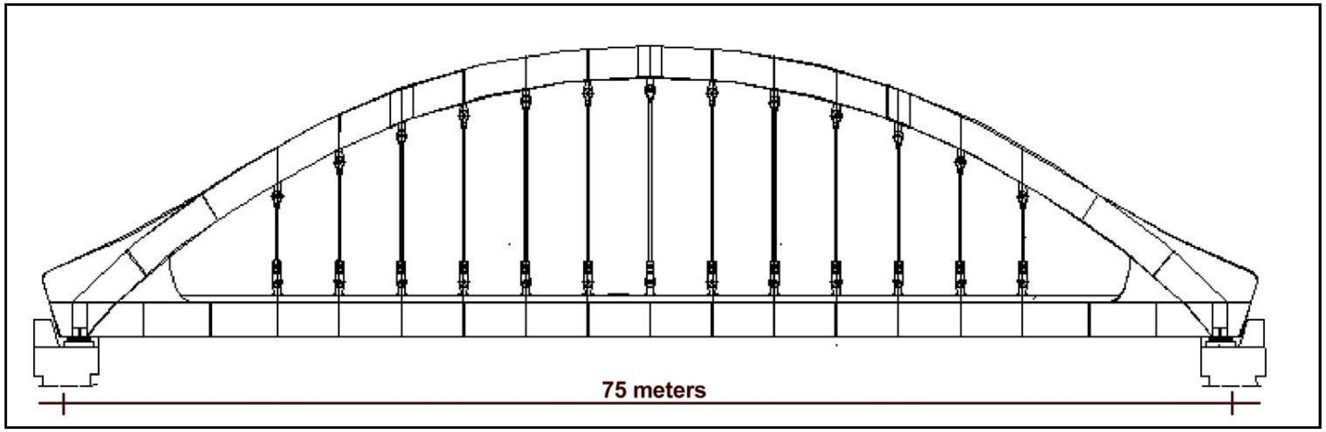
# Design and testing of the hangers for the bridge over the river Sieve for the Italian High Speed Railway

# Main aspects of the arch bridges with lower rail

- Suitable for spans ranging from 50 to 100 m
- Minimises the distance between river level and rail
- Enhanced vertical rigidity
- Reduction of noise
- Easier maintenance
- Design speed over 200 km/h

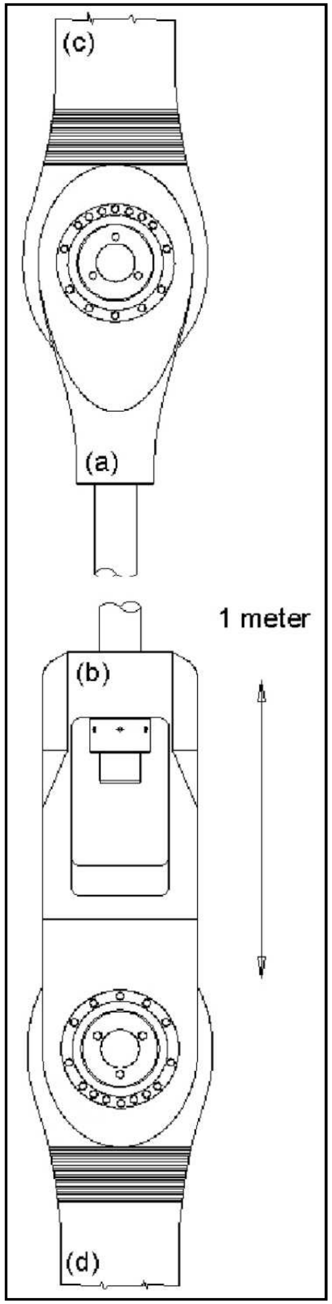
# Statical scheme of the Sieve Bridge



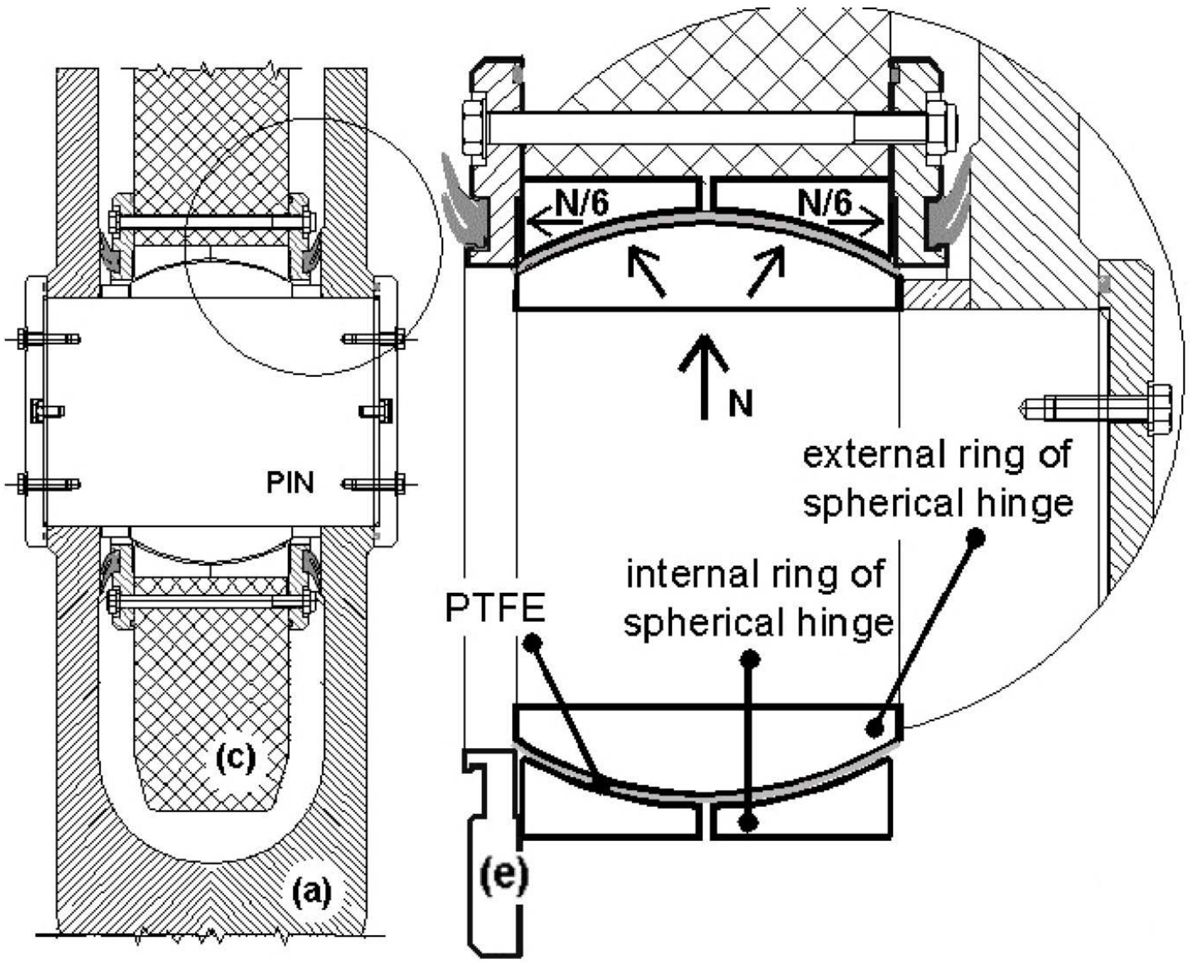

- 2 steel arches with72,2m span

- grid of steel beams with upper slab in concrete

- 26 steel hangers dia.150 mm with spherical hinges



Detail of the spherical hinges



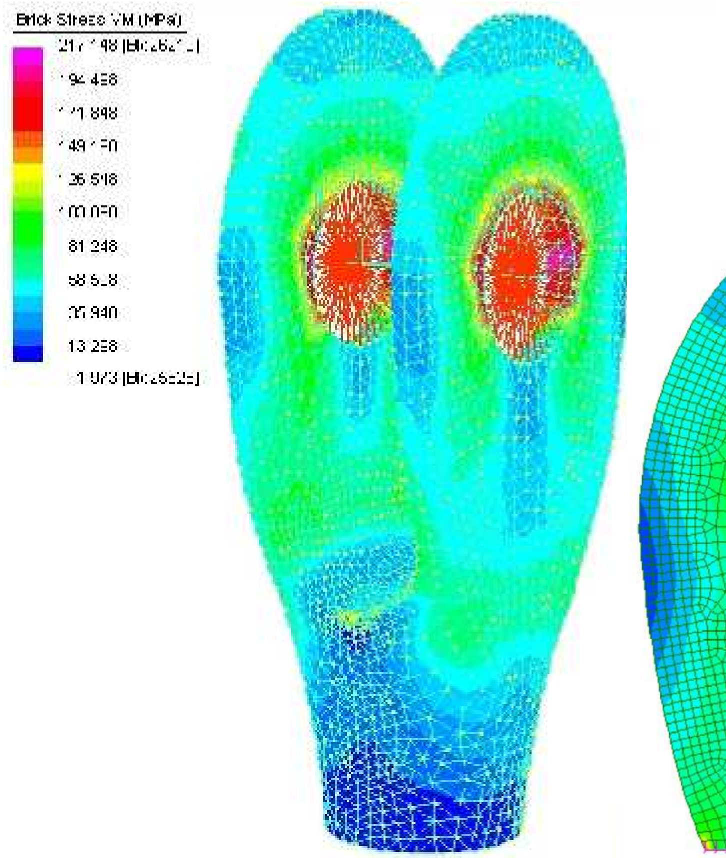

- Spherical hinges are provided with low friction sliding surface plated with PTFE and stainless steel
- Spherical hinges are considered for compensating installation misalignements only
- For the in-service conditions they are disregarded and considered as totally gripped
- Spherical hinges are made of different materials with peculiar characteristics

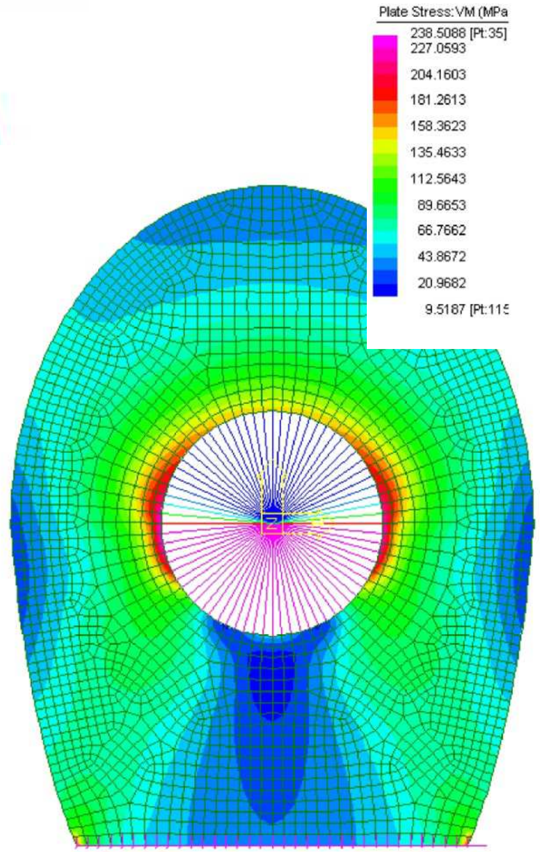
Details of the attachments to the structure of the spherical hinges

The choise of the materials has been inflienced by the following aspects:

- •Mechanical resistance of the different components
- •Fatigue resistance
- •Corrosion resistance
- •Electro-chemical compatibility

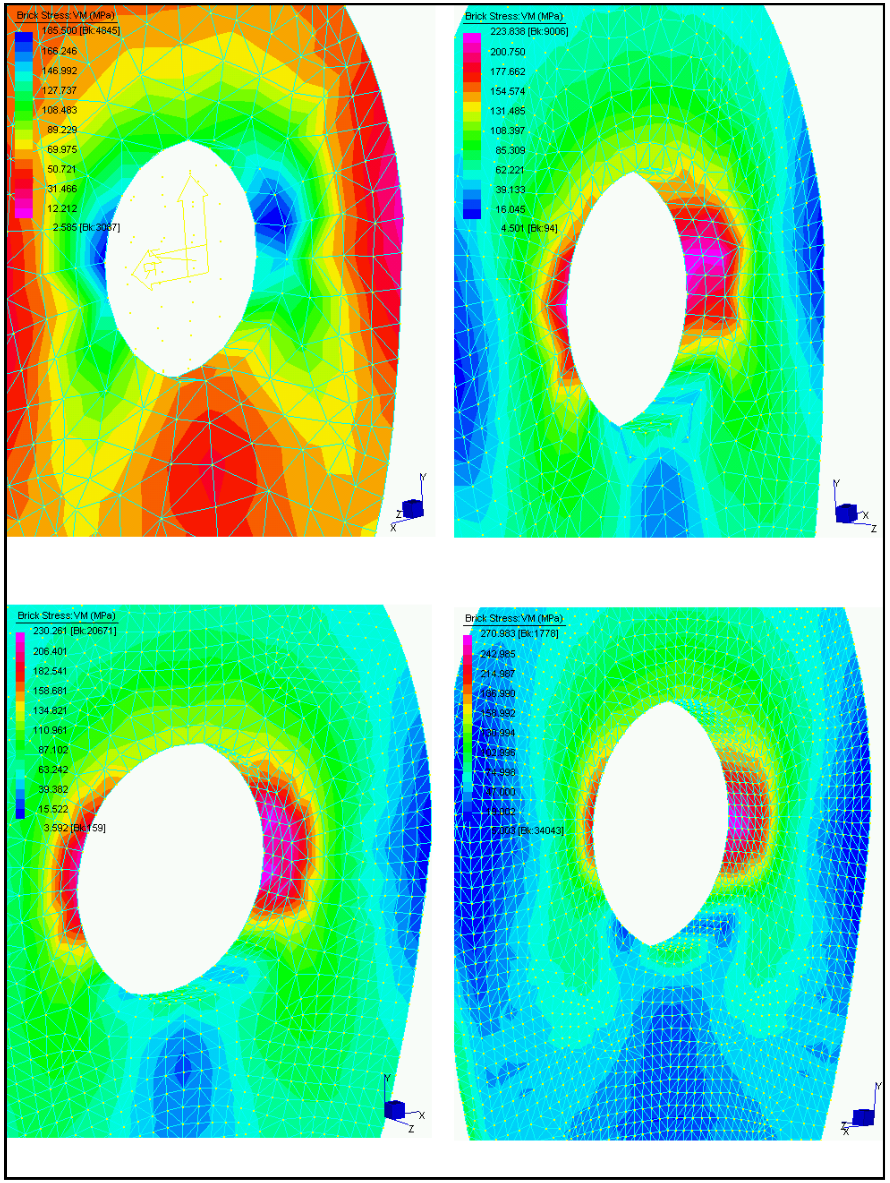
<u>Detail and mathematical model of the upper eye</u>



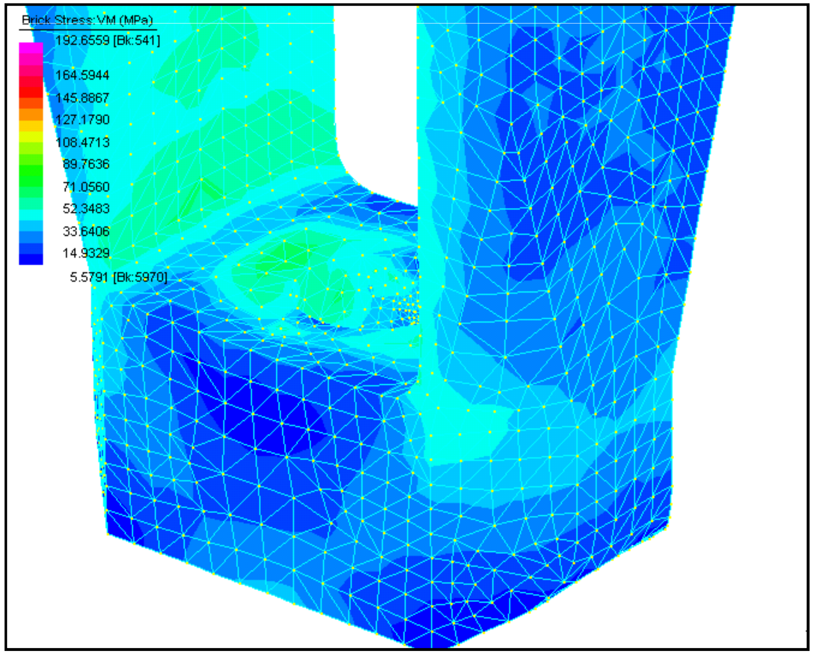




For the stress analysis has been adopted a non linear FEM ( Straus - Strand ). The contact areas has been modelled with variable stiffnes gap elements

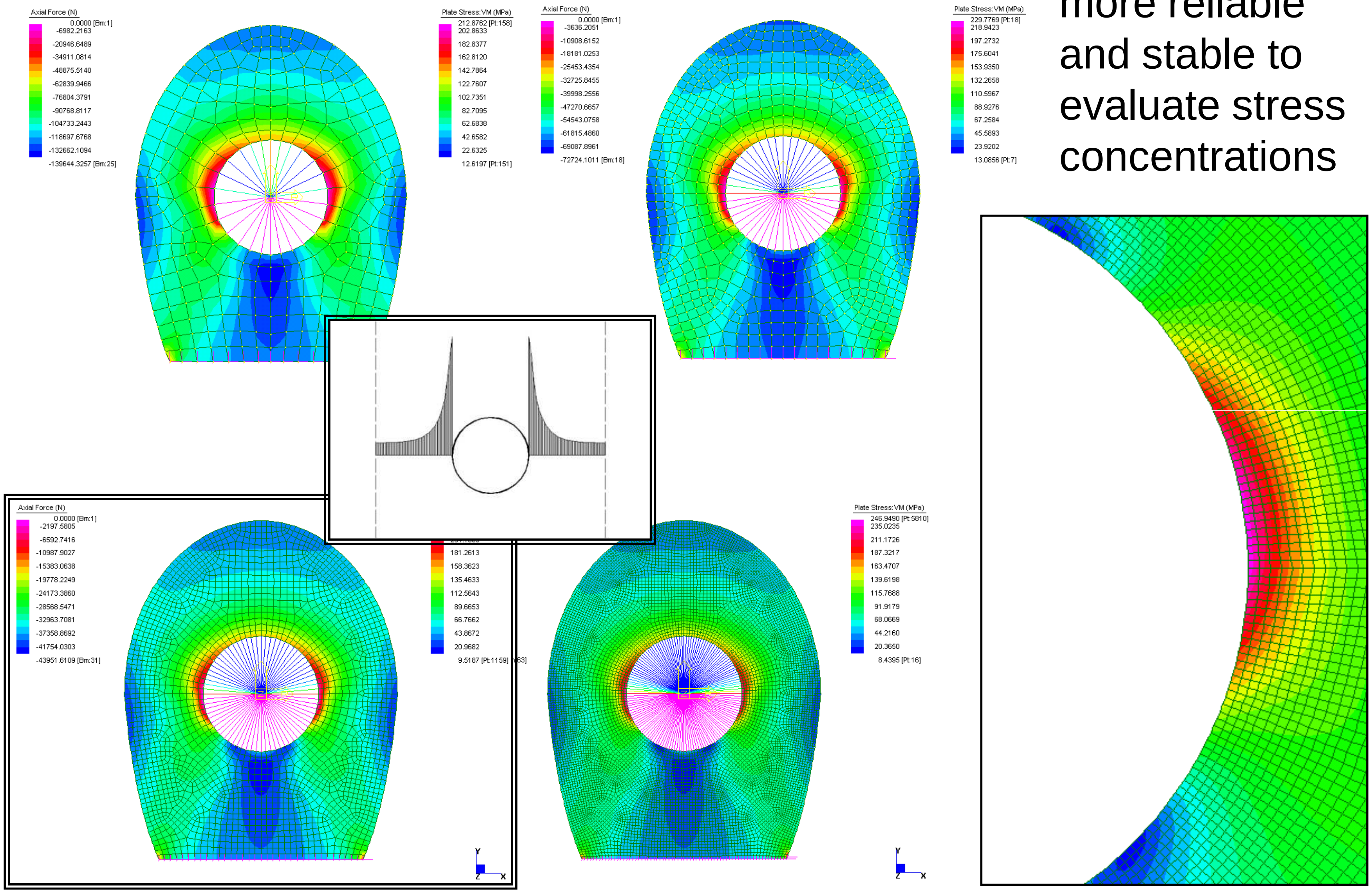
## Optimisation of the 3D modelling




The 3D modelling has been utilised to put in evidence the global stress distribution only. The mesh has been improved until constant values were achieved. The 3D model was found not suitable for the areas subject to stress concentration

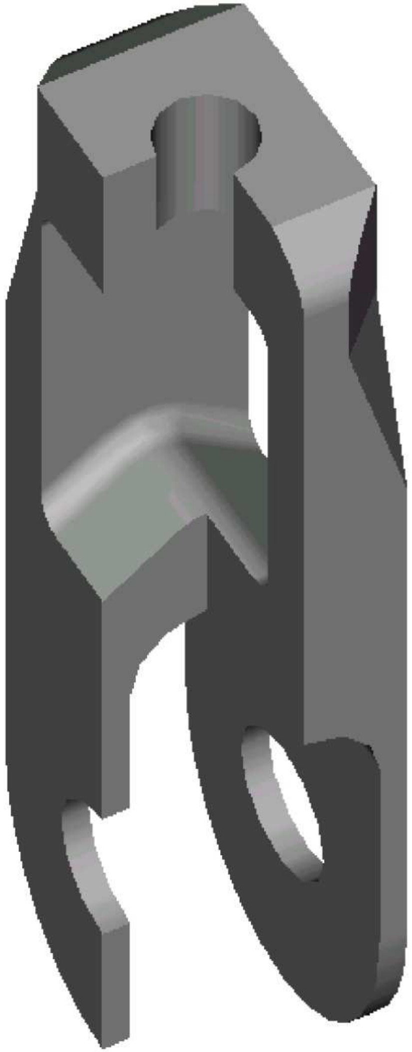


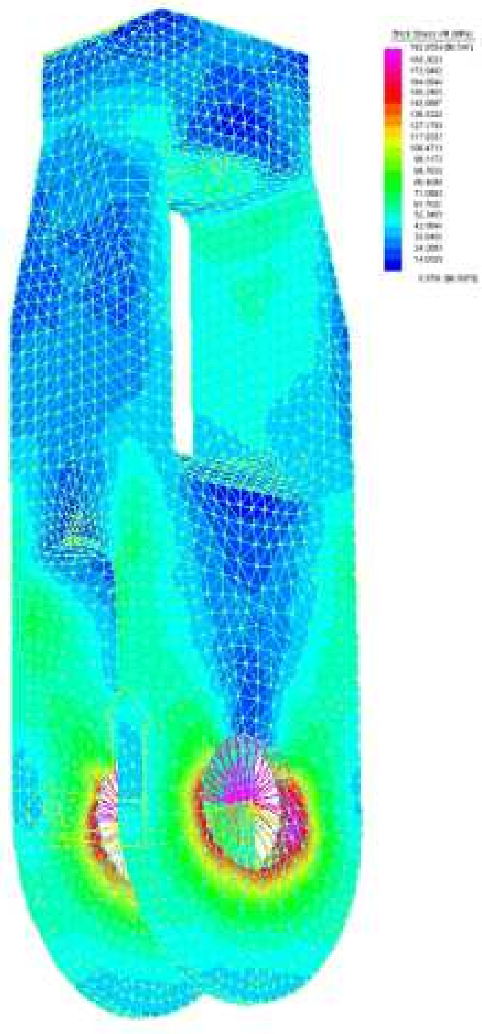
<u>2D modeling for the area around the eye</u>



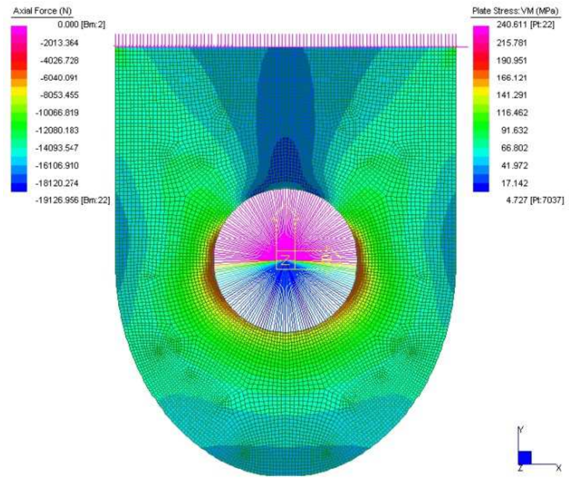

2D modeling was found to be more reliable and stable to evaluate stress concentrations

<u>3D and 2D modelling of the lower eye</u>

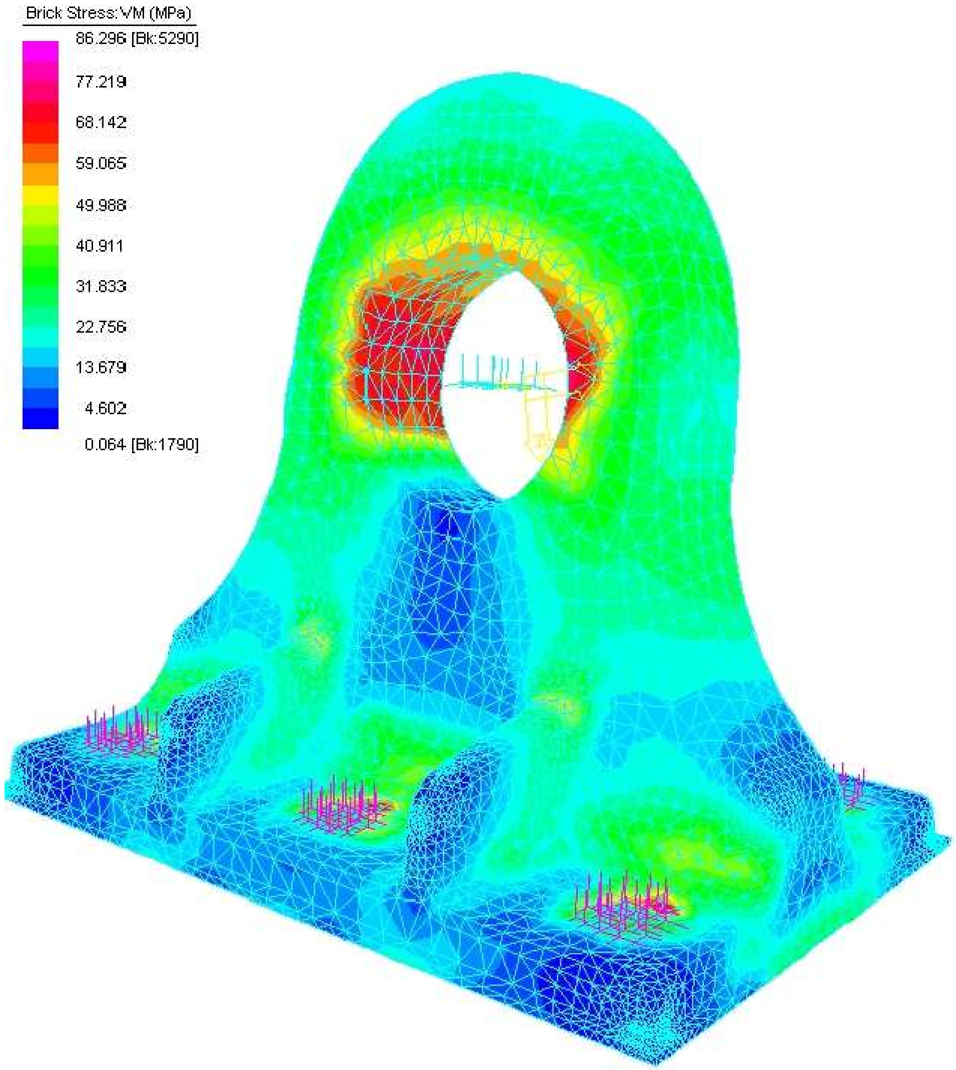




The FEM analysis has been performed in similar way to the upper eye utilising 3d analysis for global stress distribution and 2D for local effects

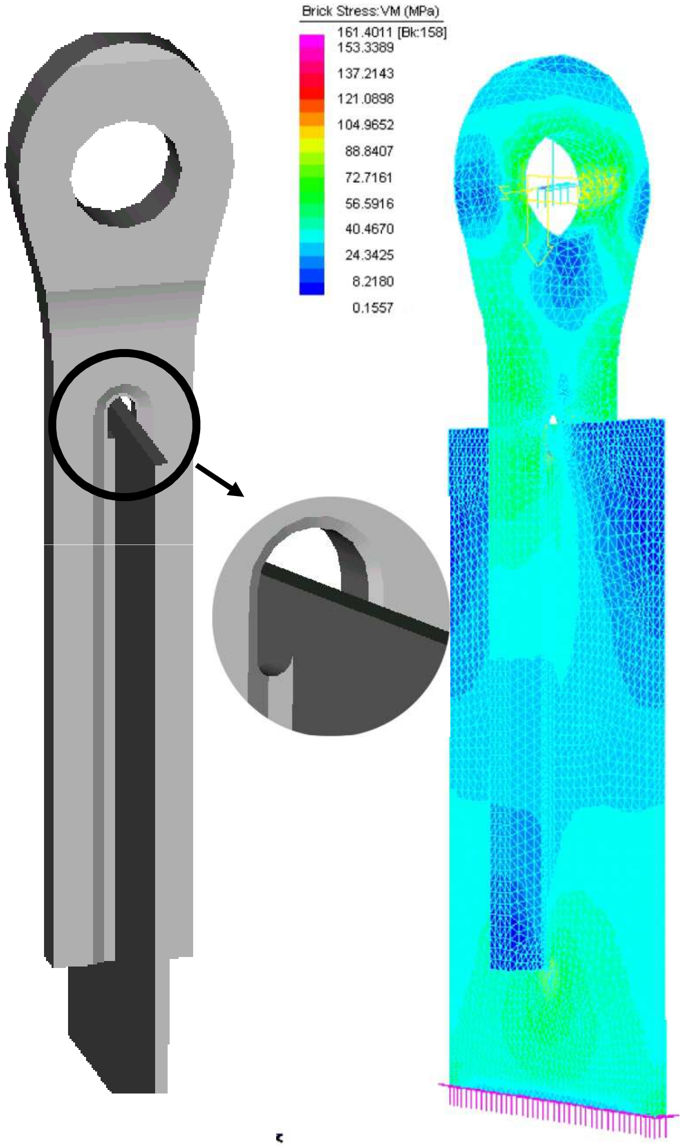


FEM for the lower connecting element developped for concrete bridges and utilised for test

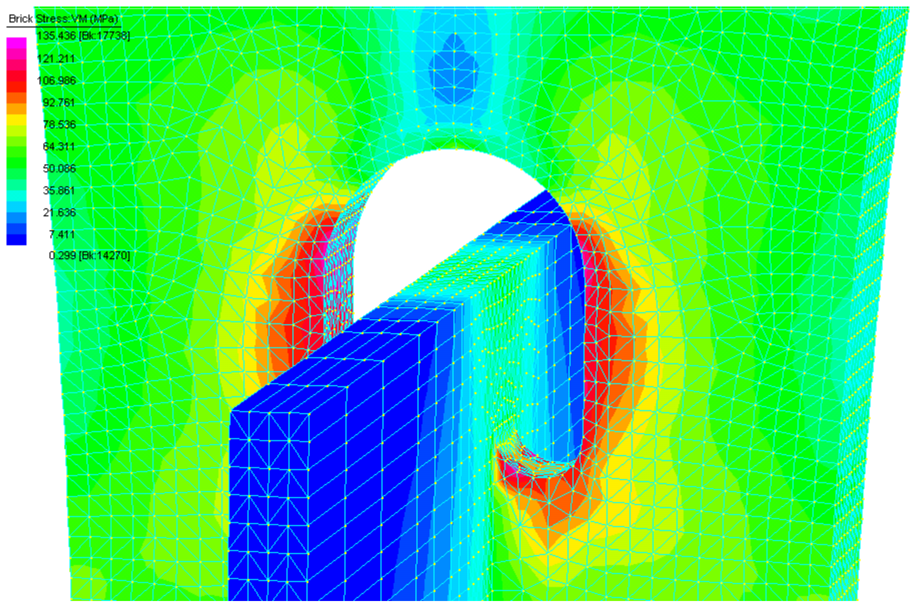



The option for utilisation with concrete arches has been developped for the bridge over the river Savena that will be executed shortly

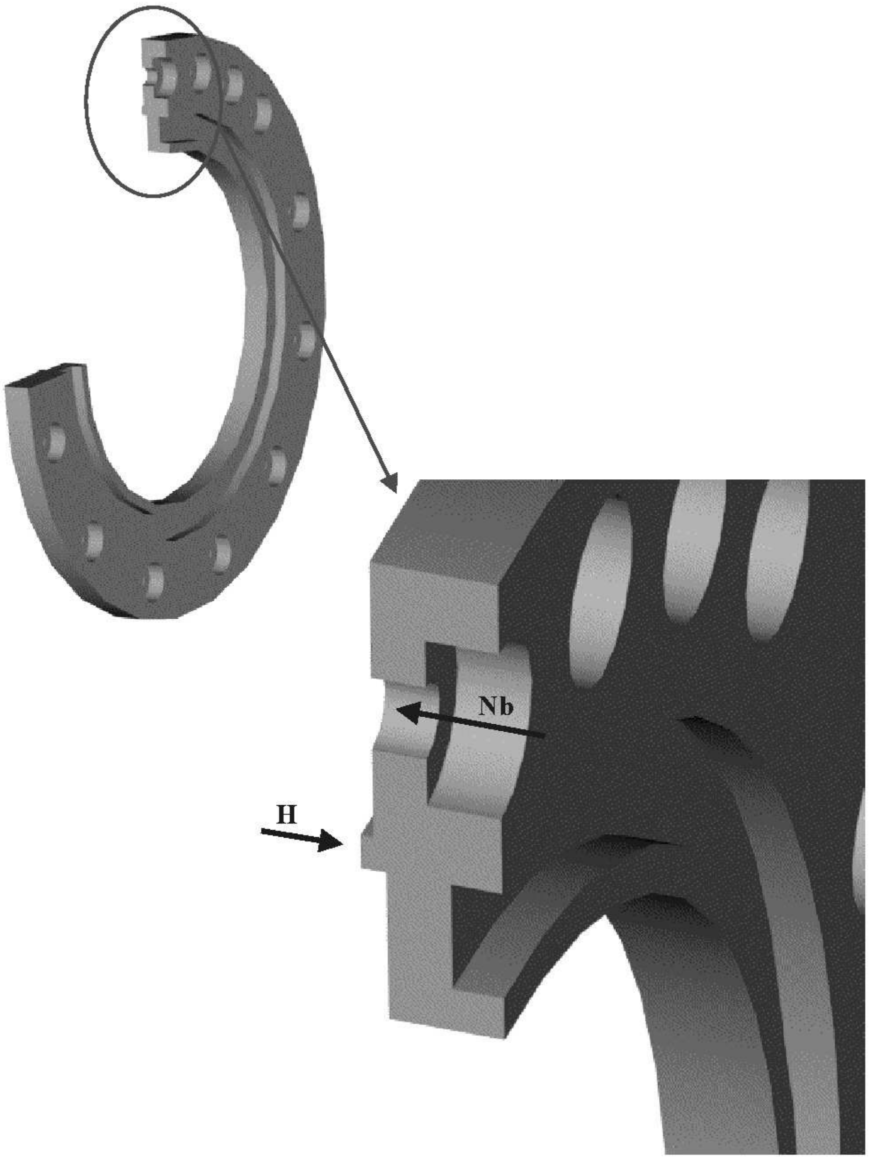
# Modelling of the upper and lower connection elements for steel bridges




The modelling allowed through a trial and error method to optimise the welded connection to the steel elemets of the bridge in order to minimise stress concentration and increase fatigue resistance

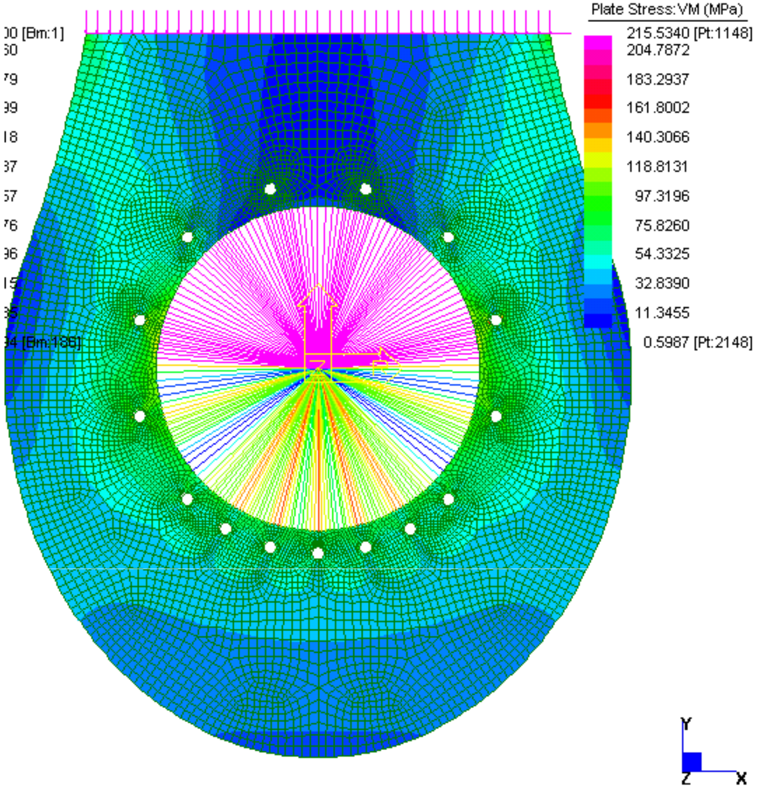


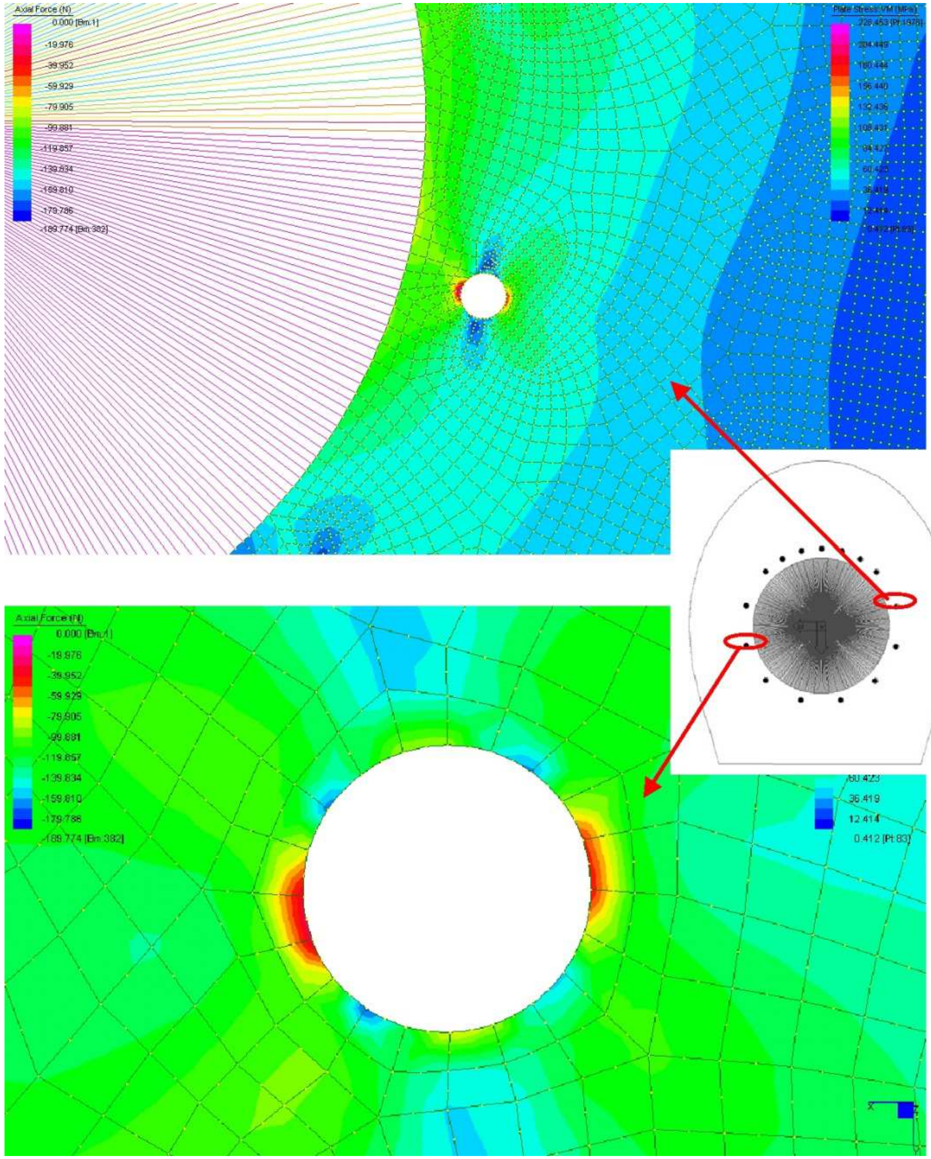
<u>Detail of the spherical hinges housing</u>




The optimisation of this detail required special care due to the stress concentration in the holes and the resistance of the flange that is subject to the force generated by the two halves of the spherical hinge

# FEM model of the connection element with holes

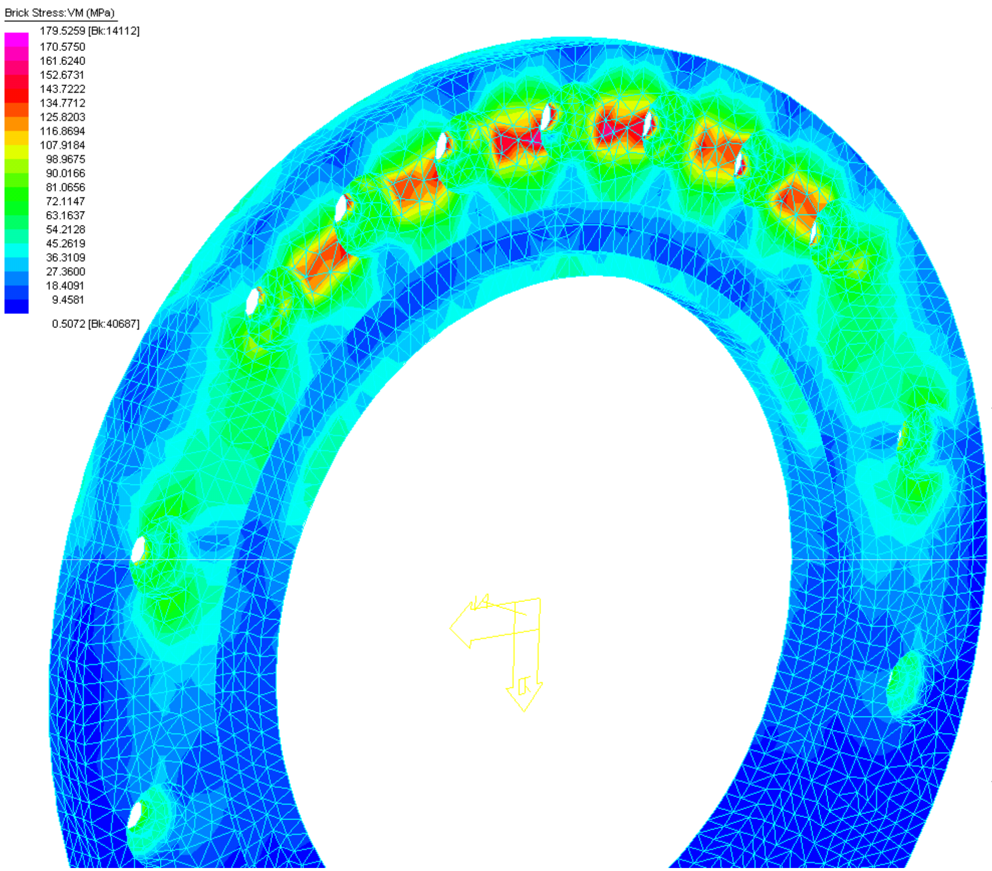


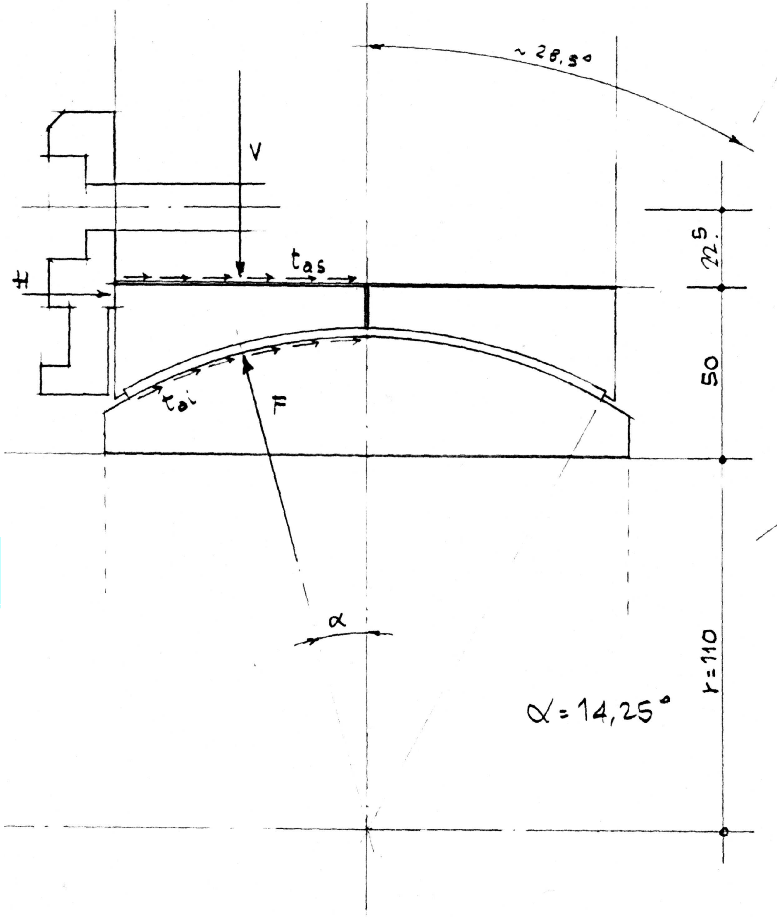



The position and number of the holes has been optimised through a trial and error method.

The best location was the one far from the maximum tension areas

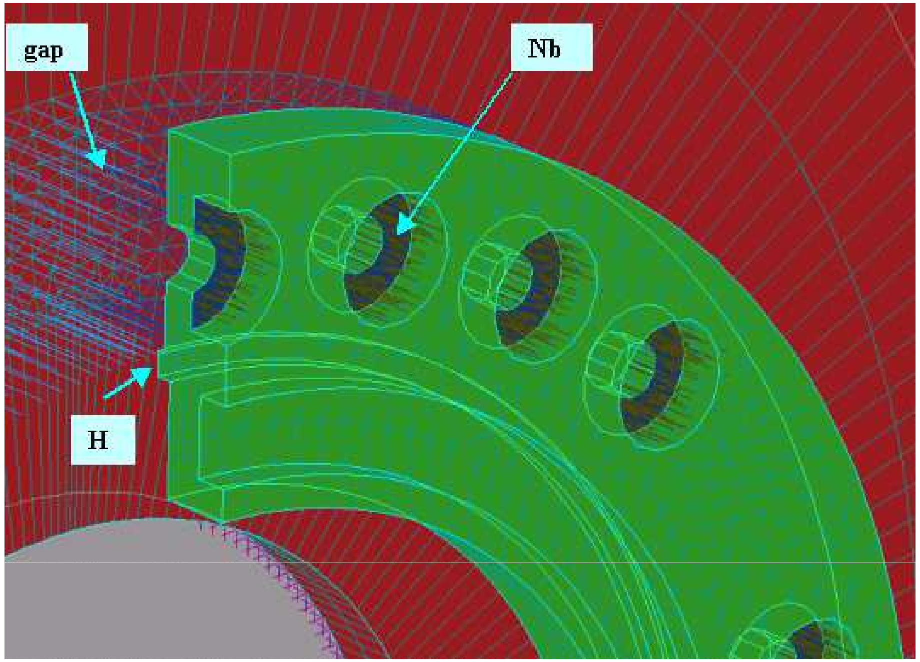
# FEM analysis of the flanges

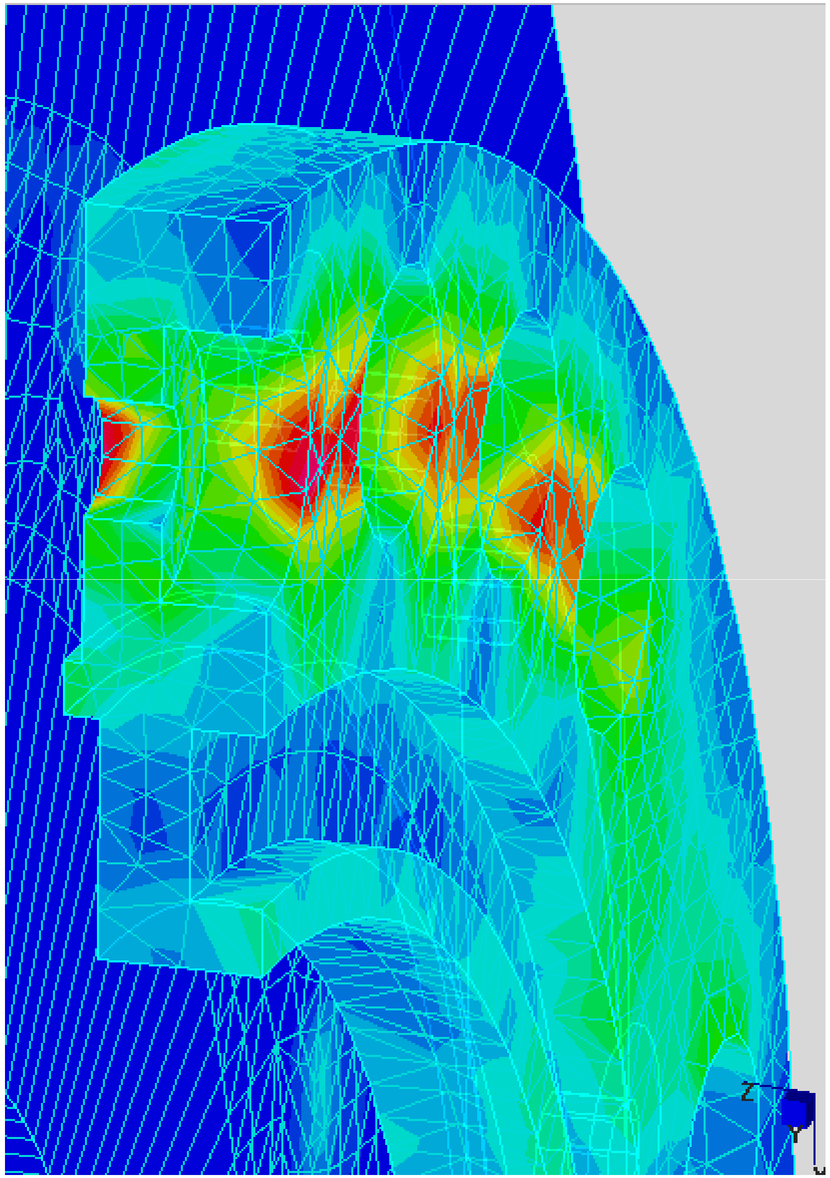



Flenges are subect to a horizontal load H generated by the inclined surface of the spherical hinge and resisted by the passing throuh, pre-tensioned bolts. It may be seen that the maximum force concentration is on the upper bolts.

# Detail of the FEM analysis of the flanges

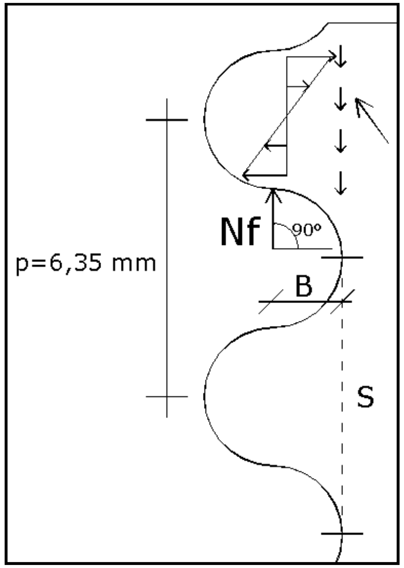


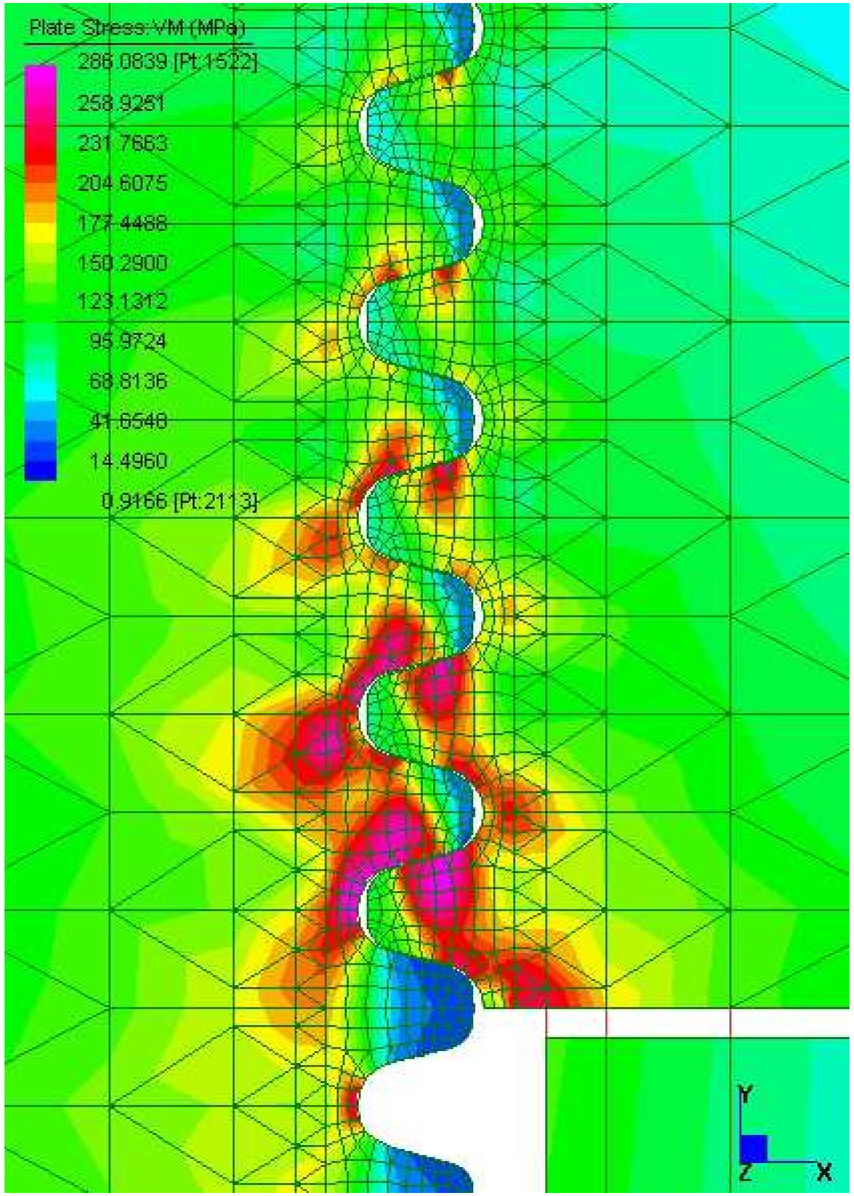
The FEM puts in evidence the stress concentation in the flange generated by the bolts pre-stressing. The contact between the flange and the connection element is simulated through gap elements. The force on the flange generated by the spherical hinge has been assumed with parabolic distribution

<u>Detai of the bar thread</u>

The thread is rolled and dimensioned to fail at a higher load of the bar itself



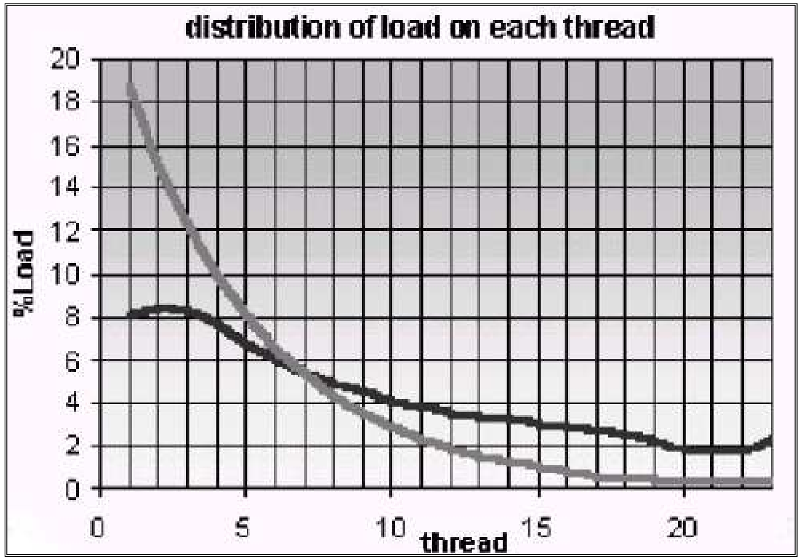
## FEM analysis of rolled thread




Two models have been investigated

- linear material model
- non linear material model

The comparison between the linear calculation and the elasto-plastic one shows a different distribution of the load among the threads:



Test set-up


Main characteristics of the test equipment:

•Dynamic system MTS with 250kW power and 600 l/min at 210 bar

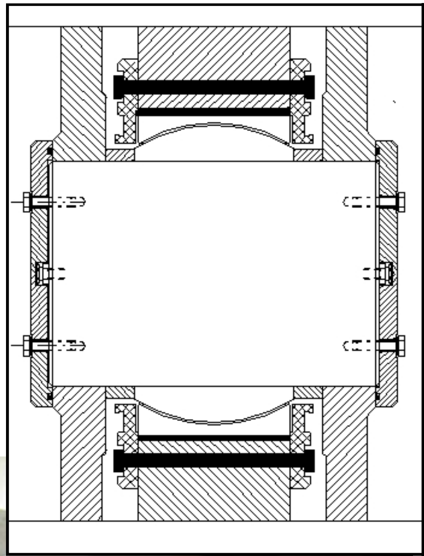
•24 channels acquisition system up to 100 Hz scanning frequency

# Summary of the tests performed

- Mechanical properties of the materials including tensile strength, impact resistance at -35°C, chemical analysis and electro-chemical compatibility
- Ultra-sound and X-ray analysis
- Geometry and roughness (before and after load tests)
- Axial static test at 2500 kN for 15 minutes (1,25 design load)
- Axial fatigue test at 1 million cycles at 5 Hz with load 1200-1800 kN
- Axial fatigue test on spherical hinges at 2,5 million cycles at 5 Hz with load 1200-1350 kN
- Dynamic rotation test of ±2° under constant tension of 1600 kN (1 million cycles at 2 Hz)

Inspection of the prototype after the execution of the test

Inspection and measurments on the spherical hinge after the execution of the test



Inspection and measurments on the spherical hinge after the execution of the test

# Conclusions

- Hangers for arch bridges have been investigated by means of mathematical models and tests
- Main aspects influencing the design has been:
  - ⇒Structural resistance
  - ⇒Fatigue resistance
  - ⇒Easy installation and replacement
  - ⇒Environmental resistance
- This structural solution resulted very reliable on all aspect and will become the symbol of the high Speed Rail between Bologna and Firenze