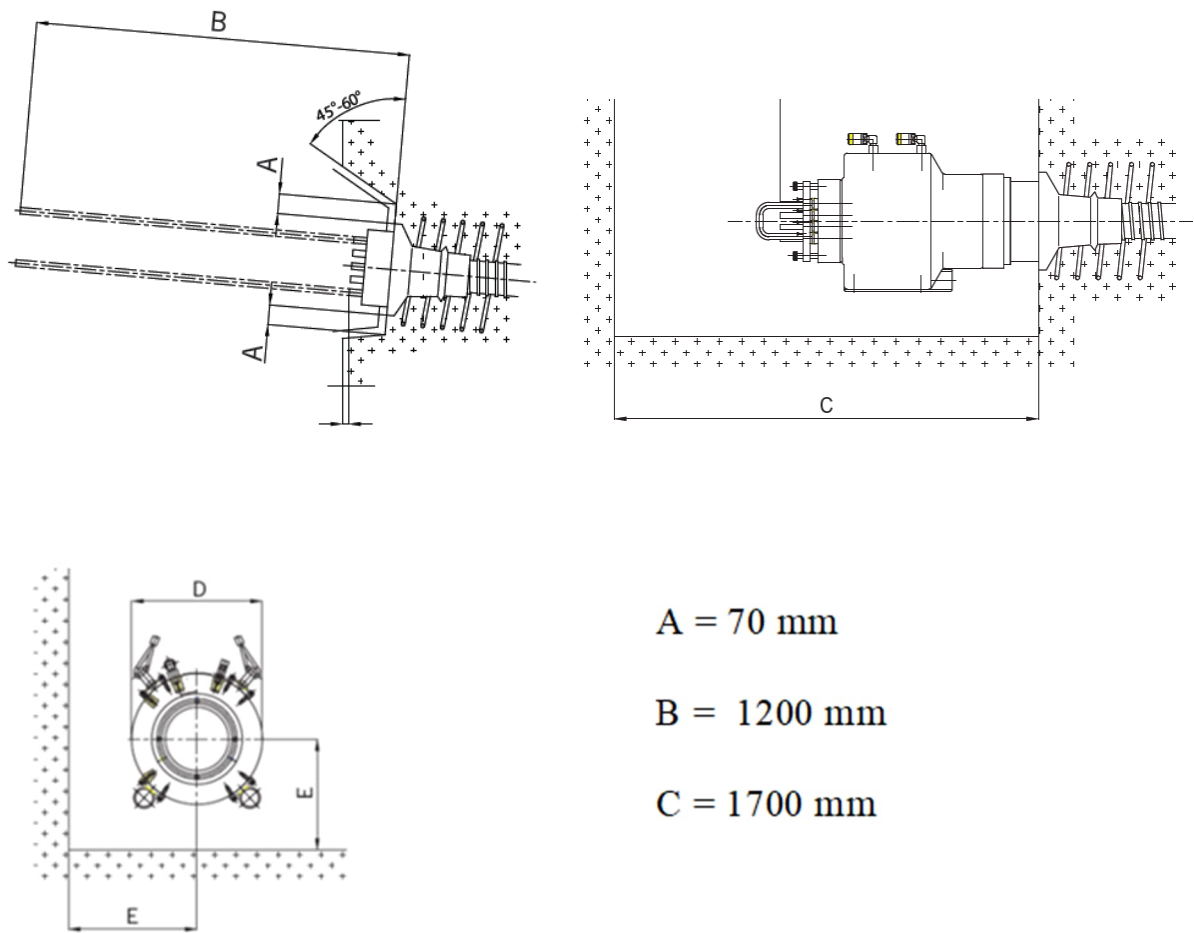
$a > 50 \text{ mm}$

$b1, c1 > 0.7d = 63 \text{ mm}$ but 100 chosen !

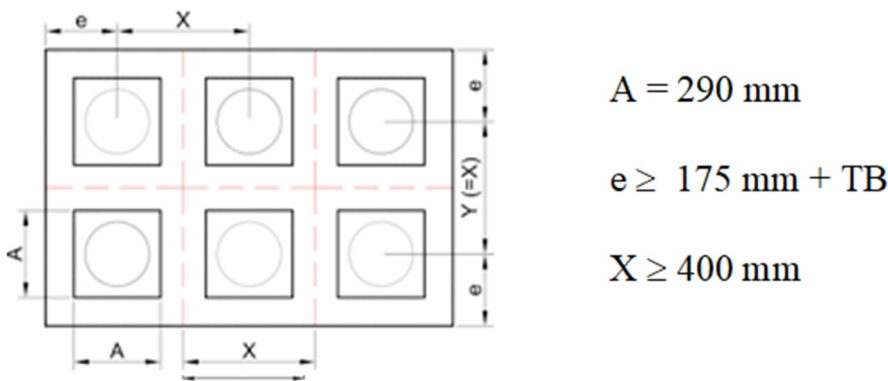
$b2, c2 > 1.0d = 90 \text{ mm}$ but 100 mm chosen !

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:35
		Date :	Created :

Demand for space during tensioning :



Measurements of cables 37φ15 :



	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:36
		Date :	Created :

3.7.3 Time concrete aging

In order to determine time losses due to shrinkage and creep all parts of bridge is assumed to be statically active 7 days after casting, see page A3:15.

Age

Age at activation time

☒ Specified directly

5.0

☐ Calculated with adjustment for temperature during curing

Set...

Age when shrinkage begins

5.0

Name

Age 5

(2)

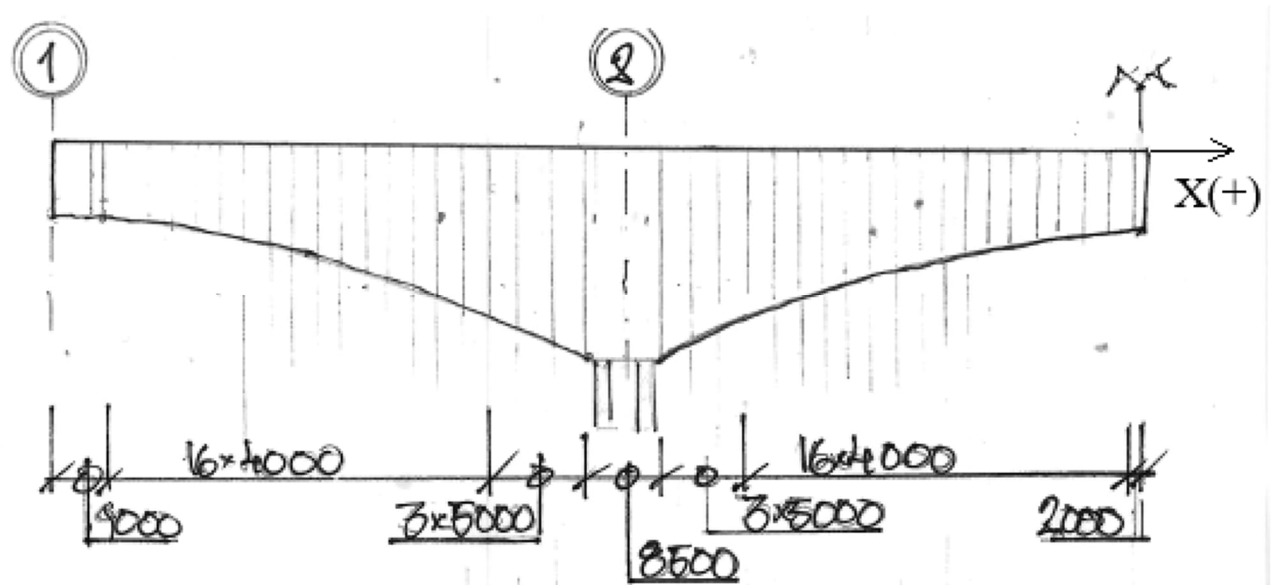


ELEVATION

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:37
		Date :	Created :

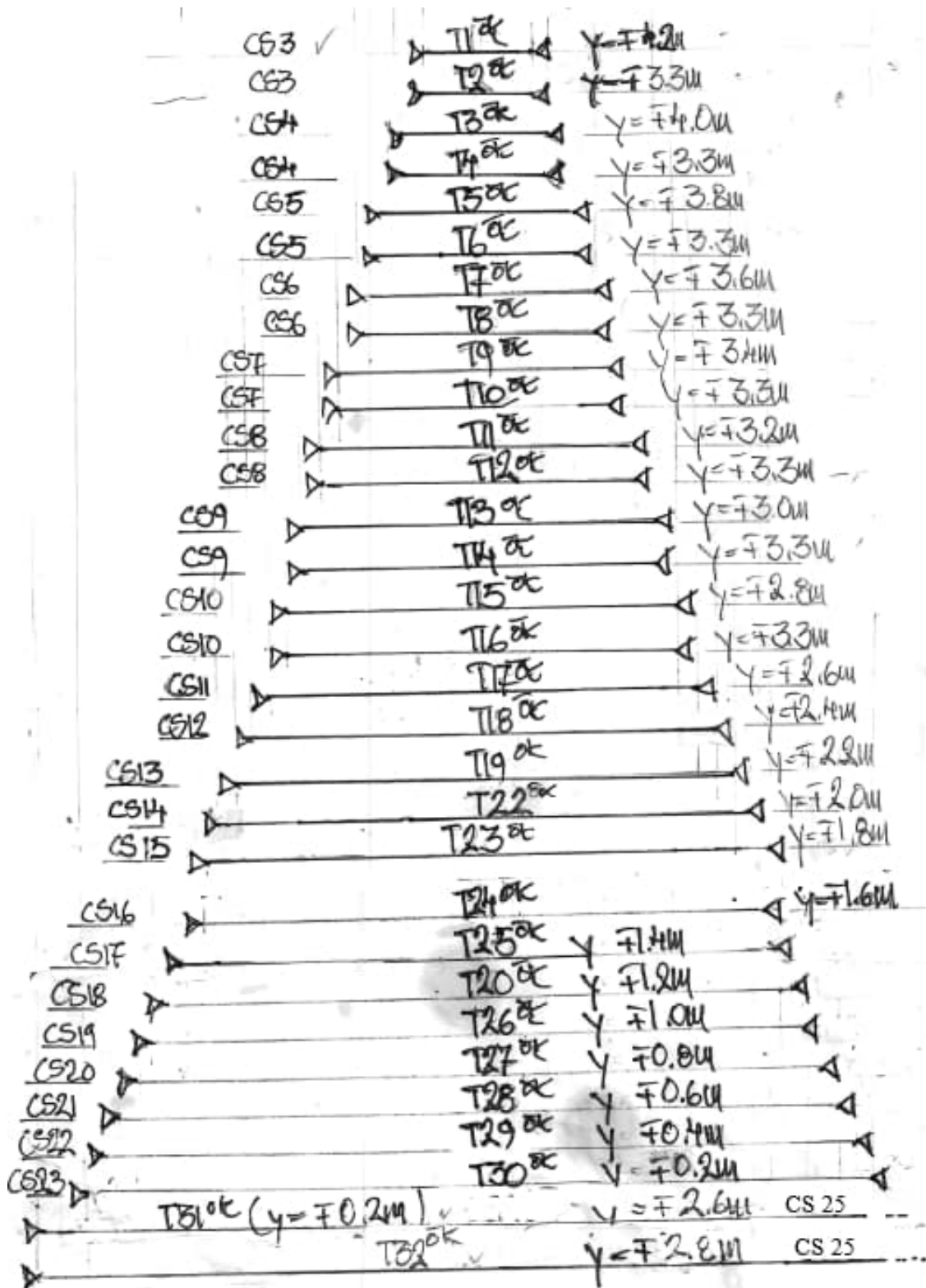
3.7.4 Tendon location

Cables are defined using “global coordinates”



ELEVATION

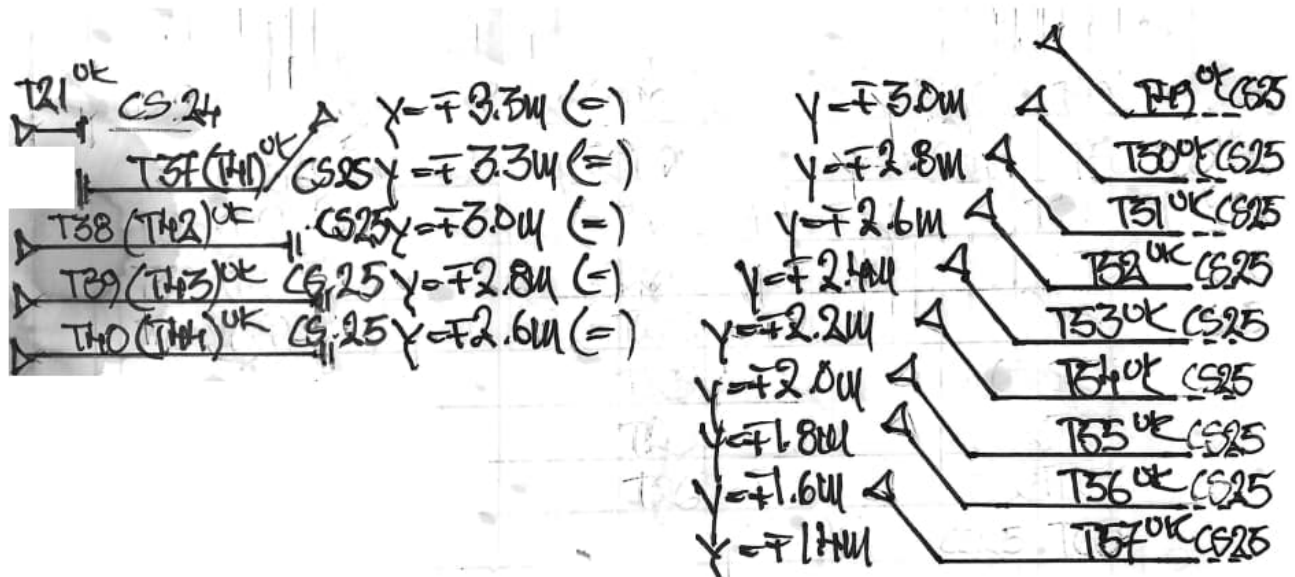
	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:38
	Pretensioned curved tapered box bridge (FCM)	Date :	Created :



ELEVATION

Cables T1-T22, T31 and T32.

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:39
	Pretensioned curved tapered box bridge (FCM)	Date :	Created :



ELEVATION

Cables T21, T37-T44 and T49-T57.

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:40
		Date :	Created :

Casting stage	Tendon	X:start	X:end	Y(+)	Nr.
CS 1:S2	-	90.75	97.75	-	-
CS 1:S3	-	263.25	270.25	-	-
CS 2:S2	-	88.00	100.50	-	-
CS 2:S3	-	260.50	273.00	-	-
CS 3:S2	T1 - S2:L	85.00	103.50	+4.2	1
"	T1 - S2:R	"	"	-4.2	2
"	T2 - S2:L	"	"	+3.3	3
"	T2 - S2:R	"	"	-3.3	4
CS 3:S3	T1 - S3:L	257.50	276.00	+4.2	5
"	T1 - S3:R	"	"	-4.2	6
"	T2 - S3:L	"	"	+3.3	7
"	T2 - S3:R	"	"	-3.3	8
CS 4:S2	T3 - S2:L	82.00	106.50	+4.0	9
"	T3 - S2:R	"	"	-4.0	10
"	T4 - S2:L	"	"	+3.3	11
"	T4 - S2:R	"	"	-3.3	12
CS 4:S3	T3 - S3:L	254.50	279.00	+4.0	13
"	T3 - S3:R	"	"	-4.0	14
"	T4 - S3:L	"	"	+3.3	15
"	T4 - S3:R	"	"	-3.3	16
CS 5:S2	T5 - S2:L	79.00	109.50	+3.8	17
"	T5 - S2:R	"	"	-3.8	18
"	T6 - S2:L	"	"	+3.3	19
"	T6 - S2:R	"	"	-3.3	20
CS 5:S3	T5 - S3:L	251.50	282.00	+3.8	21
"	T5 - S3:R	"	"	-3.8	22
"	T6 - S3:L	"	"	+3.3	23
"	T6 - S3:R	"	"	-3.3	24
CS 6:S2	T7 - S2:L	76.00	112.50	+3.6	25
"	T7 - S2:R	"	"	-3.6	26
"	T8 - S2:L	"	"	+3.3	27
"	T8 - S2:R	"	"	-3.3	28
CS 6:S3	T7 - S3:L	248.50	285.00	+3.6	29
"	T7 - S3:R	"	"	-3.6	30
"	T8 - S3:L	"	"	+3.3	31
"	T8 - S3:R	"	"	-3.3	32
-	-	m	m	m	-

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:41
		Date :	Created :

Casting stage	Tendon	X:start	X:end	y(+).	Nr.
CS 7:S2	T9 - S2:L	73.0	112.5	+3.4	33
"	T9 - S2:R	"	"	-3.4	34
"	T10 - S2:L	"	"	+3.3	35
"	T10 - S2:R	"	"	-3.3	36
CS 7:S3	T9 - S3:L	245.5	288.0	+3.4	37
"	T9 - S3:R	"	"	-3.4	38
"	T10 - S3:L	"	"	+3.3	39
"	T10 - S3:R	"	"	-3.3	40
CS 8:S2	T11- S2:L	69.0	119.5	+3.2	41
"	T11 - S2:R	"	"	-3.2	42
"	T12- S2:L	"	"	+3.3	43
"	T12 - S2:R	"	"	-3.3	44
CS 8:S3	T11- S3:L	241.5	292.0	+3.2	45
"	T11 - S3:R	"	"	-3.2	46
"	T12 - S3:L	"	"	+3.3	47
"	T12 - S3:R	"	"	-3.3	48
CS 9:S2	T13 - S2:L	65.0	123.5	+3.0	49
"	T13 - S2:R	"	"	-3.0	50
"	T14 - S2:L	"	"	+3.3	51
"	T14- S2:R	"	"	-3.3	52
CS 9:S3	T13 - S3:L	237.5	296.0	+3.0	53
"	T13 - S3:R	"	"	-3.0	54
"	T14 - S3:L	"	"	+3.3	55
"	T14 - S3:R	"	"	-3.3	56
CS 10:S2	T15 - S2:L	61.0	127.5	+2.8	57
"	T15 - S2:R	"	"	-2.8	58
"	T16 - S2:L	"	"	+3.3	59
"	T16 - S2:R	"	"	-3.3	60
CS 10:S3	T15 - S3:L	233.5	300.0	+2.8	61
"	T15 - S3:R	"	"	-2.8	62
"	T16 - S3:L	"	"	+3.3	63
"	T16 - S3:R	"	"	-3.3	64
-	-	m	m	m	-

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:42
		Date :	Created :

Casting stage	Tendon	X:start	X:end	y(+)	Nr.
CS 11:S2	T17 - S2:L	57.0	131.5	+2.6	65
"	T17 - S2:R	"	"	-2.6	66
CS 11:S3	T17 - S3:L	229.5	304.0	+2.6	67
"	T17 - S3:R	"	"	-2.6	68
CS 12:S2	T18 - S2:L	53.0	135.5	+2.4	69
"	T18 - S2:R	"	"	-2.4	70
CS 12:S3	T18 - S3:L	225.5	308.0	+2.4	71
"	T18 - S3:R	"	"	-2.4	72
CS 13:S2	T19 - S2:L	49.0	139.5	+2.2	73
"	T19 - S2:R	"	"	-2.2	74
CS 13:S3	T19 - S3:L	221.5	312.0	+2.2	75
"	T19 - S3:R	"	"	-2.2	76
CS 14:S2	T22 - S2:L	45.0	143.5	+2.0	77
"	T22 - S2:R	"	"	-2.0	78
CS 14:S3	T22 - S3:L	217.5	316.0	+2.0	79
"	T22 - S3:R	"	"	-2.0	80
CS 15:S2	T23 - S2:L	41.0	147.5	+1.8	81
"	T23 - S2:R	"	"	-1.8	82
CS 15:S3	T23 - S3:L	213.5	320.0	+1.8	83
"	T23 - S3:R	"	"	-1.8	84
CS 16:S2	T24 - S2:L	37.0	151.5	+1.6	85
"	T24 - S2:R	"	"	-1.6	86
CS 16:S3	T24 - S3:L	209.5	324.0	+1.6	87
"	T24 - S3:R	"	"	-1.6	88
CS 17:S2	T25 - S2:L	33.0	155.5	+1.4	89
"	T25 - S2:R	"	"	-1.4	90
CS 17:S3	T25 - S3:L	205.5	328.0	+1.2	91
"	T25 - S3:R	"	"	-1.2	92
CS 18:S2	T20 - S2:L	29.0	159.5	+1.2	93
"	T20 - S2:R	"	"	-1.2	94
CS 18:S3	T20 - S3:L	201.5	332.0	+1.0	95
"	T20 - S3:R	"	"	-1.0	96
CS 19:S2	T26 - S2:L	25.0	163.5	+1.0	97
"	T26 - S2:R	"	"	-1.0	98
CS 19:S3	T26 - S3:L	197.5	336.0	+1.0	99
"	T26 - S3:R	"	"	-1.0	100
-	-	m	m	m	-

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:43
		Date :	Created :

Casting stage	Tendon	X:start	X:end	y(+)	Nr.
CS 20:S2	T27 - S2:L	21.0		+0.8	101
"	T27 - S2:R	"	"	-0.8	102
CS 20:S3	T27 - S3:L	193.5		+0.8	103
"	T27 - S3:R	"	"	-0.8	104
CS 21:S2	T28 - S2:L	17.0		+0.6	105
"	T28 - S2:R	"	"	-0.6	106
CS 21:S3	T28 - S3:L	189.5		+0.4	107
"	T28 - S3:R	"	"	-0.4	108
CS 22:S2	T29 - S2:L	13.0		+0.4	109
"	T29 - S2:R	"	"	-0.4	110
CS 22:S3	T29 - S3:L	185.5		+0.4	111
"	T29 - S3:R	"	"	-0.4	112
CS 23:S2	T30 - S2:L	9.0		+0.2	113
"	T30 - S2:R	"	"	-0.2	114
CS 23:S3	T30 - S3:L	181.5		+0.2	115
	T30 - S3:R	"	"	-0.2	116
CS 24:S1	T21 - S1:L	0	7.0	+3.3	117
"	T21 - S1:R	"	"	-3.3	118
CS 24:S4	T21 - S4:L	354.0	361.0	+3.3	119
"	T21 - S4:R	"	"	-3.3	120
CS 25	T31 :L	0		+2.6	121
"	T31:R	"	"	-2.6	122
"	T32 :L	7.0		+2.8	123
"	T32:R	"	"	-2.8	124
"	T37:L	0		+3.3	125
"	T37:R	"	"	-3.3	126
"	T38 :L	0		+3.0	127
"	T38:R	"	"	-3.0	128
"	T39:L	0		+2.8	129
"	T39:R	"	"	-2.8	130
"	T40:L	0		+2.6	131
"	T40:R	"	"	-2.6	132
"	T41 :L	332.0	354.0	+3.3	133
"	T41:R	"	"	-3.3	134
"	T42:L	332.0	361.0	+3.0	135
"	T42:R	"	"	-3.0	136
"	T43:L	328.0	361.0	+2.8	137
"	T43:R	"	"	-2.8	138
-	-	m	m	m	-

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:44
		Date :	Created :

Casting stage	Tendon	X:start	X:end	y(+)	Nr.
CS 25	T44 :L	324.0	361.0	+2.6	139
"	T44:R	"	"	-2.6	140
"	T49 :L	163.5	197.5	+2.8	141
"	T49:R	"	"	-2.8	142
"	T50 :L	159.5	201.5	+2.8	143
"	T50:R	"	"	-2.8	144
"	T51 :L	155.5	205.5	+2.6	145
"	T51:R	"	"	-2.6	146
"	T52 :L	151.5	209.5	+2.4	147
"	T52:R	"	"	-2.4	148
"	T53 :L	147.5	213.5	+2.2	149
"	T53:R	"	"	-2.2	150
"	T54 :L	143.5	217.5	+2.0	151
"	T54:R	"	"	-2.0	152
"	T55 :L	139.5	221.5	+1.8	153
"	T55:R	"	"	-1.8	154
"	T56 :L	135.5	225.5	+1.6	155
"	T56:R	"	"	-1.6	156
"	T57 :L	131.5	229.5	+1.4	155
"	T57:R	"	"	-1.4	156
-	-	m	m	m	-

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:45
	Pretensioned curved tapered box bridge (FCM)	Date :	Created :

3.7.4.1 Casting stage 3: Tendon T1 & T2

Tendons are used as seen in sketches below.

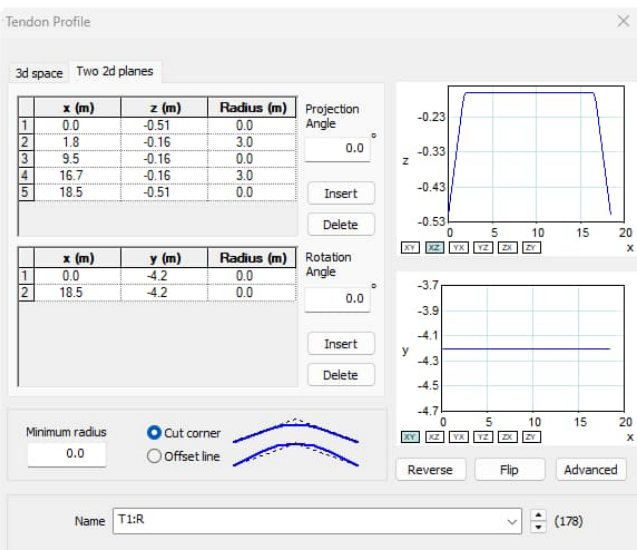
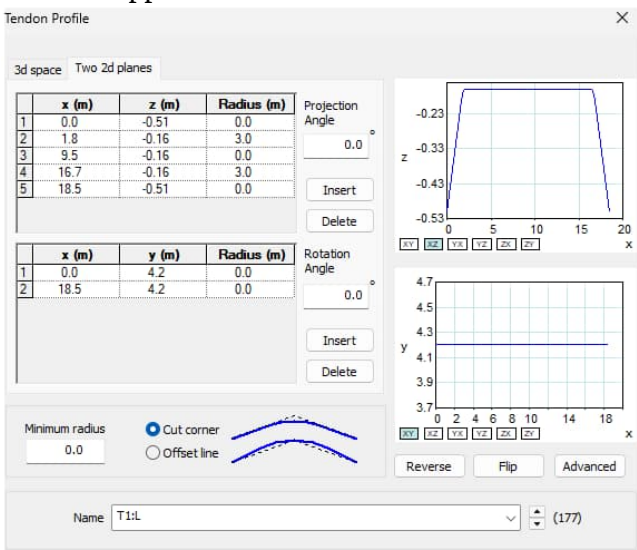


PLAN



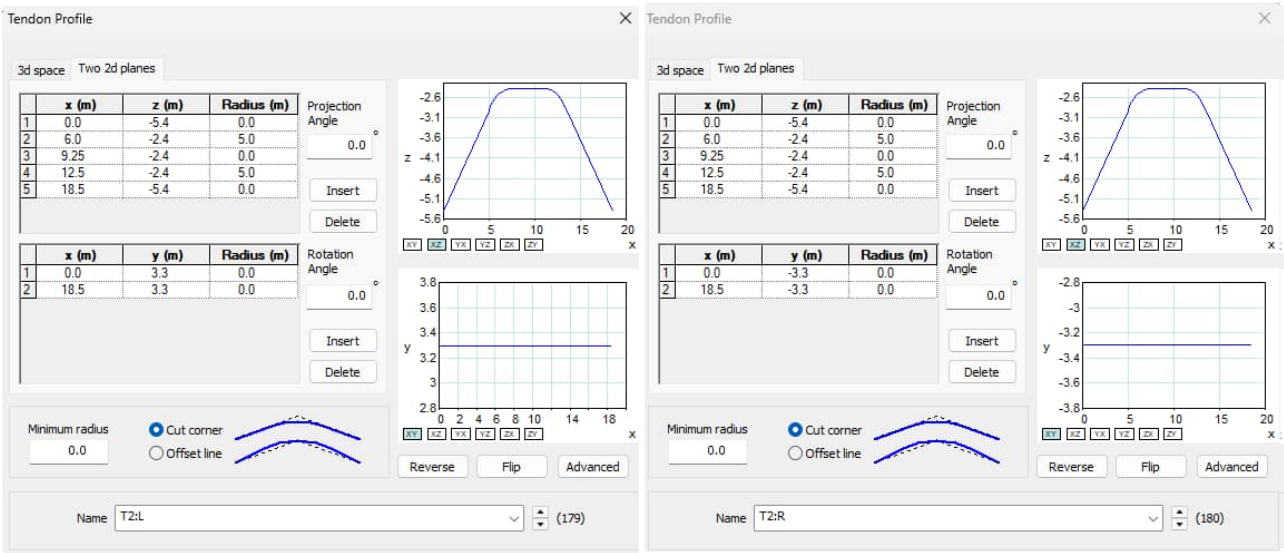
ELEVATION

Table definition tendon - T1:
See also appendix 1.



	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:46
	Pretensioned curved tapered box bridge (FCM)	Date :	Created :

Definition tendon – T2:
See also appendix 1.



	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:47
		Date :	Created :

3.7.4.2 Casting stage 4: Tendon T3 & T4

Tendons are used as seen in sketches below.



PLAN



ELEVATION

Table definition tendons:
See appendix 1.

-

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:48
		Date :	Created :

3.7.4.3 Casting stage 5: Tendon T5 & T6

Tendons are used as seen in sketches below.



PLAN



ELEVATION

Table definition tendons:
See appendix 1.

-

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:49
		Date :	Created :

3.7.4.4 Casting stage 6: Tendon T7 & T8

Tendons are used as seen in sketches below.



PLAN



ELEVATION

Table definition tendons:
See appendix 1.

-

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:50
		Date :	Created :

3.7.4.5 Casting stage 7: Tendon T9 & T10

Tendons are used as seen in sketches below.



PLAN



ELEVATION

Table definition tendons:
See appendix 1.

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:51
		Date :	Created :

3.7.4.6 Casting stage 8: Tendon T11 & T12

Tendons are used as seen in sketches below.



PLAN



ELEVATION

Table definition tendons:
See appendix 1.

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:52
		Date :	Created :

3.7.4.7 Casting stage 9: Tendon T13 & T14

Tendons are used as seen in sketches below.



PLAN



ELEVATION

Table definition tendons:
See appendix 1.

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:53
		Date :	Created :

3.7.4.8 Casting stage 10: Tendon T15 & T16

Tendons are used as seen in sketches below.



PLAN



ELEVATION

Table definition tendons:
See appendix 1.

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:54
		Date :	Created :

3.7.4.9 Casting stage 11: Tendon T17

Tendons are used as seen in sketches below.



PLAN



ELEVATION

Table definition tendons:
See appendix 1.

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:55
		Date :	Created :

3.7.4.10 Casting stage 12: Tendon T18

Tendons are used as seen in sketches below.



PLAN



ELEVATION

Table definition tendons:
See appendix 1.

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:56
		Date :	Created :

3.7.4.11 Casting stage 13: Tendon T19

Tendons are used as seen in sketches below.



PLAN



ELEVATION

Table definition tendons:
See appendix 1.

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:57
		Date :	Created :

3.7.4.12 Casting stage 14: Tendon T22

Tendons are used as seen in sketches below.



PLAN



ELEVATION

Table definition tendons:
See appendix 1.

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:58
		Date :	Created :

3.7.4.13 Casting stage 15: Tendon T23

Tendons are used as seen in sketches below.



PLAN



ELEVATION

Table definition tendons:
See appendix 1.

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:59
		Date :	Created :

3.7.4.14 Casting stage 16: Tendon T24

Tendons are used as seen in sketches below.



PLAN



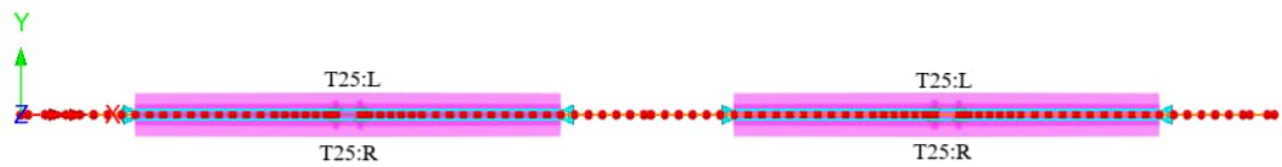
ELEVATION

Table definition tendons:
See appendix 1.

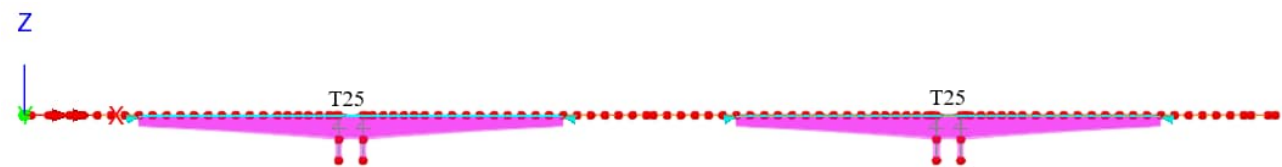
	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:60
		Date :	Created :

3.7.4.15 Casting stage 17: Tendon T25

Tendons are used as seen in sketches below.



PLAN



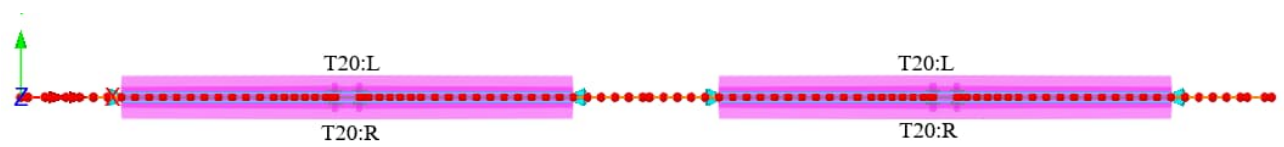
ELEVATION

Table definition tendons:
See appendix 1.

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:61
		Date :	Created :

3.7.4.16 Casting stage 18: Tendon T20

Tendons are used as seen in sketches below.



PLAN



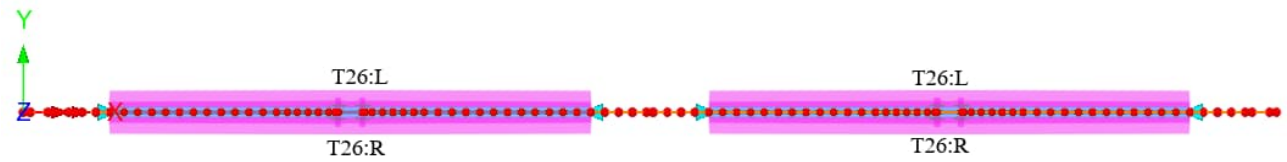
ELEVATION

Table definition tendons:
See appendix 1.

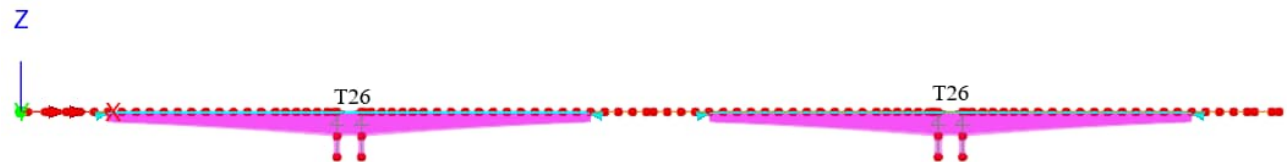
	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:62
		Date :	Created :

3.7.4.17 Casting stage 19: Tendon T26

Tendons are used as seen in sketches below.



PLAN



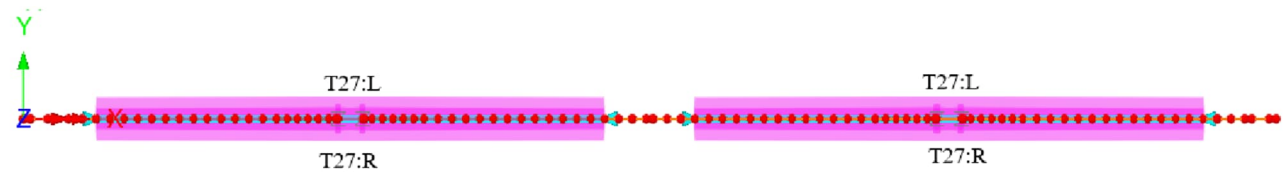
ELEVATION

Table definition tendons:
See appendix 1.

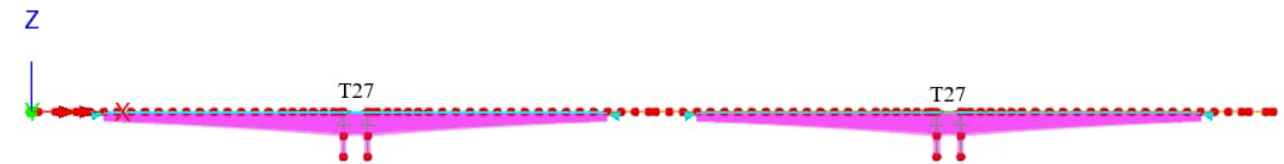
	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:63
		Date :	Created :

3.7.4.18 Casting stage 20: Tendon T27

Tendons are used as seen in sketches below.



PLAN



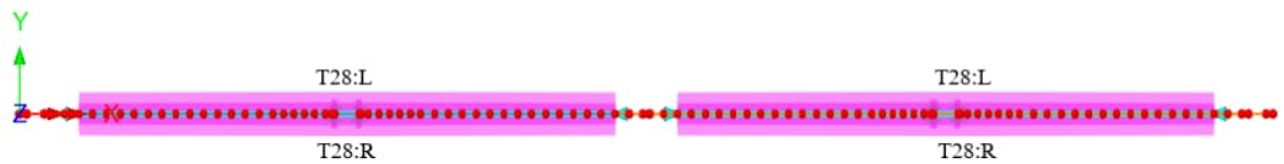
ELEVATION

Table definition tendons:
See appendix 1.

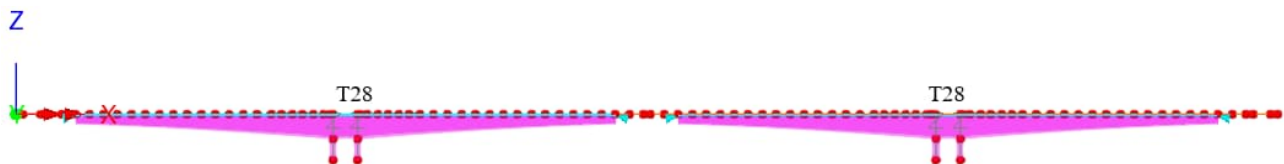
	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:64
		Date :	Created :

3.7.4.19 Casting stage 21: Tendon T28

Tendons are used as seen in sketches below.



PLAN



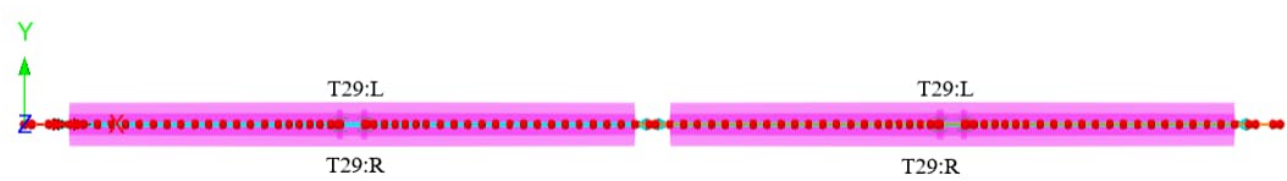
ELEVATION

Table definition tendons:
See appendix 1.

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:65
		Date :	Created :

3.7.4.20 Casting stage 22: Tendon T29

Tendons are used as seen in sketches below.



PLAN



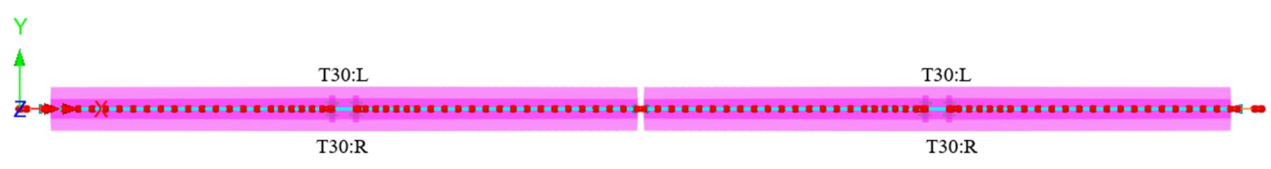
ELEVATION

Table definition tendons:
See appendix 1.

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:66
		Date :	Created :

3.7.4.21 Casting stage 23: Tendon T30

Tendons are used as seen in sketches below.



PLAN



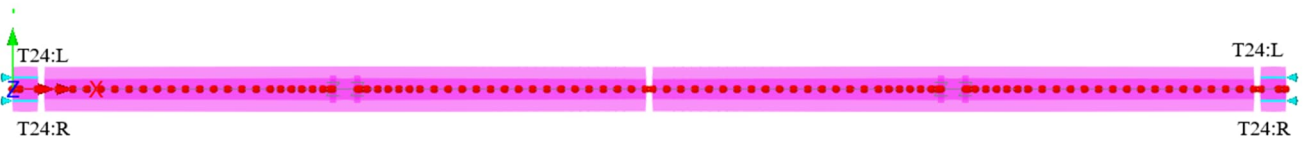
ELEVATION

Table definition tendons:
See appendix 1.

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:67
		Date :	Created :

3.7.4.22 Casting stage 24: Tendon T21

Tendons are used as seen in sketches below.



PLAN



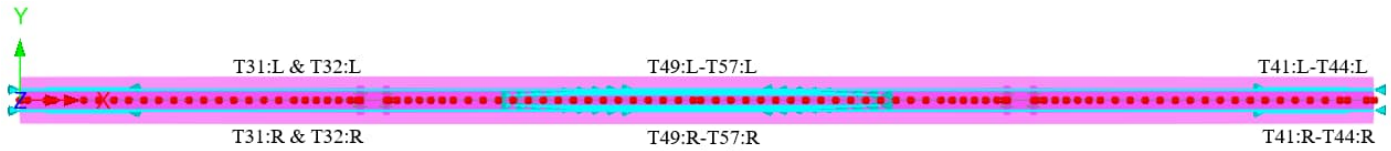
ELEVATION

Table definition tendons:
See appendix 1.

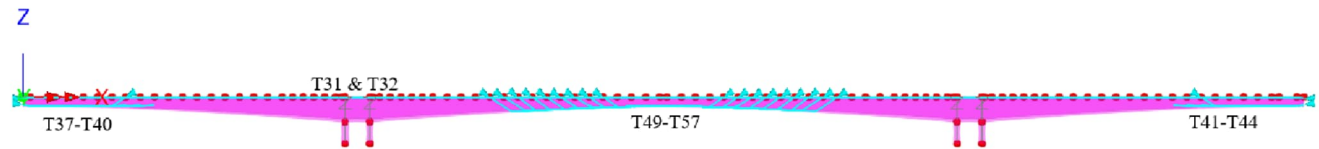
	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:68
		Date :	Created :

3.7.4.23 Casting stage 25: Tendon T37-T44 & T49-T57

Tendons are used as seen in sketches below.



PLAN



ELEVATION

Table definition tendons:
See appendix 1.

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:69
		Date :	Created :

3.7.5 Tendon material

Tendon Properties

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

☒ Losses based on time inputs and calculated stresses
☐ Approximate losses, requiring input of estimated stresses

Elastic shortening
☒ Based on design code Set losses...
☐ User-defined Set losses...
☐ Ignore effects

General

Tendon area: 4.1055E3 mm²
Modulus of elasticity for tendon: 195.0E6 kN/m²

Installation losses

Unintentional angular displacement: 0.01 rad/m
Duct friction coefficient: 0.19

Post-installation losses

Include: Yes
Tensile strength of prestressing steel: 1.86E3 N/mm²
Characteristic 0.1% proof-stress of prestressing steel, fp0....: 1.675E3 N/mm²
Relaxation class: Class 2
Relaxation loss at 1000hrs: 2.5 %

Name: Tendon material (1)

Friction coefficient installation

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

$$\mu = 0.19$$

$$k = 0.010 \frac{\text{rad}}{\text{m}}$$

Chosen prestress before locking (see page A3:33)

$$\max F_p = 4106 \text{ mm}^2 \cdot 1488 \text{ MPa} = 6110 \text{ kN} \text{ but } F_p = 6100 \text{ kN} \text{ is chosen.}$$

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:70
		Date :	Created :

3.7.6 Load definition

Slip is 6 mm but due to re-tensioning of tendons after locking slip 0 mm is applied.

Load	Angle	Slip	Left side	Right side	Prestress force
T1-T23	0	0	Active	Active	6100
T24:S1	0	0	Active	Passive	6100
T24:S4	0	0	Passive	Active	6100
T31-T32	0	0	Active	Active	6100
T37	0	0	Passive	Active	6100
T38-T40	0	0	Active	Passive	6100
T41	0	0	Active	Passive	6100
T42-T44	0	0	Passive	Active	6100
T49-T57	0	0	Active	Active	6100
-	deg	mm	-	-	kN

3.7.7 Envelope prestress

Envelope.PT::

Load case	Permanent factor	Variable factor
Prestress (stage 25)	1.00	0
Prestress (longterm)	0.90	0.20

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:71
		Date :	Created :

3.8 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 Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:72
		Date :	Created :

3.8.1 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).

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:73
		Date :	Created :

Design method D3 (set C):

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

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

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

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

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).

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:74
		Date :	Created :

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		$\Psi\gamma_{ULS-A}$	$\Psi\gamma_{ULS-B}$		$\Psi\gamma_{ULS}$
1	Dead weight	max	1.35	1.20	$\Rightarrow$	1.20
		min	1.00	1.00		1.00
2	Surfacing	max	1.49	1.33		1.33
		min	0.90	0.90		0.90
3	Filling	max	1.49	1.33		1.33
		min	0.90	0.90		0.90
4	Earth pressure	max	1.49	1.33		1.48 ^{1.)}
		min	0.90	0.90		0.90
5	Water pressure	max	1.35	1.09		1.09
		min	1.00	1.00		1.00
6	Support settlement	max	1.35	1.20		1.20
		min	1.00	1.00		1.00
7	Shrinkage	max	1.35	1.20		1.20
		min	1.00	1.00		1.00
8	Prestress	max	1.35	1.35		1.35
		min	1.00	1.00		1.00

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:75
		Date :	Created :

Variable loads:

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

⇒

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:76
		Date :	Created :

Load combination smart ULS-PERM:

Load case	Permanent factor	Variable factor
Dead weight (stage 7	1.00	0.20
Surfacing	0.90	0.43

Load combination smart ULS-VAR:

Load case	Permanent factor	Variable factor
TRAFIK	1.03	0.47

Load combination smart ULS:

Load case	Permanent factor	Variable factor
ULS-PERM	1	0
PT	1	0.35
ULS-VAR	0	1

Load combination smart ULS-0:

(Is identical to ULS but does not contain prestress)

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

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:77
		Date :	Created :

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.

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:78
		Date :	Created :

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	1.48 ^{3.)}	1.48 ^{3.)}	1.34 ^{3.)}
		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
8	Prestress	max	1.00	1.00	1.00
		min	1.00	1.00	1.00

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:79
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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

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:80
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Load combination smart *SLS-PERM* :

Loadcase	Permanent factor	Variable factor
Dead weight (stage 7)	1.00	0
Surfacing	0.90	0.20

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Load combination smart *SLS-K-VAR* :

Load case	Permanent factor	Variable factor
TRAFIK	0.75	0.25

Load combination smart *SLS-F-VAR* :

Load case	Permanent factor	Variable factor
TRAFIK	0	0.75

Load combination smart *SLS-K* :

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

..

Load combination smart *SLS-F* :

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

Load combination smart *SLS-Q* :

Load case	Permanent factor	Variable factor
Dead weight (stage 7)	1.00	0
Surfacing	1.00	0.20
Prestress (longterm)	1	0

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	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:81
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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	Egentyngd	max	1.00
		min	1.00
2	Beläggning	max	1.10
		min	0.90
3	Överfyllnad	max	1.10
		min	0.90
4	Jordtryck	max	1.48
		min	0.90
5	Vattentryck	max	1.00
		min	1.00
6	Stödförskjutning	max	1.00
		min	1.00
7	Krympning	max	1.00
		min	1.00
8	Prestress	max	1.00
		min	1.00

	Part A - CALCULATION ASSUMPTIONS Pretensioned curved tapered box bridge (FCM)	Status :	Page: A3:82
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Variable loads:

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

Load combination smart FAT.:

Load case	Permanent factor	Variable factor
Dead weight (stage 7)	1.00	0
Surfacing	1.00	0
Prestress (longterm)	1.0	0
UTM3	-	1.00