Multi-Span Large Bridges – Pacheco & Magalhães (Eds.)

An innovative system of precast segmental span-by-span construction for span lengths of above 100 m

J. Muñoz-Rojas, S. Fernández & C. Iglesias
Carlos Fernández Casado S.L., Spain

P. Pacheco, H. Coelho & A. Resende
BERD, Porto, Portugal

ABSTRACT: An innovative solution has been jointly developed by the companies BERD and CFC in order to push the limits of the span-by-span construction with precast segments to values above 100 m, which are to date exclusively in the realm of the balanced cantilever systems.

The particularity of the proposed erection system is that, in order to reduce the weight and length of the launching gantry, the construction is performed in two stages. In the first stage, a 1/2L portion of the deck is erected by extending the precast segments symmetrically on either side of the support section in symmetrical cantilevers which are then prestressed with a set of cables located in the upper slab. Next, the gantry places the central segments that are connected to the parts already built with another set of prestressing cables located in the lower slab.

The paper presents two cases for which this system has been proposed, a 3.5 km long viaduct in Cartagena (Colombia) with a classical parabolic variable-depth PC box section and 102 m long spans, and a 10 km long viaduct in India with a 124 m long extradosed structure.

1 INTRODUCTION

Prestressed concrete construction with precast segments is a very competitive solution for large and medium span viaducts. Segments may be assembled either span-by-span or applying the cantilever method. In the former case launching gantries can be used; alternatively, should the conditions underneath the deck allow, segments may be laid on provisional supports. Launching gantries can also be utilized when cantilever method is applied; other options include using hoist frames placed at the advance end or erecting the segments by means of cranes from below in case the conditions underneath the deck should allow this procedure.

We will now focus on the launching gantries system: this is the solution providing the best of performances, regardless of the conditions underneath the deck, while at the same time allowing easy access to the advance forefront of the installation. The maximum lengths of the span-by-span solution or those of the cantilever method are obviously determined by the capacity and cost of the auxiliary assembling machinery.

The usual equipment that can be found nowadays on the market places the current cost-efficiency range of the span-by-span construction around 50 m in competition with in-situ construction with a movable falsework. In the cantilever method solution, however, where only one or very few segments that need to be suspended at the same time, the spans are therefore larger, ranging about 70–90 m and even reaching over 100 m in some cases already put into practice.

As with all productive activities, technological evolution and industrial competition tend to inexorably and constantly push or modify the existent limits further. One of the systems that emerged in recent years and opened the door to such developments is the OPS system of the firm BERD. By using active prestressing in the launching gantry, the systems allows the reduction of need for steel in the metallic structure of the girders. At the same time, among other advantages, it provides a more effective and active control of the deformation during the assembly process.

Figure 1. Cantilever and span by span segmental construction with launching gantries.

In cooperation with BERD, CFC has explored the application of this system to different projects carried out with precast segments and built span-by-span, with special spans or requirements.

The first of these experiences was the New Pumarejo Bridge in Barranquilla (Colombia). In this case, span-by-span construction was envisaged for the approach viaducts. This case is extraordinary not only because of its typical span (70 m) but also because of the heavy load that is to be supported by the girder, given the exceptionally wide deck (38 m). Comparative studies showed that this proposal was cheaper than the cantilever method or the in-situ construction with a movable falsework.

The second experience presented in this paper explores the potential of the system for tackling large spans, as long as 125 m, built to date by applying only the cantilever method (L > 80 m).

The solution reached is an intermediate assembling procedure half-way between the cantilever method and the span-by-span construction. It is the result of a compromise between the pursued goal of achieving assembly pace and performance similar to the span-by-span method as well as reaching an optimal equipment cost.

2 PROPOSAL FOR THE “GREAT VIADUCT” OF CARTAGENA DE INDIAS (COLOMBIA)

2.1 *Project description*

The first application of the system was developed in cooperation with the firm OHL for the public tender called for a large viaduct in Cartagena de Indias (Colombia). This is to be a viaduct 3.5 km long, with over 30, 102 m long spans.

The deck cross section is a conventional box girder of a variable depth, 5.10 m deep at the supports and 2.40 m deep at midspan. The box girder’s upper slab is 11.70 m wide, while the lower is 5.80 m wide. To optimize the equipment and the segment handling elements, the cantilevers are to be executed in a second phase, one or two spans out of sync with the advance forefront.

2.2 *Description of the planned execution procedure*

The central question here was to find a solution to execute a deck of nearly 50.000 m^2 in a project where the spans were originally to be built applying the free cantilever method with in-situ segments. However, the deadline was an important factor given that we are dealing with a concession contract. The advantages of the industrialization involving prefabricated construction quickly proved to be the most suited solution. Since the overall span was impossible to modify, we had to think of a solution to span the 102 meters as efficiently as possible.

As mentioned above, the execution of one span is carried out in two phases:

- In the first place, a symmetrical “T” is built from the pier, with cantilevers whose length amounts to $^1/_4$ of the span.
- The central portion is then completed with the remaining segments, which are connected with one cantilever on either side.

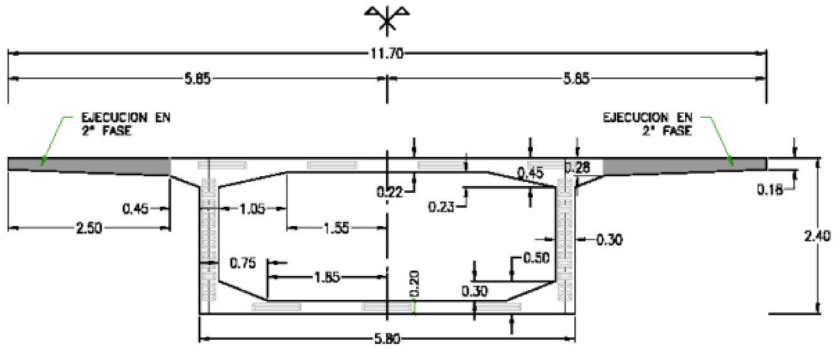

Figure 2. Typical cross section.

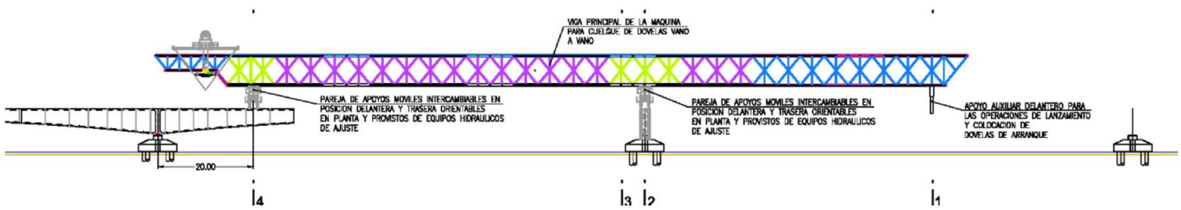

Figure 3. Elevation of the launching gantry.

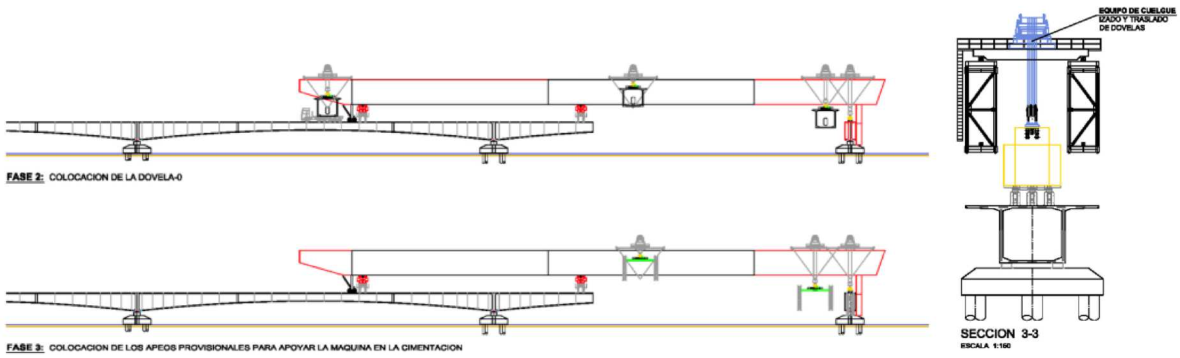

Figure 4. Erection of starting segments.

The segments are put in place by means of an upper, lattice launching gantry whose length is approximately 1.5 times that of the span. Given the features of the project, the gantry is supported at the front directly on the foundations, while in the back it rests on one end of the previously built cantilever. To optimize the prestressing of this segment, the support is carried out 20 m away from the pier axis.

The launching gantry has a couple of binary supports at the front end, used exclusively during launching operations.

The segments are lifted from the already built deck by means of hoisting units and are thereupon brought to its definitive position with the help of a winch that passes along the upper chord. They are finally suspended by adjustable elements.

2.3 *Detailed sequence*

The building sequence of a span begins by placing the girder, supported at its front, binary supports. The initial segment is then built upon the pier. This segment is the one that has the greatest depth, so in order to lighten its weight its length is reduced to 3.0 m. For the same reason the concreting of the inner diaphragm of this segment is carried out in a second phase, once it is installed in its definitive position.

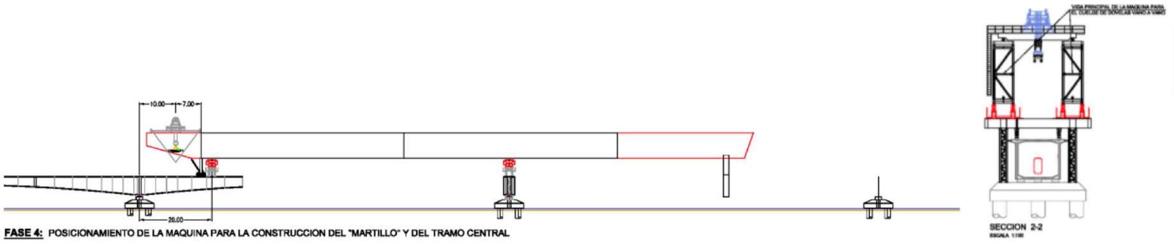

Figure 5. Working position of the launching gantry.

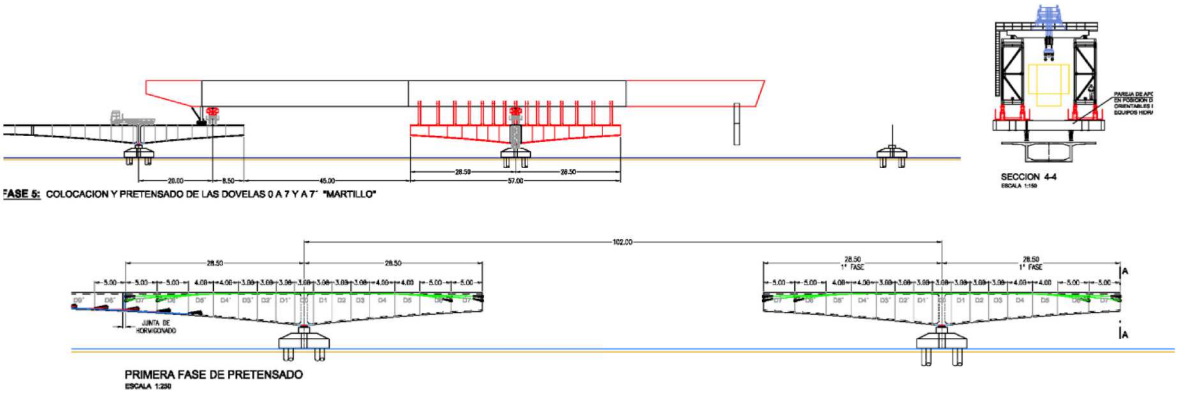

Figure 6. First stage. Erection and prestressing of segments near pier.

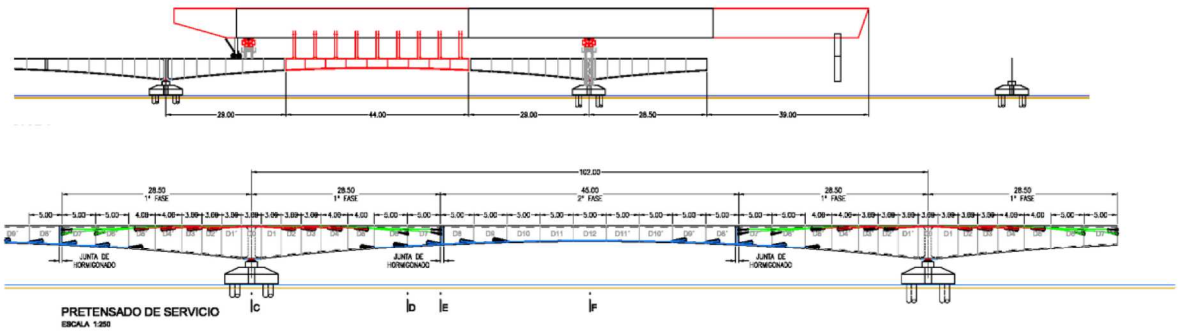

Figure 7. Second stage. Erection and prestressing of mid-span segments.

– Once the deck girder is placed the launching gantry is moved forward and placed on definitive supports in order to build the segments that rest upon the front foundations and upon the rear cantilever of the already built deck.
– The remaining segments are then placed in the following, two-phase sequence:

  In the first place, a "T" symmetrical to the piers is built with cantilevers 23.5 m long (7 segments). These segments are connected using a first set of upper cables.
– The rest of the central segments are built thereafter (11 5.0 m segments). It is at this point that the greatest stresses at the rear end of the cantilever are produced due to the support given to the device from which the segments are suspended. The prestressing installed in the previous phase is designed so that it may adequately endure this.
– Once the segments are in place and the geometrical adjustments performed with the help of two, in-situ, 0.50 m joints on either end, the second phase of prestressing cables installation begins. This phase is made up of two sets of cables, those located in the lower slab, which connect the central segments, plus an additional set of upper cables at the sections close to the piers whose function is to provide a reserve of additional compressions in these sections to help resist the final loads of the structure.

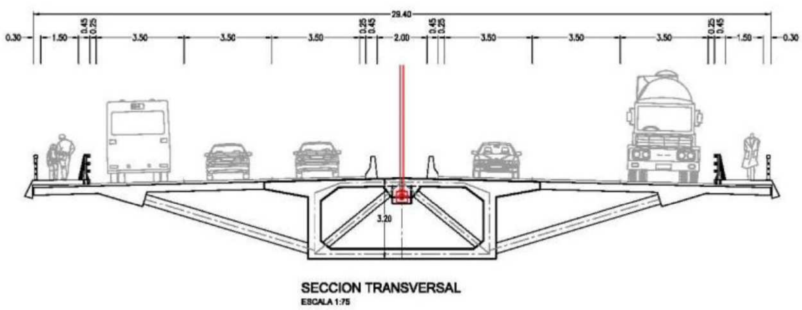

Figure 8. Typical cross section.

2.4 *Technical details*

Great Viaduct (lenght 3.5 km, span 102 m). Cartagena de Indias. Colombia. Project CFC-BERD/OHL Building Contractor. (Gonzalo García-Villalba, Mauricio Aguirre). 2014

Main deck values:

Concrete 0.66 m^3/m^2
Prestressing: 33 kg/m^2
Passive reinforcement: 125 kg/m^2

3 PROPOSAL FOR "GREEN FIELD SIX LANE EXTRADOSED CABLE BRIDGE"

3.1 *Project description*

The second project in which the application of this construction procedure was studied was an extremely long-span viaduct, almost 10 km long, over the Ganges for an international call for tenders, which is currently suspended. The required modulation dictated 123.5 m long spans along the entire viaduct, to be carried out with an extradosed stay-cables.

In this case, the great width of the cross section, 29.40 m, made us propose a two-phase execution. The first phase consisted of the execution of the central core with prefabricated, match-cast segments with epoxy-filled joints, while the second phase contained the building of the lateral cantilevers made up of in–situ slabs supported on struts.

From the point of view of the longitudinal configuration of this civil work, it is divided into 8 separate structures. On each stretch the deck is built-in at the two central piers in order to resist longitudinal actions, whereas in the rest of the bridge it is left unrestrained with the help of sliding bearings while transversely fixed at the piers.

Each stretch that begins at a pier consists of one initial segment, 3.50 m long and 12 5.00 m long segments. The 9 central segments are axially cable-stayed to a 15 m high tower. The configuration of the cable-staying is extradosed. This allows constant depth all along the deck in spite of the 123.5 m long span. The cast is, therefore, one and the same for all the segments of the entire bridge.

3.2 *Execution procedure description*

There were two main guiding ideas in the design of this viaduct, almost 10 km long and 30 m wide, is to be built:

- Firstly, the section dimensions have to be divided into small parts, mutually as independent as possible, in order to be built independently and minimize the critical path.
- Secondly, a maximum prefabrication must be achieved.

This is why we decided to apply a two-phase procedure similar to the one developed in the previously described project: a precast segmental construction performed span-by-span with a t

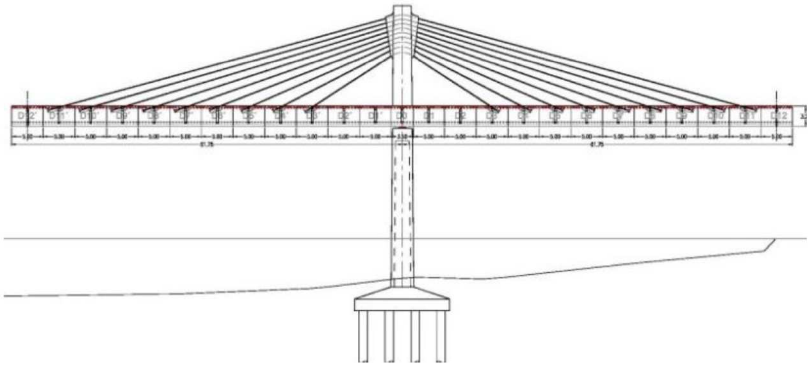

Figure 9. Elevation of typical span.

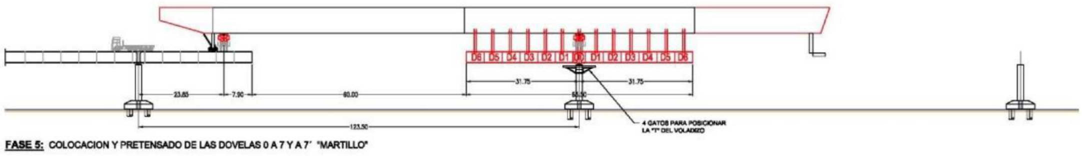

Figure 10. First stage. Erection and prestressing of segments near pier.

launching gantry as light as possible. In a first stage symmetrical cantilevers beginning at the pier are erected. Thereafter the construction of the central part is done.

The box girder is optimized in order to lighten its weight, bringing it down to a width of mere 11 m. Once the continuous girder with this central core is put in place, the lateral cantilevers are concreted resting upon prefabricated struts.

The most innovative aspect introduced in this project is the way of compensating the tensions of the segments' joints during construction. In an extradosed bridge the required compressions levels are provided by the combination of prestressing cables and the extradosed cable-staying system, which also evens out a portion of vertical reactions through the cables' slant. The customary procedure in these bridges is to gradually compensate the loads from the start by means of stay cables applying the free cantilever method aided by the prestressing. Thereafter, once the structure is completed, the remaining prestressing cables are installed and these contribute to resist the rest of the dead and live loads that will act upon the structure.

In this work the roles of the cable-staying and the prestressing are inverted. This big advantage facilitates both the execution of the tower and the installation of the stay cables without slowing down the cycle. The weight segment central core and the reactions of the launching gantry during erection are compensated by conventional prestressing, Once the continuous girder with the segment core is placed the remaining self-weights (lateral cantilevers resing upon prefabricated struts) and the dead load are resisted by the stay cables.

3.3 *Detailed sequence*

- Launching of the metallic scaffolding, hanging of the segments and their assembling in groups of 13 at the symmetrical cantilever of the front pier. As an approximate order of magnitude, the average weight of the segments is about 125 T.
- Prestressing of the segment group of the front pier's "T" at the advance forefront.
- Hanging and assembling of the segments in groups of 6 as the current span completion is accomplished.
- Prestressing of the segment group as the current span completion is accomplished.
- Shifting of the scaffolding to the following span. Return to point 2, and repetition of the operations of segment launching and hanging 80 times until completing the structure.

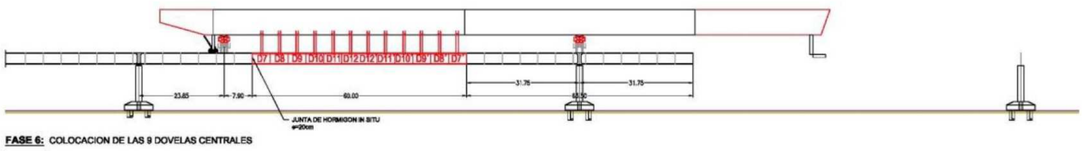

Figure 11. Second stage. Erection and prestressing of mid-span segments.

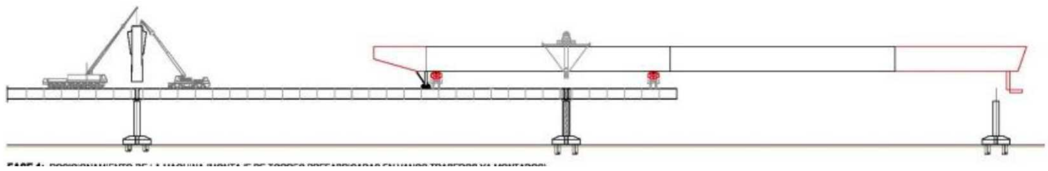

Figure 12. Third stage. Erection of prefabricates pylons.

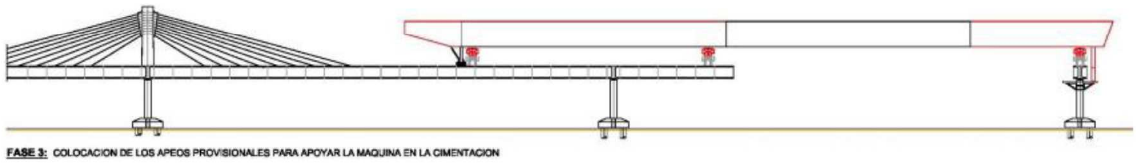

Figure 13. Fourth stage. Installation of stay cables.

- Transport and assembly of the extradosed cable-staying towers utilizing a crane. The towers are 16 m high and their weight is 150 T.
- Cable-staying (phase 1) of the deck portion composed of the central core.
- In-situ construction of lateral cantilevers with transverse form travelers.
- Cable staying (phase 2) of the deck portion composed of the complete cross section.

3.4 *Technical details*

Green Field Six Lane Extradosed Cable Bridge near Kachhi-Dargah on NH-30, close to near Bidupur in Dist. Vaishali on NH-103 (project currently suspended).

Project CFC-BERD/ISOLUX. (Javier Encinas, Pedro Vizeu). 2014

Main deck values:

- *Concrete 0.68* m^3/m^2
- *Prestressing: 33* kg/m^2
- *Stay cables: 7.1* kg/m^2
- *Passive reinforcement: 120* kg/m^2

4 CONCLUSIONS. ADVANTAGES OF THE SYSTEM

The described system for span-by-span construction with prefabricated segments in two phases differs from the usual span-by-span procedure construction. However, this solution enables the tackling of such spans as have to date only been built applying the balanced cantilever system. The advantages of this innovative solution can be summarized as follows:

- Lower investment in launching girders given the shorter span to be loaded in each phase (less structural steel, length reduction).
- Greater approximation of the sectional forces in the structure during construction to those produced in the definitive structure with the resulting optimization of the prestressing amount and distribution.

– Greater geometrical control during assembly. This is due to the fact that, on the one hand, the system allows to correct the alignment of the initial "T" , and on the other, adjust the assembling of the remaining segments by way of two closing joints.
– The two-phase sequence does not affect the cycle significantly. According to various studies, one span can be built in seven days in the case of the Cartagena viaduct (102 m long span), while in the case of the extradosed, 125 m long bridge, the pace of two spans in three weeks can be accomplished.

REFERENCE

Pacheco, P., Coelho, H., Resende, A. , Soares I. 2014. High productivity in bridge construction – the OPS effect. *9th International Conference on Short and Medium Span Bridges, July 15–18 2014*. Calgary, Alberta, Canada.