Concessionaria per la progettazione, realizzazione e gestione del collegamento stabile tra la Sicilia e il Continente Organismo di Diritto Pubblico
(Legge n° 1158 del 17 dicembre 1971, modificata dal D.Lgs. n°114 del 24 aprile 2003)

PONTE SULLO STRETTO DI MESSINA

PROGETTO DEFINITIVO

EUROLINK S.C.p.A.

IMPREGILO S.p.A. (MANDATARIA)
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Unità Funzionale	OPERA DI ATTRAVERSAMENTO	PS0210_F0
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INDICE

1 Introduction

This report presents design calculations for the secondary structures on the Messina Strait Bridge.

The secondary structures include the following components:

- Service lane
- Wind screen on service lane
- Platform along railway
- Cross overs and service areas
- Lighting mast
- Catenary mast
- Portal for road signs

1.1 Outline

This report is organized into the following sections:

- Section 1 is the introduction and outline
- Section 2 provides a list of reference materials, including design specifications, design codes and reference drawings
- Section 3 provides details of the materials used for the secondary structures
- Section 4 provides design calculations for the secondary structure components

2 Design References

2.1 Design Specifications

CG1000-P-RG-D-P-GE-00-00-00-00-00-02-A - “Design Basis, Structural, Annex,” COWI 2010.

GCG.F.05.03 “Design Development – Requirements and Guidelines,” Stretto di Messina, 2004 October 22.

GCG.G.03.02 “Structural Steel Works and Protective Treatments,” Stretto di Messina, 2004 July 30.

A9055-NOT-3-006 "Design criterion: Loads on walkways", COWI 2010.

A9055-NOT-3-012 "Design criterion: Traffic loads on cross-overs and service areas", COWI 2010.

2.2 Design Codes

“Norme tecniche per le costruzioni,” 2008 (NTC08).

EN 1991 Eurocode 1: Actions on Structures - Part 1-4: General actions - Wind actions

EN 1993 Eurocode 3: Design of Steel Structures – Part 1-1: General rules and rules for buildings

EN 1993 Eurocode 3: Design of Steel Structures – Part 1-5: Plated structural elements

EN 1993 Eurocode 3: Design of Steel Structures – Part 1-8: Design of joints

2.3 Drawings

The secondary structure design drawings for this report are listed in

Service lane	CG1000-P-AX-D-P-SS-R4-00-00-00-00-01
Wind screen (1)	CG1000-P-AX-D-P-SS-R4-00-00-00-00-02
Wind screen (2)	CG1000-P-AX-D-P-SS-R4-00-00-00-00-20
Platform along railway - Plan and elevation	CG1000-P-PX-D-P-SS-R4-00-00-00-00-01
Platform along railway - Expansion device	CG1000-P-PX-D-P-SS-R4-00-00-00-00-02
Platform along railway - Sections and details	CG1000-P-BX-D-P-SS-R4-00-00-00-00-01
Cross over - Plan and section	CG1000-P-AX-D-P-SS-R4-00-00-00-00-03
Cross over - Details	CG1000-P-BX-D-P-SS-R4-00-00-00-00-02

Sub stations - Plan and Section	CG1000-P-AX-D-P-SS-R4-00-00-00-00-21
Sub stations - Details	CG1000-P-BX-D-P-SS-R4-00-00-00-00-03
Lighting mast	CG1000-P-AX-D-P-SS-R4-00-00-00-00-04
Catenary mast	CG1000-P-AX-D-P-SS-R4-00-00-00-00-05
Crash barrier	CG1000-P-AX-D-P-SS-R4-00-00-00-00-06
Portal for road signs	CG1000-P-AX-D-P-SS-R4-00-00-00-00-16
Access facilities, overview	CG1000-P-DX-D-P-SS-R4-00-00-00-00-01
Access to suspended deck, Overview	CG1000-P-DX-D-P-SS-R4-00-00-00-00-02
Access to suspended deck, Main access	CG1000-P-AX-D-P-SS-R4-00-00-00-00-17
Access to suspended deck, Typical	CG1000-P-AX-D-P-SS-R4-00-00-00-00-07
Waggon for suspended deck	CG1000-P-AX-D-P-SS-R4-00-00-00-00-08
Access to anchor block	CG1000-P-AX-D-P-SS-R4-00-00-00-00-09
Access to bearings, expansion joints and buffers at towers (1)	CG1000-P-AX-D-P-SS-R4-00-00-00-00-10
Access to bearings, expansion joints and buffers at towers (2)	CG1000-P-AX-D-P-SS-R4-00-00-00-00-19
Access to bearings and expansion joints at terminal structure	CG1000-P-AX-D-P-SS-R4-00-00-00-00-11
Lift, stair and door facilities in tower	CG1000-P-AX-D-P-SS-R4-00-00-00-00-12
Stairs in tower and grating in cross beams, sections and details	CG1000-P-AX-D-P-SS-R4-00-00-00-00-18
Gantries for tower	CG1000-P-AX-D-P-SS-R4-PA-00-00-00-01
Access to gantry for suspended deck	CG1000-P-AX-D-P-SS-R4-00-00-00-00-13
Gantry for suspended deck	CG1000-P-AX-D-P-SS-R4-PA-00-00-00-02
Main cables carriage and hanger basket	CG1000-P-AX-D-P-SS-R4-PA-00-00-00-03
Access to main cable in the midspan and at the saddle	CG1000-P-AX-D-P-SS-R4-00-00-00-00-15
Access to tower base	CG1000-P-AX-D-P-SS-R4-00-00-00-00-14
Dehumidification, System key plan	CG1000-P-1L-D-P-SS-R4-00-00-00-00-01
Dehumidification, Anchor block chambers	CG1000-P-1A-D-P-SS-R4-00-00-00-00-01
Dehumidification, Main cables	CG1000-P-1A-D-P-SS-R4-00-00-00-00-02
Dehumidification, Suspended deck, road and railway girders	CG1000-P-1A-D-P-SS-R4-00-00-00-00-03
Dehumidification, Towers	CG1000-P-1A-D-P-SS-R4-00-00-00-00-04
Dehumidification, Terminal structures	CG1000-P-1A-D-P-SS-R4-00-00-00-00-05

Table 2-1.

Service lane	CG1000-P-AX-D-P-SS-R4-00-00-00-00-01
Wind screen (1)	CG1000-P-AX-D-P-SS-R4-00-00-00-00-02
Wind screen (2)	CG1000-P-AX-D-P-SS-R4-00-00-00-00-20
Platform along railway - Plan and elevation	CG1000-P-PX-D-P-SS-R4-00-00-00-00-01
Platform along railway - Expansion device	CG1000-P-PX-D-P-SS-R4-00-00-00-00-02
Platform along railway - Sections and details	CG1000-P-BX-D-P-SS-R4-00-00-00-00-01
Cross over - Plan and section	CG1000-P-AX-D-P-SS-R4-00-00-00-00-03
Cross over - Details	CG1000-P-BX-D-P-SS-R4-00-00-00-00-02

Sub stations - Plan and Section	CG1000-P-AX-D-P-SS-R4-00-00-00-00-21
Sub stations - Details	CG1000-P-BX-D-P-SS-R4-00-00-00-00-03
Lighting mast	CG1000-P-AX-D-P-SS-R4-00-00-00-00-04
Catenary mast	CG1000-P-AX-D-P-SS-R4-00-00-00-00-05
Crash barrier	CG1000-P-AX-D-P-SS-R4-00-00-00-00-06
Portal for road signs	CG1000-P-AX-D-P-SS-R4-00-00-00-00-16
Access facilities, overview	CG1000-P-DX-D-P-SS-R4-00-00-00-00-01
Access to suspended deck, Overview	CG1000-P-DX-D-P-SS-R4-00-00-00-00-02
Access to suspended deck, Main access	CG1000-P-AX-D-P-SS-R4-00-00-00-00-17
Access to suspended deck, Typical	CG1000-P-AX-D-P-SS-R4-00-00-00-00-07
Waggon for suspended deck	CG1000-P-AX-D-P-SS-R4-00-00-00-00-08
Access to anchor block	CG1000-P-AX-D-P-SS-R4-00-00-00-00-09
Access to bearings, expansion joints and buffers at towers (1)	CG1000-P-AX-D-P-SS-R4-00-00-00-00-10
Access to bearings, expansion joints and buffers at towers (2)	CG1000-P-AX-D-P-SS-R4-00-00-00-00-19
Access to bearings and expansion joints at terminal structure	CG1000-P-AX-D-P-SS-R4-00-00-00-00-11
Lift, stair and door facilities in tower	CG1000-P-AX-D-P-SS-R4-00-00-00-00-12
Stairs in tower and grating in cross beams, sections and details	CG1000-P-AX-D-P-SS-R4-00-00-00-00-18
Gantries for tower	CG1000-P-AX-D-P-SS-R4-PA-00-00-00-01
Access to gantry for suspended deck	CG1000-P-AX-D-P-SS-R4-00-00-00-00-13
Gantry for suspended deck	CG1000-P-AX-D-P-SS-R4-PA-00-00-00-02
Main cables carriage and hanger basket	CG1000-P-AX-D-P-SS-R4-PA-00-00-00-03
Access to main cable in the midspan and at the saddle	CG1000-P-AX-D-P-SS-R4-00-00-00-00-15
Access to tower base	CG1000-P-AX-D-P-SS-R4-00-00-00-00-14
Dehumidification, System key plan	CG1000-P-1L-D-P-SS-R4-00-00-00-00-01
Dehumidification, Anchor block chambers	CG1000-P-1A-D-P-SS-R4-00-00-00-00-01
Dehumidification, Main cables	CG1000-P-1A-D-P-SS-R4-00-00-00-00-02
Dehumidification, Suspended deck, road and railway girders	CG1000-P-1A-D-P-SS-R4-00-00-00-00-03
Dehumidification, Towers	CG1000-P-1A-D-P-SS-R4-00-00-00-00-04
Dehumidification, Terminal structures	CG1000-P-1A-D-P-SS-R4-00-00-00-00-05

Table 2-1: Secondary structure drawings.

3 Materials

The mechanical properties of the secondary structure construction materials are described in this section.

3.1 Structural Steel

Secondary structure steel components are fabricated from Grade S355J2+N structural steel. All structural steel shall be produced in accordance with EN 10025-2. The steel is assumed to have the mechanical properties listed in Table 3-1, in accordance with NTC08 Section 11.3.4.1.

Grade	Yield Strength, f_{yk} (MPa)	Tensile Strength, f_{tk} (MPa)
S 355J2+N	355	470

Table 3-1: Structural steel mechanical properties.

All structural steel is also assumed to have the following properties, in accordance with NTC08 Section 11.3.4.1:

- Elastic modulus: $E = 210{,}000$ MPa
- Poisson's ratio: $\nu = 0.3$
- Coefficient of thermal expansion: $\alpha = 12 \times 10^{-6} / °C$
- Density: $\rho = 7{,}850$ kg/m^3

The material partial factors (safety coefficients) used to verify structural steel elements are in accordance with NTC08 Sections 4.2.4.1.1 and 4.2.4.1.4 and are listed in Table 3-2.

Verification	Partial Factor
Resistance of Class 1, 2, 3 and 4 sections	$\gamma_{M0} = 1.05$
Resistance to instability of members in road and rail bridges	$\gamma_{M1} = 1.10$
Resistance to fracture of sections under tension (weakened by holes)	$\gamma_{M2} = 1.25$
Fatigue resistance (useful fatigue life criterion with significant failure consequences)	$\gamma_{mf} = 1.35$

Table 3-2: Material partial factors for structural steel.

3.2 Stainless Steel

Stainless steel is used for the aerofoils in the wind screen. The stainless steel is grade EN 1.4404 in accordance with EN10088 and is assumed to have mechanical properties shown in Table 3-3.

Grade	Yield Strength, $R_{p0.2}$ (MPa)	Tensile Strength, R_m (MPa)
EN1.4404	220	520

Table 3-3 Mechanical properties for stainless steel

The material partial factors for structural steel is assumed identical to those for structural steel, see Table 3-2.

3.3 Grating

Yield stress (according to SCARICA catalogue) f_{yd} =160MPa

3.4 High Strength Bolts

High strength structural bolts of Grade 8.8, produced in accordance with EN ISO 898, are used for all bolted connections. High strength bolts are assumed to have the mechanical properties listed in Table 3-4, in accordance with NTC08 Section 11.3.4.6.1.

Grade	Yield Strength, f_{yb} (MPa)	Tensile Strength, f_{tb} (MPa)
8.8	649	800

Table 3-4: Structural bolt mechanical properties.

The material partial factors (safety coefficients) used to verify bolted connections are in accordance with NTC08 Section 4.2.8.1.1 and are listed in Table 3-5.

Verification	Partial Factor
Resistance to bolt shear	$\gamma_{M2} = 1.25$
Resistance to bolt tension	
Resistance to bearing on plates	
ULS slip resistance	$\gamma_{M3} = 1.25$
SLS slip resistance	$\gamma_{M3} = 1.10$
Bolt preload force	$\gamma_{M7} = 1.10$

Table 3-5: Material partial factors for bolted connections.

3.5 Welding Consumables

Welding consumables shall comply with the requirements of EN 1993-1-8 Section 4.2.

Welding procedures shall be selected so as not to reduce the properties of the thermo-mechanically processed plates.

The material partial factor, $\gamma_{M2} = 1.25$, used to verify welded connections is in accordance with NTC08 Section 4.2.8.1.1.

4 Verification of secondary structure components

Verification of each secondary structure component is described in this section. Verifications for crash barrier and access facilities are not provided. For these components performance specifications are provided.

4.1 Service Lane

4.1.1 Introduction

The service lane is located on the outside of the roadway girders over the entire length of the suspension bridge. It is the primary access route for inspection and maintenance.

The outer edge of the service lane consists of a continuous edge beam that runs the entire length of the bridge. At intervals a joint that allows longitudinal movement is created in the edge beam to release longitudinal stresses. The edge beam is supported by brackets every 3.75 m. The brackets

are attached to the bottom flange of the roadway girder. IPE-beams span between the brackets and the IPE-beams are typically welded to the brackets. However, to avoid normal stresses in the IPE-beams, connections between the IPE-beams and the bracket are at intervals created to allow for small longitudinal movements. Grating spanning between the IPE-beams is placed on top of the IPE-beams to create an even surface.

The gantry rail for the suspended deck gantry is located on the edge beam.

The service lane is shown in Figure 4-1 and Figure 4-2.

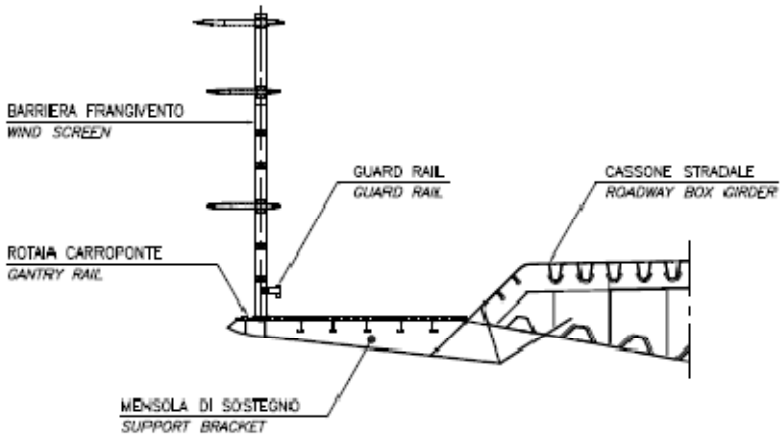

Figure 4-1 Section of service lane

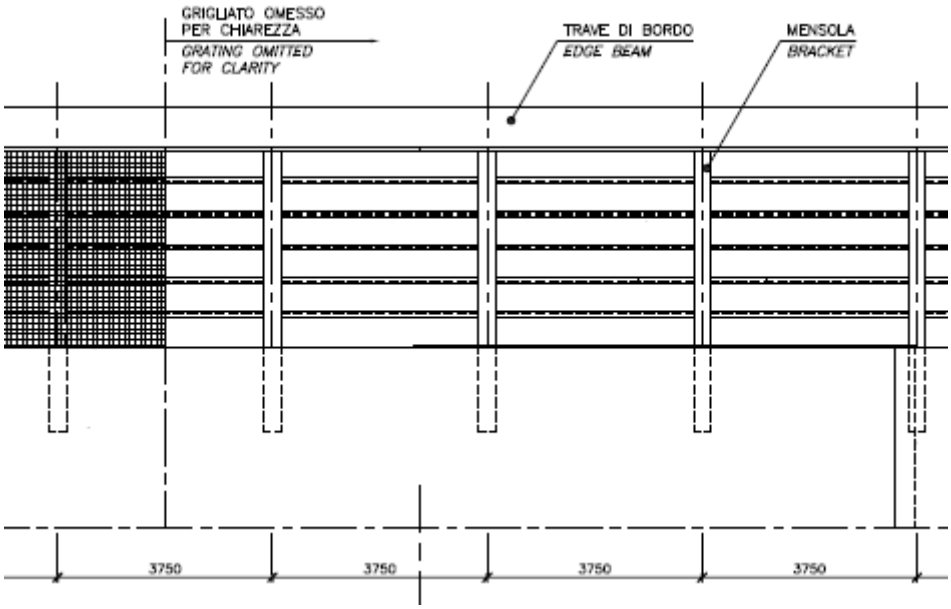

Figure 4-2 Plan of service lane - wind screen and gantry rail not shown

The service lane is illustrated in drawing CG1000-P-AX-D-P-SS-R4-00-00-00-00-01.

4.1.2 Results

A summary of the results from the verification of the service lane is given in Table 4-1.

Element	σ_{max} [MPa]	f_{yd} [MPa]	UR [-]
Bracket	322	338	0.95
Edge beam	205	338	0.61
IPE-beams	327	338	0.97

Table 4-1 Maximum stress and UR for elements in service lane

Detailed calculations of the service lane can be found in appendix 1.

4.2 Wind Screen

4.2.1 Introduction

The wind screen consists of poles every 3.75 m, which are connected to the edge beam of the service lane with a base plate. Spanning between the poles the wind screen has three horizontal aerofoils. In the lower two openings between aerofoils cladding is placed on beams spanning

horizontally and vertically respectively. The opening between the two top aerofoils is kept free. At the lower part of the poles a guard rail is attached to prevent vehicles on the service lane to collide with the wind screen. The guard rail spans between posts. The wind screen shall be provided with doors for access for inspection and maintenance of the tower.

The wind screen is shown in Figure 4-3.

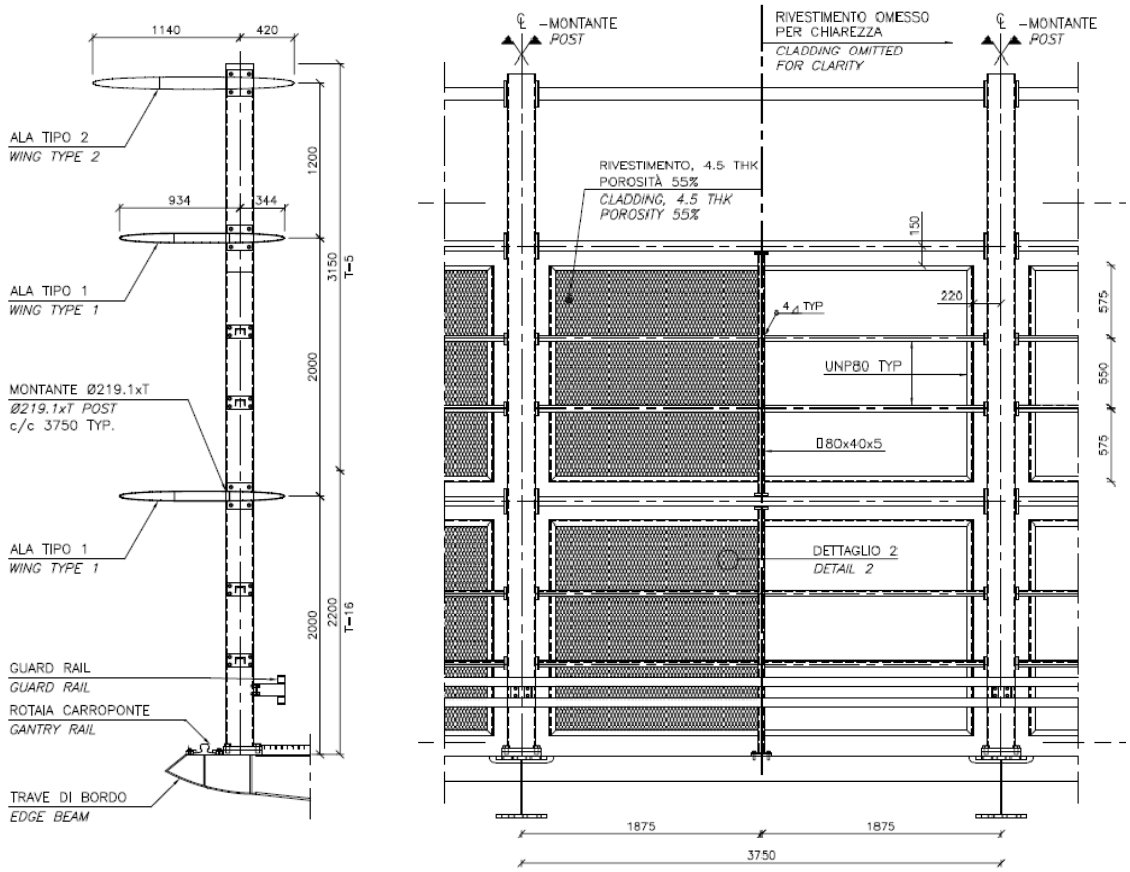

Figure 4-3 Wind screen

The service lane is illustrated in drawing CG1000-P-AX-D-P-SS-R4-00-00-00-00-01.

4.2.2 Results

A summary of the results from the verification of the wind screen is given in Table 4-2.

Element	σ_{max} [MPa]	f_{yd} [MPa]	UR [-]
Wing type 2 (stainless steel)	198	210	0.94
Wing type 1 (stainless steel)	97	210	0.46
Cladding support beams	214	338	0.63
Post	281	338	0.83

Table 4-2 Maximum stress and UR for elements in wind screen

Detailed calculations of the wind screen can be found in appendix 2.

4.3 Platform along Railway

4.3.1 Introduction

The platform runs along both sides of the railway girder. The platform shall provide escape route for train passengers in case of emergency and is only interrupted at the cross over area where the passage of the traffic must be possible. At the cross over the platform is provided with a ramp to the upper level of the cross girder.

The platform consists of grating supported by a guardrail frame attached by bolts to the railway girder - typically every 1.875m between cross girders. The guardrail frame consists of hollow section profiles. The platform is continuous along the railway girder but structurally it is not a continuous element, so that the railway girder deflection does not provide stresses in the platform elements. There is a solid wind screen mounted on the platform barrier.

The upper surface of the platform is 0.65m above the top of the rail level. The distance from the rail track centre line to the edge of the platform is 1.675m. The height of the wind screen is 1.8m and the upper part of the wind screen is about 1.6m above the platform level.

The platform along railway is shown in Figure 4-4.

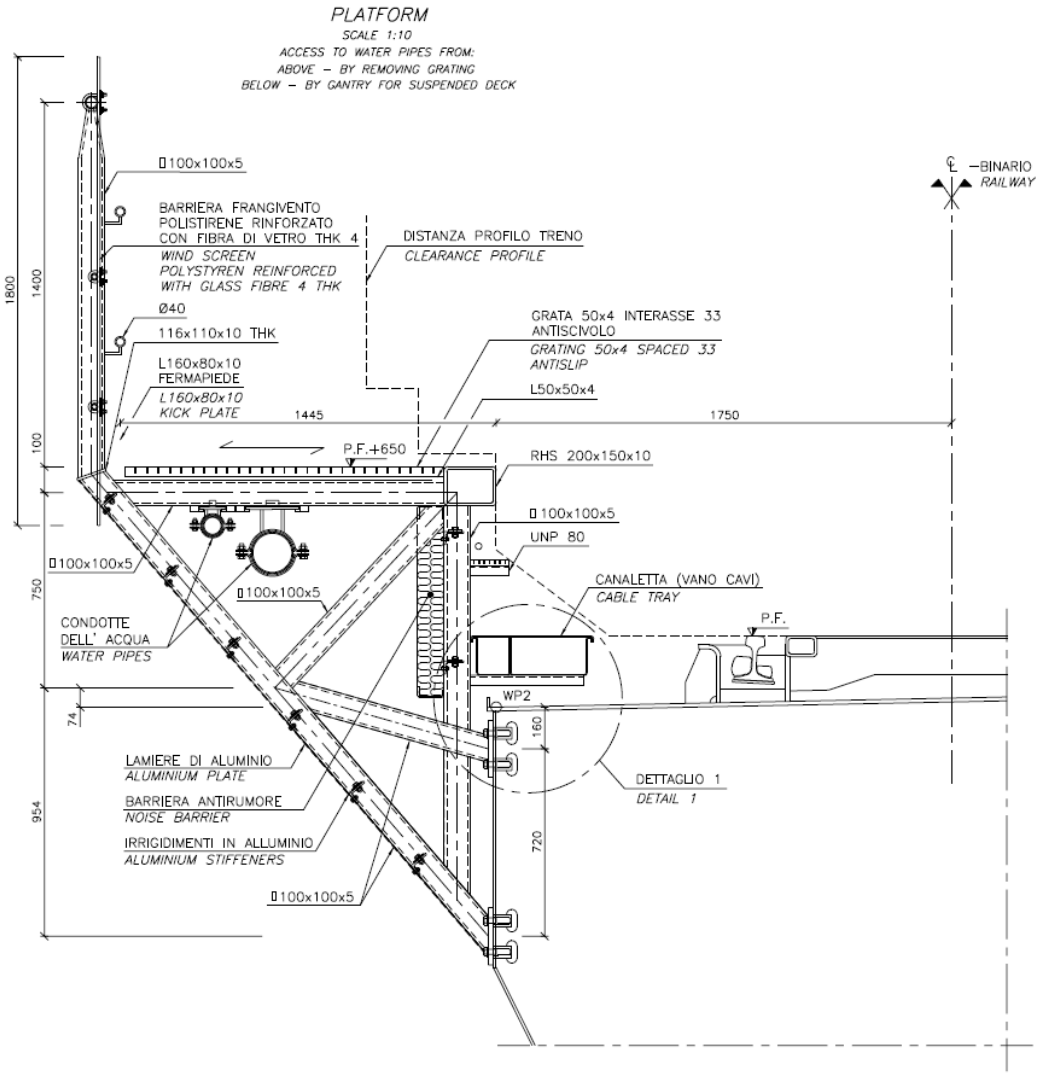

Figure 4-4 Platform along railway

4.3.2 Results

A summary of the results from the verification of the platform along railway is given in Table 4-3.

Element	σ_{max} [MPa]	f_{yd} [MPa]	UR [-]
Fixation bar	178	338	0.53
Rail guard	249	338	0.74
Barrier post	141	338	0.42
Grating	139	160	0.87

Table 4-3 Maximum stress and UR for elements in platform along railway

Detailed calculations of the platform along railway can be found in Appendix 3.

4.4 Cross Over and Service Area

4.4.1 Introduction

The cross overs and service areas span between the road- and railway girders between two cross girders. There are two cross overs and two service areas on the length of the bridge. The service areas allow for service and maintenance at a location protected from roadway traffic, and the cross overs allow for traffic to be rerouted over the railway if necessary.

The cross over and service areas consist of metal grating supported by steel I-beams, which are welded together to form a supporting grid. The I-beams are supported on elastomeric bearings constructed on individual steel consoles.

Each cross over/service area "bridge" (4 locations x 2 "bridges each" = 8 total) is 26.25m wide and spans 5.03m. Loading differs largely between the two design elements, with the cross overs designed for the total traffic load on the bridge, and the service areas designed for a large service vehicle.

The cross over and serive area are shown in Figure 4-5 and Figure 4-6.

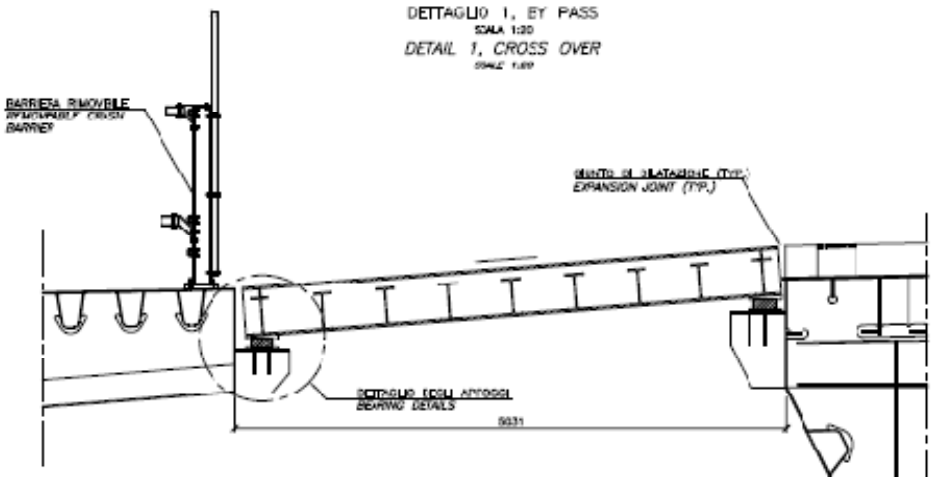

Figure 4-5 Cross Over

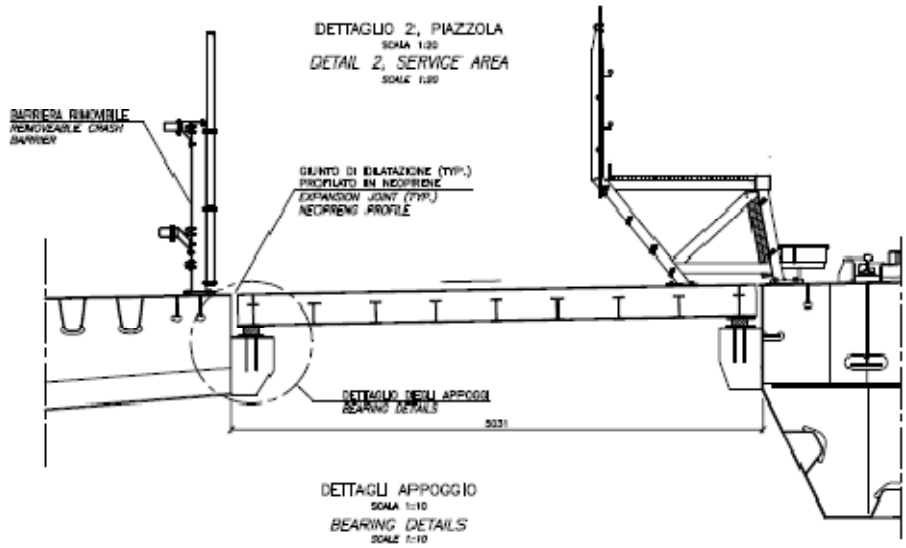

Figure 4-6 Service Area

4.4.2 Results

A summary of the results from the verification of the design elements is given in Table 4-4 and Table 4-5.

Element	σ_{max} [MPa]	f_{yd} [MPa]	UR [-]
Main beam - HEA450	308	338	0.91
Secondary beam - IPE330	254	338	0.75
Grating	159	160	0.99

Table 4-4 Maximum stress and utilization ratio (UR) for elements in the Cross over

Element	σ_{max} [MPa]	f_{yd} [MPa]	UR [-]
Main beam - IPE300	243	338	0.72
Secondary beam - IPE200	210	338	0.62
Grating	161	160	1.00

Table 4-5 Maximum stress and utilization ratio (UR) for elements in the Service Area

Detailed calculations and drawings for the Cross over and Service Area can be found in Appendix 4 - Calculations for Cross over and Service Area.

4.5 Lighting Mast

4.5.1 Introduction

Two lighting masts are located on each cross girder of the bridge on either side of the railway.

Each lighting mast is composed of a tapered CHS and connected to the bridge deck with a base plate and bolts. Stiffener plates are utilized to increase total plate capacity. All plates and the mast section are welded.

Each mast is approximately 12m high with a diameter of 180mm at the top and 270mm at the bottom. Wind loading is the controlling load pattern.

The lighting mast is shown in Figure 4-7.

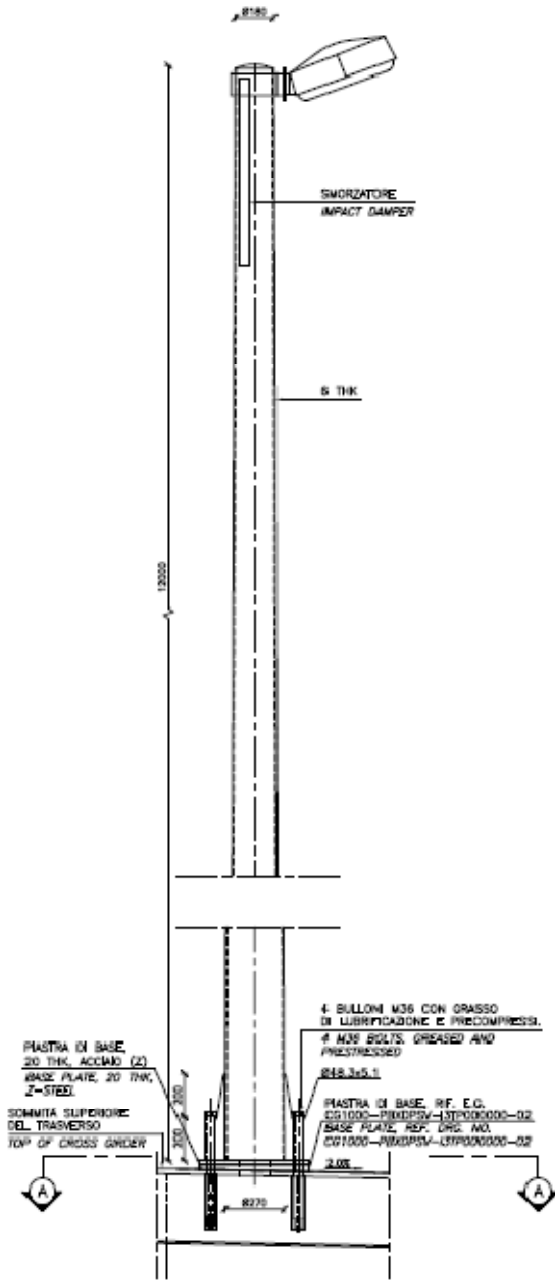

Figure 4-7 Lighting mast

4.5.2 Results

A summary of the results from the verification of the design elements is given in Table 4-6.

Element	σ_{max} [MPa]	f_{yd} [MPa]	UR [-]
Lighting Mast	156	338	0.46
Base Plate / Stiffener Plate	69	338	0.21

Table 4-6 Maximum stress and utilization ratio (UR) for elements in the Lighting Mast

Detailed calculations and drawings for the Lighting Masts can be found in Appendix 5 - Calculations for Lighting Mast, Catenary Masts, and Portal for Road Signs.

4.6 Catenary Masts

4.6.1 Introduction

Two types of catenary masts are used throughout the bridge. The masts have been designed by SINA and the connections have been designed by COWI and are included herein.

Type 1 masts are double columned masts. Type 2 masts are single masts. Both types of mast are composed of hollow steel sections and connected to the bridge deck with a base plate and bolts. Stiffener plates are utilized to increase total plate capacity. All plates and the mast sections are welded. The reactions for each mast type were given by SINA and can be found in appendix 5. The size and strength of these masts were estimate in order to design the connection.

Each mast is approximately 8m high. Wind loading is the controlling load pattern.

A catenary mast is shown in Figure 4-8.

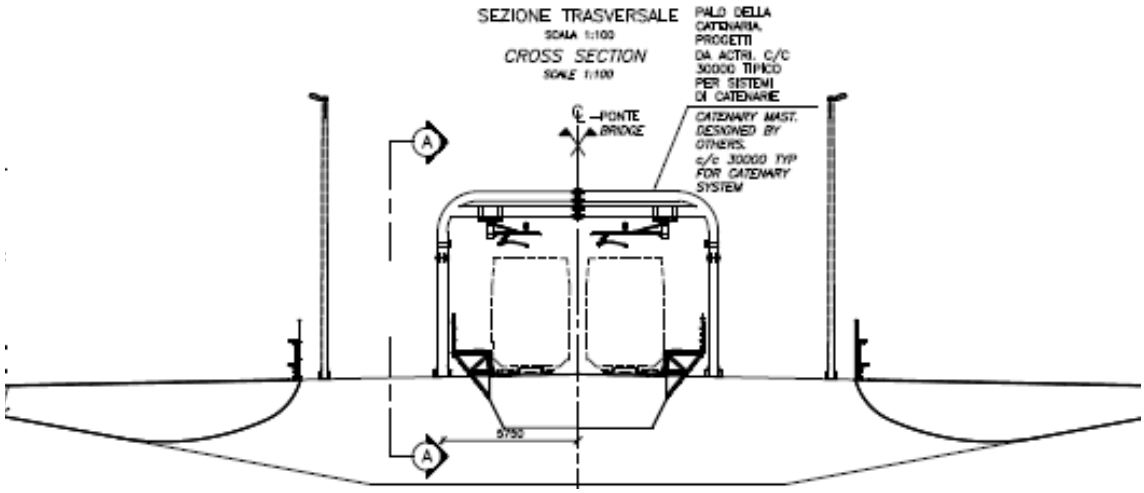

Figure 4-8 Catenary mast

4.6.2 Results

A summary of the results from the verification of the design elements is given in Table 4-7.

Type 1 Element	**σ_{max} [MPa]**	**f_{yd} [MPa]**	**UR [-]**
Double Catenary Mast	-	-	SINA design
Base Plate / Stiffener Plate	175	338	0.38
Type2 Element	**σ_{max} [MPa]**	**f_{yd} [MPa]**	**UR [-]**
Single Catenary Mast	-	-	SINA design
Base Plate / Stiffener Plate	< 175	338	< 0.38

Table 4-7 Maximum stress and utilization ratio (UR) for elements in the Catenary Masts

Detailed calculations and drawings for the Catenary Masts can be found in Appendix 5 - Calculations for Lighting Mast, Catenary Masts, and Portal for Road Signs.

4.7 Portal for Road Signs

4.7.1 Introduction

Sign portals are located in 16 places on the bridge and each portal spans across the roadway.

Each portal is composed of one horizontal RHS and two vertical RHS's, which are connected to the bridge deck with a base plate and bolts. Stiffener plates are utilized to increase total plate capacity. All plates and the vertical masts are welded.

Each portal is approximately 6.7m high and the span distance is 14.85m. A variable message sign (VMS) is attached to the horizontal RHS, which weighs approximately 1 ton. Wind loading is the controlling load pattern for the vertical masts and base plates. Dead load from sign components is the controlling load pattern for the horizontal section.

Portals for road signs is shown in Figure 4-9.

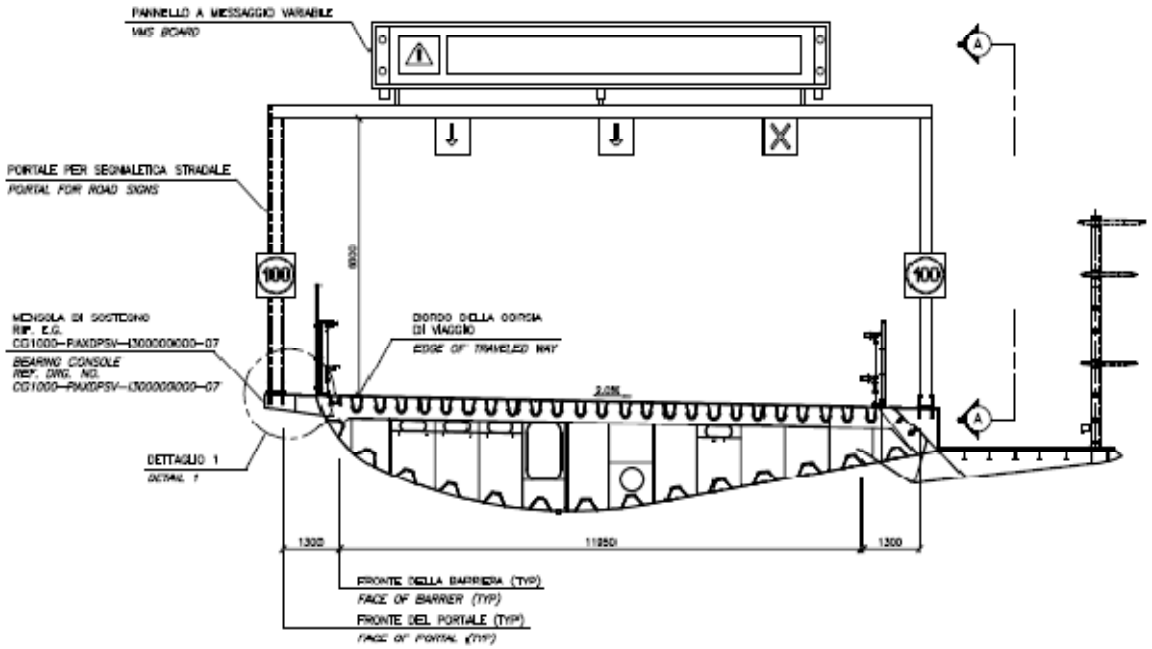

Figure 4-9 Portal for road signs

4.7.2 Results

A summary of the results from the verification of the design elements is given in Table 4-8.

Element	σ_{max} [MPa]	f_{yd} [MPa]	UR [-]
Horizonal Mast	54	338	deflection controls
Vertical Mast	324	338	0.96
Base Plate / Stiffener Plate	126	338	0.37

Table 4-8 Maximum stress and utilization ratio (UR) for elements in the portal for road signs

Detailed calculations and drawings for the portal for road signs can be found in Appendix 5 - Calculations for Lighting Mast, Catenary Masts, and Portal for Road Signs.

4.8 Platform for Sub stations

The platform for the Sub Stations span between the road- and railway girders and cover approximately half of the span between two cross girders. There are 8 Sub Stations on the length

of the bridge. The Sub Stations carry MV-switchgear, transformers, LV switchboard etc. The total payload is 8.250 tons. The Sub Stations are connected to the service lane by a gantry going under the roadway girder.

The platform for the Sub Station is shown in Figure 4-11 and Figure 4-11.

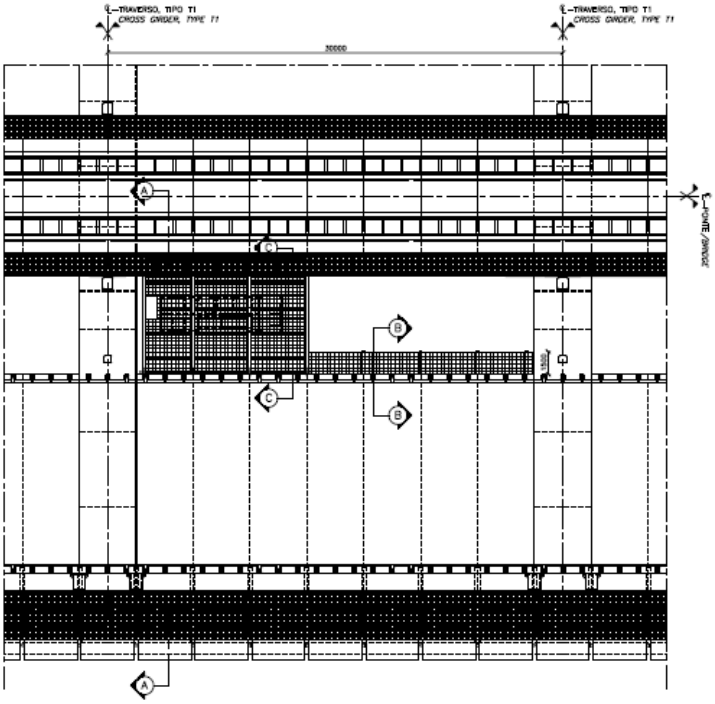

Figure 4-10:Plan of Sub Station

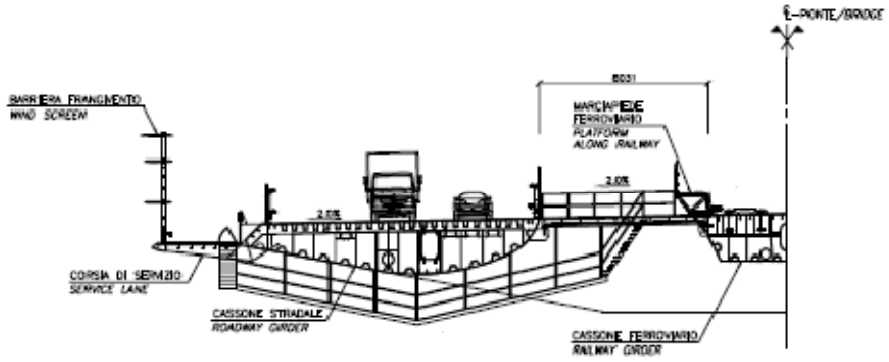

Figure 4-11: Section C-C

The platform consist of 2 layers of metal grating supported by steel I-beams, which are welded together to form a supporting grid. The I-beams are supported on elastomeric bearings constructed on individual steel consoles.

4.8.1 Results

A summary of the results from the verification of the design elements is given in Table 4-9.

Element	σ_{max} [MPa]	f_{yd} [MPa]	UR [-]
Main beam - IPE400	183	338	0.54
Secondary beam - IPE270	54	338	0.16

Table 4-9: Maximum stress and utilization ratio (UR) for elements in the Sub Stations

The deflection is maximum 20mm in the service limit state.

Detailed calculations and drawings for the platform for the Sub Stations can be found in Appendix 6 - Calculations for Sub Stations.

4.9 Grating in tower cross beams

4.9.1 Introduction

A travelling telescopic platform shall be located inside every cross beam in order to perform inspection and maintenance work. To provide a smooth surface for the telescopic platform grating is installed along the bottom of the cross beams. The grating is supported on beams spanning between the transverse stiffeners in the cross beam.

4.9.2 Results

A summary of the results from the verification of the elements are given in Table 4-10.

Element	σ_{max} [MPa]	f_{yd} [MPa]	UR [-]
Grating	**333**	**338**	**0.99**
Support beams	**77**	**338**	**0.23**

Table 4-10 Maximum stress and utilization ratio (UR) for elements for grating in tower cross beams.

The dimension of the support beams are determined to limit the deflection. The maximum deflection of the support beams are 5 mm in service limit state.

Detailed calculations of the individual elements can be found in Appendix 7 - Calculations for grating in tower cross beams.

Appendix 1 - Calculations for service lane

Appendix 2 - Calculations for wind screen

Appendix 3 - Calculations for platform along railway

Appendix 4 - Calculations for Cross over and Service Area

Appendix 5 - Calculations for Lighting Mast, Catenary Masts, and Portal for Road Signs

Appendix 6 - Calculations for Sub Stations

Appendix 7 - Calculations for grating in tower cross beams