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PONTE SULLO STRETTO DI MESSINA

PROGETTO DEFINITIVO

EUROLINK S.C.p.A.

IMPREGILO S.p.A. (MANDATARIA)
SOCIETÀ ITALIANA PER CONDOTTE D'ACQUA S.p.A. (MANDANTE)
COOPERATIVA MURATORI E CEMENTISTI - C.M.C. DI RAVENNA SOC. COOP. A.R.L. (MANDANTE)
SACYR S.A.U. (MANDANTE)
ISHIKAWAJIMA - HARIMA HEAVY INDUSTRIES CO. LTD (MANDANTE)
A.C.I. S.C.P.A. - CONSORZIO STABILE (MANDANTE)

IL PROGETTISTA	IL CONTRAENTE GENERALE	STRETTO DI MESSINA	STRETTO DI MESSINA
Ing E.M.Veje COWI Eurolink Dott. Ing. E. Pagani Ordine Ingegneri Milano n° 15408	Project Manager (Ing. P.P. Marcheselli)	Direttore Generale e RUP Validazione (Ing. G. Fiammenghi)	Amministratore Delegato (Dott. P. Ciucci)

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INDICE

1 Introduction

1.1 Scope

The purpose of this report is to present and describe the semi local model prepared at the suspended deck during for Progetto Definitivo.

1.2 Report Outline

This report is organized into the following sections:

- Section 1 includes this introduction and provides a list of references, including design specifications and design codes
- Section 2 describes the Global IBDAS model
- Section 3 describes the Element stiffness's and added weights to the analysis model
- Section 4 show selected results

1.3 References

The semi local model itself is included as a part of the global analysis model.

This report will only describe the additional information necessary for the semi local model, reference is made to the report prepared for the Global IBDAS analysis report, "CG1000-P-RG-D-P-SV-00-00-00-00-00-01", 2011 March 23, for detailed information on the global analysis model.

1.3.1 Design Specifications

[1] CG1000-P-RG-D-P-GE-00-00-00-00-00-02_C "Design Basis, Structural, Annex".

2 Description of the Girder Semi Local model

This section describes the global FE-model established for the Semi Local analysis of the suspended deck.

The semi local model is included into the global analysis model in the sense that for most parts of the bridge the global (beam) model is used but for selected parts a more detailed modelling using a combinations of shell and beam elements is used. This ensures correct boundary conditions for the detailed model. The shell model includes the girders, cross beam and diaphragms.

The term "semi local" instead of "local" is used to emphasize that some details may not be accurately modelled.

The level of detail in the semi local shell model will be made clear in the following.

2.1 Geometry

The semi local geometry model of the girder and cross beams is described below.

The semi local suspended deck model considers a 60 meter section, positioned in the main span between hanger 32 and 33.

The following structural elements are included in the semi local girder model of the Messina Strait Bridge:

- Suspended deck consisting of 2 roadway girders and 1 railway girder.
- 2 cross girders.

Diaphragms and longitudinal stiffeners are included in both the girders and the cross beams.

A plot of the global IBDAS geometry model is shown in *Figure 2.1*.

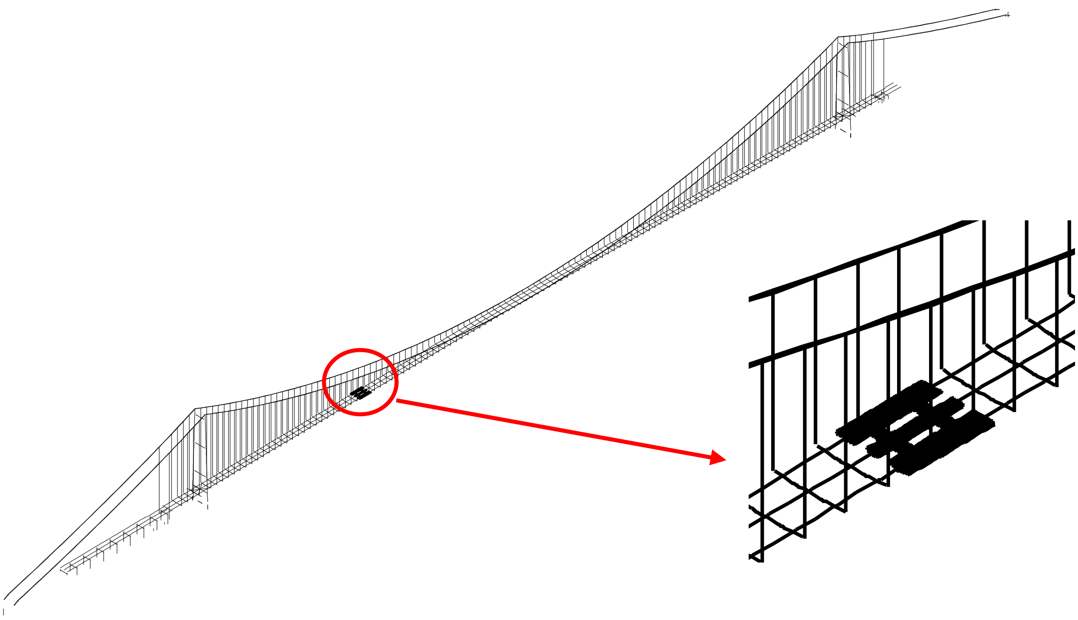

Figure 2.1: Messina Strait Bridge, geometry model (isometric view).

The different structural elements are explained in more detail in the following, which shows pictures from the model established during the Progetto Definitivo design period.

The suspended deck consists of 3 individual longitudinal girders connected by cross girders. A rendered view of the model is shown in the figure below.

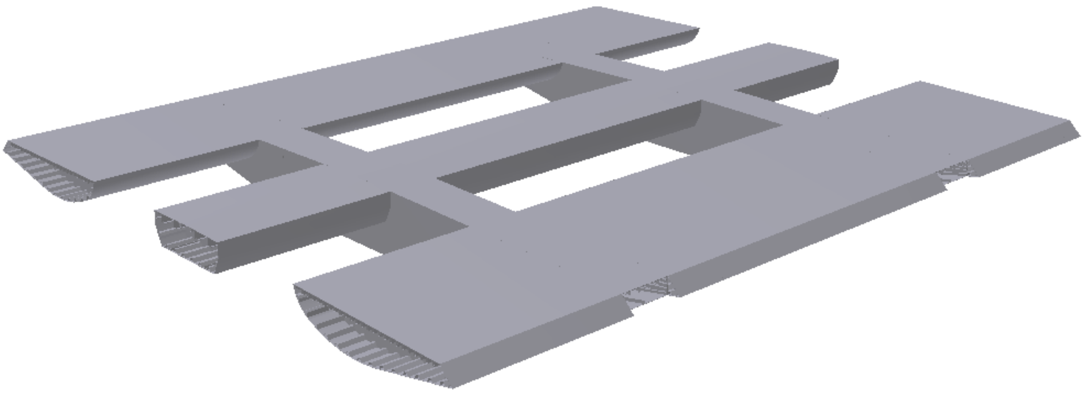

Figure 2.2: Rendered image of the suspended deck semi local model.

All the longitudinal steel skin of the girders including stiffeners is modelled with their exact geometry and plate thicknesses. The diaphragms are modelled with a uniform equivalent thickness taken into account the area of the diaphragm stiffeners, in order to achieve correct weight of the diaphragms.

Local elements such as additional stiffeners and plates near hanger anchorages are not included in the model but the weight is added. The weight of paint and welds are included as uniform distributed weight along the girders.

The hanger cross girders are modelled with the exact outer geometry and longitudinal stiffeners. The diaphragms are included with an equivalent uniform thickness taken into account man holes and stiffeners in order to achieve correct weight distribution.

The cross girders are modelled with 10 sections. This makes it possible to model the cross girder using the almost correct plate thicknesses along the length of the girders, see Figure 2.3 to Figure 2.5.

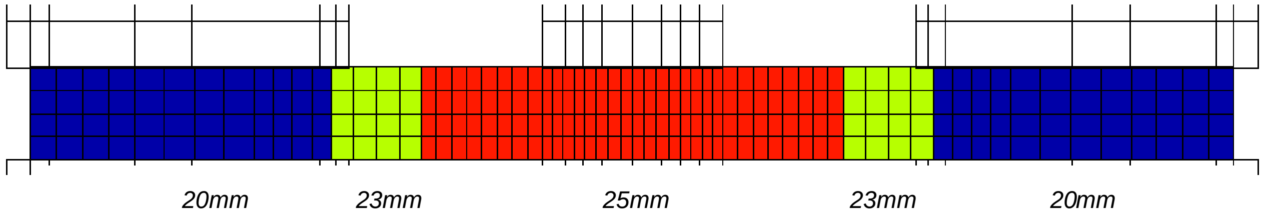

Figure 2.3: Thicknesses of top flange in cross girder.

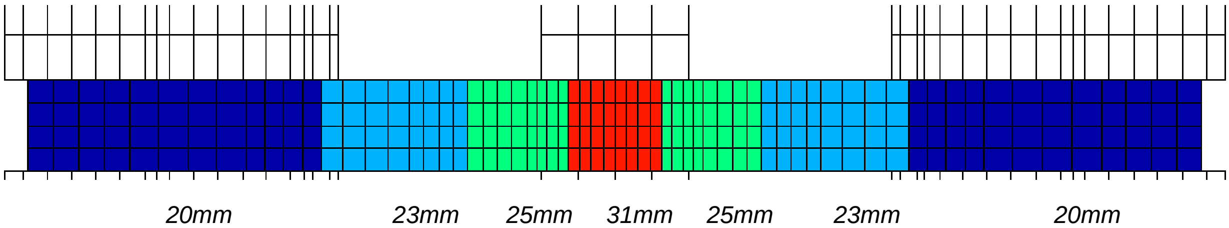

Figure 2.4: Thicknesses of bottom flange in cross girder.

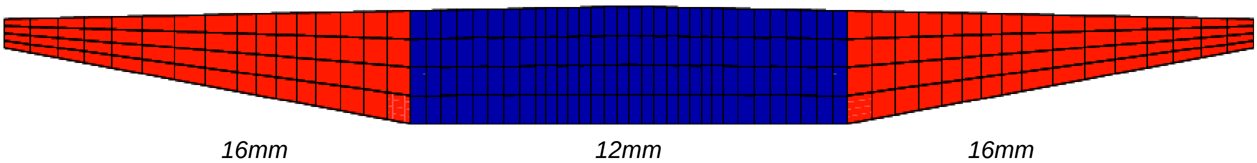

Figure 2.5: Thicknesses of web in cross girder.

Plots of the longitudinal steel girders and the cross girder are shown in Figure 2.6 to Figure 2.8. The plot shows the contour which is used by IBDAS for calculation of element properties (stiffness, mass etc.).

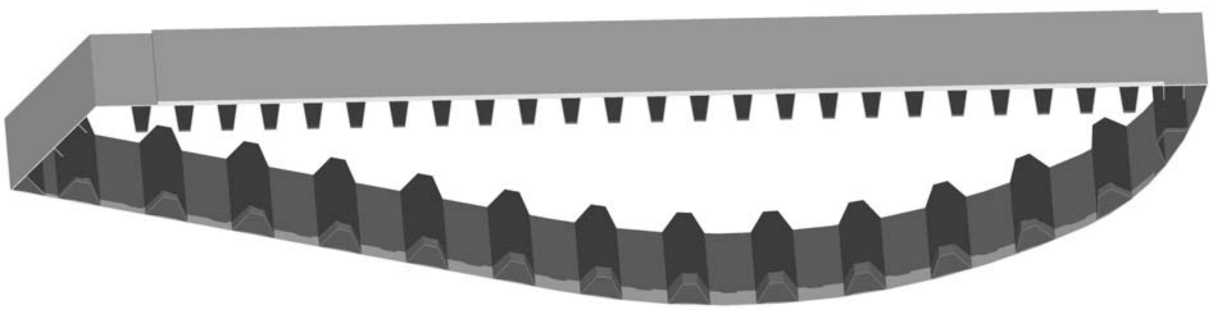

Figure 2.6: Typical cross-section of the suspended deck (road way).

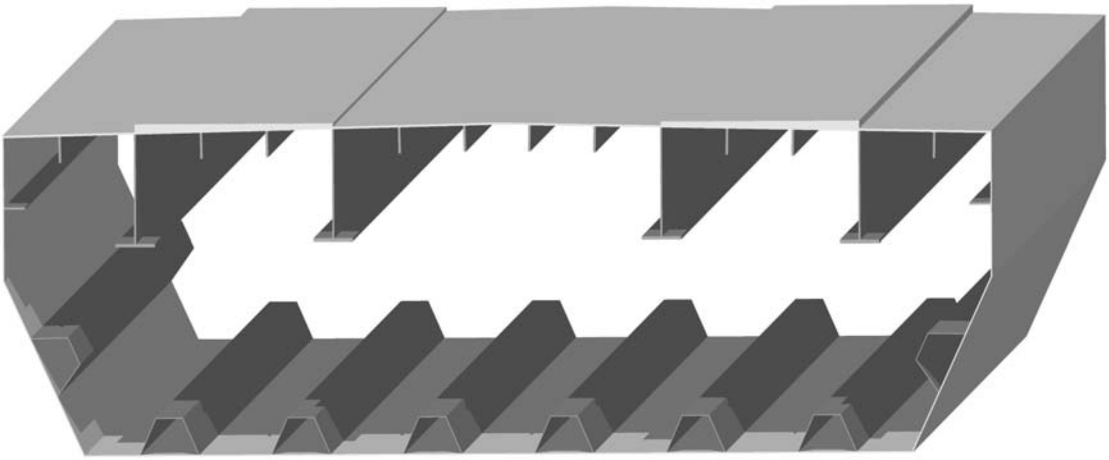

Figure 2.7: Typical cross-section of the suspended deck (rail way).

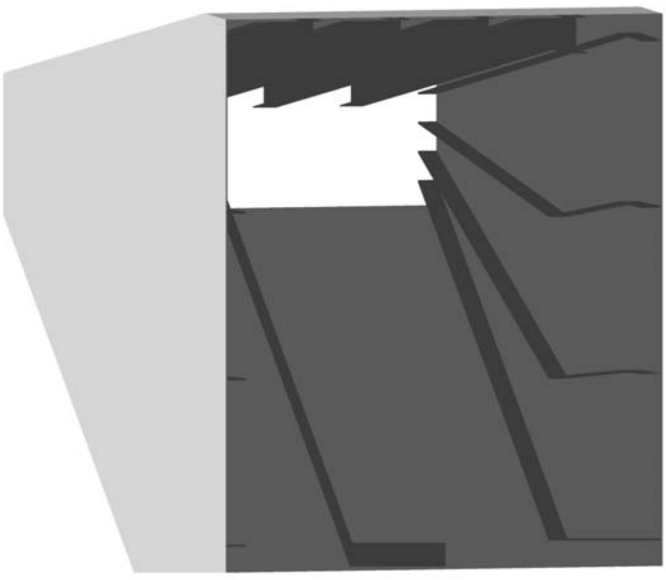

Figure 2.8: Typical cross-section of hanger cross beam.

The girders continue through the cross beams. The thickness of the top plates in road and rail girder and the thickness of the inclined bottom plate in road girders are reduced to 0.2 mm to avoid *double* plates in the semi local model.

2.2 Coordinate systems

2.2.1 Global coordinate system

In the model several coordinate systems have been defined. The global coordinate system used for reporting of e.g. displacements and reactions is a left-hand coordinate system, defined as follows:

- the **S**-axis (1^{st} axis) extends along the centre line of the bridge, positive towards Calabria, s=0 is at the centre of the main span.
- the **Y**-axis (2^{nd} axis) is orthogonal to the **S**-axis and the **Z**-axis forming a left hand coordinate system. The Y-axis thus extends horizontally transverse to the centre line of the bridge.
- the **Z**-axis (3^{rd} axis) is vertical and extends positive upward, zero at elevation 0.00 according to the project drawings.

The global coordinate system can be seen in Figure 2.9.

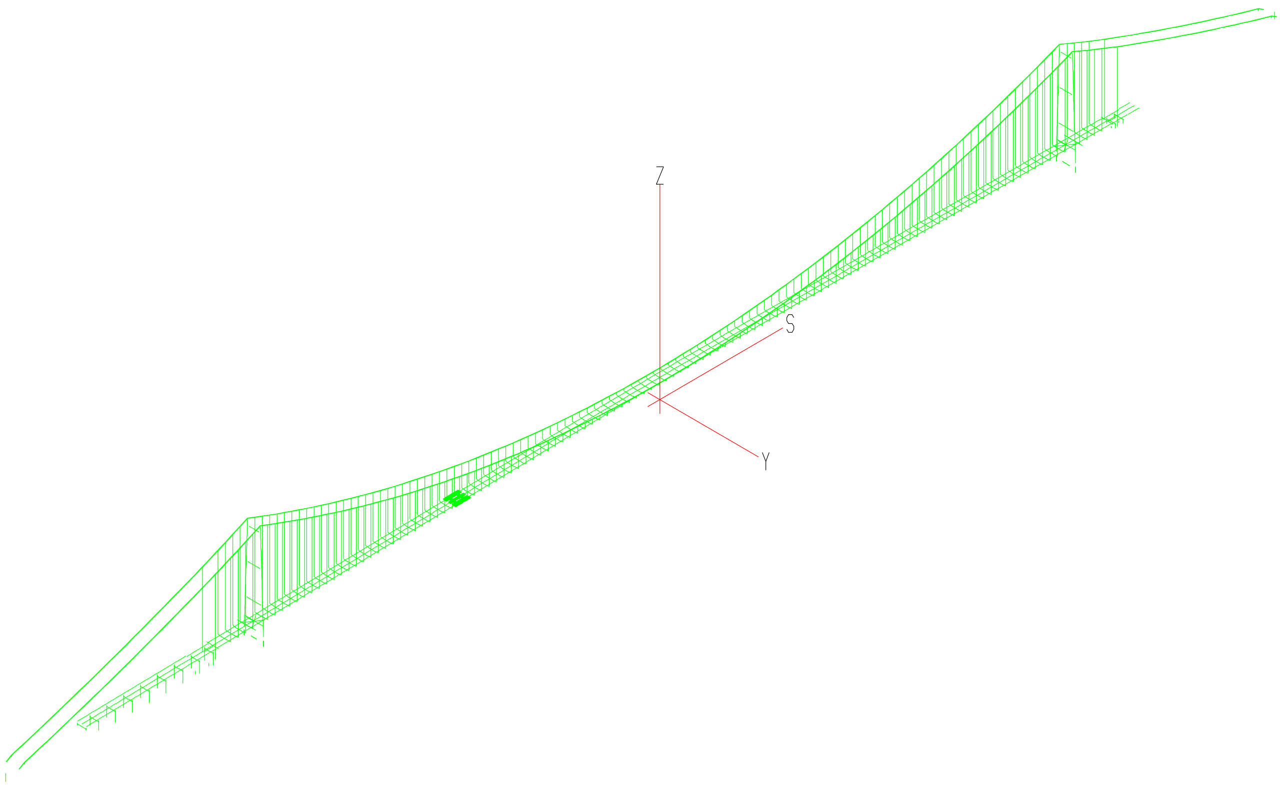

Figure 2.9: Global left hand coordinate system used in the IBDAS model. The plot also shows the entire FE-model as well as the selected semi local model at the main span deck.

2.2.2 Element coordinate systems

The following plots show the element coordinate systems for the semi local model shell elements only. The coordinate systems are all left-hand systems. These coordinate systems are used for reporting of element actions such as generalised stresses (section forces).

The girder sections follows the global s-axis and the cross beams has the s-axis along the global y-axis. The y-axis of the elements is transverse to the s-axis in-plane of the element and z-axis as an orthogonal to the element.

The coordinate systems are illustrated in the figure below.

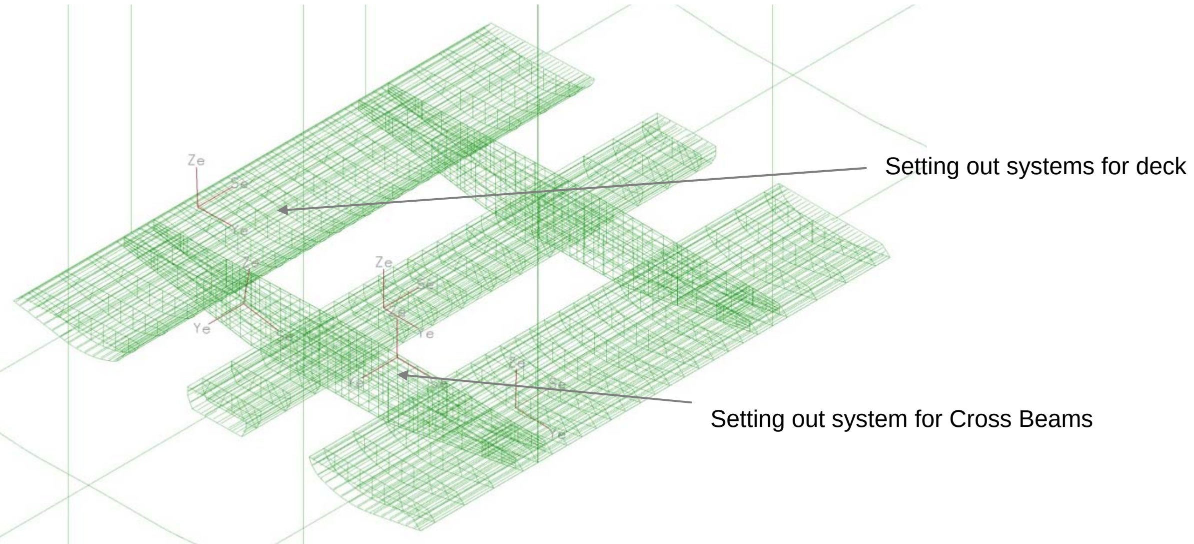

Figure 2.10: Setting out systems (left hand) at the suspended deck.

2.3 Elements

The IBDAS elements used in the global model are all 3D iso-parametric beam or truss elements. Shell elements are used in the semi local model.

Generally all structural steel members are modelled using 3-noded parabolic beam elements (IBDAS BEAM18) with 6 degrees of freedom in each node. Shear deformations are taken into account.

The hanger cables and main cables are modelled with 2-noded truss elements (IBDAS TRUSS6) with 3 degrees of freedom in each node.

The shell elements incorporated into the semi local model are using 8-noded shell elements (IBDAS SHELL48) with 8 degrees of freedom in each node, out of plane shear deformations are taken into account.

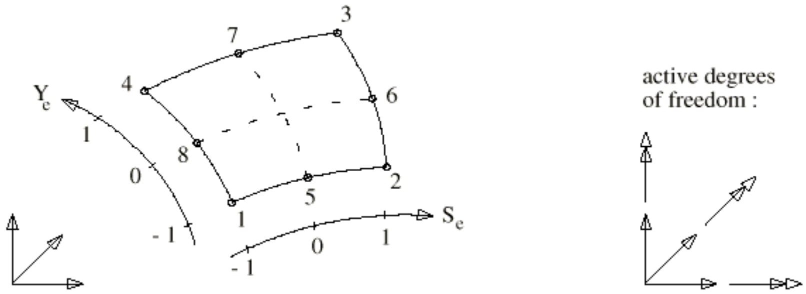

Figure 2.11: IBDAS Shell48 element.

The stiffeners are modelled with beam elements.

2.4 Support Conditions

The support conditions for the bridge are as described for the global analysis model.

3 Stiffness, Masses and Weights

3.1 Masses and Weights

The difference in the weight handling between the global and semi local model is that the diaphragms are modelled in the semi local model and thus no weight is added for diaphragms at the shell modelled part.

3.2 Sign convention

The force signs used in IBDAS are as shown below

The signs for the stress resultants in an infinitesimal element around a gauss point in a shell element are shown in the figure below. The analysis model and, thus, the results are based on the left-hand coordinate system. It should, however, be noted that it generally applies that a positive moment about a cross-section axis yields compression in the top side of the shell.

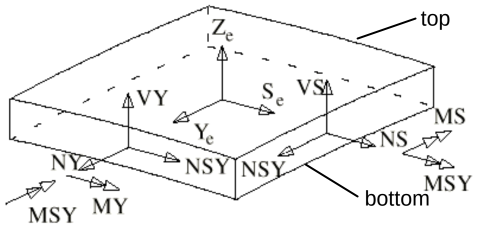

Figure 3.1: Stress results at stress point for spatial shell element. Infinitesimal element around stress point shown.

4 Results from the Semi Local

Detailed results from the semi local model will be presented in the various design reports where applicable. The present report will give selected results only

In order to avoid end effects close to the transition between beam sections and shell sections, results are only valid at a distance from the transition i.e. one diaphragm away.

Contour plots and stress value plots are taken out.

Only a very limited number of load cases are plotted in order to limit the number of plots given to the design groups

These load cases have been selected:

- Case 1 (Total permanent load) - reference condition of bridge
- Case 6500 (ULS envelope)
- Case 6550 (QL-ULS envelope)

4.1 Contour plots

The results of this type taken out from the semi local model and reported to the design group are plots showing:

- Contour plots of sss, syy and ssy stresses

- Contour plots of von mises stresses

Generally, the above types of plots are taken out for 7 different locations:

1) Top flanges in girders and cross beams

2) Bottom flanges in girders and cross beams

3) Y- web of the rail girder

4) Y+ web of the rail girder

5) Diaphragms, row 3 between cross beams

6) S+ cross beam web (s- cross beam)

7) S- cross beam web (s- Cross beam)

In *Figure 4.1* a contour plot of the maximal normal stresses for case 1 (Reference Condition) is shown. The plot is shown as an example of the information possible to obtain by use of the semi local model.

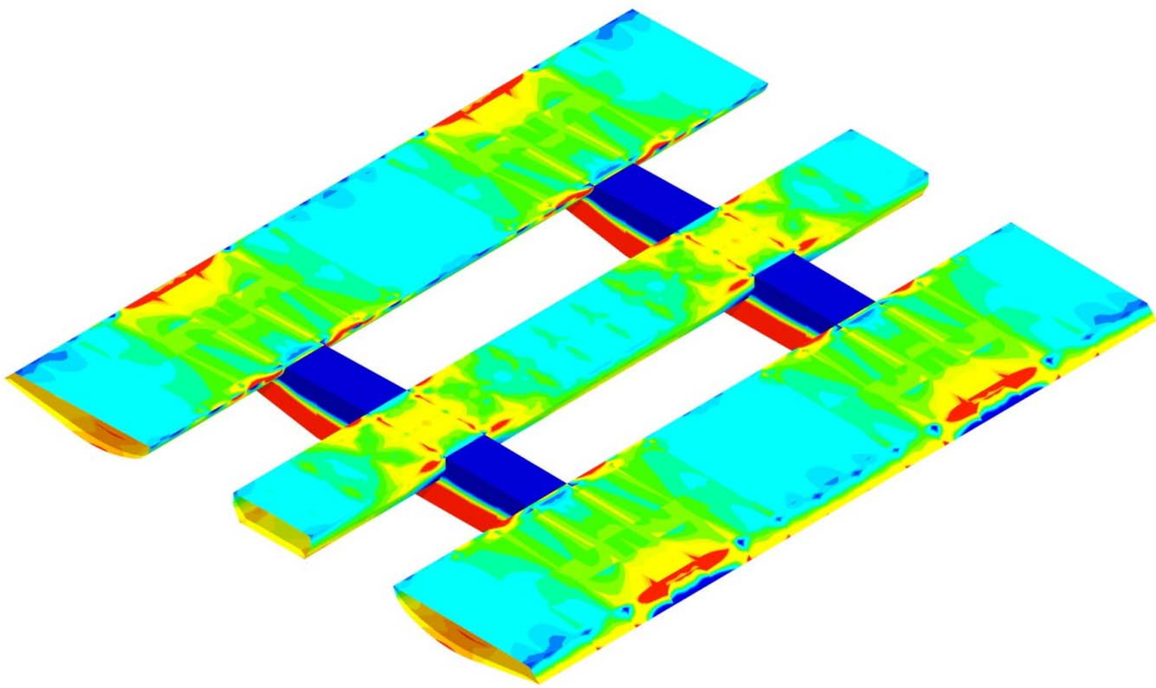

Figure 4.1: Contour plot - max normal stresses (sss) for case 1 (Reference Condition).

Appendix A includes results for Case 1 (Reference Condition), Case 6500 (ULS envelope) and Case 6550 (QL-ULS envelope).