Prefabrication of concrete box girder bridges

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Objekttyp: **Article**

Zeitschrift: **IABSE reports = Rapports AIPC = IVBH Berichte**

Band (Jahr): **64 (1991)**

PDF erstellt am: **15.08.2024**

Persistenter Link: https://doi.org/10.5169/seals-49307

Prefabrication of Concrete Box Girder Bridges

Préfabrication des ponts à poutre-caisson en béton

Vorfabrikation von Kastenträgerbrücken

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SUMMARY

The technologies described allow the production of prestressed concrete bridges, precast in a monolithic form both for simply supported and continuous beams. It combines durability, speed of construction and economy. Some works are also described with particular reference to a viaduct with a continuous box girder deck under construction in a seismic zone in Italy.

RESUME

La technologie décrite permet la production des ponts à poutre-caisson en béton précontraint, préfabriqués sous forme d'éléments monolithiques destinés aussi bien à des travées simplement appuyées qu'à des travées continues. Cette technologie joint la durabilité à la rapidité de construction et à l'économie. L'article décrit quelques ouvrages, en détaillant un viaduc de ce type, actuellement en construction dans une zone sismique en Italie.

ZUSAMMENFASSUNG

Die hier beschriebene Technologie ermöglicht die Vorfertigung monolithisch vorgespannter, einfach aufgelagerter bzw. durchlaufender Kastenträger. Sie zeichnen sich aus durch ihre Langlebigkeit, Wirtschaftlichkeit und schnelle Montage. Unter einigen beschriebenen Ausführungsbeispielen sticht besonders ein Viadukt mit einem durchlaufenden Kastenträger hervor, das zur Zeit in einer seismisch gefährdeten Zone Italiens im Bau ist.

1. INTRODUCTION

The structures and equipment described in the report have arisen out of the experience acquired by the technical staff of "FERROCEMENTO - Costruzioni e Lavori Pubblici S.p.A" in many years of activity in design and construction.
Through these technologies it was possible to obtain the prefabrication of prestressed concrete bridge decks in a monolithic form both for isostatic and continuous beams.
The aim of combining the criteria of high quality and durability with that of high speed of construction was pursued: the result achieved may be considered as the final step in the art of prefabricating viaducts.
Experience shows that, when dealing with structures obtained by assembling together many prefabricated elements, the strength and durability of the whole, hence its level of reliability, generally depends on the number and difficulty of the structural connections to be done on site.
The prefabricated bridge decks do not escape this rule: the fewer the number of connections, the greater the reliability of the structure.
The assembling procedure of precast elements is really the most important and difficult problem of a prefabrication process. In fact, connections are usually located in zones of maximum stress and consequently through the connections the performance of the whole is determined. Moreover, the assembly operation is carried out in the open air, most of the time in difficult working conditions and is to be repeated for a large number of cases; finally it is usually carried out by a labourforce encouraged to save time, which certainly does not work in favor of good quality.
Experience also shows that the durability of structures in prestressed concrete is affected by the complexity of the post-tensioning technology and shows that this sophisticated system leads, if not accurately executed, to a need for large-scale repairs a short time after completion of the structure. Accordingly, statistics in recent years have shown that in the field of bridge decks, which is the most suitable for precasting and prestressing processes, the post tensioned cables and the structural joints between precast segments too often display an advanced state of degradation shortly after completion and require costly repair operations.
As a consequence of such a disquieting situation, nowadays approaches to structural design give top priority to the criteria of durability and degradation of materials.
The construction processes and techniques described herein have had as their main aim the elimination of the above mentioned problems.
First the concept itself of "assembling and joining" was eliminated by producing the entire span in a single large precast element; then the post-tensioned cable prestressing system was partially or totally substituted by the system using pre-tensioned steel directly embedded in the concrete.
In addition to the criteria of durability and reliability, also costs and production rates were taken into due account. As regards costs, it must be said that, as in all construction processes based on prefabrication, it is necessary to produce a large number of elements in order to justify the costs of implantation and equipment. In our case, the element is an entire span, so a great number of spans becomes necessary. In other words, a long viaduct is needed: the longer the viaduct the more competitive the process.
As regards production rates, this system has greatly reduced the construction time as it is 5 to 6 times faster than any other advanced technology. With the yard in full production, entire spans of 30 to 35 m in length and 5000 kN in weight can be produced and set in place at the rate of one a day, and entire spans of 45 to 50 m and 10000 kN at the rate of one every two days with just one stock of equipment.
We have dealt with durability, economy and rapidity of construction, but it is also important to say that from an engineering point of view we are dealing with an advanced process of high technical level which leads, as we shall see in the following, to structural designs of great interest.

2. BACKGROUND

This system of construction was first used about 20 years ago to build a 3 km motorway viaduct with simply supported spans carrying dual carriageways. Each box girder span, 32 m long and weighing 5000 kN, was precast with an 8 hours continuous pouring of concrete and prestressed with the use of the pretensioning system. The completed deck was then lifted out of the formwork using 4 hydraulic jacks thus allowing the transport equipment to be placed underneath (Fig.1).

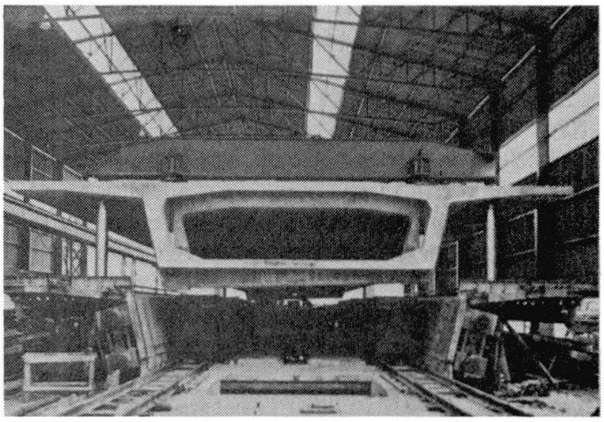

Fig.1

This equipment comprises 16 railway trolleys propelled by an external motor.

Each trolley is fitted with an outsize hollow rubber cylinder in order to distribute the weight of the element evenly, and to eliminate all problems connected with compensation of loads, dynamic factors and risk of breakdowns (Fig.2).

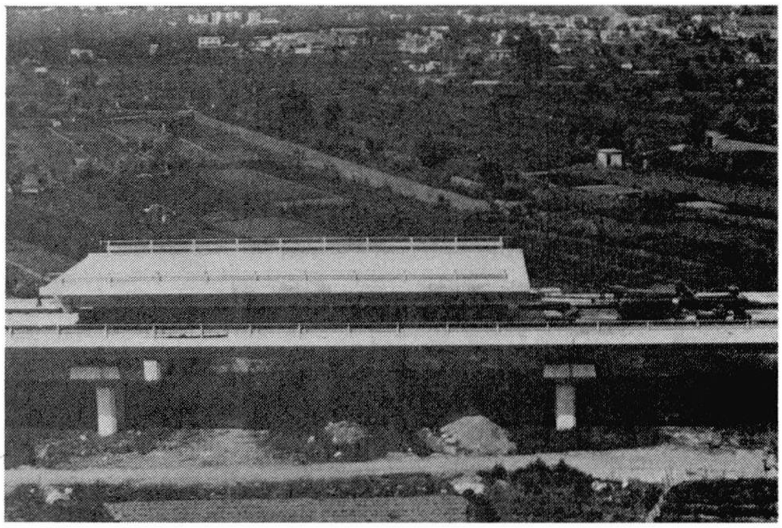

Fig.2

The trolley equipment then carries the element along the completed part of the viaduct to the launching position where it can be lowered into place. The purpose built launching equipment operates by first enveloping both the element and the trolleys. The launching gantry of the equipment then hooks up the element and lifts it off the trolleys so that they are free to return for the next cycle. The equipment then frees the space below the suspended element so that it can be lowered into place on the piers, following which it prepares itself for the next launch (Fig.3).

The launching phase takes about 2 hours. The entire cycle, from the construction of the element to its setting in place, takes 24 hours, using the hours of darkness for the steam curing phase.

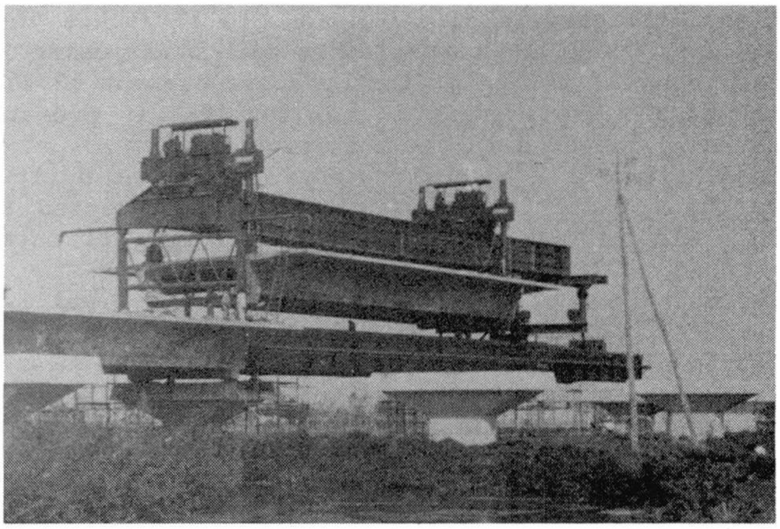

Fig.3

This construction technology has also been used to build a number of viaducts, totalling 10 km, on the Roma - Firenze "Direttissima" railway line. In this case, however, some modifications were thought opportune because the railway viaducts differ from roadway ones in that gradients are much lower, the bending radii are much greater and the live loads much heavier. In addition, the viaducts were distributed along the whole line. One modification was to substitute the transport on rails with a system on rubber wheels which made the machine faster although it was much heavier (Fig.4); the other was to adapt the launching equipment to deal with this new transport system (Fig.5).
These viaducts also used prestressed box girder decks, each span weighing 5000 kN, which were constructed and installed at the rate of one span a day.

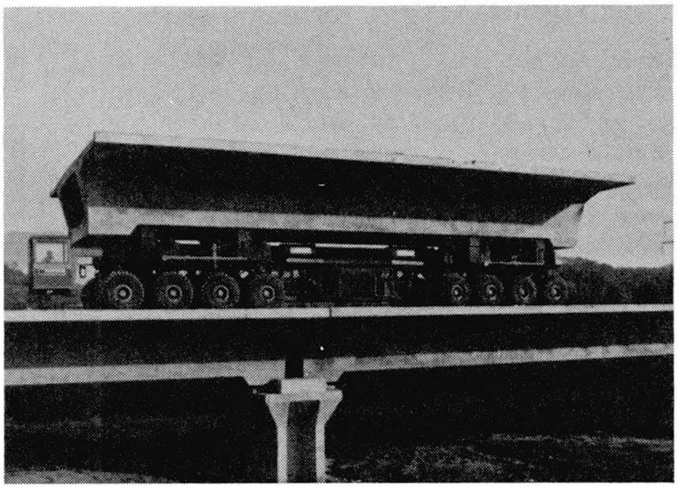

Fig.4

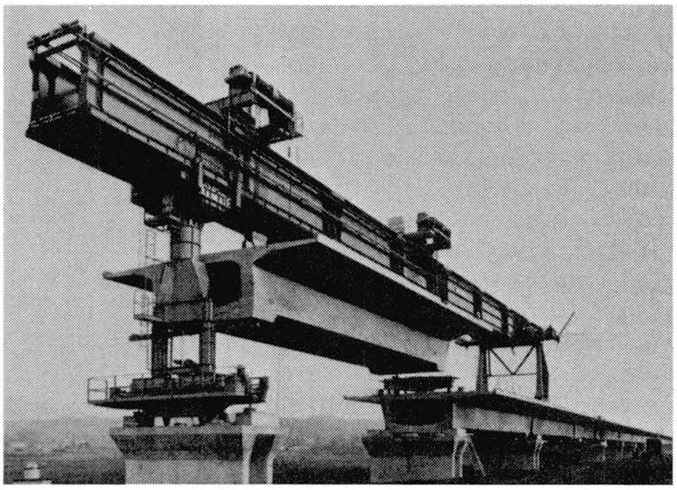

Fig.5

3. THE POGGIO IBERNA VIADUCT

The structure which best illustrates the use of this advanced technology is the Poggio Iberna viaduct, actually 2 viaducts running in parallel, which is being built as part of the Livorno - Civitavecchia - Roma motorway.
The statical scheme is a continuous beam connected with hinges to the piers.
Each viaduct, carrying a 4-lane carriageway, consists of 60 spans divided into eight stretches (i.e. 120 spans, 16 stretches in total) ranging in length from 252 m to 336 m and connected to each other using long expansion joints.
Each span is a single giant precast element 12,25 m wide, 42 m long and 9000 kN in weight. The girder, in box section, is prestressed by pre-tensioned strands directly embedded in the concrete.
These elements are constructed in a purpose-built shed located near the job-site so that production takes place in a protected area under optimal conditions; this also allows for accurate monitoring of materials and processes which are planned with industrial precision.
The main part of the pouring platform is a multi-form steel mould adjustable by computer control which is able to assume all the geometrical configurations needed to adapt the produced units to the particularly tortuous geometry which characterizes the motorway alignment in that zone. The external form is a steel mould based on a concrete structure which is also capable of resisting a 45000 kN force transferred by pre-tensioned strands.
After the concrete pouring, the steam treatment and the pretensioning steel cutting phases are over, the internal form folds inwards in order to be drawn out with a longitudinal movement, so that the element is ready for the lifting

phase.
The transport equipment moves in under the platform so that its hydraulic jacks can lift the element off the external form.
The transport equipment consists of a train of 24 fully mechanized and motorized trolleys moving on metallic wheels and rails. An automatic system of hydraulic jacks ensures that the value of the loads transmitted to the wheels is distributed evenly (Fig.6).
The giant element is transported along the previously positioned units until the whole reaches the launching equipment. This machine, similar to the one briefly described in section 2, is able to manoeuvre with same speed and safety although the dimensions and weight of the transported unit has doubled (Fig.7).
In about two hours the precast deck is launched on the piers and left resting on provisional supports.
These supports will be removed afterwards when the structural continuity of a stretch has been achieved and the continuous deck may be placed on permanent supports.
The structural continuity in the Poggio Iberna viaduct has been obtained by joining with post-tensioning cables the adjacent ends of the spans.

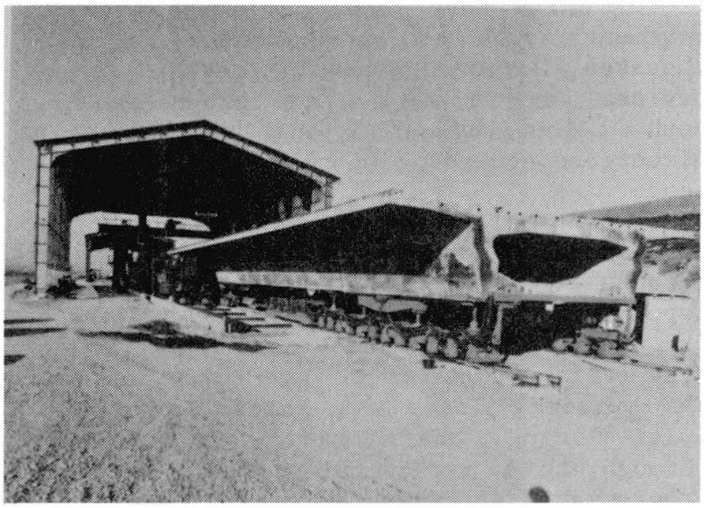

Fig.6

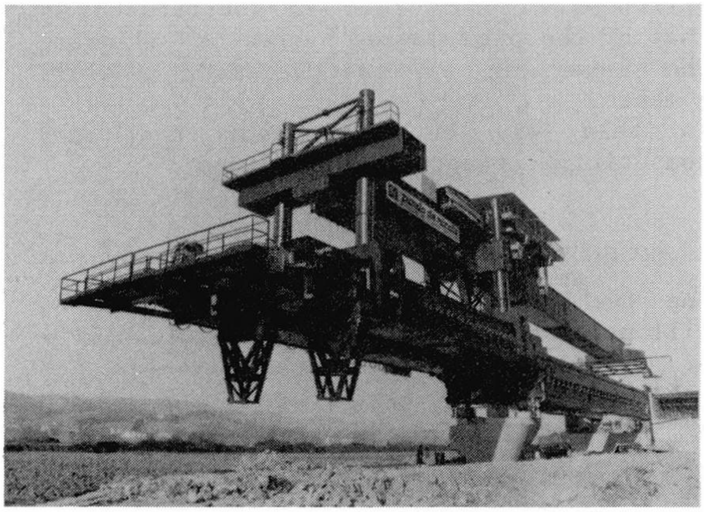

Fig.7

This operation is performed once all the elements of a viaduct are in position. However it should be pointed out that the connection between one span and another is done without recourse to supplementary castings, as the joint is made by pumping a layer of highly resistant mortar into the narrow space left in between. This kind of connection is nearly a "no-thickness joint". In other words, the deck remains, even in its continuity, monolithic and entirely prefabricated.
In addition to the results obtained with monolithic casting such as fast construction rate and a high standard of structural reliability for all the viaducts described so far, the Poggio Iberna is also characterized by the structural continuity of the deck. This is a determining factor whether seen from the point of view of user comfort, or maintenance.
Another important aspect which characterizes this viaduct has been the system developed to resist earthquakes. As aforementioned, the structure is made up of a series of hyperstatic systems, each one consisting of a long stretch of deck and piers. Each stretch is connected to the piers through anti-seismic devices capable of buffering the seismic actions in every direction. These devices, which work like hinges installed in the center of each pier, allow slow longitudinal relative movements caused by variations in temperature, shrinkage and

creep, while they impede relative dynamic movements such as those caused by earthquakes. Moreover, the stiffness of these devices can be varied and programmed in both longitudinal and transversal directions according to the design requirements.

In particular, every stretch is barycentrally connected to its central pier through an anti-seismic device of a fixed type (Fig.8), and to the other piers through anti-seismic devices of a mobile type (Fig. 9).

The vertical loads are supported by two multi-sliding bearings on each pier. Through this structural system and the programmable stiffness of the devices it is possible to modify appropriately the response of the structure to the seismic actions both in longitudinal and transversal directions. In fact, the stiffness of each pier is substituted by that of the pier-device system, so allowing the levelling of the seismic bendings moments.

In this way both a safer and more competitive structure is obtained.

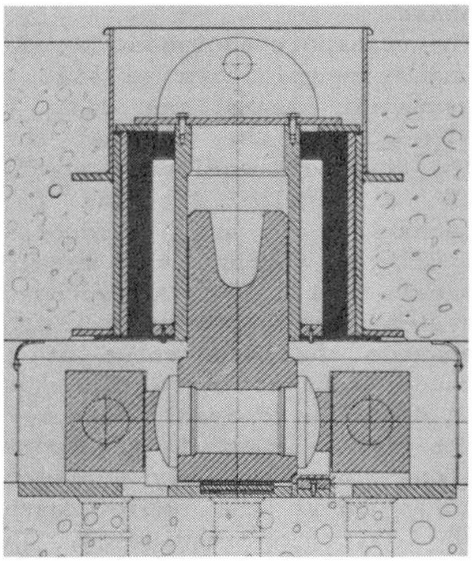

Fig.8

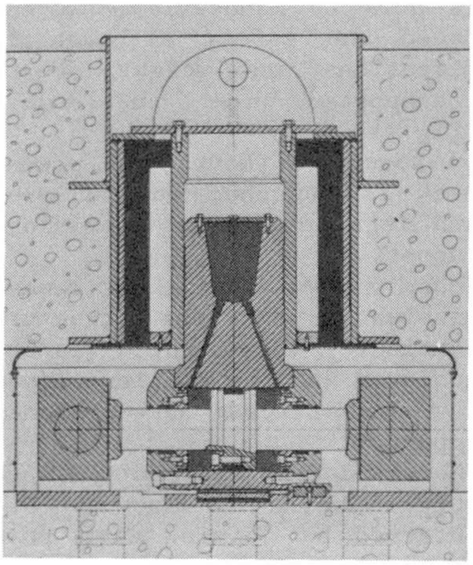

Fig.9

4. CONCLUSIONS

The technological effort in construction will never be too great if high reliability of the structure and competitiveness are achieved. The only limits are those imposed by the equipment, but as long as this evolves, the art of building will evolve with it.