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Progressive Segmental Construction

Construction à l'avancement

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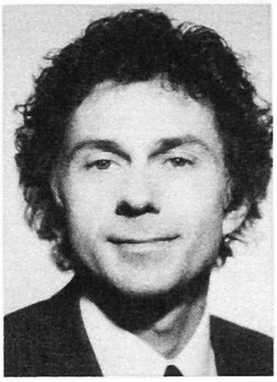

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SUMMARY

This article presents a summary of new methods recently used for construction of bridges. Progressive construction with temporary cable-staying consists in placing precast segments continuously from the first abutment to the last. The span-by-span construction system consists in assembling the segments of each span on a movable truss. It allows a high speed of erection.

RÉSUMÉ

L'article qui suit concerne les nouvelles méthodes de construction récemment mises en œuvre dans le domaine des ouvrages d'art. La construction à l'avancement avec haubanage provisoire permet une mise en place continue des voussoirs préfabriqués les uns après les autres avec un matériel léger. La construction à l'avancement par travées entières est un procédé d'exécution qui peut s'avérer très rapide avec un équipement bien étudié.

ZUSAMMENFASSUNG

Der Beitrag behandelt neue Bauverfahren, die im Bereich des Brückenbaus angewandt werden. Der Freivorbau mit provisorischer Abspannung erlaubt eine kontinuierliche Versetzung vorgefertigter Brückenelemente mit leichten Einbaugeräten. Der fortschreitende Einbau ganzer Brückenfelder kann mit zweckmässigem Einbaugerät ein sehr schnelles Bauverfahren sein.

Precasting of short segments in the field of concrete box girders has been developed in FRANCE for twenty years. Initially used for balanced cantilever erection of bridge decks, segmental construction nowadays offers many possibilities with the more recent developments of progressive placing of segments with or without temporary cable staying and span by span construction.

1. PROGRESSIVE CONSTRUCTION WITH TEMPORARY CABLE STAYING

The method is based on a very simple idea. It consists of placing the precast segments of a deck continuously from the first abutment to the other one (Fig. 1). The stability of the deck is maintained with a set of stays. Already known in the area of cast-in-place bridges, the progressive placement method has been used to build six precast bridges located in FRANCE :

ROMBAS viaduct
(deck area : 7260 m^2 - 274 segments)
WOIPPY bridge (partially)
PIERRE-LA-TRECHE bridge
(deck area : 1030 m^2 - 38 segments)
FONTENOY viaduct
(deck area : 6350 m^2 - 177 segments)
VALLON DES FLEURS viaduct
(deck area : 1160 m^2 - 47 segments)
BANQUIERE viaduct
(deck area : 3450 m^2 - 122 segments)

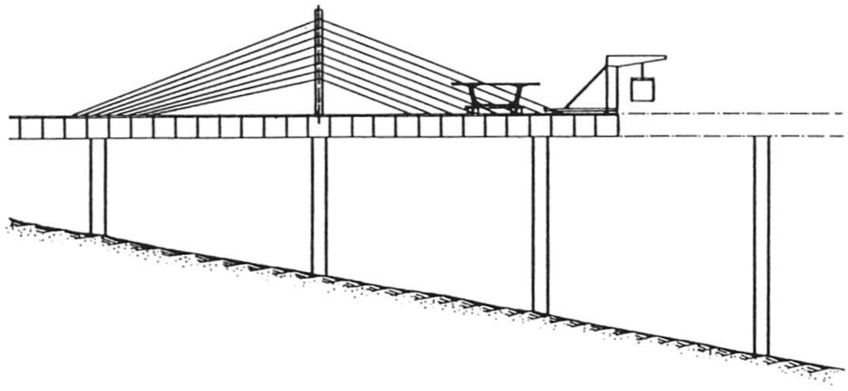

Fig. 1 - Basic principle

1.1. Special equipment

The equipment employed allows placing 3 m high segments over 55.00 m spans.

The lifting device (Fig. 2) which places the segments at the end of the erected part of the deck is 10 m high with a capacity of 50 t. It consists of a horizontal steel arm pivoting around a vertical leg fixed onto the deck. The movable winch system on the arm can lower each segment to its final position.

The mast is 16.00 m high (Fig. 3). It consists of two vertical shafts, transversally braced, fixed onto a base which can be easily moved at the beginning of the construction of a new span.

The temporary cable-stays are arranged in two planes in a nearly parallel configuration for the span under construction and almost converge towards the rear pier so that the bending moments on the previously completed spans are not affected. There are ten pairs of stays going through the mast. The stays are made of 8 strands of 15 mm nominal size anchored in steel blocks fixed onto the top slab.

Fig. 2 - The lifting device

1.2. General procedure of the construction

The first span is generally built on a temporary scaffolding but it can also be built with the same basic principle by using a temporary span at the rear of the abutment (Fig. 4).

When a span is finished, the final prestressing is installed and the construction of the new span begins with the placement of some segments by the free cantilever method. During that short phase the cable stays are removed and the mast is positioned over the last pier. At this stage, each step of the erection of the deck can be described as follows :

- Transported over the finished portion of the deck to the end of the cantilever span under construction, each new segment is placed in its final position with the lifting device (Fig. 5).
- The new segment is held by exterior temporary ties.
- The lifting device is moved to the end of the deck.
- The corresponding pair of stays is added and tensioned.

When the pier segment has been placed over the next pier, an adjustment of the deck level, if necessary, is carried out with the help of hydraulic jacks while the bearings are installed.

After the first prestressing of the new span the structure is ready for the erection of the following spans.

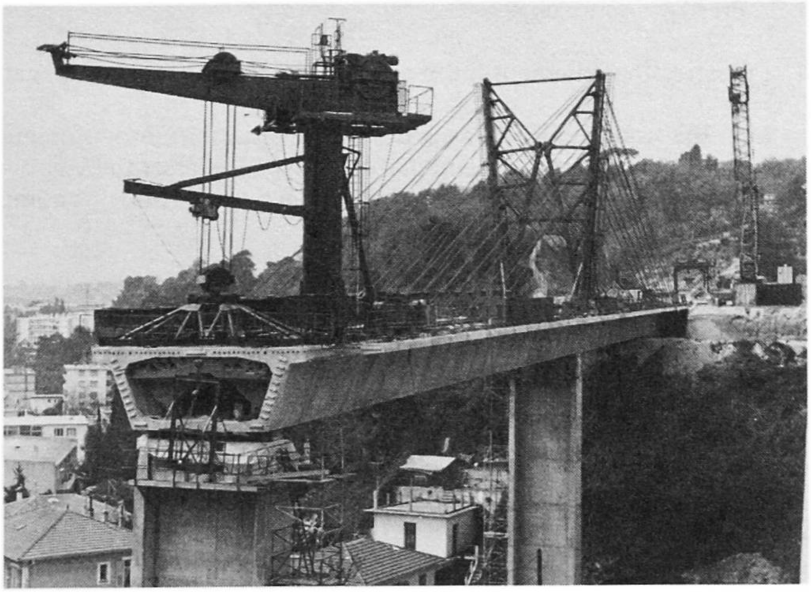

Fig. 3 - The mast and the stay arrangement

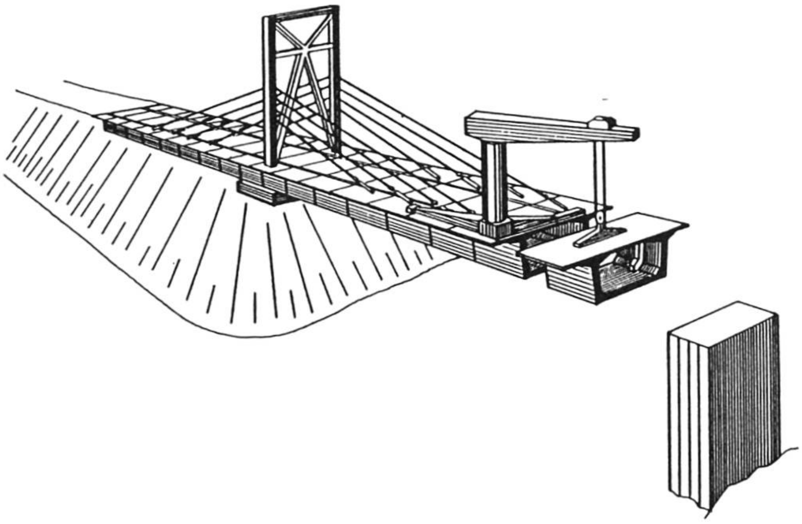

Fig. 4 - Erection of the first span

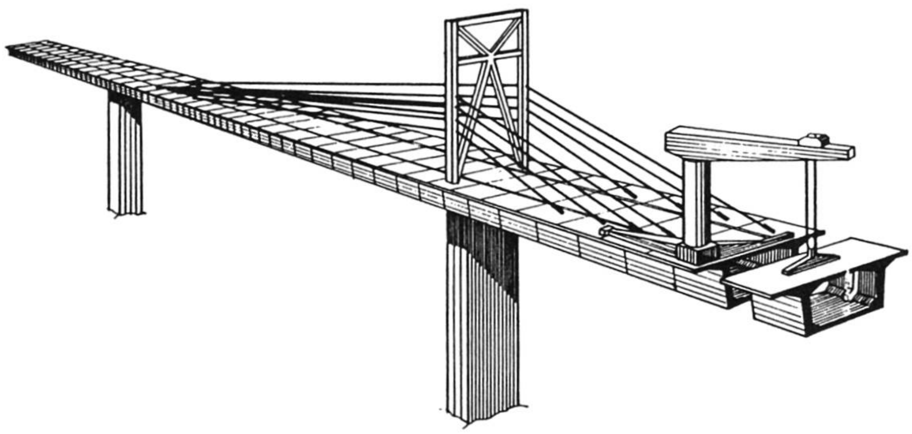

Fig. 5 - Construction of a typical span

1.3. Prestressing scheme

The prestressing scheme is more economical than those used in cantilever construction.

In fact, the stability of the deck during construction, provision and progressive placing of the segments (taking into account the temperature effects) is essentially provided by the temporary stay arrangement, so the prestressing of a total span can be done after its completion.

This means that the tendons just have to run from pier segment to pier segment and, as a consequence, can be easily anchored in the diaphragms ensuring the stiffness of the deck.

Moreover, the prestressing tendons encased in a grouted polyethylene duct, can be located outside the concrete within the void of the box girder, simply deflected in deviation saddles (Fig. 6).

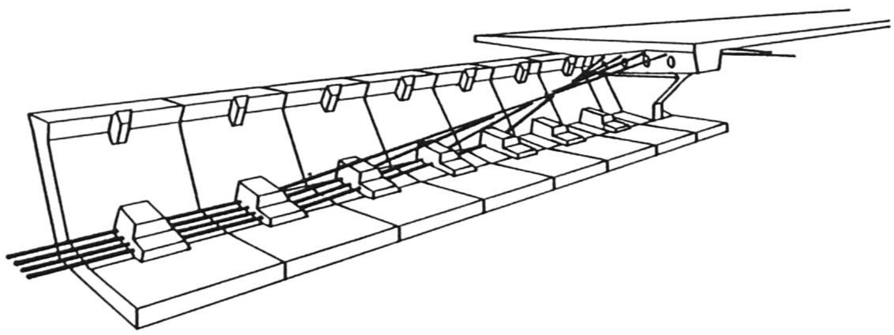

Fig. 6 - Vallon des Fleurs viaduct - External tendons

1.4. Advantages of the method

As seen above, the method allows spanning any kind of urban area and many types of obstacles, roads or rivers (Fig. 7), with a light equipment. It is even adaptable to curved bridges.

All the construction material, components and personnel are provided with a high degree of safety at the end of the deck.

With regards to the quality and the viability of the structure it must be pointed out that the permanent bending moments are those of the entire bridge as though it were cast-in-place since match-cast segments are used over the total length of the deck. There is, therefore, no redistribution of moments and stresses in box girder due to creep effects.

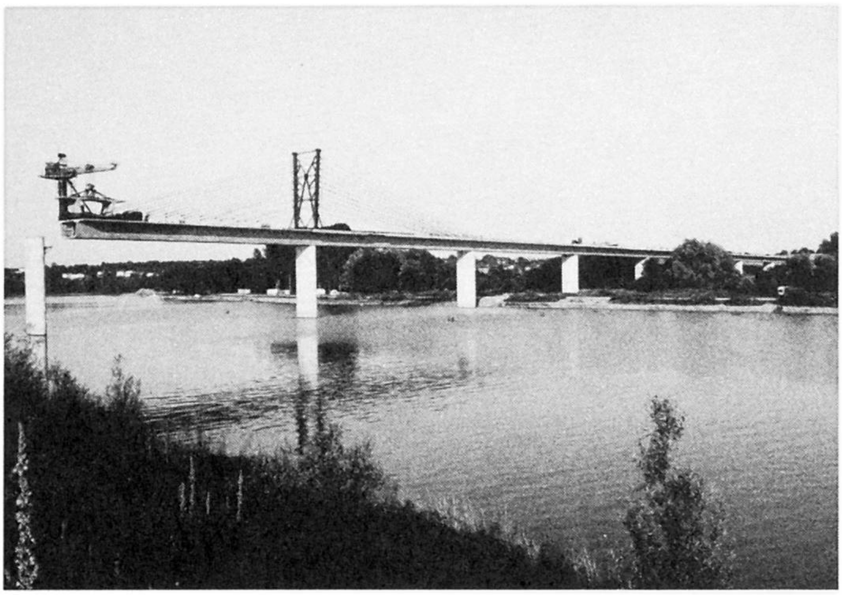

Fig. 7 - Fontenoy viaduct under construction

Finally, the possibility of using a new prestressing scheme of internal stays will provide, in the future, an essential improvement in the design of large bridges.

2. THE SPAN-BY-SPAN CONSTRUCTION

However, progressive placement, segment by segment, does not allow a high speed of erection. From this point of view, assembling the segments of a span on a truss is probably more efficient.

That is why this way of construction has been successfully developed by Mr. Jean Muller for the very large bridges to be reconstructed in the Florida Keys and designed by Figg and Muller Engineers, Inc.

2.1. Construction of Long Key bridge

Long Key bridge (Fig. 8) was the first erected with the span-by-span method. The new 12, 144 foot long structure consists of 101 spans, 118 feet in length and 2 spans 117 feet long. The 38.5 feet wide deck is 7 feet deep. It rests on precast V piers.

The deck area (467,500 s.f) could have justified heavy equipment but a rational use of the water in the Keys allowed minimization. The equipment consisted of three essential components :

- A big floating crane which lifted the segments, moved the erection truss and placed the precast elements in their final position.
- A shuttle barge which transported the segments from the precasting yard to the job site.
- An adjustable temporary steel truss attached to a C shaped lifting hook which supported the six typical segments (360 mt) plus the corresponding pier segment of a span during assembly.

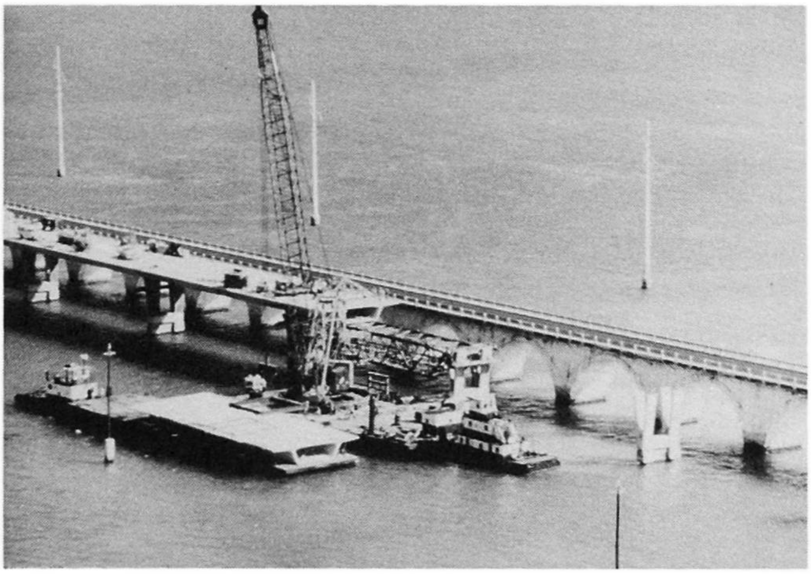

Fig. 8 - Long Key bridge under construction
(Constructor : Michael Construction Company of Florida, Inc.)

The main steps in the construction of a span took place as follows :

- After completion of a span the assembly truss was moved to the following span and rested on the bridge piers.

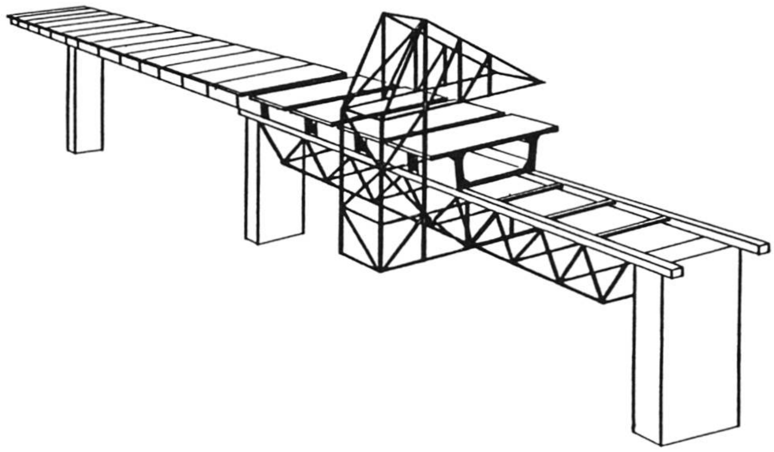

Fig. 9 - Scheme of erection of Long Key bridge

- The segments of the span were placed on individual three point sliding supports (Fig. 9) and simultaneously adjusted into the right position.
- The joint between the previously completed span and the new one was poured ; the post-tensioning was accomplished after the closure reached the required strength and the temporary truss was free for a new cycle.

2.2. Erection of Seven Miles bridge

Although the speed of construction was routinely two spans a week, it was necessary to increase this pace for the construction of Seven Mile bridge. Indeed, this very big structure (total length : 35,800 foot, width : 38'4" - Deck area 1 375 500 sf 266 spans - 2071 segments) was to be built within 3 years ; that is about one span a day.

To achieve this pace the contractor revised the Long Key method and chose to preassemble the seven typical segments before setting the span.

Barges delivered the superstructure elements to the site where they were placed atop a steel lifting frame aboard a shuttle barge. There, the segments were aligned and connected with four temporary strands. Then the assembly barge moved beneath the bridge for placing the span. The pier segment also accompanied the preassembled span. After completion of a span the self launching truss first lifted the pier segment to the top of the next pier (Fig. 11). Resting on this new support, the gantry was launched and finally raised the lifting frame bearing the segmental span from the barge below (Fig. 12). After having placed that portion of span against the pier segment, the closure joints were concreted and the longitudinal tendons fully tensioned.

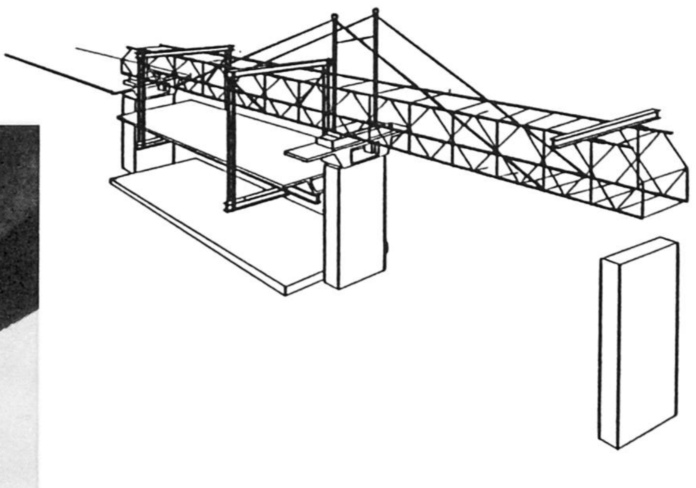

Fig. 11 - Placement of the pier segment

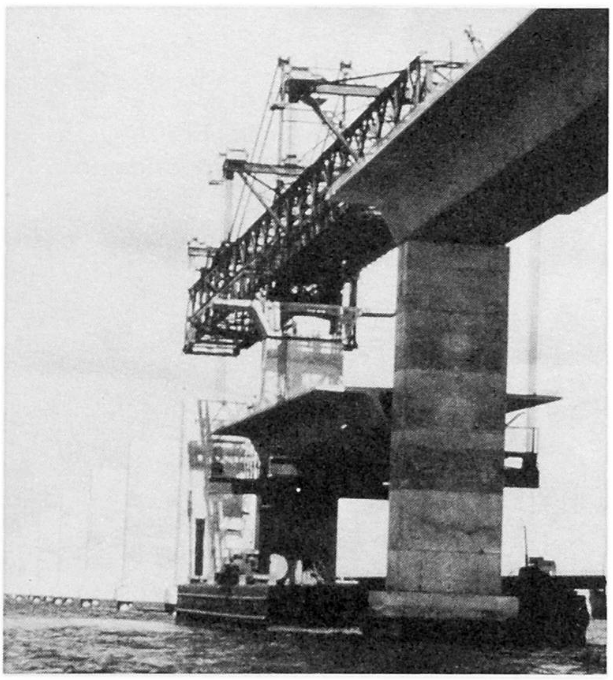

Fig. 10 - Seven Mile bridge construction
(Constructor : Misener Marine Construction, Inc.)

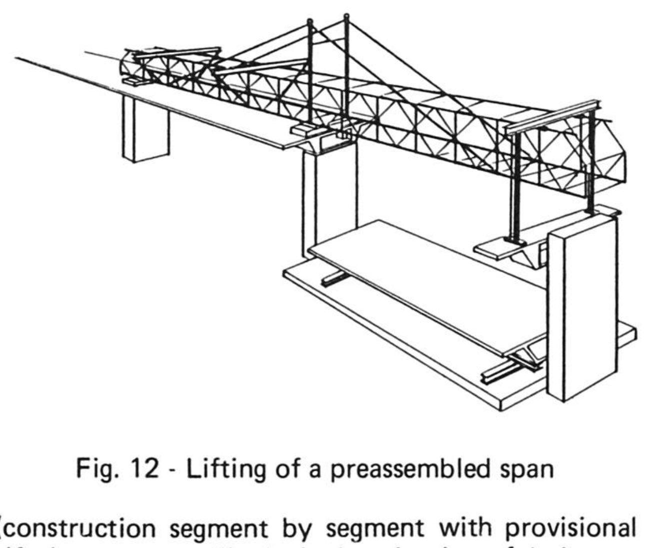

Fig. 12 - Lifting of a preassembled span

2.3. Future trends

These examples show the advantages of progressive segmental construction in terms of simplicity, construction time and efficiency in prestressing.

Already used to solve environmental problems (construction segment by segment with provisional piers) or to build span-by-span from the deck itself, the concept will stir the imagination of designers. It will probably become more and more competitive and provide a high degree of quality to future projects.