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EurolinK

PONTE SULLO STRETTO DI MESSINA

PROGETTO DEFINITIVO

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INDICE

1 Introduction

The purpose of this document is to give an introduction to the structural and geotechnical design verification principles and results for the Sicilian and Calabrian anchor blocks for the Messina Strait Bridge.

The structural verification has been reported in the following design reports:

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- Semi-local FE Model Description
- Earth pressures for structural model
- Structural Calculation Report, Sicily Anchor Block
- Structural Calculation Report, Calabria Anchor Block

The geotechnical verification has been reported in the following design reports:

- Sicily Anchor Block - earthquake induced displacements and safety against ultimate limit states
- Sicily Anchor Block - evaluation of block behaviour via 3D FE analyses and of bearing capacity
- Calabria Anchor Block - earthquake induced displacements and safety against ultimate limit states
- Calabria Anchor Block - evaluation of block behaviour via 3D FE analyses and of bearing capacity
- Seismic analyses for soil-foundation systems

2 Technical description

In the present Definitivo Design the overall dimensions of the anchor blocks from the Tender Design have generally been maintained; however the following modifications have been introduced:

- The Sicily anchor block has been moved approximately 10m towards East, to avoid interference between the main cables and the adjacent cemetery. This movement also influences the locations of the other bridge foundations, as the bridge alignment was rotated around the Calabria anchor block.
- The shapes of the anchor blocks have been slightly adjusted in order to facilitate the casting of the anchor blocks in 3m × 11m × 26m sections. This mainly affects the base of the anchor blocks and the fill compartments.
- The walls of the Sicilian anchor block are made flush with the diaphragm walls used for the construction pit. This means that the "overhanging" upper exterior beam has been deleted. This change has also a slight influence on the overall widths of the anchor block.
- The use of coupled reinforcement ø 46mm bars has been replaced with lapped bars of smaller diameter.
- The anchorage of the PPWS strands at the anchor block is changed from DYWIDAG bars to looped post-tensioned tendons.
- The heavy fill of the Calabrian anchor block has been replaced by ordinary sand fill.
- The concrete for the mass concrete has been changed to a slow hardening concrete type, generating less heat during hydration.

2.1 Sicily anchor block

The external dimensions of the anchor block are shown in the Definitivo drawing (General arrangement).

The Sicilian anchor block is founded above the ground water table in Messina Gravels. Jet grouted soil zones are provided in front of and below the anchor block to (slightly) increase the sliding load capacity of the anchor block. This jet grouting has been designed for Eurolink by RockSoil.

The main part of the anchor block will be cast in blocks of 3m × 11m × 26m. The blocks will be staggered in order to avoid through going vertical casting joints. The reinforcement of each block will be prepared as prefabricated cages to be installed in one operation.

The main cables are connected to the anchor block through steel crossheads that are anchored to the concrete massif by post tensioned looped VSL tendons 6-19.

The roof of the splay saddle chamber shall be constructed as a 300 mm in-situ cast reinforced concrete slab supported on prefabricated preinstalled prestressed concrete beams.

At the rear end of the anchor block prefabricated elements shall be installed as support for the terraced soil compartments.

For the Sicilian anchor block a concrete grade C30/37 has generally been assumed. However in the heavily stressed zones in the front part of the anchor block and underneath the anchor crossheads and at the saddle supports a concrete grade C35/45 concrete is assumed. The walls and roofs of the splay saddle chambers as well as the prefabricated elements at the rear end of the anchor block are foreseen with concrete grade C45/55.

Landscaping fill will be placed above the rear part of the anchor block in order to reinstate the original ground level within the anchor block area. Landscaping is to be designed by Eurolink.

The lay-out of the Sicilian anchor block appears from Figure 2-1.

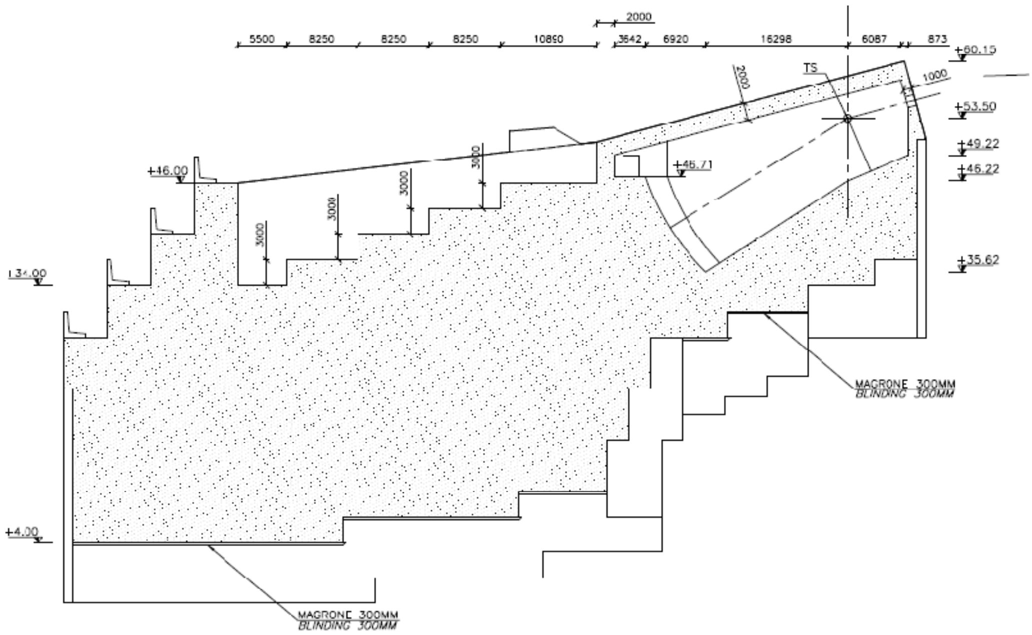

Figure 2-1 Lay-out of Sicilian anchor block

2.2 Calabrian anchor block

The external dimensions of the anchor block are shown in the Definitivo drawing (General arrangement).

The Calabrian anchor block is founded in Pezzo Conglomerate below the ground water table.

The main part of the anchor block will be cast in blocks of 3m × 11m × 26m. The blocks will be staggered in order to avoid through going vertical casting joints. The reinforcement of each block will be prepared as prefabricated cages to be installed in one operation.

The main cables are connected to the anchor block through steel crossheads that are anchored to the concrete massif by post tensioned looped VSL tendons 6-19.

The roof of the splay saddle chamber shall be constructed as a 300 mm in-situ cast reinforced concrete slab supported on prefabricated preinstalled prestressed concrete beams.

For the Calabrian anchor block a concrete grade C30/37 has generally been assumed. However in the heavily stressed zones in the front part of the anchor block and underneath the anchor crossheads and at the saddle supports a concrete grade C35/45 concrete is assumed. The walls and roofs of the splay saddle chambers are foreseen with concrete grade C45/55.

Landscaping fill will be placed on top of the rear part of the anchor block, in order to reduce the visual impact of the anchor block. The landscaping is designed by Eurolink.

The lay-out of the Calabrian anchor block appears from Figure 2-2.

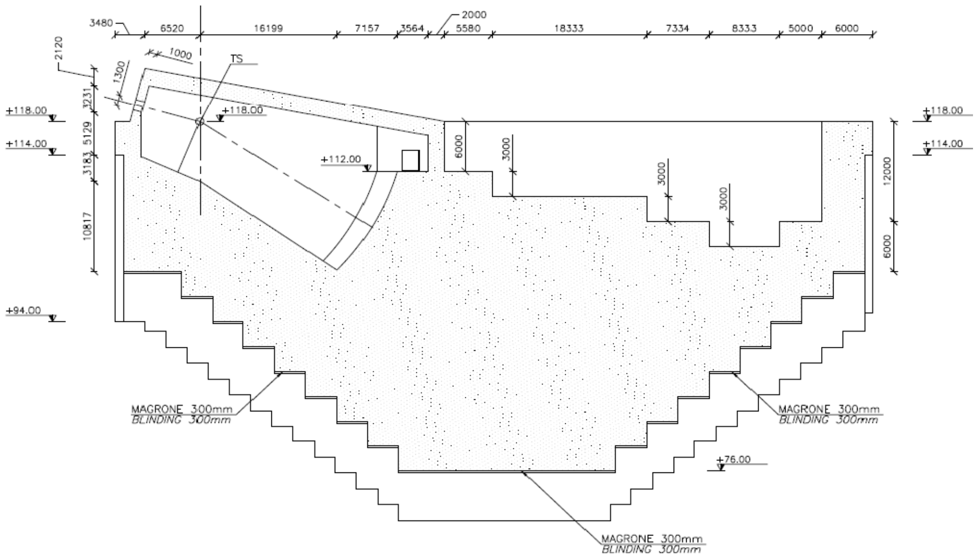

Figure 2-2 Lay-out of the Calabrian anchor block

3 Soil conditions and material properties

3.1 Soil conditions

The soil stratigraphy and the geotechnical characterisation are described in the report: “Updated geotechnical characterisation based on the 2010 site and laboratory investigations, Annex” (CG1003-P-RG-D-P-SB-G3-00-00-00-00_01_A) prepared by Professors S. Rampello and A. Flora under an agreement with Eurolink, The report includes the results from the in situ tests planned for the Progetto Definitivo, together with laboratory tests carried out on undisturbed frozen samples and on samples reconstituted at values of relative densities in the range of 40 to 80 %. .

The soil properties and soil stratigraphy from the above report have been used for the structural and geotechnical verification for the Progetto Definitivo.

3.2 Materials

3.2.1 Concrete

The main properties of the concrete used for the anchor blocks are summarised in Table 3-2. The characteristic concrete cylinder strength should be achieved after 60 days.

Table 3-2 Concrete material properties

Strength class	Characteristic cylinder strength, f_{ck}	Design cylinder strength, $f_{cd} = f_{ck}/\gamma_C$	Characteristic axial tensile strength, $f_{ctk,0.05}$	Mean tensile strength, f_{ctm}	Modulus of elasticity, E_{cm}
	[N/mm^2]	[N/mm^2]	[N/mm^2]	[N/mm^2]	[kN/mm^2]
C30/37	30	20	2.0	2.9	33
C35/45	35	23	2.2	3.2	34
C45/55	45	30	2.7	3.8	36

The partial safety factor for concrete for ULS is $\gamma_C = 1.5$; the coefficient taking account of long term effects on the compressive stress and of unfavourable effects resulting from the way the load is applied is $\alpha_{cc} = 0.85$.

The concrete material behaviour is modelled by either a parabola-rectangle relation with properties $\varepsilon_{c2} = 0.2\%$, $\varepsilon_{cu} = 0.35\%$, f_{cd} or a bi-linear relation with properties $\varepsilon_{c3} = 0.175\%$, $\varepsilon_{cu} = 0.35\%$, f_{cd}.

The tension strength of concrete is neglected for structural verification.

Creep and shrinkage properties are considered in the semi-local FE model (IBDAS).

3.2.2 Reinforcement

Reinforcement B450 is used with the main properties as summarised in Table 3-3.

Table 3-3 Reinforcement material properties

Strength class	Characteristic yield strength, f_{yk}	Characteristic tensile strength, f_{tk}	Characteristic strain at maximum force, ε_{uk}	Density, γ_c	Modulus of elasticity, E_s
	[N/mm^2]	[N/mm^2]	[%]	[T/m^3]	[kN/mm^2]
B450	450	450	5.0	7.85	200

The partial safety factor for reinforcing steel is $\gamma_C = 1.15$ for persistent and transient design situations.

The stress strain relation for compression is modelled as elasto-plastic with the following properties: $\varepsilon_{yd} = f_{yd}/E_s$, ε_{ud} = 3.5%, f_{yd}.

3.2.3 Prestressing

VSL Post-Tensioning tendons with main properties as summarised in Table 3-4 are used for the anchorage of the main cables in the anchor blocks. Prestressing is also used for the prefabricated beams of the splay chamber roof.

Table 3-4 Prestressing material properties

Designation	Number of strands	Steel grade, $f_{p0,1k}$ /f_{pk}	Cross-section area, A_{pe}	Proof strength (0.1% proof stress), $F_{p0,1k}$	Characteristic breaking load, F_{pek}	Modulus of elasticity, E_p	Maximum stressing force $P_{max,d}$
	[-]	[N/mm^2]	[mm^2]	[kN]	[kN]	[kN/mm^2]	[MN]
EN10138-3 Y1860S7-15.7	19	1,640/1,860	2,850	4,674	5,301	205	3.688

The partial safety factor for prestressing steel is γ_s = 1.15 for ULS.

The relaxation loss is calculated according to EN 1992-2:2005 Section 3.3.2. Ordinary relaxation properties (Class 1 relaxation) are assigned to the prestressing steel.

3.2.4 Ballast material

Sand with a density of γ_{Ba} = 17kN/m^3 is used as ballast material in the basins of the anchor blocks.

4 Loads and load combinations

The calculations are based on the load factors and load combinations specified in tender document GCG.F.04.01. The specified peak ground acceleration levels a_p (PGA) in GCG.F.04.01 Table 18 are taken as peak free-field ground accelerations at the base of the anchor blocks.

Design Approach 1 shall be used for design of foundations according to NTC 2008. The associated load combinations and load and material factors are defined in the report: Design Basis, Structural, Annex, document CG1000-P-RG-D-P-GE-00-00-00-00-00-02.

The forces in the main cables used for the structural calculations of the anchor blocks are taken from the global IBDAS model version 3.3c. The forces from the most recent global IBDAS model version 3.3f are approximately 2% lower than the design cable forces from version 3.3c, thus resulting in a small additional structural safety.

The forces in the main cables used for the geotechnical calculations of the anchor blocks are taken from the global IBDAS model from the tender design. These forces have been compared with the updated cable forces obtained from global IBDAS models 3.3b and version 3.3f in appendices to the geotechnical reports. It is found that the adopted ultimate limit state cable forces from the tender design are 7 % and 8 % higher than the IBDAS version 3.3f cable forces for the Calabria and Sicily anchor block, respectively, thus resulting in a conservative estimate of the geotechnical behaviour of the anchor blocks.

5 Structural Design

The anchor blocks of the Messina Strait Bridge are very large massive and essentially rigid reinforced concrete structures embedded into the ground at the Sicily and Calabria locations. The controlling load cases for design of the anchor blocks include the load combinations with seismic action.

The seismic response of massive structures embedded in soil is subject to the effects of soil-structure interaction (SSI). In contrast to an assumed rigid foundation and fixed base subject to free-field motion, the prime SSI effects to consider are the flexibility of the soil and the effect of the large mass and soil deformations modifying the free-field ground motions. The effect associated with the structure stiffness is the kinematic interaction. That related to structure mass is the inertial interaction, which defines the soil reaction to be applied onto the anchor blocks structural model.

The sections below outlines the method for implementation of the analysis of the anchor blocks for design considering SSI.

5.1 Method for Seismic Analysis

The structural analyses of the anchor blocks are based on pseudo-static analysis based on the response spectre given in GCG.F.04.01.

The pseudo-static design process for the structural design of the anchor blocks consists of the following steps:

- The forces in the main cables are calculated in the global IBDAS model for all load combinations including earthquake loadings.
- The rigid structure in soil adopts an effective horizontal seismic coefficient, k_x, representing the static force equivalent to inertia from the oscillatory ground acceleration.
- The effective horizontal seismic coefficient is defined as k_h = 0.5 pga, where pga is the peak ground acceleration, according to Mononobe-Okabe, 1926 and 1929, refer also Eurocode 8 - Part 5.

The following combinations of elastic pseudo-static seismic coefficients are calculated for each pseudo-static load combination:

- 100% horizontal in combination with 30% vertical acceleration (case 1)
- 30% horizontal in combination with 100% vertical acceleration (case 2).

The pseudo-static approach does not include the beneficial effect due to the large plan dimensions of the rigid anchor block. Kinematic interaction due to this effect (tau effect) results in an effective averaging of the free-field translational motions over the large dimension, causing less seismic excitation of the structure. For the size of foundation (~100m) and given soil profile at the Sicily or Calabria anchorages, a reduction tau factor of between 0.70 and 0.85 is reasonable.

Potentially flexible components of the anchor block structures are checked for potential seismic-induced dynamic amplification, e.g. roof beams of the anchor housing. If necessary inertial forces are corrected for dynamic amplification.

5.2 Soil reaction for structural modelling

The anchor blocks are influenced by the main cable force, self weight and acceleration forces from seismic events. These loads are balanced by the soil reaction from the soil acting onto the anchor blocks.

The soil reaction onto each anchor block is calculated in a geotechnical analyses by an ABAQUS model. This soil reaction is then applied as external load to the semi-local structural FE model (IBDAS) of the anchor blocks.

As the anchor blocks are very much stiffer than the surrounding soil and will be designed to resist the induced forces, they are modelled as rigid parts, i.e. with infinite stiffness.
Since the FE models are two-dimensional, a plane strain approximation is needed.
A longitudinal cut has been made in the centre of the anchor blocks. For the Calabria Anchor Block, the plane strain depth is directly interpreted as the width of the block, 100 m. For the Sicily Anchor Block however, the width is varying from 90.0 m to 129.6 m. Conservatively, a plane strain depth of 100 m have been applied for the Sicily Anchor Block as well.

The modelled plane strain geometries are shown in Figure 5-1.

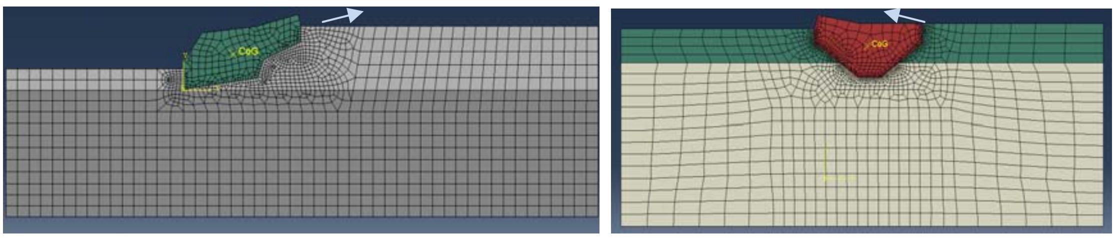

Figure 5-1 FEM geometry. The colour shift in the soil indicates the location of the water table. Left: Sicily. Right: Calabria. The blue arrows indicate the cables

The two-dimensional analyses yield only stresses on the in-plane anchor block surfaces. Thus, no stresses are calculated on the sides of the anchor blocks parallel to the bridge longitudinal direction. As a conservative approximation for the reinforced concrete verification, the sides are assumed stress-free. In the correct three-dimensional case, the earth pressures will be distributed more evenly on the anchor blocks.

The jet-grouted soil as well as the diaphragm walls have been disregarded in the analyses.

The seismic-induced earth pressures for each load case are derived from the pseudo-static approach in the ABAQAS geotechnical analyses.

In Figure 5-2 and Figure 5-3, examples of calculated earth pressures acting onto the Sicily and Calabria anchor blocks respectively are shown.

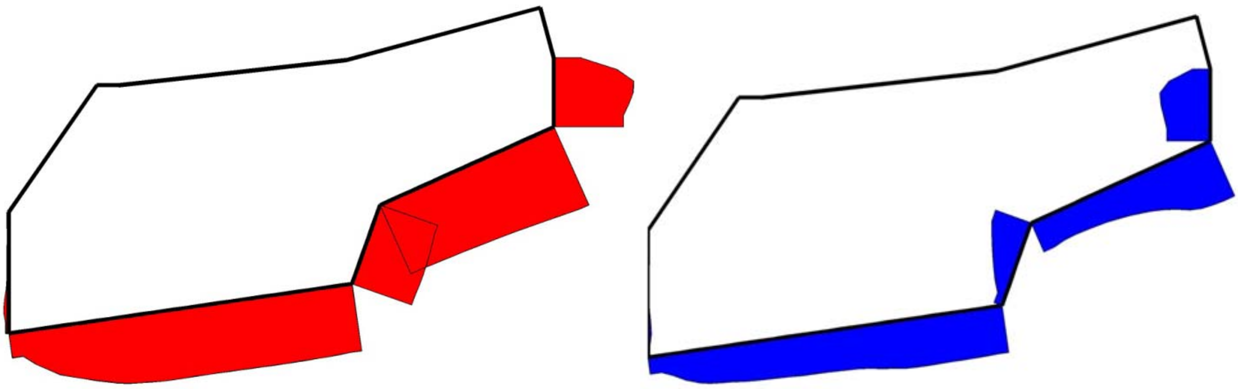

Figure 5-2 Example of earth pressures acting on the surface of the Sicily Anchor Block for ULS loading with earthquake. Left: Normal stress, with maximum of $\sigma = 793\ kPa$. Right: Shear stress with maximum absolute value of $\tau = 531\ kPa$.

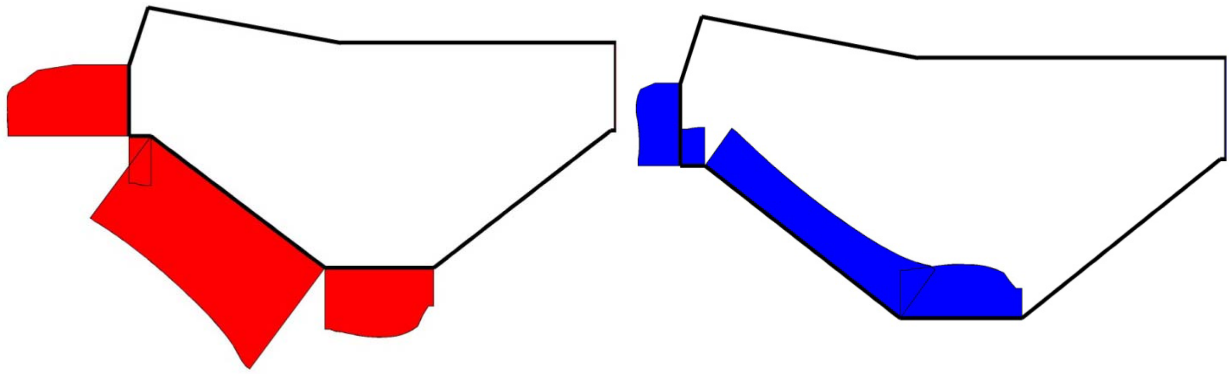

Figure 5-3 Example of earth pressures acting on the surface of the Calabria Anchor Block for ULS loading with earthquake. Left: Normal stress, with maximum of $\sigma = 1202\ kPa$. Right: Shear stress with maximum absolute value of $\tau = 522\ kPa$.

5.3 Structural calculations

Local IBDAS models have been prepared for the calculation of the general reinforcement in the anchor blocks. The cable forces calculated in the global IBDAS model and the soil reactions calculated in the local ABAQUS model have been applied as external loads to the anchor blocks.
For pseudo-static analyses inertia forces are applied to the ABAQUS models as well as to the local IBDAS models.

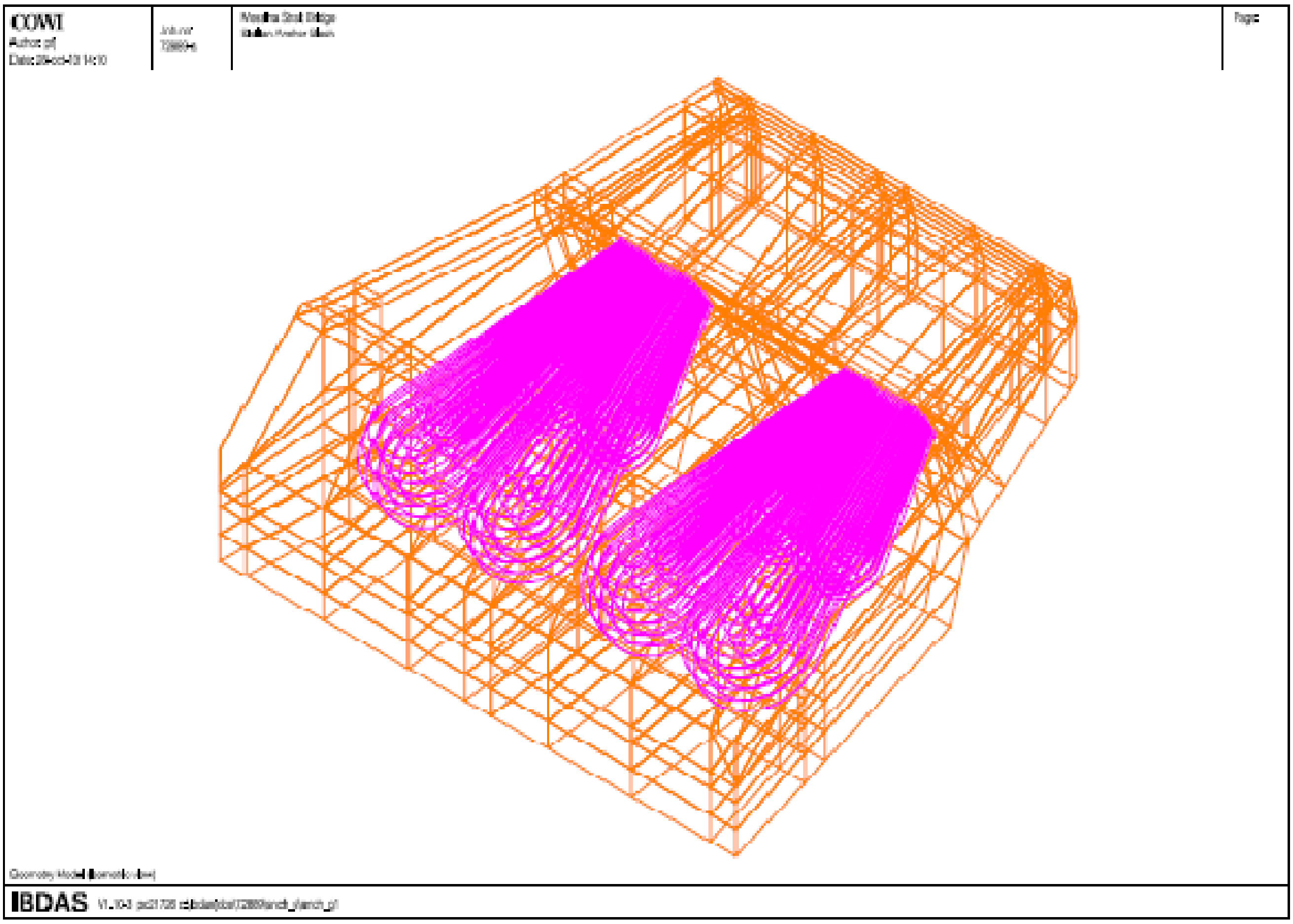

Figure 5-4 IBDAS model of Sicilian anchor block

5.3.1 Cable anchorage

5.3.1.1 General / minimum reinforcement

The reinforcement verification has been performed in steps. Initially a general reinforcement mesh corresponding to the minimum reinforcement requirement in all three directions has been provided for the whole structure and the verification of the utilization ratios (UR) of the bars have been calculated in all stress points.

The required minimum reinforcement has been calculated according to EN 1992-2:2005 Section 7.3.2.

The anchor blocks are assumed to be cast in blocks of 3m × 11m × 26m with general reinforcement directed in all three dimensions, i.e. in longitudinal (s), transverse (y) and vertical (z) direction, respectively.

The general reinforcement arrangement can be seen in Figure 5-5. The general reinforcement is placed in groups of reinforcement 'walls' (plans defined in vertical and longitudinal or transverse direction). The distribution between groups of reinforcement of reinforcement 'walls' in groups originates from the demand that no vertical reinforcement shall be placed in a distance of 1m from each block surface.

The horizontal distance between bars is 250mm and 200mm for the Calabria and Sicily anchor blocks, respectively.

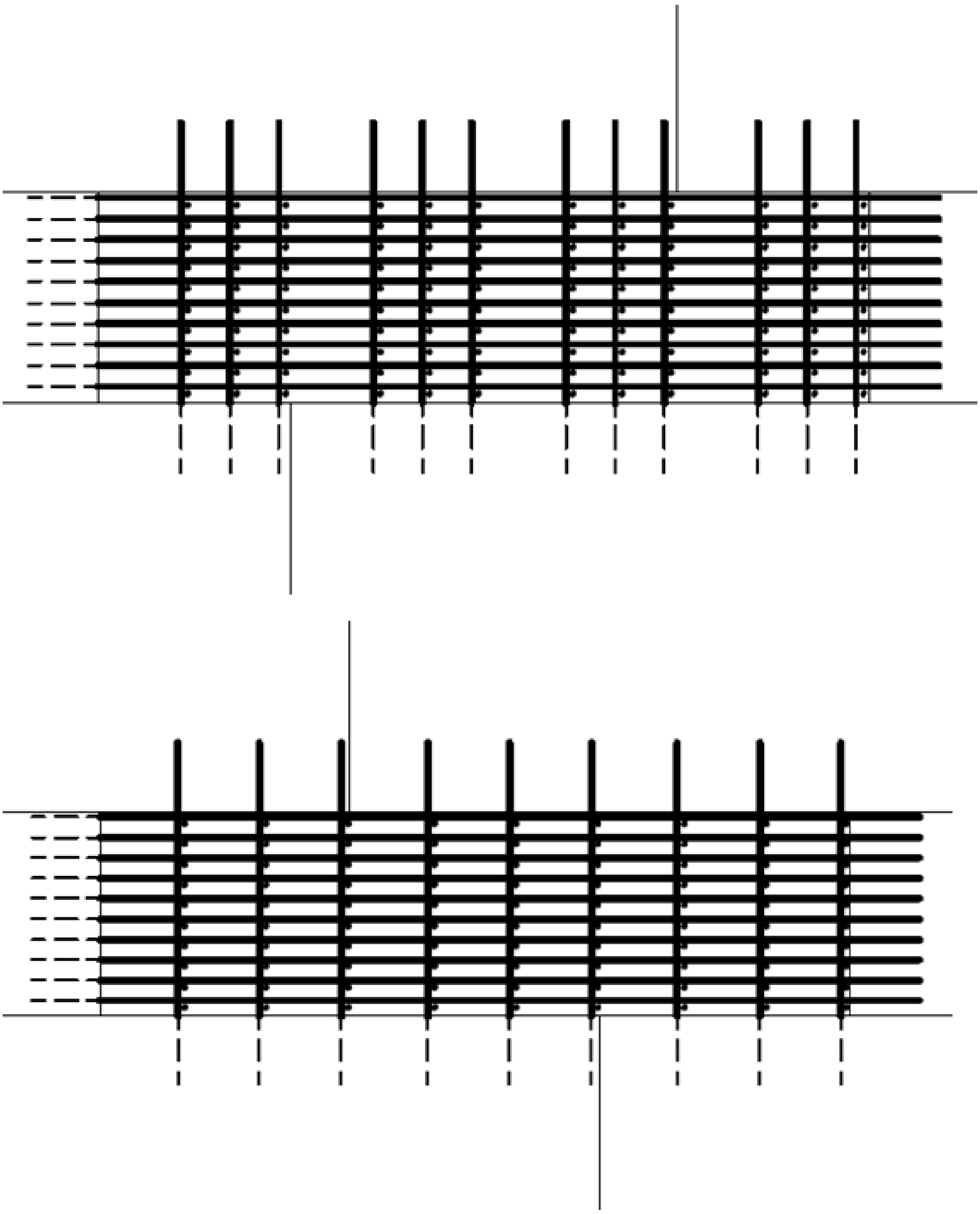

Figure 5-5 Arrangement of reinforcement 'walls' for the Calabrian (above) and Sicilian (below) anchor block.

5.3.2 Supplementary reinforcement

In areas where the reinforcement was found to be over-utilised (UR greater than 1.0) additional reinforcement has been provided and the local IBDAS model was re-run to confirm that sufficient reinforcement had been provided to meet the strength requirements. Additional reinforcement has mainly been provided in the anchorage zones and in the front part of the anchor blocks below the splay saddle.

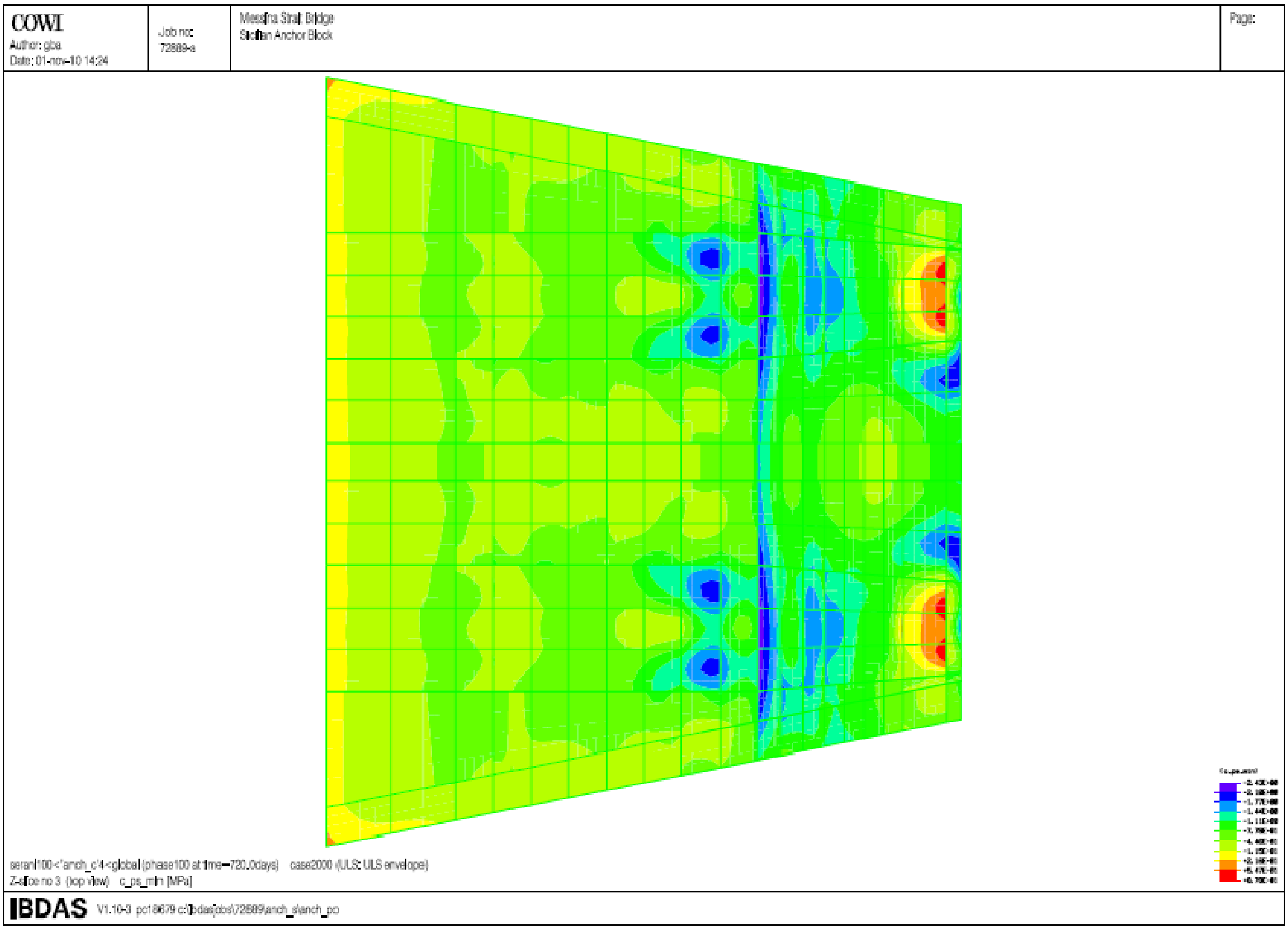

Figure 5-6 Section in IBDAS model of Sicilian anchor block, showing the utilisation ratio of steel reinforcement

The dense minimum and supplementary reinforcement based on a bar diameter of 25mm will intersect with the prestressing loops. In case a general or additional reinforcement bar intersects with a prestressing loop the reinforcement bar will be cut. The gap in the reinforcement bar will be closed by a new bar of sufficient length (including length of cut and lap length) placed in direct vicinity of the cut reinforcement bar.

5.3.3 Surface reinforcement

A surface reinforcement dia. 25mm per 250mm×250mm fulfilling the code requirements to minimum reinforcement has been applied to all external surfaces of the anchor blocks.

The surface reinforcement shall prevent extensive cracking of the concrete. This is assumed to be fulfilled, if the stresses in the surface reinforcement steel do not exceed 200N/mm^2 in serviceability limit state.

The strength of the provided reinforcement in the anchor blocks is generally less than the tensile strength of the uncracked concrete section.

6 Geotechnical Design

6.1 Seismic performance

Seismic performance of the anchor blocks was evaluated using two approaches: the pseudo-static approach, in which the anchor block is assumed to be in a state of limit equilibrium under the action of inertial and static forces, and the displacement-based approach, in which the earthquake-induced displacements of the anchor block are evaluated for a number of input seismic motions.

6.1.1 Safety against sliding

For evaluation of safety against sliding, design resistances were computed considering the contributions of the sliding resistance at the base and at the block sides and that of the passive resistance in front of the block.

In the analyses three possible sliding mechanisms were assumed for each anchor block. Companion plane strain FE analyses of the anchor blocks permitted to evaluate the prevailing inclination of the displacement vectors under ULS loading conditions.

Safety against sliding under static loading conditions is not be evaluated in the report since the pseudo-static loading conditions are the most critical.

6.1.1.1 Pseudo-static approach

In the pseudostatic approach, safety of the block against eventual failure mechanisms is ensured comparing the design actions with the design resistances, the first increased and the second reduced by partial factors of safety.

For the pseudo-static conditions, both design actions and design resistances were computed using the pseudo-static seismic coefficients given by the Italian building code. The obtained results showed that safety against sliding is adequately satisfied for the main cable forces provided by the global IBDAS model version 3.3f.

6.1.1.2 Displacement-based approach

In the displacement-based approach, the critical acceleration is first determined through the pseudo-static approach and the cumulative displacement of the potential sliding mass is then evaluated using the sliding block analysis, in which the equation of the relative motion is integrated twice with the critical acceleration used as a reference datum.

In the displacement-based approach, the earth resistance ΔR mobilised in front of the block was assumed to progressively increase with increasing relative displacement u induced by earthquake loading. In this condition, its contribution was neglected in the expression of the critical seismic coefficient and was included in the equation of relative motion. The relationship between ΔR and relative displacement was evaluated by best fitting the $u - \Delta R$ data as obtained from 2D FE analyses in which uniform horizontal displacements are applied to an ideal smooth wall.

In order to reduce the pore water pressure acting on the Calabrian anchor block, construction of a drainage tunnel was planned in the tender design. This drainage tunnel would ensure a ground water table not higher than +88 m LMM. Eurolink has decided to eliminate this drainage tunnel in the Progetto Definitivo. However, some drainage may result from the future rail tunnels adjacent to the anchor block. Safety verifications were thus carried out both considering and neglecting the effect of the drainage tunnel.

Earthquake-induced displacements were computed using 30 input accelerograms. The horizontal component of the selected acceleration time histories was scaled to 0.58 g, while the vertical component was scaled either by the same factor used for the corresponding horizontal component, or to 0.58 g as well. Computations were repeated assuming both directions of applications of the horizontal accelerograms.

The results show that the earthquake-induced displacements decrease with decreasing inclination of the sliding mechanism.

For the Sicily anchor block, the maximum displacement is 1 mm for mechanism 2 ($\alpha = 26°$) and 33 mm for mechanism 3 ($\alpha = 8°$).

For the Calabria anchor block, the maximum displacement is 14 mm for mechanism 2 ($\alpha = 23.5°$) and 69 mm for mechanism 3 ($\alpha = 0°$) if the effect of the drainage tunnel is accounted for, while it is 21 mm for mechanism 2 and 72 mm for mechanism 3 if the effect of the drainage tunnel is neglected.

6.1.2 Bearing capacity and safety against rotation

Bearing capacity and safety against rotation were estimated following the prescriptions of D.M. 14.01.2008; the results show that the requirements are satisfied for the considered loading conditions.

6.2 3D FE analyses of anchor blocks

The FE analyses were mainly carried out for evaluating the displacement field and the stress state induced in the foundation soil by the main cable forces. To this purpose, the whole construction sequence was simulated in the analyses that were carried out in terms of effective stresses, assuming drained conditions for the soil. The following sequence of steps was considered: computation of the initial stress state; pre-excavation of the construction area; activation of diaphragm walls and jet grouting; progressive excavation to reach the base of the anchor block with simultaneous activation of the levels of the retaining anchor; progressive activation of the anchor block; filling of the pre-excavated area and of the ballast chambers with granular material; application of the design loads (SILS, SLS2 and ULS loading conditions); incremental analysis with increasing external forces.

The behaviour of the anchor blocks was studied through static 3D FE analysis using the code *Plaxis*^{3D} *Foundation*.

In the FE analyses, the mechanical behaviour of the soil was described using the Hardening Soil model, that is an elastic-plastic rate independent model with isotropic hardening, capable of reproducing soil non-linearity due to the occurrence of plastic strains from the beginning of the loading process; the anchor block concrete and the ballast material were described as linear elastic materials; the diaphragm walls were modelled as WALL shell elements, while the retaining anchors as SPRINGS elements. Jet-grouted soil was assimilated to an elastic-plastic material with Mohr-Coulomb failure criterion.

In the model, the elastic behaviour is defined by isotropic elasticity through a stress-dependent Young's modulus, *E*'. For plastic loading from isotropic stress states, the model predicts a non linear stress-strain relationship with tangent initial modulus equal to *E*′. Values of *E*′ were related to the shear modulus at small-strain G_0 obtained from the cross-hole test carried out at the site. A simplified soil profile was assumed, characterised by lower values of the shear stiffness.

6.2.1 Sicily anchor block

Forces in the main cables at Sicily anchor block were provided from the global IBDAS model for three different load combinations (SILS, SLS2 and ULS). The direction of the force is inclined 15 degrees to the horizontal and directed upwards, towards the Sicily tower.

Starting from the computed displacements, two kinematic mechanisms for the block were reconstructed: one is of pure translation and the other one is of roto-translation around the centre of gravity.

Under SILS, SLS2 and ULS loading conditions the average displacement is of about 27 mm, 28 mm and 35 mm, respectively; the average inclination is of about 14° to the horizontal for all the above loading conditions (SILS, SLS2 and ULS). The anchor block behaviour to the application of the external loads mainly consists in a translational movement, directed towards the tower, associated with a rotational downwards movement.

An evaluation of the ultimate failure load for the anchor block, carried out using an hyperbolic best-fitting of the load-displacement data, provided an ultimate load equal of 15100 to 16500 MN. This results in a safety factor against external increasing forces of 3.75 to 4.15 for ULS loading condition.

6.2.2 Calabria anchor block

Forces in the main cables at Calabria Anchor Block have been provided by the structural analyses in the tender design, for three different load combinations (SILS, SLS2 and ULS). The direction of the force is inclined of 15 degrees to the horizontal and directed upwards, towards the Calabria tower.

The results of the finite element analyses are mainly exposed as load-displacement curves; ten representative points of the anchor block have been selected to this purpose. The preliminary stages of the analysis (i.e. excavation of the pit supported by retaining walls and anchors, construction of the block, removing of the provisional retaining anchors, restoring of the initial hydraulic conditions) were simulated to fully reproduce the soil stress state at the beginning of the loading process. The displacements calculated in these stages were reset to zero and the load-displacement curves refer to the application of external loads only.

The obtained results allow the following observations:

1. The anchor block behaviour to the application of the external loads consists in a translational movement, directed towards the seashore (z-direction), associated with a rotational downwards movement in the y-z plane.
2. The global horizontal displacement of the block, directed towards the seashore is smaller than 10 mm, for each of the three loading conditions. The total vertical displacement, upwards directed, is lower than 2 mm, while horizontal displacement in x-direction (orthogonal to the bridge axis) is practically equal to zero.
3. The rotation values in the vertical y-z plane are of some thousandth of degree (directed

towards the seashore), while they are practically equal to zero in the x-y direction. The values of rotation in the x-z plane are low and show a slight influence of the inclined soil stratigraphy on the block response.

4. A comparitive analysis indicates a relatively small influence of the uppermost 4 m of soil on the block response.
5. The average direction of the block movement, for each of the loading conditions, is directed upwards, with an inclination to the horizontal equal to about 10 degrees.
6. An evaluation of the ultimate failure load for the anchor block, carried out using an hyperbolic best-fitting of the load-displacement data, provides a ultimate load equal to about 11000 MN. This results in a safety factor against external increasing forces of about 2.75 for ULS loads and of about 3.5 for SILS load.
7. In the φ' – c' reduction analyses the strength properties of the soils were increasingly reduced by increasing the factor Msf, whose physical meaning is comparable to a safety factor. A conservative value of Msf, valid for each of the three loading conditions, is equal to about 3. The comparative analysis, with a 4 m deep excavation around the block, yielded a conservative value of Msf = 2.5, thus confirming the importance of refilling the area around the block with soil, after construction.