CONSTRUCTION OF A 55-METRE SPAN STEEL ARCH BRIDGE WITHOUT USING CRANES, SCAFFOLDING, FALSEWORK OR TEMPORARY STRUCTURES

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SUMMARY

The “Santa Maria Picula” bridge is located in central Mexico in Santa Maria Picula, San Luis Potosi, Mexico, in the eastern mountains of Mexico(¨sierra Madre Oriental¨)spanning over the “Rio Claro”. Some problems faced at the construction stages were: a) Due to its localization, access was almost impossible for heavyweight (+ 6 meters long) trucks. Construction of a temporary road or widening the existing one, dramatically increased the bridge cost due to characteristics of the zone like big mountains, cliffs and stream flows. b) The river couldn’t be affected in any way, so the use of scaffolding was not an option for the construction procedure. c) The construction budget was limited, and the use of the local labor was mandatory. This paper describes the construction procedure used to build the arch bridge lowering the building price without sacrificing the structural integrity.

Keywords: *Steel arch bridges, arch bridges, construction arch bridges, bridges.*

1. INTRODUCTION

In the last years many important and big bridges like Hardanger bridge opened in 2013, Yi Sun-Sin bridge opened in 2012, Baluarte bridge opened in 2012, have been designed and constructed, competing for records as the longest, tallest and also for their technologic implementations. But what is important and valuable? It is not as valuable the bridge that allows the communications between two small villages, where people die because the lack of a bridge on rainy seasons as the bridge spanning to reduce the time of arrival in a big city?

Due the vast Mexican territory (1’964,375 km^2) and the diversity of its topography the construction of the infrastructure becomes difficult and expensive.

In 2011, Mexico had 141361 (37.8%) km of paved roads and 232901(62.8%) km of unpaved roads, from the last one, nearly 64 % are improved roads, 3.7% tertiary roads and 32.33% dirt roads, 34.7% belongs to highway roads, 45.2% to rural roads and 20.1% to dirt roads [1].

As seen in the numbers the construction of new bridges is often done where the access is difficult and expensive. Beside the numbers, most of the times the Mexican practice is to build the bridge before constructing roads leading to a more difficult building scene.

2. DESCRIPTION

The "Santa Maria Picula" bridge is a 110 m bridge length composed of four spans, 15, 20, 55 and 20 meters. The 55 m span is a deck arc with open spandrel and the other three spans are steel I type girders with concrete deck. The clear rise of the arch is 15 meters. The main girders carrying the concrete slab are connected to the arch by I type beams (Fig. 1). The bridge is located in central Mexico in Santa Maria Picula, San Luis Potosi, Mexico, in the eastern mountains of Mexico (¨Sierra Madre Oriental¨) spanning over the "Rio Claro" river, one of the most important rivers in the Region, which connects with the Amajac river.

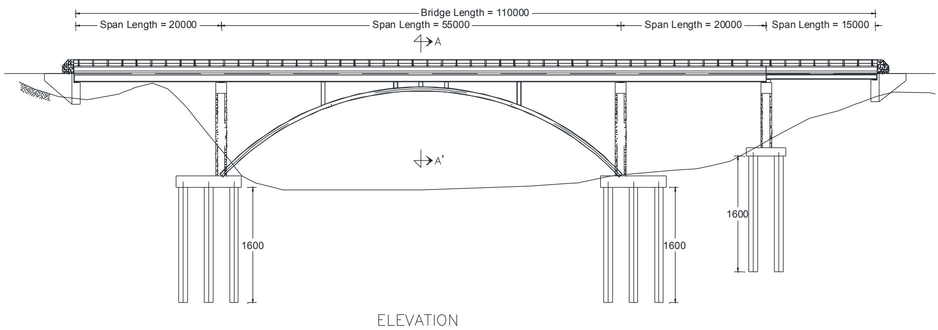

Fig. 1. *General view.*

The arch is formed by 4 arch ribs of I type beam, each one composed of three plates, both flanges are 319 mm wide and 41.4 mm thick, the web is 23 mm thick and 502 mm depth, all the plates have a Fy = 345 Mpa. The open spandrel columns are I type beams (W 533.4 mm x 247.30 kg/m) and the main girder is a composed section with an I beam (1016 mm x 272.70 kg/m) (Fig. 2).

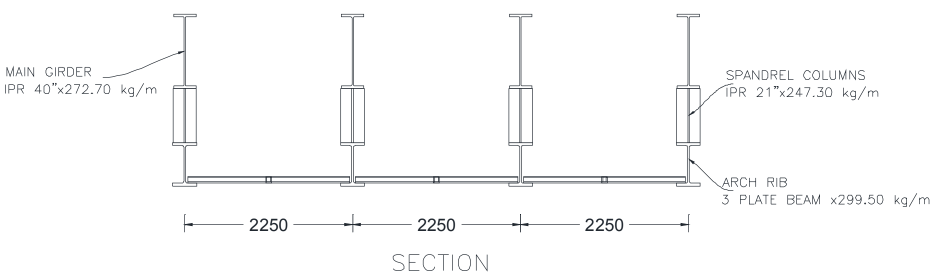

Fig. 2. *Section at midspan.*

The substructure of the bridge has 3 elliptic hollow columns with 9000 mm in the major axe and 2000 at minor axe, over a pile cap settled on nine 1000 mm diameter piles with a length of 16000 mm.

3. CONSTRUCTION METHOD

Due the topographic problems, it was impracticable to introduce big cranes to the site. The path to the bridge was full of narrow and tight curves, being impossible to drive with a truck no longer than 6 meters. So the use of big cranes only was allowed if the path was modified, increasing the total cost of the bridge. Besides the not use of big cranes problem, the assembly of the bridge should be done completely at site.

Several known methods of arch bridge construction such: Melan scaffolding, cantilever construction, swing, scaffolding, were investigated leading to the use of cranes and the widening of the path, and again raising the price of the bridge. All these construction methods are very well developed, becoming economical and safe for the long span bridges, but not for small and medium size. This new used method was mainly idealized to help reducing the construction procedure costs, and the future application of it to small and mid-size steel arch bridges.

The construction procedure is as follows:

1. The construction of the sub structure (piers, abutment, foundations) must be completely finished.
2. The first part of the arch rib, approximately 6000 mm, will be collocated at cantilever, with about 1000 mm embedded at the foundation (Fig. 3).

Fig. 3. *Start of the arch ring embedded on the foundation.*

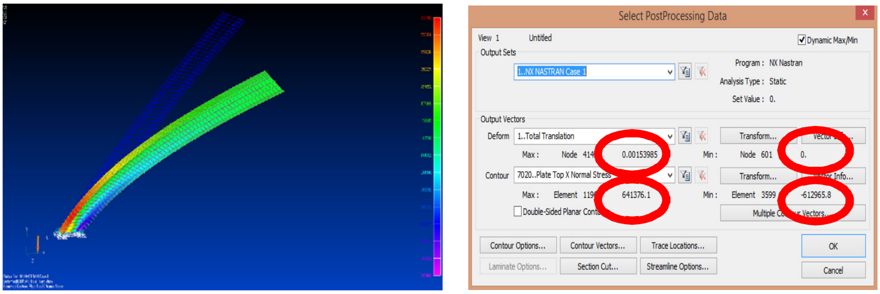

Fig. 4. *Finite element model of the 6000 mm arch ring embedded in the foundation.*

3. Due the problems with the path to the site, the beams where translated with a 6000 mm long. They were assembled and welded at the site to form the main beam with a 55000 mm span. The whole process was done while the construction of the sub structure was done. The girders that will carry a reinforcement concrete slab were assembled by pairs to prevent lateral bending while launching. The two beams were linked by square tubes like diaphragms. The beams were positioned over rollers, which will allow the easy movement of the girders (Fig. 5).

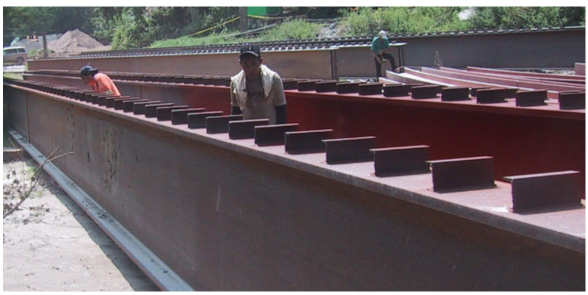

Fig. 5. *Main girders been assembled.*

4. To prevent a possible fall of the beams a couple of 25.4 mm cables are collocated along the spans, and embracing the abutment at the opposite size where the main girders are being assembled. these are safety cables, that are able to carry the main girders. These cables also serve as a guide for the girders when they pass the half of the length and start to have inclination caused by the self-weight. The cables pass through a device collocated at the end of the beam (Fig. 6).

Fig. 6. Colocation of the safety cables along the span to prevent a possible collapse of the main girders.

5. Two truss tower with a height about 2500 mm are positioned at the top of the column located at the opposite side of the main girders, these towers will carry a pulley that will be connected with another pulley collocated at the nose of the main girder. A 25.4 mm cable will be located between the two pulleys with one end at the pulley located at the girder and the other end located on a tirfor that is located and braced at the opposite abutment (Fig. 7).

6. With the use of the manual tirfor winch, the main girders located over rollers are moved until they reach the pile where the truss towers are located. They are located over the bearings at their final position. The movement of the 55000 millimetres takes about 12 hours. On the opposite end of the girder another cable is located to a pulley. This cable is a clamping cable that retains the beams not allowing them to move rapidly, especially when the girders are inclined (Fig. 8).

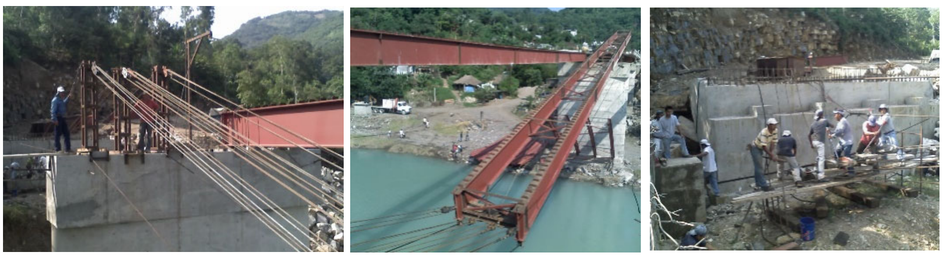

Fig. 7. *Truss towers with a pulley, one end of the cable is located at the nose of the beam and the other end is being pulled by a tirfor. The tirfors are braced at the abutment, which serve as a dead anchor. Here the labour is the motor of the process.*

Fig. 8. *The girders are located over rollers that allow the movement, the girder are pulled till they reach the pile with the truss towers.*

7. Once the main girders are at the final position, are used like a travel crane. The rest of the arch pieces with a 6000 millimetres long approx. are lifted from both ends of the span and moved to the correct position at the arch with the help of a trolley pole. When the piece of arch rib is at position it is welded with the rest of the cantilever arch. All this process was analysed by finite element analysis (Fig. 9).

Fig. 9. *The girders are used as a travel crane and with the help of a trolley pole the rest of the arch ring pieces are moved through the span.*

8. The last arch rib piece is located and the arch now is closed, now it acts like an arch structure.
9. The self-weight acting at the main girders produce camber. With the help of hydraulic jacks positioned at the crown of the arch the camber is counteracted and steel columns are collocated between the arch and the main girders (Fig. 10).

Fig. 10. *The camber is counteracted using hydraulic jacks, the positioning the spandrel columns.*

10. The final step is to collocate the reinforcement concrete (Fig. 11).

Fig. 11. *Final stage, the concrete slab.*

All the elements (except tirfors) used for the launching of the girders and the collocation of the arch are made by the workers, facilitating and cheapen the repairing process of them.

The deformations produced on all the steps mentioned above were controlled using a total station with a laser. From the colocation of the cables to the measure of the camber.

All the deformations were compared to the once obtained in a mathematical model. The models were done on the STAAD.pro and FEMAP\ NASTRAN software using plates with a finite element analysis (Fig. 12).

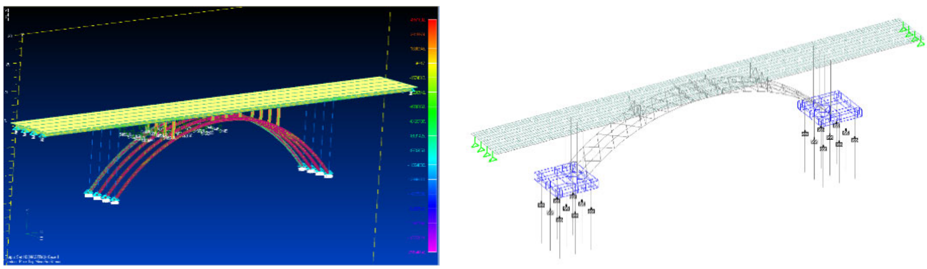

Fig. 12. *Left model with 109909 nodes, 40 beam type elements and 106876 plate elements. Right model with 2723 nodes, 2759 beam type elements, 1900 plate elements and 42 solid elements.*

Fig. 13. *Santa Maria Picula bridge.*

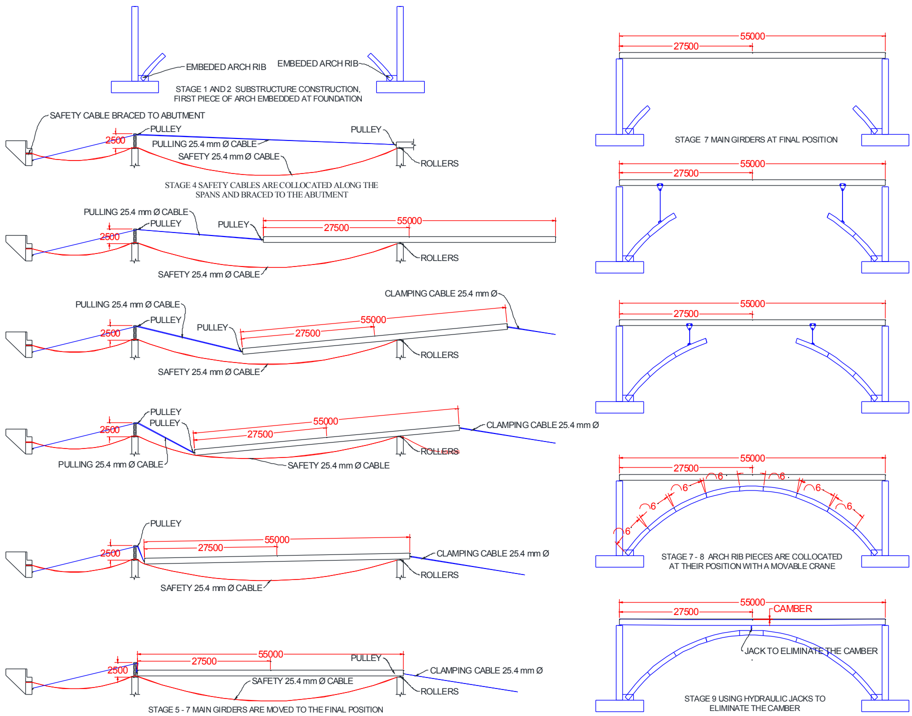

Fig. 14. Graphic construction stages of the method.

4. CONCLUSION

The methods of construction considered by the Ministry of transport in Mexico are: scaffolding, cable stayed cantilever, cantilever and the swing. [2]

The total construction cost was reduced to the half by using this procedure rather than the traditional methods. This leads to the use of steel arch bridges in small or medium span without location problems or path problems. The local labour was used and trained to be welders, moulders and metal workers.

Besides the learning, must of the villagers were involved somehow at the bridge construction, feeling that the bridge belongs to them. They learned to care the bridge.

Expecting this process to be used, promoted and added as a new construction method.

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