METHOD FOR CONSTRUCTING A CABLE-STAYED BRIDGE

The invention relates to a method for building a cable-stayed bridge of the type comprising a deck, at least one tower, and inclined cable stays mounted between the tower and the deck.

Among these building methods, the invention relates more particularly to a method for building a cable-stayed bridge by push-launching its deck.

The techniques of push-launching are well known in the field of bridge building. Successive sections of the deck are constructed or assembled in bridge-side sites, from which sides the bridge is pushed out as progress is made with building it.

In general, as it extends, the deck rests on pre-built bridge piles. A more lightweight cutwater fixed at the front of the deck prevents it from tilting at the start of the pushing, and avoids there being too much unsupported overhang between the piles. When a relatively long distance has to be covered between two piles, the cutwater is no longer sufficient to counter such overhangs.

Document FR-A-2 693 492, discloses a method for building a cable-stayed bridge by push-launching its deck. In that document, the upper portion of a tower is erected on the deck and the cable stays are fitted prior to the pushing-out operation. It is this cable-stayed assembly which is pushed out onto already-built piles, as far as a position in which the upper portion of the tower is over a pile, which completes the building of the pylon.

This method seems to be very tricky to implement. It is ill-suited to the case of relatively robust constructions, and to cases where the cable-stayed portions of the bridge cover relatively long distances between the supports on the ground.

It is a particular objective of the present invention to make the building of cable-stayed bridges

easier when the cable-stayed portion has to cover a fairly long distance.

To this end, the method for building a cable-stayed bridge according to the invention is characterized in that once the tower has been built, at least one support cable is attached to this tower, the support cable is connected to a portion of the deck and said deck portion is push-launched from one end of the bridge, the support cable contributing to supporting the deck portion while it is being push-launched.

In preferred embodiments of this invention, recourse is further had to one and/or other of the following arrangements:

- the support cable is connected to the deck portion via at least one support to which are fixed, on the one hand, the support cable and, on the other hand, at least one retaining cable which is anchored towards said end of the bridge, the deck portion being designed to slide with respect to the support during push-launching, while the support is more or less static;

- a longitudinal rail with at least one flank intended to bear slidingly on rollers mounted on the support is fixed to the deck;

- as the deck portion is push-launched, static supports are set in place at a front end of the deck portion, these being connected to the tower by support cables and to a fixed anchoring point by retaining cables;

- the support cable retains the deck portion at a point which is fixed with respect to the deck portion, the length of this support cable, between said fixed point and its point of attachment to the tower, being rendered variable by adjusting means;

- the adjusting means comprise a cylinder articulated to a front end of the deck facing away from the said end of the bridge;

- the adjusting means comprise a cylinder which is fixed to the ground at the same end as said end of

the bridge so that the support cable runs around the front end of the deck portion from underneath;

- while the tower is being prepared, anchoring zones are formed in the tower for anchoring the cable stays, and the support cable is attached to the tower in one of these zones.

Other features and advantages of the invention will become apparent in the course of the following description of three of its embodiments which are given by way of nonlimiting example with reference to the appended drawings.

In the drawings:

- Figure 1 is an overall schematic view of a cable-stayed bridge depicted in the course of the stage of push-launching a first portion of its deck according to a first embodiment of the method of the invention, and in the course of the stage of push-launching a second portion of its deck according to a second embodiment of the invention,

- Figure 2 is a schematic overall view of the cable-stayed bridge of Figure 1, once the definitive placement of its deck sections has been completed,

- Figure 3 is a diagram of the first deck portion pushed out according to an alternative form of embodiment of the method of Figure 1,

- Figures 4A and 4B are, respectively, a side view of the support depicted in Figure 1 and a view in vertical section on IV-IV of this support.

The exemplary cable-stayed bridge depicted in Figures 1 and 2, intended to span an obstacle 1, for example comprising a waterway, comprises:

- two foundations 2, 3 built respectively on the two opposite sides of the zone to be spanned (hereafter known as the left bank in the case of foundation 2 and the right bank in the case of foundation 3, with reference to Figures 1 and 2),

- one or more towers 4 built in the obstacle 1; in the example drawn, the bridge has an asymmetric

overall appearance with just one tower 4 erected closer to the left bank than to the right bank;

- piles 5 built in the obstacle 1 toward the right bank;

- a deck 6.

The distance between the tower 4 and the nearest pile 5 is relatively great and, in this example, is equal to about 170 m. This is why a cable-stayed structure is used to support the deck in this zone.

The tower 4 is used for mounting a collection of inclined cable stays. These cable stays each have an upper end anchored in a respective anchoring zone formed in the tower 4. The cable stays directed toward the right bank have their lower end anchored in the deck. Those, 7, directed toward the left bank have their lower end anchored in the ground, near the foundation 2, so as to balance the bending moments applied to the tower 4 by the cable stays which are fixed to the deck 6.

In the example under consideration, the deck 6 has two portions, one, 6a, extending from the left bank and the other, 6b, extending from the right bank.

Each of these two portions is push-launched from the bank using systems 8, 9 mounted respectively on the foundations 2, 3. These systems 8, 9 are of conventional construction. Each of them comprises, for example, one or more cylinders installed on the edge of the foundation adjacent to the obstacle 1 and exerting tensile forces on the cables connected to a pushing member applied to the rear of the deck portion.

Each deck portion 6a, 6b is built in successive sections in a respective assembly work site installed on the foundation 2, 3. It may be manufactured directly on this work site, particularly in the case of a concrete deck, or simply assembled from prefabricated elements. As it is progressively built, it is pushed

out horizontally by the system 8, 9 to free up the assembly zone.

The deck portion 6a is depicted in its definitive position in figure 2. It extends from the foundation 2 on the left bank, rests on the pylon 4 in which an appropriate passage (for example with the structure of an inverted Y) is formed, and protrudes beyond the tower 4 toward the right bank over a distance d_1. As this distance d_1 may be fairly long (for example 40 m long), one or more inclined cables 10 are envisioned to support the overhanging part of the portion 6a from the tower 4.

In accordance with the invention, this inclined cable 10 represented in figures 1 and 2 supports the deck portion 6a while it is being push-launched. The procedure may, in particular, be as follows.

Once part of the deck portion 6a, for example from the foundation 2 to the tower 4 has been produced, with a protrusion d_0 beyond the tower ($d_0<d_1$) as depicted in figure 1, the support cable 10 is installed by anchoring its upper end in an anchoring zone M_1 formed in the tower 4, and by connecting it to a cylinder 11 articulated to a fixed point with respect to the deck portion 6a. The cylinder 11 can be operated in such a way as to adjust the length of the support cable 10 up to its anchorage to the tower 4. As the deck portion 6a is push-launched from the left bank, the cylinder 8 is operated in such a way that the length of the support cable 10 between the tower 4 and the deck portion 6a adapts to suit the current position of the point of articulation of the cylinder 11. The deck portion 6a is thus push-launched as far as the position depicted in figure 2.

In the example depicted, the anchoring zone M_1 comprises, in a way known per se, a metal tube which is firmly attached to the tower 4 at the time of preparation of the latter, this tube being intended to receive, via its end facing toward the right bank, the

upper end of the support cable 10. The strands of the upper end of the cable 10 are clamped in the respective jaws of an anchoring head arranged in a conventional way on the other side of the metal tube. In order to allow the support cable 10 the required angular excursion between the initial and final positions of the deck portion 6a which are depicted in figures 1 and 2, the lower wall of the tube in the anchoring zone M_1 is convex, preferably with a constant radius of curvature in a vertical plane passing through the axis of the tube.

In the above example, the deck portion 6a is built out as far as the tower 4 by other means, for example by corbeling out or by pushing out on temporary piles erected between the foundation 2 and the tower 4. However, it should be noted that the progression of the deck portion 6a as far as the tower 4 can also take place using support cables and a push-launching system if the zone M_1 at which the support cable 10 is anchored allows sufficient angular excursion, or otherwise by providing two support cables 10 used in succession (one for push-launching as far as the tower 4 and the other for beyond that).

Figure 3 schematically depicts the progression of the deck portion 6a according to an alternative form of the method according to the invention, between its initial position depicted in solid line and corresponding to that of figure 1 and its definitive position depicted in chain line and corresponding to that of figure 2.

This embodiment differs from the previous one in that the cylinder 11 to which the support cable 10 is connected is no longer articulated to a point which is fixed with respect to the deck but to a support 12 which is anchored in the ground near the foundation 2. This cylinder 11 is arranged in such a way that the support cable 10 extends between the anchoring zone M_1 and the cylinder 11, running, from underneath, around a

deflection member 13, for example with a roller, mounted on the deck portion 6a. This member 13 may in particular be placed at the front end of the deck portion 6a so as to hold the latter up from the front during the push-launching. In the same way as in the previous embodiment, the cylinder 11 can be controlled so as to adjust the length of the support cable 10 until such point as it is anchored on the tower 4. When the deck portion 6a is being push-launched from the left bank, the cylinder 11 is controlled in such a way that the lengths of the support cable 10 between the tower 4 and the deck portion 6a and between the deck portion 6a and the point of articulation of the cylinder 11, adapt to suit the current position of the deflection member 13. The deck portion 6a is thus push-launched as far as the position depicted in chain line in figure 3.

As far as the deck portion 6b is concerned, this is also depicted in its definitive position in figure 2. It extends from the foundation 3 on the right bank as far as the front end of the deck portion 6a where the two portions are assembled. The deck portion 6b has a part which rests on the piles 5 and a part which extends beyond the nearest pile 5 to the tower 4 by a distance d'_1. Given the fact that this distance d'_1 may be fairly long (for example over 100 m) and that the overhanging part of the portion 6b from the above pile 5 can also be relatively massive, one or more inclined cables 14, preferably several, are provided, as in the case of the push-launching of the deck portion 6a, to support the overhanging part of the deck portion 6b. These cables 14 are connected to static supports 15 from which respective horizontal cables 16, anchored near the foundation 3, extend, to retain the overhanging part of the deck portion 6b.

According to the invention, the deck portion 6b is, while being push-launched, not only supported by the inclined cables 14, but also retained by the

horizontal cables 16, as depicted schematically in figure 2.

It should be noted that the push-launching of the deck portion 6b may be performed either before or after the deck portion 6a is push-launched, or alternatively at the same time as the latter operation.

In the example under consideration, the procedure is as follows.

First, as depicted in figure 1, a part of the deck portion 6b is produced and set in place on the piles 5, protruding by d'_0 beyond the pile 5 closest to the tower 4 ($d'_0 < d'_1$). The part of the deck portion 6b may be set in place in the conventional way by push-launching toward the left bank, the underside of the part of the deck portion 6b gliding over appropriate saddles installed at the tops of the piles 5 (see, for example, FR-A-2 758 835).

A temporary cable 18 is then installed between two points 17a, 17b, for example fixed to the deck portions 6a, 6b, this cable being run through a pulley 19 mounted at the top of the tower 4. The cable 18 is located a vertical plane laterally offset with respect to the plane(s) in which the inclined support cables 14 will extend. This cable 18 has the purpose of carrying a shuttle 20. One end of a support cable 14 is anchored in an appropriate zone M_2 formed at the top of the tower 4, and its other end is attached to the shuttle 20 brought up close to the tower. By moving the shuttle 20 toward the point 17b, the support cable 14 is slung across the distance separating the two deck portions 6a, 6b. This operation will be repeated for each of the support cables 14 fitted in turn. It may be noted that the temporary cable 28 is optional, it being possible for other means to be employed for fitting the cables 14.

The lower end of the cable 14 is fixed to a support 15 depicted in figures 4A and 4B. In the example depicted, the lower end of the cable 14 is

fixed by means of an anchoring block 21 to a plate 22 connected to a clevis 23 by bolts 24 that allow the distance between the plate 22 and the clevis 23 to be adjusted. The clevis 23 is articulated on the support 15 about an axis X. The support 15 comprises, for example, two parallel flanges 25 assembled by bolts 26. Spacer pieces 27 are placed around the bolts 26 between the two flanges 25 to maintain the separation thereof. At the axis X, located at the upper part of the support 15, the clevis 23 fits between the flanges 25, an axial rod, not depicted, providing the articulation. Between the two flanks of the clevis 23, a cylindrical spacer piece 28 is placed in alignment with the axis X and the articulation rod passes through it. This spacer piece 28 is provided with holes 29 which serve for the attachment of the horizontal cables 16.

In the lower part of the support 15, the inside of each flange 25 supports a bearing 30 which may be in the form of a roller pivoting about an axis Y perpendicular to the flanges. As depicted in figure 4B, the bearings 30 collaborate with a rail 31 fixed to the deck portion 6b. The rail 31 has the shape of an I section arranged parallel to the direction of the deck, the central web of the I standing up vertically and lying between the two bearings 30. The upper flanges of the I section bear on the tops of the bearings 30 so as to support the deck portion 6b while at the same time allowing it to slide in the direction of the left bank.

Once the lower end of the cable 14 has been fixed to the support 15, the latter is engaged on the rail 31, then the horizontal cable or cables 16 is or are fixed. The opposite ends of these cables 16 are anchored in the ground near to the foundation 3. In order to avoid cluttering the work site zone in which the deck is assembled, an angular deflection device 32 may be provided at the front of the foundation 3, the anchoring points 33 for the horizontal cables 16 being located laterally with respect to the foundation 3.

Once the first support 15 has been mounted, the push-launching of the deck portion 6b is continued, the portion then sliding with respect to the static support 15.

When the overhanging mass at the front of the deck portion 6b is once again fairly great, further support cables 14, supports 15 and horizontal cables 16 are installed in the same way as before. Along the direction of the deck, the distance between two consecutive supports 15 is, for example, of the order of 10 meters. The horizontal cables 16 may pass inside the supports 15 previously installed (between the spacer pieces 27, 28), or alongside these supports 15 if appropriate deflectors are fitted.

The inclined support cables 14 fitted in succession exert bending moments directed toward the right bank on the tower 4. To compensate for this, retaining cable stays 7, anchored to the ground and to the tower (figures 1 and 2) are installed on the other side of the tower 4, toward the left bank, as these cables 14 are progressively fitted. These retaining cable stays 7 may be definitive cable stays of the construction.

Once the operations of push-launching the two deck portions 6a, 6b have been completed, these portions are secured together in the central span of the bridge.

In general, the inclined support cables 10, 14 used while the deck is being push-launched will be temporary cables, replaced by the definitive cable stays of the construction after the two deck portions 6a and 6b have been assembled. The inclined cables 10, 14 are replaced one by one or in small groups, so that the cables and stays remaining in place continue to support the deck. The definitive cable stays have their upper ends fixed in respective anchoring zones of the tower 4 which, as a preference, were used for anchoring the inclined support cables 10, 14. Their lower ends

are fixed to the deck, for example by respective anchoring blocks placed under the deck, through which guide tubes containing the stays pass, in the customary way.

The construction method which has just been described hereinabove particularly has the advantage of being well suited particularly to the case where the divide separating the two deck portions that are to be joined is great or in cases where access to the zone separating the two banks is tricky or prohibited.

As goes without saying, and as is sufficiently obvious from the foregoing, the invention is not in any way restricted to those embodiments which have been more especially explained hereinabove; on the contrary, it encompasses all variants thereof and, in particular:

- in cases where the overhanging part of the deck portion 6a would be too great, it would be possible, in place of a single support cable 10, to use a number of cables 10 so as to distribute the support force across various points of the deck portion 6a while it is being pushed out horizontally. Each cable 10 would then be attached by its upper end to a corresponding anchoring zone formed in the tower 4 and fixed by its lower end to a corresponding cylinder 11 articulated at a fixed point with respect to the deck portion 6a (figures 1 and 2) or with respect to the ground with a deflection over a member 13 (figure 3),

- in the method version described with reference to the right-hand part figures 1 and 2, the inclined support cable 14 and the horizontal retaining cable 16 could consist of two portions of one and the same cable deflected angularly at the support 15,

- depending on the dimensions and the mass of the deck portion 6a, 6b, at least some of the support cables 10, 14 could be duplicated and juxtaposed across the width of the deck, thus keeping the assembly better balanced,

- in certain cases, the inclined cables used to support the deck portion 6b could be designed to form the definitive cable stays of the bridge, which would make it possible for these not to have to be removed once the bridge building was complete; in this case, definitive anchorage of these cable stays to the deck portion 6b is achieved at the end of the push-launching operation, once the supports 15 have been removed one by one.

CLAIMS

1. Method for building a cable-stayed bridge comprising a deck (6), at least one tower (4), and inclined cable stays (7) mounted between the tower (4) and the deck (6), characterized in that once the tower (4) has been built, at least one support cable (10; 14) is attached to this tower, the support cable (10; 14) is connected to a portion of the deck (6a; 6b), and said deck portion is push-launched from one end (2; 3) of the bridge, the support cable (10; 14) contributing to supporting the deck portion (6a; 6b) while it is being push-launched.

2. Method according to Claim 1, characterized in that the support cable (14) is connected to the deck portion (6b) via at least one support (15) to which are fixed, on the one hand, the support cable (14) and, on the other hand, at least one retaining cable (16) which is anchored towards said end of the bridge (3), the deck portion (6b) being designed to slide with respect to the support (15) during push-launching, while the support is more or less static.

3. Method according to Claim 2, characterized in that a longitudinal rail (31) with at least one flank intended to bear slidingly on rollers (30) mounted on the support (15) is fixed to the deck portion (6b).

4. Method according to Claim 2 or 3, in which, as the deck portion (6b) is push-launched, static supports (15) are set in place at a front end of the deck portion, these being connected to the tower (4) by support cables (14) and to a fixed anchoring point (33) by retaining cables (16).

5. Method according to Claim 1, characterized in that the support cable (10; 14) retains the deck portion (6a, 6b) at a point which is fixed with respect to the deck portion, the length of this support cable, between said fixed point and its point of attachment to

* C L M S *

the tower (4), being rendered variable by adjusting means.

6. Method acording to Claim 5, characterized in that the adjusting means comprise a cylinder (11) articulated to a front end of the deck (6a) facing away from the said end (2) of the bridge.

7. Method according to Claim 5, characterized in that the adjusting means comprise a cylinder (11) which is fixed to the ground at the same end as said end (2) of the bridge so that the support cable (10) runs around the front end of the deck portion (6a) from underneath.

8. Method according to any one of Claims 1 to 7, characterized in that while the tower (4) is being prepared, anchoring zones are formed in the tower for anchoring the cable stays, and in that the support cable (10; 14) is attached to the tower (4) in one of these zones.

* C L M S *