

LARGE MOVEABLE SCAFFOLDING SYSTEM

This is a project where an innovative post-tensioning technology is applied to the construction equipment itself, increasing the worldwide state-of-the-art limits of post-tensioned, in-place, span-by-span deck construction (Fig. 1).

It is known that to achieve optimized bridge decks, it is fundamental to ensure an adequate construction method plus bridge design-integrated solution.

Until now, most bridges with spans ranging from 245 to 310 ft (75 to 94 m) were erected with steel decks, with the free cantilever method (precast or in-place) or with the precast full-segment method. In several countries worldwide, steel decks were and still are systematically adopted.

Published studies¹ prove that cast-in-place, span-by-span post-tensioned deck erection is a construction method which, due to the continuity of the main girder in several spans, enables strong reduction of flexural moments during the construction stage. Several advantages emerge from this—geometric control is simplified, creep effects are less relevant, among others. Additionally, this method allows the reduction of a facility's needs and the dependency of accesses—so critical in several urban projects. Until 2016, the state-of-the-art of this method was limited to spans up to 257 ft (78 m), or less.²

There was a critical issue to overcome mentioned in regards to the state-of-the-art span limit: until very recently,

the weight of large scaffoldings used to erect span-by-span, cast-in-place decks was too heavy—thus, strongly conditioning the bridge design itself and becoming anti-economical. That was verified, for example, in a study on a bridge erected in Germany in the 1970s, where a large, heavy, movable scaffolding system (MSS) was used.³ Although the technical performance indicators on this experience were clearly positive,⁴ according to available knowledge, in the nearly 40 years that followed, such a magnitude of multi-span viaducts was never repeated. Eventually, the reason for this is related with the MSS weight (which was approximately 2200 tons [2000 metric tons]).⁵ It is very probable that the magnitude of such equipment weight implied high equipment costs and, indirectly, the high cost of the structure materials (high consumption) because this equipment weight would surely influence the bridge design itself. As mentioned before, a few years later, a study was published in which the economic indicators of that very project are stated, thus concluding that such an MSS application was not economically efficient.³

During the first decade of this century, the author was part of a team that developed an innovative, actively controlled post-tensioning technology which proved to enable a significant reduction of the MSS's weight (among other features).^{6,7} In 2011, the first studies on the application of this technology to larger movable scaffoldings were



Fig. 1—Large moveable scaffolding system.

performed.⁸ In this technology, the jack becomes, itself, part of the scaffolding structure and is controlled by a PLC. The PLC receives signals of the scaffolding deformation during the placing operation. These signals are given by sensors strategically located in the scaffolding (Fig. 2).

In 2014, an R&D project (present Project) was started to deeply study the application of mentioned technology to large movable scaffoldings systems (LMSS). In that very year, a project involving four high-speed railway viaducts was identified in Turkey, where a surprising amount of materials consumption reduction was predicted if the new technology was applied. The original design of the four viaducts was predicted for the cast-in-place free cantilever method.

The extension of the four viaducts is 3.9 miles (6.3 km) and the construction area is a little more than 850,000 ft² (79,000 m²).

The Project includes four viaducts (V7, V9, V10, and V15) of the Ankara-Sivas HSR Line (Fig. 3). The four viaducts were originally designed to be built by the free cantilever method (in-place). In Fig. 3, the lateral view of one of the viaducts is presented, with several 295 ft (90 m) spans (294 ft [90 m] being the larger spans).

The predicted material savings—more than 35%—were shared with the stakeholders of the Project and in that year, stakeholders took the decision to change the construction method.

The major challenges to ensure the adequacy of the LMSS for the proposed method were:

- In terms of LMSS weight: to ensure that the LMSS was not governing the deck design, a LMSS global traveling mass of approximately 1300 to 1500 tons (1180 to 1360 metric tons) was to be achieved.
- In terms of LMSS main girder midspan deflection: to ensure that the LMSS midspan deflection was lower than $L/2000$ (where L is the span), the use of actively controlled post-tensioning was fundamental.
- In terms of LMSS productivity: to ensure a target working cycle of 14 days (148 ft/week [45m/week])—so as to achieve a better production cycle than what could be obtained with four pairs of form-travelers (100 ft/week = $4 \times 2 \times 12.5$ ft/ week [30 m/week = $4 \times 2 \times 3.8$ m/week])—

in which each form-traveler produces an approximate 12.5 ft (3.8 m) segment per week (considering the original free cantilever method and being 12.5 ft (3.8 m) the approximate average extension of the in situ segments).

- In terms of LMSS stability for wind actions: to ensure that the LMSS is stable and safe, in particular, during the launching stage.

The LMSS project was developed, achieving a global weight within the predicted limits. The equipment was designed to achieve the predicted production cycle and the actively controlled post-tensioning system was tested, assuring deformations below the predicted limits ($L/2000$). Also, wind tunnel tests with a reduced-scale model were performed, ensuring adequate and safe launching operations.

The construction of the first viaduct was started in 2017 and ended in 2018 (Fig. 4 and 5). It was a reliable, simple, and safe operation. All targets were achieved, including the production cycle, which once reached the value of 170 ft/week (51 m/week).

In the end, materials savings were 39%, overcoming the predicted values.⁹

The main aspects of the Project are:

- It is innovative to act on the construction equipment to implement and upgrade bridge engineering and bridge design state of the art; and
- The active control of the post-tensioning applied in the large scaffolding is an innovation itself.



Fig. 2—Actively controlled prestressing jack.



Fig. 3—Viaduct V10 of the Ankara-Sivas HSR Line (Turkey)—lateral view.



Fig. 4— Large movable scaffolding system.



Fig. 5—Large movable scaffolding system.

But more importantly:

- The worldwide state of the art limits of post-tensioned, span by span, cast in place decks has increased from 257 ft (78 m) to approximately 300 ft (91 m);
- This method is much more economical than steel decks with any type of construction method;
- This method enables material consumptions reductions above 35% when compared, for example, with the free cantilever method;
- This method has very low dependency on accesses (as the scaffolding “flies” over the piers);
- This method has very reduced facility’s demands;
- This method is compatible with very slender decks, with aesthetic important benefits; and
- This method enables very simple geometric control—better constructability.

With the present innovation, there is an upgrade on bridge engineering state-of-the-art and in particular in post-tensioned decks state of the art. Certainly one of the post-tensioned constructive methods strongly increases its competitiveness regarding other constructive methods for the span range 245 to 310 ft (75 to 94 m), in particular, when compared with steel decks or free cantilever methods.

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Owner: TCDD

Engineer: Pedro Pacheco

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PT Supplier: Mota-Engil Prefabricados

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