Stretto di Messina

Concessionaria per la progettazione, realizzazione e gestione del collegamento stabile tra la Sicilia
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EurolinK

PONTE SULLO STRETTO DI MESSINA

PROGETTO DEFINITIVO

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INDICE

1 Executive Summary

The Messina Strait Bridge will span the Messina Strait between Calabria on the Italian mainland and the island of Sicily and will provide the first fixed link between Calabria and Sicily. The suspension bridge crossing comprises a 3,300 m main span, which will be longest in the world when constructed.

The bridge carries four marked vehicle lanes, two emergency lanes and two rail lines. The bridge superstructure comprises three separate orthotropic deck steel box girders, one for each of the Sicily and Calabria bound roadways and one for the railway. The three box girders are connected by transverse steel box cross girders spaced at 30 m. The superstructure is supported by pairs of hanger cables connected to each cross beam end. The hangers are connected to pairs of main cables on each side of the bridge (four main cables). The main cables are anchored at each bridge end in massive reinforced concrete anchor blocks. The main cables are supported by two steel main towers, each with a height of 399 m above mean sea level. The main towers are founded on reinforced and post-tensioned concrete footings, which are supported on underlying rock formations.

In the current Progetto Definitivo project phase, the tender design is further developed in preparation for the subsequent Progetto Esecutivo phase.

This report describes the secondary structures proposed for the bridge.

Secondary structures consist of the following elements:

SERVICE LANE

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.

WIND SCREEN

The wind screen on the service lane reduces the wind speed across the bridge.

PLATFORM ALONG RAILWAY GIRDER

The platform along the railway is located on both sides of the railway girder and the purpose is to evacuate people from the train if necessary. Platform is integrated with guardrail for trains. The platform is continuous over the entire bridge length only stopped twice to make space for the cross over.

CROSS OVER

At two locations a cross over connects the road girders and the railway girder between two cross girders giving the possibility to pass from one roadway girder to the other in special cases. At the cross over the crash barriers are removable.

SERVICE AREA

The service area is similar to the cross over but it is not possible to pass from one roadway girder to the other and the platform along railway girder is continuous. From the two locations where the service areas are located it is possible to have a base for service works.

LIGHTING MASTS

The road lighting system contributes to the safety of the road users by providing adequate illumination to reveal all the features of the road and the traffic that are important to the drivers.

CATENARY MASTS

The catenary mast supports the catenary system. At special locations double masts are installed for adopting the load of counter weights.

PORTALS FOR ROAD SIGNS

The portal supports the signs for the traffic management on the roadway.

CRASH BARRIERS

The crash barriers are continuous over the entire bridge length and should provide a safe barrier for the road traffic.

ACCESS FACILITIES

All access facilities for the bridge are designed to obtain complete and easy access to all areas of the bridge structure and installations for the purpose of inspection and maintenance.

The primary maintenance access to the bridge is from the service lanes, which allow access without disturbing the traffic. From the service lanes there is access to:

- Suspended deck
- Towers
- Main cables
- Hanger cables.

Further access to the above mentioned elements is described below.

Suspended deck:

- All exterior surfaces of the three bridge girders and the cross beams will be accessible either directly from a gantry for suspended deck or from telescoping platforms on each gantry.
- Main access entrances from both service lanes to the interior of the suspended deck will be arranged at 360 m intervals.
- Supplementary entrances from both service lanes must be arranged at 30 m intervals.
- Longitudinal walkways are arranged inside the three bridge girders.
- A transport wagon will be arranged in the two roadway bridge girders.
- Transversal walkways between the three bridge girders and through the cross beams will be arranged at 30 m intervals, i.e. at each cross beam.

Towers:

- Entrance to each tower leg through doors in the wind screen at the service lanes and the tower base.
- Complete access to all inner surfaces of the tower legs by lifts, stairs and ladders.

- Access to the outer surfaces of the towers legs by climbing gantries.
- Access to all cross beams via openings in each tower leg.
- Access to all inner surfaces of the cross beams by telescoping platforms.
- Access to the top of cross beams through doors in both tower legs.
- Access to saddle rooms
- Access to exterior vertical surfaces and bottom of cross beams by gantries.
- Access to top of the upper cross beam via stairs and hatch.
- Access to top of the tower saddles via enclosed stairways.
- Access to the joint between saddle and cable shroud by a fixed platform
- Access to the lower surface of the cable shroud by removable platform

Main cables:

- Main cable carriages - Access to all surfaces of the main cables, cable clamps and upper hanger sockets.
- By stairways from service lane to walkways on main cables.
- By stairway from the tower saddles to walkways on main cables.
- By stairway from the anchor blocks to walkways on main cables.
- By stairway to the splayed cable inside anchor block

Hanger cables:

- Lower areas by truck with mobile aerial platform.
- Upper areas by hanger basket.

Walkways and platforms will provide the primary access to bearings, expansion joints and hydraulic buffers. The same applies inside the anchor block.

All access facilities must be provided with sufficient lighting for orientation and carrying out inspection and maintenance.

DEHUMIDIFICATION

The purpose of the dehumidification systems in the bridge is to dehumidify the air inside the bridge structures and thereby minimise need for further protection of the interior surfaces of the structure. To obtain the above the bridge shall be equipped with dehumidification plants with ventilation fans for circulation of the dehumidified air, with an average year value of 40% relative humidity as a maximum and with an extreme value over 1 hour/day of 50% relative humidity. This shall prevent corrosion of the internal steel surfaces.

The dehumidification plants dehumidify the air inside the bridge as well as the ambient air entering for equalisation of pressure in the structures, which will occur because of climate conditions and a not fully airtight bridge structure.

Air must circulate through the steel structures so use of ductwork will be minimised.

2 Introduction

2.1 Scope

This report describes the design principles of the secondary structures for the Progetto Definitivo project phase.

2.2 References

2.2.1 Design Specifications

1 GCG.G.02.01 rev.0. Construction of the street and railway connections: Norms for the execution of the civil works - street and railway infrastructures. Stretto di Messina, 2004 July 6.

2 GCG.G.03.04. Various works. Stretto di Messina, 2010, July 15.

3 CG.10.00-P-RG-D-P-GE-00-00-00-00-00-02-A - “Design Basis, Structural, Annex,” COWI 2010

4 GCG.F.05.03 rev. 1. Technical specifications for the definitive and the executive project of the bridge - Design development requirements & guidelines. Stretto di Messina, 2004 October 22.

5 GCG.G.03.02. Technical specifications for the construction of the suspension bridge - Structural steel works and protective treatment, Stretto di Messina, 2004 July 30.

6 G.C.G.F. 04.01 Engineering - definitive and detailed design. Basis of design and expected performance levels for the bridge, Stretto di Messina 27 October 2004

2.2.2 Codes and standards

7 EN 1990-2:2007 Basis of structural design

8 EN 1991 Eurocode 1: Actions on structures

9 EN 1993 Eurocode 3: Design of steel structures

10 Pressure Equipment Directive 97/23/EC

11 Machinery Directive 2006/42/EF

12 Low Voltage Equipment Directive 2006/95/EC

13 Electromagnetic Compability 89/336/EEC

3 Limit States

This section describes the limit states in accordance with the project design basis GCG.F.04.01 and NTC 2008. The performance of the secondary structures is verified at Serviceability Limit States (1 and 2) and Ultimate Limit States.

3.1 Serviceability Limit States

NTC 2008 Section 2.2.2 defines the following Serviceability Limit States (SLS) that are to be evaluated in a structural design:

- Local damage that can reduce the durability of the structure.

- Displacement or deformations that could limit the use of the structure, its efficiency and its appearance.
- Displacement or deformations that could compromise the efficiency and appearance of non-structural elements, plants and machinery.
- Vibrations that could compromise the use of the structure.
- Damage caused by fatigue that could compromise durability.
- Corrosion and/or excessive deterioration in materials due to atmospheric exposure.

The project design basis GCG.F.04.01 Section 3.1 specifies the performance requirements for the structure under two levels of serviceability, or normal usage loads. The SLS performance requirements are listed in Table 3.1.

Table 3.1 SLS performance requirements

Limit State	***Performance Requirement***
SLS1	*Road and rail runability is guaranteed.* *No structural damage.* *Structure remains elastic and all deformations are reversible.*
SLS2	*As for SLS1 except that only rail runability is guaranteed.*

3.2 Ultimate Limit States

NTC 2008 Section 2.2.1 defines the following Ultimate Limit States (ULS) that are to be evaluated in a structural design:

- Loss of equilibrium of the structure or part of it.
- Excessive displacement or deformation.
- Arrival at the maximum resistance capacity of parts of the structure, joints or foundations.
- Arrival at the maximum resistance capacity of the structure as a whole.
- Arrival at ground collapse mechanisms.
- Instability of parts of the structure or structure as a whole.
- The project design basis GCG.F.04.01 Section 3.1 specifies the performance requirements for the structure under ultimate or rare loads. The performance requirements are listed in Table 3.2.

Table 3.2 ULS performance requirements

Limit State	***Performance Requirement***
ULS	*Temporary loss of serviceability is allowed.* *The main structural system maintains its full integrity.* *Structural damage to secondary components is repairable by means of extraordinary maintenance works.*

4 Materials

The mechanical properties of the materials used for the secondary structures are described in this section.

4.1 Structural Steel

The secondary structures components are mainly fabricated from Grade S 355 steel, produced in accordance with EN 10025-2. The steels are assumed to have the mechanical properties listed in Table 4.1, in accordance with NTC 2008 Section 11.3.4.1. The steel fabricator has confirmed that the mechanical properties will not vary with material thickness for thicknesses less than 100 mm, as is typical for rolled steel products.

Table 4.1 Structural steel mechanical properties

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

All structural steel is also assumed to have the following properties, in accordance with NTC 2008 Section 11.3.4.1:

Elastic modulus: $E = 210{,}000\ \text{MPa}$

Poisson's ratio: $\nu = 0.3$

Shear modulus: $G = 77{,}000\ \mathrm{MPa}$

Coefficient of thermal expansion: $\alpha = 12 \times 10^{-6}/°C$

Density: $\rho = 7850\ \mathrm{kg/m^3}$

The material partial factors (safety coefficients) used to verify structural steel elements are in accordance with NTC 2008 Section 4.2.4.1.1, 4.2.4.1.4 and are listed in Table 4.2.

Table 4.2 Material partial factors for structural steel

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)	$\gamma_M = 1.35$

4.2 High Strength Bolts

High strength structural bolts of Grade 8.8, produced in accordance with EN ISO 898, are used for all bolted connections and splices. High strength bolts are assumed to have the mechanical properties listed in Table 4.3, in accordance with NTC 2008 Section 11.3.4.6.1.

Table 4.3 Structural bolt mechanical properties

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

The material partial factors (safety coefficients) used to verify bolted connections and splices are in accordance with NTC 2008 Section 4.2.8.1.1 and are listed in Table 4.4.

Table 4.4 Material partial factors for bolted connections and splices

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

4.3 Welding Consumables

The material partial factors (safety coefficients) used to verify welded connections are in accordance with NTC 2008 Section 4.2.8.1.1 and are listed in Table 4.5.

Table 4.5 Material partial factors for welded connections

Verification	***Partial Factor***
Resistance to weldings to partial penetration and fillet weld	$\gamma_{M2} = 1.25$
ULS slip resistance	$\gamma_{M3} = 1.25$
SLS slip resistance	$\gamma_{M3} = 1.10$

4.4 Aluminium

The exact type of aluminium alloy will be decided later. Typical values for aluminium alloys are listed below.

Elastic modulus: $E = 70{,}000\ MPa$

Poisson's ratio: $\nu = 0.33$

Shear modulus: $G = 26{,}000\ MPa$

Coefficient of thermal expansion: $\alpha = 23{,}1 \times 10^{-6} / {}^{\circ}C$

Density: $\rho = 2700\ kg/m^3$

4.5 Stainless Steel

All mechanical installations related to the dehumidification system shall be stainless steel AISI 316L or painted or otherwise protected in such a way that they will sustain without further maintenance for a period of minimum 25 years in the surroundings and environmental conditions that are present in the Messina area.

The outdoor ductwork shall be stainless steel AISI 316L and flexible ductwork on main cables and hangers shall be wind, weather and UV resistant.

5 Service Lane

5.1 Introduction

This technical design report contains the concept for the service lane attached to the suspended deck of the Messina Strait Bridge.

5.2 Scope of Work

The scope of work for the service lane is as follows:

- All structural parts of the service lane including gratings.
- Rail for gantry for suspended deck.

The scope of work for Progetto Definitivo covers calculations, drawings and bill of quantities.

The design of the service lane shall include integration of the service lane into the overall bridge deck design considering interface requirements from other parts of the bridge project.

5.3 Design Principles

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 service lane provides access for inspection of interior parts of the girders. Furthermore the service lane provides access to inspection of the main cable in the mid span and to inspection of the tower. Also the service lane provides an escape route in case of emergency or an accident on the bridge.

The outer edge of the service lane consists of a continuous edge beam that runs the entire length of the bridge, and 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 in the service lane.

5.4 Requirements

The service lane is designed for the following loads:

- Uniformly distributed live load of 5 kN/m^2
- Axle loads from service equipment/crane of 80 kN and 40 kN respectively, 1.30 m wide, 3.00 m spaced and load pads of 0.2 m x 0.2 m.

Furthermore the service lane has to carry the loads from the suspended deck gantry and the wind screen.

The deformation of the edge beam and bracket must be small enough as to allow for operating the gantry for suspended deck.

The deformation of the beams must be limited to max l/400 to allow vehicles to drive on the service lane.

To allow for main access to the interior of the girders at every 360 m an access hatch is placed in the service lane. The access hatch in the service lane give access to a platform below the girder and from there access to the inside of the girder.

6 Wind Screen

6.1 Introduction

This technical design report contains the concept for the wind screen placed on the service lane of the Messina Strait Bridge.

6.2 Scope of Work

The scope of work for the wind screen include all structural parts of the wind screen including aerofoils and guard rail

The scope of work for Progetto Definitivo covers calculations, drawings and bill of quantities.

The design of the wind screen shall include integration of the wind screen into the overall bridge deck design considering interface requirements from other parts of the bridge project.

6.3 Design Principles

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 in the tower.

6.4 Requirements

The wind screen is designed for mean wind speed over an interval of 10 minutes. Furthermore the wind screen shall be able to resist vertical load as a result of wind flow over the aerofoils of the wind screen.

The cladding must be 55% air void.

7 Platform along Railway Girder

7.1 Introduction

This technical design report contains the concept for the platform along the railway girder of the Messina Strait Bridge.

7.2 Scope of Work

The scope of work for the platform along the railway girder is as follows:

- The support structure of the platform
- The railing along the platform
- Access to the cross over and service areas.
- Guardrail for trains

The scope of work for Progetto Definitivo covers calculations, drawings and bill of quantities.

The design of the platform along the railway girder shall include integration of the platform into the overall bridge deck design considering interface requirements from other parts of the bridge project.

7.3 Design Principles

The platform along the railway girder is located on both sides of the girder and the purpose is to evacuate people from the trains if necessary. The railway walkway is integrated with guardrail which prevents accidental train overturning. The platform is continuous from the start to the end of the bridge only stopped twice to make space for the crossovers. A platform has 6 exit points - one at each end of the bridge, at each of the two cross over and at the two service areas.

The platform is designed as a frame, attached to the railway girder at approximately every 1,875 meter. Between the top of the railway girder and the platform along the railway girder a noise barrier is attached. The barrier of the platform also serves as a wind screen.

When designing the platform one should consider limiting the weight while at the same time limiting the deflection and limiting the noise from the trains.

7.4 Requirements

The design of the platform shall satisfy the demands of the Italian railway authorities considering size and position of the platform and the height of the railing. The guardrail shall resist force due to the overturning moment of the train.

8 Cross Over and Service Area

8.1 Introduction

This technical design report contains the concept for the cross overs and service areas between the road girders of the Messina Strait Bridge.

There are two cross overs and two service areas. The cross overs are between cross girder no 45 and 46 and between cross girder 74 and 75, while the service areas are between cross girder 15 and 16 and between cross girder 104 and 105.

8.2 Scope of Work

The scope of work for the cross overs and service areas are as listed below

- Main and secondary beams.
- Railing between the road and railway girder on both sides.
- Grating.
- Bearings and expansion joints

The scope of work for Progetto Definitivo covers calculations, drawings and bill of quantities.

The design of the cross overs and service areas shall include integration of these into the overall bridge design, considering interface requirements from other parts of the bridge project.

8.3 Design Principles

8.3.1 Cross Over

The cross over connects the road girders and the railway girder between to cross girders. The distance between the road girder and the railway girder is approximately 5 meters. The cross over is a grillage with hot dip galvanized gratings on top. The grillage consists of main beams spanning between a console on the roadway girder and a console on the railway girder and secondary beams connecting the main beams. The consoles have elastomeric bearings and an expansion joints between the cross over and the bridge girder.

The crash barrier is removable to allow vehicles to access the opposite road girder in case of emergency.

The railway track is provided with a special surfacing for the middle ten meters of the cross over to allow vehicles to pass to the opposite road girder in case of emergency. The longitudinal profile of the platform along the railway girder is modified to allow traffic to pass.

8.3.2 Service Area

The service areas are almost similar to the cross overs but it is not possible to pass the railway girder and the platform along the railway girder is continuous.

The crash barrier is removeable to allow the inspection and maintenance vehicles to access the service area.

8.4 Requirements

The cross over shall carry full traffic load or load from people being evacuated from the train. The cross overs, the service areas and both ends of the bridge are the only exits from the platforms along the railway girders.

The design of the cross over/service area should be integrated into the overall bridge design in order to give the vehicles a clear overview of the area.

9 Lighting Masts

9.1 Introduction

This technical design report contains the concept for lighting masts, which must be used on the suspended deck of the Messina Strait Bridge.

9.2 Scope of Work

The scope of work for the light masts is as follows:

- All structural parts of the lighting masts on the suspended deck including baseplate and fastening bolts.
- Vibration dampers.

The scope of work for Progetto Definitivo covers calculations, drawings and bill of quantities.

The design of the lighting masts shall include integration of masts into the overall bridge deck design, considering interface requirements from other parts of the bridge project.

9.3 Design Principles

The lighting masts consist of a conical mast pole with a base plate for fixation to a thick doubler plate welded to the steel deck plate. The height of the mast poles is 12 m and the distance between them are 30 m - to ensure adequate illumination. A standard component will be used for the lighting fixture. The mast poles will be equipped with a simple vibration damper in the top to minimize wind induced vibrations if required.

9.4 Requirements

The road lighting system contributes to the safety of the road users by providing adequate illumination to reveal all the features of the road and the traffic that are important to the drivers. The road lighting will enable the drivers to perceive the route, the traffic pattern and possible obstacles ahead at the maximum design speed.

The masts shall be designed to avoid significant amplitudes as well as accelerations, which may cause damage to the lighting source.

10 Catenary Masts

10.1 Introduction

This technical design report contains the concept for catenary masts, which must be used on the suspended deck of the Messina Strait Bridge.

10.2 Scope of Work

The scope of work for the catenary masts is as follows:

- Base plate and fastening bolts.
- The design of the catenary masts is provided by SINA

The scope of work for Progetto Definitivo covers calculations, drawings and bill of quantities.

The design of the catenary masts shall include integration of masts into the overall bridge deck design, considering interface requirements from other parts of the bridge project.

10.3 Design Principles

The catenary masts consist mast pole with a base plate for fixation to a thick doubler plate welded to the steel deck plate. Close to the tower and at the bridge end they will be attached to side of railway girder. The masts will be placed with an equal distance of 30 m at every cross girder.

10.4 Requirements

The masts shall be designed to resist loads from wind and the catenary system. At special locations double masts are installed e.g. for adopting the load of counter weights.

The masts shall be designed to allow replacement of 3 kV DC with 25 kV AC power supply and shall be prepared for possible additional loads.

11 Portals for road signs

11.1 Introduction

This technical design report contains the concept for portals for road signs, which must be used on the suspended deck of the Messina Strait Bridge.

11.2 Scope of Work

The scope of work for the portals for road signs is as follows:

- All structural parts of the portals on the suspended deck including base plate and fastening bolts.

The scope of work for Progetto Definitivo covers calculations, drawings and bill of quantities.

The design of the portals shall include integration of portals into the overall bridge deck design, considering interface requirements from other parts of the bridge project.

11.3 Design Principles

The portals for road signs are frame portals made of a rectangular hollow section with a base plate for fixation to a thick doubler plate welded to the steel deck plate. The masts will be placed according to the traffic management layout.

11.4 Requirements

The masts shall be designed to carry the road signs and resist loads from wind. The signs shall be accessed by a caged ladder.

12 Crash Barrier

12.1 Introduction

This technical design report contains the concept for the crash barrier along the roadway of the Messina Strait Bridge.

12.2 Scope of Work

The scope of work for the crash barrier is as follows:

- All structural parts of the crash barrier including wind screen

The scope of work for Progetto Definitivo covers technical performance specification, drawings and bill of quantities.

The design of the crash barrier shall include integration of the crash barriers into the overall bridge deck design considering interface requirements from other parts of the bridge project.

12.3 Design Principles

The crash barrier consists of vertical posts connected to the road girder and horizontal guard rails. The vertical posts are placed at equal intervals and support two horizontal guard rails running the entire length of the roadway. The crash barrier will be equipped with a wind screen.

At locations of SOS-stations it will be possible to access the service lane from the roadway through emergency doors in the crash barriers. At cross-over areas it will be possible to gain access between the roadway and the railway girders through removable crash barriers.

12.4 Requirements

The crash barriers must be continuous and without projections.

The crash barriers must be designed to withstand the impact forces required in the design codes and fulfil national standards.

13 Access Facilities

Based on previous experience the amount of time used to maintain the access facilities and gantries can be larger than the time spent using them for their purpose. This is mainly a problem for permanent facilities which are rarely used and exposed to the harsh environment/weather.

The strategy for the access facilities is to keep the amount of permanent structures to a minimum, while at the same time making a work and cost efficient system.

13.1 Access to Suspended Deck

13.1.1 Introduction

This technical design report contains the concept for the inspection and maintenance walkways, which must be used inside the suspended deck of the Messina Strait Bridge.

13.1.2 Scope of Work

The complete access facilities for the suspended deck covered by this report are as follows:

- Access to interior walkways in the bridge girders, cc 360 m
- Cross access between bridge girders, cc 30 m
- Access walkways in suspended bridge deck
- Wagon in suspended deck and rails.

The scope of work for Progetto Definitivo covers technical performance specifications in accordance with general requirements for the contract, calculations, drawings and bill of quantities.

The design of the walkways shall include integration of the access facilities into the overall bridge deck design, considering interface requirements from other parts of the bridge project.

13.1.3 Design Principles

ACCESS TO INTERIOR WALKWAYS IN BRIDGE GIRDERS

Main access from the service lane to the inside of the roadway box girder shall be provided at intervals of 360 m. This shall be performed by an external walkway placed below the roadway bridge deck.

The interior walkway shall be accessed through a hatch in the service lane deck and a ladder to the roadway girder. The interior walkway leads to a door to the cross girder and thereby allow passage between the three bridge decks.

The external access walkway shall have a minimal width of 2.0 m and a minimal clear height of 1.9 m. The access shall not obstruct passage of the gantries for suspended deck.

Supplementary access openings shall be provided adjacent to the service lane, either at each cross beam or midway between two cross beams i.e. cc 30 m. W x H = min. 0.8 x 0.5 m. These openings shall allow for emergency transportation of a person on a stretcher.

Special access openings (min. opening W x H = 1.5 x 1.0 m) in the side of the bridge cross girders shall be provided at intervals of 120 m to give access for installation of electrical panels etc.

All external openings shall have watertight doors/hatches which can be opened from the inside without a key in emergencies.

All external openings shall be equipped with a surveillance system with intrusion alarms and lacking closure.

ACCESS WALKWAYS AND WAGON IN SUSPENDED DECK

Longitudinal walkways consisting of gratings with railings are arranged inside the three bridge girders.

All interior pathways shall have minimal clear openings of W x H = 0.6 x 1.3 m.

The bottom edge of all internal doors/hatches shall not be more than 400 mm above the walking surface.

A continuous longitudinal rail system shall be provided in each roadway box girder with the purpose of transporting personnel, materials and equipment. The rails shall be placed in the pathway through the diaphragms and provide passage of a wagon.

CROSS ACCESS BETWEEN BRIDGE GIRDERS

Transversal walkways between the three bridge girders and through the cross girders must be arranged at each cross girder. Access is possible through openings and via stairs and ladders.

All interior pathways shall have minimal clear openings of W x H = 0.6 x 1.3 m.

The bottom edge of all internal doors/hatches shall not be more than 400 mm above the walking surface.

Walkways consist of gratings with railings.

13.1.4 Requirements

The access facilities shall be designed so that the following main objectives are fulfilled:

- Walkways shall give access to all inner parts for inspection and maintenance with sufficient clearance to internal pipelines etc.
- Hatches and manholes are giving access to the bridge girders
- All relevant safety aspects are provided
- The wagon in the roadway girder does not damage the bridge deck structure, in particular the adjacent structures and equipment
- The facilities are robust and have a long service lifetime

The walkways shall be equipped with necessary installations to provide safe transport and working conditions, e.g. normal and emergency lighting, emergency telephones, alarms etc.

13.2 Access to Anchor Block

13.2.1 Introduction

This technical design report contains the concept for the inspection and maintenance walkways, which must be used in the anchor blocks of the Messina Strait Bridge.

13.2.2 Scope of work

The complete access facilities for the anchor blocks covered by this specification are as follows:

- Access to interior walkways in the anchor block
- Access for inspection of splay saddles

The scope of work for Progetto Definitivo covers technical performance specifications in accordance with general requirements for the contract, calculations, drawings and bill of quantities.

The design of the walkways shall include integration of the access facilities into the overall anchor block design, considering interface requirements from other parts of the bridge project.

13.2.3 Design principles

The interior walkways in the anchor block shall be accessed from the outside through a watertight door which can be opened from the inside without a key in emergencies.

The concrete structure is used for the interior walkways and stairways when possible, elsewhere the walkways consists of grating with railings.

All external openings shall be equipped with a surveillance system with intrusion alarms and lacking closure.

13.2.4 Requirements

The access facilities shall be designed so that the following main objectives are fulfilled:

- Walkways giving access to all inner parts for inspection and maintenance
- Doors shall give access to the anchor block
- All relevant safety aspects are provided
- The facilities are robust and have a long service lifetime

The walkways shall be equipped with necessary installations to provide safe transport and working conditions, e.g. normal and emergency lighting, emergency telephones, alarms etc.

13.3 Lifts, Stairs and Doors in Tower

13.3.1 Introduction

This technical design report contains the concept for the lifts, stairs and doors, which must be used in the tower of the Messina Strait Bridge.

13.3.2 Scope of Work

The complete facilities for lifts, stairs and door facilities in tower covered by this report are as follows:

- Access lifts, stairs and doors in tower.

- Inspection and escape ladders in tower.
- Access stairs and inspection lifting platform in tower cross beams.
- Access to main cable saddle on tower top.

The scope of work for Progetto Definitivo covers technical performance specifications in accordance with general requirements for the contract, drawings and bill of quantities.

The design of the lifts, stairs, ladders and doors shall include integration of the access facilities into the overall bridge tower design, considering interface requirements from other parts of the bridge project.

13.3.3 Design principles

ACCESS LIFTS, STAIRS AND DOORS IN TOWER

The towers must be equipped with lifts, stairs and ladders to give access for inspection of the entire inside surface of the towers, tower cross beams, main cable saddle and other mechanical and electrical systems.

The lift will have windows for inspections at intermediate stops at tower assemblies and stairs.

Doors and hatches in the tower shall be provided as follows:

- Entrance to each tower leg through doors located at the service lane level and at the tower base.
- Access openings between stairway and lift/ladder shaft.
- Escape openings between lift shaft and stairway shaft.
- Access to all cross beams via openings in each tower leg.
- Access to the top of cross beams through doors in both tower legs.
- Access to top of the upper cross beam via stairs and hatch.
- Access to saddle room
- Access doors to top of the tower saddles via enclosed stairways.

- Access doors to the outer surfaces of the towers to climbing gantries.

WALKWAYS

The tower legs shall be equipped with inspection walkways at the circumference of the central part of the tower legs. The walkways may be connected to the longitudinal/transverse stiffeners for the tower leg and shall be accessible from the stairway. The walkways shall be minimum 1m wide and provided with railings.

INSPECTION AND ESCAPE LADDERS IN TOWER

The tower legs shall be equipped with inspection ladders in the entire height of the tower. Caged ladders shall be installed in each corner of the tower leg which is not accessible from the staircase or lift.

The lift shaft shall be equipped with escape ladders with intermediate deck and exit doors to deck and stairways at each cross beam in the tower.

ACCESS STAIRS AND INSPECTION PLATFORM IN TOWER CROSS BEAM

The tower cross beams at top of the tower shall be equipped with access stairways from bottom to top of the cross beam.

All cross beams shall include a mobile telescopic platform for giving inspection access to the entire interior of the cross beam structures.

ACCESS TO SADDLE ROOM

The saddle room will be accessible by caged ladders from the highest stairway level. Access shall be provided through holes to each cell in the saddle room.

ACCESS TO MAIN CABLE SADDLE AND MAIN CABLE WALKWAY

Cross beam 3 shall be provided with an enclosed access stairway to the tower saddle and main cable walkway.

13.3.4 Requirements

The access facilities shall be designed in such a way that the following main objectives are fulfilled:

- Lifts, stairways, ladders, platforms etc. must give access to all interior parts for inspection and maintenance.
- Doors are located at tower base, at bottom and top of cross beams, at bridge deck levels and at cable saddle giving access to the whole interior of the tower legs and cross beams.
- All relevant safety aspects are provided.
- The facilities do not damage the tower structure, in particular the adjacent structures and equipment.
- The facilities are robust and have a long service lifetime.

The lifts and stairs shall be equipped with necessary installations to provide safe transport and working conditions, e.g. normal and emergency lighting, emergency telephone, alarm etc. They shall be lockable, electrically and mechanically, while in working position in the tower.

All external openings must have watertight doors/hatches which in emergencies can be opened from the inside without a key.

All external openings shall be equipped with a surveillance system with intrusion alarms and lacking closure. Particular attention shall be paid to areas next to suspended deck and tower base to prevent intrusion.

13.4 Gantries for Tower

13.4.1 Introduction

This technical design report contains the concept for the gantries, which must be used for the tower of the Messina Strait Bridge.

13.4.2 Scope of Work

The complete access facilities for the gantries for tower covered by this report are as follows:

- Climbing gantries for the tower legs
- Gantries on the tower cross beams.

The scope of work for Progetto Definitivo covers technical performance specifications in accordance with general requirements for the contract, drawings and bill of quantities.

The design of the gantries shall include integration of the access facilities into the overall tower design, considering interface requirements from other parts of the bridge project.

13.4.3 Design principles

GENERAL

The bridge towers must be equipped with climbing gantries on the legs and travelling gantries including baskets on the tower cross beams.

CLIMBING GANTRIES FOR THE TOWER LEGS

Climbing gantries shall be provided for access to all external surfaces of the towers.

The climbing gantry must be a sky climber type surrounding the tower leg with removable parts to allow for passage of cross beams, hydraulic buffers and the suspended deck including the aerofoils on the windscreen. The gantry shall be erected and demounted at tower base. Fixed hoists in each tower leg at top of each tower cross beam level shall hoist the gantry step-by-step from tower base to the upper cross beam by successively changing to the subsequent hoist system.

TRAVELLING GANTRIES ON THE TOWER CROSS BEAM

Travelling gantries for external access of the tower cross beams shall be provided. One gantry on each tower cross beams i.e. 6 gantries in total.

The gantries must be provided with internal hoisted basket (2 pieces) to give access to the sides and bottom of the cross beams.

13.4.4 Requirements

The facilities shall be designed in such a way that the following main objectives are fulfilled:

- The gantries shall be easy to erect and operate.
- All relevant safety aspects are provided for.
- The gantries do not damage the tower, in particular the surface treatment, or adjacent structures and equipment.
- The gantries are robust and have a long service lifetime.

CLIMBING GANTRIES

The gantry must be easy to erect from base of tower and shall include removable parts to allow for passage of cross beams, hydraulic buffers and the suspended deck.

The railing shall be a structural part to ensure the structural stability while passing the hydraulic buffers.

When the gantry is erected a coordinated wire system including blocks and demountable beams through sealed openings in the tower leg can be arranged for lifting the gantry.

The gantry can be operated from base of tower to top of upper cross beam by successively hooking on and releasing the gantry to/from the subsequent hoist.

At the top of tower saddles Professional Rope Access Technician inspection will be performed.

All gantries must be provided with handrails and rails for safety wire to the extent required by Italian Regulations.

The gantries must be horizontally stabilized by guiding magnetic wheels against the tower.

The design shall provide an optimal and safe operation without damage to any elements or the tower surface coating. Special cut-outs in the shape of the gantry shall be made for passage of the floodlight luminaires on the tower.

Easy and safe access to gantries must be provided through doors in the tower legs at top of cross beam levels.

The gantries must be operational from the gantry and/or the tower by a mobile control panel.

The climbing gantry system must be equipped with separate safety wires.

The climbing gantry shall be stored in a lockable indoor environment when not used.

TRAVELLING GANTRIES

The gantry must be supported by a base frame which is travelling on rails mounted on top of the cross beam. The gantry base must be equipped with a motorized drive and hoist for lifting basket and miscellaneous equipment.

The gantry truss must be hanging on the gantry base and will include the sides and bottom of the cross beam.

The sides of the cross beam are accessed by basket hoisted inside the vertical gantry truss. The basket also gives access to the gantry platform below the cross beam between the vertical gantry trusses.

The gantry base shall be self-aligning.

The gantry for the cross beam must be able to travel the entire length of the cross beam between the tower legs. The gantry on the upper cross beam shall be able to pass the enclosed stairway to the saddle.

The vertical gantry truss can be supported by horizontal guide beams with magnetic wheels.

The gantry rail and guide beams must be replaceable.

The gantry base shall provide free access profile to pass on the cross beam during operation and in case of emergency.

Each basket shall be propelled by its own hoist.

When not in use the vertical gantry truss and the platform shall be demounted and stored inside the tower. The gantry base shall be parked and stored under a cover.

13.5 Gantry for Suspended Deck

13.5.1 Introduction

This technical design report contains the concept for the gantries, which will be used for inspection and maintenance of the suspended deck of the Messina Strait Bridge.

13.5.2 Scope of Work

The scope of work for the gantry for the suspended deck covered by this report is as follows:

- Inspection and maintenance gantries for suspended deck
- Access platform to gantry
- Loading crane for gantry.

The scope of work for Progetto Definitivo covers technical performance specifications in accordance with general requirements for the contract, these technical requirements, drawings and bill of quantities.

The design of the gantry shall include integration of the access facilities into the overall bridge deck design, considering interface requirements from other parts of the bridge project.

13.5.3 Design Principles

The suspension bridge must be equipped with mobile self-propelled inspection gantries at the suspended deck on both sides of the towers. Thus two inspection gantries for the main span and two inspection gantries for the side span of the suspended bridge are needed.

The facilities shall be designed in such a way that the following main objectives are fulfilled:

- The gantries shall provide access for inspection and maintenance.
- The gantries shall be easy to operate.
- All relevant safety aspects are provided.
- The gantries do not damage adjacent bridge structures and equipment.

- The gantries are robust and have a long service lifetime.

Inspection and maintenance for terminal structure and drop-in spans will be carried out from mobile aerial platforms on terrain.

13.5.4 Requirements

GANTRIES

Gantries will provide inspection access to the entire external surface of the bottom of the suspended bridge deck, including vertical and inclined surfaces.

Four gantries shall be provided. Two for the main span and two for the side spans.

Each gantry shall be provided with two telescopic platforms for access to all surfaces.

The gantries shall be accessible from both service lanes via stairs.

The gantries shall have a width of a least 5 m and be self propelled.

The suspended bridge deck must be provided with rails at the sides of the service lane for support and transportation of the gantries.

The gantries shall be provided with telescopic platforms in order to give access to the entire height of the bridge cross girders and to the surfaces of the road- and railway girders which are above direct reach from the gantry working area.

The telescopic platform shall operate in the whole length of the gantries and arrangements for fixing/parking shall be included.

The following areas will not be available for inspection from gantries:

- The drop-in span
- The terminal structure

ACCESS PLATFORM TO GANTRY

Access platforms to gantries shall be extended from the first and enlarged bridge cross girder closest to the tower where the gantry shall be parked.

The platforms shall serve lifting of equipment and give access to the parked gantries.

The access platform shall include a loading crane for lifting service equipment from ground level to the access platform level.

Easy and safe access by ladder/stair must be provided from the service lane to the gantry working deck, when parked anywhere along the length of the suspended bridge.

All ladders must be provided with rail for safety wire to the extent required by Italian regulations.

13.6 Inspection of terminal structure and drop-in Span

13.6.1 Introduction

These technical specifications contain the requirements for the mobile aerial platform and access to bearings, expansion joints and buffers at the tower and access to terminal structure, which are to be used for inspection and maintenance of elements of Messina Strait Bridge.

The inspection gantries for suspended deck in the main span and side span can not be transferred to the drop-in span due to the presence of articulation system and towers.

The mobile aerial platform, access to bearings, expansion joints and buffers at the tower and access to terminal structure, shall give access for inspection and maintenance to all external parts in the suspended deck in the drop-in span and at terminal structure.

The design shall provide an optimal and safe operation without damage to any bridge elements or the corrosion protection. In particular the surface treatment of the bridge elements shall be protected.

13.6.2 Scope of Work

The scope of work for the inspection and maintenance of the terminal structures and drop-in spans includes following elements:

- Mobile aerial platforms
- Access spot and access road
- Access to bearings, expansion joints and buffers at the tower
- Access to terminal structure

The scope of work for Progetto Definitivo covers technical performance specifications in accordance with general requirements for the contract, technical requirements, drawings and bill of quantities.

The design of the gantry shall include integration of the access facilities into the overall bridge deck design, considering interface requirements from other parts of the bridge project.

13.6.3 Design Principles

GENERAL

All access facilities shall be accessible for authorised personnel only.

All access facilities shall be equipped with necessary installations to provide safe transport and working conditions, e.g. normal and emergency lighting, emergency telephones, alarms etc.

All access facilities should not deteriorate or damage corrosion protection of any bridge elements.

MOBILE AERIAL PLATFORM

Mobile aerial platforms for the drop-in spans shall be provided. One for each drop-in span and terminal structure of the bridge.

The mobile aerial platform shall give access from the terrain below the suspended deck for inspection and maintenance to all external parts in the suspended deck in the drop-in span which are not available by inspection gantry for suspended deck or from walkways for access to bearings, expansion joints and buffers at the tower.

Mobile aerial platform shall give access from the terrain below the suspended deck for inspection and maintenance to all external parts at terminal structure which are not available by terminal structure walkways.

The mobile aerial platforms shall be designed in such a way that the following main objectives are fulfilled:

- Mobile aerial platforms shall give safe and stable access during inspection and maintenance works.
- Mobile aerial platforms shall be easy to erect and to operate
- All relevant safety aspects are provided.
- Mobile aerial platform is robust and have a long service lifetime.

ACCESS TO BEARINGS, EXPANSION JOINTS AND BUFFERS AT THE TOWER

Access walkways, platforms, ladders and stairways under drop-in span shall give access and allow inspection and maintenance of the whole articulation system including the lower surfaces of articulation system beams.

All walkways and stairways of access to bearings, expansion joints and buffers at the tower shall accommodate the movements and rotations of the articulation system.

ACCESS TO TERMINAL STRUCTURE

Access to terminal structure provides access to bearings and expansion joints at the terminal structure.

13.6.4 Requirements

The facilities shall be designed in such a way that the following main objectives are fulfilled:

MOBILE AERIAL PLATFORM

The mobile aerial platform shall give access from the terrain below the suspended deck for inspection and maintenance to all external parts in the suspended deck in the drop-in span and terminal structures.

ACCESS TO BEARINGS, EXPANSION JOINTS AND BUFFERS AT THE TOWER

Access stairways and walkways below drop-in span shall give access and allow inspection and maintenance of the articulation system.

The access stairways will be accessible from bridge girder openings and from hatches in the service lane deck.

ACCESS TO TERMINAL STRUCTURE

Access to terminal structures allows for the inspection and maintenance works of bearings and expansion joints at the terminal structure.

Access to terminal structure for expansion joints and bearings is achievable from roadway girder.

Bearings at the terminal structures are not fully achievable from access walkways and shall also be inspected from mobile aerial platform.

13.7 Main Cables Carriage and Hanger Basket

13.7.1 Introduction

This technical design report contains the concept for the inspection and maintenance of the main cables and hangers of the Messina Strait Bridge.

13.7.2 Scope of Work

The scope of work for the main cable carriage and hanger basket can be summarized in the following headlines:

- Cable walkway
- Cable carriage
- Hanger basket
- Access to walkway on main cables at centre of bridge, top of tower and anchor blocks.

The scope of work for Progetto Definitivo covers technical performance specifications in accordance with the general requirements of the contract and this technical specification including enclosed drawings.

The design of the cable carriage, hanger basket and access platforms shall include integration of the access facilities into the overall bridge design, considering interface requirements from other parts of the bridge project.

13.7.3 Design principles

GENERAL

The inspection and maintenance of the suspended bridge main cables and hangers shall mainly be done from cable carriage. The carriage will move between the top of the tower to either the anchor block or midspan. The cable carriage shall be easily accessed from anchor blocks, top of tower and centre of bridge. The facilities shall be designed in such a way that the following main objectives are fulfilled:

- The carriages and hanger basket shall give access to all external parts for inspection and maintenance.
- Ladders at access lanes and centre of bridge shall give access to walkways on main cables.
- Stairways to the tower saddles shall give access to walkways on main cables.
- Stairways at anchor blocks shall give access to walkways on main cables.
- The carriage and the basket shall be easy to erect on the main cable and easy to operate.
- All relevant safety aspects are provided for.
- The carriage and the basket do not damage the cable, in particular the surface treatment, or adjacent structures and equipment.
- The carriage and basket are robust and have a long service lifetime.

WALKWAY ON MAIN CABLES

The walkway on main cables must have a friction surface.

Two hand strands shall be provided for each cable for safety. Handstrands will also be used for attachment of safety harnesses with two hooks.

MAIN CABLE CARRIAGE

A sufficient number of carriages for the main cables shall be provided.

The horizontal base frame for the carriages shall be supported and shall move on handstrands

The "normal working area" for the carriage is outside approximately 350 m of the centre part of the bridge. Under special conditions the carriage shall be able to work in "Extended working area" including the centre part of the bridge.

The carriage shall be easy to erect on the supporting cables at anchor blocks and at the centre of the bridge. Installation of the carriage shall be performed directly from a truck with crane on the service lane.

The carriage must be towed by a powered towing system between the top of the bridge tower and the anchor block or midspan. The towing system must be powered by a winch haul located at top of the tower.

HANGER BASKET

The hanger basket must be a sky climber/mobile hoist type and capable of giving access to the hole length (approx. 350m) of the hangers.

The hanger basket must be operational from the service lane or from the carriage, whichever suits the inspection and maintenance program best.

MOBILE AERIAL PLATFORM

At the centre of the bridge, the main cable and hangers must be accessible from a mobile aerial platform ("normal working area" is approximately 350 m).

The mobile aerial platform must be able to give access to the cable walkway as well as to the cable carriage.

13.7.3.1 Access to walkways on main cables

Access stairways/ladders at anchor blocks, top of tower and mid span of the bridge shall give access to cable walkways and the cable carriage and hanger basket facilities.

The stairway shall have sufficient working space to facilitate the access and parking of the carriages including inspection and maintenance equipment.

13.7.4 Requirements

GENERAL

The cable carriage and hanger basket must be able to access the following areas for inspection and maintenance:

- The entire circumference of the main cables over the entire length
- All parts of the cable clamps including the tensioning rods
- Tensioning control of rods in cables clamps
- Hanger cable forks, pins and sockets
- Surface treatment on cables and clamps
- Handstrands and handstrand posts
- Carriage support cables and supporting posts.

The following areas will not be available for inspection from carriages and baskets:

- The mid span of the bridge (approximately 350 m) (normally).
- Main cables inside anchor blocks.
- Main cables inside shrouds at the saddle and anchorage blocks

The carriage must be robust and have a service lifetime of minimum 25 years and enough space for the necessary equipment.

WALKWAYS ON MAIN CABLES

The hand strand system must be continuous along the entire bridge.

Tensioning of the handstrands shall limit the lateral movement caused by horizontal loads.

MAIN CABLE CARRIAGES

The carriage for the main cables must be able to travel the entire length of the main cable between the mid span/anchor block and the tower top.

The design shall provide an optimal and safe operation without damage to any elements or the corrosion protection and without excessive deformation of the hand ropes or supports.

The design of the towing wire, handstrands and supports shall take into account the requirements of the carriage and ensure easy and safe passage.

It must be ensured that the carriage does not disturb the roadway traffic by coming into the free profile by means of stop blocks or the like.

HANGER BASKETS

Hanger baskets shall provide access to the entire height of the hanger cables.

Each basket shall be lifted by its own hoist.

The hanger basket may be incorporated in the carriage.

MOBILE AERIAL PLATFORM

The mobile aerial platform shall be able to serve the inspection of the main cables and hanger clamp at the centre of the bridge in a length of approx. 350 m.

ACCESS STAIRWAY/LADDERS TO MAIN CABLES

Access stairways to main cables and carriage shall be constructed from the bridge deck structure without interferences with the required free space profile for the roadway deck and service lane. The design of the anchor blocks and tower saddle shall allow for easy access to the main cables.

14 Dehumidification

14.1 Introduction

These technical specifications contain the requirements for the dehumidification systems, which must be used in the Messina Strait Bridge.

14.2 Scope of Work

The scope of works covers the dehumidification sub-systems in:

- The main cables
- The suspended deck, road and railway box girders and cross beams
- The terminal structures
- The tower saddles
- The towers
- The anchor block chambers

The dehumidification systems shall be optimised for lowest life cycle cost. This means an integrated system, which gives the best economy, lowest construction, operation and maintenance costs.

The scope of work for Progetto Definitivo covers technical performance specifications in accordance with general requirements for the contract, these technical requirements, drawings and bill of quantities.

14.3 Design Principles

14.3.1 General

The purpose of the dehumidification systems in the bridge is to dehumidify the air inside the bridge structures and thereby protect the interior surfaces of the structures from corrosion. To ensure this the bridge will be equipped with dehumidification plants with ventilation fans for circulation of the dehumidified air, with an average year round value of 40% relative humidity as a maximum and with an extreme value over 1 hour/day of 50% relative humidity. This will prevent corrosion of the internal steel surfaces.

The dehumidification plants dehumidify the air in the bridge structures as well as the ambient air entering for equalisation of pressure in the structures, which will occur because of climate conditions and leakages.

The systems will consist of a minimum number of dehumidification plants with low electrical consumption and all plants will be easily accessible.

The systems will require some ductwork, but the use of ductwork will be minimised due to utilisation of the structural elements as ducts.

The dehumidification systems will be designed for unmanned and unattended constant operation. They will be durable and require a minimum of maintenance.

DEHUMIDIFICATION CONCEPT

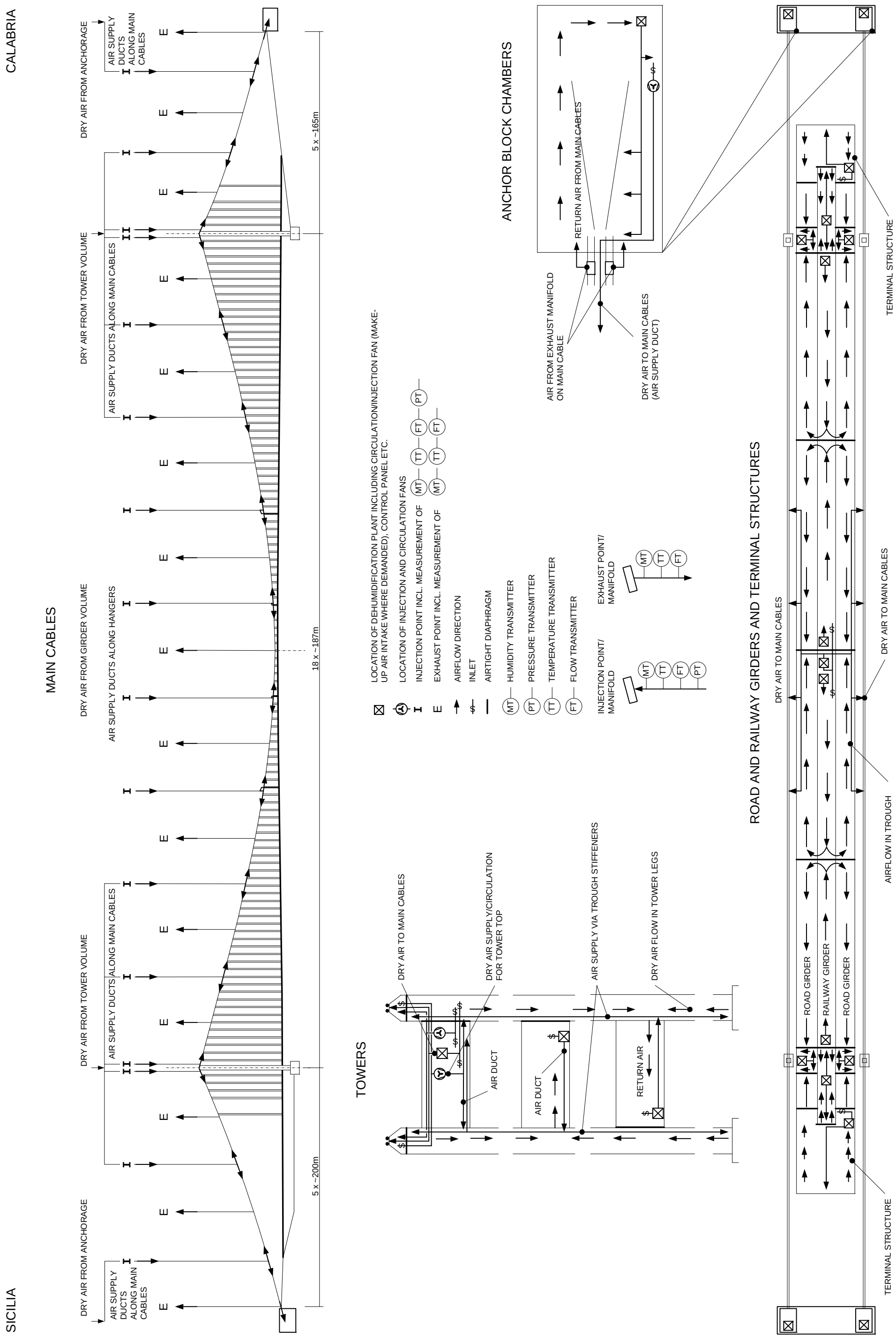

Figure 14.1 Dehumidification concept

14.3.2 Main cables

Corrosion protection of the main cables is based on a controlled volume of dry air surrounding the cable strands. There will be a continuous flow of dry air inside the main cables, supplied from a number of dehumidification plants.

In general it is not regarded feasible to recirculate air from the cables. The system will be designed to operate with a certain leakage rate from the cables to the ambient air and a slight overpressure is maintained in the cable to prevent intrusion of air and moisture from the outside. The maximum pressure inside the cable will be limited to reduce stress on the wrapping and limit injection fan power consumption.

The air flow resistance along the main cables, combined with the leakage, will require multiple injection points along the cables with air flow up and down in a number of sections. Each injection point serves a section of the main cable, and air is flowing from the injection point in both directions to the nearest exhaust points. Dry air will be supplied via ducts from the main box girders, tower legs and anchor block chambers connected to a number of injection points located along the cables. The system is therefore based on air supply from other dehumidified structure volumes, which will act as a buffer tank and minimise electrical consumption.

The system means a limited number of plants, but a more complex interaction between the different elements of the bridge. The operation of the system requires conscientious monitoring because it must be controlled that flow and pressure in each of the sections are adequate to secure permanent protection at any time without dead points along the cable.

At all injection and exhaust points, monitoring instruments are installed for permanent monitoring of system operation and documentation for corrosion protection. Temperature, humidity, flow and pressure at injection points and temperature, humidity and flow at exhaust points.

14.3.3 Suspended deck, road and railway box girders and cross beams

Corrosion protection of the inner surface of the box girders is based on drying and circulating the air volume contained inside the structures.

The requirement for distribution ductwork is minimized by utilizing the structural elements. For the dehumidification system, the suspended deck box girders can be regarded as three large parallel steel pipes, connected by the cross beams.

The dehumidification sections will be separated by airtight diaphragms and doors/hatches will be designed airtight.

The structure will be sealed airtight to the ambient air, and doors/hatches will also be designed airtight, be able to stand the specified differential pressure, and be equipped with switches for remote signal in case they are not closed.

Air pressure in the structure varies with the temperature. To reduce inflow of humid air from outside, and consequently also reduce operation cost, air pressure in the box girders will be allowed to fluctuate within certain limits. This is controlled by a damper arrangement connected to two pressure switches (high and low limit respectively). If the differential pressure, relative to outside, exceeds the preset value, the damper will open to equalize the pressure. For safety reasons, the damper will also open in case of power failure to prevent excessive pressures, which may stress the structure.

The pressure control damper arrangement is located at the upstream (low pressure) side of the dehumidification plant to let the humid air entering from the damper pass the plant before circulating in the structure.

Dry air from the box girders is used for supply of dry air to some of the injection points on the main cables and the dehumidification unit will be designed according to the additional inflow of outside air. A make-up air intake will be provided with balancing damper, instruments, etc.

14.3.4 Terminal structures

Corrosion protection is based on drying and circulating the air volume contained inside the structures.

The dehumidification plant is located in one side of the structure and dried air is supplied to the opposite side via one main air supply duct. The duct branches out and blows air in all longitudinal bulkhead chambers, which flows back to the extraction duct at the plant side of the structure.

The structure will be sealed airtight to the ambient air, and doors/hatches will also be designed airtight, be able to stand the specified differential pressure, and be equipped with switches for remote signal in case they are not closed.

As air exchange to the outside will be limited, effective protection is possible with low air circulation rate.

Air pressure in the structure varies with the temperature. To reduce inflow of humid air from outside, and consequently operation cost, air pressure in the structure will be allowed to fluctuate within certain limits. This is controlled by a damper arrangement connected to two pressure switches (high and low limit respectively). If the differential pressure, relative to outside, exceeds the preset value, the damper will open to equalize the pressure. For safety reasons, the damper will also open in case of power failure to prevent excessive pressures, which may stress the structure.

The pressure control damper arrangement is located at the upstream (low pressure) side of the dehumidification plant to let the humid air entering from the damper pass the plant before circulating in the structure.

14.3.5 Tower saddles

Corrosion protection is based on supply of dry air to the volume contained inside the saddle structure.

The saddle structure will be sealed airtight to the ambient air, and doors/hatches will also be designed airtight and equipped with switches for remote signal in case the door does not close.

For each saddle, dried air is supplied from the plant located in the tower top cross beam via air supply duct and the air is returned to the plant via extraction duct.

Due to the limited volume to the structure, no pressure control system is required.

14.3.6 Towers

Corrosion protection is based on drying and circulating the air volume contained inside the structure. The requirement for distribution ductwork is minimized by utilizing the structural elements. For the dehumidification system, the tower legs structure can be regarded as a number of parallel steel channels.

The towers are dehumidified by two plants, each serving one leg. The structure will be sealed airtight to the ambient air, and doors/hatches will also be designed airtight, able to stand the specified differential pressure, and equipped with switches for remote signal in case they are not closed. Between the legs, at the one end of the cross beams the beams are sealed by airtight diaphragms.

For each leg, dried air is supplied from the plant to a trough stiffener, which functions as a duct. In the top and bottom of the leg, openings are provided, where the air can flow from the supply air corner and circulate back to the plant through the other channels.

The dehumidification plant, including dehumidification unit, air circulation fan, air filters, dampers and the control panel are located in the low cross beam.

Air pressure in the structure varies with the temperature. To reduce inflow of humid air from outside, and consequently the operating costs, the air pressure in the tower will be allowed to fluctuate within certain limits. This is controlled by a damper arrangement connected to two pressure switches (high and low limit respectively). If the average differential pressure, relative to outside, exceeds the preset value, the damper will open to equalize the pressure. For safety reasons, the damper will also open in case of power failure, to prevent excessive pressures, which may stress the structure.

The pressure control damper arrangement is located at the upstream (low pressure) side of the dehumidification plant; to let the humid air entering from the damper pass the plant before circulating in the structure.

Dry air from the towers is used for supply of dry air to some of the injection points on the main cables and the dehumidification unit will be designed according to the additional inflow of outside air. A make-up air intake will be provided with balancing damper, instruments, etc.

14.3.7 Anchor block chambers

Corrosion protection of the main cable strands and other steel elements in the anchor block chamber is based on drying and circulating the air volume contained inside the structure.

The chambers will be sealed airtight to the ambient air; doors/hatches will also be designed airtight and be equipped with switches for remote signal in case the not is door closed.

For each chamber, dried air is supplied from the plant placed above the back wall of the chamber. A duct from the plant carries dray air to the upper end, and the air flows back to plant from here.

The dehumidification plant, including dehumidification unit, air circulation fan, air filters, dampers and the control panel are located in the lower end of the chamber.

Due to the slow pressure fluctuations, no pressure control damper system is required.

Dry air from the chambers is used for supply of dry air to some injection points on the main cables and the dehumidification unit will be designed according to the additional inflow of outside air. A make-up air intake will be provided with balancing damper, instruments, etc.

The air from the main cables is discharged through an exhaust manifold just outside the anchor blocks for measuring the air humidity, temperature and flow. The exhaust air is lead via a duct into the anchorage. The rest of the air from the main cables is discharged where the cables spread in the chamber. This will reduce the mount of makeup air needed for the main cables to a minimum.

14.4 Requirements

14.4.1 Design Requirements

The design of the dehumidification system shall be able to fulfil the following requirements inside the steel bridge structure:

- Infiltration of outside air 2% of structure volume/hour.
- Maximum 50% relative air humidity within 1 hour/day.
- Relative air humidity max 40 % yearly average (operation preset limit value 40%).
- Dehumidification systems capacity:
  - General, min 0.25 g (water to be removed)/hour per m^3 dehumidified structure volume.
  - Box girders and towers plant including make-up air for main cables, min 0.55 g (water to be removed)//hour per m^3 dehumidified structure volume.
  - Anchor block chamber plant, min 0.45 g (water to be removed)/hour per m^3 dehumidified structure volume.

- Supplementary plant for main cables, min 2.5 g (water to be removed)/hour per m^3 dehumidified structure volume.

- Air circulation rate:
  - Min 2 times per 24 hours for box girders, terminal structures and anchor block chambers.
  - Min 4 times per 24 hours for towers and saddles.
  - Min 24 times per 24 hours for main cables.
- Differential pressure range for pressure control damper system: ±400 Pa (pressure switch hysteresis <20 Pa).
- Distance between injection points max 400m corresponding to airtight cables.
- Air pressure at injection points max 2 kPa.
- The machinery of the dehumidification plant shall be placed on vibration isolators.
- The friction loss of the ductwork shall not exceed: 1 Pa/m.
- The air velocity in the ducts shall not exceed: 6 m/s.
- The air velocity in the air intake shall not exceed: 2.5 m/s.
- The working load/operation range ratio of the components shall not exceed: 75%.
- The functional behaviour of the dehumidification systems shall be monitored continuously by means of instrumentation as follows. Signals shall be connected to and monitored from the Control and Monitoring System/Supervisory Control and Data Acquisition(CMS/SCADA):
  - Relative air humidity
  - Pressure
  - Temperature
  - Velocity (air flow).
- The sound level must not exceed the following values:
  - Inside structure: 70 dB(A)
  - Outside structure: 60 dB(A).

14.4.2 Control

The dehumidification plants shall be designed as an autonomic unit as can operate without any control signals form the CMS/SCADA system.

During normal conditions the start and stop of the system shall be controlled by electronic humidity sensors connected to dehumidification local control panel, as shown on drawings.

In case the relative air humidity exceeds the preset limit value, the system shall start, automatically controlled by the dehumidification control panel. In case of falling value, the system shall automatically stop at the lower preset value.

Humidity and temperature recording shall be at minimum two relevant locations for each area to be dehumidified.

Hour counters for recording operation time for the dehumidification unit and ammeter for recording of power consumption to be installed for each plant and connected to CMS/SCADA system.

An emergency off switch shall be installed at each dehumidification plant.

14.4.3 Remote Control and Monitoring

The dehumidification control panel shall be connected via CMS/SCADA system.

Signals and operational functions shall be accessible at the terminal rack in the dehumidification control board.

All above data shall be recorded and displayed.