Stretto di Messina

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)

EurolinK

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
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Unità Funzionale	OPERA D'ATTRAVERSAMENTO	PS0081_F0
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Raggruppamento di opere/attività	Implicato	
Opera - tratto d'opera - parte d'opera	Generale	
Titolo del documento	Design Report - Special Design Investigations	

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NOME DEL FILE: PS0081_F0

INDICE

1 Introduction

The report contains the results of the special design investigations of hanger replacement and hanger rupture considered at the ultimate limit state. All results presented in the report are based on the global IBDAS beam-model version 3.3.

2 Hanger Replacement

Regarding the replacement of hangers the effect of removing the hangers while the bridge is under operation has been calculated in IBDAS and the effect on the suspended deck has been verified in ADVERS using the sectional forces calculated in the global model. In ADVERS stresses, buckling behaviour and various code checks has been performed.

For the verification of the suspended deck structure during the hanger replacement a few different locations has been selected in the side span and in the main span, see Figure 2-1. The result of the analysis for the suspended deck can be seen in the following ADVERS output figures. Only the roadway girder has been considered.

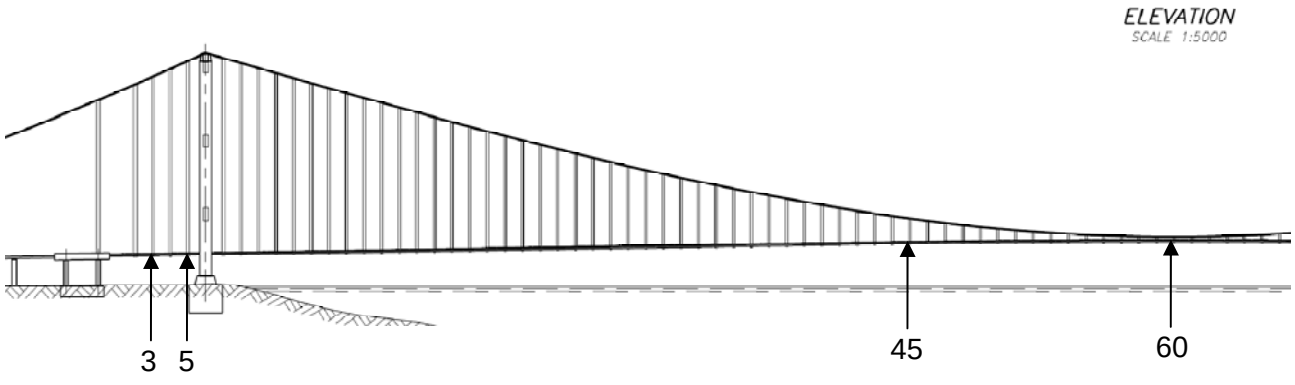
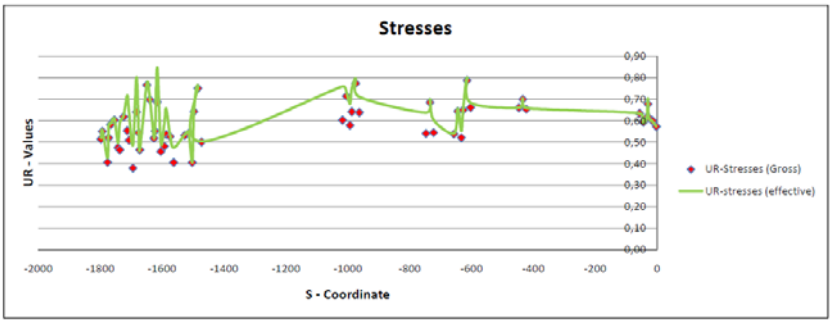
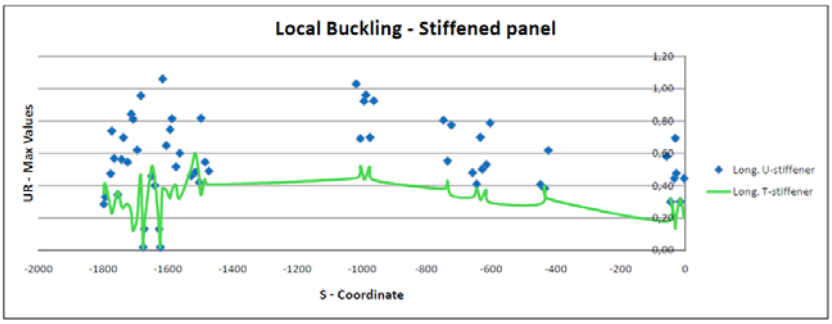


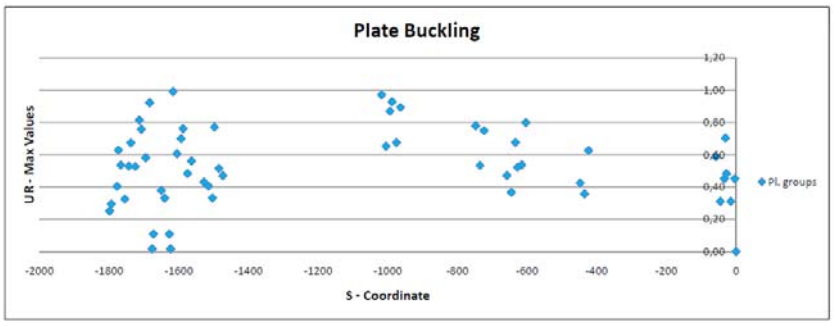
Figure 2-1 Location of selected hangers considered for replacement

2.1 ADVERS results

From ADVERS the following results are obtained for the roadway girder for the hanger replacement operation of hangers 3, 5, 45 and 60.







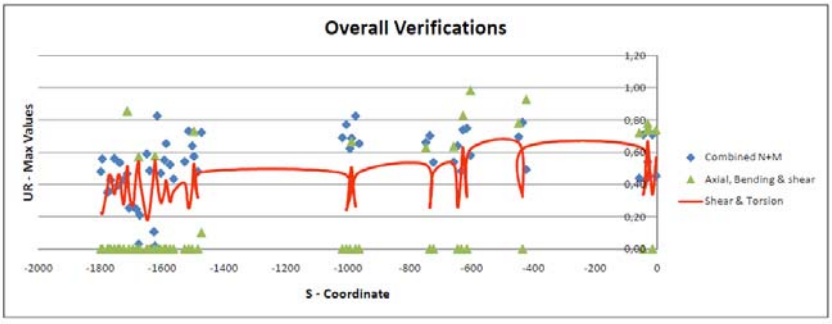
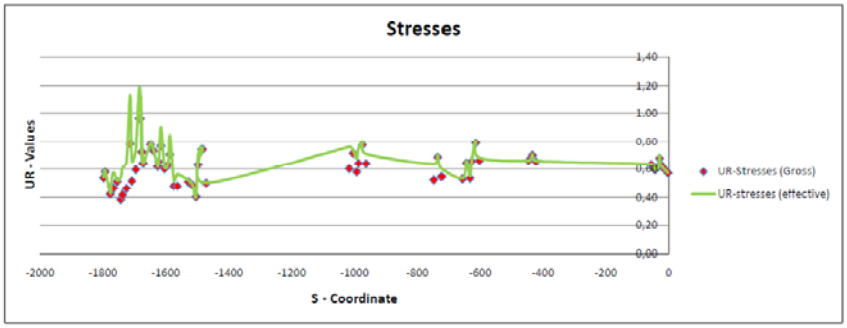
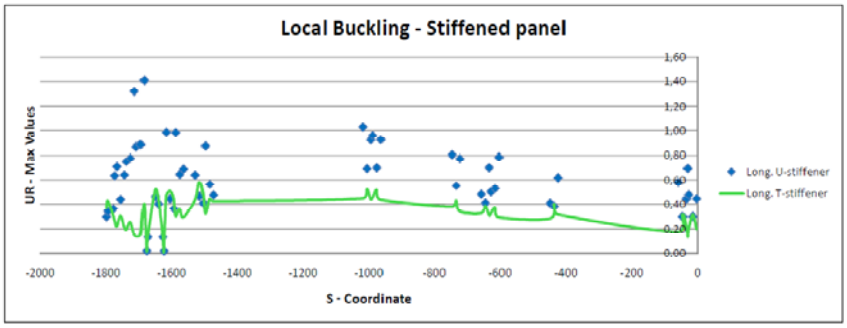
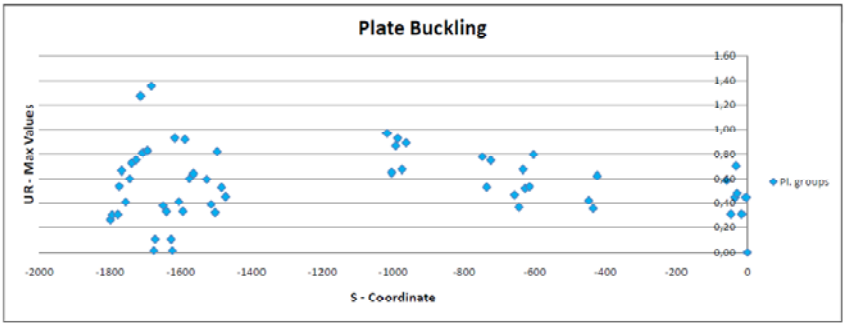


Figure 2-2 Roadway girder, ADVERS results for replacement of hanger 3 (s=-1740 m)

From the results for hanger 3 it can be seen that a buckling problem occurs for the longitudinal trough stiffeners (U-stiffeners). This problem is mainly for the stiffeners located on the bottom plate, since a larger span result in increased compressive stresses at this location.







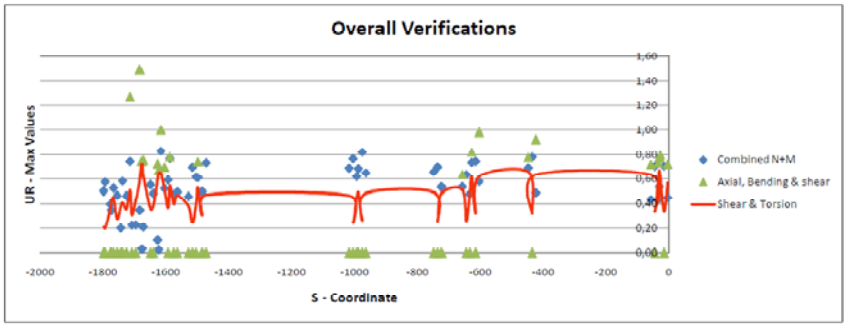


Figure 2-3 Roadway girder, ADVERS results for replacement of hanger 5 (s=-1680 m)

From the results for hanger 5 it can be seen that a severe stress problem occurs in the side span at the location of the missing hanger with a utilisation ratio of UR=1.20. This will demand a significant reinforcement of the girder steel in order to cope with this demand. Also large buckling problem occurs for the longitudinal trough stiffeners. This problem is due to the increase in span length at the drop-in span from 60 m to 90 m. It is mainly for the stiffeners located on the bottom plate due the larger span length increases compressive stresses at this location.

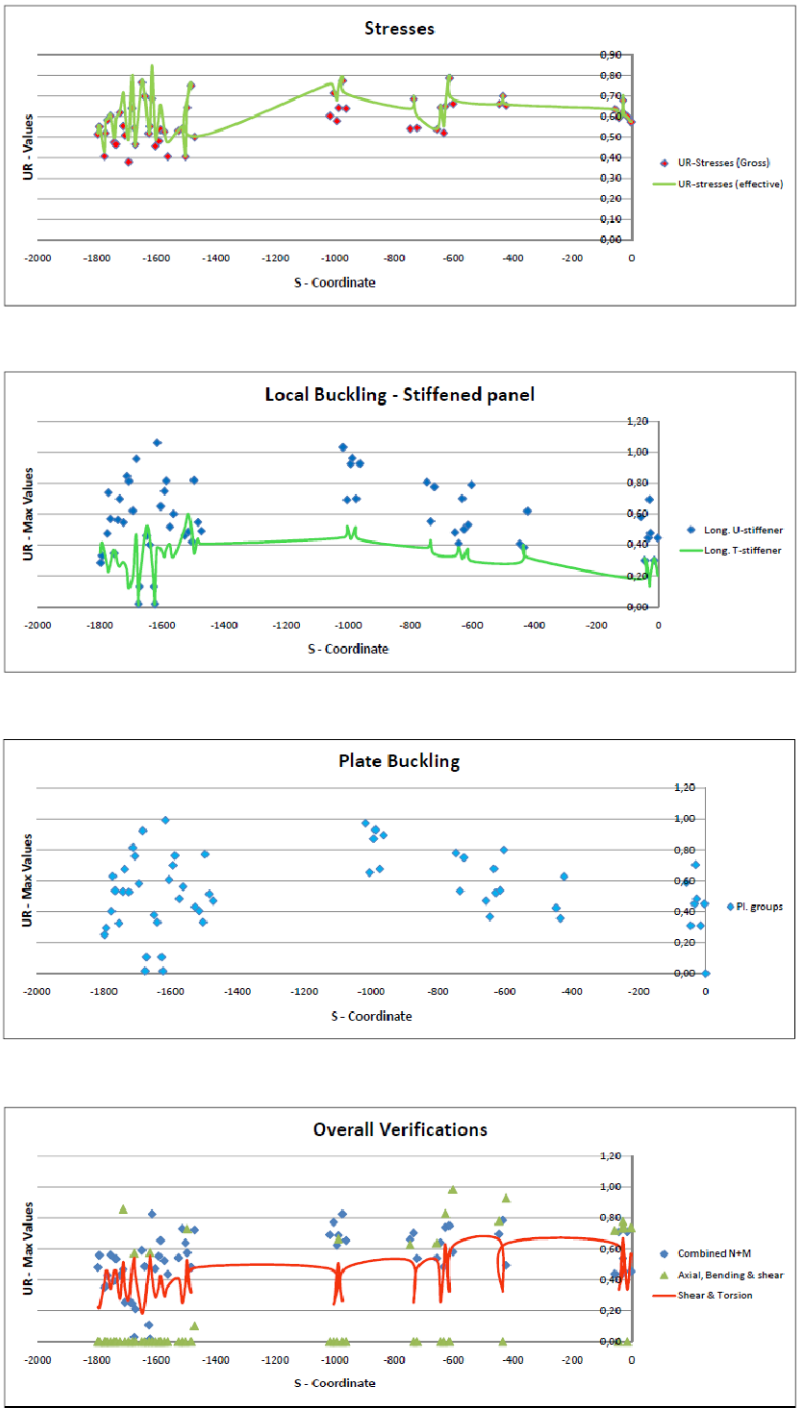
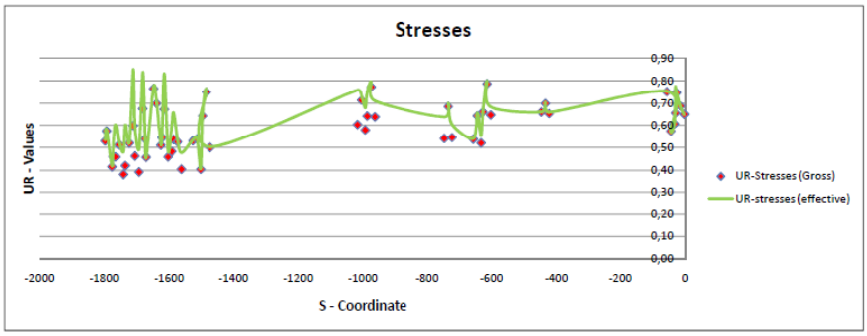
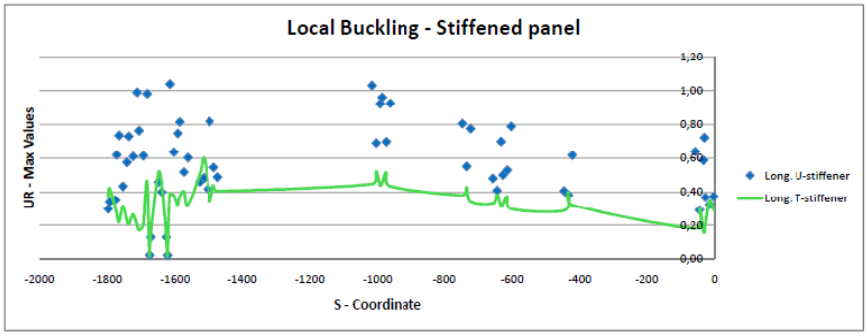
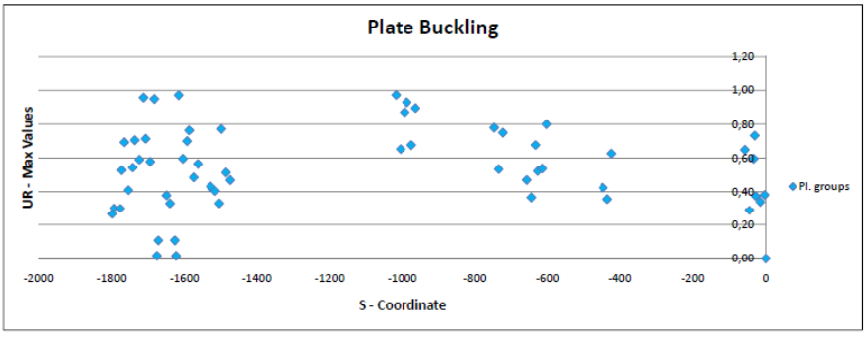


Figure 2-4 Roadway girder, ADVERS results for replacement of hanger 45 (s=-450 m)

From the results for hanger 45 it can be seen that all utilisation ratios are below 1.00 at the hanger location, and a replacement here is therefore possible considering the suspended deck structure.







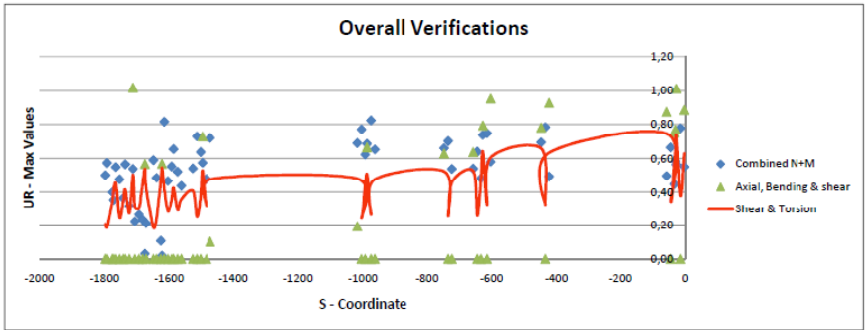


Figure 2-5 ADVERS results for replacement of hanger 60 (s=0 m)

From the results for hanger 60 it can be seen that a larger shear force is introduced at the adjacent spans resulting in a utilisation factor of UR=1.02 demanding reinforcement of the girder at this location due to the replacement operation.

3 Hanger Rupture

The analysis in IBDAS has been done in the dynamic region assuming instant rupture of both hangers simultaneously. The effect of hanger rupture on the suspended deck has been verified using ADVERS and the sectional forces calculated from the global IBDAS model.

For the verification of the suspended deck structure during the hanger rupture a few different locations has been selected in the side span and at the towers, see Figure 3-1. These locations have been chosen due to expectation of large dynamic effects in this area. Most critical is the tie-down hanger and the hangers supporting the 60m drop-in span, since the girder span will increase significantly during rupture.

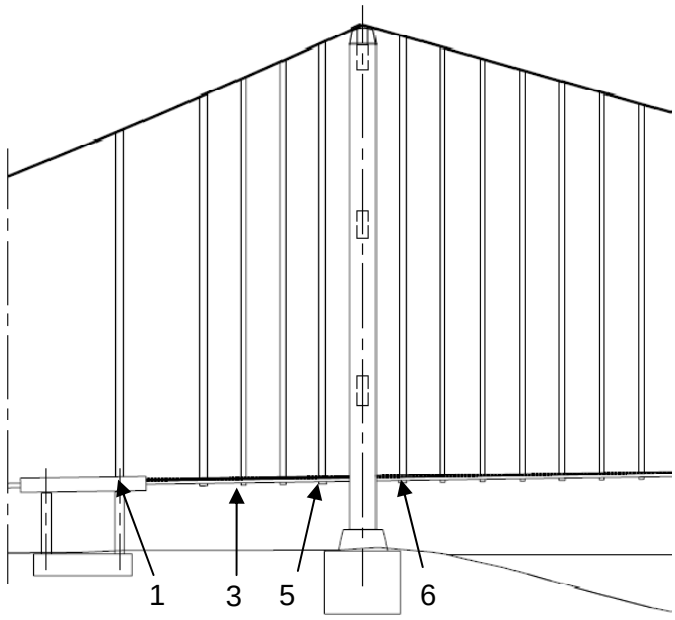


Figure 3-1 Location of hangers considered for rupture

In accordance with the Design Basis the accidental load situation such as hanger rupture has been considered using a material partial safety factor of γ_M=1.0. The result of the analysis can be seen in the following for roadway, railway and cross girders.

3.1.1 Roadway Girder

The calculations of the effect of hanger rupture on the roadway girder can be seen in the following figures. It can be seen that the roadway girder has sufficient capacity in case of rupture of the considered hangers. For rupture of hanger 1 and 5 a utilisation factor UR>1.00 are calculated for local buckling of stiffeners. However, this calculation is for a location close to a cross girder, where buckling is not to be considered, and in the adjacent point no buckling problems occur, thus indicating that no problem exists.

Sectional force curves are given in the following illustrating the calculated sectional forces from the global IBDAS model in few discrete points. These curves illustrate the behaviour and effect in the girder due to rupture of selected hangers. All results are ULS envelopes and show the max sectional forces in 3-4 points within a girder section.

From the various section force curves it is evident that rupture of a hanger has a large effect on the adjacent spans, indicated by a peak in forces at the location of rupture mainly due to the dynamic effects. It can also be seen that the effect fades out rapidly through the bridge. Largest effects are visible in the side span due to the rigidity of the shorter span here enlarges the dynamic effect from the cables.

3.1.1.1 Rupture, Hanger 1

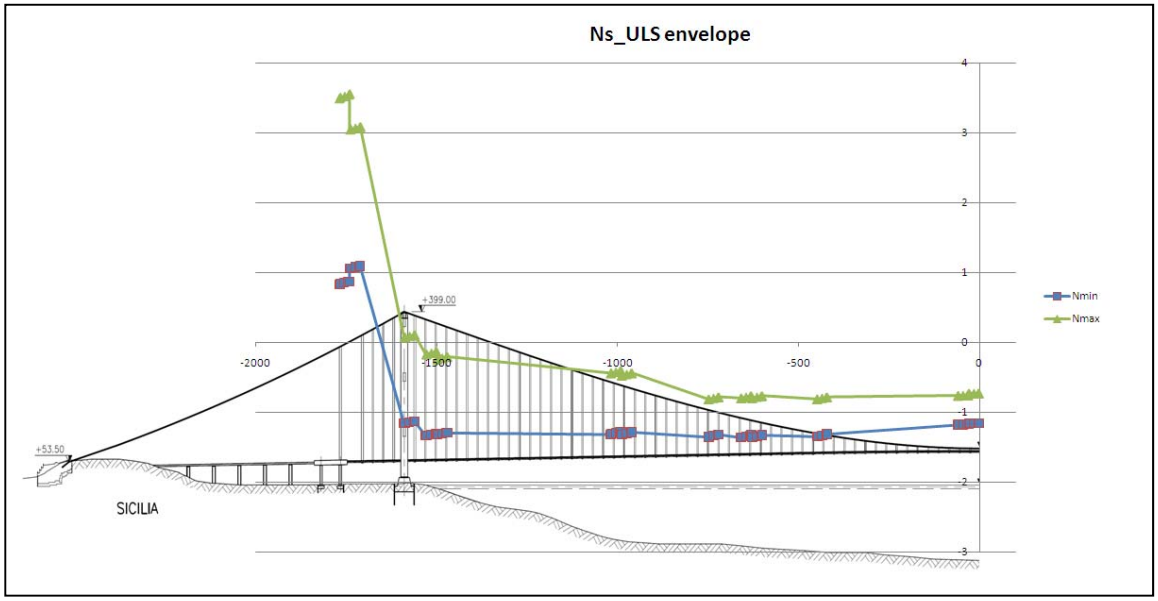


Figure 3-2 Sectional forces in road girder for rupture of hanger 1, Normal force (MN)

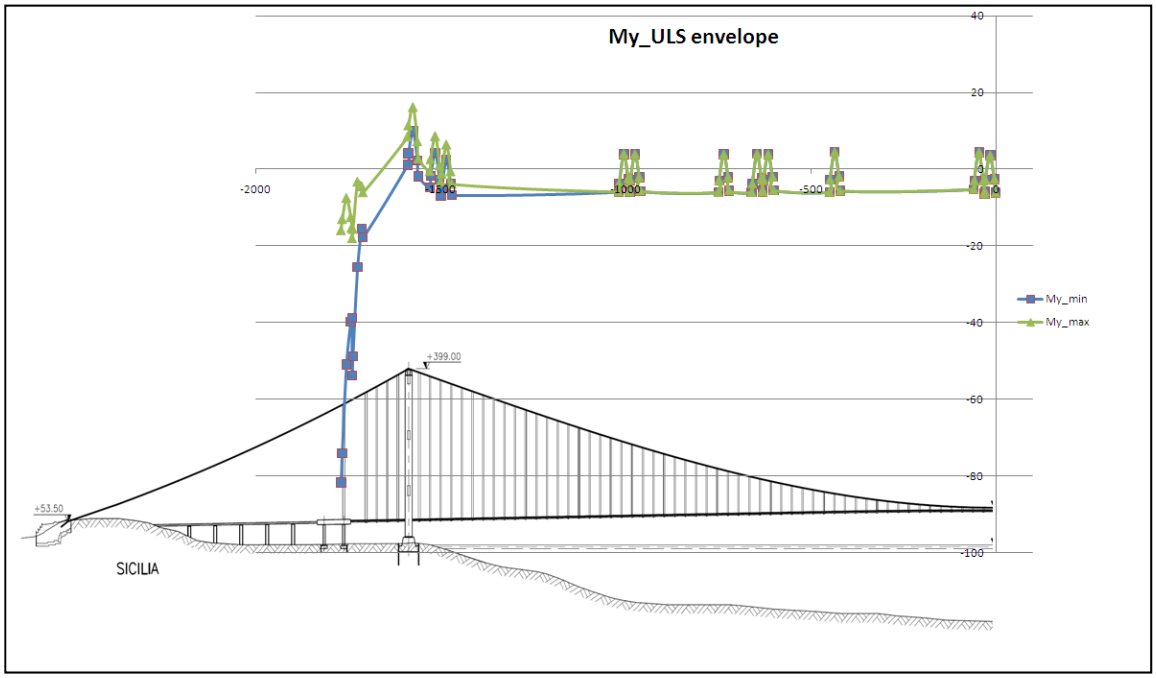


Figure 3-3 Sectional forces in road girder for rupture of hanger 1, Moment (MNm)

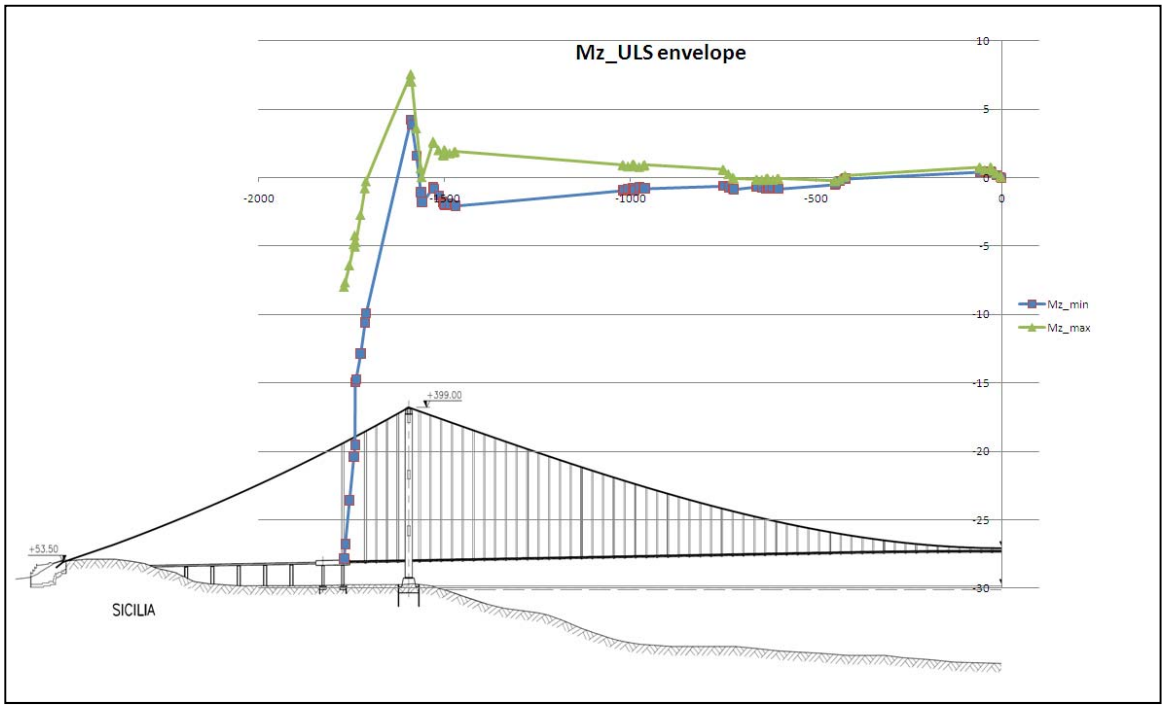
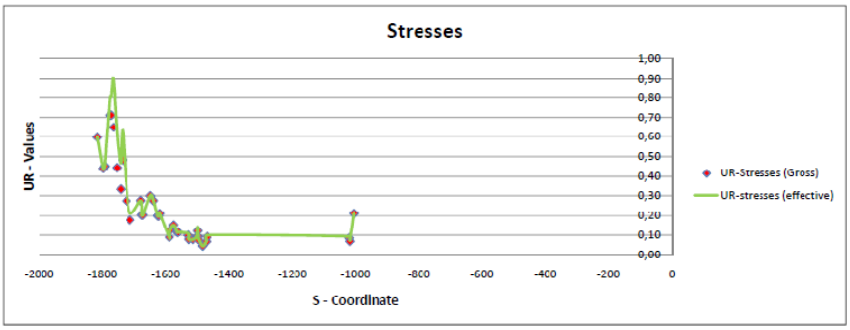
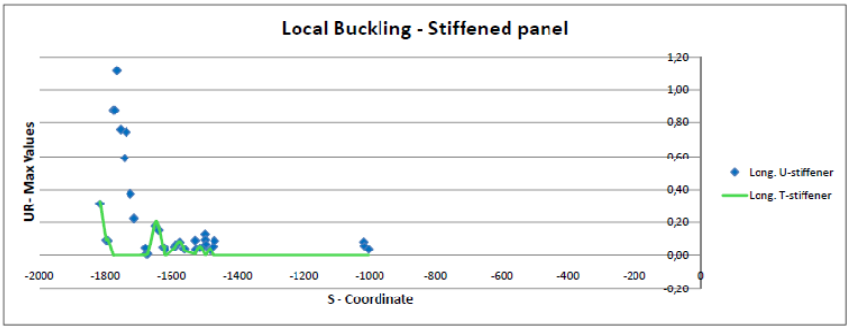
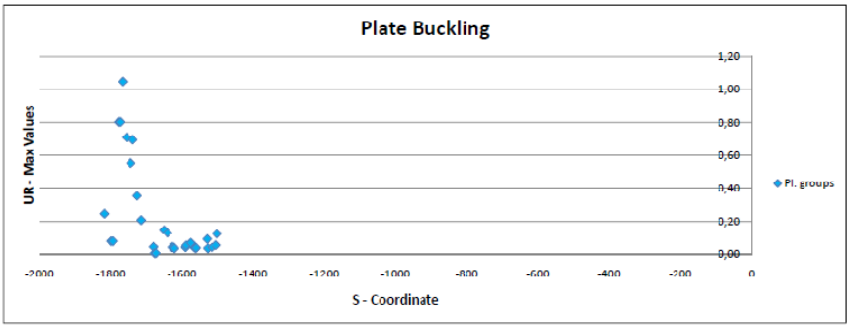


Figure 3-4 Sectional forces in road girder for rupture of hanger 1, Moment (MNm)







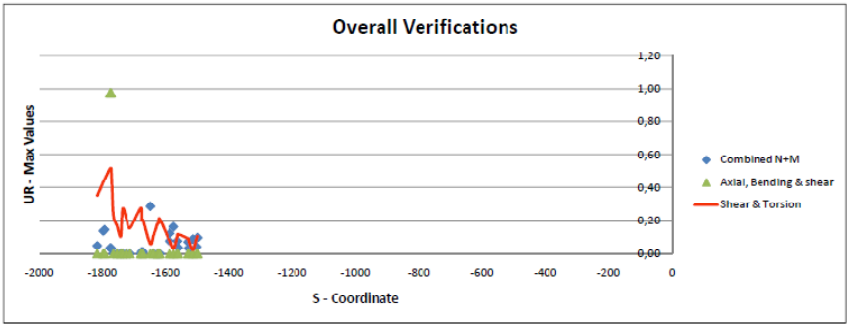


Figure 3-5 ADVERS results for rupture of Hanger 1, roadway girder

3.1.1.2 Rupture, Hanger 3

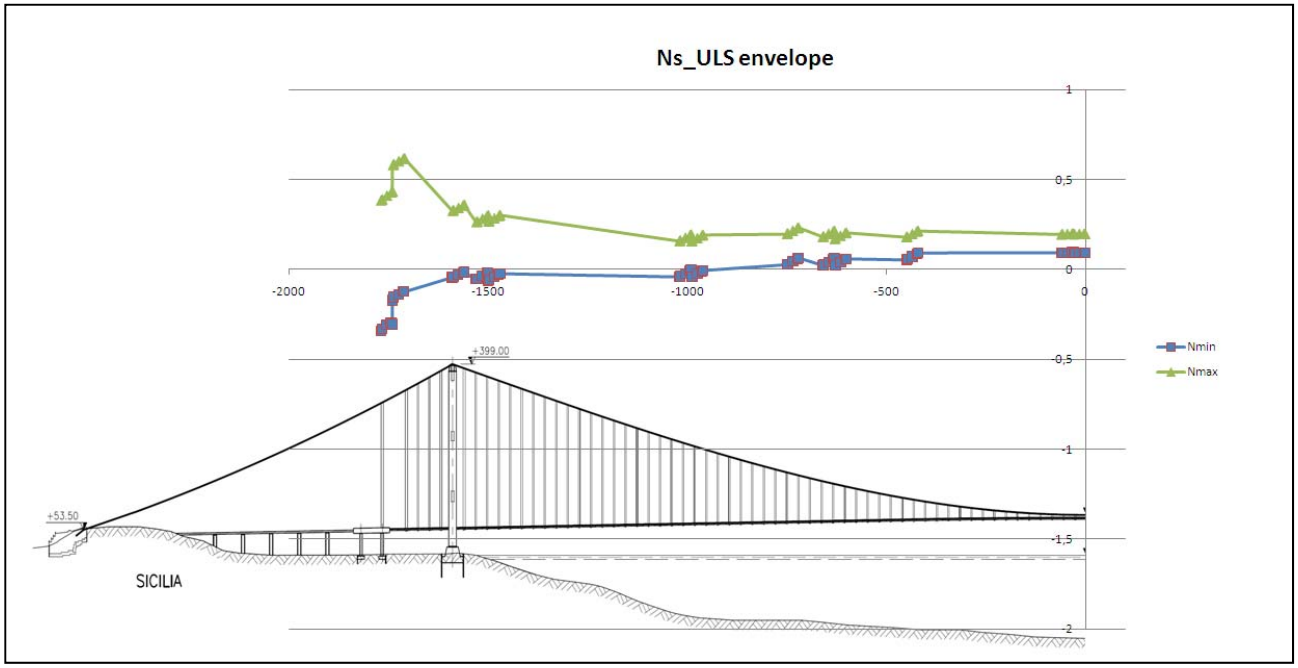


Figure 3-6 Sectional forces in road girder for rupture of hanger 3, Normal force (MN)

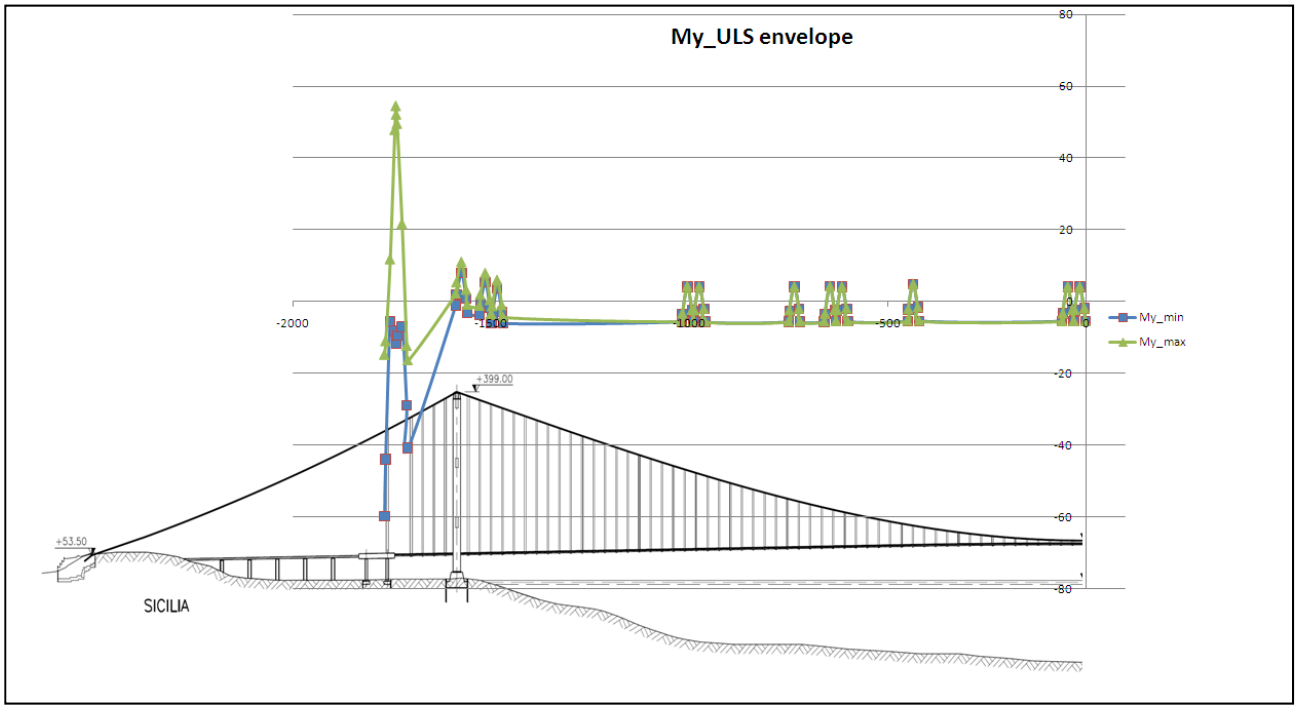


Figure 3-7 Sectional forces in road girder for rupture of hanger 3, Moment (MNm)

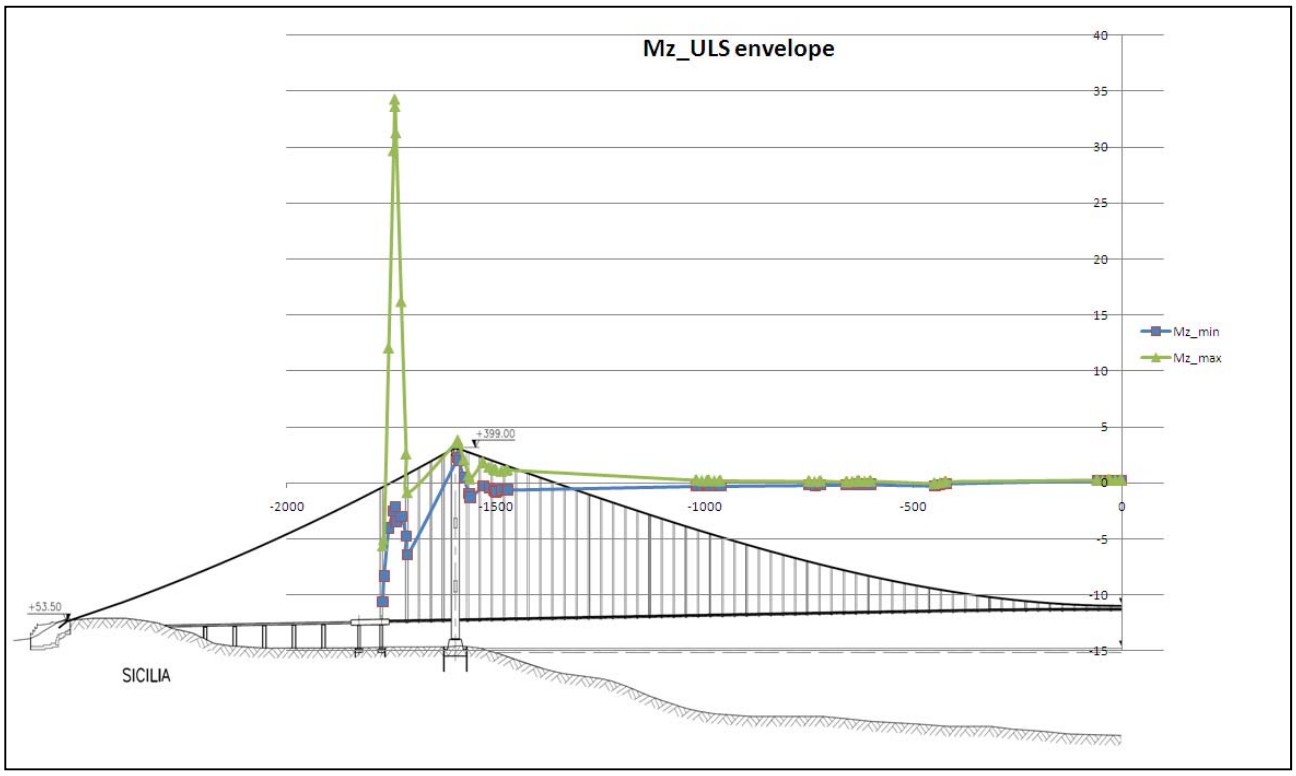
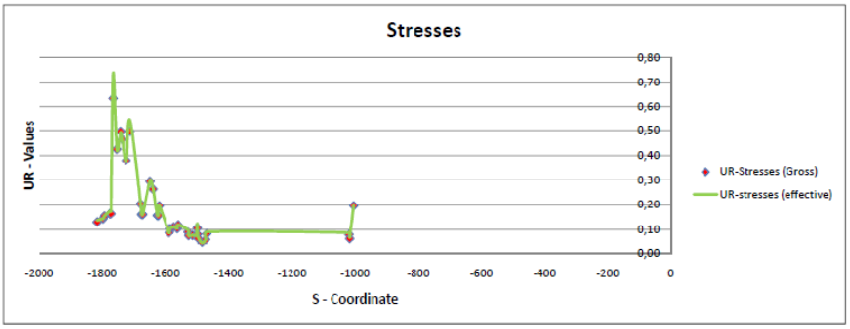
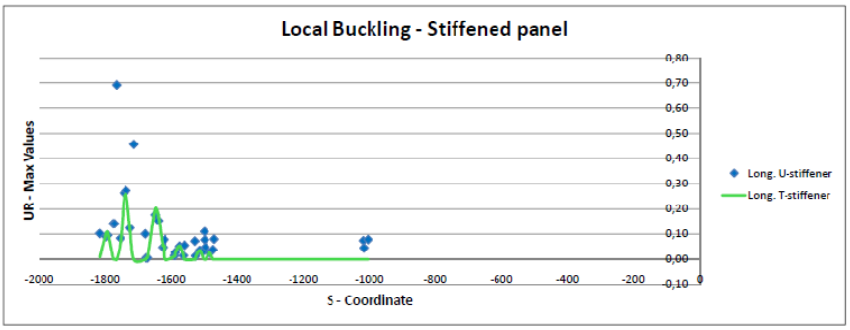
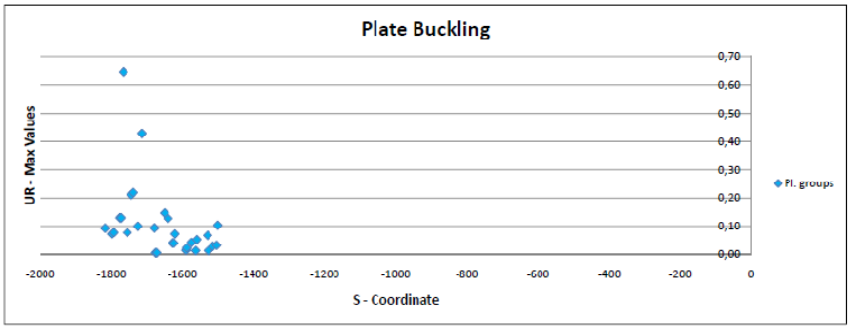


Figure 3-8 Sectional forces in road girder for rupture of hanger 3, Moment (MNm)







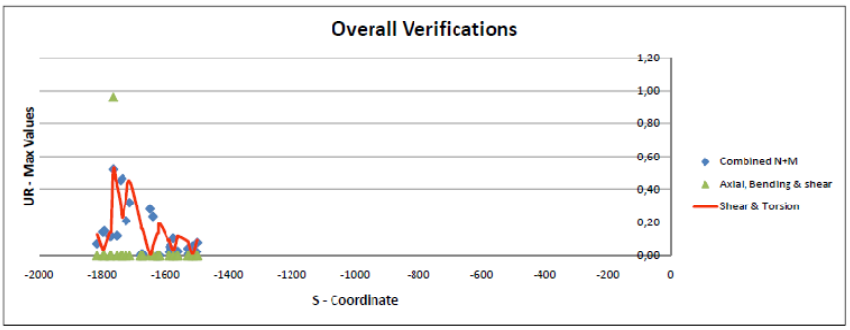


Figure 3-9 ADVERS results for rupture of Hanger 3, roadway girder

3.1.1.3 Rupture, Hanger 5

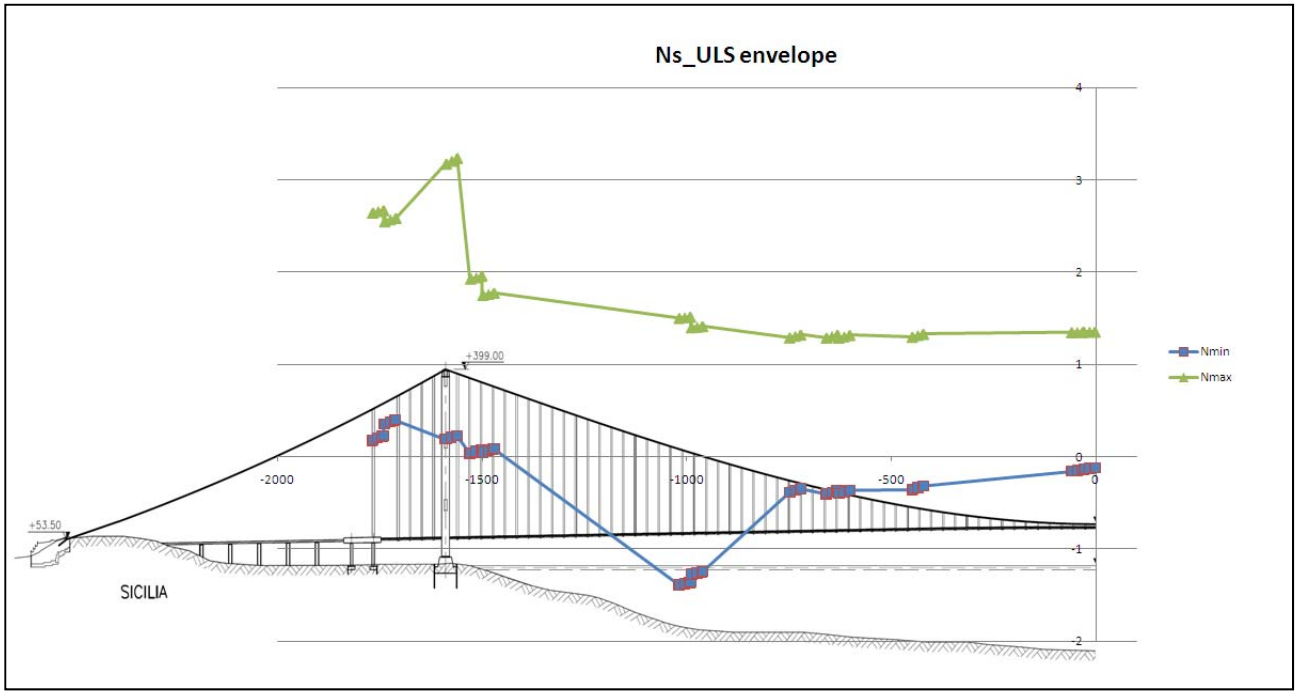


Figure 3-10 Sectional forces in road girder for rupture of hanger 5, Normal force (MN)

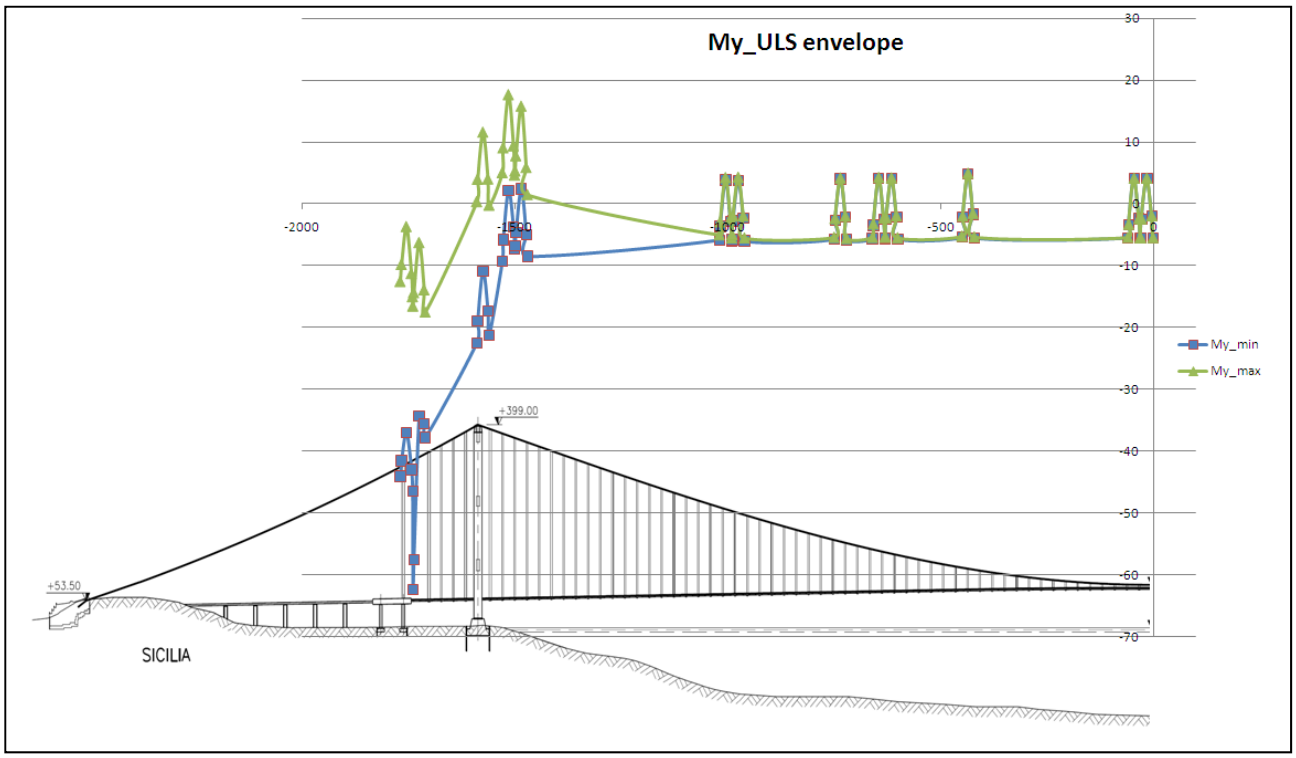


Figure 3-11 Sectional forces in road girder for rupture of hanger 5, Moment (MNm)

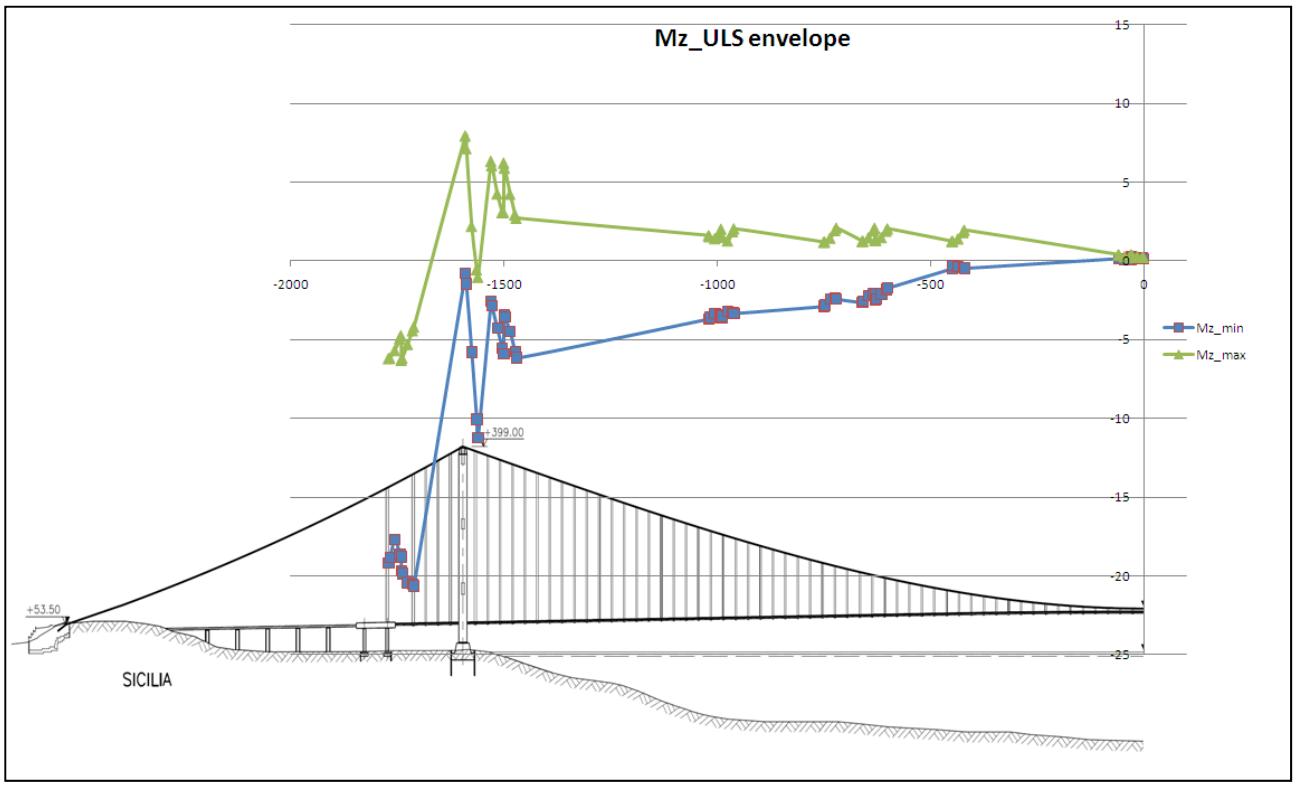
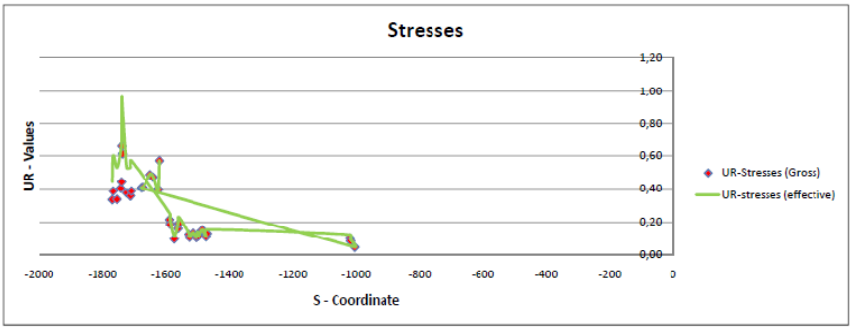
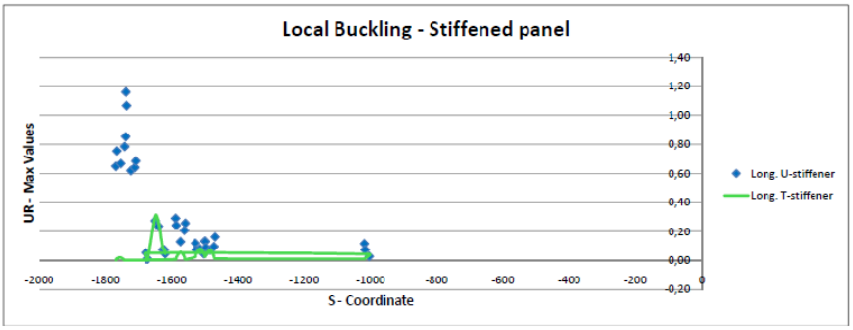
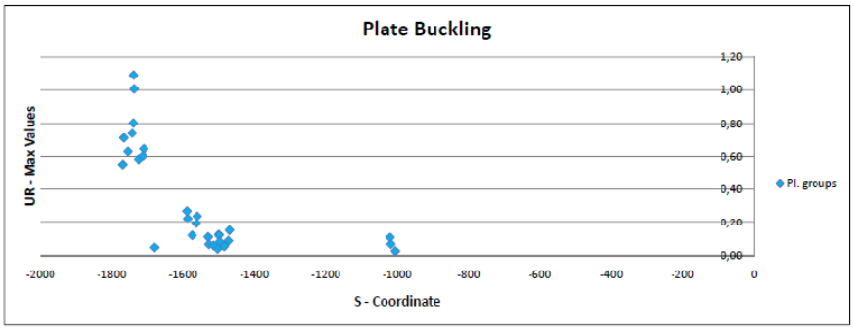


Figure 3-12 Sectional forces in road girder for rupture of hanger 5, Moment (MNm)







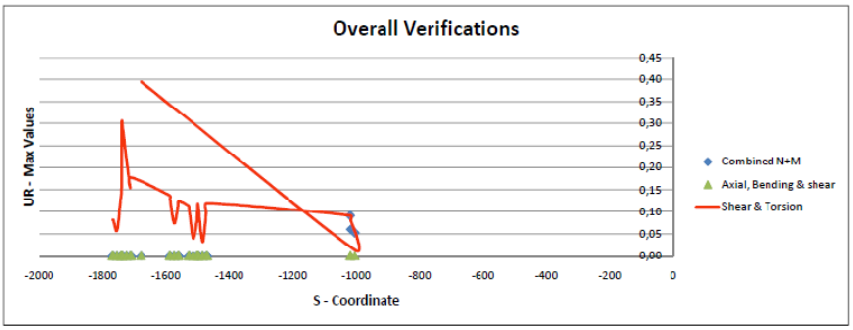


Figure 3-13 ADVERS results for rupture of Hanger 5, roadway girder

3.1.1.4 Rupture, Hanger 6

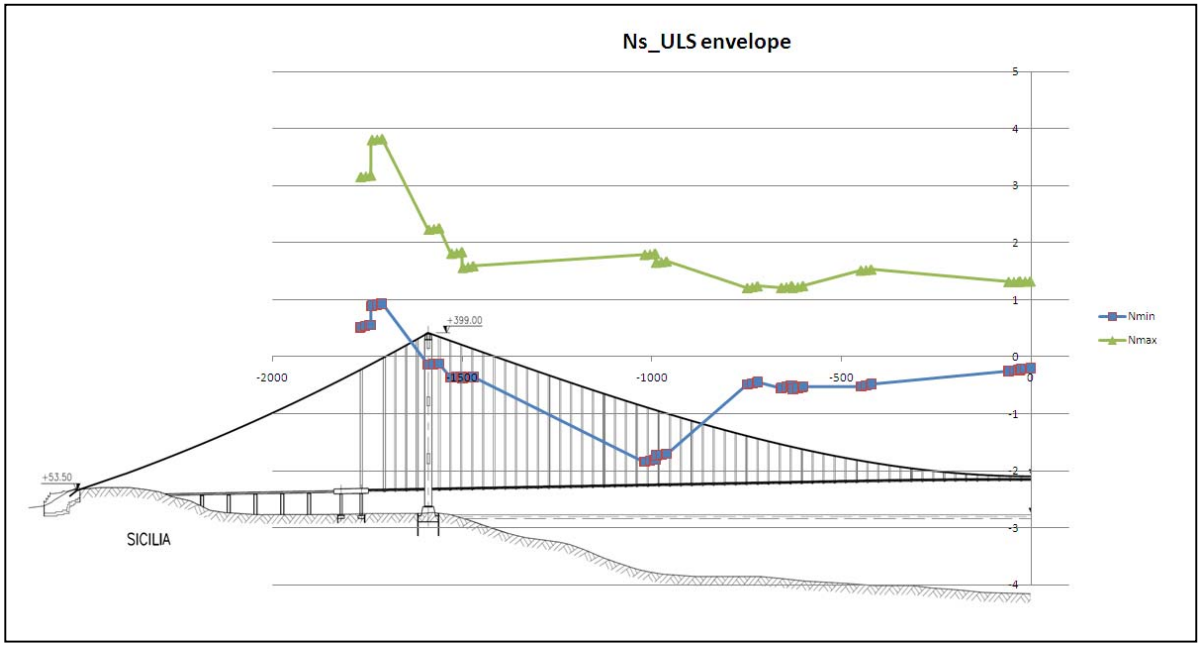


Figure 3-14 Sectional forces in road girder for rupture of hanger 6, Normal force (MN)

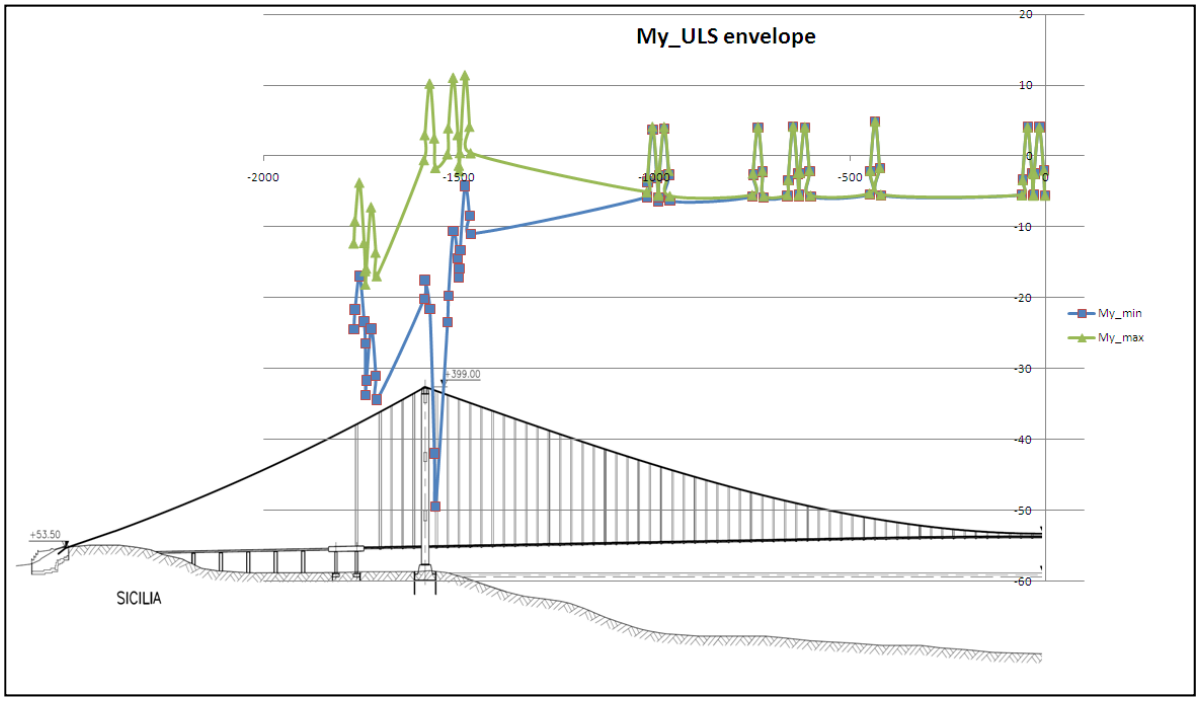


Figure 3-15 Sectional forces in road girder for rupture of hanger 6, Moment (MNm)

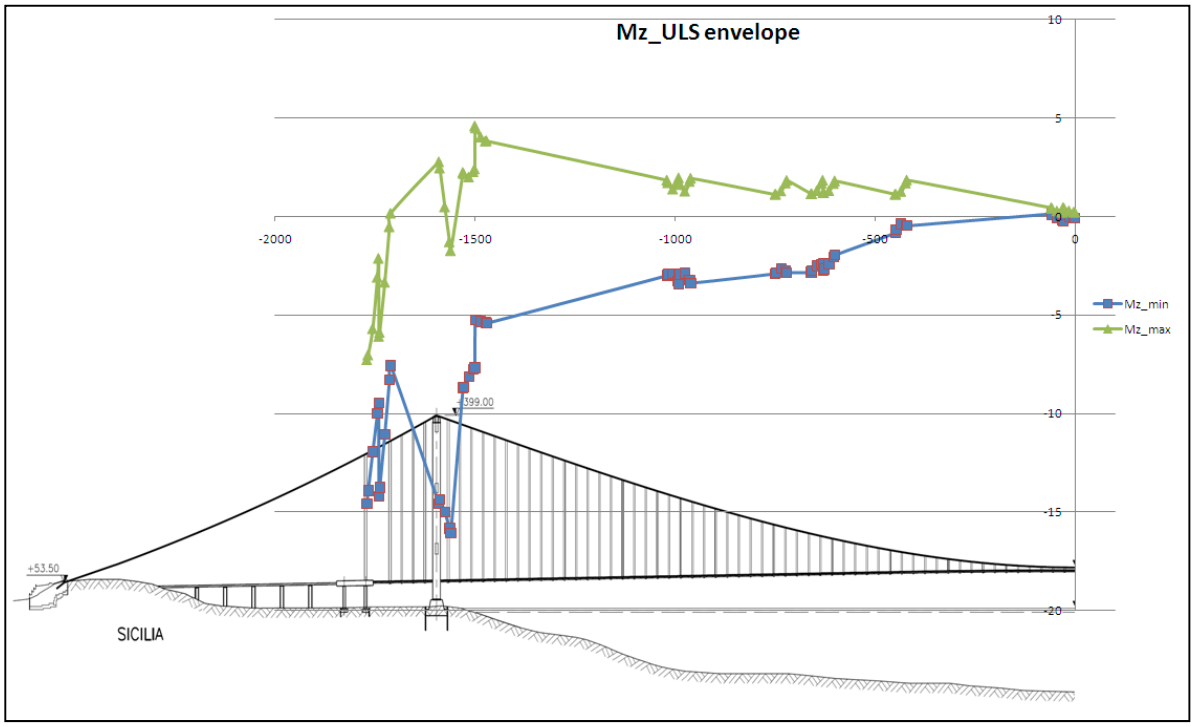
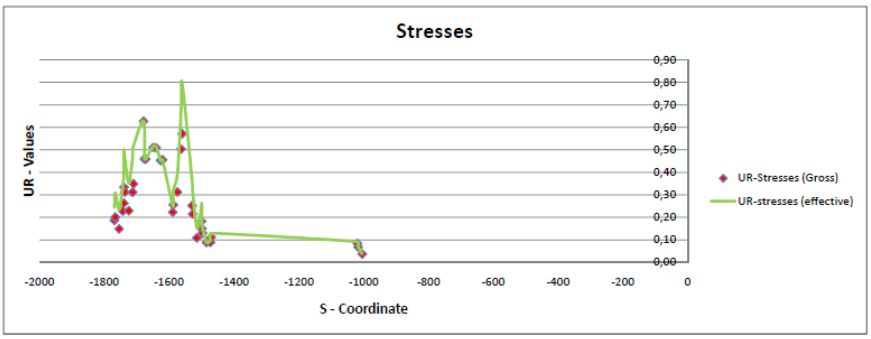
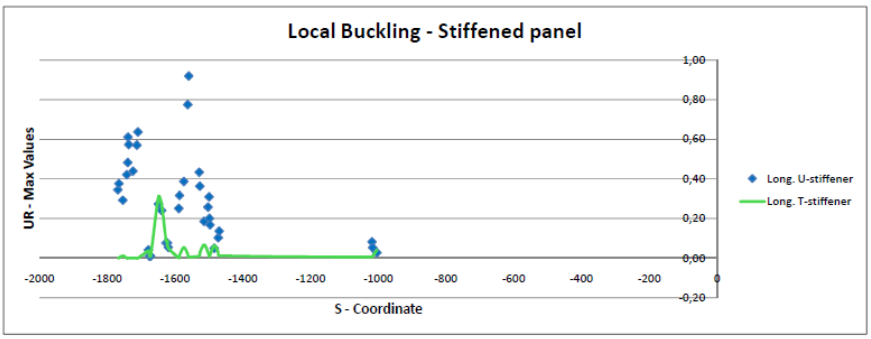
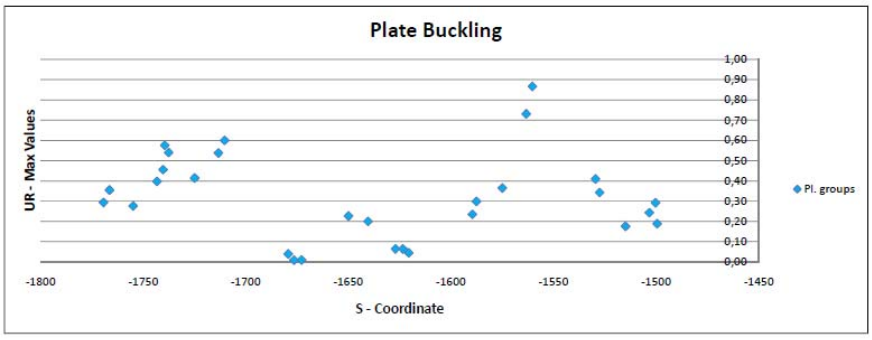


Figure 3-16 Sectional forces in road girder for rupture of hanger 6, Moment (MNm)







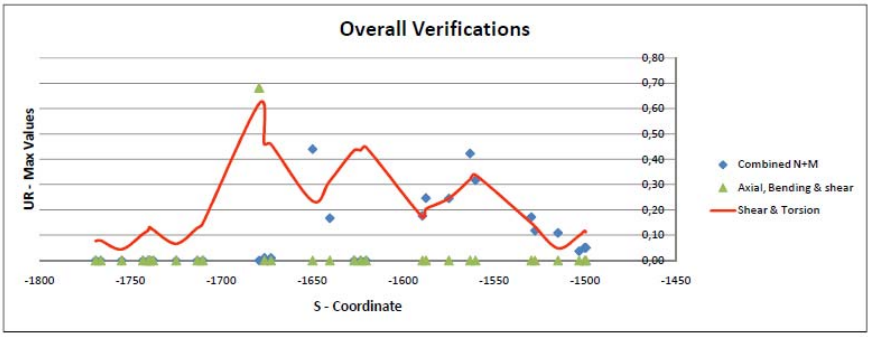


Figure 3-17 ADVERS results for rupture of Hanger 6, roadway girder

3.1.1.5 Rupture, Hanger 30

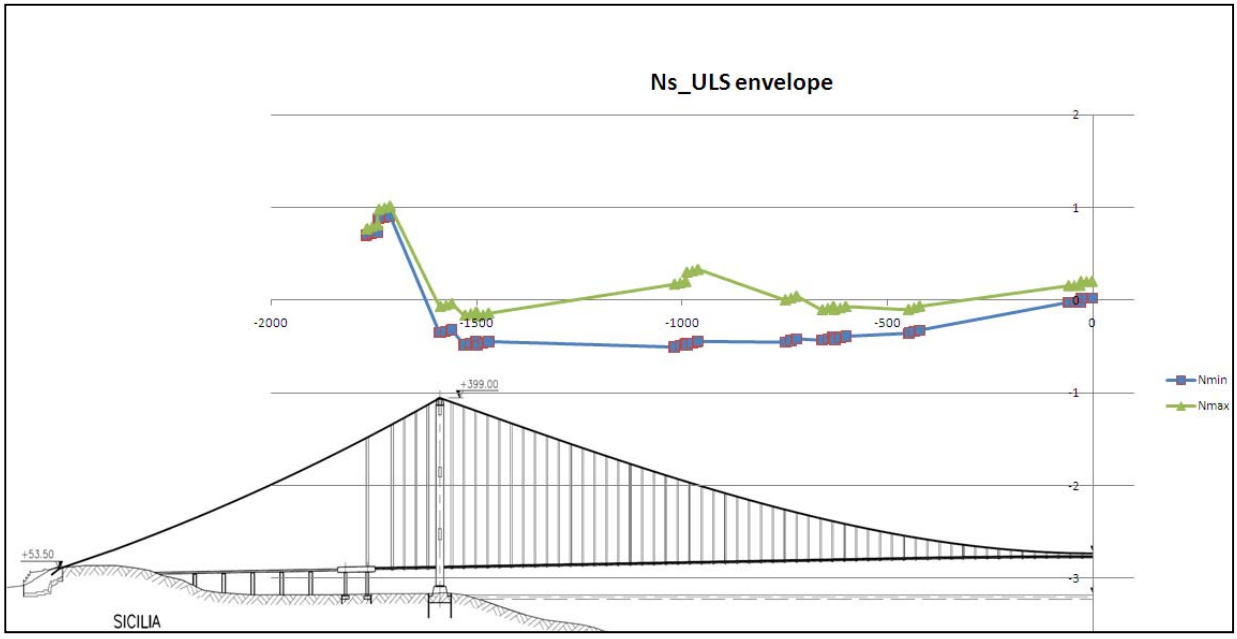


Figure 3-18 Sectional forces in road girder for rupture of hanger 30, Normal force (MN)

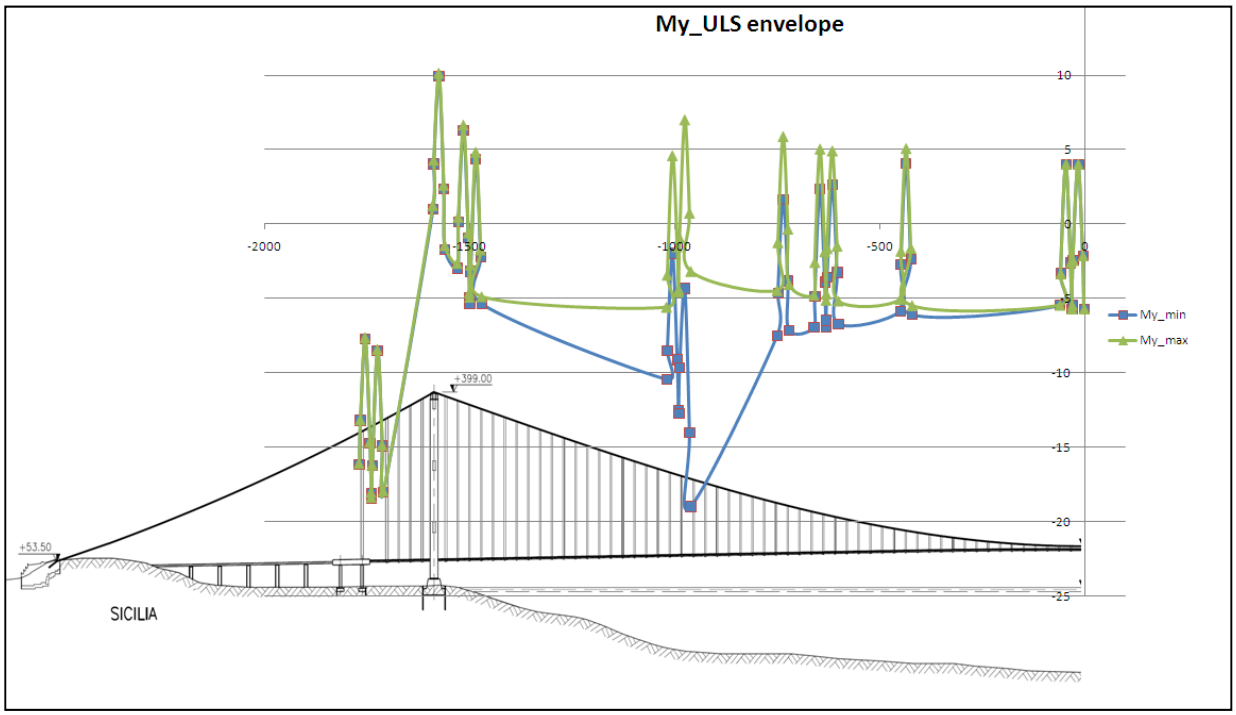


Figure 3-19 Sectional forces in road girder for rupture of hanger 30, Moment (MNm)

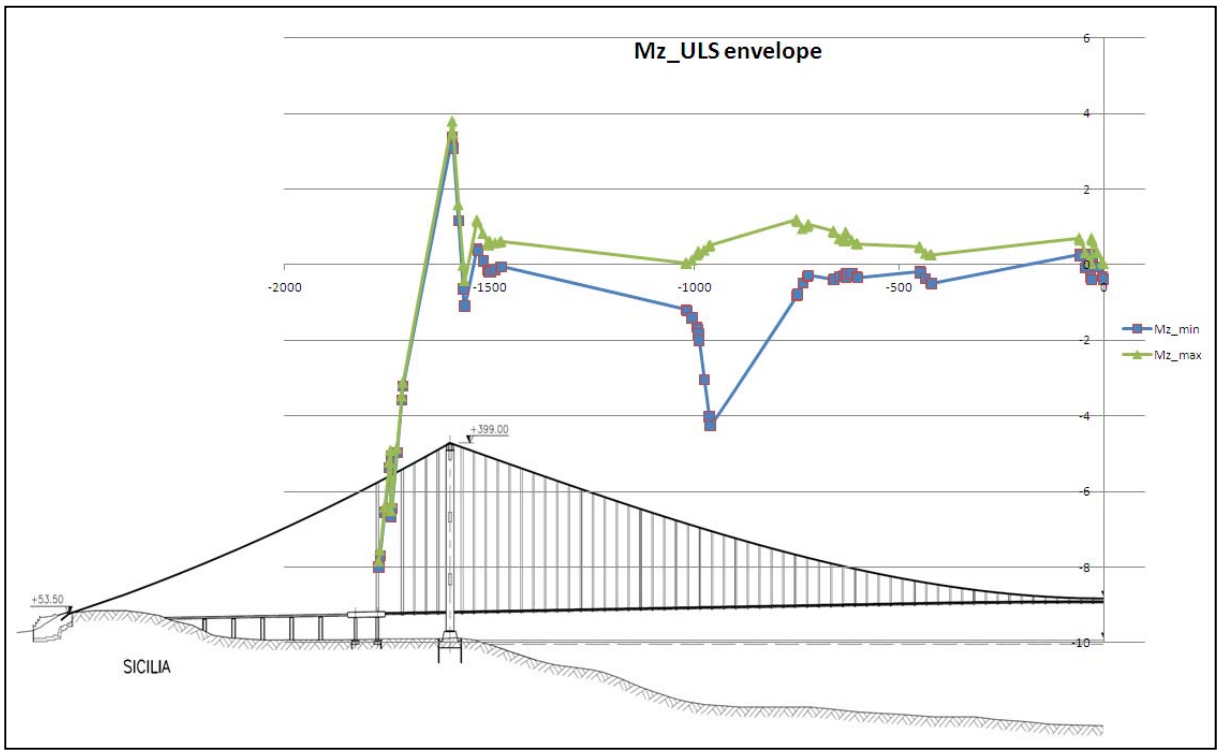
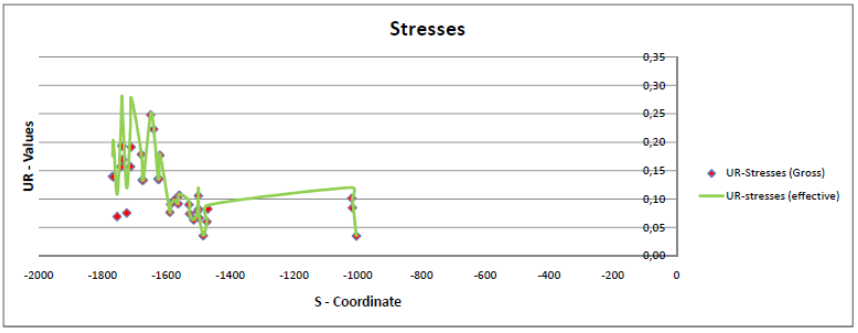
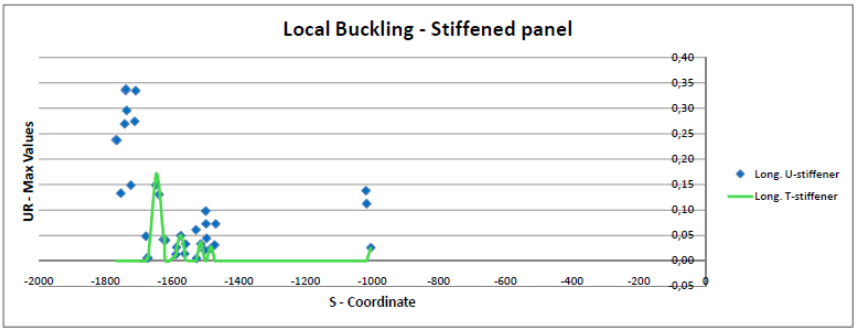
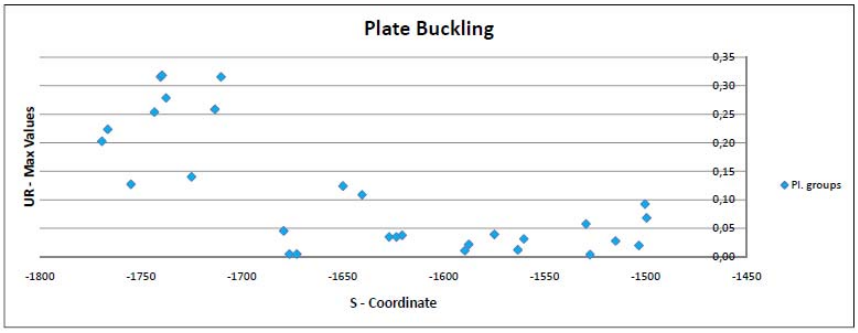


Figure 3-20 Sectional forces in road girder for rupture of hanger 30, Moment (MNm)







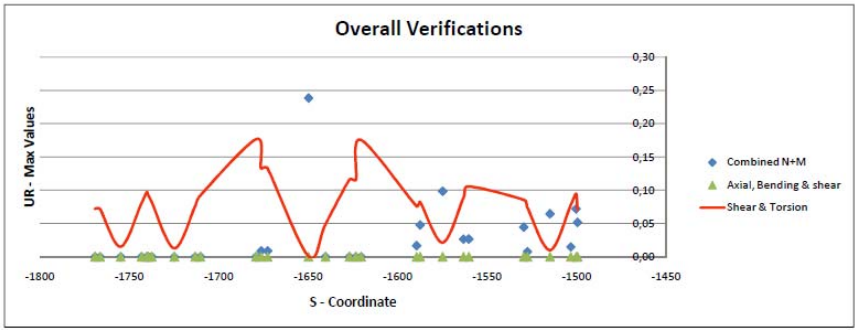


Figure 3-21 ADVERS results for rupture of Hanger 30, roadway girder

3.1.2 Railway Girder

The calculations of the effect of hanger rupture on the railway girder are parted in girder types due to the calculation method used in ADVERS. From the results in the following figures it can be seen that the railway girder has sufficient capacity in case of rupture of the considered hangers.

Sectional force curves are given in the following illustrating the calculated sectional forces from the global IBDAS model in few discrete point. These curves illustrate the behaviour and effect in the girder due to rupture of selected hangers. All results are ULS envelopes and show the max sectional forces in 3-4 points within a girder section.

From the various section force curves it is evident that rupture of a hanger has a large effect on the adjacent spans, indicated by a peak in forces at the location of rupture mainly due to the dynamic effects. It can also be seen that the effect fades out rapidly through the bridge.

3.1.2.1 Rupture, Hanger 3

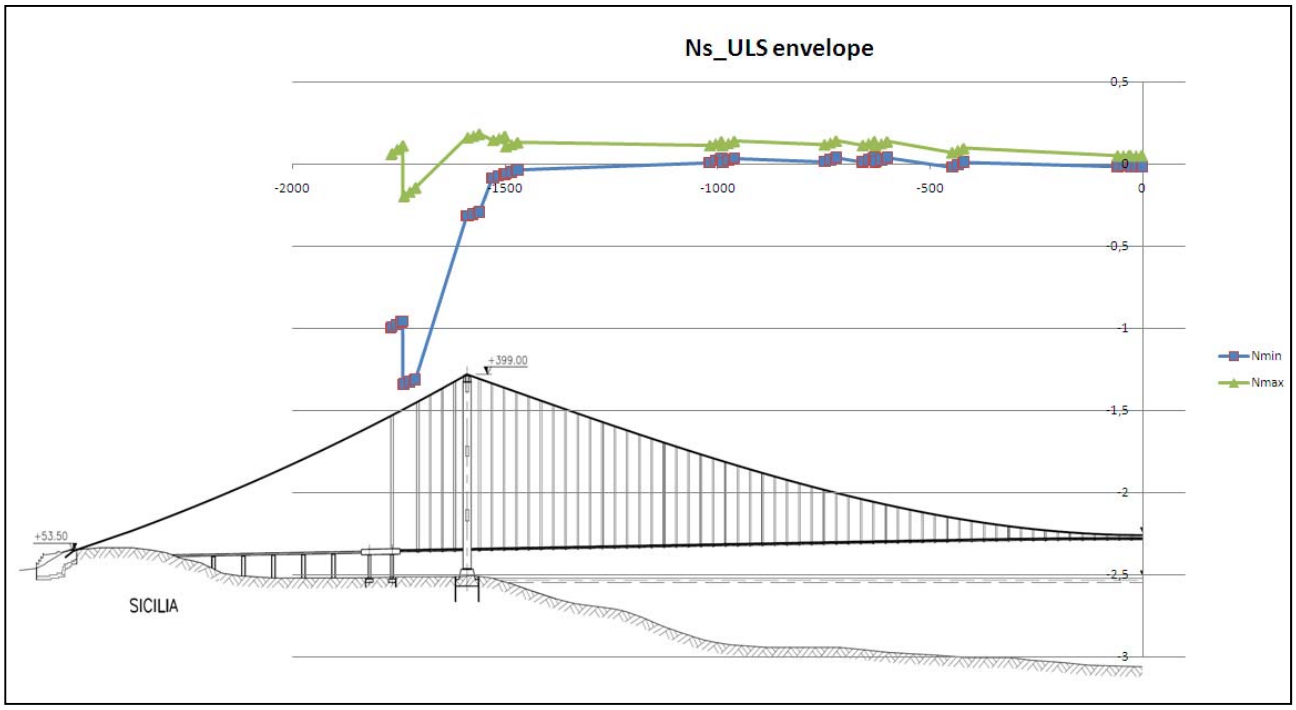


Figure 3-22 Sectional forces in rail girder for rupture of hanger 3, Normal force (MN)

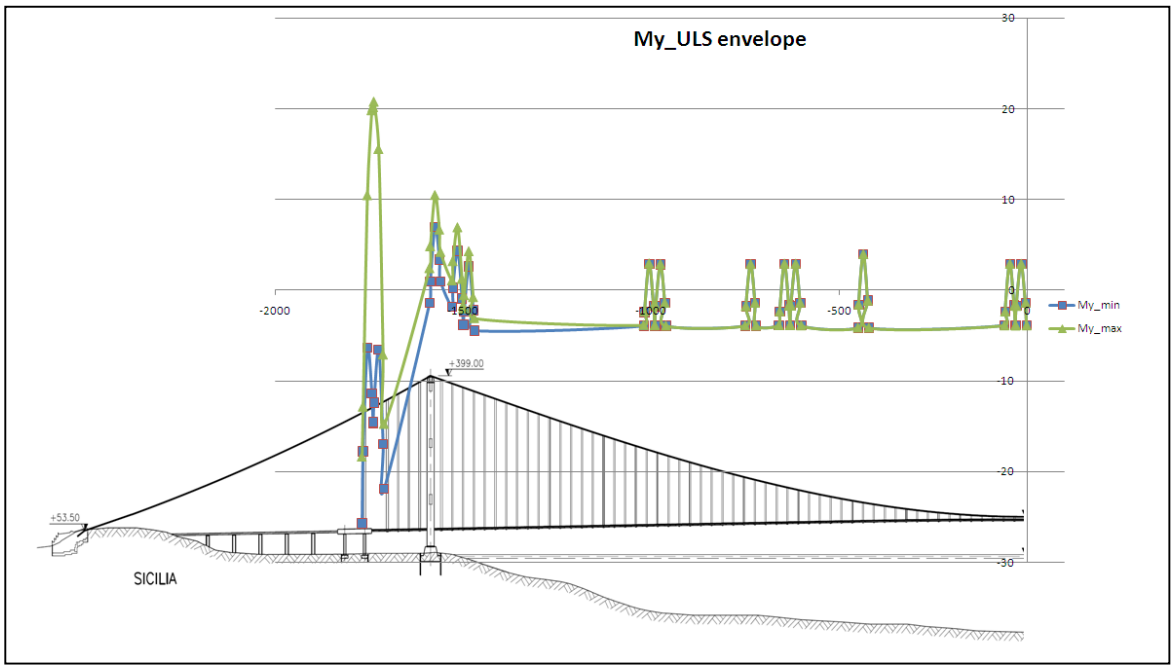


Figure 3-23 Sectional forces in rail girder for rupture of hanger 3, Moment (MNm)

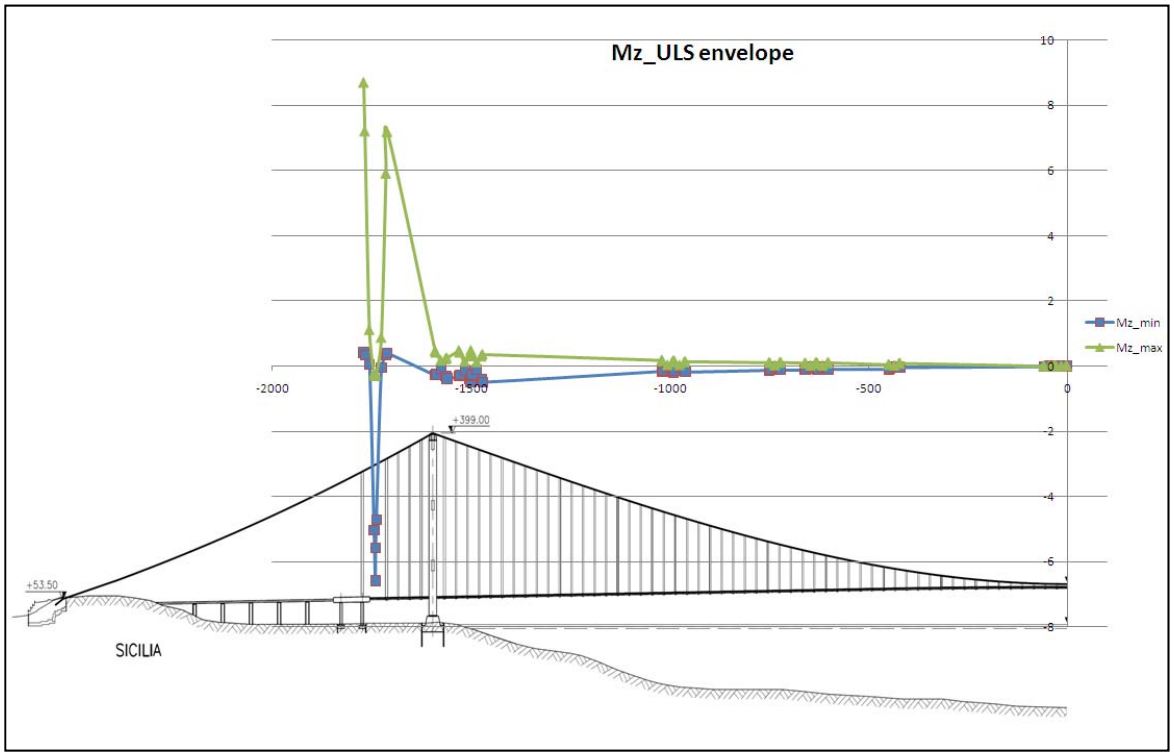
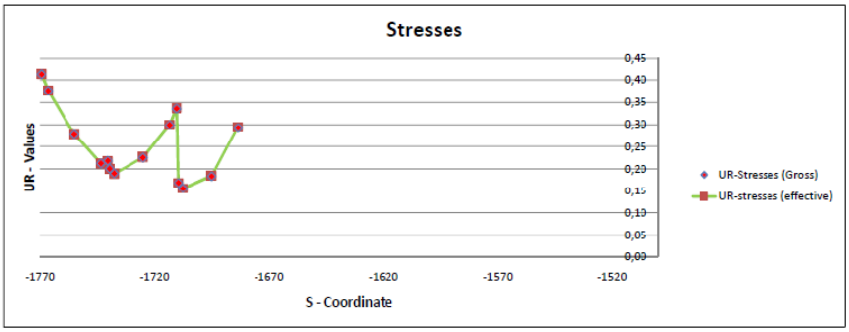
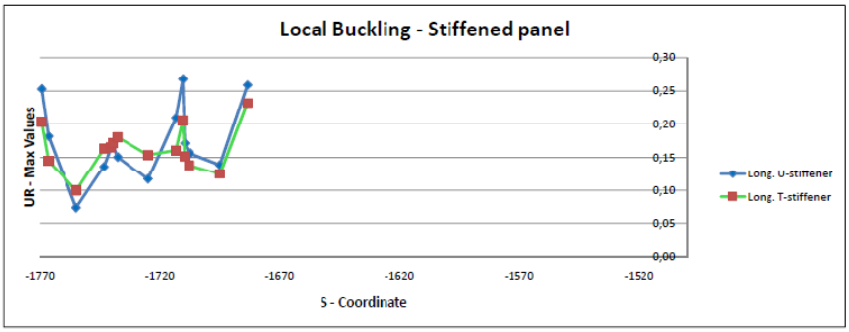
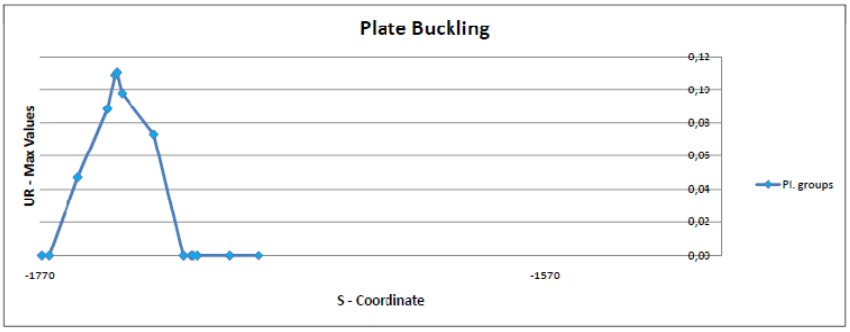


Figure 3-24 Sectional forces in rail girder for rupture of hanger 3, Moment (MNm)







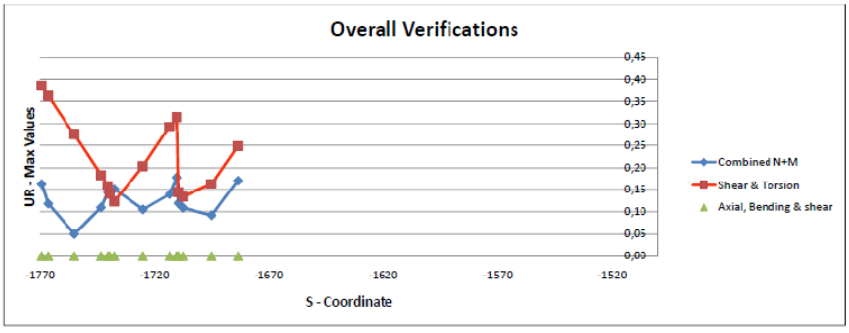


Figure 3-25 ADVERS results for rupture of Hanger 3, railway girder CF3/5/6

3.1.2.2 Rupture, Hanger 5

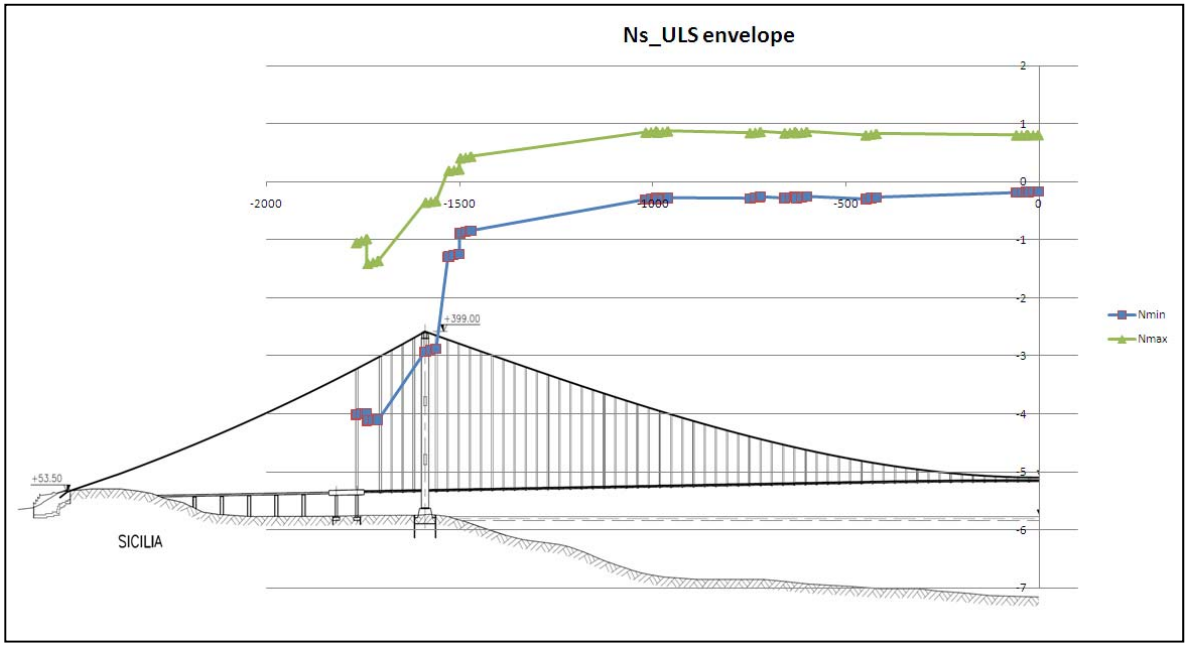


Figure 3-26 Sectional forces in rail girder for rupture of hanger 5, Normal force (MN)

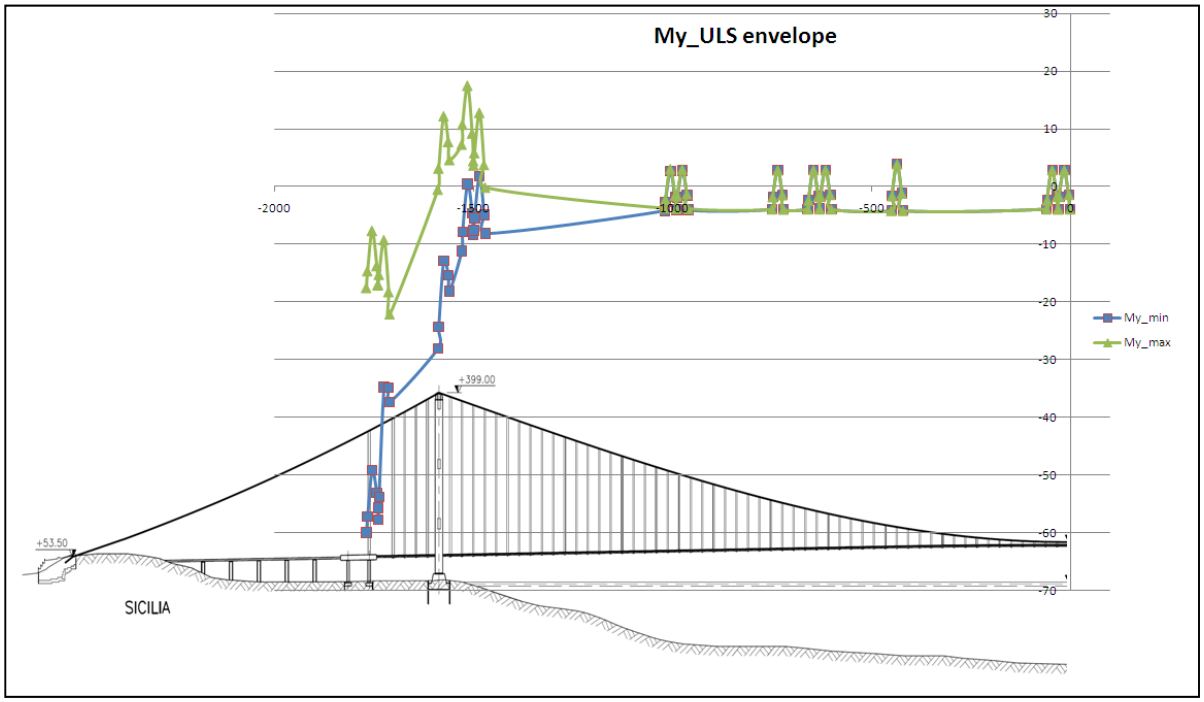


Figure 3-27 Sectional forces in rail girder for rupture of hanger 5, Moment (MNm)

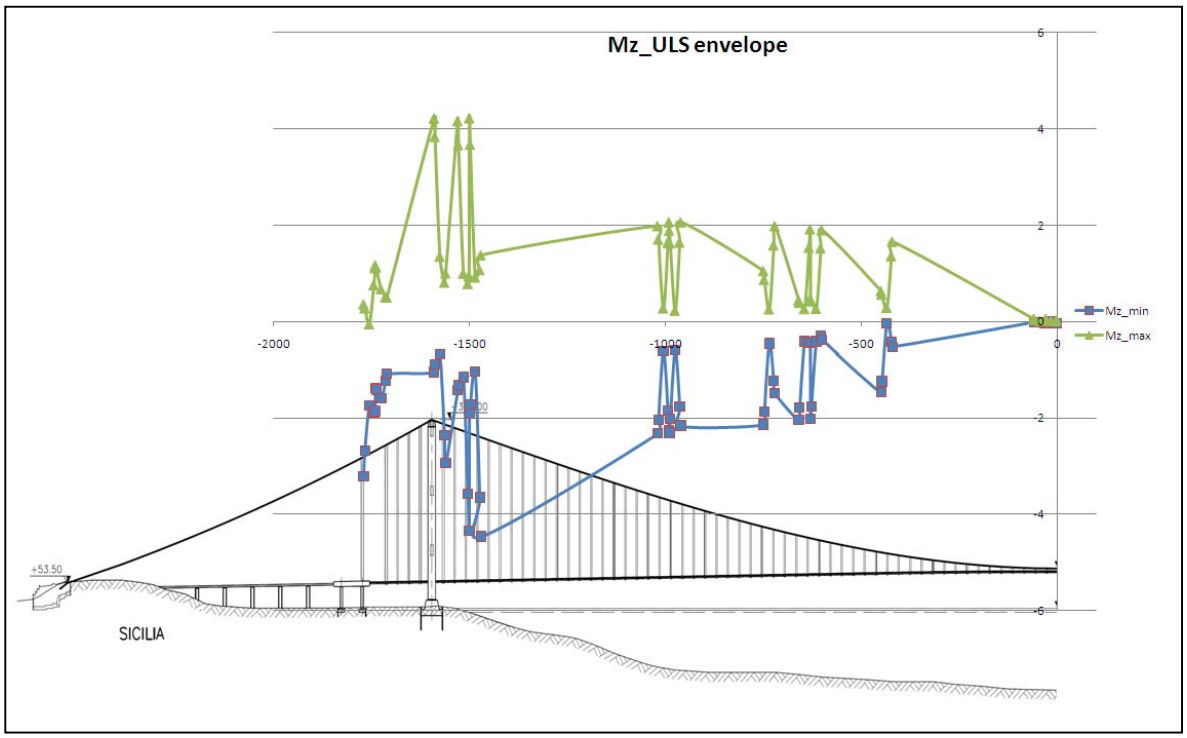
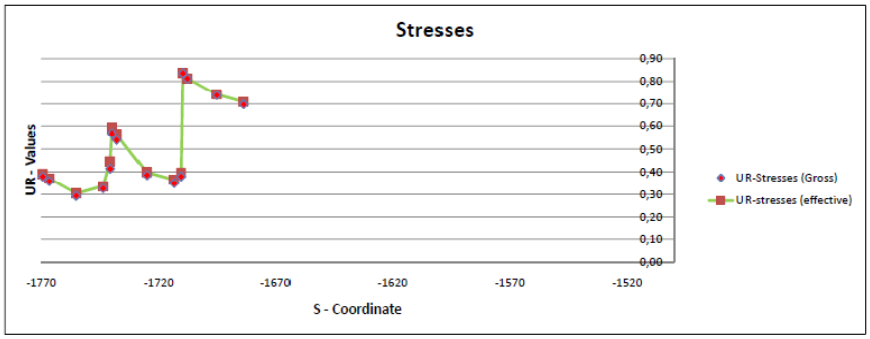
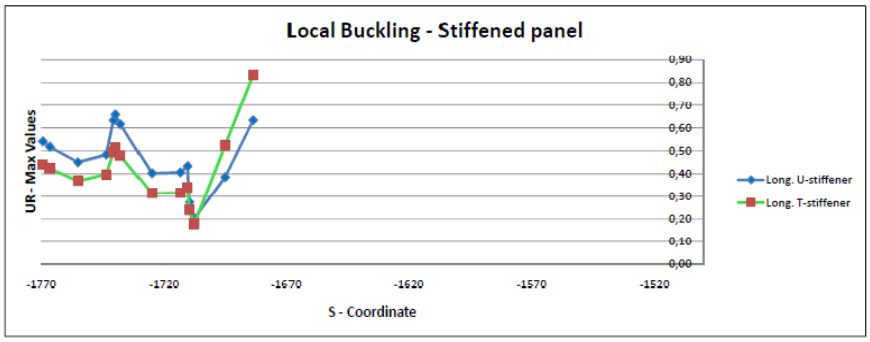
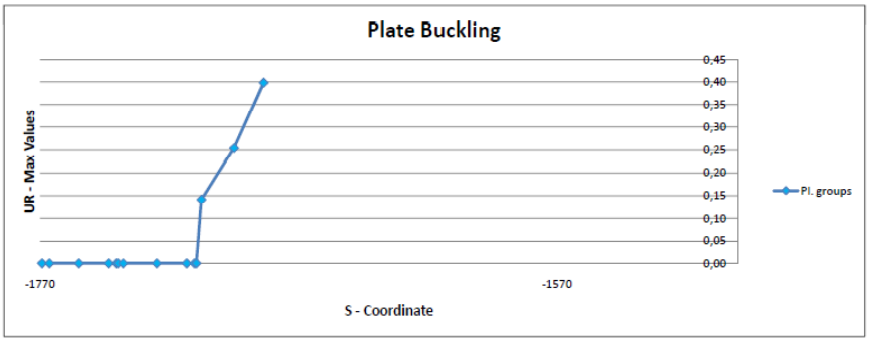


Figure 3-28 Sectional forces in rail girder for rupture of hanger 5, Moment (MNm)







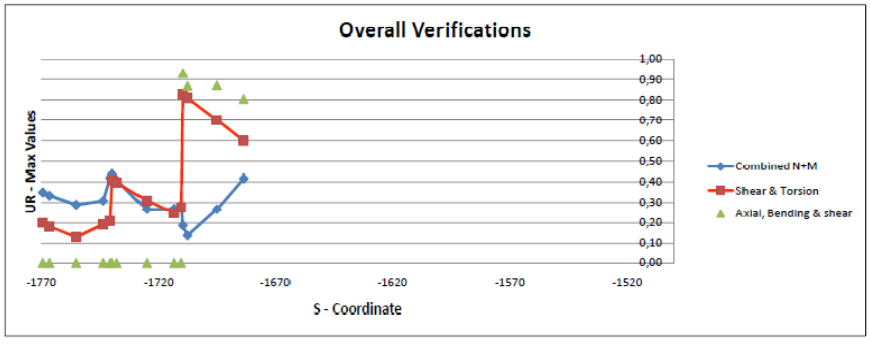
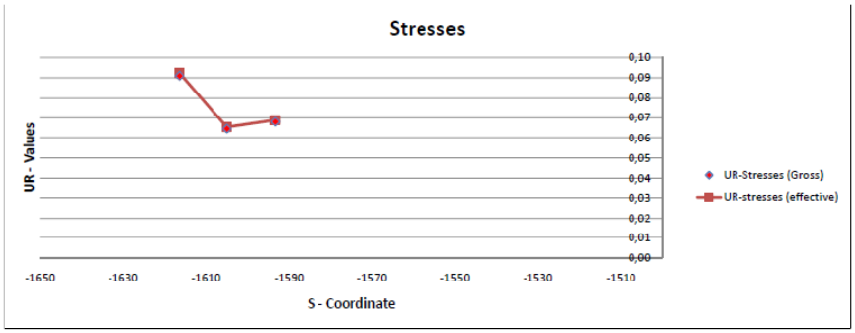
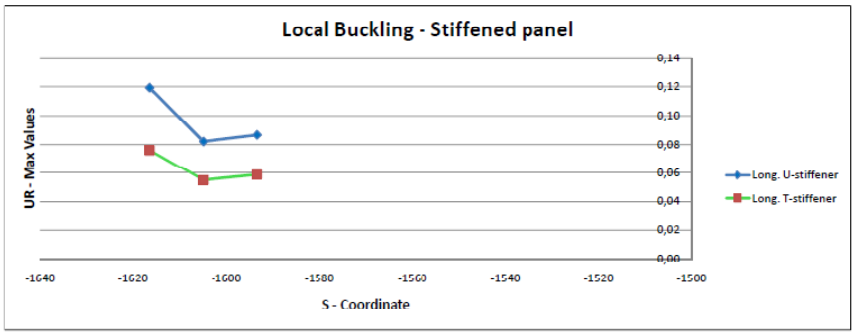
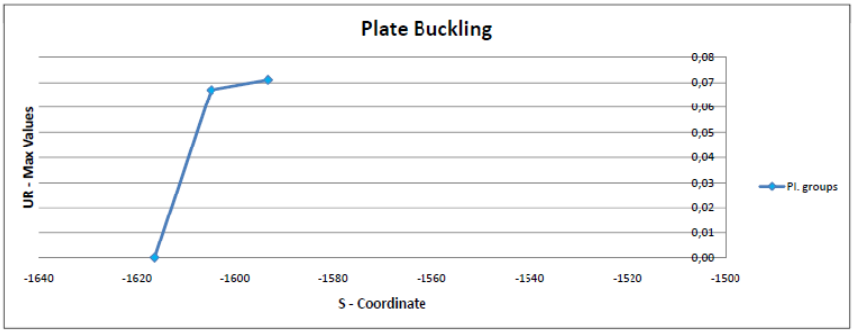


Figure 3-29 ADVERS results for rupture of Hanger 5, railway girder CF3/5/6







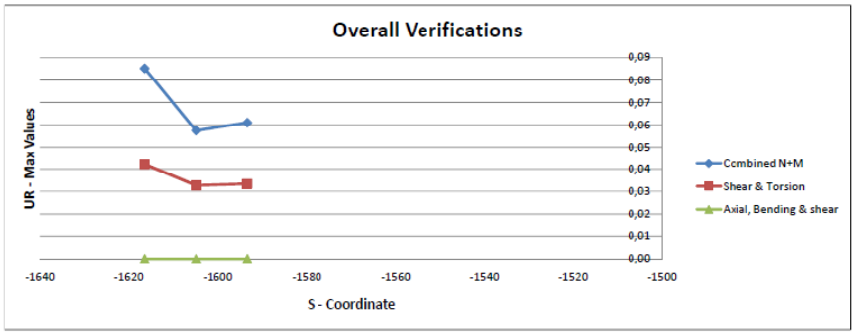


Figure 3-30 ADVERS results for rupture of Hanger 5, railway girder CF4

3.1.2.3 Rupture, Hanger 6

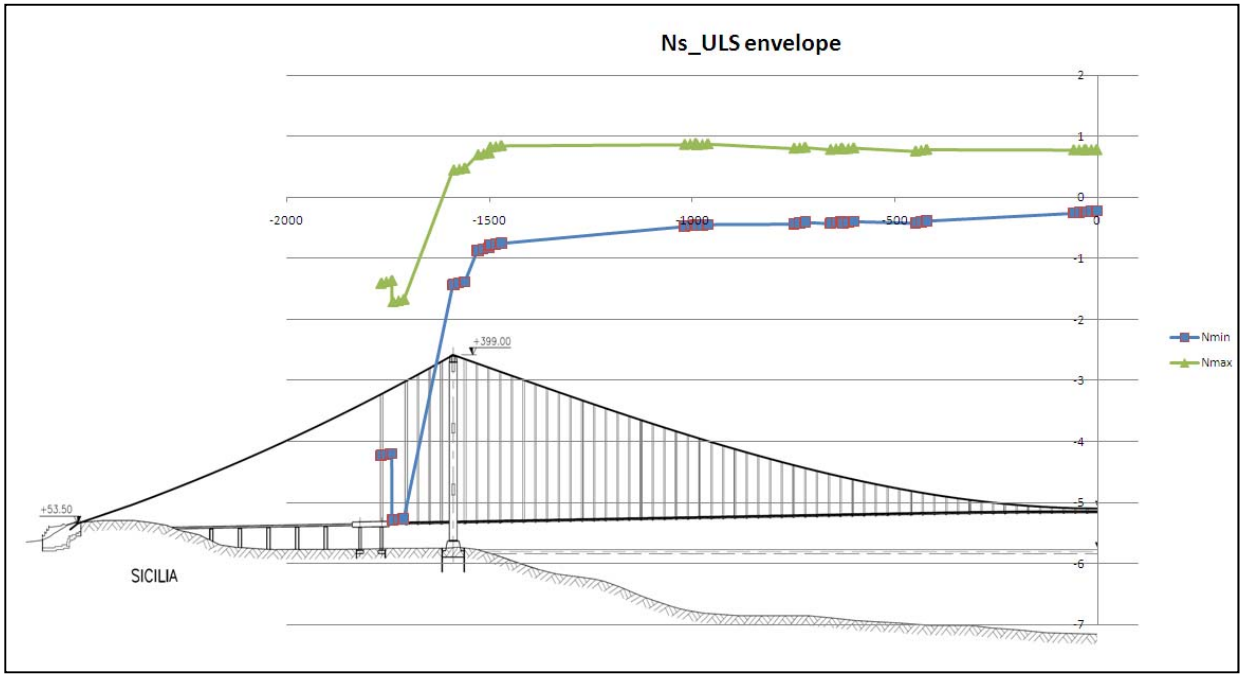


Figure 3-31 Sectional forces in rail girder for rupture of hanger 6, Normal force (MN)

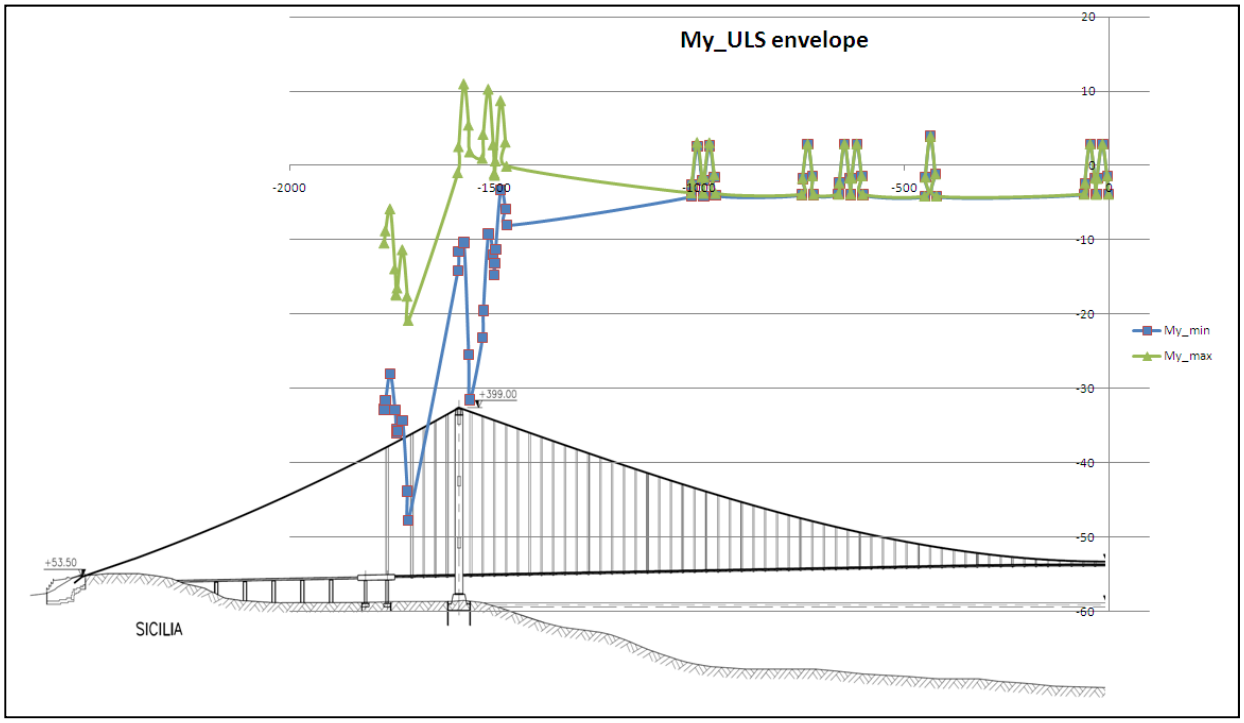


Figure 3-32 Sectional forces in rail girder for rupture of hanger 6, Moment (MNm)

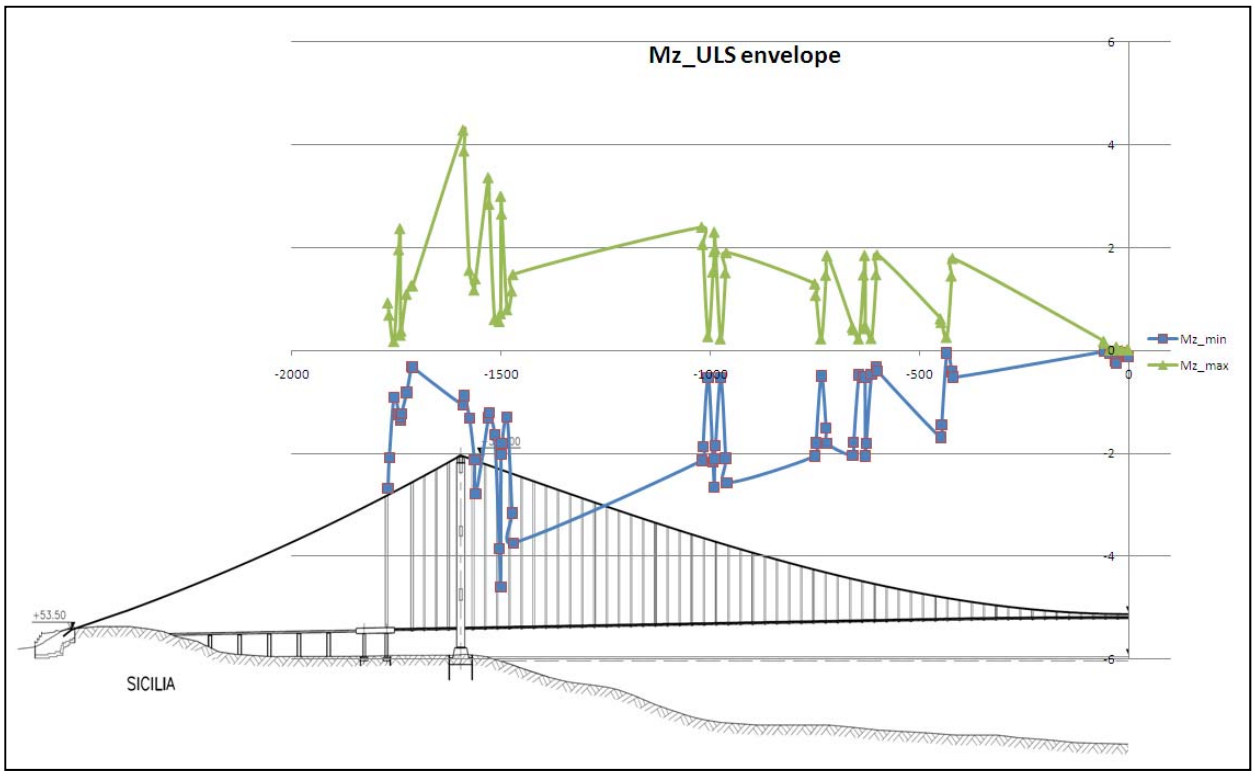
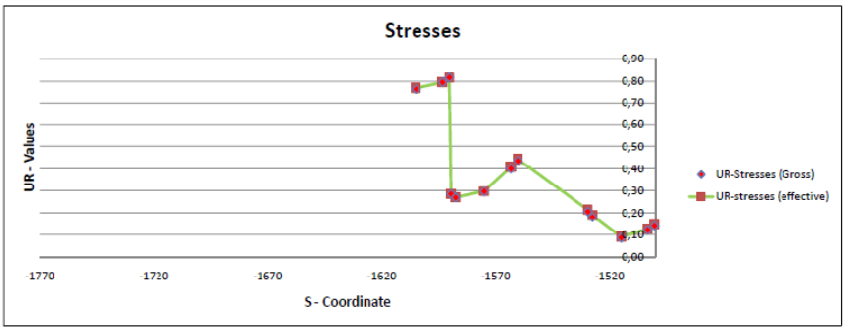
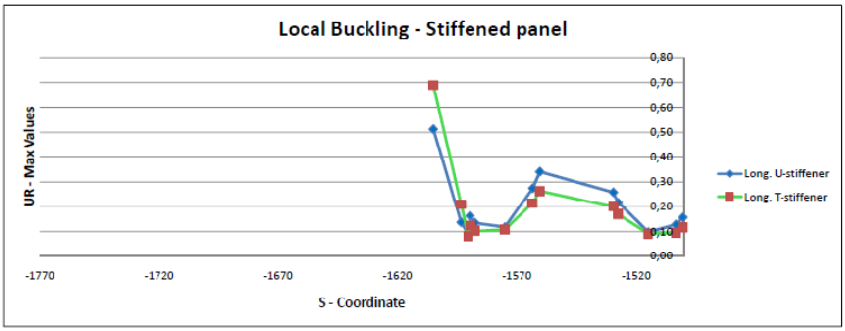
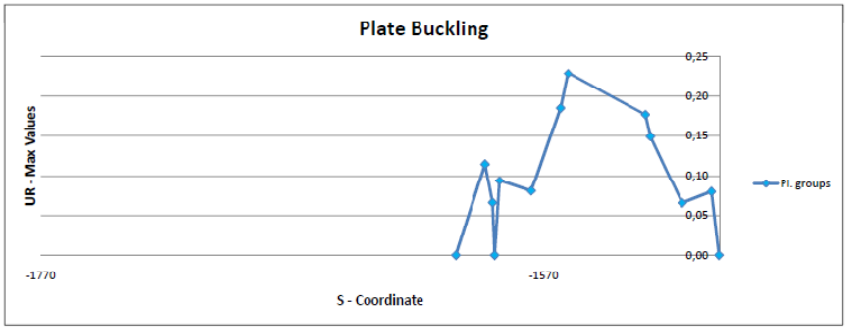


Figure 3-33 Sectional forces in rail girder for rupture of hanger 6, Moment (MNm)







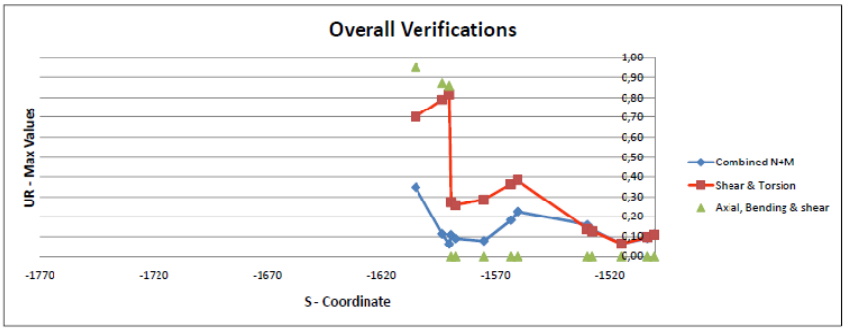
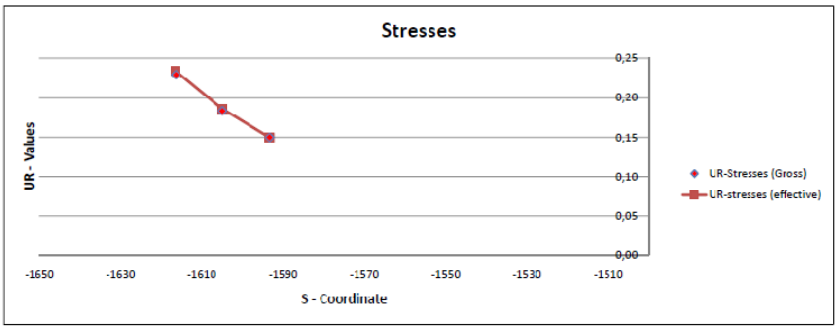
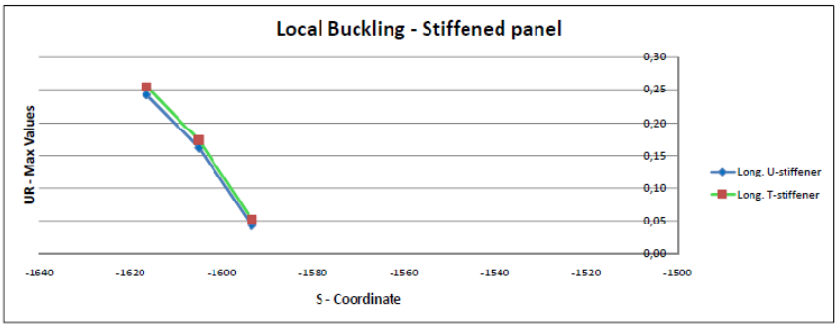
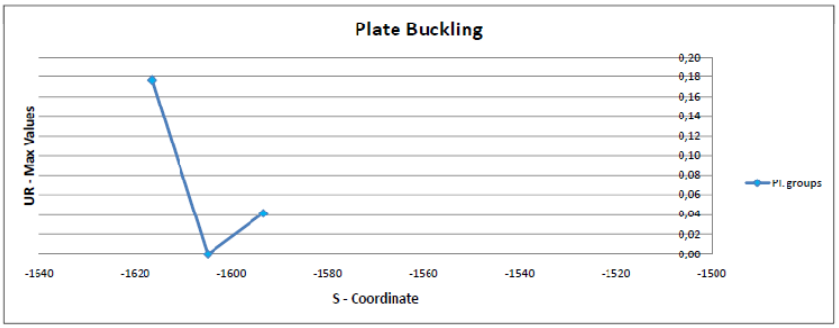


Figure 3-34 ADVERS results for rupture of Hanger 6, railway girder CF3/5/6







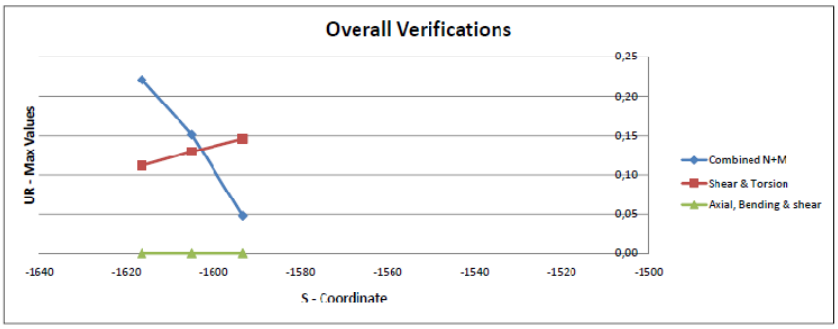


Figure 3-35 ADVERS results for rupture of Hanger 6, railway girder CF4

3.1.2.4 Rupture, Hanger 30

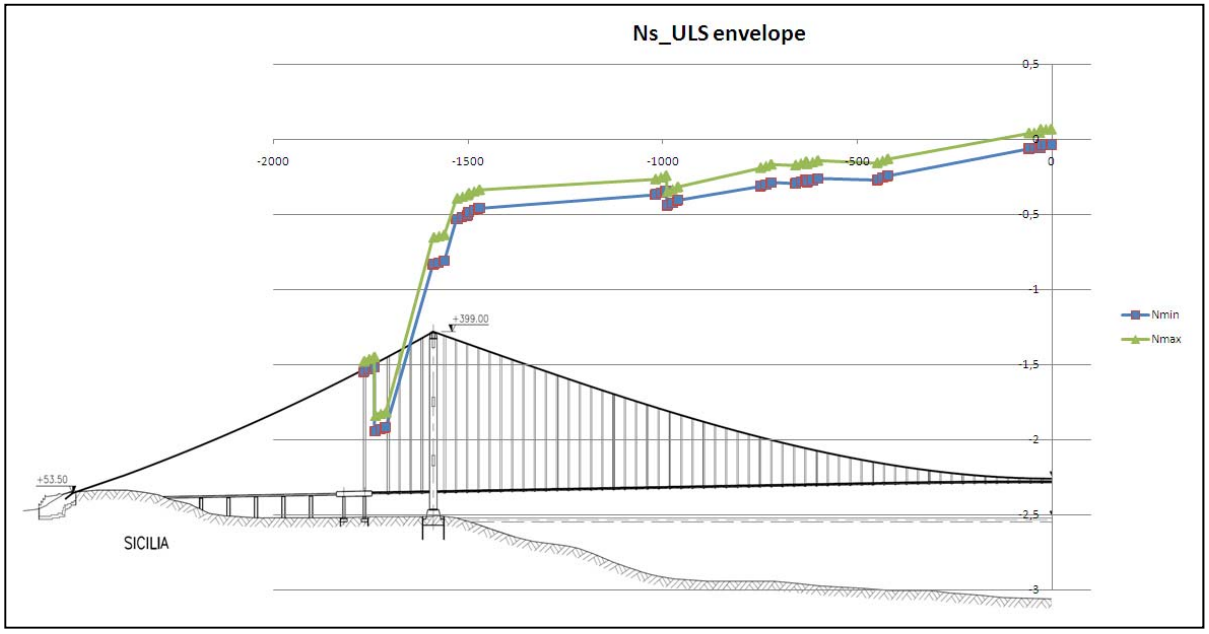


Figure 3-36 Sectional forces in rail girder for rupture of hanger 30, Normal force (MN)

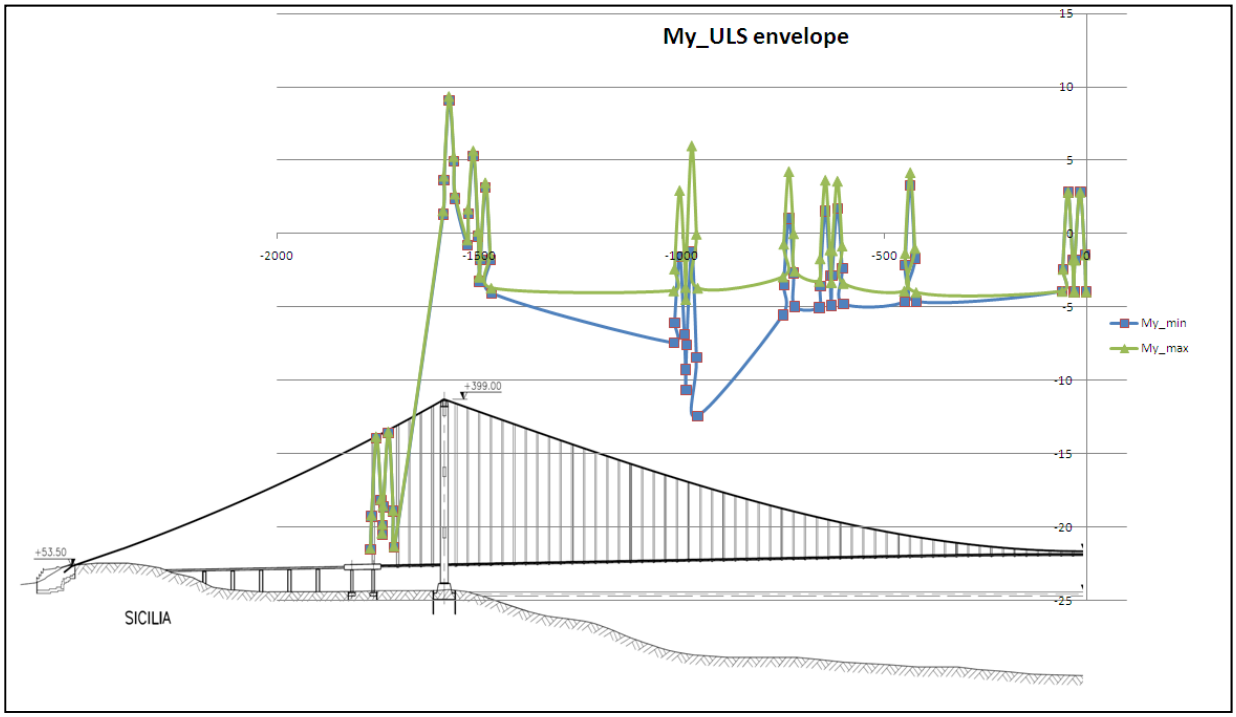


Figure 3-37 Sectional forces in rail girder for rupture of hanger 30, Moment (MNm)

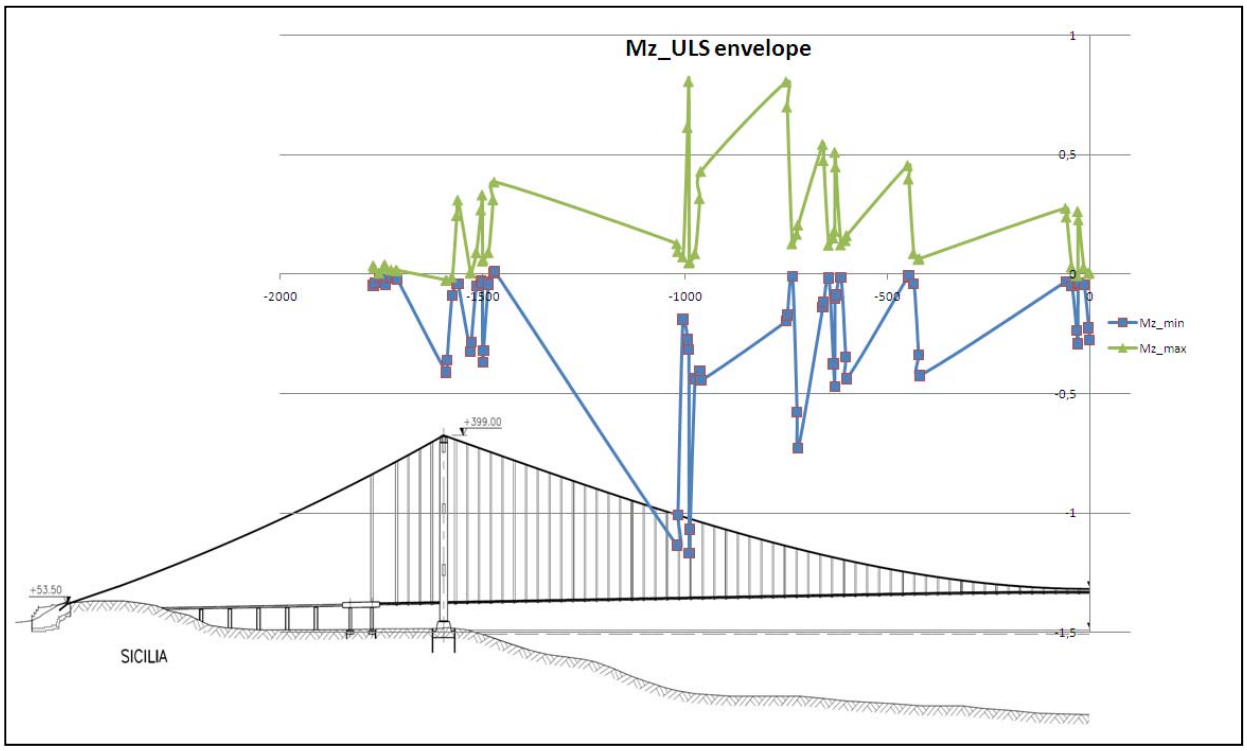
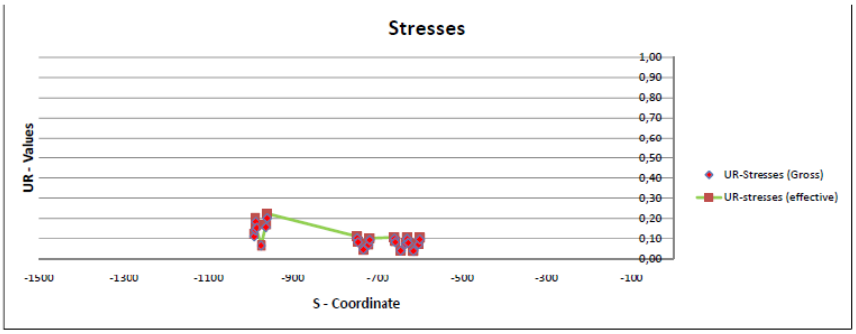
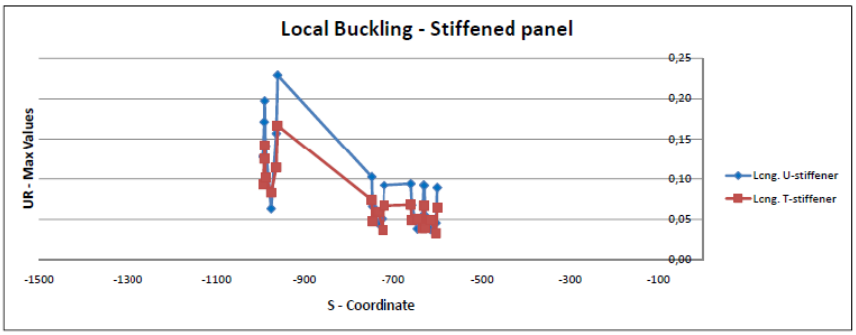
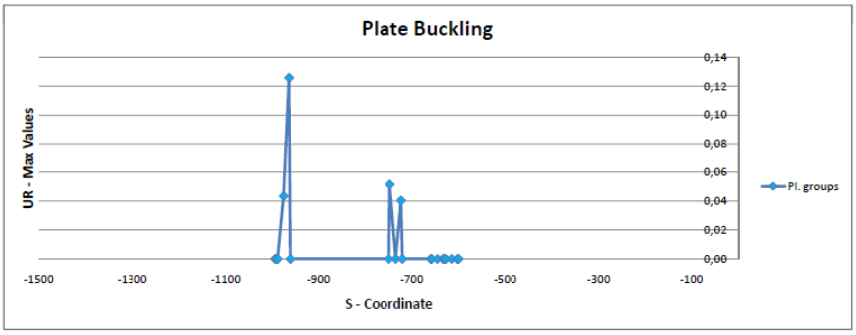


Figure 3-38 Sectional forces in rail girder for rupture of hanger 30, Moment (MNm)







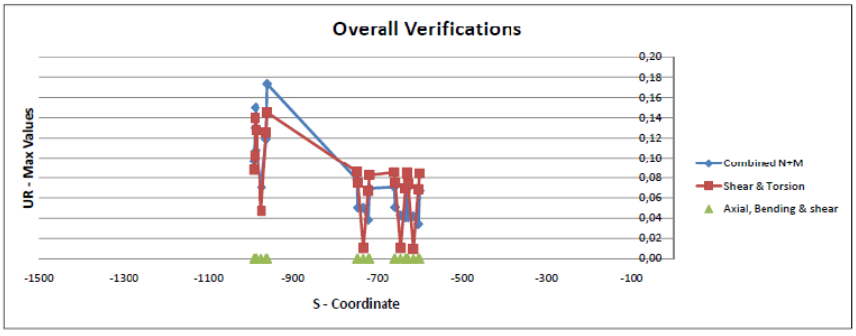


Figure 3-39 ADVERS results for rupture of Hanger 30, railway girder CF1

3.1.3 Cross Girders

The calculations of the effect of hanger rupture on the cross girders can be seen in the following figures. For the cross girders three different sections in each cross girder is considered for the verification in ADVERS named section 1 to 3 from the railway towards the road girder, see Figure 3-40.

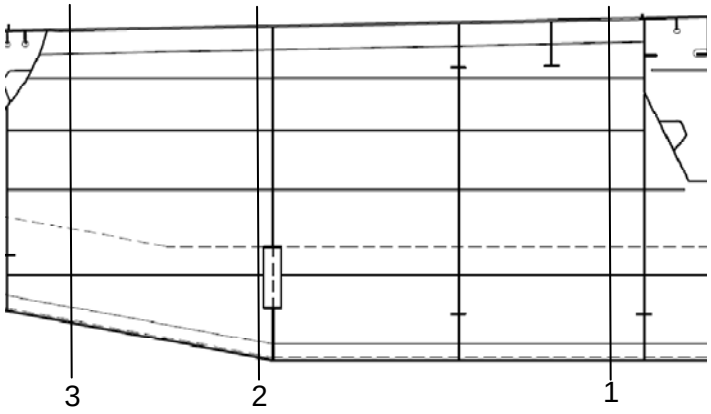


Figure 3-40 Location of investigated sections in the cross girder

In general it can be seen that the most critical section in the cross girder is at section 2. It can be seen that the cross girders has sufficient capacity in case of rupture of the considered hangers having UR<1.0.

Sectional force curves are given in the following illustrating the calculated sectional forces from the global IBDAS model in few discrete points. These curves illustrate the behaviour and effect in the girder due to rupture of selected hangers. All results are ULS envelopes and show the max sectional forces in the cross girder. For the sectional forces only values from section 1 is given.

From the various section force curves it is evident that rupture of a hanger has a large effect on the adjacent cross girders, indicated by a peak in forces at the location of rupture mainly due to the dynamic effects. It can also be seen that the effect fades out rapidly through the bridge.

3.1.3.1 Rupture, Hanger 3

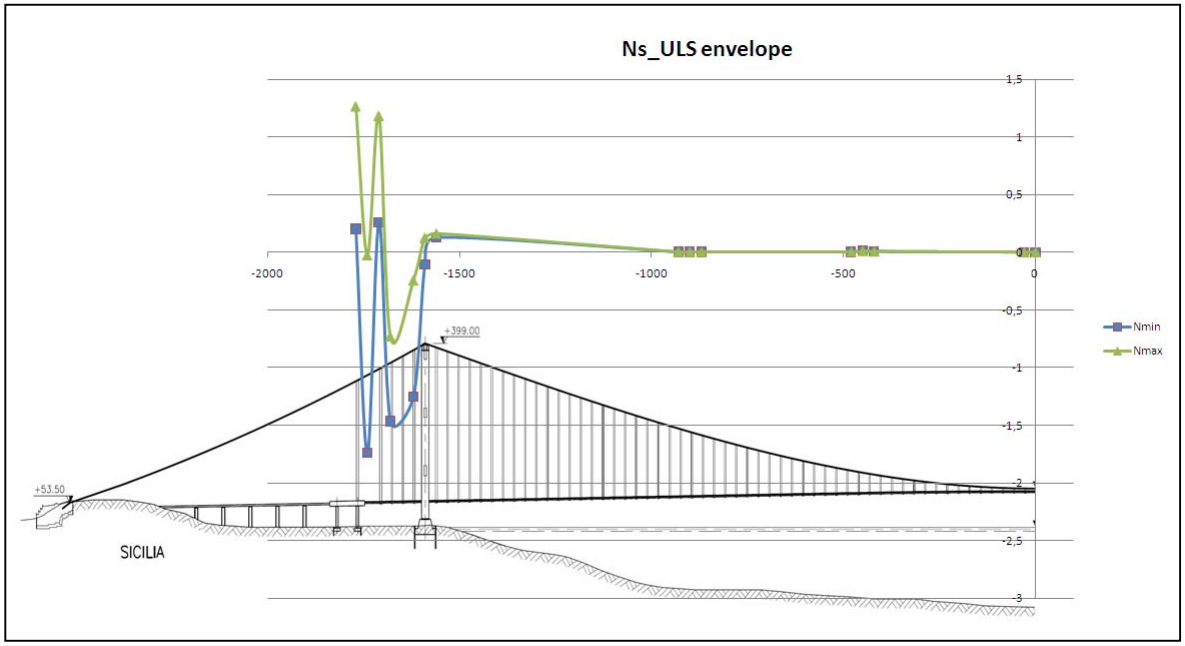


Figure 3-41 Sectional forces in cross girder for rupture of hanger 3, Normal force (MN)

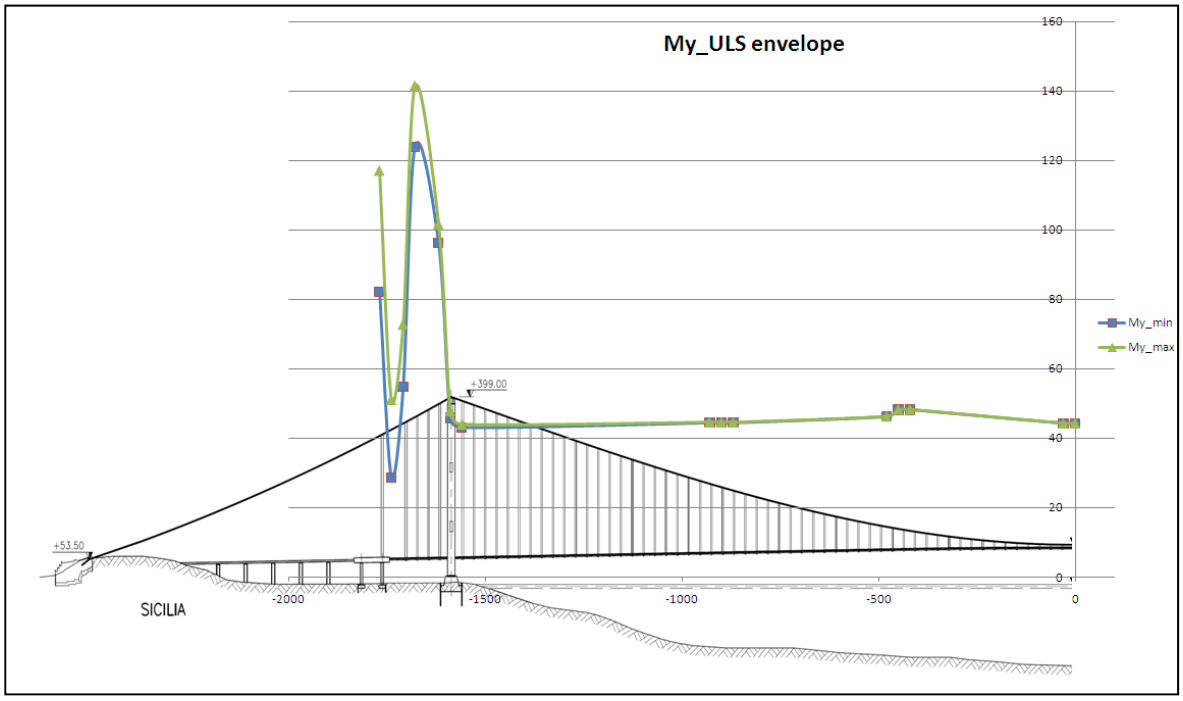


Figure 3-42 Sectional forces in cross girder for rupture of hanger 3, Moment (MNm)

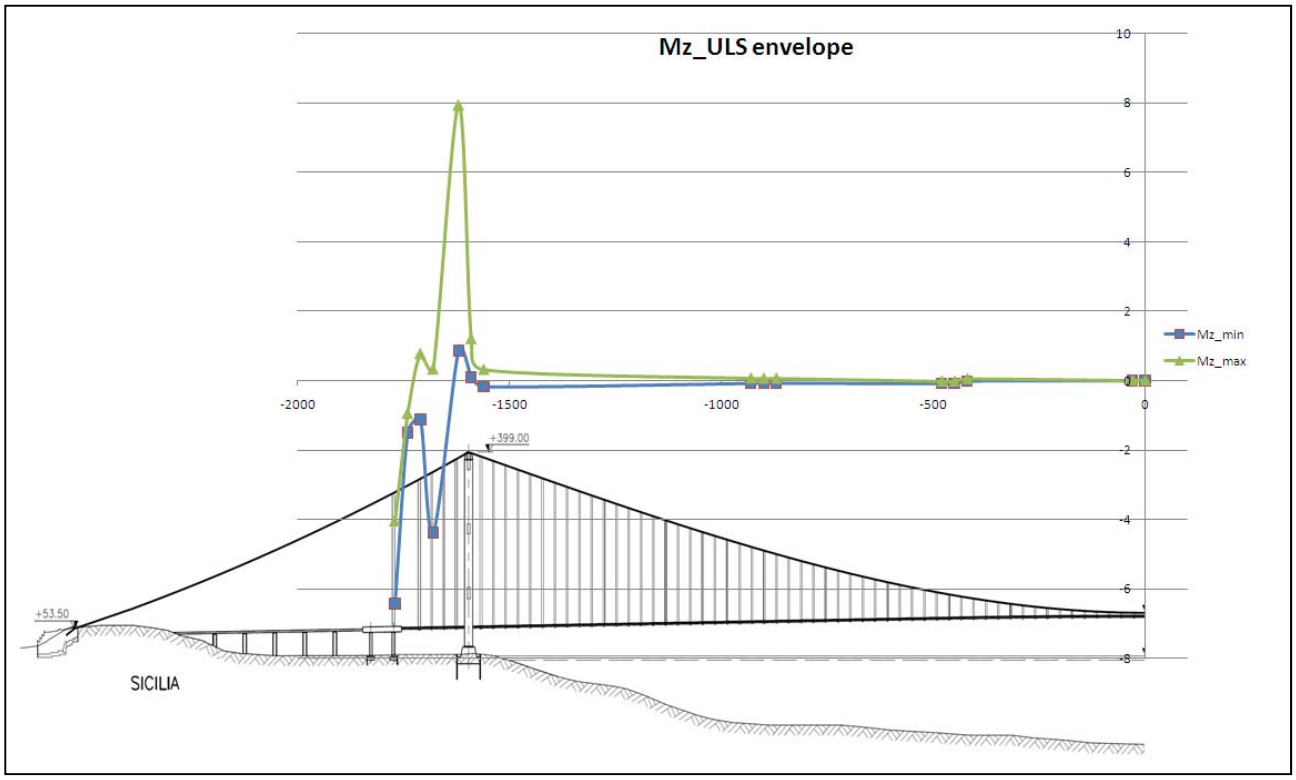


Figure 3-43 Sectional forces in cross girder for rupture of hanger 3, Moment (MNm)

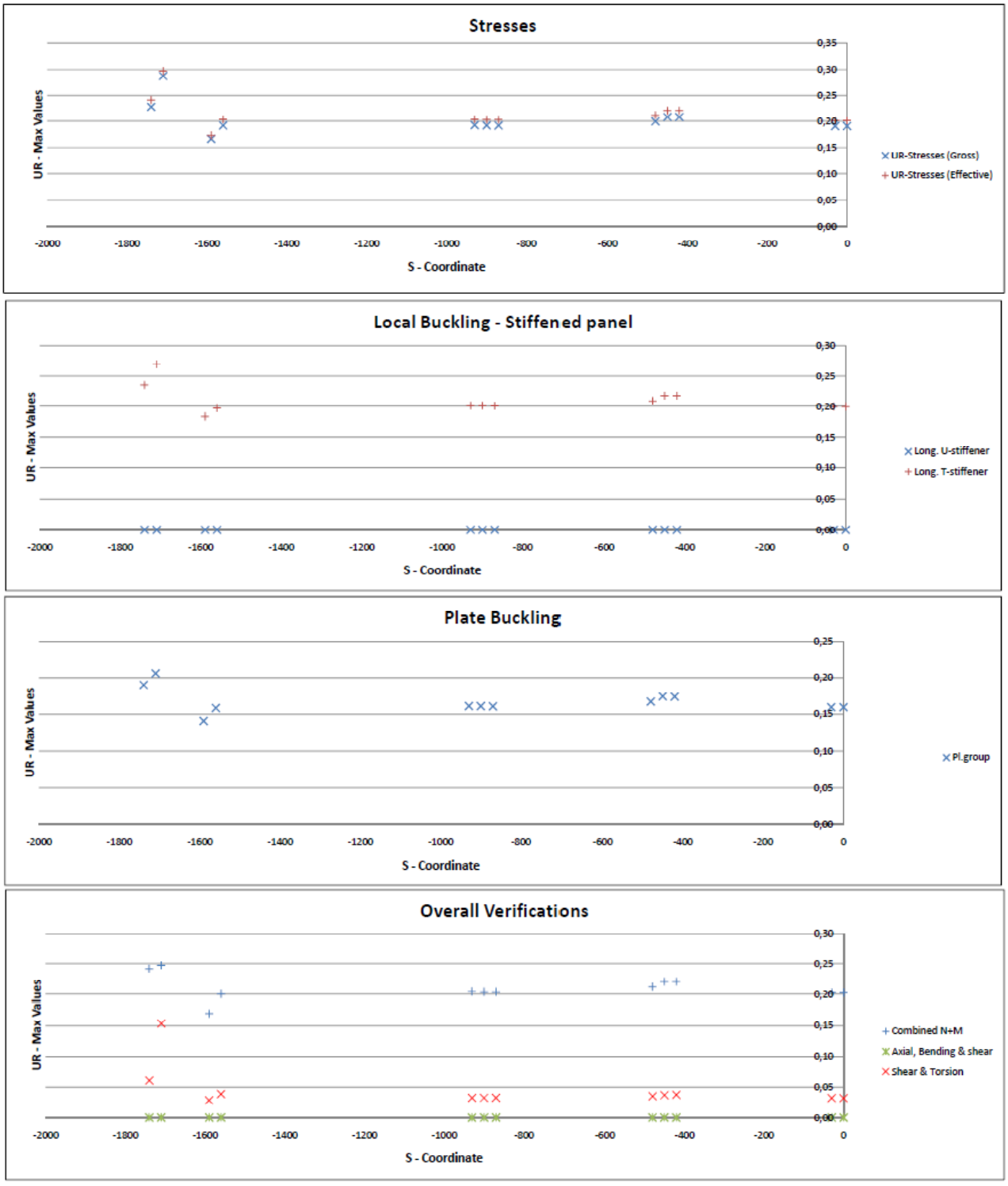


Figure 3-44 ADVERS results for rupture of Hanger 3, cross girder T1/T3 section 1

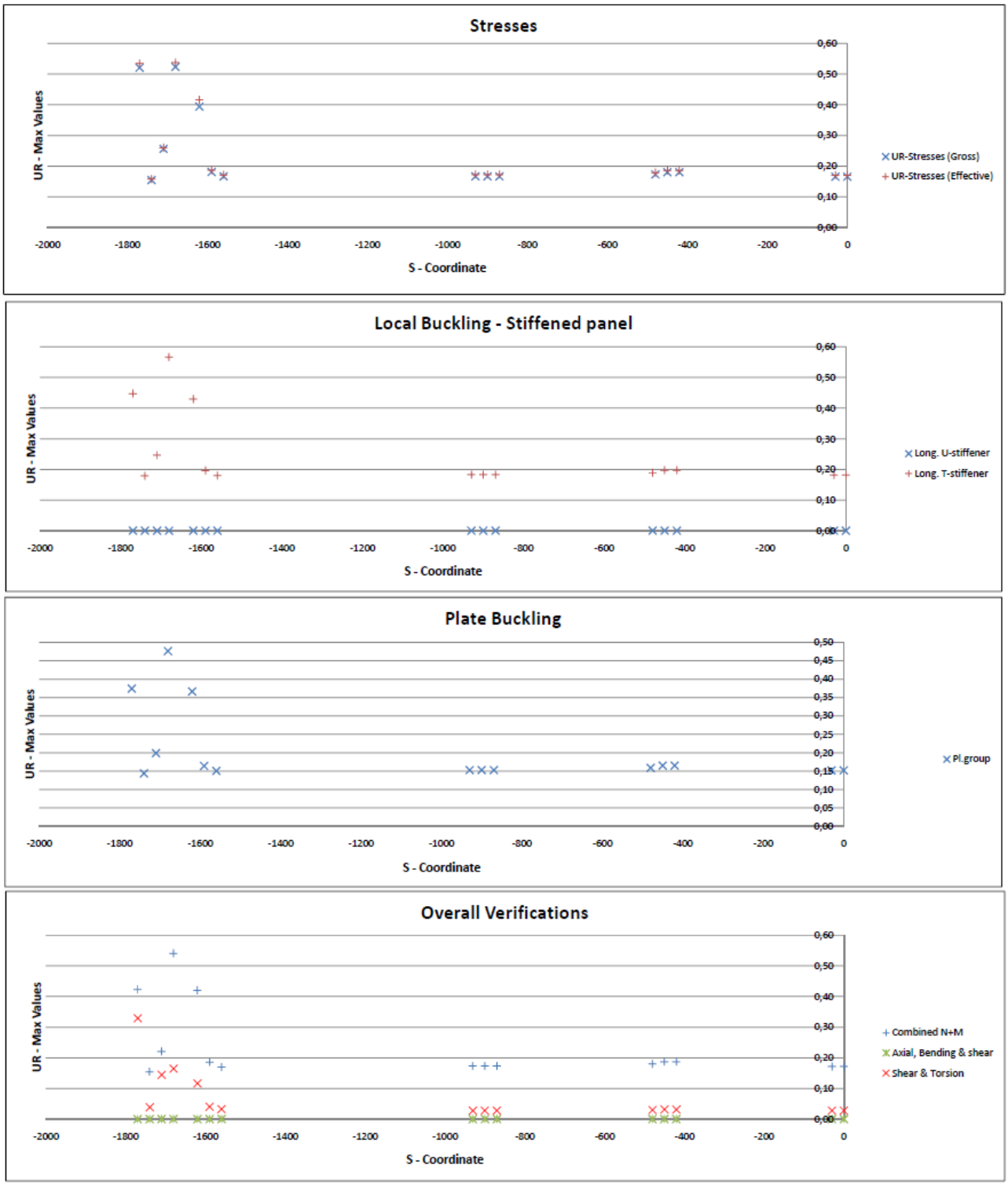


Figure 3-45 ADVERS results for rupture of Hanger 3, cross girder T1/T3 section 2

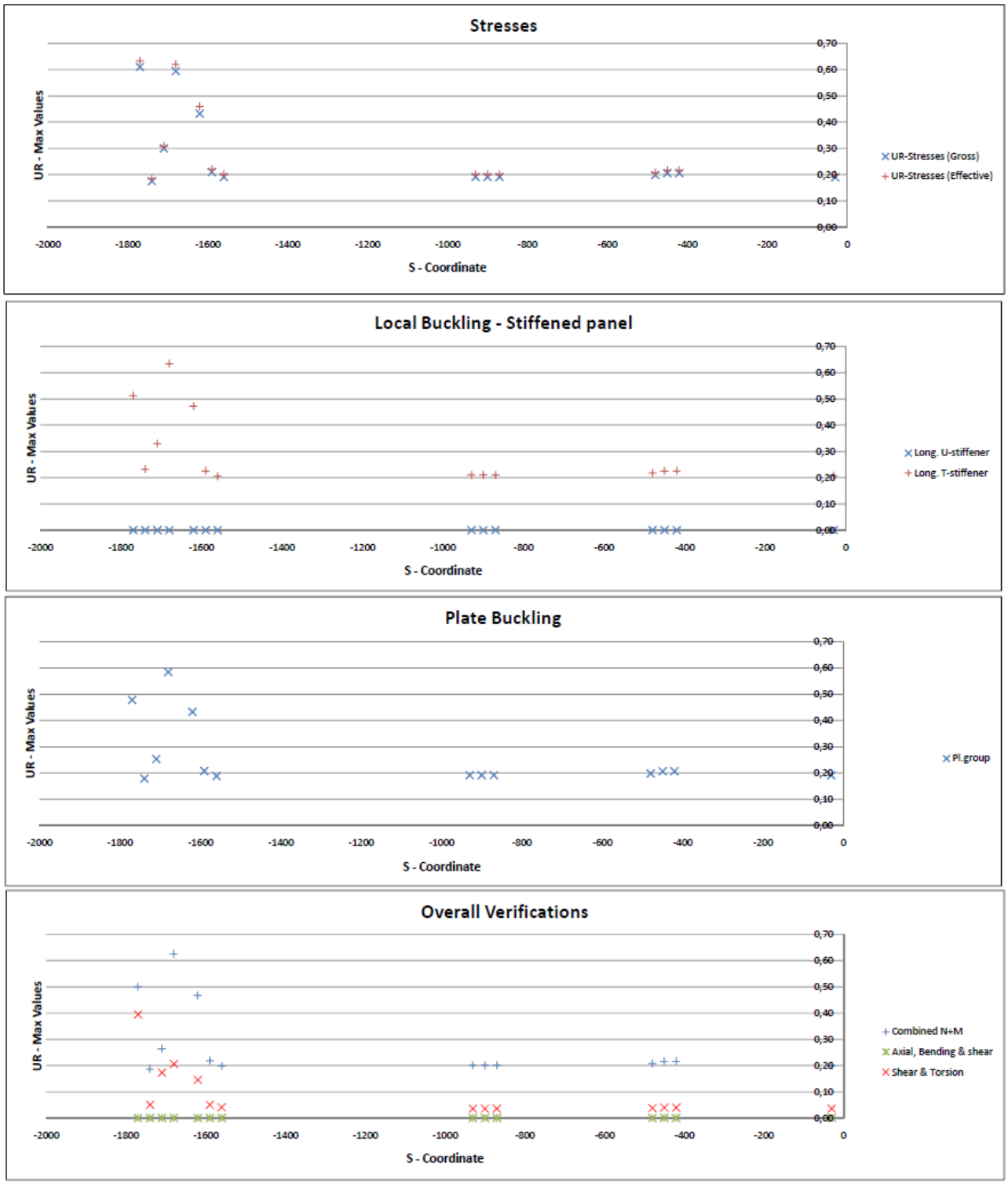


Figure 3-46 ADVERS results for rupture of Hanger 3, cross girder T1/T3 section 3

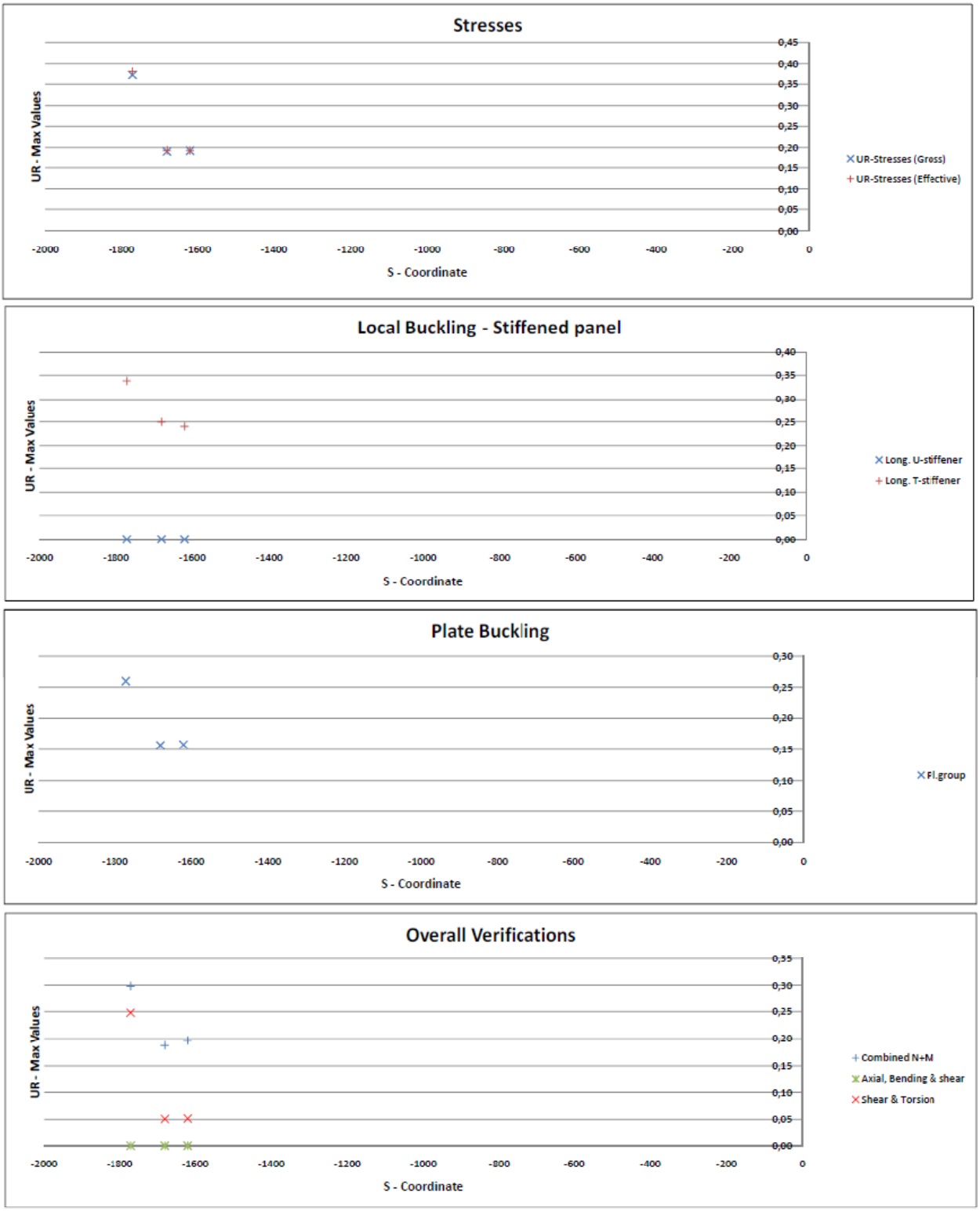


Figure 3-47 ADVERS results for rupture of Hanger 3, cross girder T4a/T4b/T6 section 1

3.1.3.2 Rupture, Hanger 5

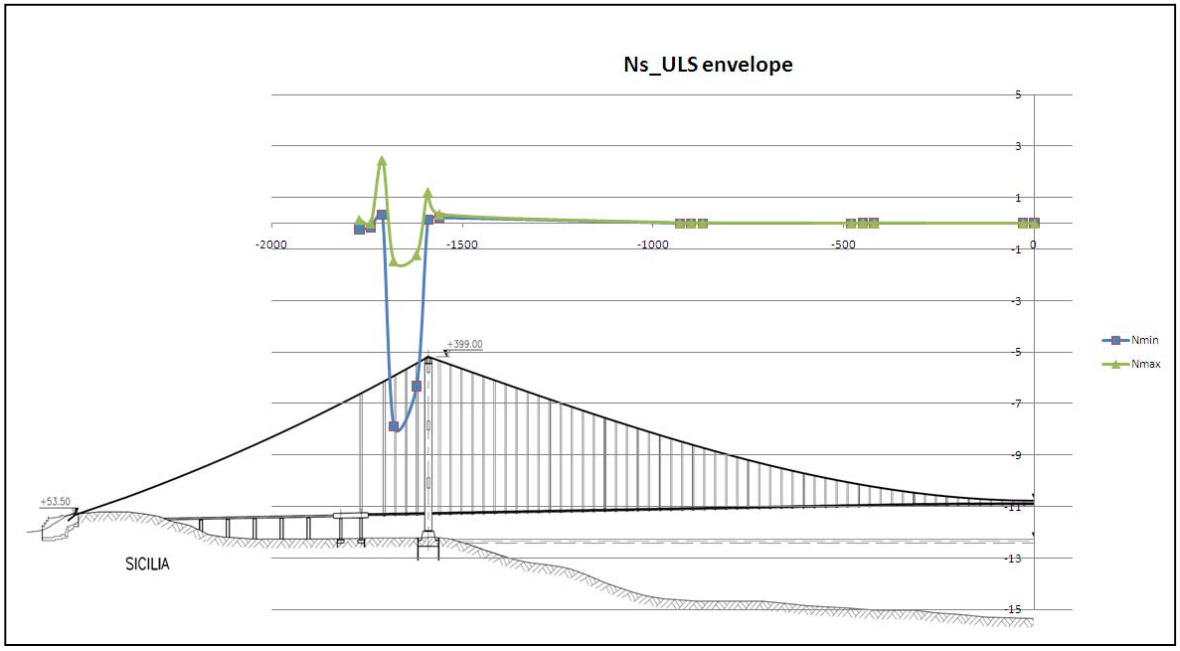


Figure 3-48 Sectional forces in cross girder for rupture of hanger 5, Normal force (MN)

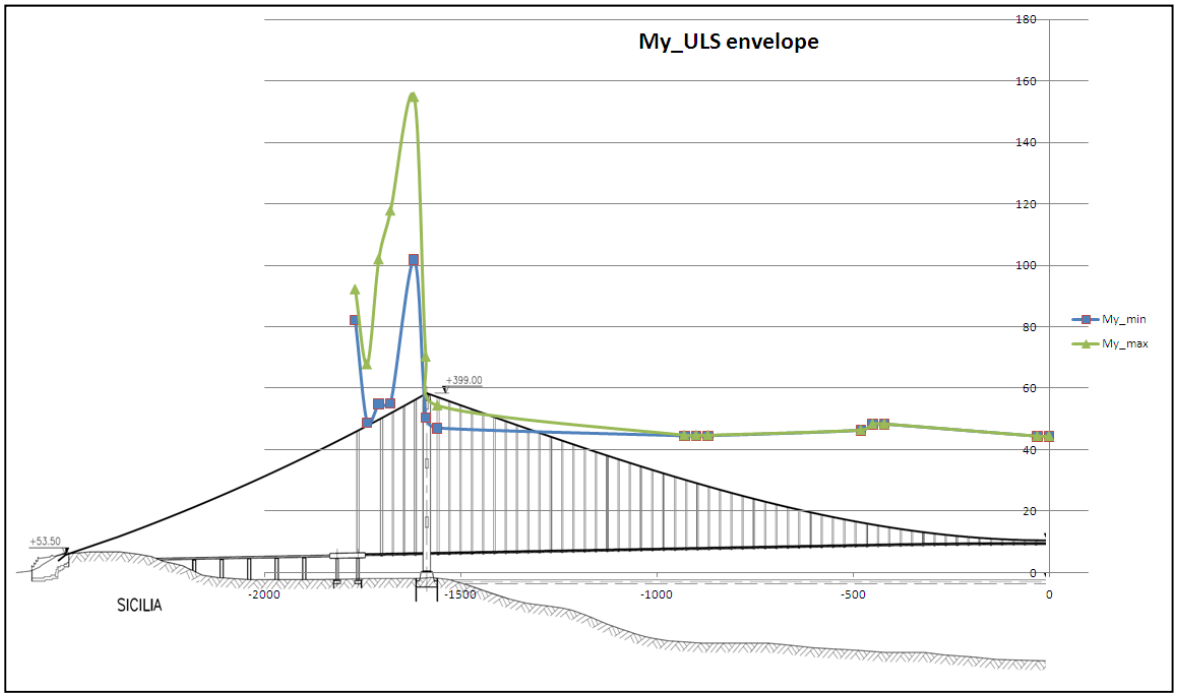


Figure 3-49 Sectional forces in cross girder for rupture of hanger 5, Moment (MNm)

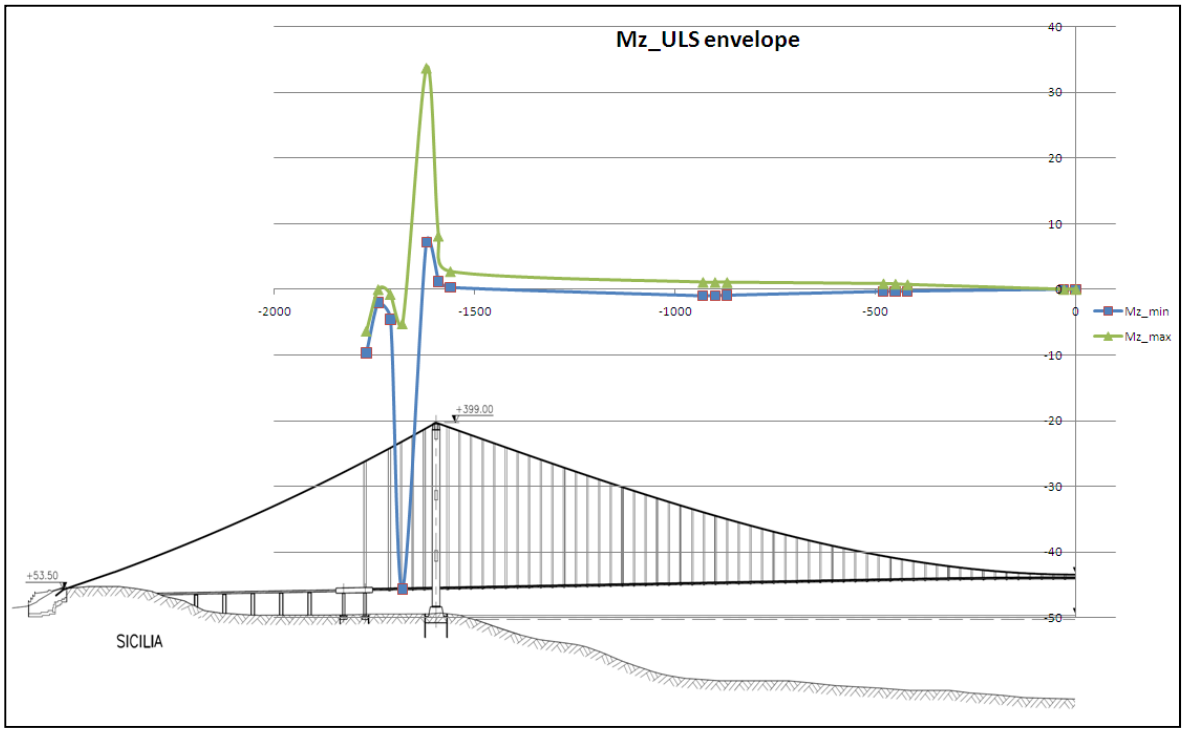


Figure 3-50 Sectional forces in cross girder for rupture of hanger 5, Moment (MNm)

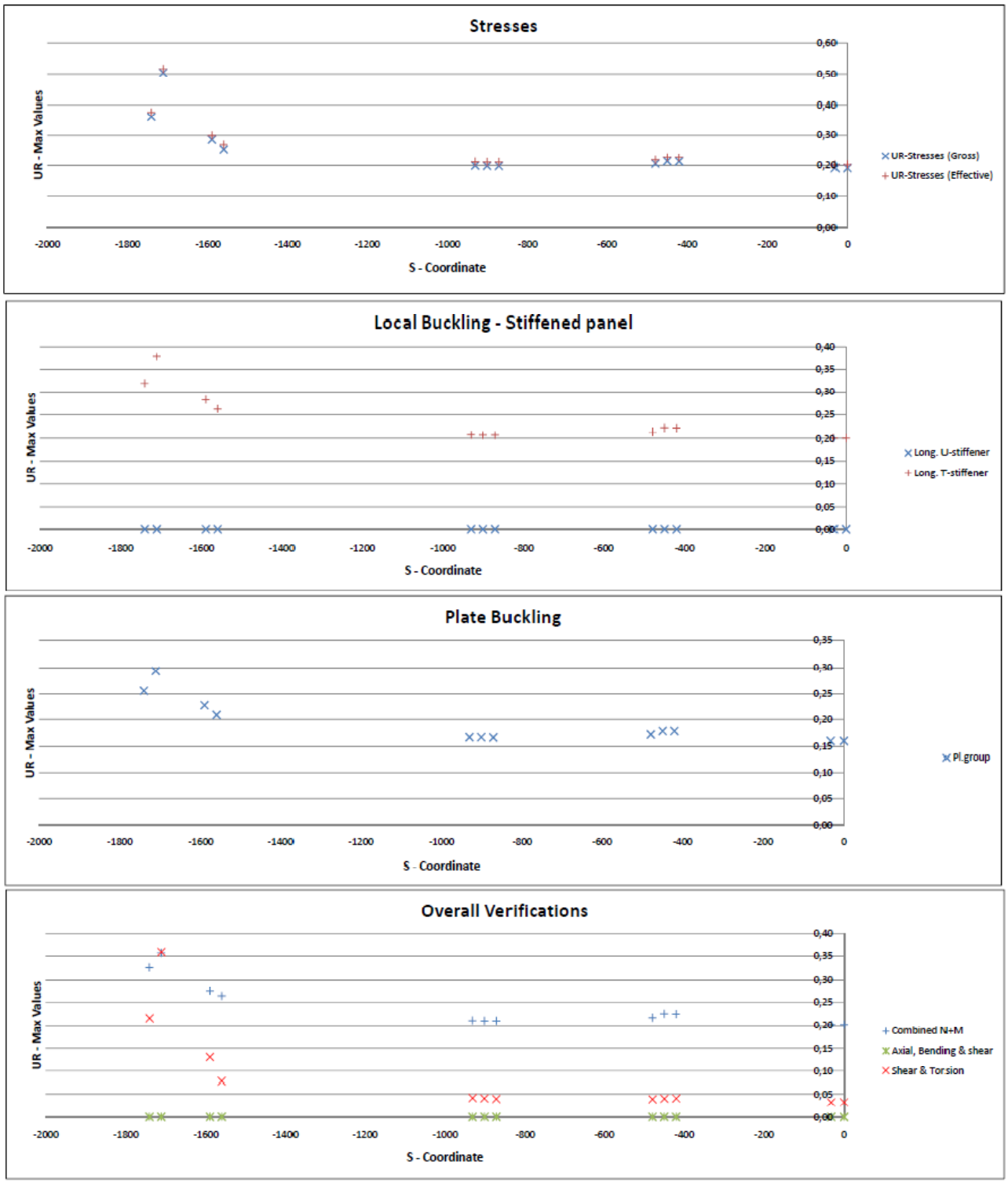


Figure 3-51 ADVERS results for rupture of Hanger 5, cross girder T1/T3 section 1

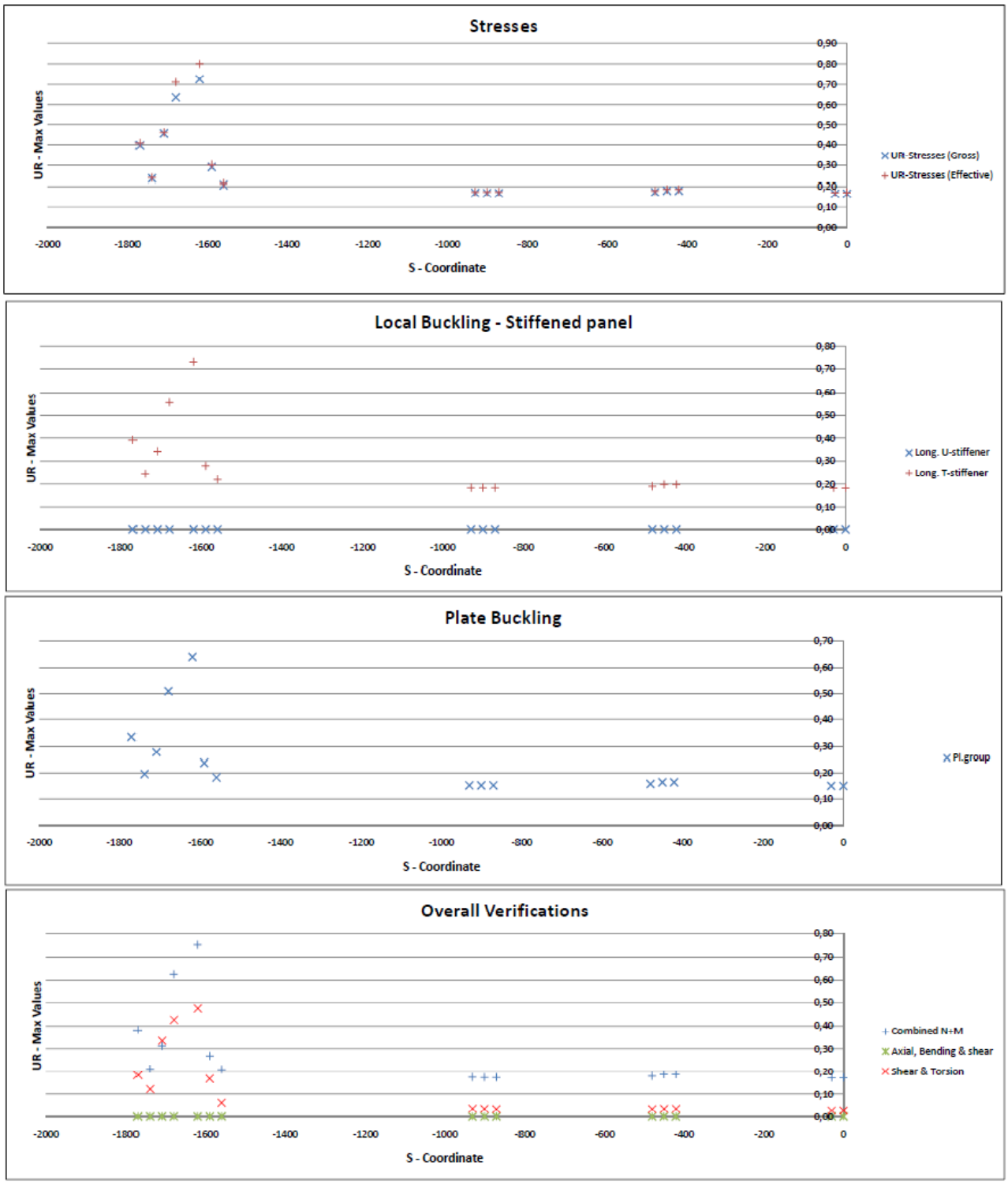


Figure 3-52 ADVERS results for rupture of Hanger 5, cross girder T1/T3 section 2

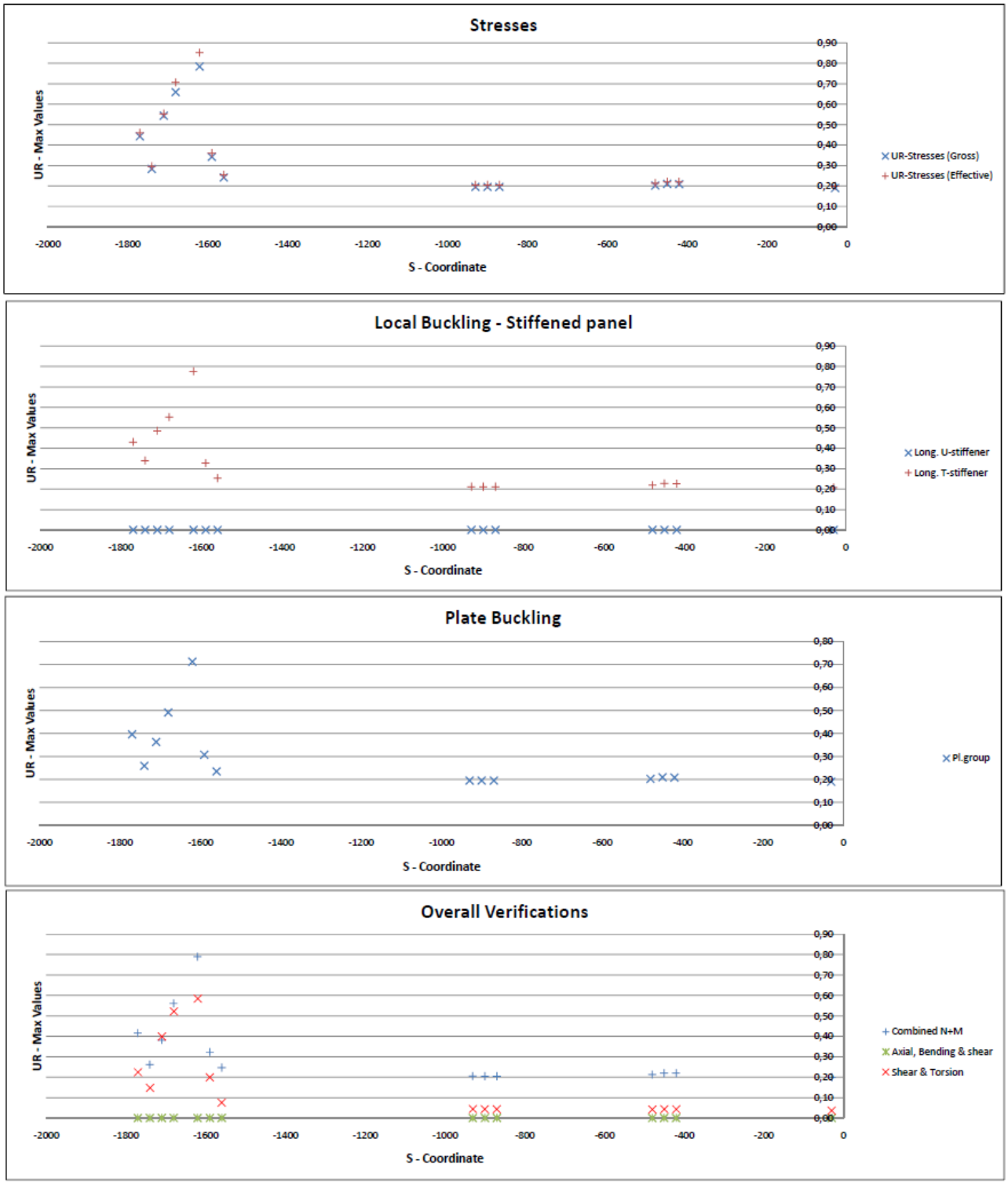
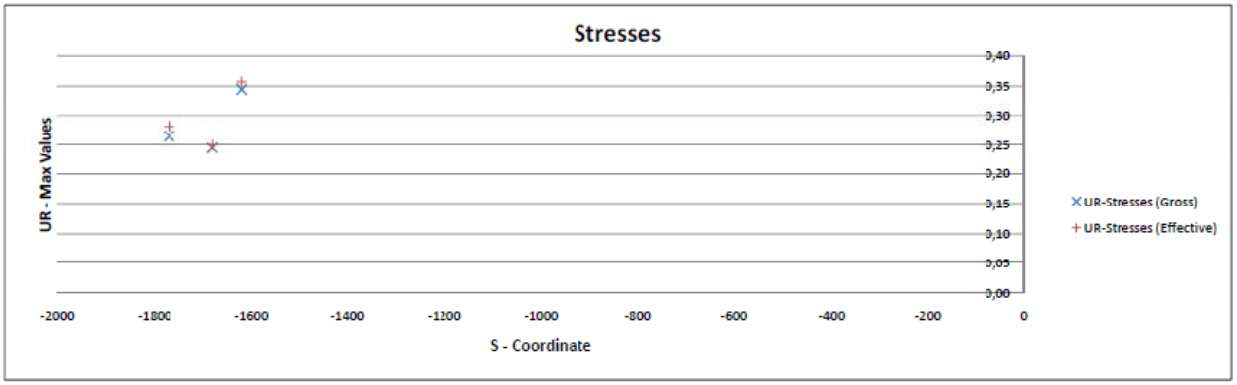
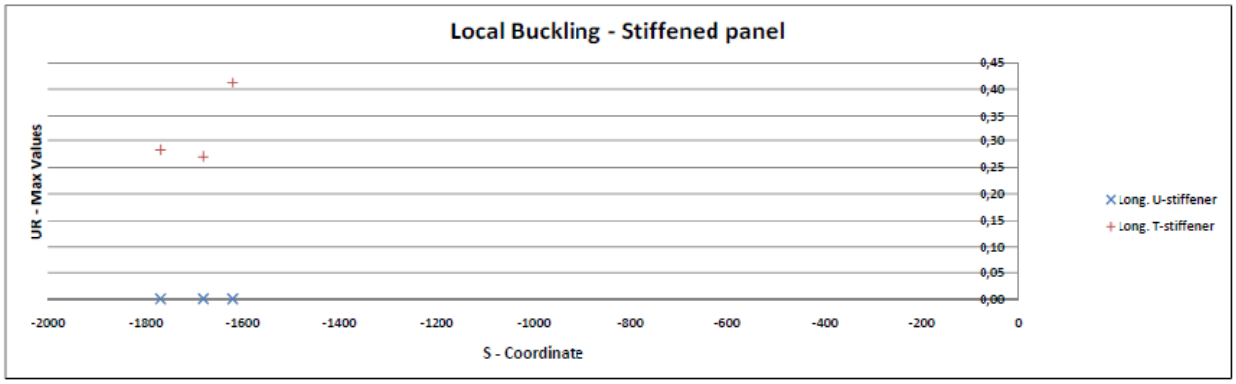
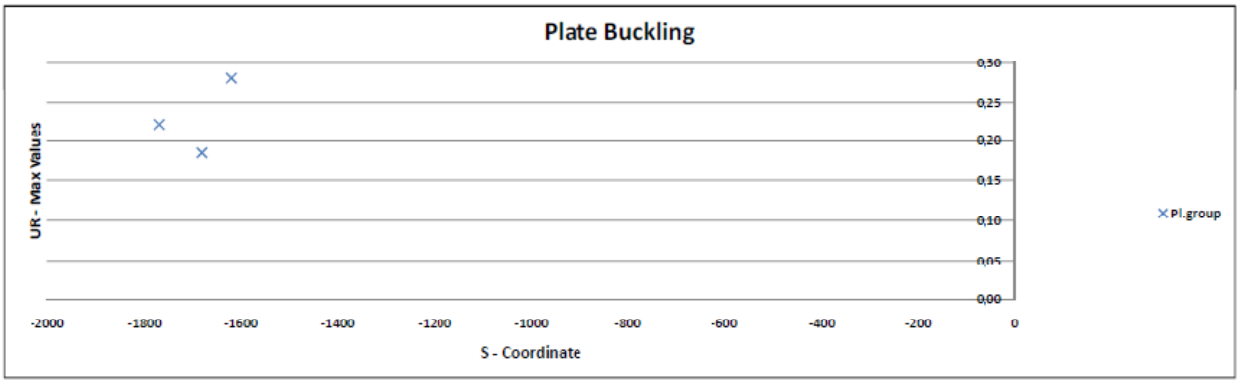


Figure 3-53 ADVERS results for rupture of Hanger 5, cross girder T1/T3 section 3







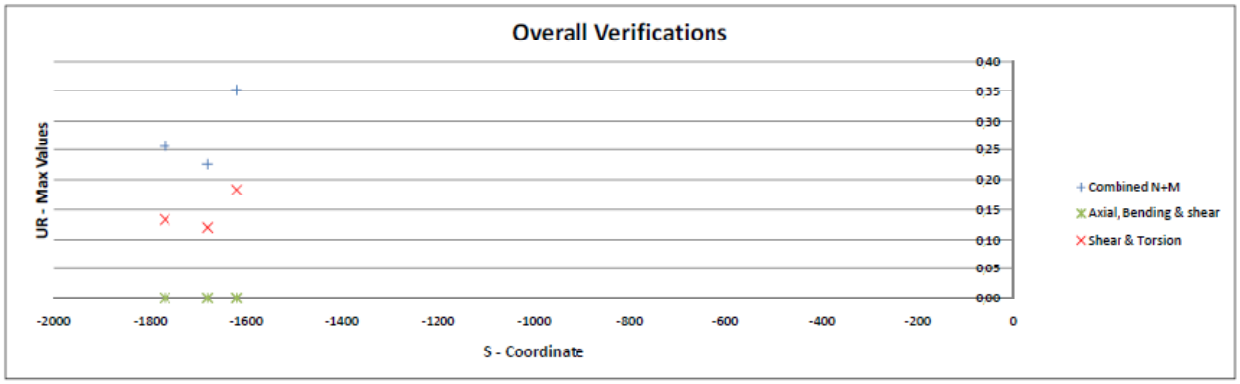


Figure 3-54 ADVERS results for rupture of Hanger 5, cross girder T4a/T4b/T6 section 1

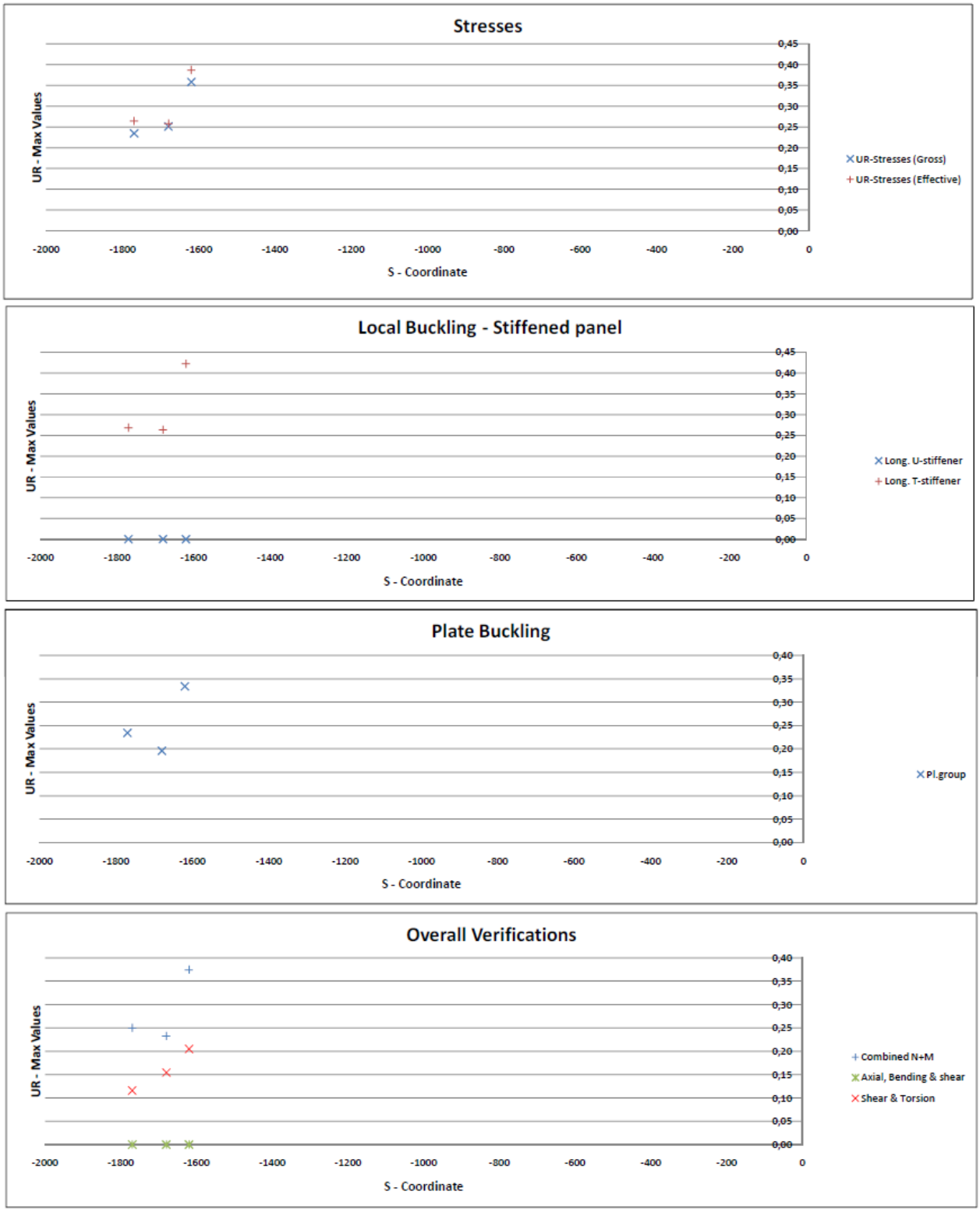


Figure 3-55 ADVERS results for rupture of Hanger 5, cross girder T4a/T4b/T6 section 2

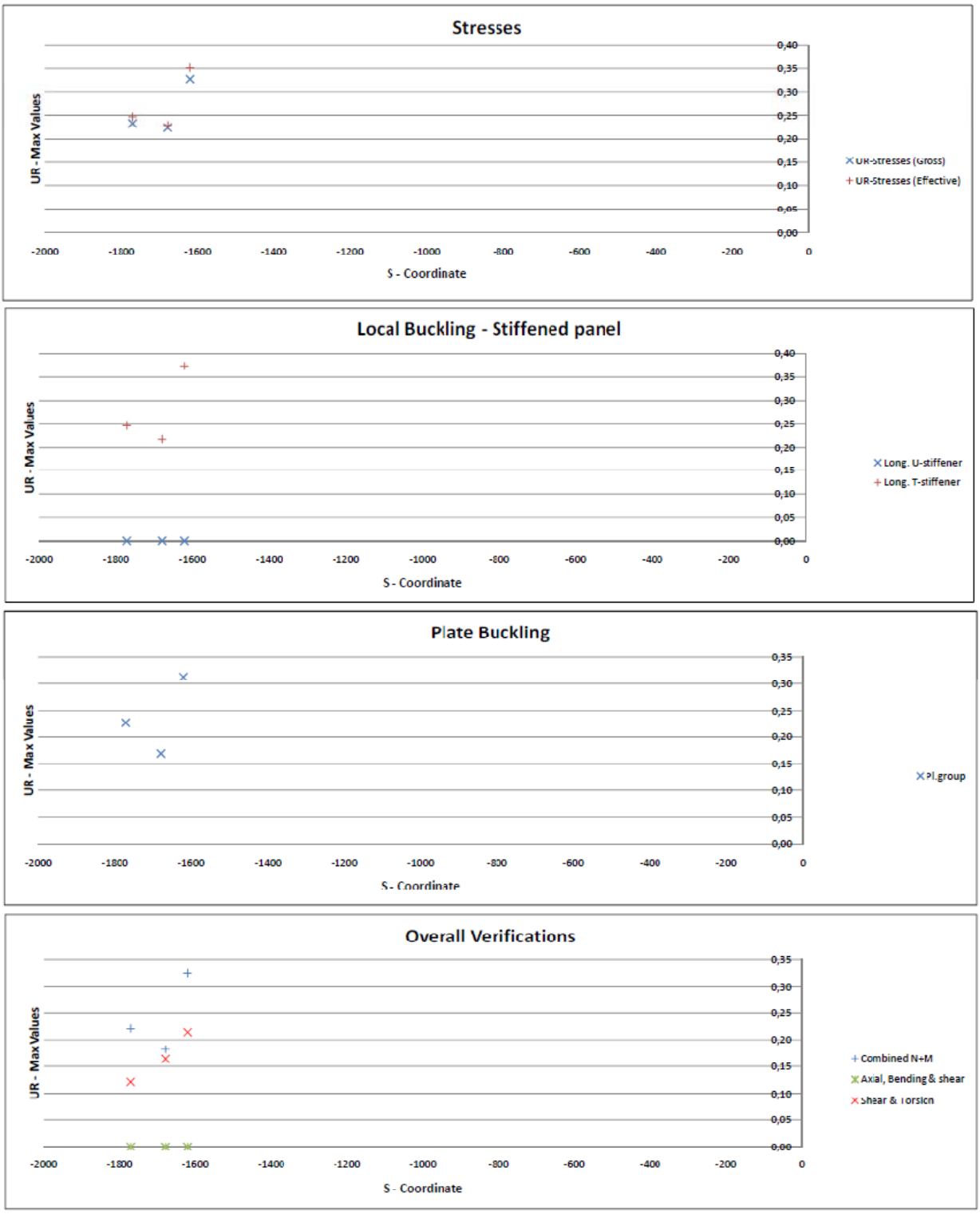


Figure 3-56 ADVERS results for rupture of Hanger 5, cross girder T4a/T4b/T6 section 3

3.1.3.3 Rupture, Hanger 6

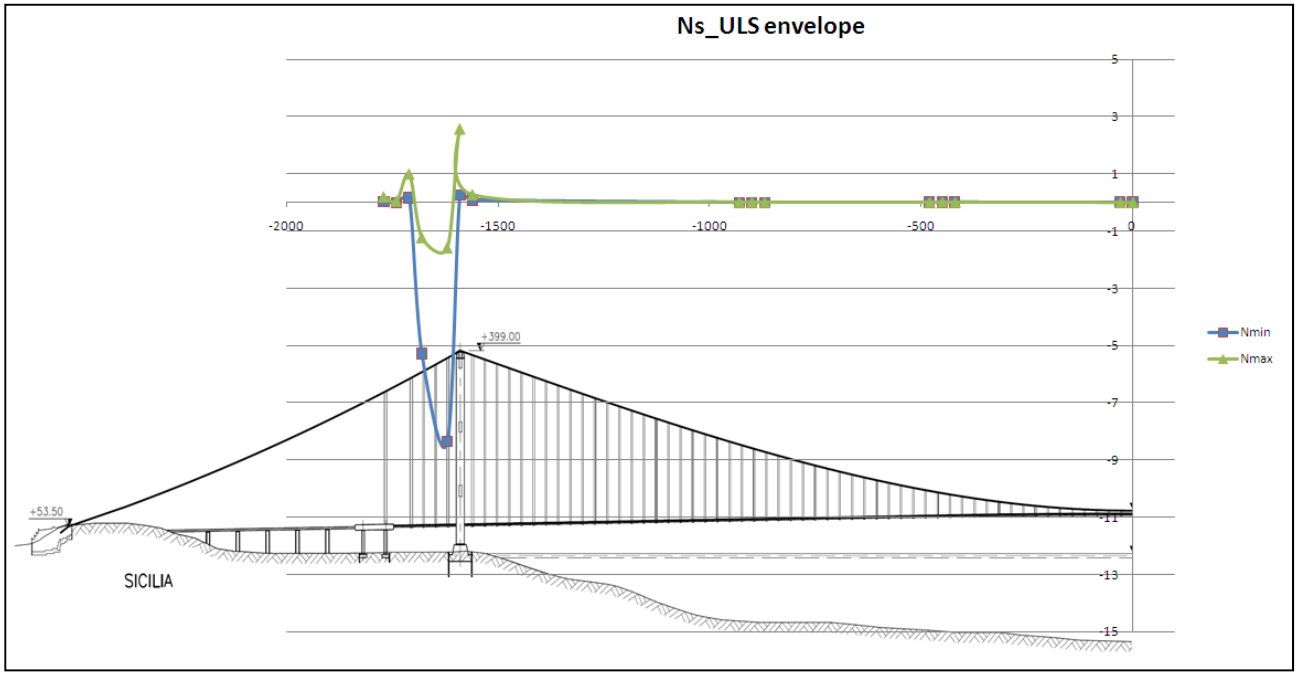


Figure 3-57 Sectional forces in cross girder for rupture of hanger 6, Normal force (MN)

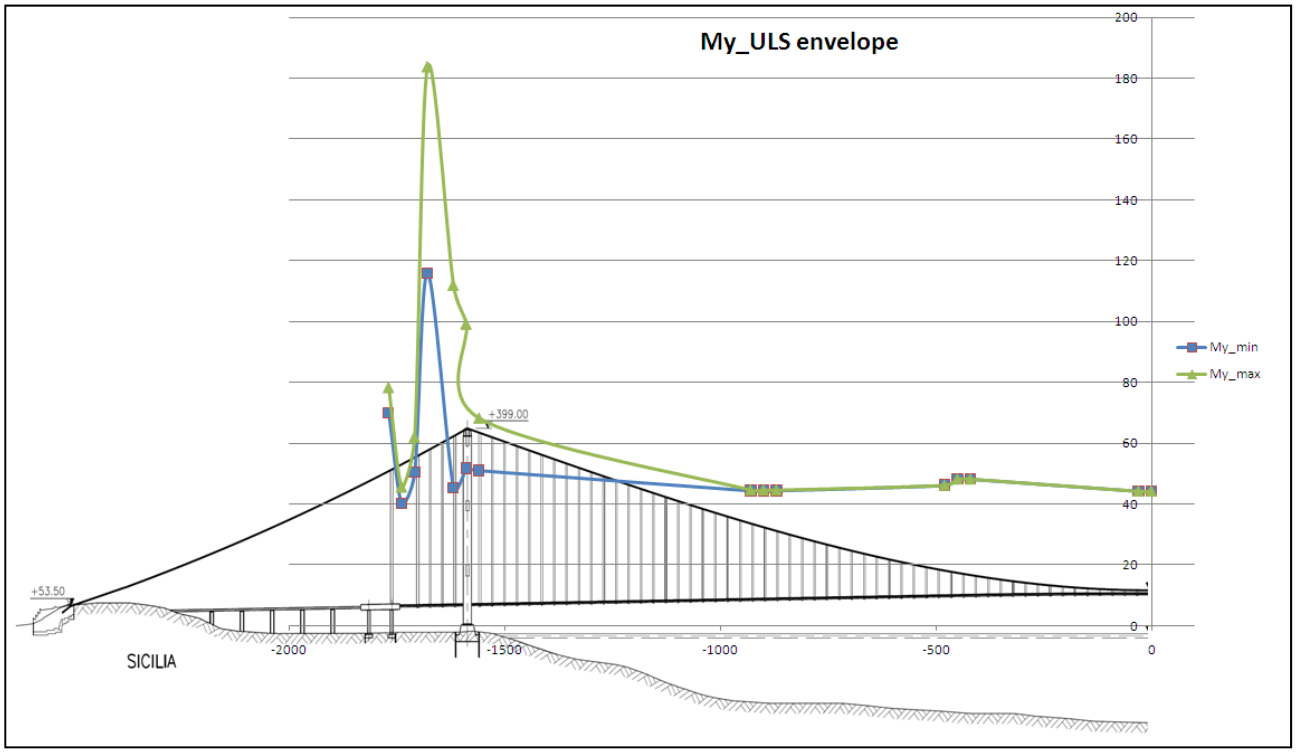


Figure 3-58 Sectional forces in cross girder for rupture of hanger 6, Moment (MNm)

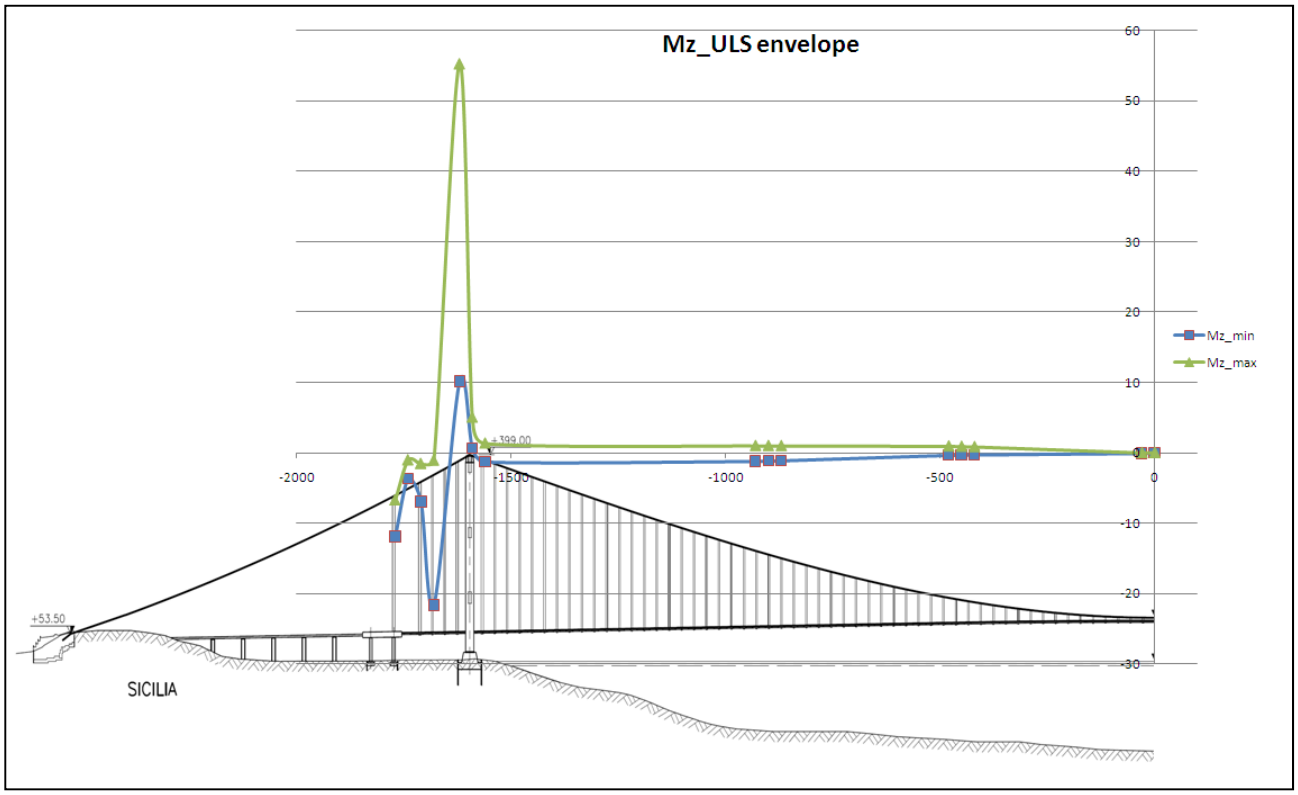


Figure 3-59 Sectional forces in cross girder for rupture of hanger 6, Moment (MNm)

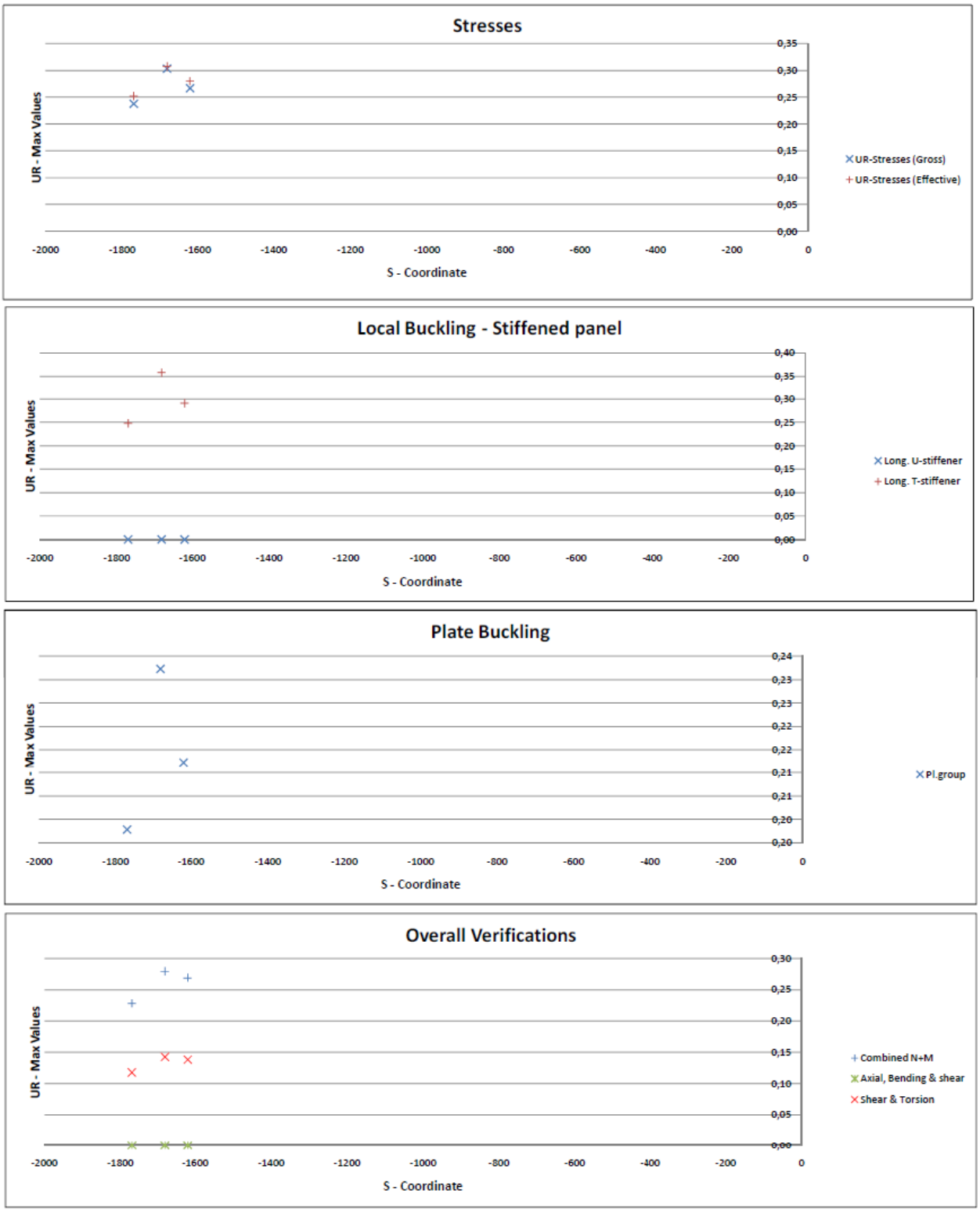


Figure 3-60 ADVERS results for rupture of Hanger 6, cross girder T4a/T4b/T6 section 1

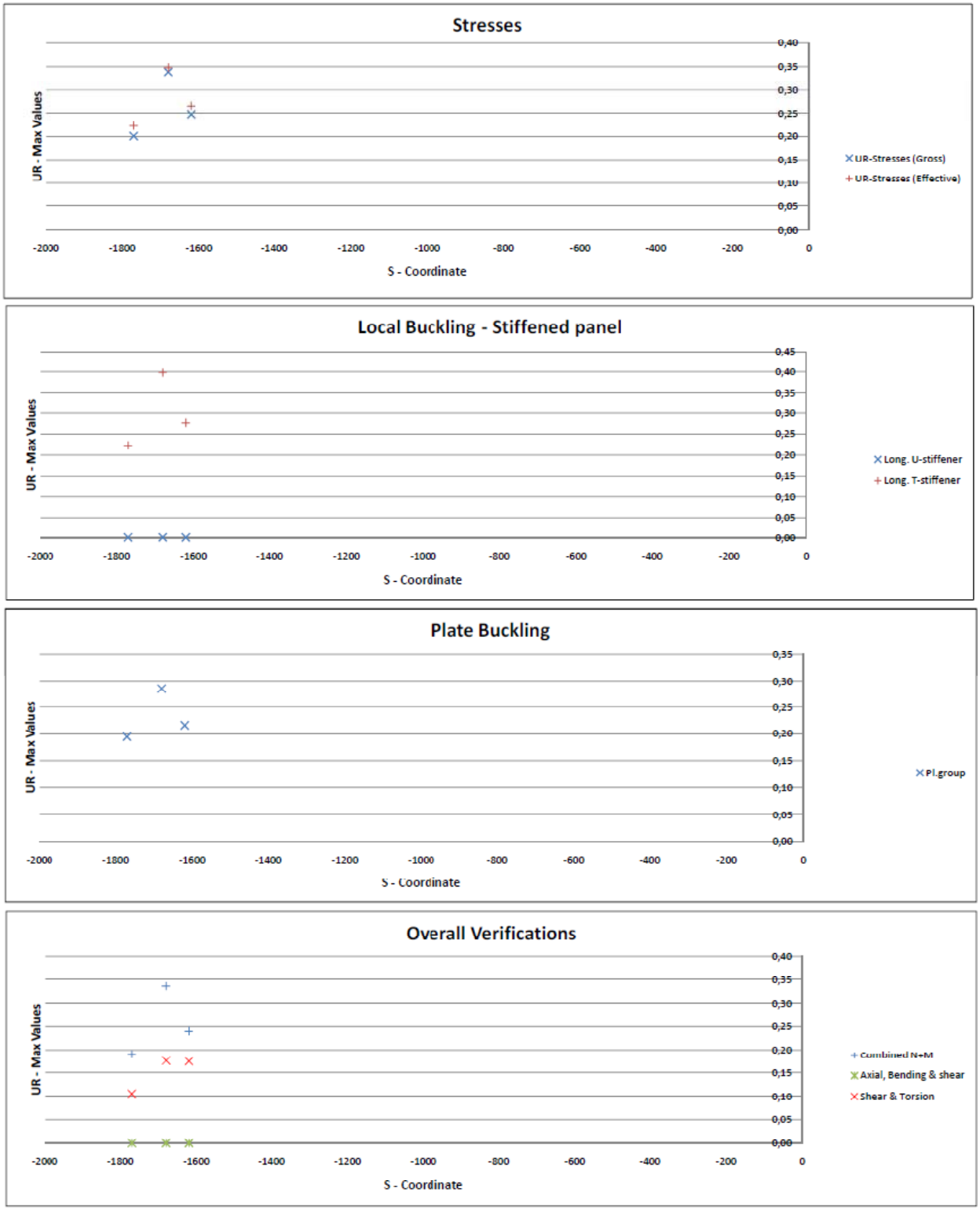


Figure 3-61 ADVERS results for rupture of Hanger 6, cross girder T4a/T4b/T6 section 2

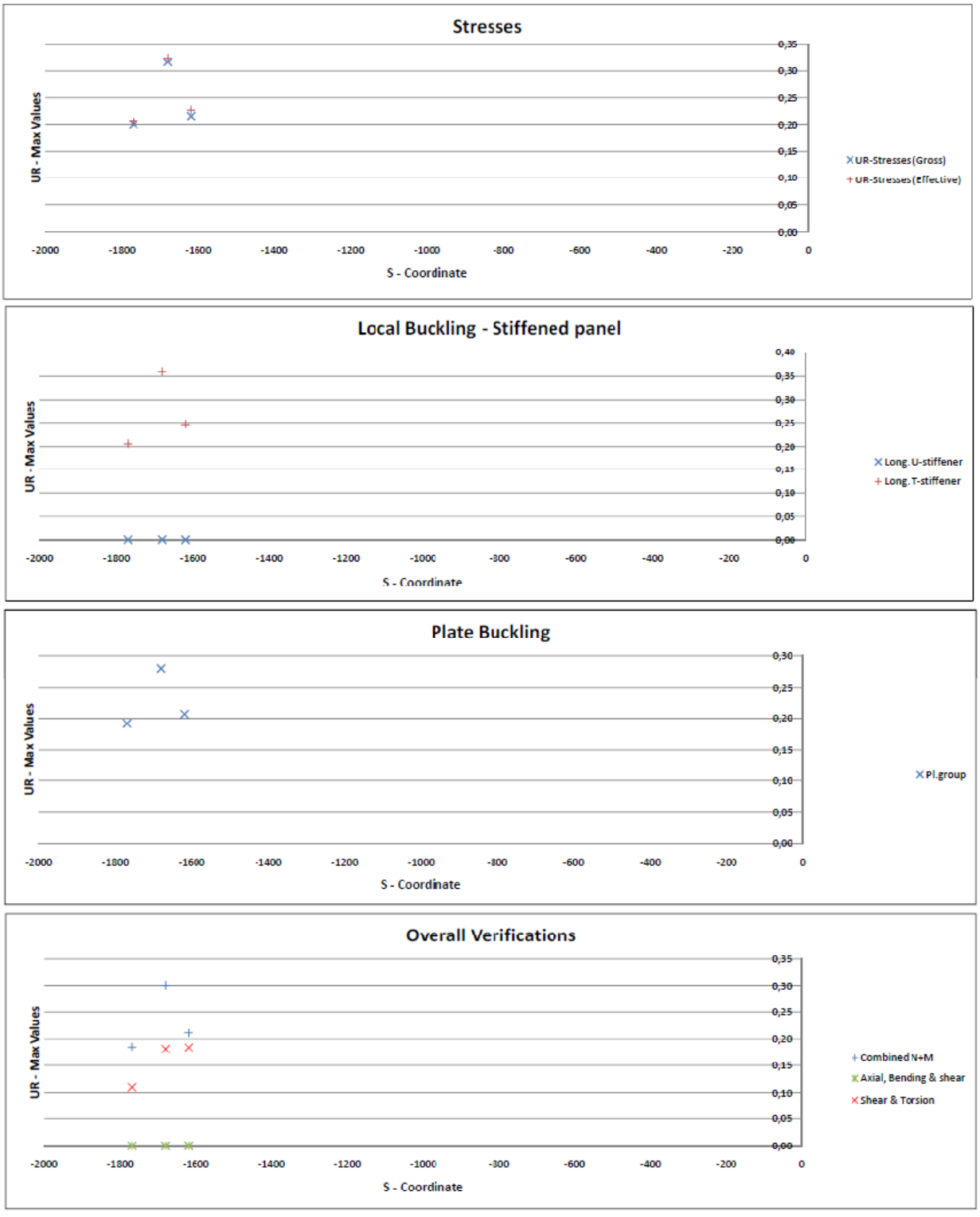


Figure 3-62 ADVERS results for rupture of Hanger 6, cross girder T4a/T4b/T6 section 3