A special report

Ten years of experience in precast segmental construction

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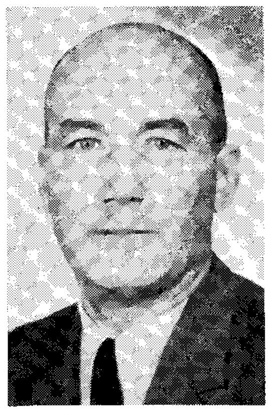
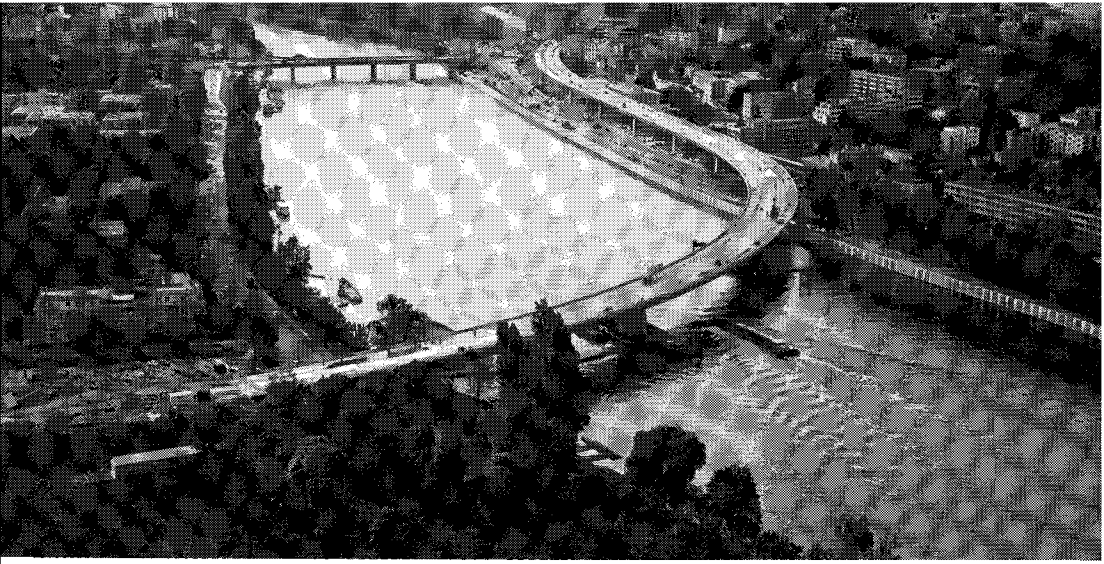
This state-of-the art report is drawn from the practical job experience of an engineer who became intimately involved in the design and construction intricacies of precast prestressed segmental construction from its very earliest beginning.



As bridge spans increased in length, it became apparent that conventional precast prestressed concrete girders would soon be limited by their maximum transportable weights and/or lengths. For example, when delivered over highways, the length of precast girders is usually limited to 100 ft (30 m) maximum.

The answer to this problem lay in the development of precast prestressed segmental construction in which the benefits of both precasting and post-tensioning could be combined advantageously.

In segmental construction, large quantities of high quality precast units (or segments) are manufactured under controlled factory conditions and then transported with conventional carriers to the job site. There, the segments are assembled easily and lifted into place on the superstructure. The segments themselves are then tied together using post-tensioning.



Saint-Cloud

Segmental construction is very efficient in congested urban areas (causing only a minimum of traffic disruption) and also is very adaptable over long stretches of water or rugged terrain. Since expensive falsework is eliminated, there is little interference with the environment.

Another major advantage of segmental construction is that by a small variation in the precasting operation (or of the jointing material between the segments), a structure can be produced to take up any required horizontal or vertical curvature as well as the required superelevation.

Scope of Survey

There are two broad systems established using segmental construction. The difference between these two systems lies in the formation of the joint between the adjacent segments.

On the one hand, there is the system where a cast-in-place concrete joint (mortar or grout joint) is used between the precast elements. This joint is usually of the order of 3 to 4 in. (75 to 100 mm). This type of joint will not be considered in this report.

In the other and more prevailing system the jointing material is an epoxy resin which is of only very nominal thickness (not greater than 1/32 in. or 0.8 mm). Because of these very tight tolerances, special techniques must be developed to fabricate segments with ends suitable for epoxy resin jointing.

To minimize the joint thickness it is necessary to obtain a perfect fit between the mating ends of adjacent segments. This is achieved by casting each segment against the end face of the preceding one (so-called match casting), and later erecting the segments in the same order they were cast.

This state of-the-art report will only consider segmental construction with match-cast segments in which the jointing material between adjacent segments is an epoxy resin.

The author, whose company pioneered in the development of precast prestressed segmental construction, reports on the state-of-the-art of this versatile and fast-growing construction technique.

The report confines itself to the discussion of segmental construction with match-cast segments in which the jointing material between adjacent segments is an epoxy resin.

Following a historical review of the development of segmental construction, design considerations are given for a typical segment and glued joint, choice of structural system and erection technique, selection of transverse cross section, design of longitudinal members, design of piers and stability during construction, control of deflections, precasting methods, and hoisting equipment needed for erecting the segments.

The last part of the report describes the application of segmental construction to freeway overpasses and the latest technique of progressive segment placing.

It is concluded that precast segmental construction is an efficient and economical construction method for medium to long-span structures.

Historical Review

Although the principle of segmental construction has been known by design engineers for at least a few decades, it was not until 1952 that a single span county bridge in New York State, designed by the Freyssinet Co., was built using that concept.

The bridge girders were divided longitudinally into three precast segments which were cast end to end. After curing, the segments were transported to the job site where they were reassembled and post-tensioned with cold joints.

This project was the first use, although admittedly on a small scale, of a technique called match-making segmental construction. Since then the technique has been refined and has developed into an important world wide construction method suited to a broad range of applications and in particular bridges.

The first major commercial application of segmental construction was done in France 10 years later (1962). This landmark was the Choisy-le-Roi bridge over the Seine River, south of Paris, designed and built by Entreprises Campenon Bernard. Several other structures of the same type were built in due course. At the same time, the techniques of precasting segments and placing them in the structure were continually refined.

For example, the 10,000-ft long Oleron Viaduct, built between 1964 and 1966, made use of the launching gantry for the first time. With this equipment the segments could be moved over the completed part of the structure and placed in cantilever sections over successive piers. Using this method an average rate of 900 ft (270 m) of finished deck per month was attained.

As time went on, improvements were made in precasting methods and in gantry design to allow for larger segments and longer spans which curved in plan.

The technique of segmental construction not only gained rapid acceptance in France but spread to other countries. For example, the Netherlands, Switzerland and later Brazil and New Zealand adopted the method. Many other countries are today using the segmental technique for various applications. Currently, several bridges of segmental construction have been built or are under contract in North America.

Meanwhile, the advantages of precast segmental design have been extended to short-span structures. This field was previously reserved to other construction methods such as cast in place or precast girders.

Recent projects have shown that an urban elevated viaduct can be erected at the rate of two to three complete spans of 120 to 150 ft (35 to 45 m) per week. Also, a deck for freeway overpasses could be constructed in less than one week at a cost substantially lower than any other construction method.

Figs. 1.1 through 1.20 present a panorama of some precast segmental structures built between 1963 and 1973. The examples further show that with segmental construction it is possible to attain many variations of bridge shapes which are both functional and esthetic.

Typical Segment and Glued Joint

Although the concept of match-cast segments can be applied to many different types and shapes of structural members, special consideration should be given to box sections since these are the most commonly used units.

As can be seen from Fig. 2, there is a distinct difference between a precast segmental deck and a precast girder deck. For example, in the typical girder structure, long slender members are assembled transversely to form a typical span with a conventional cast-in-place deck. However, in segmental construction, the method is based on the assembly by post-tensioning of segments laid longitudinally end to end, thus comprising the total deck width.

Hence, precast segmental construction can be considered to be an alternative method to cast-in-place box girder construction. Very significantly, though, the use of segments eliminates the need for falsework but at the same time retains the advantages of optimum depth and structural rigidity.

Fig. 3 shows typical sections of a simple box segment. This type of segment would be appropriate for a cantilevered roadway slab such as would accommodate a two-lane bridge.

The segments are cast in series against each other preferably in the same order as they will be assembled subsequently in the structure. The joints are perfectly matched and consequently there is no need for conventional mortar joints except at certain specific locations.

End sections such as (1) are provided with keys in the webs (2), to insure temporarily the transfer of shear stresses during construction while an additional key (3) allows transverse alignment during erection.

Ribs and/or anchor blocks are now commonly used inside the box girder for anchoring the permanent longitudinal prestressing units and/or for temporary assembly of the segments.

Fig. 4 shows how a typical segment is assembled to the rest of the structure by temporary devices placed, for example, at the top and bottom slab levels. The two loads, F1 and F2, can be resolved together with the segment weight, W, into a resultant, R, inclined with respect to the joint between segment (S) and the previous one.

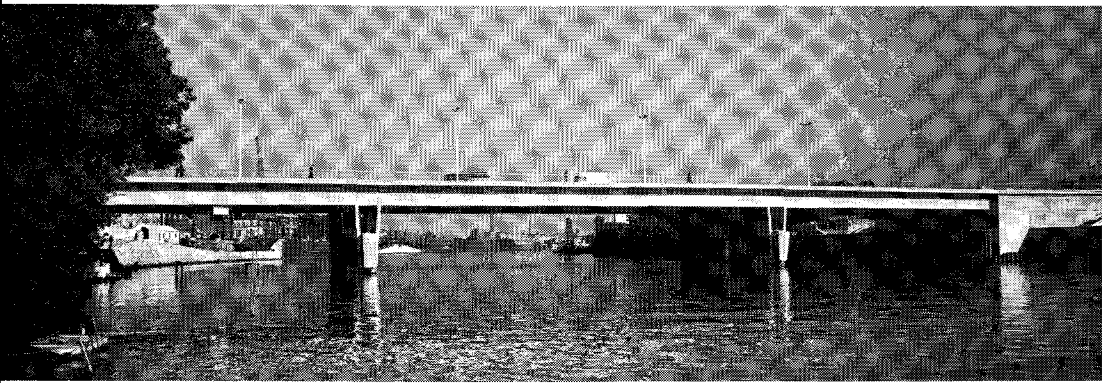


Fig. 1.1. Choisy-le-Roi (over the Seine River).

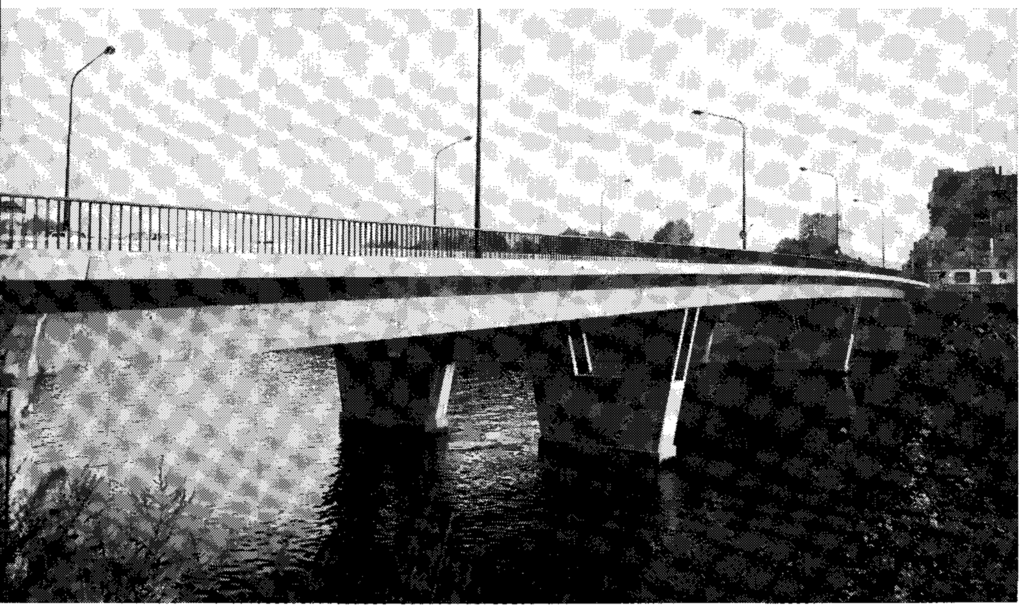


Fig. 1.2. Courbevoie.

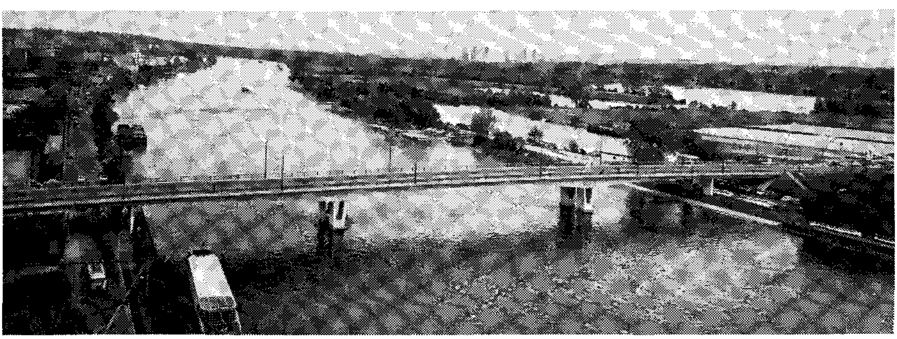


Fig. 1.3. Juvisy.

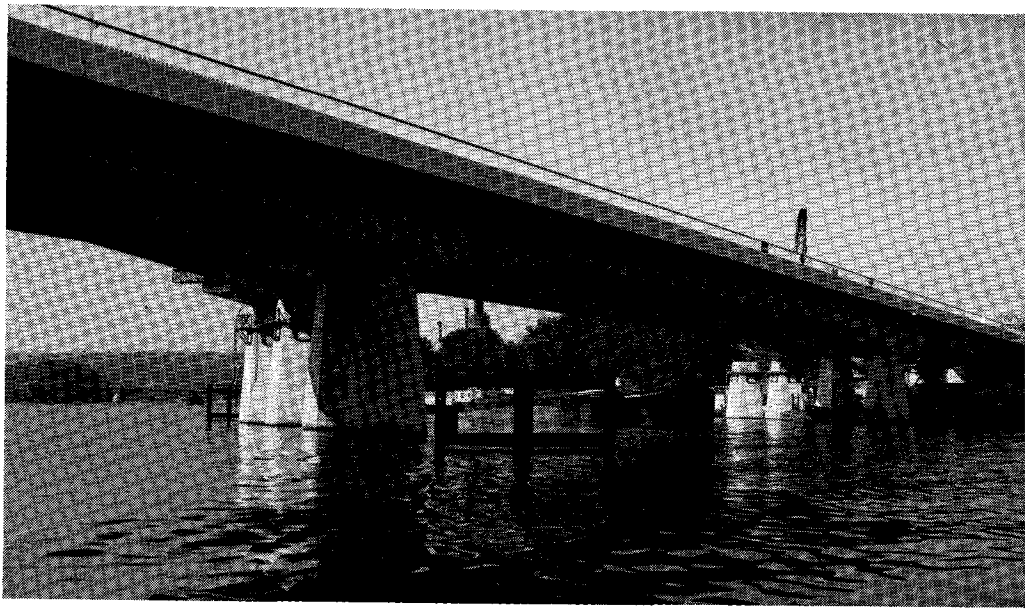


Fig. 1.4. Paris Belt (downstream bridge).

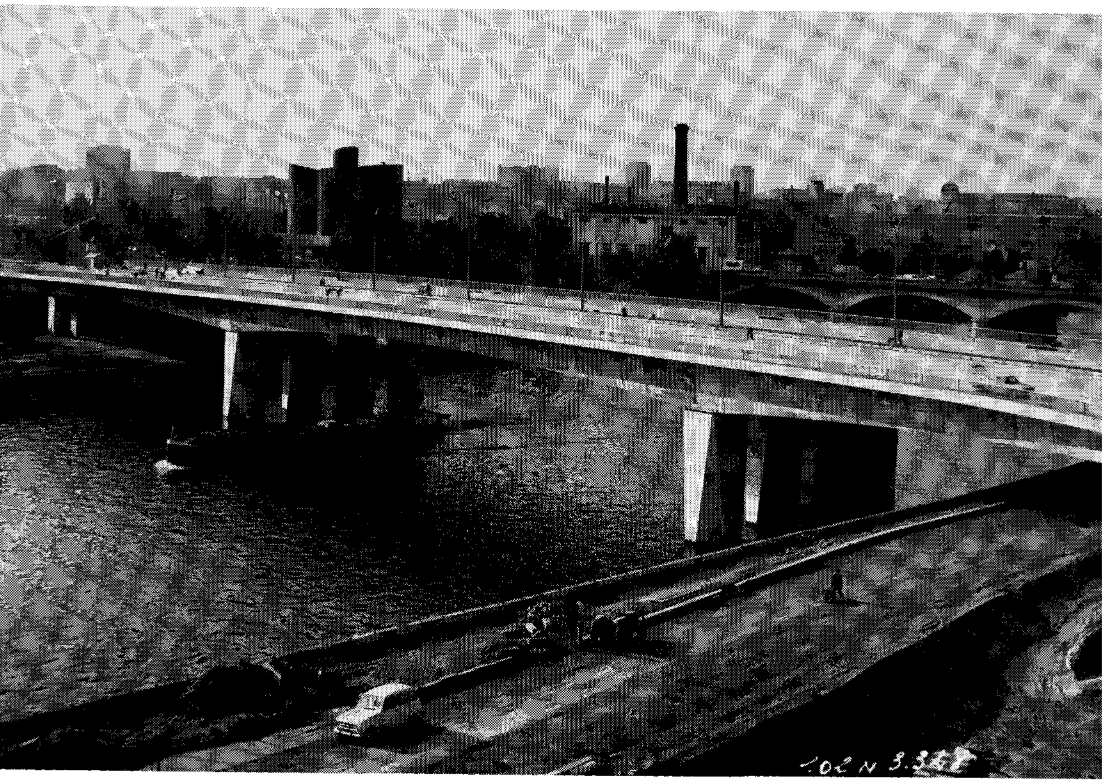


Fig. 1.5. Paris Belt (upstream bridge).

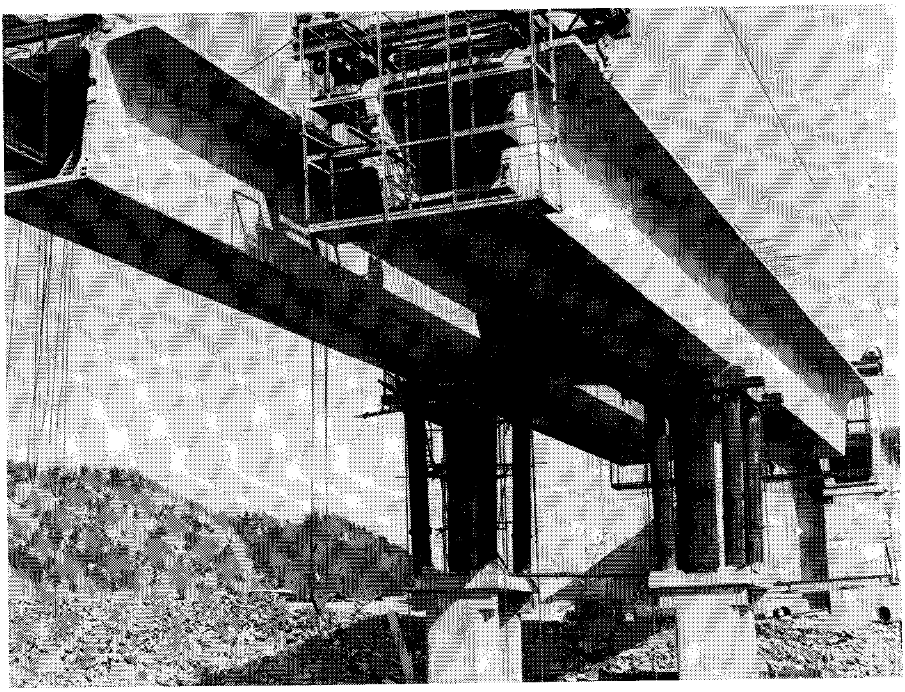


Fig. 1.6. Pierre Benite.

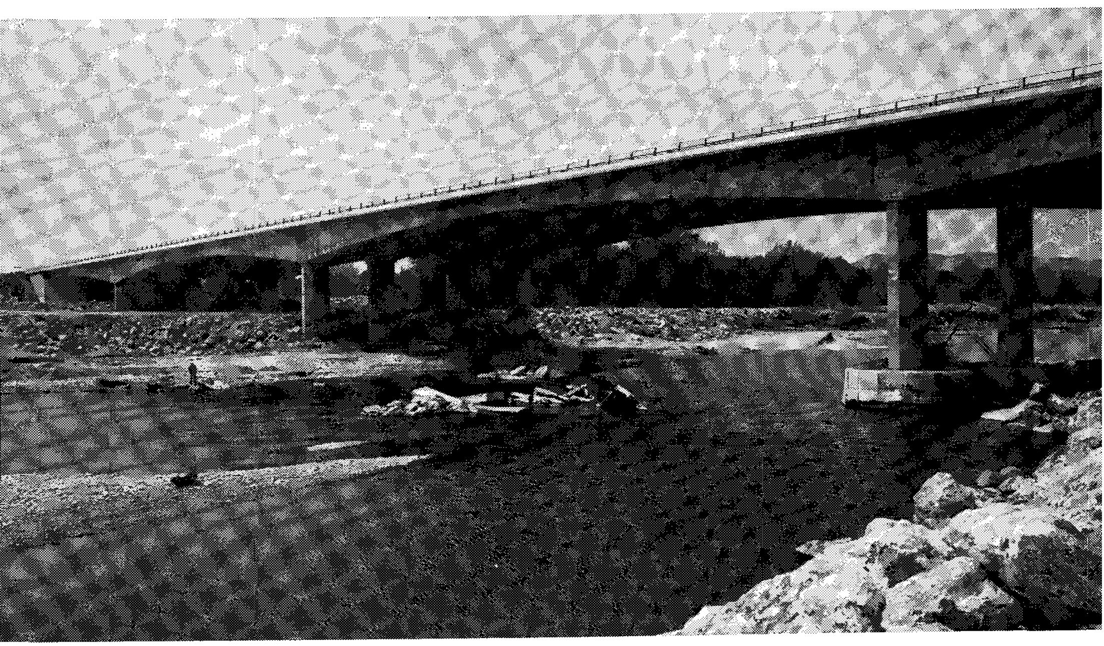


Fig. 1.7. Gardon.

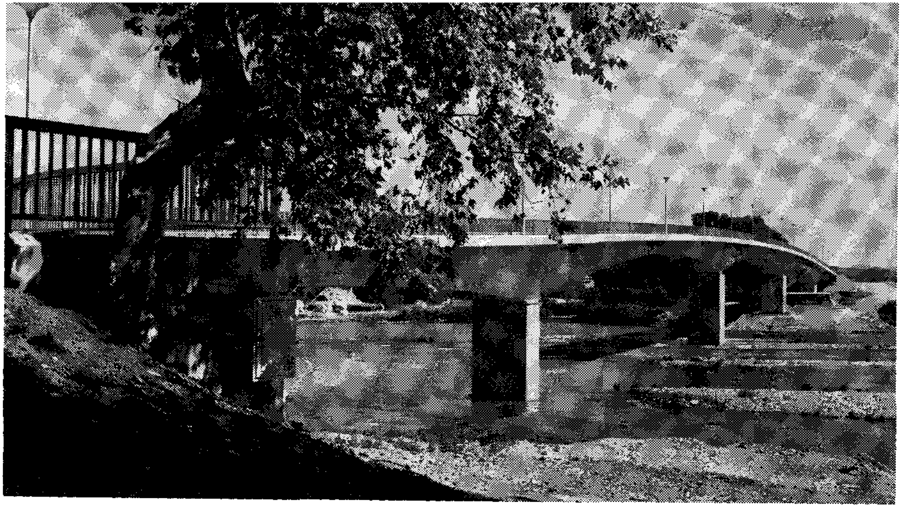


Fig. 1.8. Bourg-Saint-Andeol.

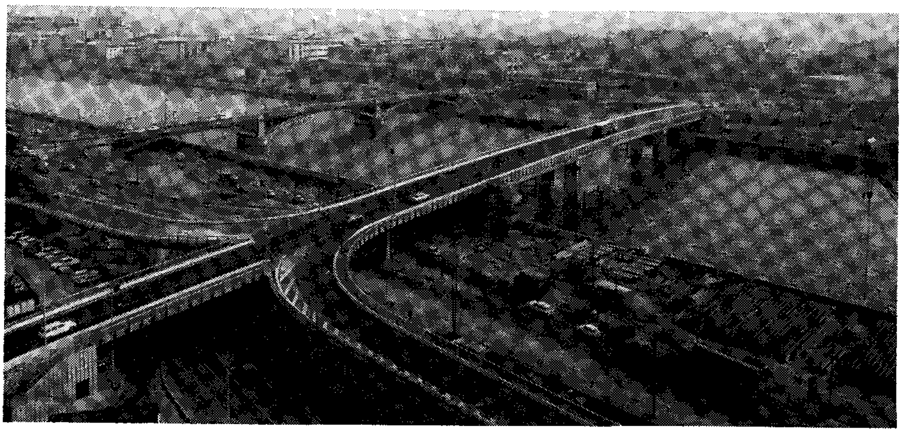


Fig. 1.9. Conflans.

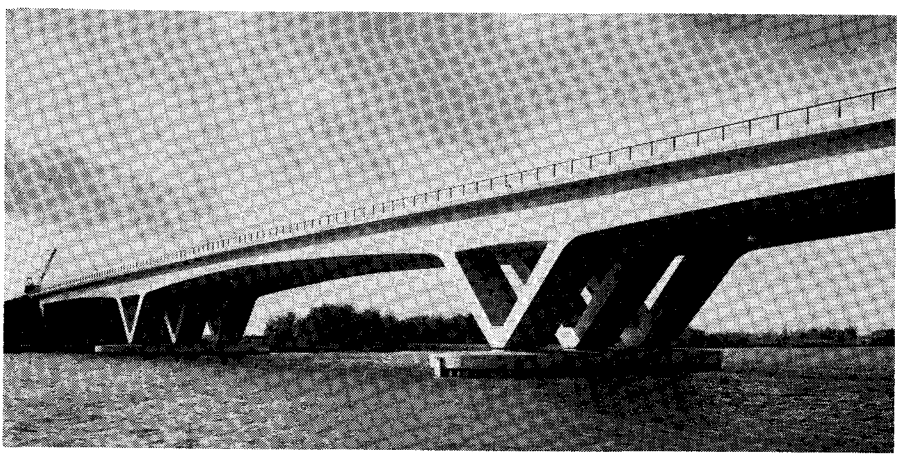


Fig. 1.10. Brielse Meer (Holland).

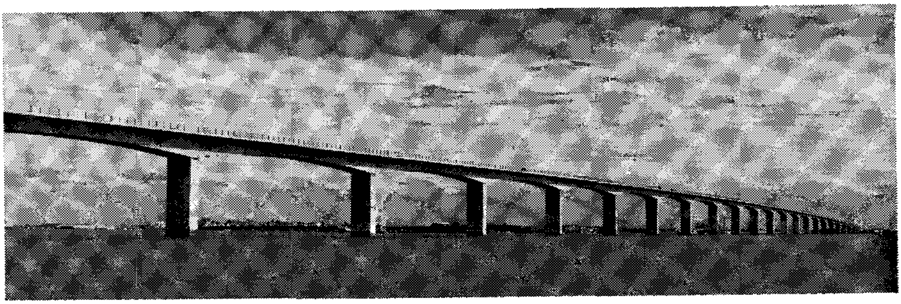


Fig. 1.11. Oleron Viaduct.

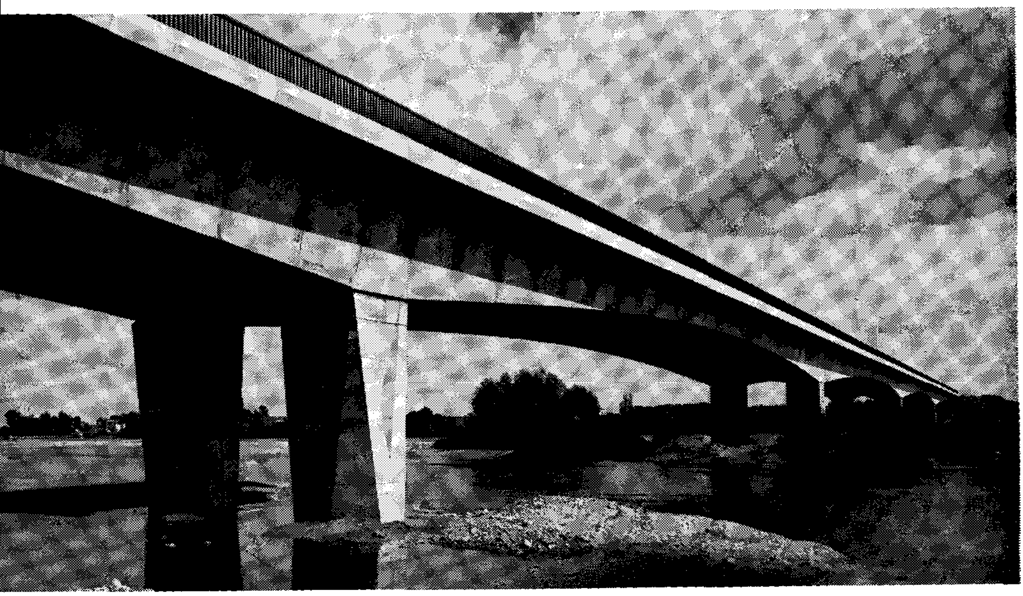


Fig. 1.12. Blois.

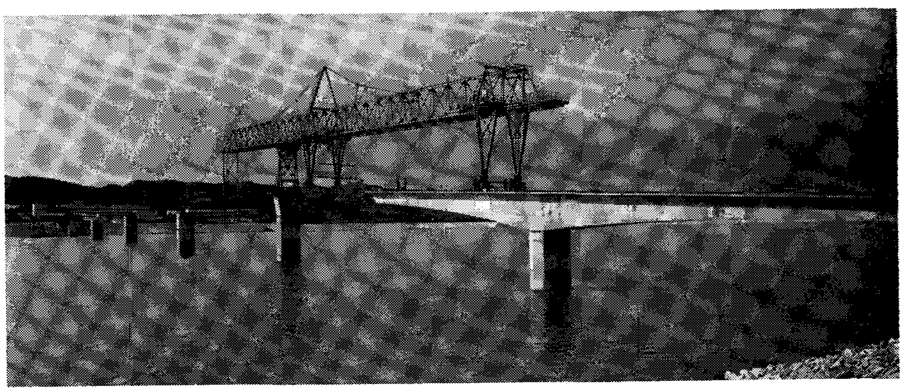


Fig. 1.13. Aramon.

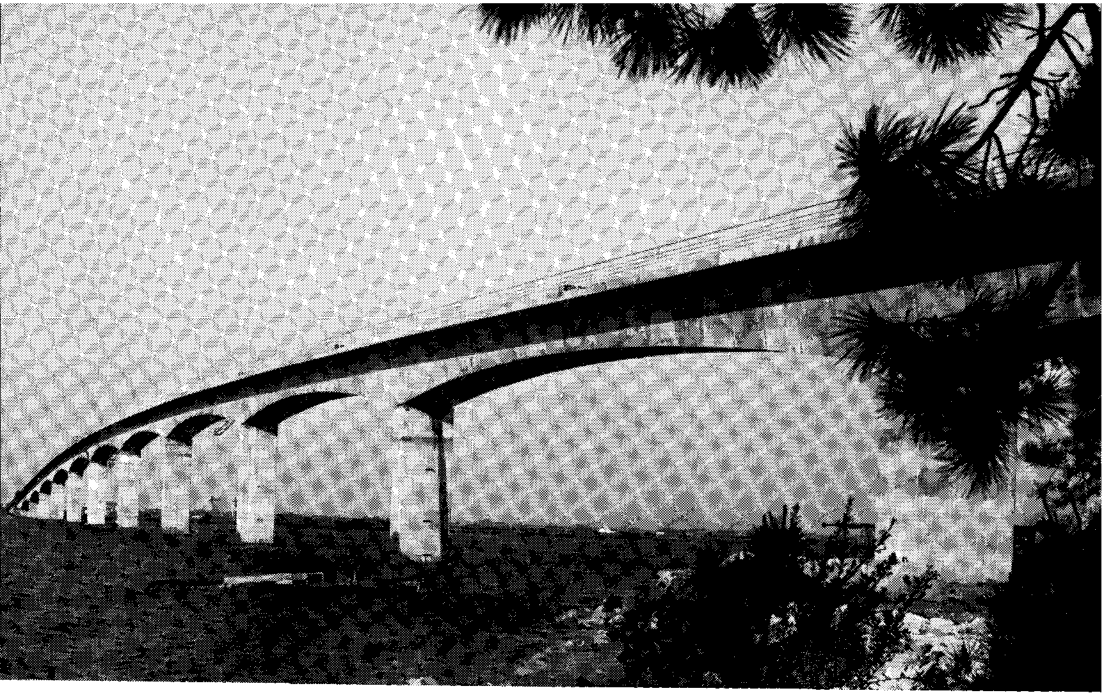


Fig. 1.14. Seudre.

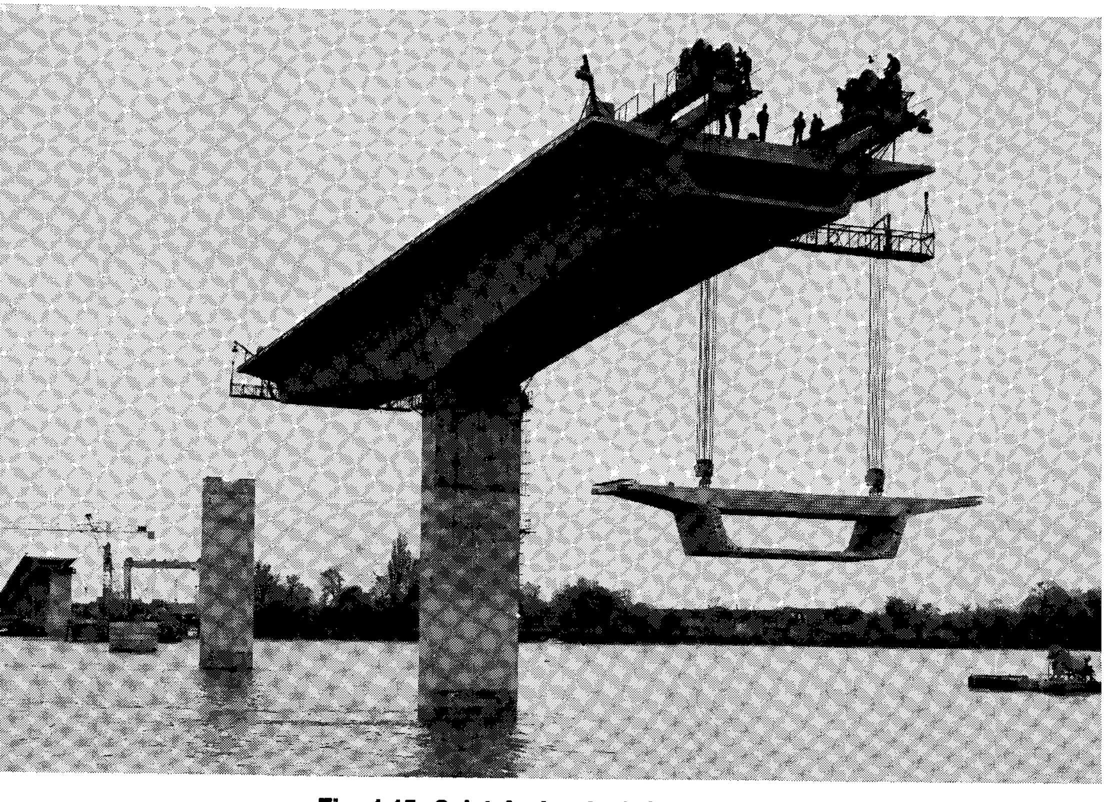


Fig. 1.15. Saint-Andre-de-Cubzac.

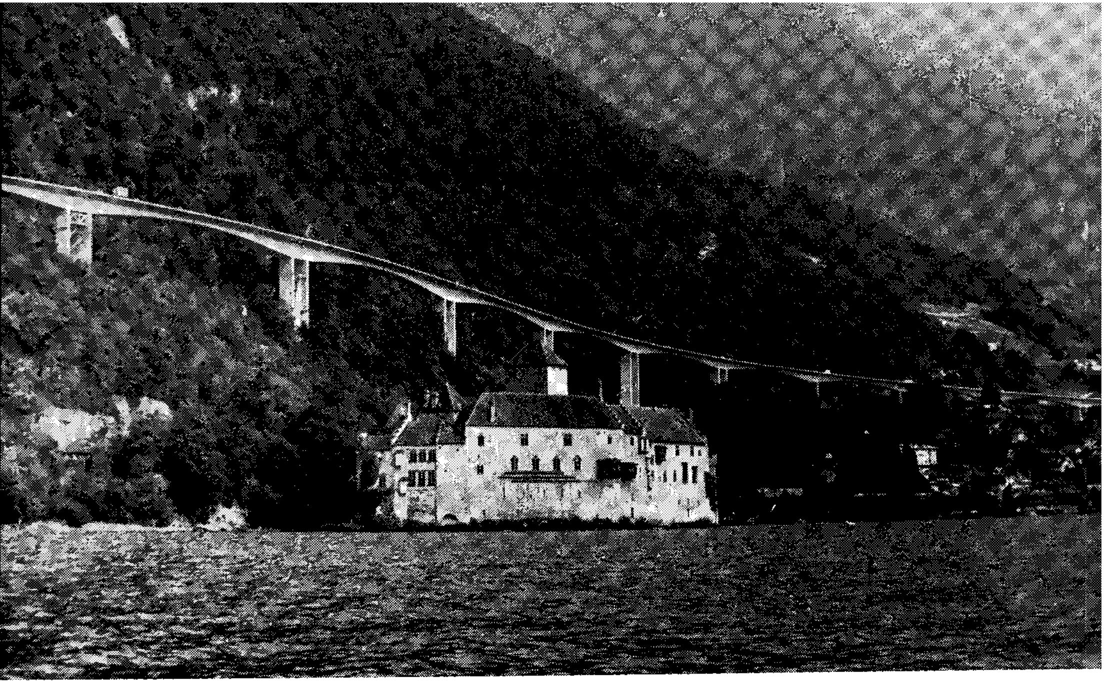


Fig. 1.16. Chillon Viaducts (Switzerland).

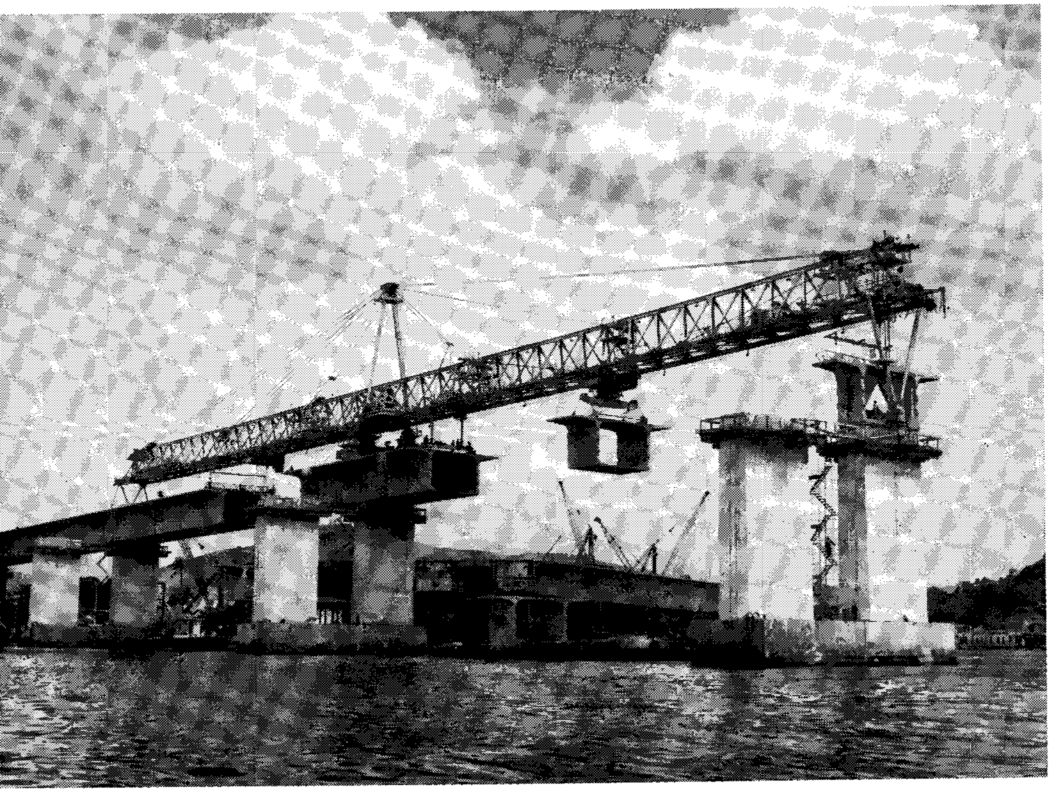


Fig. 1.17. Rio-Niteroi (Brazil).

Fig. 1.18. B.3. Viaducts (Paris).

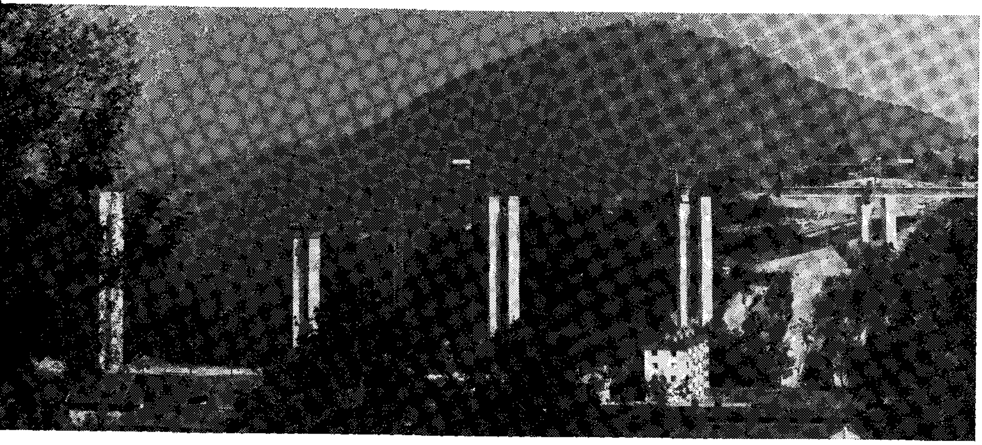
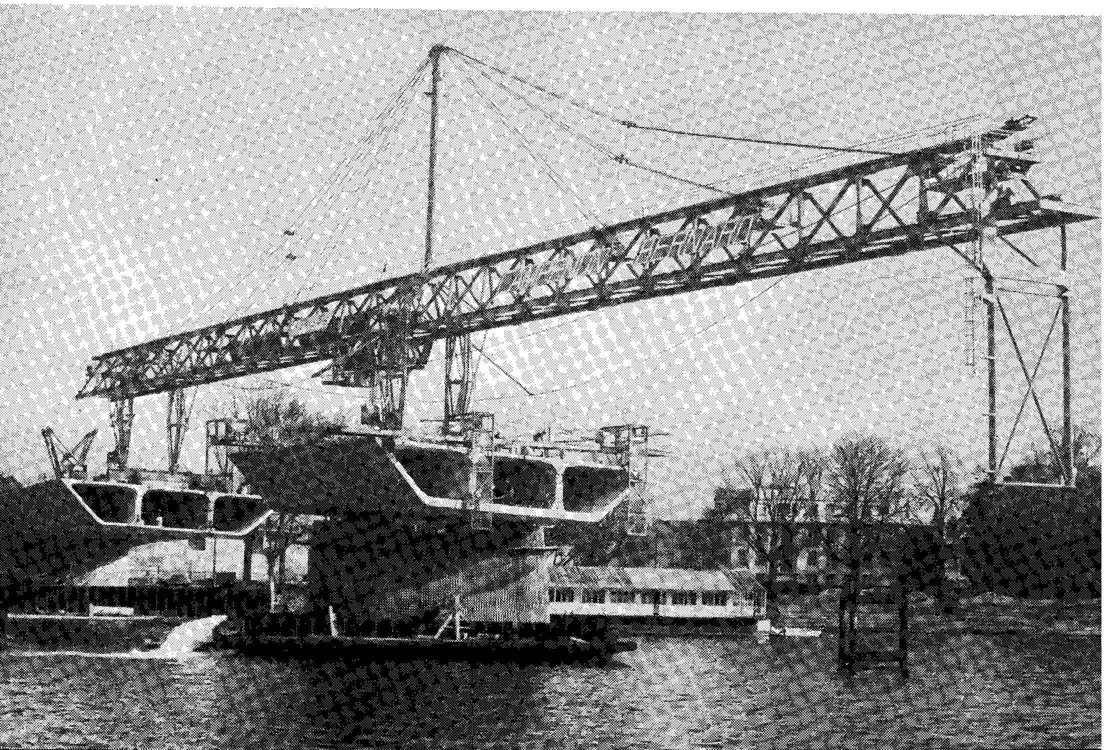


Fig. 1.19. Alpine motorways viaducts.

Fig. 1.20. Saint-Cloud.



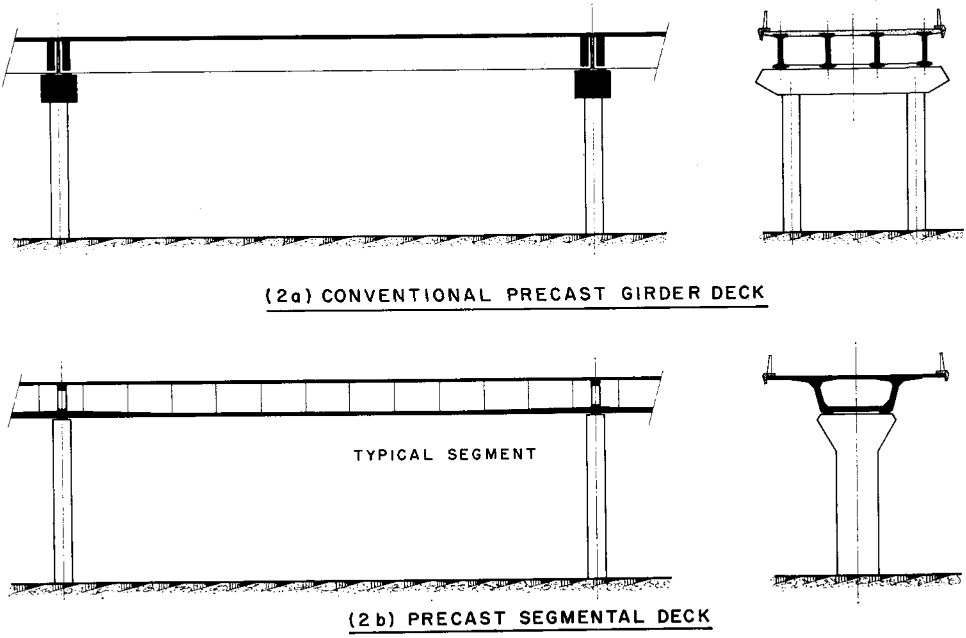


Fig. 2. Comparison between a precast girder deck system and a segmental design.

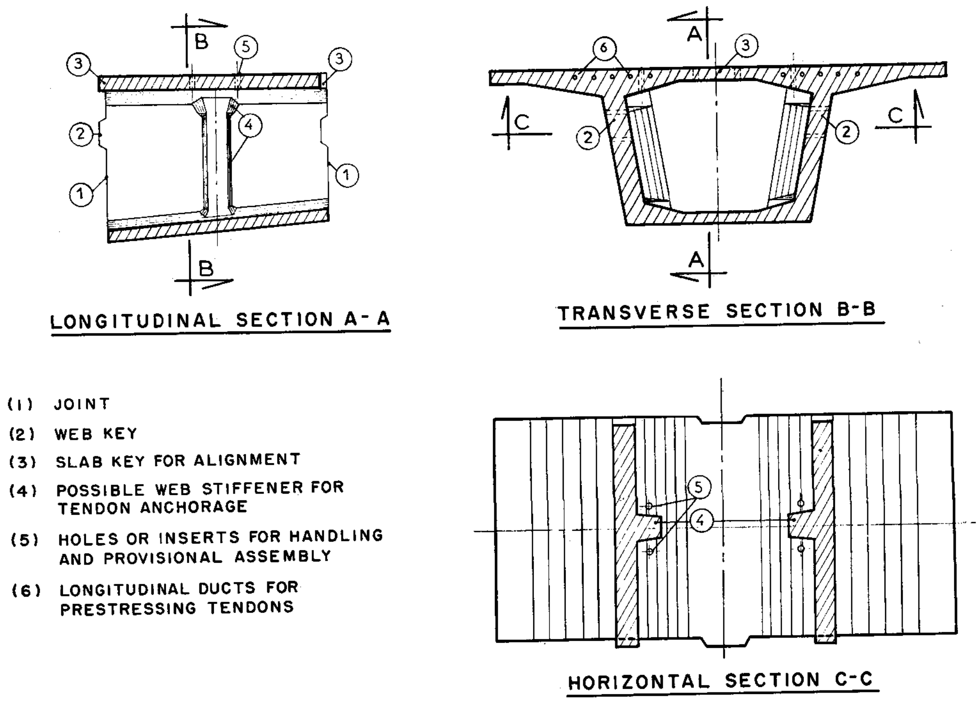


Fig. 3. Typical precast segment (contrast with Fig. 5).

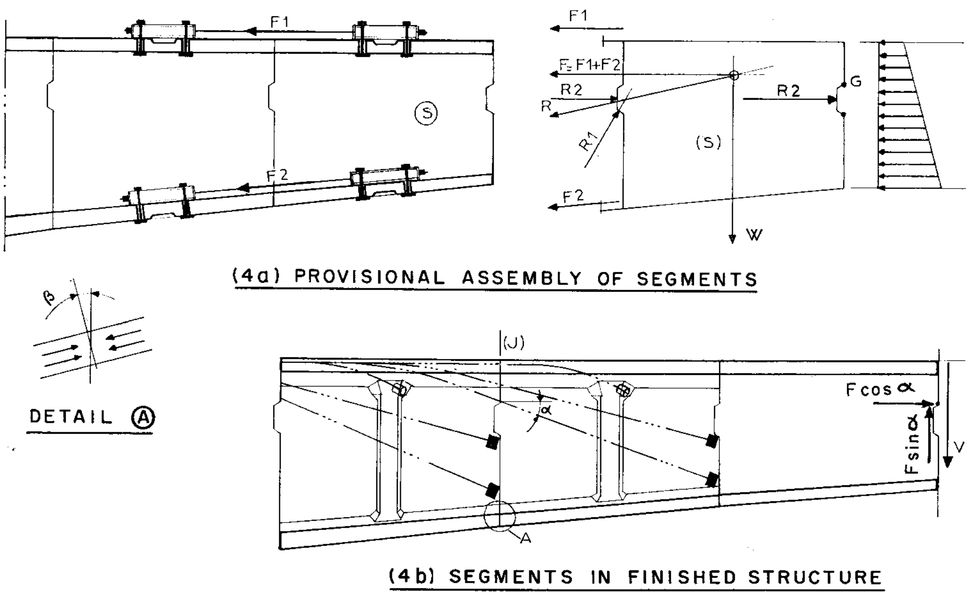


Fig. 4. Typical segment in relation to finished structure and force system.

Epoxy Joint

At the time of assembly the thin epoxy glue used in the joint acts only as a lubricant. Thus, the epoxy joint has little shear or friction capability and the shear force through the joint can be carried only by the web keys. Together, the keys contribute, with reaction R1 (perpendicular to the lower face of the interlock), to the stability of the unit while the balance R2 of the resultant force induces compressive stresses in the fresh joint.

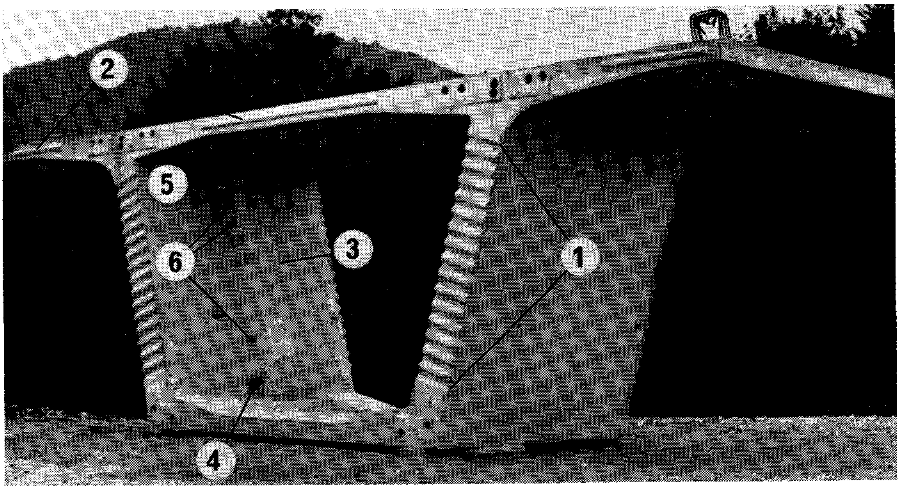
It is considered prudent to select the location and magnitude of the temporary prestress forces, F1 and F2, in such a way so as to induce compressive stresses in the total height of the section even to the point of obtaining a uniform stress distribution (R2 then being at the level of the center of gravity).

In general, the fresh glue in the joint has a dual purpose during construction, i.e., as a lubricant and as a means of achieving perfect matching.

In the completed structure the hardened glue will further provide the joint water tightness and contribute also to the structural rigidity of the members. In cold climates where deicing materials are used on bridge pavements, proper treatment of the joint at the roadway slab level is essential. Tightness of the joint is also essential for efficient cement grouting of the prestressing units across the various joints where ducts are necessarily interrupted.

It should be noted that in the early development of segmental construction the main purpose of the glue was to transfer across the joints both bending and shear stresses between adjacent segments. Epoxy glues properly selected, mixed, and placed show strengths well above those of concrete, although it is difficult to restore the tensile strength of concrete across a joint.

This attribute of epoxies was never considered mandatory because segmental structures are usually fully pre-



KEY

(1) Castellated web key.

(2) Slab key for alignment.

(3) Web stiffener.

(4) Tendon duct and anchorage for final assembly.

(5) Insert for handling and temporary assembly.

(6) Tendon ducts for temporary assembly.

Fig. 5. Precast segment with multiple keys and internal stiffeners (contrast with Fig. 3).

stressed and thus no appreciable tensile stresses develop at any point across the joints. It is more important for the glue to have the capability of transferring shear stresses which may reach a magnitude of 600 psi (42.3 kg/cm^2).

Improper choice or use of the epoxy glue may be critical with respect to shear strength. However, quality control is about the same for epoxy glues as for any other structural material such as concrete (including grouts and admixtures).

The next refinement in the evolution of epoxy joints was the development of a method whereby the epoxy glue could be relieved of any structural function. This improvement was thought to have the advantage of simplicity, safety, and cost. The new multiple key designs embody this concept (see Fig. 5).

Webs and chords of the section are provided with a large number of small interlocking keys designed to carry all stresses across the joint with no structural assistance from the glue. Today, the major purpose of epoxies used in segment joints is three-fold:

1. To lubricate the adjoining surfaces of the segments.
2. To perfectly match the adjoining segments.
3. To provide water tightness and durability at the joints.

A further improvement to the original concept of the glued joint was recently brought about with regard to the tensile strength of the joints and the continuity of the non-prestressed longitudinal reinforcement. There are today satisfactory ways of placing dowels or tensioned bolts across the joints.

Choice of Structural System and Principle of Construction

In general, the precast segmental technique is closely related to the method of construction and the structural system employed.

This is the reason why precast segmental design has often been identified with cantilever construction which was used in most applications. However, other construction methods are available which will be discussed below.

Cantilever construction

In this construction method the segments are placed in balanced cantilever starting generally from a pier in a symmetrical operation.

The designer should always remember that construction proceeds with symmetrical cantilever deck sections centered above the piers and not with complete spans between successive piers. For a typical three-span structure, the side spans should preferably be only 65 percent of the main center span (instead of 80 percent in conventional cast-in-place structures). This is done to reduce to a minimum the length of the deck portion next to the abutment which cannot be conveniently built in balanced cantilever (see Fig. 6).

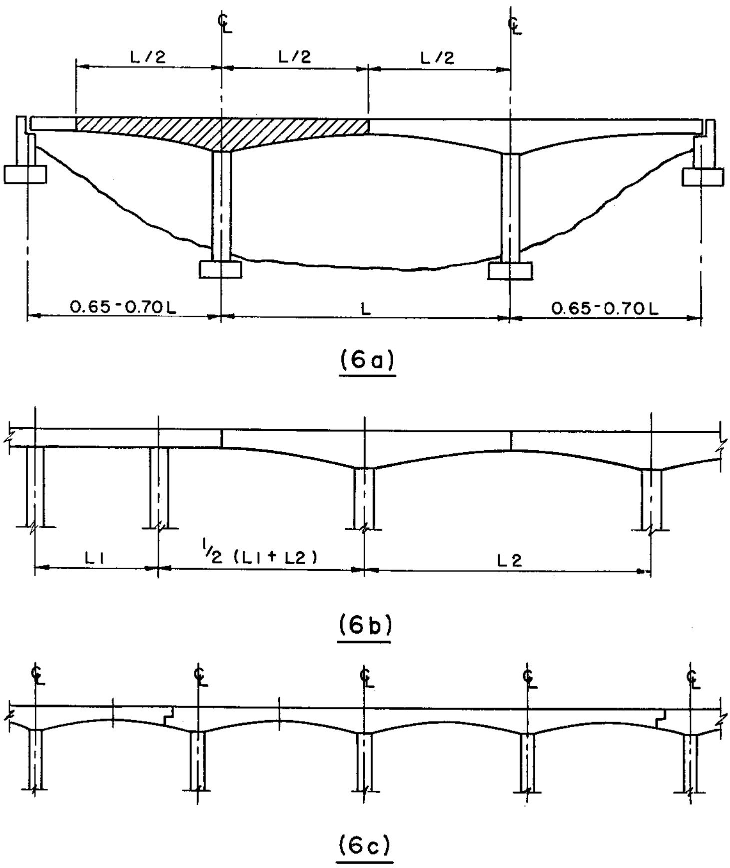


Fig. 6. Cantilever construction showing choice of span lengths and location of expansion joints.

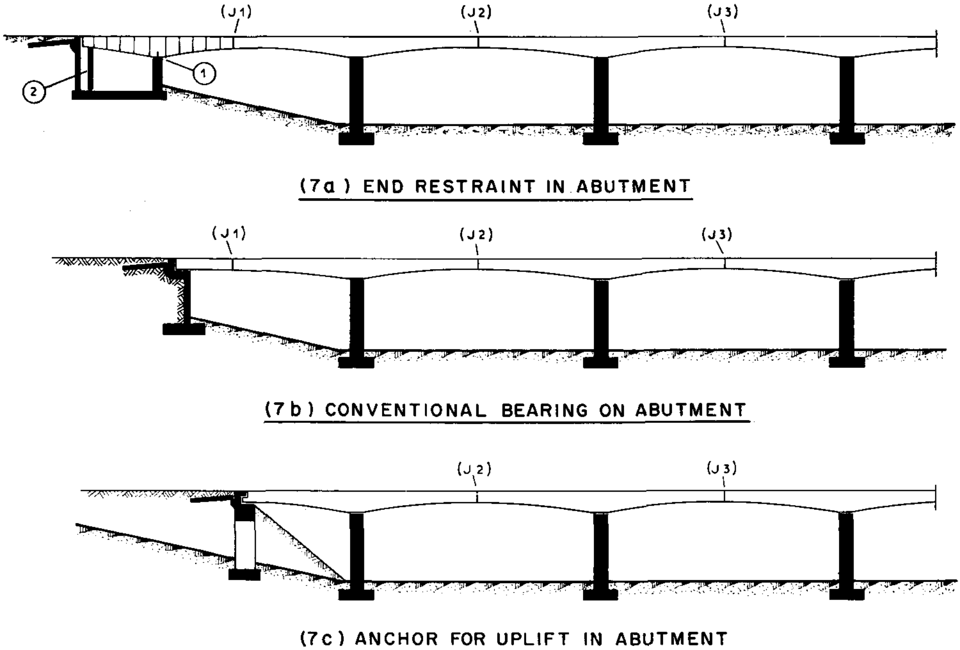


Fig. 7. Construction of end spans.

Where two different spans L1 and L2 (for example at the transition between approaches and main spans in a viaduct), an intermediate span of average length will optimize the use of the cantilever concept.

Individual cantilever sections are subsequently assembled into a continuous deck in most cases and no permanent hinges are maintained near the center of the various spans. Continuous decks up to more than 2000 ft (600 m) long have been built in this manner and have been satisfactory to both the owner (because of low maintenance cost) and the user (because of the good riding surface).

On very long structures, however, intermediate expansion joints are necessary because of volume changes. These joints should preferably be located near the contraflexure point to avoid the objectionable angle break which often develops when the joint is located at midspan.

Construction of end spans

Because of unavoidable requirements in the layout of piers, it may not always be possible to select the optimum span arrangement. Thus, the end spans may very well be much above or below the optimum length (see Fig. 7).

(a) *Long end spans*—In this case, a bridge deck may be extended over the abutment wall to provide a short additional span.

With reference to Fig. 7 a conventional bearing (1) is provided over the front abutment wall, while a rear prestressed tie (2) will oppose uplift and permit cantilever construction to proceed outwards from the abutment up to the joint section (J1) where a connection is made with the cantilever construction starting from the first intermediate pier.

(b) *Normal end spans*—Here, a special segment is placed over the abutment and one or two segments are temporarily cantilevered out so as to reach the first balanced cantilever constructed from the next pier.

(c) *Short end spans*—In this situation, cantilever construction starts from the first pier and reaches the abutment on one side well before the midspan section of the following span. An uplift reaction has to be transferred to the abutment during construction and in the completed structure.

Consequently, the webs of the main box girder deck are cantilevered over the expansion joint into slots provided in the main abutment wall (see Fig. 8). The neoprene bearings are placed above the web cantilever rather than below to transfer the uplift force while allowing the deck to expand freely.

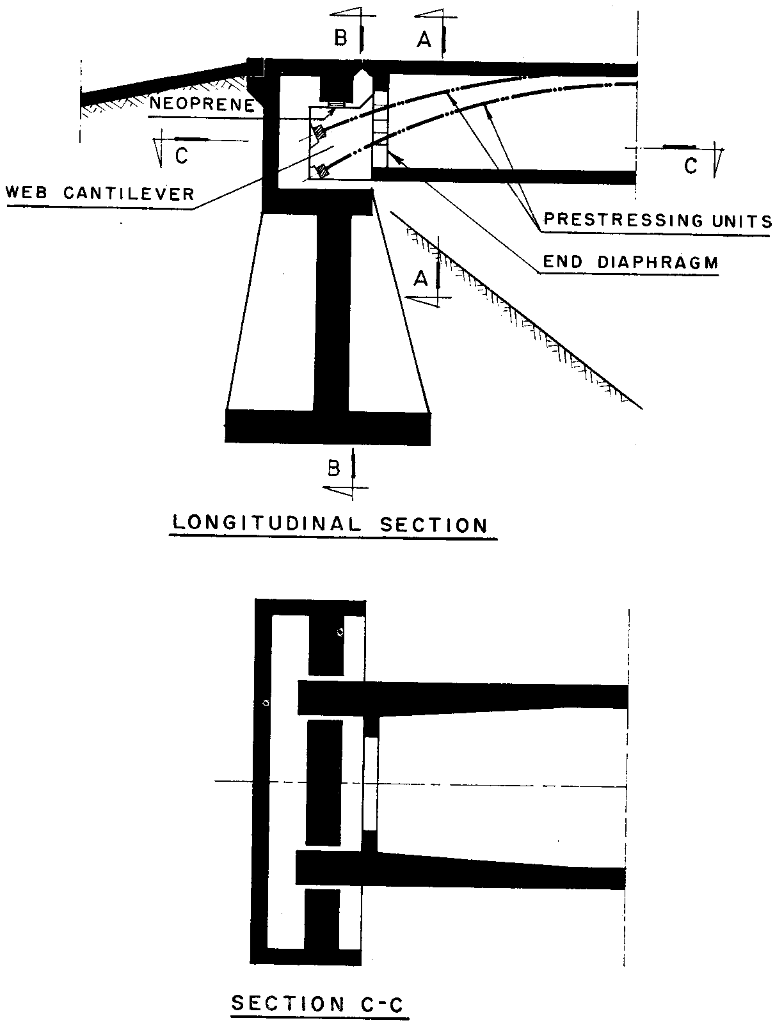


Fig. 8. End span anchor in abutment for uplift.

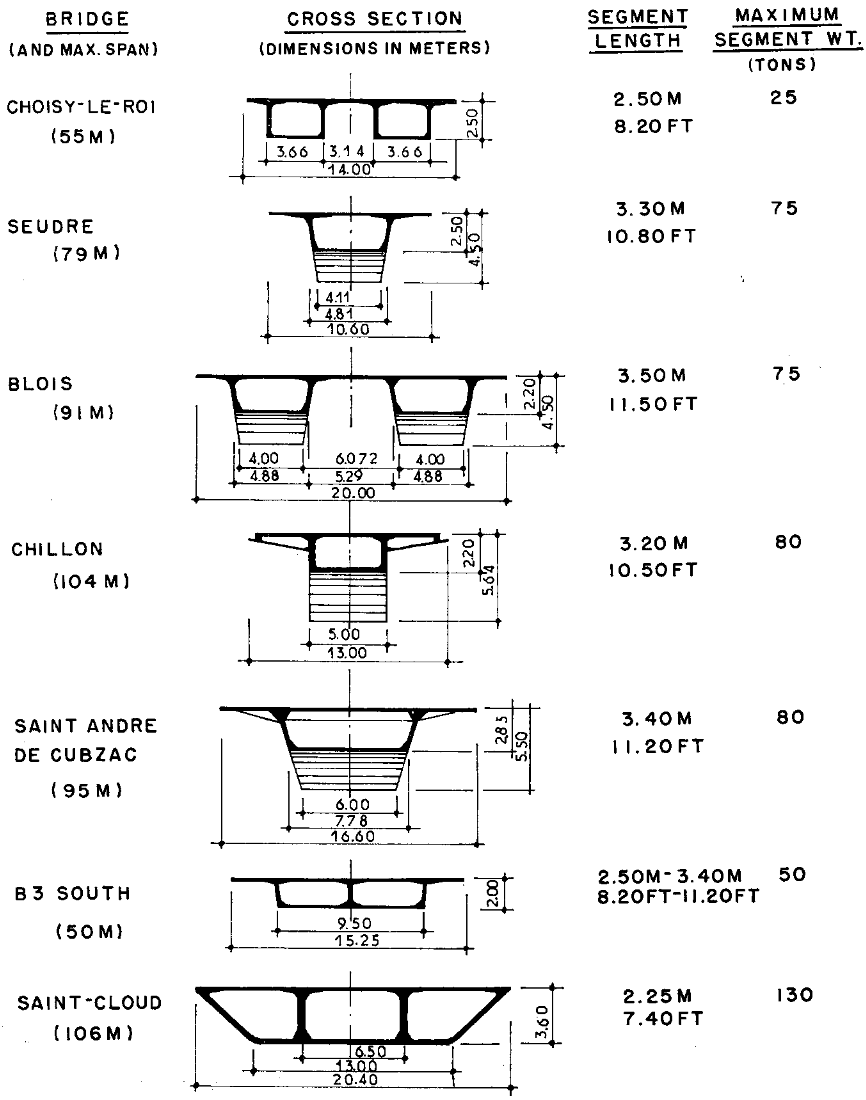


Fig. 9. Evolution of segment shape and weight.

Selection of Transverse Cross Section

In general, box girders have been shown to be best suited to most design and construction requirements. In addition, the torsional rigidity of the section provides excellent stability during construction and later during the life of the structure.

Because cantilever construction induces high dead load moments over the supports, the large bottom chord required to carry the compressive stresses is conveniently obtained in the box design. At ultimate, the strength of the compression flange is such that the limiting capacity of the prestressing tendons is exhausted thus avoiding an early brittle concrete failure.

Depending upon the deck width, the design of the transverse cross section will vary. For example:

1. Up to 40 ft (approx. 12 m), a conventional single box with two webs may be used.

2. For wider decks, several individual boxes are assembled transversely by prestressing. However, for single box girders, a more refined design is used: three or four webs (with either vertical or tapered facia) for widths up to 70 ft (approx. 21 m).

3. For intermediate widths, single box girders may be used in conjunction with a ribbed roadway slab (e.g., St-André de Cubzac Viaducts) or boxed cantilevers (e.g., Chillon Viaducts).

Fig. 9 summarizes some pertinent design features of various cross sections. The bridge sections further show the trend towards an increase in size and unit weight of the segments. Note, for example, the difference between:

(a) Choisy-le-Roi (1962) where two parallel box girders with 25-ton segments were used for a 46-ft (14 m) wide deck, and

(b) Saint-Cloud (1972) where a single box girder with four webs and 130-ton segments were used for a 67-ft (20 m) wide deck.

Design of Longitudinal Members

Shape of deck in elevation

A constant depth design has the advantage of simplicity for construction and is sometimes preferred for esthetic reasons. However, the constant depth section is not economical in the present state of the art for spans much longer than 200 ft (60 m).

For longer spans, a variable depth with circular soffits or straight haunches should be used because the deeper sections are better able to resist the cantilever moments.

Design of longitudinal prestress

To resist the increasing dead load moments over the piers during the cantilever operation, prestressing tendons are placed at each step of the erection. Running in the deck slab through preformed holes, tendons are anchored symmetrically in each pair of segments.

It might be noted that in earlier structures, anchors were placed in the outer face of the segments. However, there is now a tendency to have the anchors in the haunches inside the box section because it is preferable to place the segments and stress the tendons in two independent operations.

Continuity of individual cantilevers meeting at the center of the successive spans is achieved by another series of prestressing tendons installed after placing the drop-in segment and casting the joint between adjacent deck sections. Most of the tendons run at the soffit level to resist the positive bending moments along the spans while the cantilever prestress is designed to resist all dead and live moments over the supports.

Overlapping the two series of prestressing tendons is often achieved by draping most of the tendons in the webs. If straight tendons are used, a vertical web prestressing is generally required for that purpose. This vertical prestress also takes care of shear stresses, particularly in constant depth decks.

Redistribution of moments due to concrete creep and prestress losses

In continuous structures the final stresses in the completed structure are substantially different from what they were initially during construction. However, subsequent volume changes in the materials will induce deformations which will tend to make the initial and final stresses get closer to each other. This means that there will be a redistribution in the moments of the structure.

In general, the negative moments over the piers will decrease while the positive moments at midspan will increase by a corresponding amount.

This redistribution of moments should be allowed for in the design.

Ultimate capacity of structure

Because the moments near the center of the spans are relatively small in the elastic stage, the amount of continuity prestress is usually substantially lower than that of cantilever prestress. Thus, there is little need for tendons at the deck slab level.

The capacity of the structure to withstand reversals (for example, in an unloaded span when a live load is applied in the adjacent spans) is consequently very limited. Thus, the ultimate strength should be carefully checked since it may be necessary to place additional tendons at midspan to insure continuity between the longer cantilever tendons at deck slab level. This check is important because a negative plastic hinge must not be allowed to appear before the other sections have reached their ultimate capacity.

Design of Piers and Stability During Construction

Piers with many different shapes have been used in conjunction with cantilever construction. For example, single piers, double piers, and moment-resisting piers have all been used.

Single slender piers

If in the finished structure the piers are designed solely to transfer the deck loads to the foundations (including horizontal loads), there is the likelihood that the piers will be unable to resist the unsymmetrical moments due to the cantilever construction (i.e., with one segment plus the equipment load).

Thus, temporary shoring is often required (see Fig. 10) at considerable cost.

More recently, the stability of the cantilever under construction has been provided by the equipment used for placing the segments.

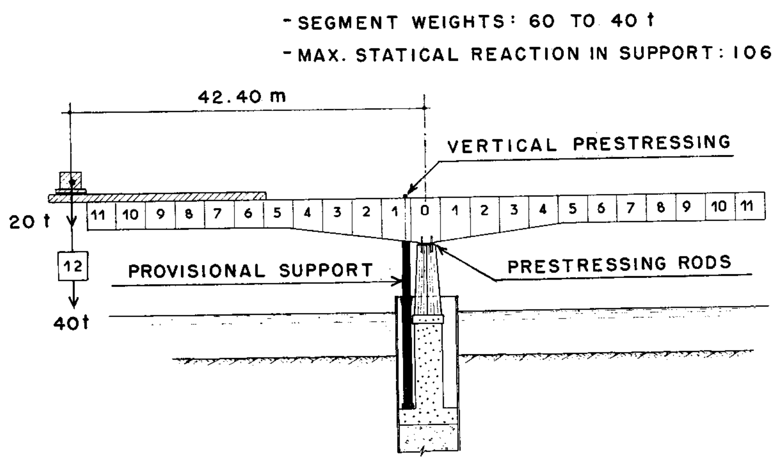


Fig. 10. Stability during construction.

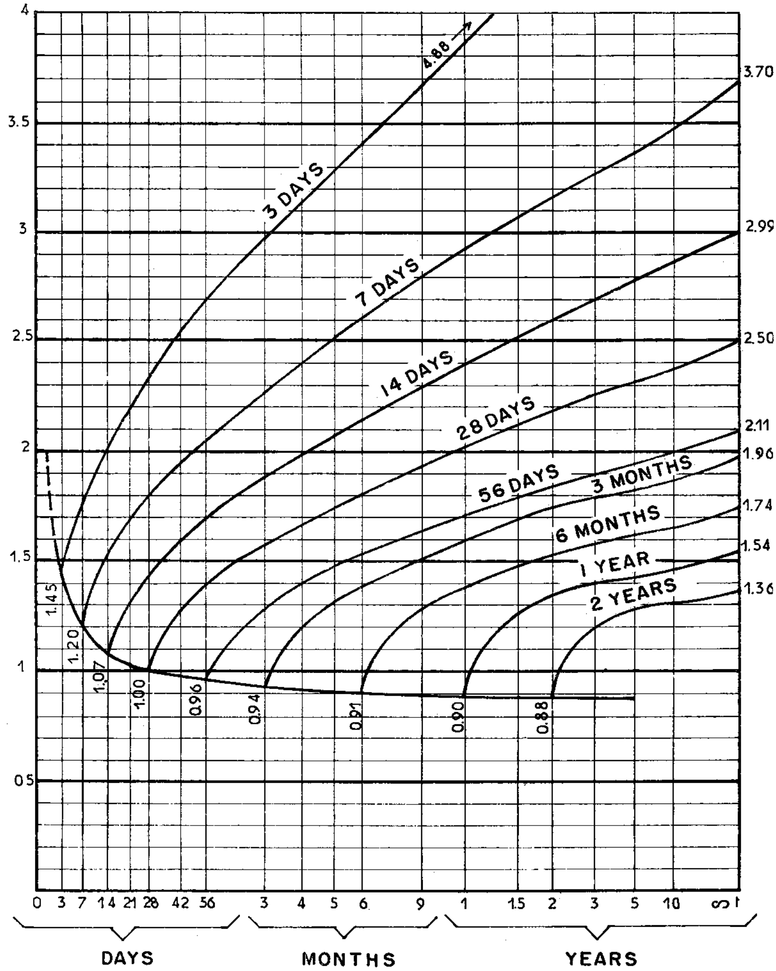


Fig. 11. Concrete strains versus age and duration of loading. Note that strain is given as a dimensionless ratio between the actual strain and the reference strain of a 28-day old concrete subjected to short-term load.

Twin piers

With double piers, two parallel converging walls make up the pier structure, which usually rests on a single foundation.

Such a configuration was successfully used at Choisy-le-Roi, Courbevoie, and Juvisy, and later for the Chillon Viaducts. Stability during construction is excellent and requires little temporary equipment (except for some bracing between the slender walls to prevent elastic instability).

Moment resisting piers

These piers are designed to withstand the unbalanced moments during construction while temporary vertical prestress rods make a rigid connection between the deck and the pier cap.

When the ratio between span lengths and pier height allows it, the above

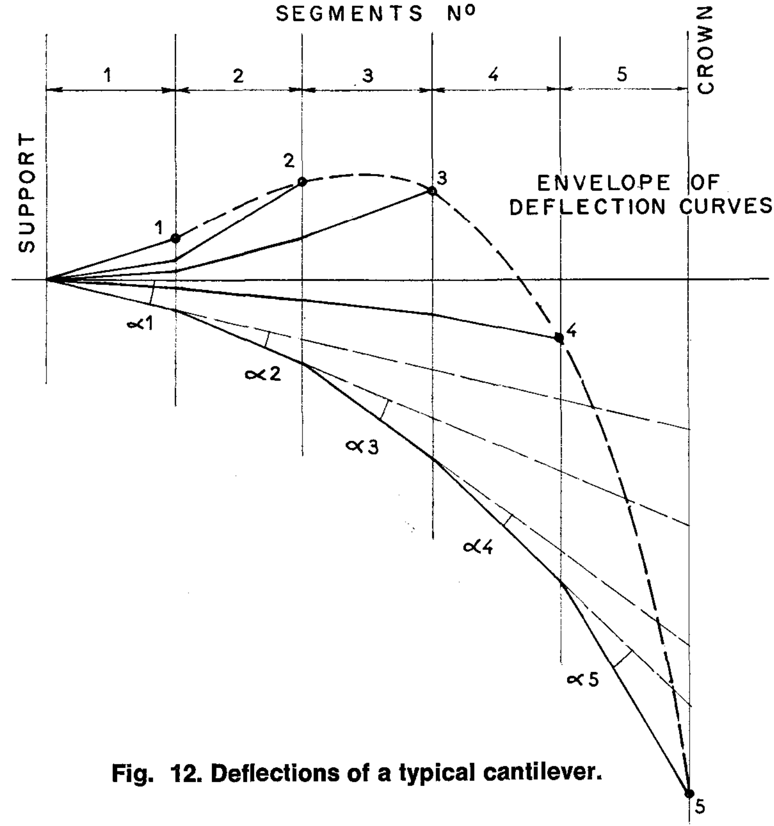


Fig. 12. Deflections of a typical cantilever.

rigid connection and the corresponding frame action may be maintained permanently between the deck and piers.

Another method is to use twin neoprene bearings which allow for deck expansion. With this device full advantage is taken of the elastic restraint between the piers and the deck and the capacity to transfer live load moments at midspan.

Flat jacks are usually placed between the pier top and the deck soffits to permit the substitution of temporary bearings for the permanent neoprene pads.

Calculation and Control of Deflections

The key to understanding deflection control in segmental structures is to be able to accurately predict the long-term behavior of concrete under sustained loading applied at different ages. Figure 11 shows the variation of concrete strains in relation to age and duration of load. Note that in Fig. 11 the strain is given in terms of a dimensionless ratio between the actual strain and the reference strain of a 28-day old concrete subjected to a short-term load.

Short-term strains vary little with the age of concrete at the time of first loading (except at a very early age).

However, long-term strains are significantly affected by the age of concrete. For example, a 3-day old concrete will show a final strain 2½ times greater than a 3-month old concrete.

Fortunately, in precast construction these deformations are significantly reduced because the segments are usually stored a few weeks before final erection. Thus, precasting the segments is a distinct advantage over casting them in place because the deflections of a precast cantilever are usually less than one-half those of an equivalent cast-in-place cantilever.

A step-by-step computation of the deflection curves of a cantilever is made to follow the erection sequence. A typical plot of this calculation is shown in Fig. 12. An accurate determination of the deflection will also be needed to compute the necessary camber used during segment casting in order to obtain the required profile of the finished deck.

Precasting Methods

There are basically two methods in use for precasting segments, namely, casting beds and casting machines.

1. *Casting beds*—In this method, an entire or one-half a cantilever span is cast on a bed which reproduces exactly the profile of the deck soffit with due allowance for camber.

2. *Casting machines*—In this second method, single casting units are designed to have a variable geometry corresponding to the bridge profile.

Fig. 13 shows the principle of the casting bed system. The position of each segment is fixed and the formwork travels along the bed. When many sets of formwork are available, several different segments may be cast at the same time.

For a small structure, it may be sufficient to use a bed for only one-half of a cantilever.

Casting beds have been used for several structures such as Choisy-le-Roi (see Fig. 14), Courbevoie, and Oléron.

In the casting machine method, the formwork remains fixed while the segments progress from the casting position to the match-cast position as shown

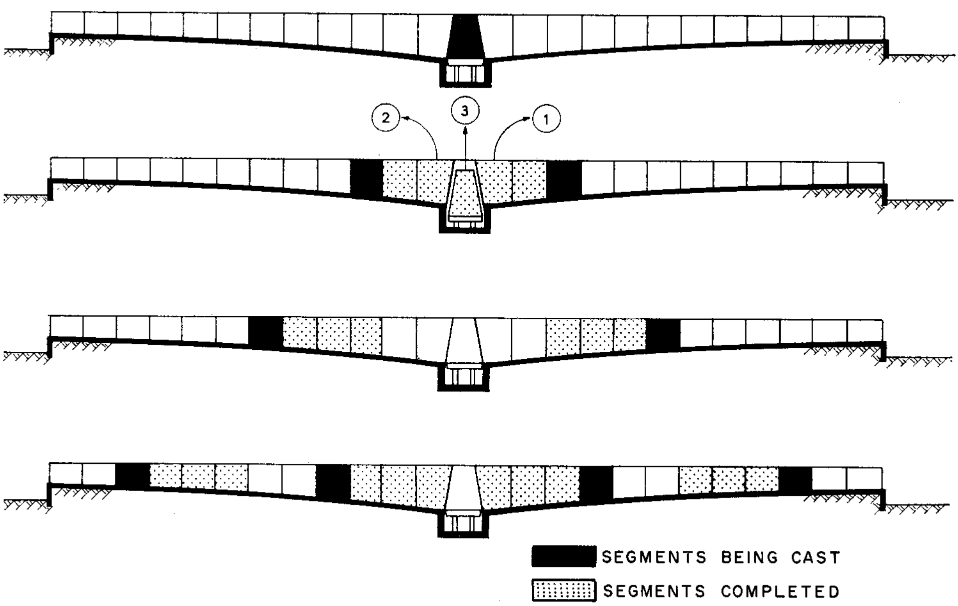


Fig. 13. Typical precasting bed.

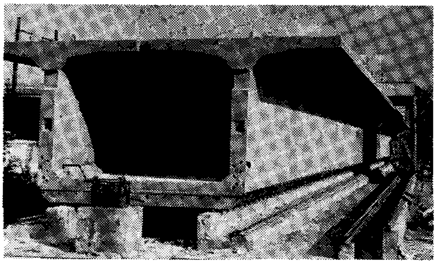


Fig. 14. Choisy-le-Roi showing segments on precasting bed.

in Figs. 15a and 15b.

The mold soffit remains with each segment until removed for storage. This soffit is equipped for longitudinal transfer and position adjustment. The external forms are usually hinged for easy stripping.

One end of the machine is blanked off by a fixed bulkhead while the other end matches the preceding segment. The internal form is of the collapsible type (with removable lower panels for height variation as required). It may be retracted through the bulkhead to leave the space entirely free for placing the prefabricated cage of reinforcing steel and prestressing ducts. An overall view of some typical casting machines is shown in Fig. 16.

One segment can be easily cast per day if adequate curing is provided and if preheated concrete is used in cold weather.

Vertical casting of the segments (they are cast on edge) is an improvement on the horizontal casting technique because it allows easier concrete placing and vibration.

Horizontal casting was first used at the Pierre-Bénite bridges for a straight structure. The concept was extended to curved bridges with variable height girders such as the Chillon Viaducts. However, on the B3 South Viaducts the sheer magnitude of the project and the time constraint on construction made mass production necessary. A central plant produced two units per day for several months on each of the five casting machines.

Placing Segments

Several methods have been developed for placing the precast segments on the superstructure. They can be classified as follows:

Cranes

Mobile cranes moving on land or floating on pontoons are commonly used where access is available. For example, Choisy-le-Roi, Courbevoie, and the Belt bridges were constructed using moving cranes.

Occasionally, a portal crane straddling the deck has been used with tracks installed on temporary trestles on either side of the bridge.

Winch and beam

In this method a lifting device, attached to an already completed part of the deck, raises the segments which have been brought to the bridge site by land carrier or barge. The segments are lifted into place by winches carried at deck level on a short cantilever mechanism anchored on the bridge.

In the first applications (for example, Pierre-Bénite and part of the Belt bridges) the segment over the pier had to be placed independently (either cast in place or handled by a separate mobile crane).

Recently, this drawback has been overcome (for example, the Saint-André de Cubzac Viaducts). Now the precast pier segment may be placed on the pier with the same basic equipment cantilevered temporarily out of a tower attached to the pier.

Launching gantry

In this method a special mechanism travels along the completed spans and

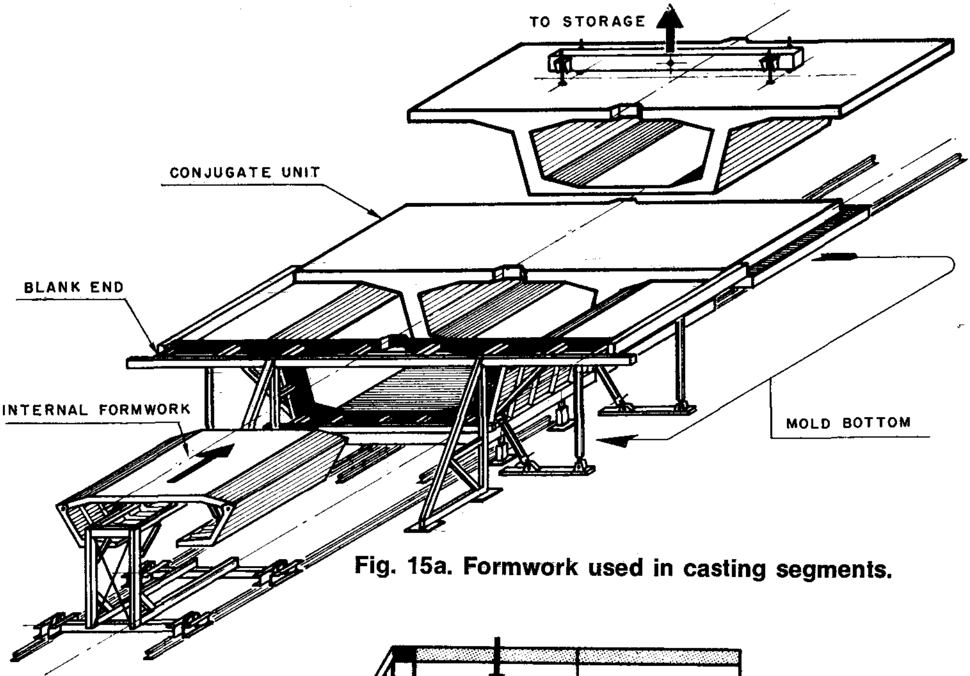


Fig. 15a. Formwork used in casting segments.

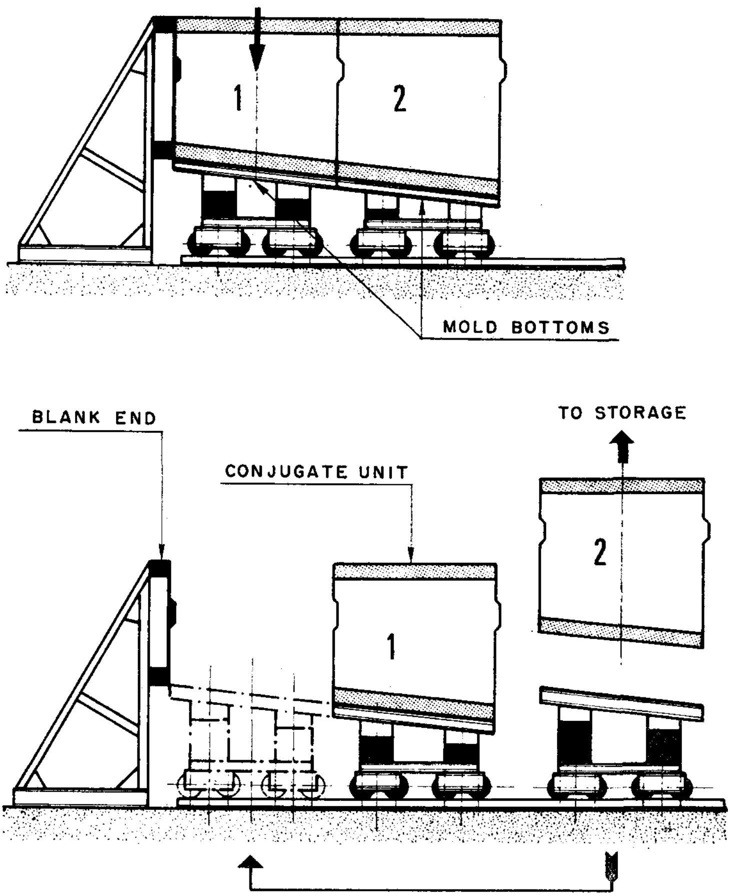


Fig. 15b. Steps used in precasting operation.

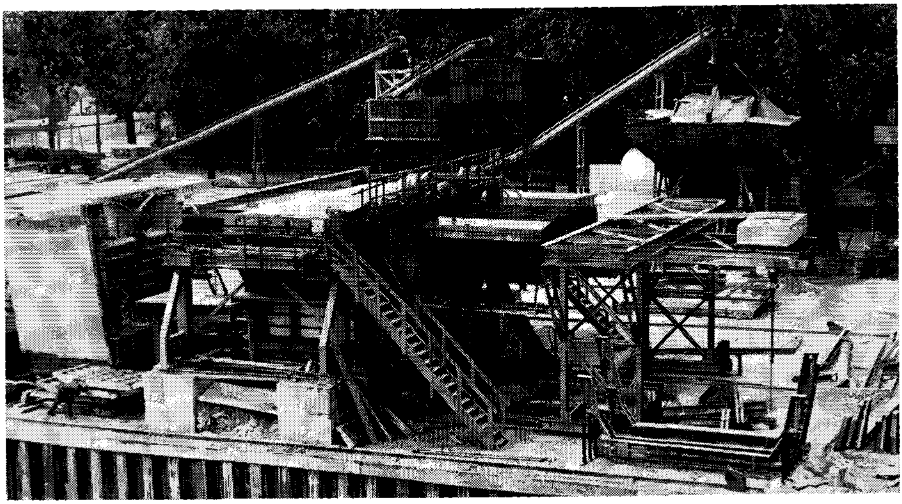


Fig. 16. Precasting machine for Paris Belt bridges.

maintains the work flow at the deck level.

The crane gantry, which was first used for the Oléron Viaduct, contributed significantly to the development of precast segmental construction.

The principle behind segmental erection using the crane gantry system is shown in Fig. 17. An essential component in the system is a truss girder which has a length somewhat greater than the maximum bridge span.

The system consists essentially of:

1. A main truss where the bottom chords act as rolling tracks.

2. Three leg frames which may or may not be fixed to the main truss. Note that the rear and center frames allow the segments to go through their end ways.

3. A trolley which can travel along the girder and is capable of longitudinal, transverse, and vertical movement as well as horizontal rotations.

To complete a full construction cycle for a typical span, the gantry assumes three successive positions:

1. For placing typical segments in cantilever, the center leg rests directly over a pier while the rear leg is seated towards the end of the previously completed deck cantilever.

2. For placing the segment over the adjacent pier, the girder is moved along the completed deck until the center leg reaches the end of the cantilever. The front leg rests on a temporary corbel fixed to the pier while the pier segment is placed and adjusted into position.

3. Finally, the segment placing trolley is used as a launching cradle with the help of an auxiliary tower bearing on the newly placed pier segments. The gantry is then transferred to its initial position one span further thus allowing the segment placing cycle to repeat itself.

For structures combining vertical and horizontal curvatures, including variable superelevation, the launching gantry can be designed to follow the geometry of the bridge while maintaining operational stability and segment placing capability.

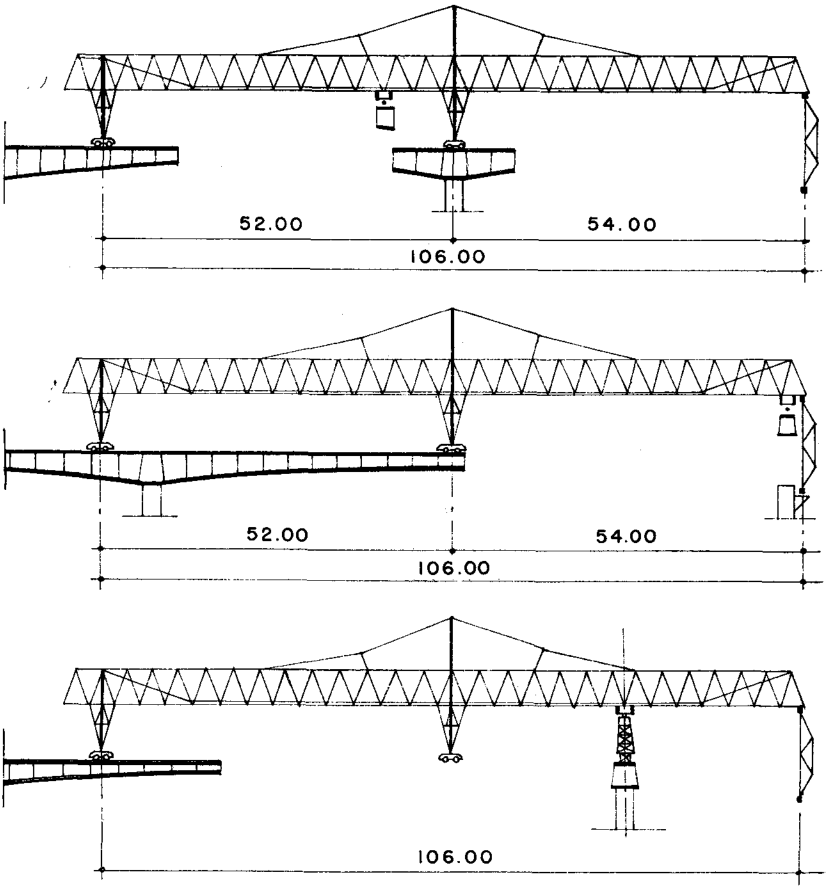


Fig. 17. Operational stages of a launching gantry (first type).

In the last few years several important technical improvements have been made in gantry design. These advancements are exemplified starting at the Chillon Viaducts in Switzerland and later at the Saint-Cloud bridge where 130-ton segments were easily placed in a 337-ft (102 m) span with a 1090-ft (330 m) radius of curvature in place (see Fig. 1-20).

It should be noted that on certain structures, a somewhat different approach is used in designing the launching gantry system (see Fig. 20).

The total length of the truss girder is now slightly greater than twice the maximum span length. In this system, all three gantry supports rest directly over a pier. Although the investment cost is higher in this system than in the original concept, this type of gantry has several advantages. For example:

1. The completed deck carries no gantry reactions.

2. Stability against unsymmetrical loading due to unbalanced cantilever erection may be provided by the gantry.

3. The pier segment may be placed

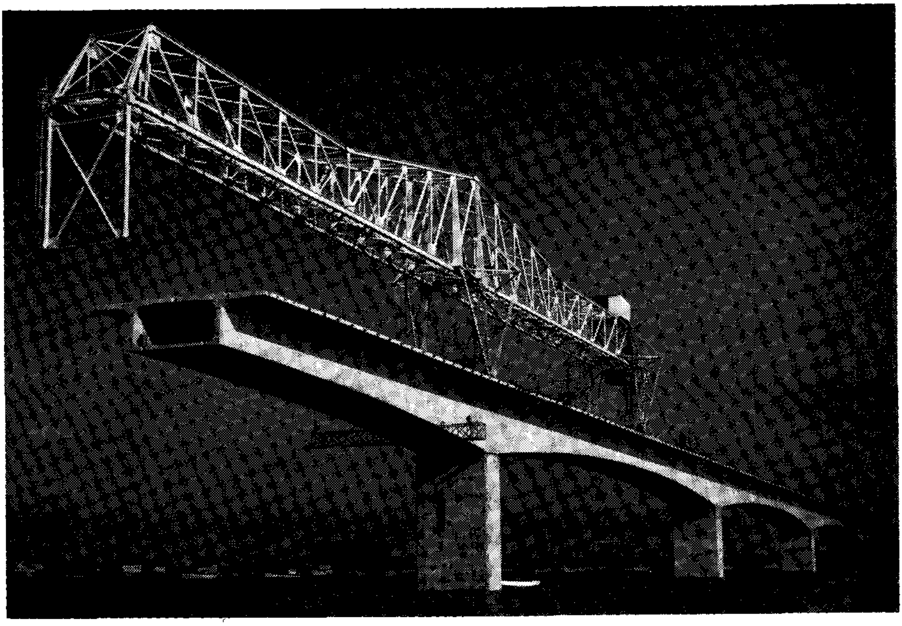


Fig. 18. Oleron gantry.

and adjusted during the normal placing cycle for the preceding cantilever spans.

4. Construction time may be further reduced if two placing trolleys are used.

In the advanced system, segments may be moved in place over the completed bridge (or beneath the bridge). This procedure was used on the large Rio-Niteroi bridge where all segments were floated on pontoons and lifted into place by four 540-ft (164 m) long launching gantries weighing 400 tons each (see Fig. 1-17). A similar approach was also used for the B3 South Viaducts near Paris (see Fig. 1-18).

Segmental Design for Freeway Overpasses

A recent example of the wide applicability of precast segmental construction is demonstrated in the Rhone-Alpes motorway. This project will involve the construction of 150 overpasses to be built over a 5-year period. The bridges are three-span structures with main spans ranging from 60 to 100 ft (18 to 30 m).

Some significant features include vertical precasting of segments, the complete elimination of the conventional closure joint, and the use of conventional prestressing cable profiles instead of the cantilever-type cable arrangement.

Stability during construction is provided by secondary supports close to the piers and temporary prestress using bars anchored along the deck surface (see the diagram in Fig. 21). The total construction time for a single overpass (foundations plus piers and deck) is less than 2 weeks (see Fig. 22).

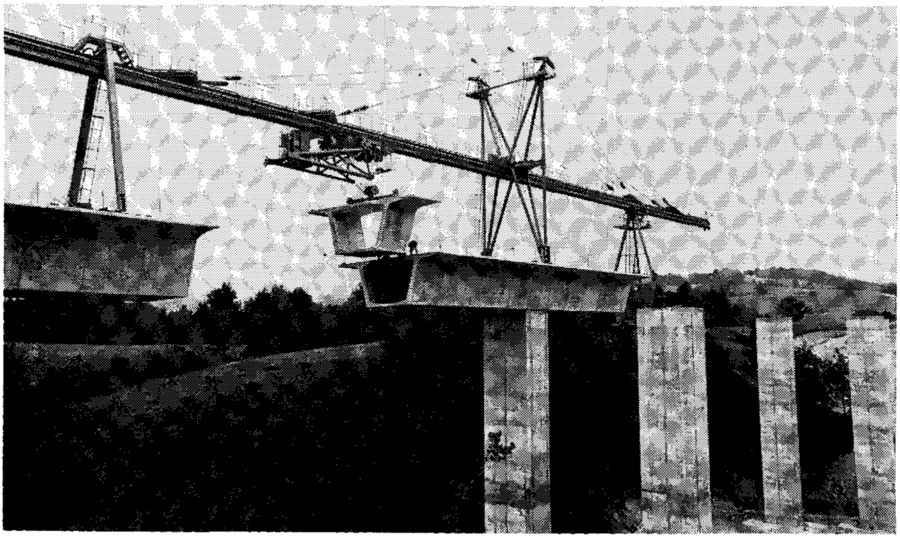


Fig. 19. Alpine motorways gantry.

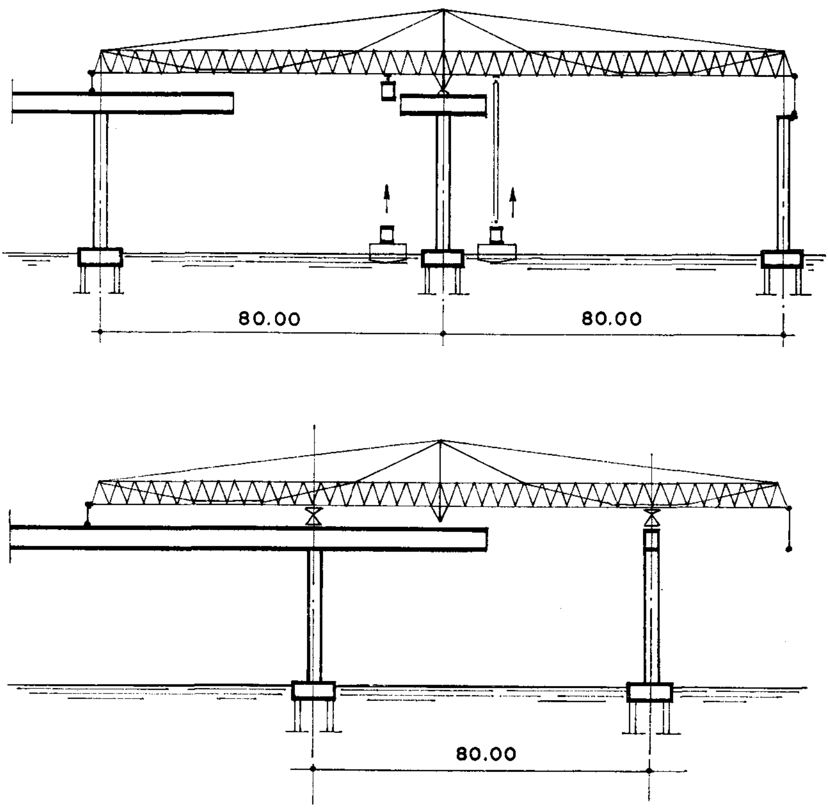


Fig. 20. Operational stages of a launching gantry (second type).

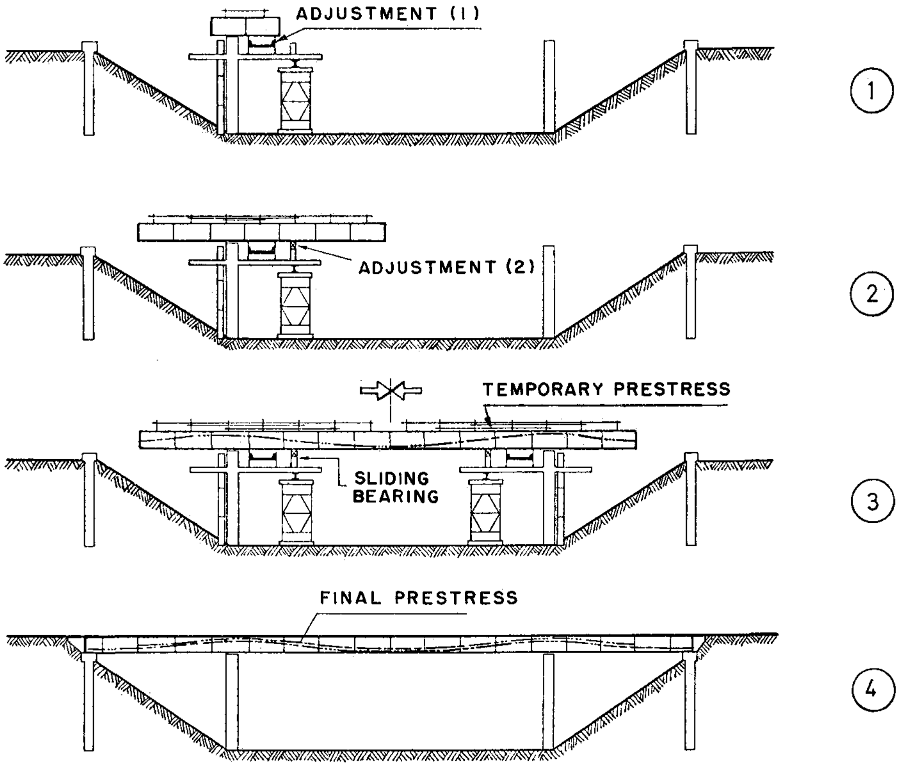


Fig. 21. Construction of precast overpasses.

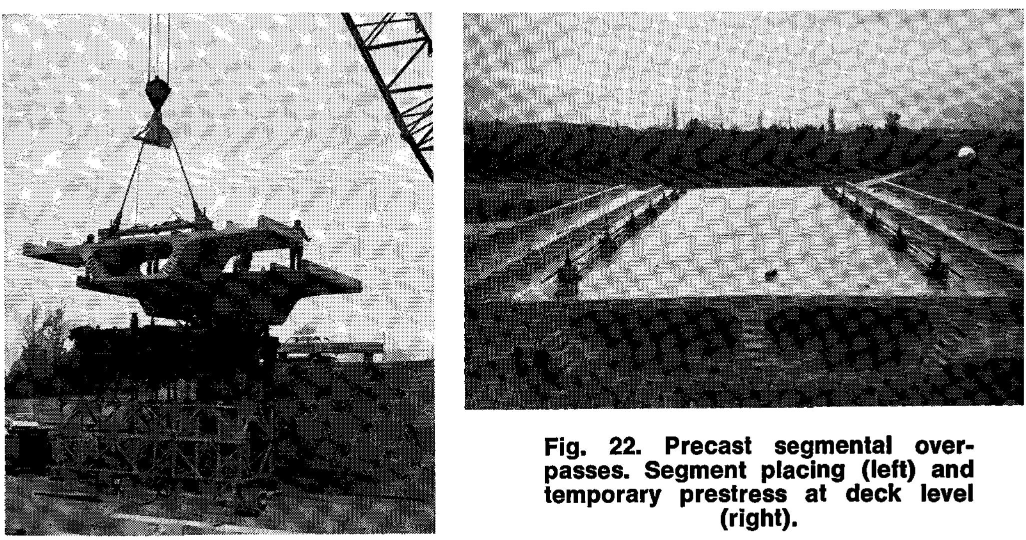


Fig. 22. Precast segmental overpasses. Segment placing (left) and temporary prestress at deck level (right).

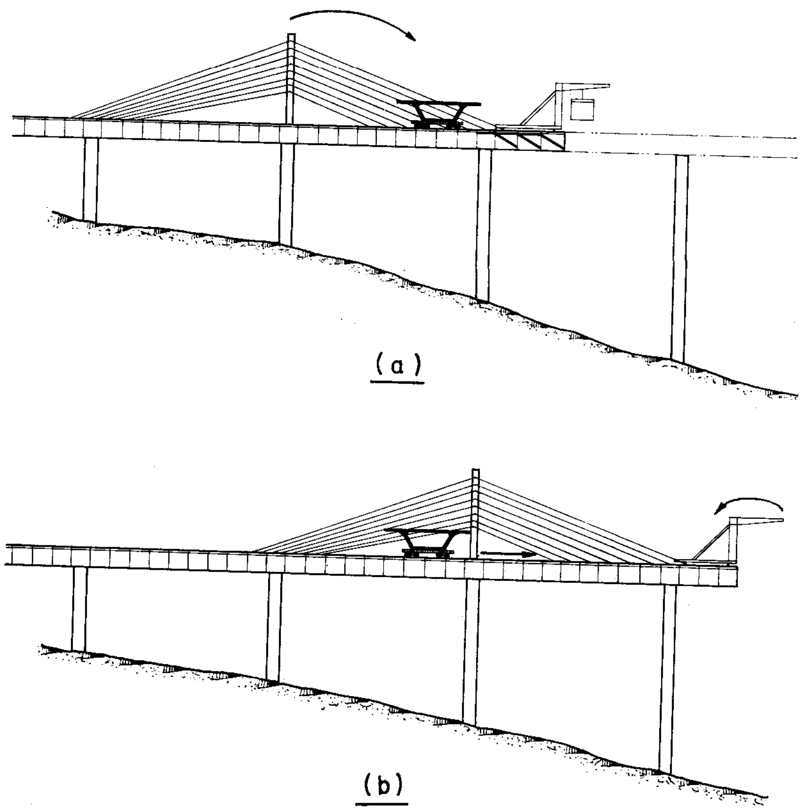


Fig. 23. Construction sequence (elevation) using progressive segment placing.

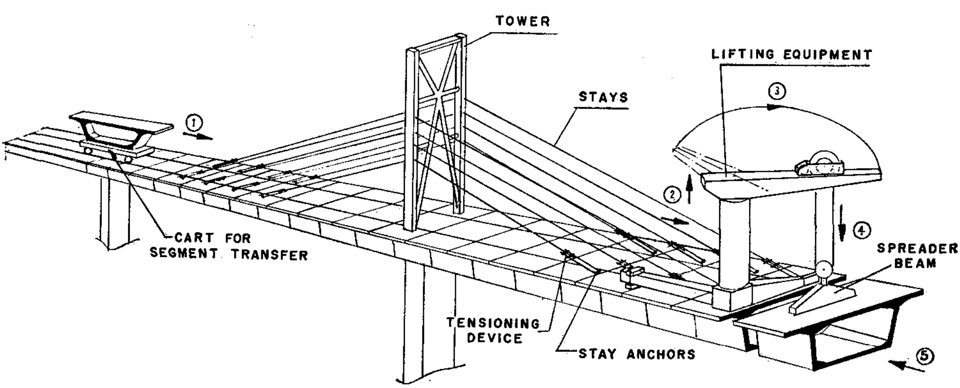


Fig. 24. Construction sequence (isometric view) using progressive segment placing.

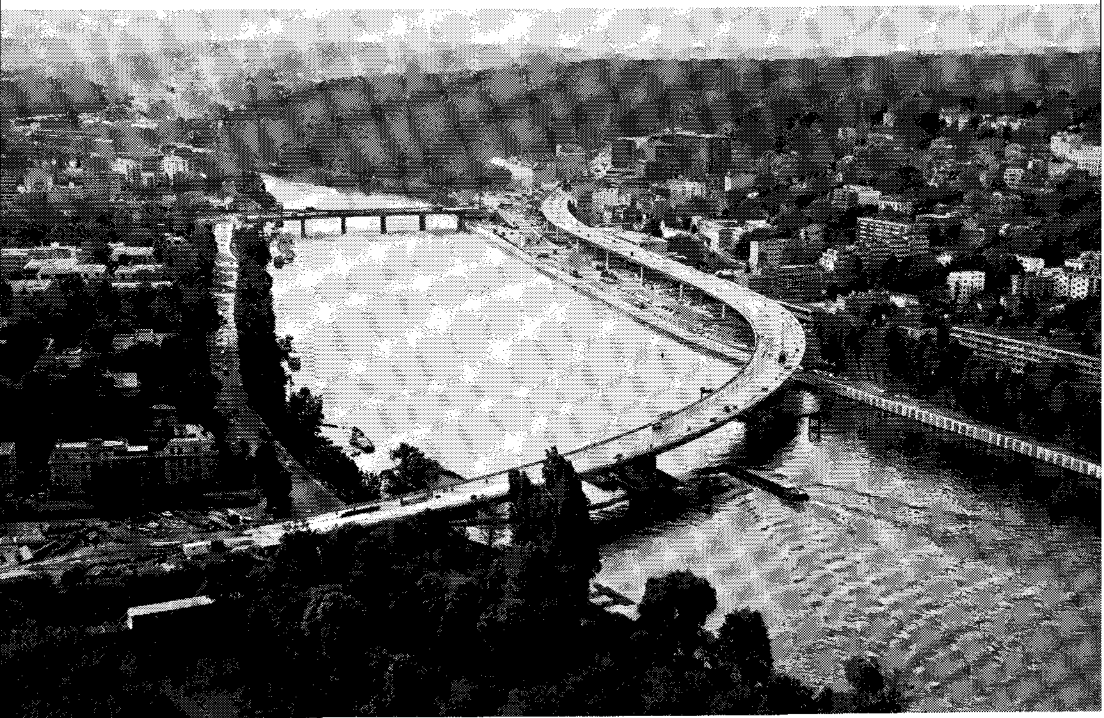


Fig. 25. Saint-Cloud (completed structure).

Progressive Placing

The latest development of precast segmental construction embodies the concept of progressive placing. This approach actually comes directly from cantilever design. Here, segments are placed continuously from one end of the deck to the other in successive cantilevers on the same side of the various piers rather than in balanced cantilever at each pier.

When the deck reaches one pier, permanent bearings are installed and construction proceeds to the next span.

Some noteworthy advantages of the method are:

1. The operations are continuous and are performed at the deck level.

2. The method seems to be of interest primarily in the 100 to 160-ft (30 to 50 m) span range where conventional cantilever construction is not always economical.

3. During construction the piers are not subjected to unbalanced moments although the vertical reaction is substantially increased.

One disadvantage of the method is that construction of the first span must be carried out with a special system.

It should also be noted that the stresses in the deck are completely reversed during construction and after completion.

Consequently, special stabilization devices must be used temporarily to keep the concrete stresses within safe limits and to minimize the amount of temporary prestress.

A tower and guy cable system has been used effectively to control the undesirable temporary stresses.

Figs. 23 and 24 show schematically the principle of progressive segment placing together with some of the construction details.

Conclusions

Following this brief survey of precast segmental construction with match-cast glued joints, we may now summarize the principal conclusions of the study.

1. Precast segmental construction has been shown to be an efficient and economical construction method for medium to long-span structures.

2. The method is applicable to most types of structures. Even structures that are curved in plan with variable superelevation may be easily accommodated (see Fig. 25).

3. By precasting the segments under controlled factory conditions, high quality units with precise dimensioned tolerances are obtained.

4. With precasting, the concrete shrinkage and creep will have a greatly reduced effect both during erection and in the completed structure because the segments will already have attained most of their desired strength.

5. Falsework and temporary supports are usually completely eliminated as well as the related hazards due to unknown soil conditions.

6. Where clearance requirements during construction are critical, there may be further savings on the approach structures because no head room is needed for falsework.

7. Interference with existing traffic during construction is significantly reduced and expensive detours can be eliminated.

8. The speed of erection may be chosen to suit the job requirements. Segmental construction is much faster than any other currently used erection method.

9. Construction is not greatly influenced by weather conditions. The precast segments can be manufactured with mass production techniques in enclosed factories and brought to the project site at any desired time.

10. The overall labor requirement is less than for conventional construction methods while a major part of the work force on site is replaced by plant labor.

11. The cost savings in comparison to conventional construction methods have reached 20 percent on several projects. For example, in France, one precast segmental bridge design has been shown to be one-half the cost of a similar steel bridge design.

12. Last but not least, the technique shows an exceptionally high safety record. If all the structures designed and built or supervised by the author's company are combined (representing more than 6,000,000 sq ft (560,000 m^2) of deck and 17,000 segments), only one incident is found where one segment was dropped and lost (with no injury to a workman). Furthermore, no accident has been reported on projects using launching gantries.

With the experience and success gained during the last decade it may be concluded confidently that precast segmental construction is today competitive in a very wide range of applications with other materials and construction systems while adding a further refinement to the intrinsic advantages of prestressed concrete.

This report is based on a talk presented at the FIP/PCI Congress, New York City, May 28, 1974.

Discussion of this report is invited. Please forward your discussion to PCI Headquarters by June 1, 1975.