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Long Span Concrete Bridges: Influence of Construction Techniques

Ponts en béton de grande portée: influence des techniques de construction

Betonbrücken mit grosser Spannweite: Einfluss der Bautechnik

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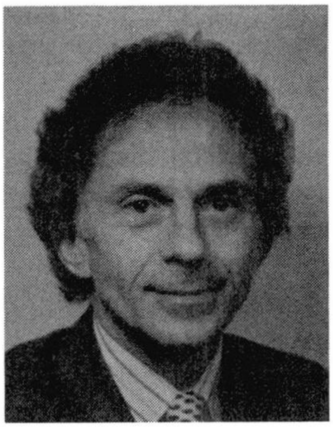

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SUMMARY

For more than 25 years, the construction of large bridges has been marked by the association of intensive pre-fabrication of box-girders in match-cast sections, and by the cantilever assembly of these segments using powerful movable launching gantries. Associated with modern, well-designed external prestressing, this technique is extremely successful nowadays due to the quality and reliability of the structures obtained. In parallel with this, cable-stayed bridges are spanning gaps that are wider and wider, and it is essential for a modern bridge designer to completely master all of these different possibilities.

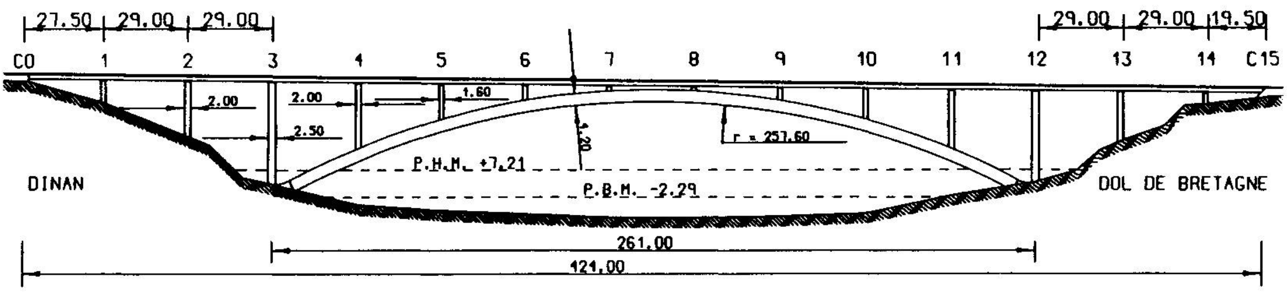
RESUME

Depuis plus de 25 ans, l'éxécution des grands ponts est marquée par l'association d'une préfabrication intensive des poutres caissons par tronçons conjugués les uns aux autres et d'une mise en place de ces éléments en encorbellement à l'aide de portiques de pose autodéplaçables et puissants. Associée à une précontrainte extérieure moderne et bien conçue, cette technique connait aujourd'hui un essor considérable lié à la qualité et à la fiabilité des structures ainsi construites. Parallèlement les ponts à haubans franchissent des brèches de plus en plus grandes et le concepteur d'aujourd'hui se doit de maitriser parfaitement toutes ces possibilités.

ZUSAMMENFASSUNG

Seit über 25 Jahren werden bei grossen Brücken die vorgefertigten Trägersegmente aneianderliegender Abschnitte von leistungsstarken, selbstfahrenden Montagebühnen zusammengefügt. In Verbindung mit einer modernen und gut konzipierten äusseren Vorspannung ist diese Technik heute aufgrund der Qualität und der Zuverlässigkeit der hiermit erstellten Bauwerke weit verbreitet. Parallel hierzu überqueren Schrägseilbrücken immer grössere Täler und der heutige Brückenbauer muss alle diese Bauweisen einwandfrei beherrschen.

Large civil Engineering structures have always been designed taking into account a certain number of parameters of which the following are the most usual ; geographical location ; available materials ; known and practicable construction methods and most probably economic and esthetic considerations.
During the last century a number of new materials were created, steel and concrete replacing wood and stone and traditional construction methods have been improved.
Structures and forms have been simultaneously adapted to the evolution of resistant materials and the imagination of construction Engineers.
Developed at the beginning of the century, the idea of prestressing, which is generally considered to be the most homogeneous and fruitful construction technique ever imagined, is today undergoing a spectacular regeneration responsible for renewing our present knowledge and perhaps our way of thinking.
However, if reinforced and prestressed box-girder beams of variable depth were rapidly adopted for balanced cantilever construction, which remains the most adapted construction method for large spans, PREFABRICATION OF SEGMENTS will be first mentioned because of the considerable advantages it brings to this construction method.
Whilst forms and structures were based on the engineer's knowhow it is becoming apparent that the best construction method is also that which is the most suited to the structure to be built, to the chosen architecture and the best technological solutions.



LA RANCE BRIDGE -
A structure made of an high strengh concrete arch supporting a composite deck

It is quite obvious that this trend is justified by the search for quality and perfection in construction methods, which become easier, safer and quicker.
This lead to the development of new construction methods and span by span, or segment by segment, progressive construction were considerably improved since 1980 in France and the United States.
As a result of this the cost of equipment and labour per square metre of bridge deck is less and less and in any case lower than the corresponding cost of raw materials.
In spite of this the quality and lightness of the structures thus built are also responsible for the huge success of all the structures constructed in this way and numerous examples shows clearly how interaction between construction technology and design is rather an advantage than a problem to be solved more or less elegantly by engineers.
We will see that structural lightness and geometrical simplicity are the result of the on-going research for increased competitiveness and must be associated with the use of EXTERNAL PRESTRESSING which has the great advantage of obeying clear and precise design rules.
External prestressing of concrete presents, for Civil Engineering structures, practical and theoretical advantages which have lead during the past few years to large constructions in all fields where traditional prestressing allowed a fruitful development of structural methods and techniques.
It has been opening up new horizons for some time now, with the appearance of 3-dimensional

concrete frames, composite steel-concrete structures built with the aim of bringing together lightweight properties and efficiency.
Experience now acquired allows a rigourous explanation of the basic properties of simple and well-balanced cable layouts in external prestressing, as well as the quality of structures built in this way.
Research carried out in this field has allowed the optimization of the design of incrementally launched bridges.
In an other way, as they are extending considerably the competitive span range of concrete bridges, concrete CABLE STAYED BRIDGES will be finally presented as a powerful concept.
Directly derived from the idea of prestressing in the field of segmental cantilever construction, concrete decks uniformly supported by inclined cable stays can be indeed erected easily with the today's technology.
The stay forces generate a normal force in the concrete wich is the best material to resist compressive forces and then the right material to the right place.

1. PREFABRICATION

The construction of bridges has, for nearly 30 years, been marked by the association of two major concepts : combined PREFABRICATION of single or multicell box girders in short sections (segments) and the CANTILEVER ASSEMBLY of these prefabricated elements across the bridge supports using mobile launching gantries.
This method of construction has been in constant evolution, since the OLERON viaduct was built between 1964 and 1966, and is often used for the construction of large bridges with fairly wide and variable spans.
BALANCED CANTILEVER CONSTRUCTION USING A LAUNCHING GIRDER has now been technologically mastered, and is perfectly adapted to bridges located on difficult sites where work is difficult. It enables the quality and reliability of support structures to be improved under interesting economic conditions. It can be used to build bridges of varying widths, whatever their horizontal and vertical alignment.

1.1. Principle of manufacturing bridge segments

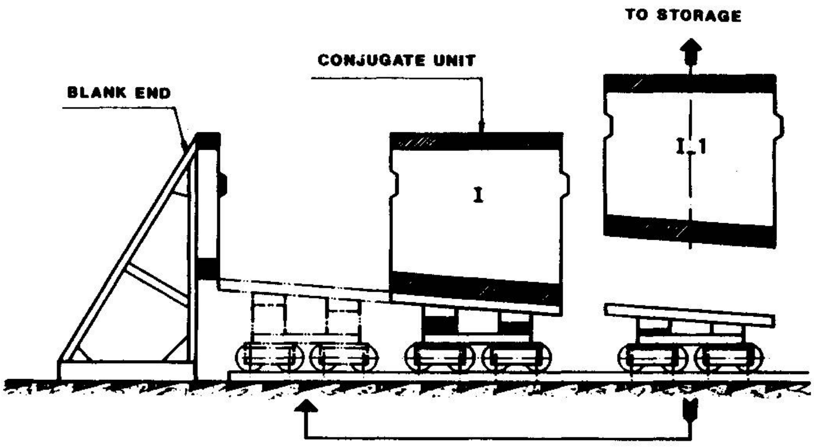
Although the traditional prefabrication of precast prestressed concrete girders has never really been a practical problem, due to the fact that the prefabricated girders could be concreted then installed individually, the same cannot be said for box girders cut up into segments.
In the first bridges constructed with short elements, (bridges over the Marne), the major problem (final assembly) was partially solved by Freyssinet, who joined the segments with mortar during the construction process.
These mortar joints, and the resulting constraints, remained an obstacle which prevented the method from developing for a long time.
It was necessary to produce extremely thin joints. The idea was simple, but putting it into practice was another matter :
- The joints between segments were liable to become the weak points of the construction, the stresses could be unevenly shared and water may seep through and attack the cables, all this had to be avoided.
- The continuity of the material had to be restored in the most perfect manner, after prestressing the deck.

1.1.1. Segment matching

Segments cast in series against each other in the same order as they will be assembled, after coating of mating faces with epoxy, was to be the only satisfactory solution.

During prefabrication, the segments are CONJUGATED such as the joints are perfectly matched, the face of a completed segment being used as a formwork for the new segment to be cast.

Correct positioning of the segments with respect to each other (centring) is obtained by means of a multiple key system on the mating faces.



FABRICATION OF SEGMENTS -
Steps used in precasting operation

1.1.2. Equipment used

The prefabrication installations used can be organised very differently, depending on the available area on the site or on the type of segments to be produced. These installations usually consist of concrete casting units (cells) used to prefabricate standard segments only, plus one concrete casting unit used to produce pier or abutment segments.

1.1.3. Application of epoxy glue

This description of the principle used to produce the segments would be imcomplete if no mention were made of the way in which the continuity of the deck is restored, when the different segments are assembled together.

Match-cast joints allow to obtain an excellent degree of geometrical precision, but the result is even more satisfactory if a film of glue is applied when the segments are assembled together.

Used in this way, the epoxy glue has four functions :

- During construction, before hardening :
  . it lubricates the contact surfaces when the segments are assembled, whilst the keys temporarily absorb the shear forces,
  . it compensates minor imperfections in the combined surfaces.
- When the bridge is finished, after hardening :
  . it constitutes a waterproof seal in the joints, particulary under the road surfaces,
  . it plays a part in the strength of the structure, by transmitting the compression and shear stresses through the joints.

The multiple keys spread out over the mating surfaces of the segments are nevertheless capable, on their own, of providing the resistance of the deck to the extreme shear stresses in each joint, when the bridge is opened to traffic.

1.2. Construction using a launching girder

The construction of bridges by successive cantilever progression from the supports is a very ancient technique, that has been put into practice with all the materials used and developed throughout the history of mankind.

The original idea of this method was furthermore simple and natural, since it consisted in taking advantage of the decreasing gap as the bridge progressed.

The method has been taken up again, and developed, since the invention of reinforced and prestressed concrete. The traditional method consists in casting bridge decks in successive

symmetrical sections on either side of the piers, supporting the formwork on the part of the bridge that is already built and resistant.
This method was used to build a great number of bridges, but it only started to be widely used between 1950 and 1960 ; nowadays, it is used to construct very long span bridges, including cable-stayed structures.
However, the construction of bridges by successive cantilever progression, and casting the segments directly in position, does have its disadvantages which clearly limit its area of use :
. The concrete has to be stressed before it has had time to reach certain age,
. The method involves many delicate operations when the piers are difficult to reach.
The concept of prefabrication, applied to box girders, has solved all these problems through the design of a fast and practical system for installing the prefabricated segments.

1.2.1. Principle used to install the segments

The first bridge to be built by successive cantilever progression, using prefabricated segments (Choisy-Le-Roi bridge), was constructed using a high capacity floating crane which carried and installed the segments symmetrically on either side of the piers (according to the standard principle).
The most efficient method, however, is to install the prefabricated segments using a steel girder launched over the deck part to be built.
This process, which was used for the first time in the construction of the Oléron viaduct, now makes it possible to take advantage of the high production rate of the segments, since the rate of installation of the prefabricated segments can be as high as their production rate.
The method basically consists in installing a steel girder with two legs (one in the centre and one at the rear), the length of which is somewhat greater than the maximum bridge span, on the first segment of the new symetrical deck cantilever to be constructed, and on the end of the deck that has already been built.
The girder is equipped with a trolley, which runs on the lower chords of the girder, enabling the successive segments to be installed.
Due to the static configuration of this type of girder, the segments necessary for the construction of the deck can be supplied over the bridge itself, which explains the power and success of the process - a very large number of bridges have been built in this way, both in FRANCE and ABROAD.
Movable launching gantries used are normally designed specifically for the bridges they are to be used on. They can be designed to install segments of 130 t. with spans of 120 m.
They consist of a steel truss girder, built-in two tunnel legs which provide the opening for the segments to pass through.
For large spans, the main girder is reinforced by a cable suspension system spread out over the upper chords.
The central leg and rear leg are supported on steel beams, which enable the necessary adjustments to be made according to the curve and inclination of the deck : a temporary front leg enables the first segments of each double cantilever to be installed.

1.2.2. Operational stages of the construction

The part of the end span, which usually completes the first symetrical cantilever in order to correctly balance the moments in the final bridge, is placed on a system of temporary supports (multiple bents - scaffolding).
The installation gantry is then placed on the access ramp behind the abutment, and the precast segments are successively installed outwards from the abutment. They are assembled together, after gluing the joints, and secured by a temporary pre-stressing system.
When this initial phase has been completed, the launching gantry is moved onto the part of the

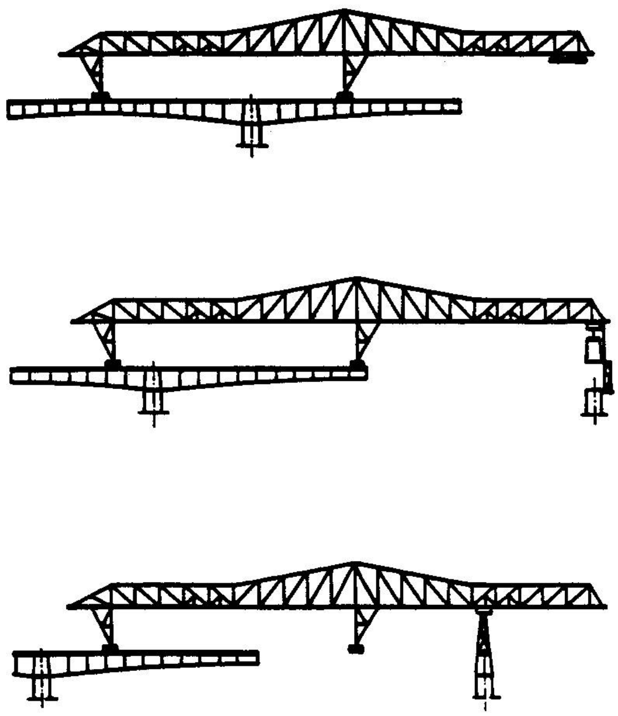
deck that has been constructed, so that the trolley can install the segments on the first pier, which will be used as a support for an auxiliary tower for the first launch of the gantry.

When the launch has been completed, and the central leg is supported on the centre-line of the first pier, the construction proceeds with the installation of the segments which constitute the first symetrical cantilever.

At the end of this second phase, the two parts of the deck, constructed entirely independently, are connected together by casting a concrete joint between them and, the next day, by tensioning the prestressing cables passing through the deck.

The launching gantry can then be moved again to the end of the cantilever that has just been completed, in a position which enables the installation of the segments on the following pier ; it is then launched for the construction of corresponding balanced deck cantilever, which is subsequently joined to the part of the deck that has already been constructed.

These steps are then repeated until the gantry has completely crossed the gap to be bridged.



LAUNCHING GIRDER - **Operational stages**

1.3. Advantages of prefabrication and construction using a launching girder

The advantages of prefabrication are noticeable in all fields where reinforced and pre-stressed concrete play an important part.

To begin with, concrete which is produced on solid ground, on a site that can be set up as efficiently as necessary, is normally of better quality than concrete which is cast direclty on site. It is more homogeneous, stronger, of a better colour, and its edges are sharper.

Secondly, prefabrication means that segments can be produced well before being fitted to the bridge structure, i.e., well before being prestressed. The concrete will therefore be older than concrete which is cast directly on-site, when the cables are tensioned for the first time. This means that there will be less creep and less residual shrinkage : the various distortions will be reduced.

Finally, the construction time of the bridge deck is greatly reduced, since it no longer depends on concrete hardening times. Provided that there is enough room to store the segments produced, the construction time will depend only on the transport, installation, adjustment and prestressing of the segments.

Construction by successive cantilever assembly, using a movable launching gantry, enables the deck to be built without the need for any intermediate support. Furthermore, the bridge under construction is itself used to supply the facilities needed for its own construction : personnel, segments, jacks, prestressing cables.

This process therfore makes it possible to span rivers, railway lines and roads without affecting their normal operation. It enables congested areas to be spanned without any difficulty. It makes it possible to build curved bridges of varying widths with a great degree of flexibility.

The major disadvantage of construction by successive cantilever assembly of prestressed reinforced concrete bridges, i.e. creep, cannot be totally eliminated, but the fact that there is no overloading of the box sections at the ends of the consoles during assembly of the cantilevers, the speedy execution, plus the undeniable advantages of prefabrication, all widely contribute to reducing the effects of creep.
With the use of high-performance steels, and the concept of stay-cables, the equipment used has reached a stage of perfection which tends to limit future progress.
For very large bridges, the performances of the method can nevertheless still be improved by producing girders of a length which is longer than two consecutive spans ; this would mean that the girder would, after a single displacement, be able to install the standard segments of the double cantilever under erection and the pier segments of the next one to be constructed.

1.4. Tendon layout

The principle of the longitudinal prestressing in a bridge erected by successive balanced cantilever construction is therefore particularly simple, since it necessary comprises two types of tendons :
. The cantilever tendons, which ensure the final assembly of all the segments as they are installed
. The continuity tendons, which rigidly integrate the successive double deck cantilevers in order to produce the final bridge.
This principle makes it possible to modulate the prestressing, and adapt it remarkably well to the stresses generated in the bridge during its construction, to the cutting up into short sections (segments), and to the final stresses involved. Furthermore, it is this technique that has contributed to the success of the process in the field of prestressed concrete bridges.
Although very economical, these standard dispositions do have certain disadvantages, which affect the quality of the prestressing :
. The prestressing tendons are too much deviated,
. The anchorages located in the webs are impractical,
. The anchor concrete blocks inside the box girders cause considerable local deviations.

2. EXTERNAL PRESTRESSING

The research carried out has shown that the idea of external prestressing is not new. Several bridges were built in France with tendons outside the concrete as early as 1950.
Unfortunately the technology employed in these structures was umpractical and unreliable, as can be judged by the state of the tendons at the present time.
More than 20 years had gone by before this simple idea was brought back into use, because of the repeated experience with :
- Temporary prestressing (cantilever stability, blocking pin joints, incremental launching...) outside the concrete because it was more adaptable and less expensive,
- Repair and reinforcement of existing structures because it was the only solution,
and definitely adopted in large prestressed structures.

2.1 Practical advantages of external prestressing

Henceforth, the elimination of tendons which were habitually located inside the concrete (at gussets or spread out in the webs) constitues a large improvement in the quality of the structure. It also opens up new horizons for geometry and materials and presents many advantages :

Better concreting conditions
Threading and tensioning problems eliminated
Suppression of discontinuities in tendon profile
Supression of injection tubes in the top slab

Ease of visual and eventually mechanical checking of the prestressing
Possibility of cable replacement or addition
Large independance between the structure and its prestressing

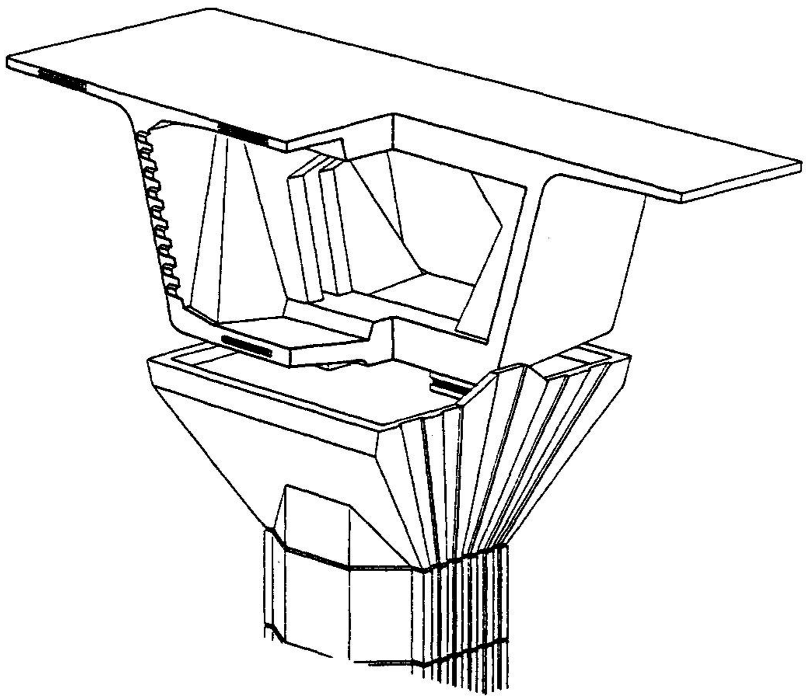
2.2. The theoretical advantages of external prestressing

External prestressing improves, therefore, the general quality of prestressed structures ; these advantages are well attuned to the present day trends towards safety, elimination of defects and the option of easy and permanent checking.
Nevertheless safety and durability are also the result of the perfect operation of the structures designed and the contribution to this made by the modern technology of external prestressing is considerable.

2.2.1 Elimination of ducts embedded in the concrete
Generally speaking, the elimination of ducts in the concrete reduces the risk of local weakening of the cross-section at locations where concreting is critical and where forces such as transverse bending moments, general and local shear inevitably accumulate.
The suppression of "holes" corresponding to the duct passage along a section throughout the web height puts aside any controversy about web resistance to shear forces.
In the absence of such voids during construction and of the heterogenious state (tendon + grout + duct) in service it is certain that the compression paths are not deviated and consequently do not become fragile.
In other words, in all important cross-sectional zones (gussets, webs, slabs) external prestressing improves the structural resistance to all the forces applied to it and with less materials.

2.2.2. Tendon profile simplicity

External prestressing tendons present the advantage of being less deviated. The tendon profile is simple and easy to respect. It has many straight sections for which friction coefficients are inexistant because duct wobble is impossible. Recent technological developments eliminate the risk of alignment errors in deviation saddles and anchorage blisters. The curvature friction coefficient, which depends closely upon the technology employed, can be much lower than that normally used for the calculation of friction losses and the final prestressing forces in external prestressing tendons are much higher than those obtained in classical internal prestressing tendons.


ARCINS BRIDGE - The pair of pier segments after final placement

2.2.3. Anchorages

Here again, the profile simplicity, which is the result of geometrical and physical analysis, leads to

a concentration of anchorages in the diaphragms normally provided at piers and abutments. These diaphragms are naturally massive and clearly adapted to receive the large forces applied by the anchorages.
This disposition is one of the most important advantages of external prestressing (in spite of its apparent discretion) because it eliminates the anchorages spread out along the total length of the structure which are at the origin of high local tensile and shear stresses in areas where the general forces are not sufficient to provide the required resistance (continuity cables in the bottom slab for example).

2.2.4. Structural lightness

The logical consequence of the advantages cited above and therefore of the use of external prestressing is the dead weight saving. For equal structural resistance it is possible to reduce the web thickness, gusset volumes and, as will be seen later, the bottom slab thickness without weakening the cross-section.
On the contrary, the homogenious character of all the cross-sections throughout the structure is an additional advantage.
The load reduction due to lower dead weight is favourable both during service and construction.

2.2.5. Prestressing efficiency

The improved quality of the prestressing and the reduced cross-sectional area lead to an increase in the stresses resulting from the axial prestressing force.
These factors compensate for the loss of eccentricity which can be encountered with external prestressing and permit a better exploitation of certain construction methods at the time of conception.

2.3. Important applications of external prestressing

It was towards the latter part of the 1970's that the first spectacular applications of external prestressing were to be seen, combined with innovative construction methods. In the meantime, the need for repairing and reinforcing existing structures provided the necessary experience and a better understanding of its possibilities.

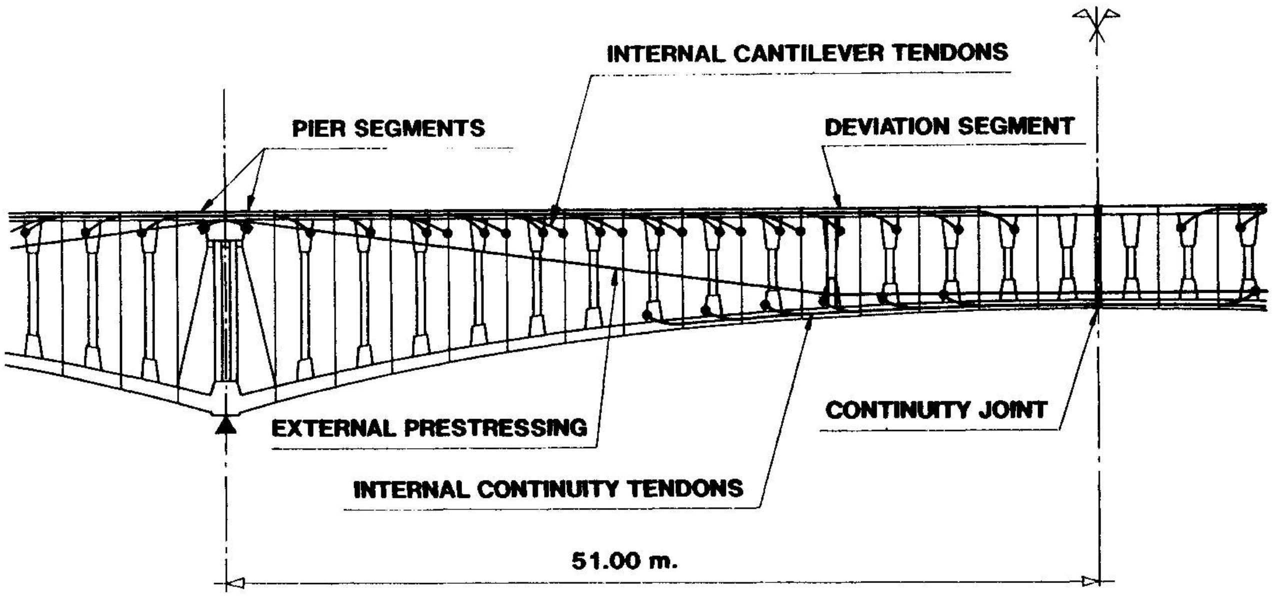
2.3.1. Structures built by segmental progressive construction

It was in the framework of structures built in such a way as to be likened to cast-in-situ structures that the prestressing stay was developed.
Long Key Bridge (Florida -USA-) was the first modern bridge to use such a method and be entirely equiped with external prestressing.
This entirely prefabricated structure of which no element weighed more than 60 t was built by the span by span construction method, the segments being placed on a mobile steel truss and assembled by prestressing before moving the truss to the next span.
This construction method eliminates all stability and resistance problems during construction because the spans are subject to their own weight only after all the prestressing has been stressed.
The tendon layout is extremely simple.
All tendons are installed in a similar way to certain cable stays in polyethylene ducts outside the concrete, cement grouted and anchored on either side of the pier segment.
Many other bridges of this type were built later using either the span concept or the segmental progressive construction with temporary cable stays (Campenon Bernard - France) which lead to a final structure with exactly the same forces and moments as the same structure constructed entirely on formwork in one construction phase.
In all of these structures the external prestress has the remarkable advantage of being continuous in each span, so there is no discontinuity in the prestressing forces, and the structural lightness

(generally less than 0.50 m mean thickness) is clearly seen to be a principal characteristic of this type of construction.

2.3.2. Balanced cantilever segmental Bridges

The structures previously mentioned comprise a tendon profile in a certain manner linked to the construction method and not directly transposable to more traditional means, in particular balanced cantilever construction.
However, the simplicity and absense of discontinuity of continuous exposed tendons is a seducing factor for bridge designers and has lead to the development of better tendon profiles than was usual in these structures.



ARCINS BRIDGE - A modern tendon layout

The tendons comprise three families :
- The necessary cantilever tendons, inside the top slab gussets and almost entirely straight,
- Some continuity tendons, inside the bottom slab gussets and almost entirely straight also,
- A maximum of continuous exposed tendons, placed at the end of construction and anchored at the abutment diaphragms,
and these tendon families are found with regularity in the structures built by the balanced cantilever method.

2.4.3. New structures with total external prestressing

Finally, the theoritical developments achieved during the last few years lead also to the design of a completely new type of incrementally launched bridge where the prestressing used is totally external wether temporary or permanent.
All of these examples show how developments in technonoly and construction methods have been integrated into the construction of economic structures.
But over and above this progress, new structures which may be the "structures of the future" are begining to take form thanks to the new degrees of freedom found in external prestressing and Cmore especially in the field of composite steel-concrete structures for which Campenon Bernard, imagined a framework where the webs would be made of thin corrugated steel panels, which would not drain axial compressive forces and which increase the efficiency of the cross-section in combined bending and axial load, several bridges having already been built in this way.

3. CABLE-STAYED CONCRETE BRIDGES

The rapid development of cable-stayed bridges, over the past 25 years, lead to three successive generations of stay-supported decks depending on the choice of the geometrical configuration and the number of the stays which are subject to a wide variety of considerations.

3.1. The first generations of cable-stayed bridges

The concrete bridges of the first type consisted of decks, with high bending stiffness and a large amount of prestressing, supported by few stays. The cable stays were used to replace intermediate bearings which could not be acceptable for various reasons and the statical scheme of these bridges was similar to a continuous girder with many spans additionally prestressed by the stays. The bridge deck carrying the main bending moments had to be very stiff and heavily prestressed. The cable-stays generated large forces requiring massive anchorage systems.

As long as a large number of stays simplifies the anchorage and distribution of forces to the deck, the second generation consists of concrete cable-stayed bridges with many stays resting on the main piers at each tower (partical suspension). These bridges constitute a natural extension of traditional concrete bridges, erected by the balanced cantilever method, since the cables providing stability and resistance for the typical double cantilever are placed outside the concrete and simply deviated at the towers. The deck of the bridges can be compared to a girder supported by an elastic bearing system with moderate bending stiffness. Compared to the first generation bridges they have the two following major advantages :

- The transmission of the concentrated forces from the stays to the deck is simplified due to the fact that they are reduced as well as the length between suspension points and so the bending moments in the deck.
- The replacement of the stays, in the event of an accident, can be easily insured without interrupting the traffic because the supression of one stay involve a small change of the distribution of forces in the structure.

Brotonne Bridge is the prototype of such bridges (1278.4 m long). World record in the domain of prestressed concrete structures for several years and undoubtly at the origin of a great number of very similar and large concrete cable-stayed bridges throughout the world, it consists of a cable-stayed unit, about 640 m long, and two approach viaducts. The stayed portion of the structure includes the main span (320 m) and two lateral spans (143.5 m) connected to the approaches. The stays are placed in a single plane along the longitudinal axis of the bridge.

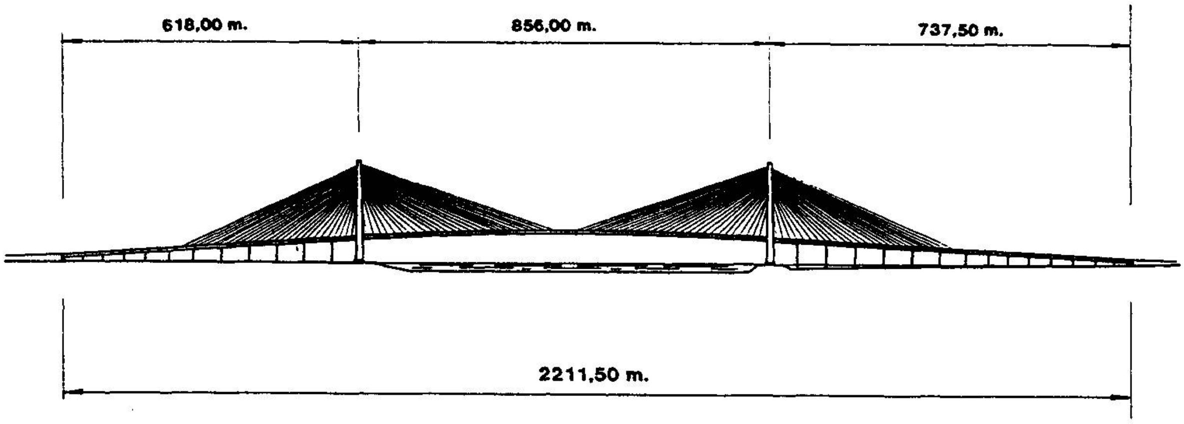
As the erection of Brotonne Bridge attracted the attention of Engineers during 3 years as an application of the balance cantilever method to very large concrete bridges a third generation of cable-stayed concrete bridges progressively appareared in major projects. This generation involves new design in which the stays support the whole deck, over its entire length, since the deck does rest on the bottom part of the towers. The performance of this type of structure is thus different from that of a simply bent girder. In reality the deck constitutes the compression chord of a reticulated lattice, where the stays are the tensioned diagonals and the tower the compressed strut. As a result, the height of the deck is almost independant of the length of the main span and can be limited, on the condition that it resists buckling and that the longitudinal deflection remain compatible with the operating conditions.

3.2. Last development in the field of cable stayed bridges

Modern concrete cable-stayed bridges are therefore characterized by very closely spaced stays. The spacing (several meters) corresponds to the length of one or two segments and provides a high level of bending strength with a reasonnable deck depth (generally between 1.5 and 3.0 meters).

Nevertheless the designers can choose a lot of parameters and more especially "lateral span length-

main span length" ration, height of pylons, number of stay planes and corresponding deck cross-sections, with regard to the main geometrical characteristics of the site and depending on special architectural considerations.
This is the reason why the interaction between construction problems in this field and structural choices will be carefully taken into consideration as showned by the experience gained when the erection of super spans will start soon :
The first one will be the Normandie Bridge, with the world's longest cable-stayed span (856 m long), located near the English Channel port of Le Havre.



NORMANDIE BRIDGE - **A super span 856 m long**

Designed by M. VIRLOGEUX (French Department of Tranportation) the Normandie Bridge consists of two approach concrete viaducts extending from the abutments to the Y reverse shaped towers and to the central steel deck of the main span trough two concrete cantilevers. Due to the reduced depth of the box-girder selected both for aerostability reasons and limited transverse wind-induced forces in the main span, the typical span length of the access viaducts was less than 50 meters in the preliminary design.
It was then possible to construct easily the bridge from one abutment to the middle of the central span, either by incremental launching or progressive segmental construction of the concrete and steel girders without any discontinuity (excepted at the level of the transverse beam of each tower).
In addition to the fact that the main span could be secured during its construction this project offers numerous advantages :

- The various problems of erection of the main span are greatly reduced,
- The high number of lateral piers increases the number of back stays which are distributed in the whole rear stay system. (allowing the distribution of the top anchorages along a highest part of the pylons) but the difference of linear weight between concrete approaches and steel part of the main span prevent any uplift of the deck on side piers
- This multiplication and distribution of back stays along the whole structure allows for a decreased displacement of the main span and towers more especially under loading of the 856 meters long span. On the contrary when the side spans are loaded no forces are generated in the stays and the total range of moments consequently generated in the main span is subsequently reduced.