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.

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Unità Funzionale	OPERA D'ATTRAVERSAMENTO	PS0159_F0
Tipo di sistema	SOVRASTRUTTURE	
Raggruppamento di opere/attività	STRUTTURE TERMINALI	
Opera - tratto d'opera - parte d'opera	General	
Titolo del documento	Design Report – Secondary Elements	

CODICE: C G 1 0 0 2 P C L D P S V S 8 0 0 0 0 0 0 0 0 2 F0

REV	DATA	DESCRIZIONE	REDATTO	VERIFICATO	APPROVATO
F0	20-06-2011	EMISSIONE FINALE	SP	AB	MC/LSJ

NOME DEL FILE: PS0159_FO.doc

INDICE

1 Executive Summary

The terminal structures are the approach infrastructures connecting the suspension bridge with the existing road and railway network on the two sides.

On the Sicilia side the terminal structure is linked to the bridge and to the Pantano Viaduct, while on the Calabria side it is linked to the bridge and to a viaduct and connections to the existing infrastructures coming from Villa S. Giovanni.

The terminal structures have a composite section of steel and concrete. The decks are made up of a steel framed structure, 60.870 m wide. The length differs between Sicilia and Calabria side; and comprises 94.200 m (Sicilia side) and 71.202 m (Calabria side) respectively. The concrete slab laying over the deck has a thickness of 300 mm (250 mm concrete and 50 mm of predalles) along road lane and 400 mm along rail lane (350 mm concrete and 50 mm of predalles).

The deck of each terminal structure supports a railway, 2 roadways, and 2 service lanes. The railway platform consists of two tracks, with a distance of 4 meters between axes and two pedestrian walkways; the total transversal length of the rail platform is 10.098 m.

The roadways are made up of 2 road lanes with a width of 3.75 m and an emergency lane of the same size, with a total transversal length of 11.95 m , and they contains also a service lane 3.75 m wide of Anas S.p.A. (Azienda Nazionale Autonoma delle Strade).

The service lane is located on the outside of the roadway over the entire length of the suspended deck and the terminal structures. It is the primary access route for inspection and maintenance.

Along the railway a platform is located on either side of the railway tracks for evacuation if necessary. The platform is continuous over the entire terminal structure length and has to be 1.518 m wide minimum.

Both service lanes and platforms for evacuation are part of the main structure.

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

The terminal structures have just one span with a cantilevered overhang of 19.600 m at each end. They are connected to the main cable system by tie-down hanger cables, which - via an opening through the superstructure of the Terminal Structure - are tied-down into the substructure.

Bearing devices are located where the suspended deck and the viaduct lands on the terminal structure whilst the terminal structure itself is supported by bearings above the piers. Walkways and platforms will provide the primary access to bearings.

Piers are made of reinforced concrete with a 2-cell box section (dimensions 14 m x 7 m and with a thickness of 0.8 m). At the top, they are connected with a reinforced concrete beam section (28 m x 7 m), with a section conformed to allow jack housing.

This report describes the design of the secondary structures in relation to the terminal structures.

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

Secondary structures in relation to the terminal structures consist of the following elements:

LIGHT 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.

CRASH BARRIERS

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

ACCESS FACILITIES

It is essential that all access facilities for the terminal structures are designed to obtain complete and easy access to all areas of the terminal structures and installations for the purpose of inspection and maintenance.

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

- Deck
- Tie-down Hangers
- Bearings and expansion joints
- Dehumidification unit

Further access to the above mentioned elements is described below.

Deck:

- Main access entrances from both service lanes to the interior of the each terminal structure deck will be arranged.
- Walkways are arranged to the areas that need to be inspected, i.e. the dehumidification unit, the bearing support areas and the longitudinal buffer support areas.
- Openings/hatches which allows access to bearings and expansion joints where the suspended deck lands on the terminal structure

Tie-down Hangers:

- Access to tie-down hangers supports from the piers.
- Access to tie-down hangers holes from deck through access doors, stairs and walkways.

Walkways and platforms will provide the primary access to bearings, expansion joints and hydraulic buffers in addition the access which is foreseen by use of mobile lifts from terrain level

Access to the piers shall also be provided, as described below:

- Entrance to each pier through doors located at the tower base.
- Complete access to all inner surfaces of the piers by stairs and ladders.
- Access to the top of cross beams through doors in both piers.
- Access to top of the upper cross beam via stairs and hatches.

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

DEHUMIDIFICATION

The purpose of the dehumidification systems in the terminal structures is to dehumidify the air inside the terminal structures and thereby minimise need for further protection of the interior surfaces of the structure. To obtain this each terminal structure is equipped with dehumidification plant and ducts for circulation of the air, with an average year round value of 40% relative humidity as a maximum and with an extreme value over 24 hours of 50% relative humidity. This shall prevent corrosion of the internal steel surfaces.

DRAINAGE DUCT

Tender design included in the Messina bridge design 3 major drainage pipes in each girder. This has now been reduced to 1 drainage pipe per road girder and two drain pipes in rail girder with a maximum diameter of 400 mm. In the terminal structures, the same sort of drainage pipes used in the bridge has been indicated. Two pipes will run along the two roadways.

2 Introduction

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 terminal structures are the approach infrastructures connecting the suspension bridge with the existing road and railway network on the two sides.

On the Sicilia side the terminal structure is linked to the bridge and to the Pantano Viaduct, while on the Calabria side it is linked to the bridge and to a viaduct and connections to the existing infrastructures coming from Villa S. Giovanni.

The terminal structures have a composite section of steel and concrete. The decks are made up of a steel framed structure, 60.870 m wide. The length differs between Sicilia and Calabria side; and comprises 94.200 m (Sicilia side) and 71.202 m (Calabria side) respectively. The concrete slab laying over the deck has a thickness of 300 mm (250 mm concrete and 50 mm of predalles) along road lane and 400 mm along rail lane (350 mm concrete and 50 mm of predalles).

The deck of each terminal structure supports a railway, 2 roadways, and 2 service lanes. The railway platform consists of two tracks, with a distance of 4 meters between axes and two pedestrian walkways; the total transversal length of the rail platform is 10.098 m.

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

2.1 Scope

This report describes the design of the secondary structures for the terminal structures. The Design Report identifies and summarise the design principles for the various structural parts and access facilities.

2.2 Report Outline

This report is organized into the following sections:

- *Section 1* - Executive summary
- *Section 2* - gives a brief introduction/presentation of the project and provides a list of reference materials, including design specifications, design codes and material specifications.
- *Section 3* - describes the limit states.
- *Section 4* - provides a short introduction of the materials for the secondary structures.
- *Section 5* - Light masts.
- *Section 6* - Catenary masts.
- *Section 7* - Crash barriers.
- *Section 8* - Access facilities.
- *Section 9* – Dehumidification
- *Section 10* – Drainage duct

Section 5 to 10 and the different access facilities are structured the same way. The section starts with an introduction. Then the design principles and the requirements are presented.

2.3 References

2.3.1 Design Specifications

GCG.F.04.01 “Engineering – Definitive and Detailed Design: Basis of Design and Expected Performance Levels,” Stretto di Messina, 2004 October 27.

2.3.2 Design Codes

NTC-08: DM14.1.2008 - “Norme tecniche per le costruzioni,” 2008 (NTC08).

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 1-4: Supplementary rules for stainless steels

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.

EN 1993 Eurocode 3: Design of Steel Structures – Part 1-9: Fatigue.

EN 1993 Eurocode 3: Design of Steel Structures – Part 1-10: Selection of steel for fracture toughness and through thickness properties.

EN 1993 Eurocode 3: Design of Steel Structures – Part 2: Steel Bridges.

EN 1998 Eurocode 8: Design of structures for earthquake resistance.

EN 1999 Eurocode 9: Design of aluminium structures - Part 1-1: General structural rules

Rete Ferroviaria Italia - Istruzione No. 44F “Verifiche a fatica dei ponti ferroviari”

2.3.3 Material Specifications

EN 10025-1:2004 Hot rolled products of structural steels – Part 1: General technical delivery conditions.

EN 10025-2:2004 Hot rolled products of structural steels – Part 2: Technical delivery conditions for non-alloy structural steels.

EN 10025-3:2004 Hot rolled products of structural steels – Part 3: Technical delivery conditions for normalized / normalized rolled weldable fine grain structural steels.

EN 10025-4:2004 Hot rolled products of structural steels – Part 4: Technical delivery conditions for thermomechanical rolled weldable fine grain structural steels.

EN 10164:1993 Steel products with improved deformation properties perpendicular to the surface of the product – Technical delivery conditions.

EN ISO 898-1:2001 Mechanical properties of fasteners (made of carbon steel and alloy steel) – Part 1: Bolts, screws and studs (ISO 898-1:1999).

EN 20898-2:1994 Mechanical properties of fasteners – Part 2: Nuts with specified proof load values – coarse thread (ISO 898-2:1992).

UNI EN 14399-3: 2005 High-strength structural bolting assemblies for preloading - Part 3: System HR - Hexagon bolt and nut assemblies

EN 485 Aluminium and aluminium alloys - Sheet, strip and plate - Part 1-4.

EN 755 Aluminium and aluminium alloys - Extruded rod/bar, tube and profiles- Part 1-9.

3 Materials

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

3.1 Structural Steel

The secondary structures components are 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 3.1, in accordance with NTC 2008 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: 210000 MPa $E = 210{,}000$ MPa
- Poisson's ratio: 0.3
- Shear modulus: 80769 MPa
- Coefficient of thermal expansion: 12 x 10^{-6} / °C $\alpha = 12 \times 10^{-6}/°C$
- Density: 7850 kg/m^3 $\rho = 7850$ kg/m^3

The material partial factors 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 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)	$\gamma_M = 1.35$

Table 3.2 Material partial factors for structural steel

3.2 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 3.3, in accordance with NTC 2008 Section 11.3.4.6.1.

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

Table 3.3 Structural bolt mechanical properties

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 3.4.

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	$\gamma_{M7} = 1.10$

Table 3.4 Material partial factors for bolted connections and splices

3.3 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 3.5.

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	$\gamma_{M3} = 1.10$

Table 3.5 Material partial factors for welded connections

3.4 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: $\upsilon = 0.33$

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

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

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

3.5 Stainless Steel

All mechanical installations related to the dehumidification system shall be made of 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.

4 Light Masts

4.1 Introduction

This design report contains the concept for fixing the light masts at the terminal structures. The light mast itself is identical to those used on the suspended bridge deck.

4.2 Design Principles

The light masts consist of a conical pole with a base plate for fixation to the concrete deck of the terminal structures. The fixation will be realized with the following:

- pipe through the concrete deck
- prestressed bolt to eliminate fatigue effects
- neoprene gasket to ensure adequate air tightness due to the dehumidification

The principle is illustrated in Figure 4-1:

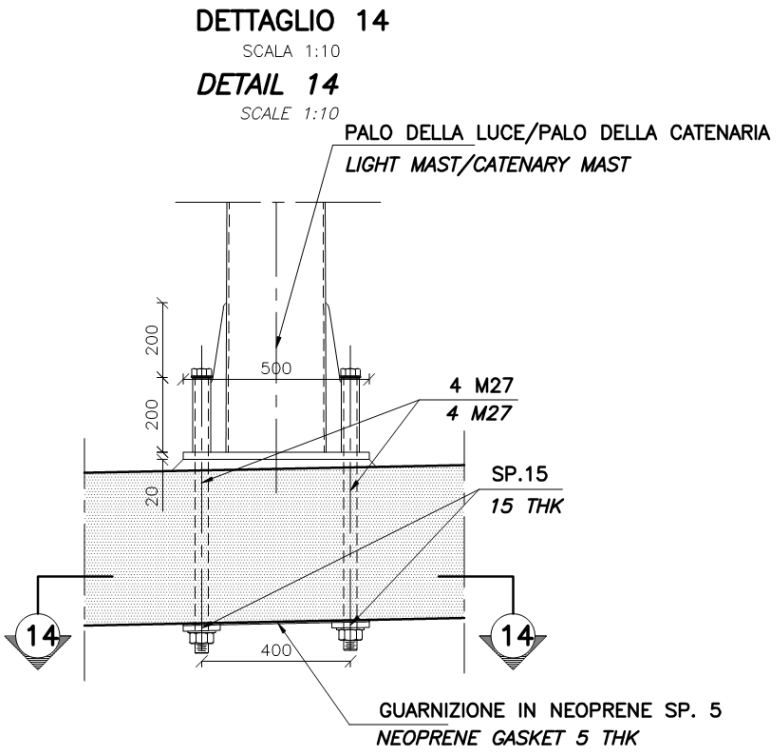

Figure 4-1: Fixation of light mast and catenary masts

The mast poles will be equipped with a simple vibration damper in the top to minimize wind induced vibrations.

5 Catenary Masts

5.1 Introduction

This design report contains the concept for fixing the catenary masts at the terminal structures. The catenary mast itself is identical to those used on the suspended bridge deck.

5.2 Design Principles

The catenary masts consist of a circular hollow section mast pole with a base plate for fixation to the concrete deck of the terminal structures.

The same type of fixation used for the light masts will be realized for the catenary masts - please refer to section 4.2

6 Crash Barrier

6.1 Introduction

This design report contains the concept for fixing the crash barrier at the terminal structures. The crash barrier itself is identical to those used on the suspended bridge deck.

6.2 Design Principles

The light masts consist of a conical pole with a base plate for fixation to the concrete deck of the terminal structures. The fixation will be realized with the following:

- pipe through the concrete deck
- prestressed bolt to eliminate fatigue
- neoprene gasket to ensure adequate air tightness due to the dehumidification
- the fixation of the crash barrier to be designed wit an ultimate capacity of 1.5 × capacity of the post of the crash barrier in order to let the crash barrier yield before the deck structure

The principle is illustrated in Figure 6-1:

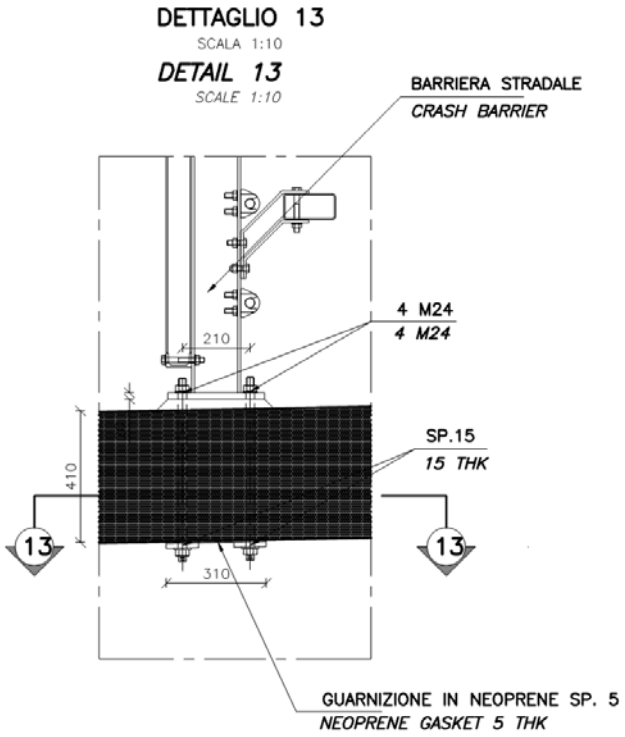

Figure 6-1: Fixation of crash barrier

The vertical posts are placed at equal intervals and support the two horizontal guard rails running the entire length of the roadway.

7 Access Facilities

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

For the deck all openings to the outside must be of airtight quality and self-closing due to the dehumidification.

In general all access facilities are fixed to the structure via designated brackets which are welded to primary structure in order avoid penetrations of the primary structure.

7.1 Access to deck

7.1.1 Introduction

This design report describes the concept for inspection and maintenance walkways, which must be used in the deck of the terminal structures.

7.1.2 Scope of Work

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

- Access to interior walkways in the deck, via service lanes
- Access walkways inside terminal structure deck

7.1.3 Design Principles

ACCESS WALKWAYS IN TERMINAL STRUCTURE DECK

Walkways consist of gratings with railings and are arranged inside the deck.

All interior walkways 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 over the walking surface.

Walkways/access is illustrated in Figure 7-1, Figure 7-2 and Figure 7-3.

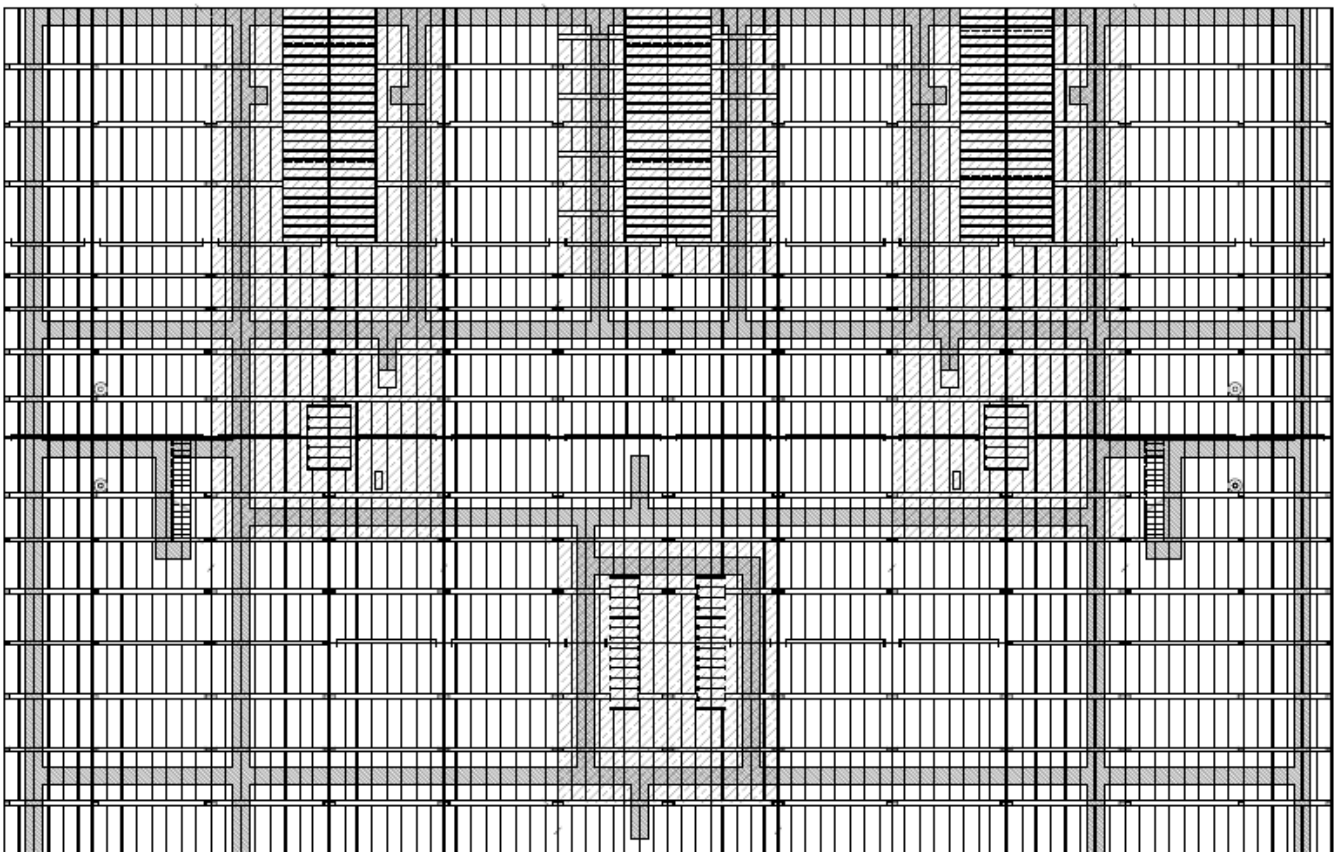

Figure 7-1: Access around bearing area at suspended deck landing (Sicilia side shown - extract)

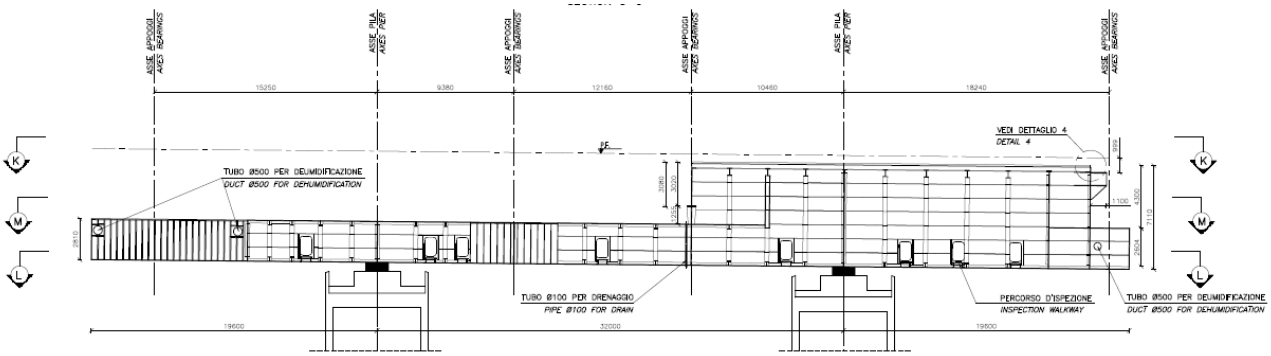

Figure 7-2: Access openings in longitudinal diaphragms (Calabria side shown)

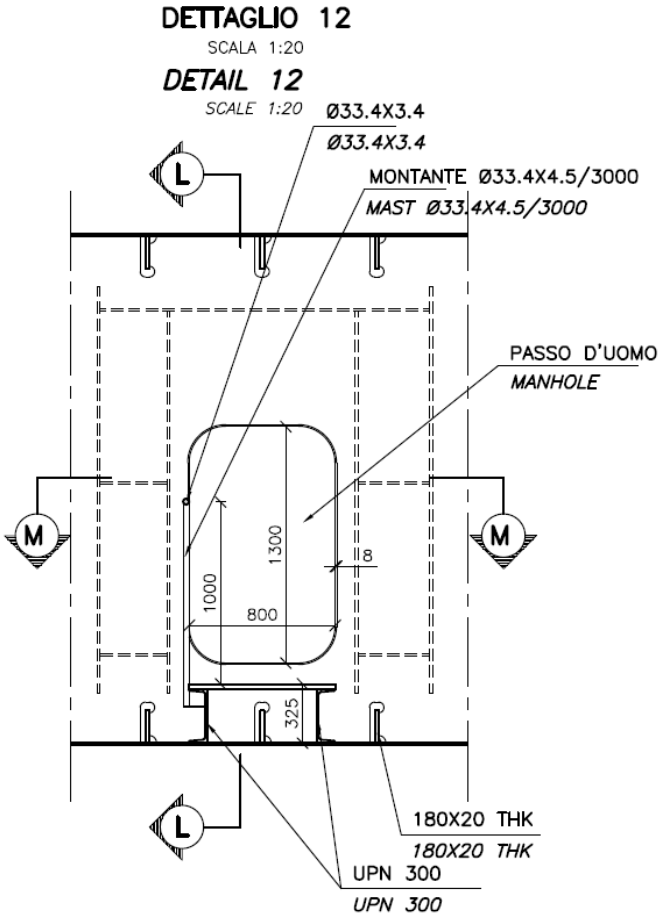

Figure 7-3: Walkway and man hole

7.1.4 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 free space to access and exit the deck
- All relevant safety aspects are provided for
- 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.

7.2 Access to Bearings, Expansion Joints, Hydraulic Buffers and Tie-Down Hangers

7.2.1 Introduction

This design report describes the concept for inspection and maintenance walkways and platforms, which must be used to get access to bearings, expansion joints and hydraulic buffers for the terminal structures.

7.2.2 Scope of Work

The complete access facilities for bearings, expansion joints and hydraulic buffers and tie-down hangers are covered by this report, as follows:

- Walkways and platforms for inspection of bearings and expansion joints
- Stairways and ladders to access to tie-down hangers from the piers
- Walkways and doors to access to tie-down hangers from the deck
- Openings/hatches to gain access to bearings and expansion joints where the suspended deck lands on the terminal structure

7.2.3 Design principles

Bearings and expansion joints shall be accessed through openings/hatches in the deck and stairs from service lane to platforms and walkways.

Buffers will be accessed via lifting platform from the ground.

It shall be possible to do inspection and normal maintenance without disturbing the daily traffic.

7.2.4 Requirements

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

- Walkways shall give access to all bearings, expansion joints and hydraulic buffers for inspection and maintenance

- All relevant safety aspects are provided for
- Screening should be provided for all equipment sensitive for sunlight and rain
- 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.

7.3 Stairs and Doors in Piers

7.3.1 Introduction

This design report describes the concept for stairs and doors, which must be used in Piers of the Terminal structures.

7.3.2 Scope of Work

The complete facilities for stairs and door facilities in terminal structures covered by this report are as follows:

- Access stairs and doors in piers.
- Inspection and escape ladders in piers

7.3.3 Design principles

STAIRS AND DOORS IN PIERS

The terminal structures must be equipped with stairs and ladders to give access for inspection of the entire inside surfaces of the piers, and other mechanical and electrical systems.

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

- Entrance to each pier through doors located at the base.
- Openings in pier diaphragms for vertical access.
- Access to the cross beams via openings in each pier.

- Access to the top of cross beam via stairs and hatches in the deck.

INSPECTION AND ESCAPE LADDERS IN PIERS

The piers shall be equipped with inspection ladders in the entire height.

ACCESS STAIRS AND INSPECTION PLATFORM IN PIERS BEAM

The cross beams at top of the piers shall be accessed through a door in the pier from the inside and through hatches from the deck.

7.3.4 Requirements

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

- Stairways, ladders, platforms etc. must give access to all interior parts for inspection and maintenance.
- Doors are located at pier base and at cross beams giving access to the whole interior of the piers and cross beams.
- All relevant safety aspects are provided for.
- The facilities do not damage the piers structure, in particular the adjacent structures and equipment.
- The facilities are robust and have a long service lifetime.

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

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 at deck and base to prevent intrusion.

8 Dehumidification

8.1 Introduction

This design report describes the concept for air distribution for the dehumidification of the terminal structures.

The general technical specifications and performance specification for the dehumidification plant is described in separate reports.

8.2 Scope of Work

The scope of works covers the provision of sufficient number of openings to allow duct penetrations and adequate airflow.

8.3 Design Principles

8.3.1 General

The purpose of the dehumidification systems in the terminal structures is to dehumidify the air inside the terminal structures and thereby protect the interior surfaces of the structure form corrosion. To obtain this, each terminal structure shall be equipped with a dehumidification plants and ducts for circulation of air, with an average year round value of 40% relative humidity as a maximum and with an extreme value over 24 hours of 50% relative humidity. This shall prevent corrosion of the internal steel surfaces.

The dehumidification plants dehumidify the air in the terminal structure deck as well the as ambient air entering.

The system will consist of one dehumidification plant for each terminal structure with low electrical consumption. Each plant will be easily accessible.

The system will require some ductwork.

8.3.2 Deck

The dehumidification plant will be located towards the seaside and close to the walkway for easy access.

The airflow is as follows:

- From the plant a duct brings the dry air to the viaduct end of the terminal structure deck
- At the viaduct end the dehumidified air is distributed to the compartments inside the deck.
- Dry air flows towards the suspended deck end and absorbs water during the flow
- At the suspended deck end the moist air is directed to the dehumidification plant where it is desiccated and the flow process is repeated

The principle is illustrated in Figure 8-1.

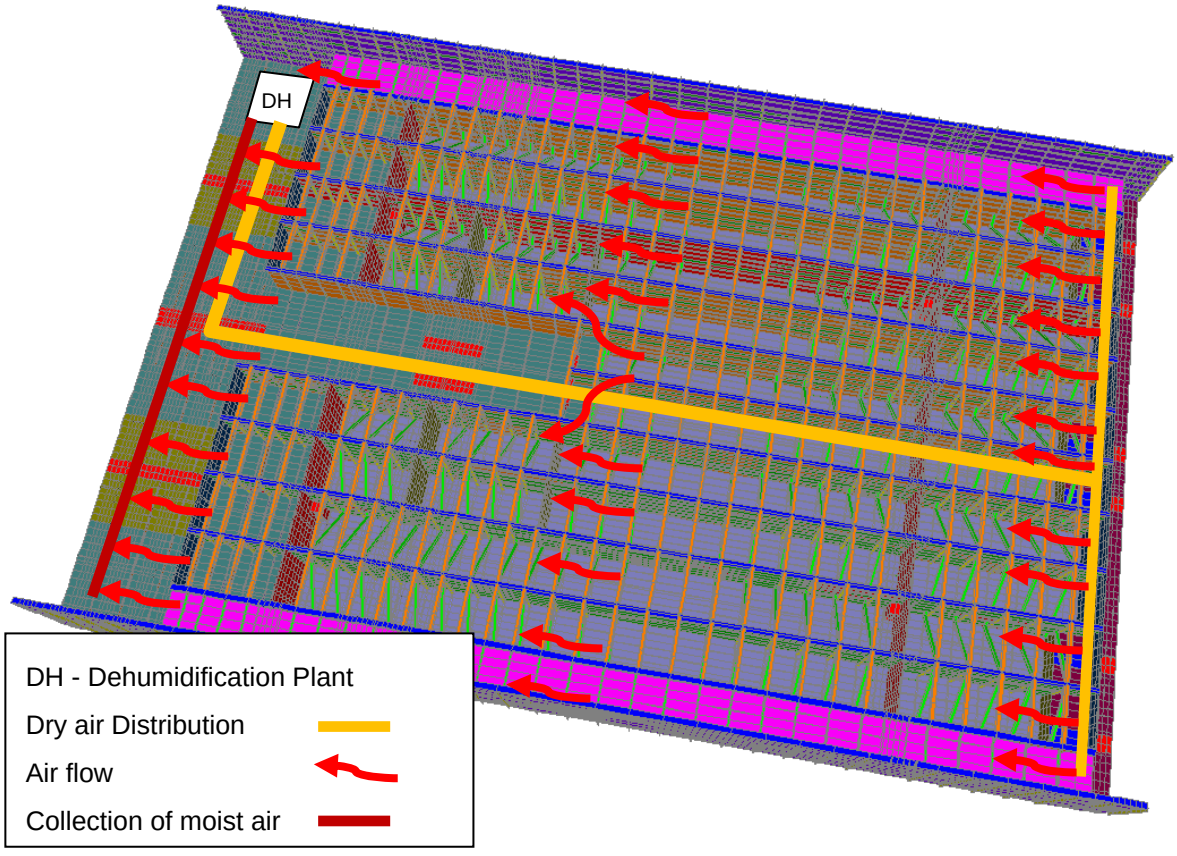

Figure 8-1: Dehumidification principle - airflow

Ductworks vary between Ø500 - Ø600 and openings are provided in diaphragms whereas the dehumidified air flows though those access openings which are necessary for walkways.

At the dehumidification plant openings in the soffit are necessary for pressure relief valves and dampers. Flanges for these components are provided in stainless steel grade 316L

9 Drainage

The same sort of drainage duct used in the suspended deck has been indicated for the terminal structures.

This consists of 1 drainage pipe per roadway with a maximum diameter of 400 mm.

The two pipes from the terminal structures will convert the collected rain into a drainage system of pipes inside the piers of terminal structures, both in Sicily and in Calabria side.

Drains and drainage pipe is illustrated in Figure 9-1.

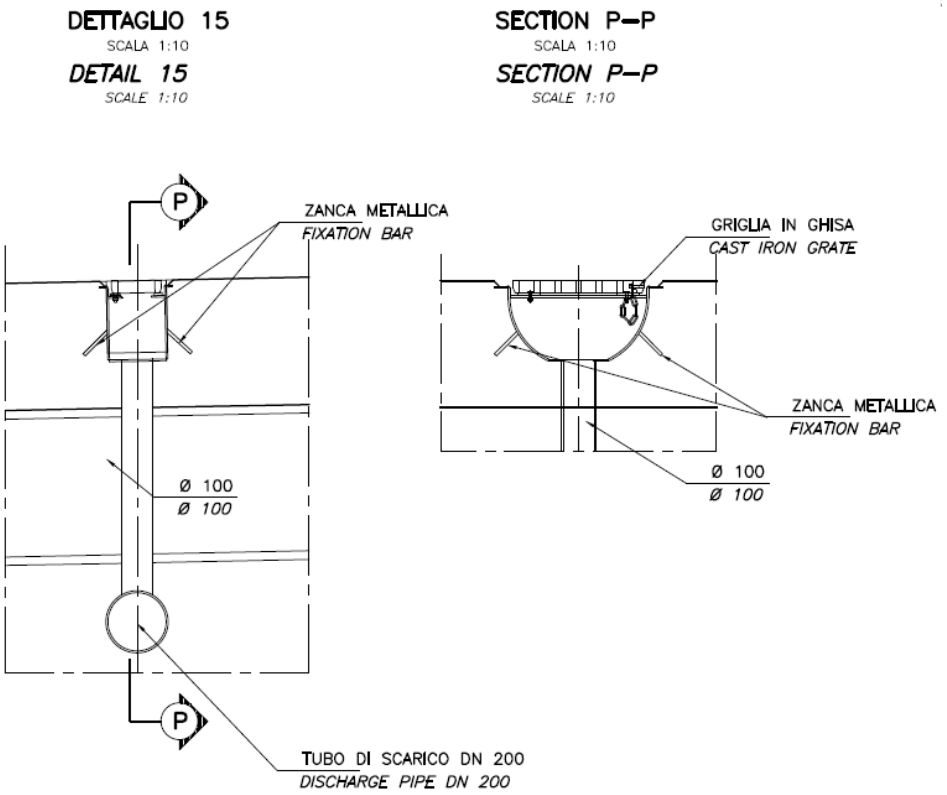

Figure 9-1: Drainage

10 Others

Fire hydrants

Fire hydrants are required on the deck and fixations to the deck will be provided via anchors or similar into the concrete deck.

Electrical

Inside the terminal structure there will be provided supports/brackets for cable trays for power supply and other electrical equipment for, inter alia, the dehumidification plant, lighting, light masts, alarms and structural monitoring.

Penetrations for cables to the outside must enter through an airtight fitting (Brattberg or similar).

Cables ladders will run through the pier legs and enter the deck through an airtight fitting (Brattberg or similar).

Inside the deck cable trays will carry the necessary electrical equipment.

It is, however, expected that the electrical equipment inside the deck is relatively minimal.