The Cieza Viaduct

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Summary:

In the last few years the amount of arch bridges built in Spain has increased considerably. Even though these type of bridges are expensive structures and their construction is very time consuming, due to the ancillary equipment needed, it is obvious that their beauty and adaptation into the landscape makes them a very interesting type of structure.

A new innovative construction process was developed by using precast elements for both arch and deck. This allowed to build a classic arch bridge with a reduced budget, in nearly half the time it would have taken using traditional methods. However this process complicates the calculations that are needed for the structure because of the high complexity and amount of the different construction stages.

1 INTRODUCTION

The Cieza Viaduct initially was projected as prestressed concrete slab. The construction process would involve building the arch with provisional tie rods first, and then the deck afterwards. This system has three main disadvantages:

- When building the arch, a provisional upright must be put on the pier placed on the roots of the arch.
- When building the deck two falseworks must be used simultaneously to concrete even a span as small as 22m.
- The traditional way of constructing an arch requires a gantry with cantilever to concrete the arch and, later, a falsework to concrete the deck. As these two elements don’t interact easily, sometimes the arch and the deck have to be built separately, the building process for the structure gets delayed.

It is obvious that building the arch and the deck at the same time, rather than in succession, will save time and also reduce the amount of auxiliary equipment required. The possibility of using a precast arch with a 141m span was discussed in order to build both parts using only one auxiliary element: a launching gantry of precast elements.

This system erects both the precast elements of the arch and the precast girders of the superstructure. Both types of elements are picked up on the rear part of the falsework by two trolleys.

Figure 1. View of semi-arch during construction

The advantages of this system are quite obvious:

- Only one launching gantry is needed, instead of both a gantry with cantilevers and a complete falsework;
- The use of precast elements gives the usual advantages of this process: a homogeneous finished product; comprehensive quality control; and quick erection time.

2 THE CIEZA VIADUCT

The Cieza Viaduct is a classical arch bridge and has a 141m span between both roots and a height of 32m. It follows a 2º parabola and the edge varies between 2.60m at the root and 1.80 at the crown section.

Since the deck is curved, the piers are supported with certain eccentricity on the line of the arch. This eccentricity has been optimized in order to minimize the torsional moment of the arch.

Due to this eccentricity the arch must be at least 5.50m wide.

The arch has a hollow rectangular cross-section, being the flange and web of the walls 0.25m wide.

Figure 2. Front view of arch segment

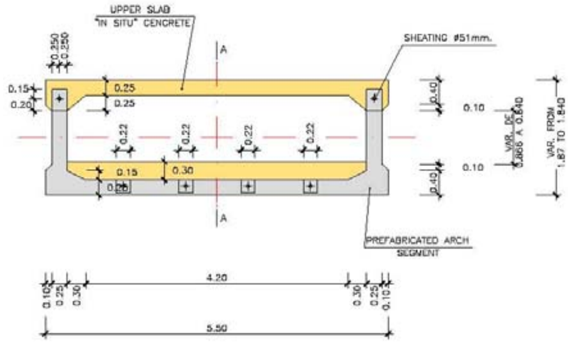


Figure 3. Cross section of arch segment

The deck comprises 13 spans for the left carriageway and 14 spans for the right carriageway.

The spans are set as follows:

- Left carriageway 13-17-17-10x18.6
- Right carriageway 13-17-17-8x18.6-17-17-10

Over the arch there are 8 spans of 18.6m on both carriageways. The 7th pier is placed at the crown. In the original project the spans were 22m wide. This was altered to reduce the weight of the heaviest beam to be launched.

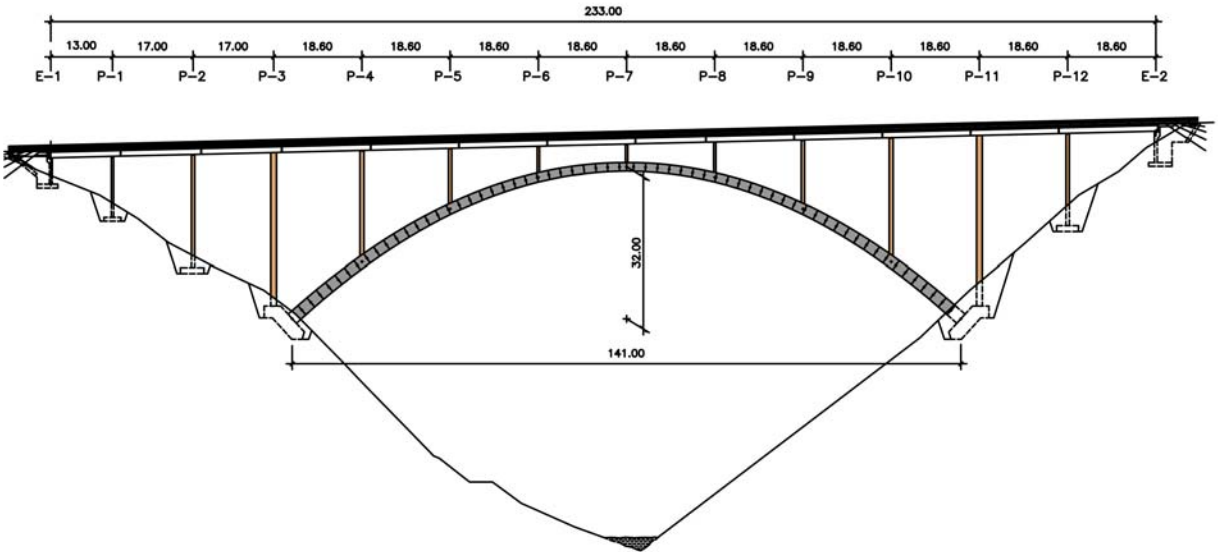


Figure 4. General view of the left carriageway

The deck is formed by a precast box girder with a 1.20m height. The lower face of the beam is less than 3.96m wide.

On top of the beam goes a concrete slab. This is 0.20m thick at the ends of the cantilever and 0.35m thick on the beam.

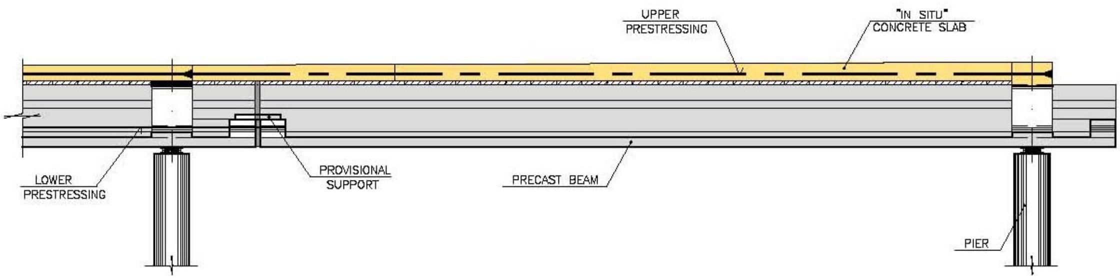


Figure 5. Launching of deck

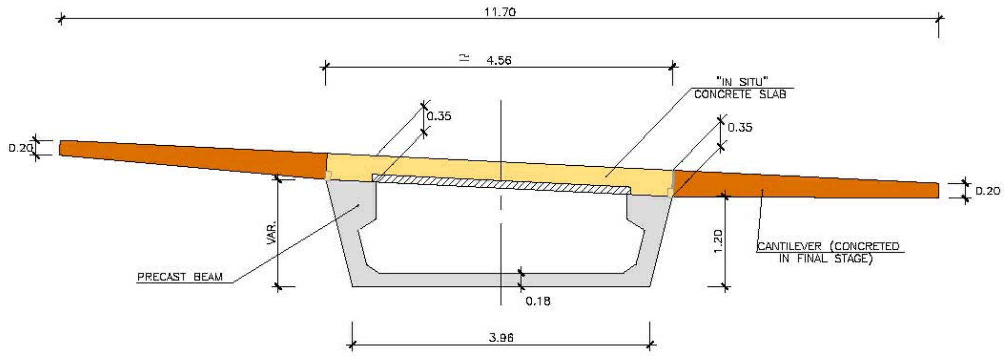


Figure 6. Cross section of deck

The beams are installed with 9/10 of their length on one span and 1/10 at the following span. The joint will be made using a mortar joint 10cm thick, overlapping the lower prestressing (at the joint) and the continuous slab.

Central prestressing has been chosen to make the stress processes easier and reduce the number of deviation blocks in the deck and the slab, therefore simplifying the construction process.

The prestressing can be divided into three categories:

- Prestressing with precast beams. This has been calculated with the minimum required to cope with the weight forces for the deck and the slab together.

- Lower prestressing of beam. This is a horizontal exterior prestressing on the lower deck of the beam. The bottom joint of the beams is done by overlapping the lower cables on the phase front.

- Upper prestressing of deck. This prestressing is also straight and it takes place on the compression slab, in the area between the webs of the beams. In this case, the cables are joined with couplers slightly away from the joints of the beams.

The number of cables for each span varies slightly depending on their position within the deck.

Figure 7. Launching of precast beam

3 CONSTRUCTION PROCESS

The general construction process for the bridge consists of a cantilever system for both the deck and the arch, and for the piers, consisting of the deck, arch and the piers with provisional triangulation. The truss is formed by a compressed chord (the arch), a chord of traction (the deck) and diagonals that are the provisional tie rods.

The general construction process can be divided into several recurrent phases within the 4 spans for each semiarch of the bridge:

- Installation of groups of 3 precast segments for the arch and positioning of a couple of provisional bracing bars. Concreting of lower ribs between segments and upper slab. Repetition of launching of precast segments until reaching position of pier.

- Concreting on site of the diaphragm of piers and positioning of the provisional tie rod formed by two HEB-360.

- Concreting of pier with climbing formwork. Installation of precast beam and concreting of wet joint.
- Tensioning cables for the deck of the previous span, and concreting the slab between the webs of the beam. Removal of provisional bars.

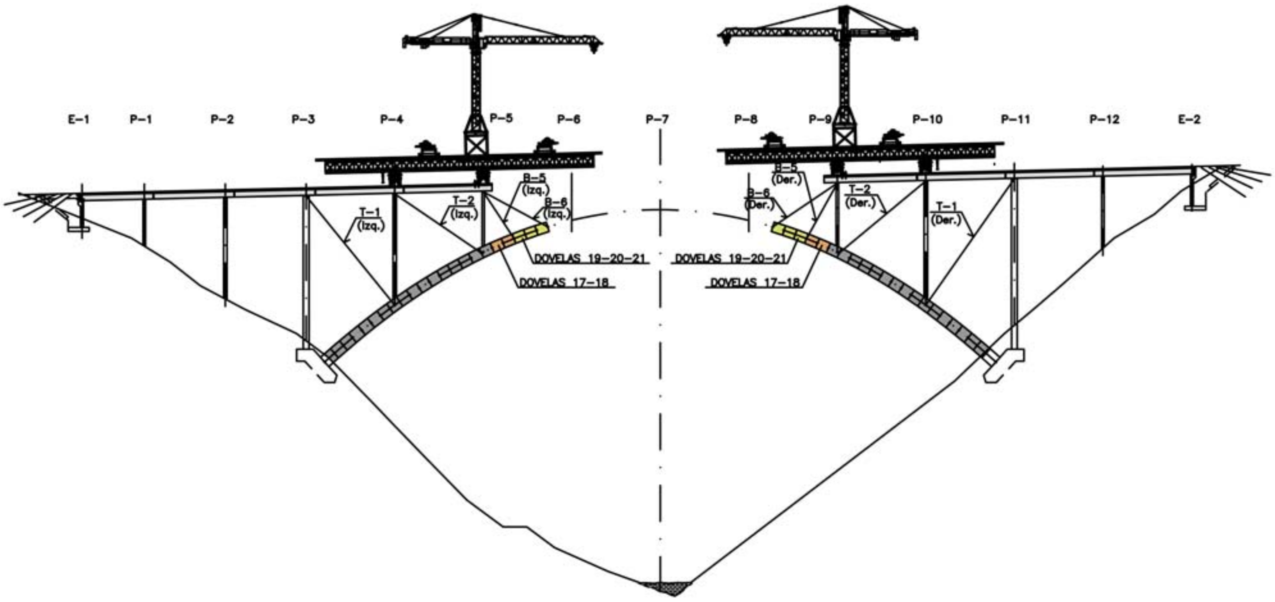


Figure 8. Schematic view of construction stage

Each semiarch has been divided into 30 segments each 2.50m long. As well as these, there is the initial segment, which is partly precast (to give the initial direction to the line of the arch) and partly built on site; and the end segment, which is 3m long and the keystone of the arch.

The precast part of the arch is only formed by the lower slab and the two side webs up to the lower part of the upper deck (see figure 3).

Each segment was precast in a precast concrete plant with a specific falsework so that it fitted with the previous one. The installation was done in groups of 3 segments. Each segment was joined to the previous one by means of two prestressed bars at the upper end of the web, and two provisional devices in the middle of the web. An epoxy resin is used for joining the segments.

Each 3 segment group was linked to the deck with 2 provisional bars in order to minimize the local reinforced connection between segments. Afterwards the upper slab was concreted which is the only monolithic connection between the arch segments.

As explained earlier, the deck is built with a precast concrete box girder in “U-shape” (see figure 7).

On three of the beams of each semiarch it was necessary to leave the openings ready for the provisional tie rods completed.

These tie rods were adjusted with two hydraulic jacks per tie rod from the upper part of the deck. As mentioned above, during the construction of the arch, only the section of the slab between the webs of the beam needs concreting.

The cantilevers were concrete at a final stage, after having completed the arch and deck to minimize the self weight of the structure during construction.

The concreting of the cantilevers was carried out with a launching gantry.

4 REQUIRED CALCULATIONS

As seen above, the construction method for the arch bridge has a high complexity. It is necessary to considerate a great number of different construction stages and a variation of the cross sections due to the stepwise concreting of the arch and the superstructure.

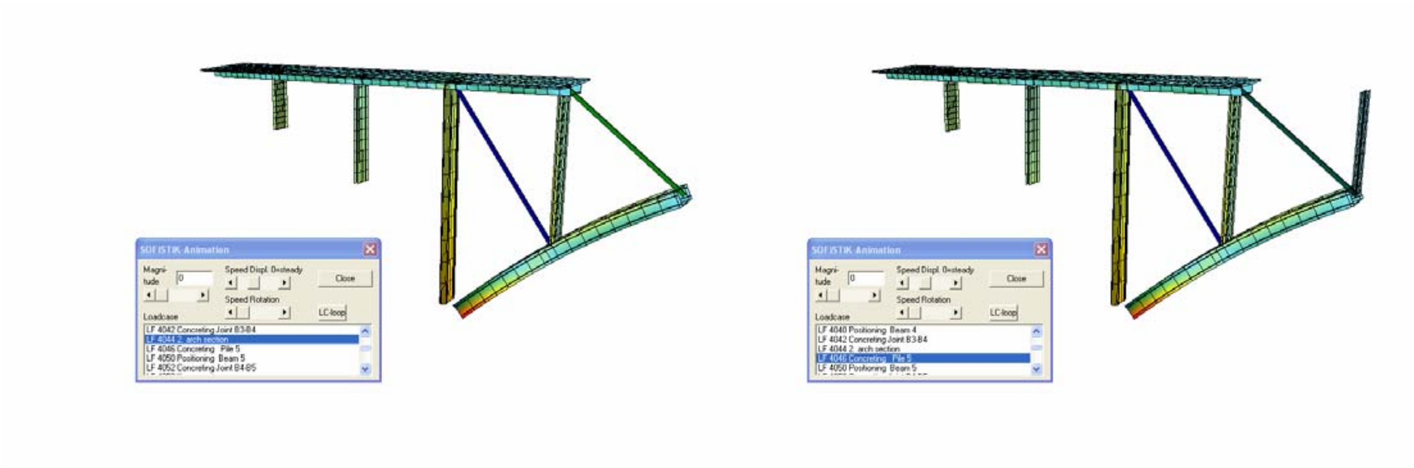


Figure 9. View of construction stages in sofistik

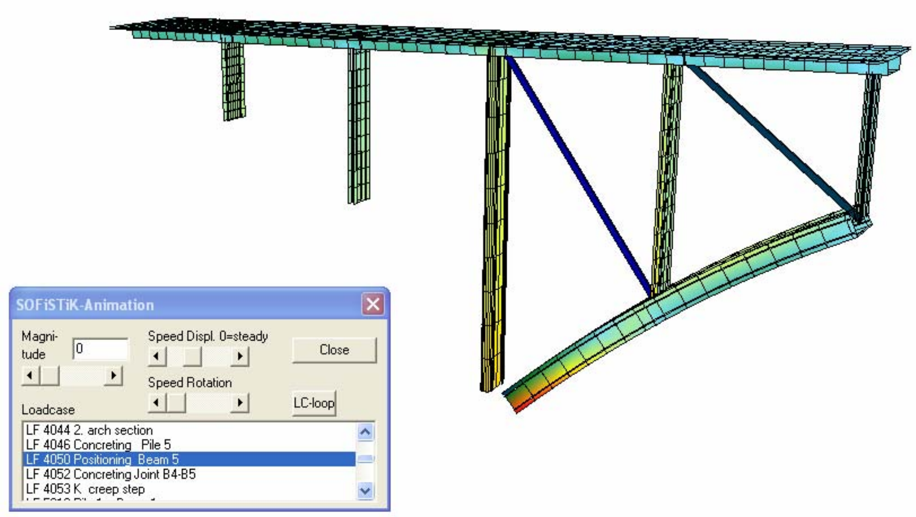


Figure 10. Construction stage in sofistik after beam erection

A calculation model was needed that allows to realize the following analysis:

- In the arch segments, the only monolithic connection is the upper slab. This requires an analysis of the stresses during all the construction stages to avoid an opening of the joints between the segments.

- As the superstructure has three different prestressings which are acting upon different cross sections it was also necessary to verify the tensile stresses during construction to anticipate crack building in the beams.

- The axial forces in the provisional bracing bars and in the tie rods had to be adjusted in several stages of the construction.

- A topographical leveling was made on the construction site. The only way to regulate the deflections of the arch was to adjust the axial forces in the tie rods. Therefore it was necessary to analyze these variations and their influence on the structure. This was even complicated by the tight schedule on the construction site.

- The different construction stages and the varying stiffness of the elements have a significant influence on the forces. These have been taken into account for the design in ultimate limit state and also for the analysis of service state.

- Creep and shrinkage becomes important because of the interaction of precast elements and the elements that are concreted on the construction site.

The modul CSM (“Construction Stage Manager”) of Sofistik was used to reproduce the arch bridge with all its construction stages. It implements an input in table form to define stages, additional loads and creeping steps.

5 REALIZED MODEL IN SOFISTIK

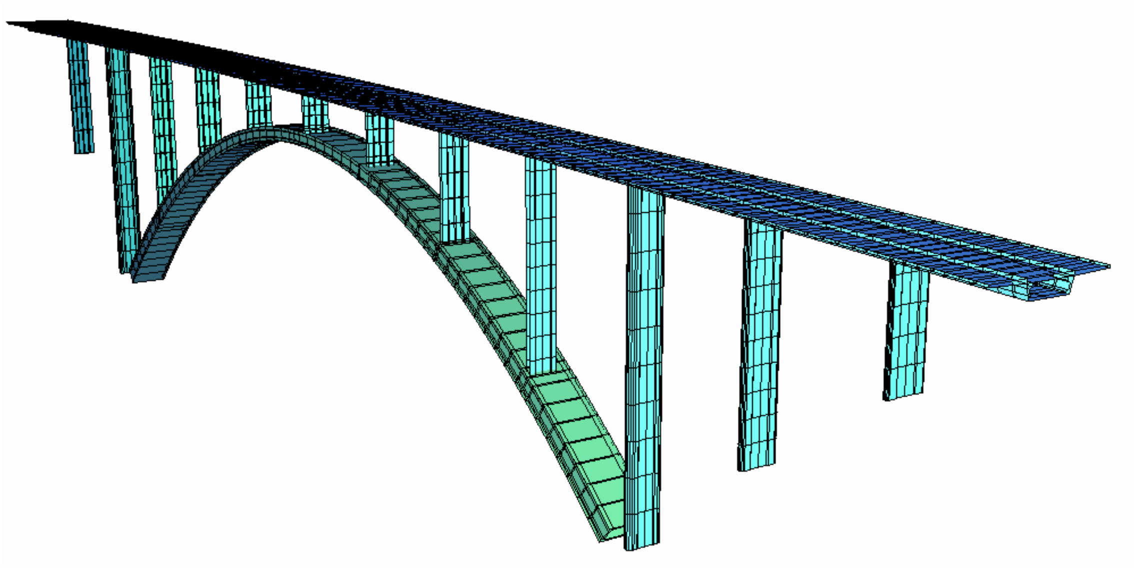
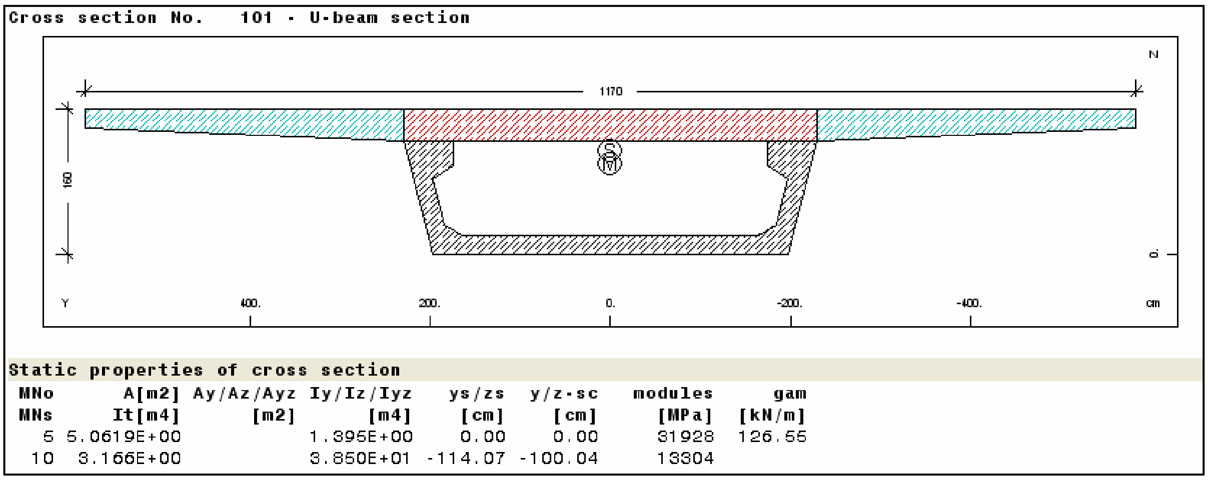


Figure 11. Perspective view of sofistik-model

A spatial frame model with beams was used for the calculation. The cross sections for the superstructure and for the arch were defined with their corresponding construction stages.



MNo MNs	A[m2] It[m4]	Ay/Az/Ayz [m2]	Iy/Iz/Iyz [m4]	ys/zs [cm]	y/z-sc [cm]	modules [MPa]	gam [kN/m]
5	5.0619E+00		1.395E+00	0.00	0.00	31928	126.55
10	3.166E+00		3.850E+01	-114.07	-100.04	13304	

Figure 12. Defined cross section in “AQUA”

As the assignment of the partial sections is already made in ‘AQUA’ the respective self weight gets automatically activated in the corresponding construction stage. Different material numbers are used to allow the stress analysis of the cross section.

```
$------ cross section of superstructure ---------
sect 101+#1 mno 5 mrf 10  btyp beam

cs no 10+#2 titl 'U-beam section'
poly type opz ; vert no y z
            101    0.00e-2   -0.00e-2
            102  198.00e-2   -0.00e-2
            103  229.25e-2 -125.00e-2

poly type ipz ; vert no y z
            101 -174.45e-2  -125.00e-2
            102 -174.45e-2   -98.00e-2
            103 -197.95e-2   -83.00e-2
            104 -185.24e-2   -32.16e-2
            105 -165.45e-2   -21.00e-2

cs no 13+#2 titl 'center slab'
poly type opz mno 15; vert no y z
            101  229.25e-2 -125.00e-2
            102  229.25e-2 -160.00e-2

cs no 110+#2 titl 'cantilevers'
poly type o mno 25; vert no y z
            101 -229.25e-2 -125.00e-2
            102 -229.25e-2 -160.00e-2
            103 -585.00e-2 -160.00e-2
            104 -585.00e-2 -140.00e-2

poly type o  mno 25; vert no y z
            105 +229.25e-2 -125.00e-2
            106 +229.25e-2 -160.00e-2
            107 +585.00e-2 -160.00e-2
            108 +585.00e-2 -140.00e-2
```

Figure 13. Input of cross section in "AQUA"

The group numbers of the beams were determined according to the launching process. The deactivation of the provisional bracing bars and the tie rods had to be defined in the 'grp'-command of the CSM.

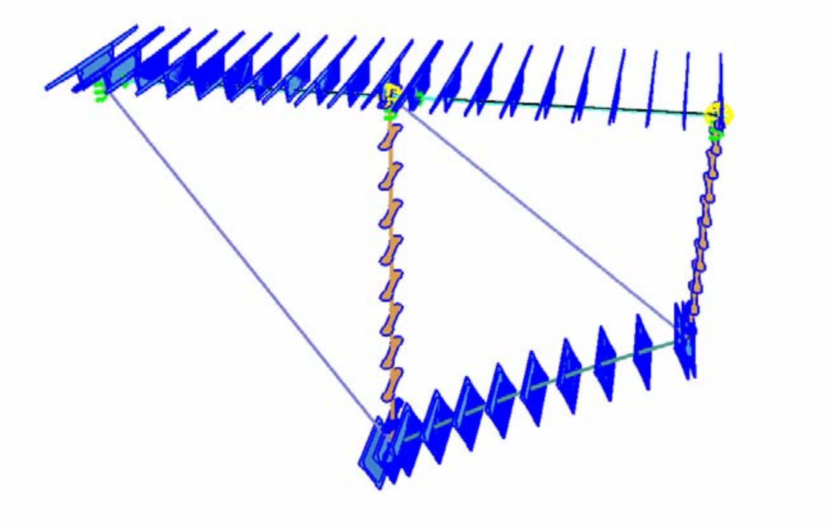


Figure 14. Spatial frame model in "Sofistik"

The lower prestress of the superstructure is already applied in the precast plant and has therefore only a statically determined component. By its activation each beam of the superstructure is fixed to the previous one by a spring-element that allows rotation but not the translation. Thereby it is possible to avoid a hyperstatic reaction of the lower prestress. The spring-element gets deactivated when the joint of the two beams is concreted. This is realized by a shorter beam element of 10 cm between the two beams with a higher group number.

Additional loads had to be defined for the weight of the launching gantry, a provisional live load, dead load and also for the tensioning of the tie rods. This tensioning was realized by an additional strain in axial direction which corresponds to the jack movement.

6 RESULTS

In the analysis with the ‘Construction stage manager’ it was possible to calculate the resulting forces for the different stages and to realize a stress check for the arch segments and the superstructure.

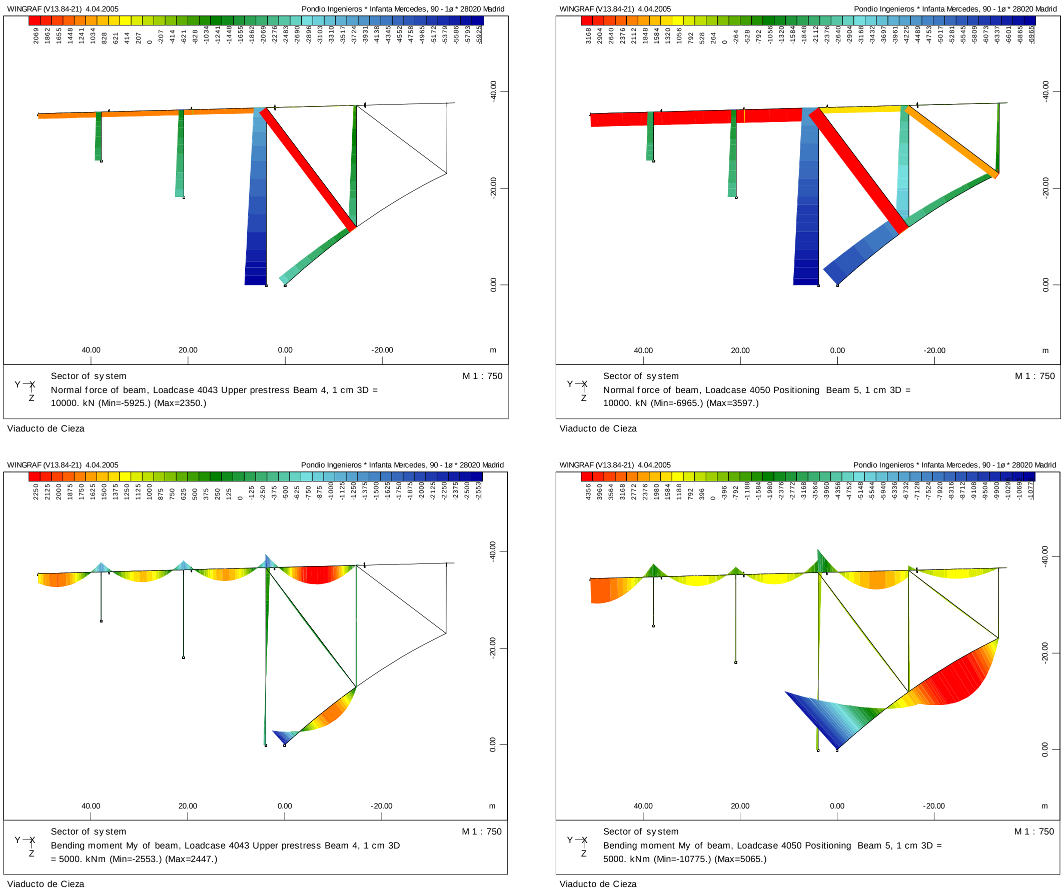


Figure 15. Axial forces and moments for self weight evolution

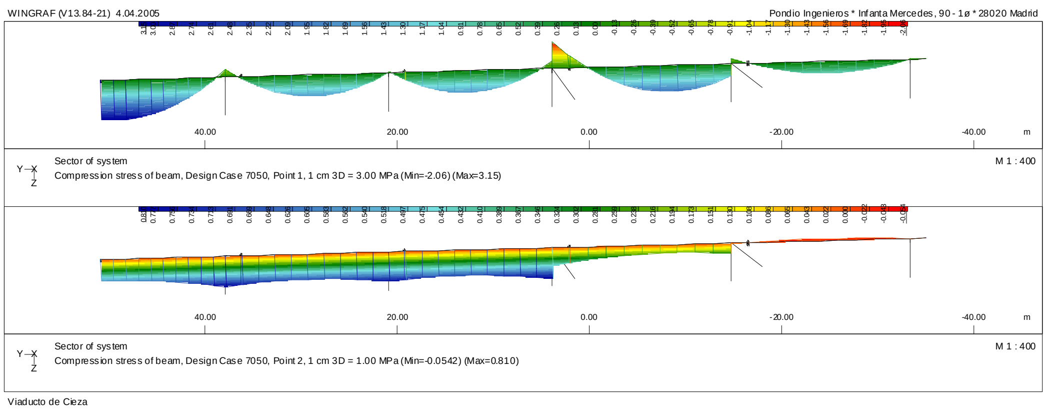


Figure 16. Tensions in bottom and upper edge of precast beam for self weight evolution

Figure 17. View of Cieza viaduct

7 LITERATURE

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