PROCEEDINGS PAPER

Long Span Prestressed Concrete Bridges Utilizing Precast Elements

Presented at the Ninth Annual Convention of the Prestressed Concrete Institute

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SYNOPSIS

The use of precast concrete segments, erected, and prestressed, offers a practicable, expeditious, and economical way of building long span bridges. It is essential however, that the design of the bridge be integrated with the construction and erection methods.

Special manufacturing techniques can be developed to economically produce precast concrete elements of very high strength and to very accurate dimensions.

Special techniques are essential to ensure the monolithic nature of the completed structure and to permit the integration of design with the erection procedure. These techniques include making joints, producing composite action with cast-in-place concrete, stage prestressing, employing external tendons, negative-moment tendons encased in deck concrete, lightweight concrete, concentrated tendons, and varying the cross-section of girders so as to locate the heavier segments where they may be most easily erected.

Consideration of erection methods has led to the development in segmental prestressed concrete construction of bridge schemes particularly adapted to this type of construction. These include the cantilever-suspended span, tied-arch, double-cantilever, and arch-cantilever methods.

Erection techniques which have been used successfully on major long-span bridges, include floating supports, moveable falsework, cantilever erection, launching, and suspended erection.

Major bridges with spans up to 1000 feet have been constructed by these methods and techniques in Europe, Australia, and the U.S.S.R. and offer many advantages for long span bridge construction in this country.

The use of precast concrete segments, erected and prestressed, offers a practical, expeditious, and economical way of building long span bridges. Because of the heavy weights and complexities involved, it is essential that the design and erection be integrated. Leading speakers at the recent Congress of the Federation Internationale De La Precontrainte in Rome have emphasized the inter-relationship of final structure and construction methods and the need for close coordination between designer and contractor.

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Prestressed concrete can be shown to be very economical for long span bridges, as far as material costs are concerned, and this includes consideration of seismic effects and foundation requirements. To achieve true over-all economy, feasibility of erection and low cost of construction must be achieved.

Precast methods are well adapted to such long span prestressed concrete bridges. Precasting offers the following advantages:

a. Attainment and control of highest quality concrete through plant production.
b. Economy of manufacture of precast elements, at a plant site rather than over water on falsework.
c. New techniques simplify and speed erection and field construction.
d. Accuracy of section and profile can be obtained, and the problem of deflections during construction can be overcome.

Precast methods are being employed on major bridges throughout the world. A few of the more notable of these are:

a. Hammersmith Flyover, London; a 16 span structure, with spans up to 140 ft.
b. Gladesville Bridge, Sydney; a 1000 foot arch of precast segments assembled by precasting techniques.
c. Tasman Bridge, Hobart, Tasmania, with main spans of 197, 310, and 197 feet, rising to a height of 145 feet above sea level.
d. Silverwater Bridge, Sydney, with spans of over 200 feet.
e. Outlet Sluice Bridge, Haringvliet, Netherlands; consisting of 17 spans of 197 feet which support the sluice gates as well as serve as a roadway.
f. The bridge across the Moscow River in the vicinity of an automobile plant at Likhachev, with a span of 485 feet.
g. Bridge across the River Oyat, near Leningrad, with a span of 210 feet.
h. Bridge across Yenisei River, near Krasnoyarsk, in Siberia, a prestressed concrete arch-cantilever of 492 feet.
i. Bridge across Danube River at New Garden, Yugoslavia, with prestressed arch spans of 690 feet and 543 feet.

The efficient construction of long span prestressed concrete bridges of precast elements requires the integration of three main considerations: the basic bridge scheme, the erection method, and the application of suitable techniques of jointing, stressing, etc. This paper will discuss these three considerations and describe some of the new developments in these areas.

I. TECHNIQUES

Proper techniques must be employed to ensure the monolithic behavior of the completed structure and to facilitate erection. The techniques which make these long span prestressed concrete bridges practicable and economical are not widely known or utilized in the United States, but actually almost all have been successfully employed on major bridge construction in this country.

A. *Segmental construction* employs

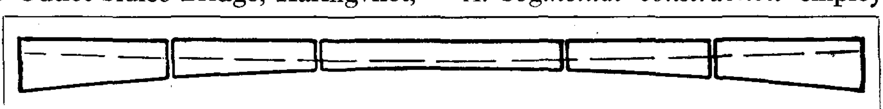

Fig. 1—SEGMENTAL CONSTRUCTION

precast segments cast of highest quality concrete, in sizes which can be transported and erected. The segments generally range from 5 to 50 tons in weight and from 6 to 100 feet in length.

The segments are usually reinforced with mild steel and are designed to be connected by post-tensioning after erection. However, the segments may be prestressed in themselves. This may consist of temporary post-tensioning to aid during transportation and erection or the segments may be prestressed during their manufacture in such a manner that the prestressing is also efficient in the final position. For example, the central segment of a span can be prestressed as a simple span for transportation and erection. This initial prestressing will be additive to the connecting post-tensioning, the total providing the needed prestress at the center of the span. Segments may be pretensioned during manufacture in the transverse direction, e.g., across the deck, and later post-tensioned longitudinally after erection.

The shorter segments usually are cast in the manufacturing plant in a vertical position, just as large diameter concrete pipe is cast. Forming is thus facilitated and heavy external and internal vibration is used to place and consolidate the dry concrete in relatively thin sections. Steam curing is frequently employed to obtain quick and thorough curing with minimum shrinkage. Concrete strengths of 7000 psi cylinder strength or greater are obtainable in North American plants where good aggregates are available.

Segmental construction was employed for the viaduct and tunnel portions of the Bay Bridge reconstruction project.

B. *Joints* are obviously of the utmost importance in connecting the precast segments. Stress across these joints may be very high. A number of types of joints have been employed.

Reinforced concrete joints 8 in. to 24 in. in width have been widely used. Reinforcing steel has been left projecting from the ends of the segments; these usually are connected by lapping or welding. High strength concrete is placed and consolidated in the joint. The attainment of high early strength is achieved by low water-cement ratios, high early strength cements, and steam curing. Steam curing of joints was employed on the Bay Bridge reconstruction, and on the Likhachev Bridge across the Moscow River.

Normally, the ends of the segments are constructed as vertical planes, with roughened surfaces. However, for the sluiceway bridge across the Haringvliet near Rotterdam, very high shears had to be transmitted as well as high direct stress and transverse prestress. Extensive tests were conducted. As a result pyramidal indentations of dimensions slightly greater than the maximum size of coarse aggregate were formed in the abutting faces. These tests showed that reinforcing steel across the joint was of no benefit to the ultimate strength, and that shallow indentations were of no value. The deeper indentations adopted allowed the coarse aggregate to lock into them. These concreted joints were 20 in. in width.

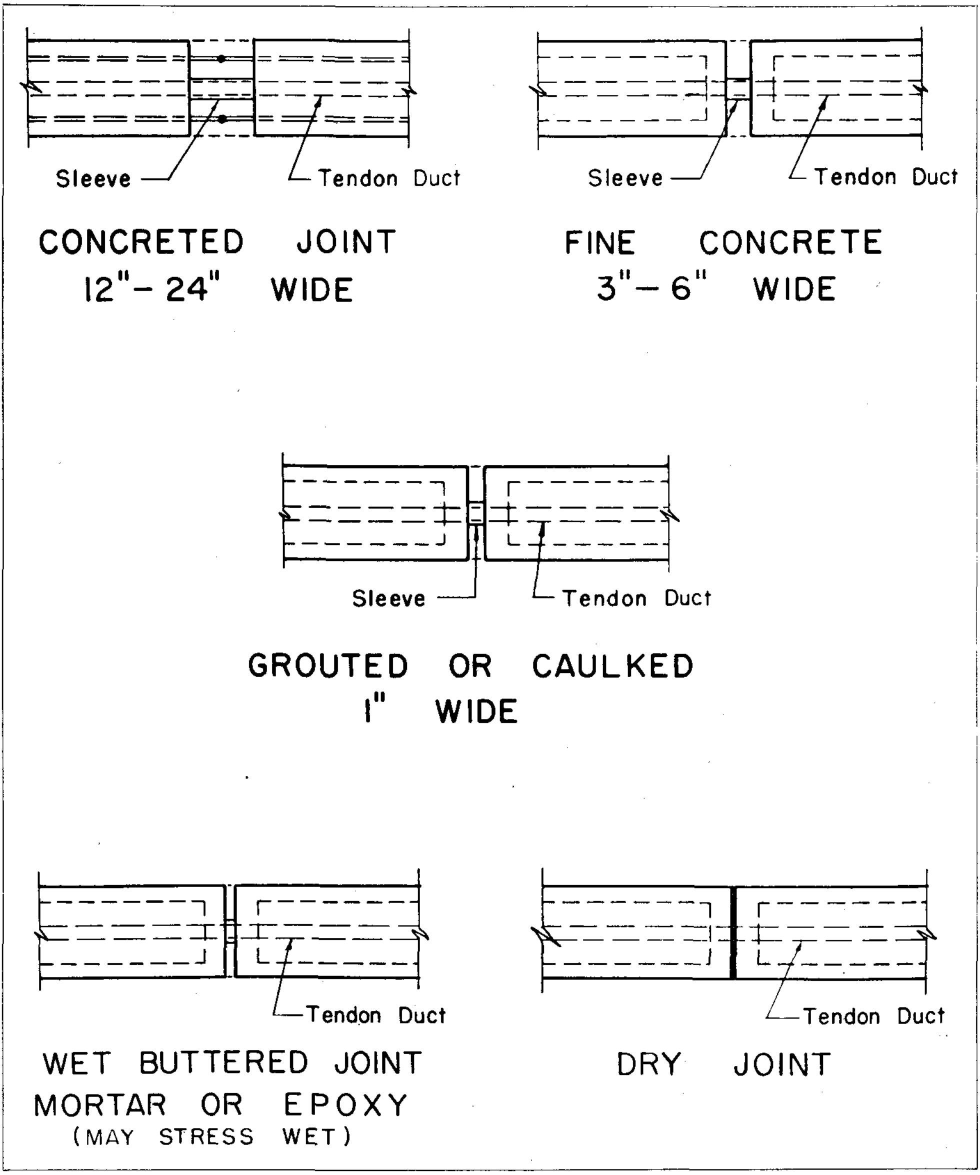

Fig. 2—JOINT TYPES

Poured concrete joints of 3 in. in width have been found to be the most successful in British and Australian practice. Mixes are rich, using pea gravel for coarse aggregate, and high early strength cement.

"Buttered" joints of mortar have generally not proven successful due to stress concentrations from inequality of mortar thickness. There have been some recent developments in stressing "buttered" joints while still wet; however, this technique has obvious practical difficulties.

Caulked or dry packed joints of 1 in. in width have been tried, but it was found to be very difficult to achieve uniformly good workmanship.

Epoxy coatings may prove beneficial, used either as the jointing material or as an aid to bond with a poured concrete joint. Tests of epoxy joints stressed wet are reported to show promise.

Dry joints, where the segments butt directly against each other, have many advantages. They require special techniques and care in manufacture and match-marking of individual segments. However, they enable speedy and economical assembly in the field and assure a perfect joint.

Dry joints have been employed in France, U.S.S.R., and also in California in the tunnel portion of the Bay Bridge reconstruction project, where 220 units were jointed and prestressed with dry joints.

The proven method, to date, is to cast each unit against the preceding segment. This generally requires a second handling of each segment in the manufacturing plant. Segments are then match-marked for erection.

The dry joint surfaces on the Bay Bridge tunnel units were 2 in. x 4 in. in area, but no trouble occurred due to wraping shrinkage after casting. Chamfering of the edges of the joints was found desirable to prevent local spalling when stressing.

Grinding has been proposed as another method of preparing dry joints. A practical difficulty here is in finding a base for a template or for measurements which will permit checking the entire contact area to the 1/32 in. accuracy required.

Another potential method, applicable where longer segments are being employed, would be to cast the end blocks separately. This separate casting of end blocks already is being extensively employed in Europe to obtain better concreting in the densely reinforced end sections. These end blocks would be cast flat, one against the other. When later erected in the forms for the casting of the full length segment of say 40 feet in length, the two ends would be assured of a perfect fit. But steps must be taken to ensure that axes coincide. Each precast segment must be set in the forms in a plane perpendicular to the axis of the segment. If the least dimension of the end block is 4 feet and its alignment can only be measured to 1/16 in., then the end of the overall 40 foot segment could be as much as 5/8 in. out of alignment. This may be within acceptable limits, and there are a number of possible steps by which even better alignment can be achieved if needed.

Epoxy coating of dry joints has been proposed and may have special applications.

All concreted joints introduce the problem of providing duct

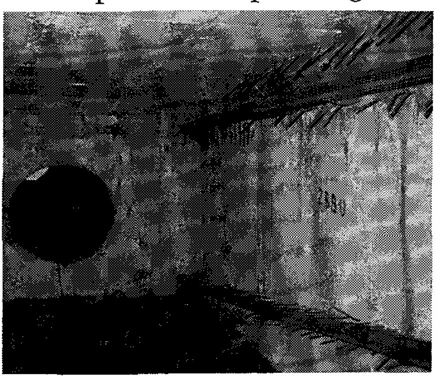

Fig. 3—"External Tendons" inside a box girder on the Silverwater Bridge, Sydney, Australia.

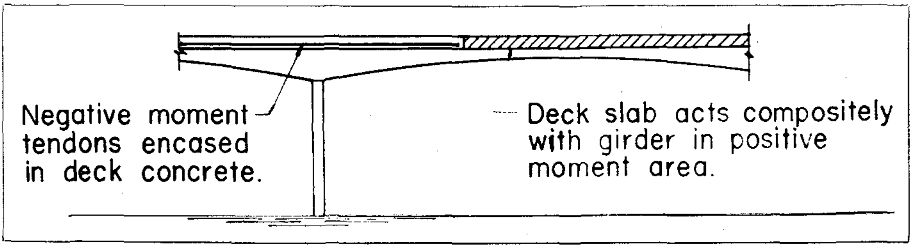

Fig. 4—COMPOSITE CONSTRUCTION

continuity across the joint, except where external tendons are used. For forming the duct in the joints, inflatable formers, such as Duc-tubes, have been extensively used, but the section of the duct is slightly reduced at the joint. Plastic and metal sleeves also have been widely used. In grouting the post tensioning tendons, grout may escape at the joint and seal adjoining ducts. Therefore, grouting should be deferred until all cables are stressed, and then performed at one time.

C. *Composite construction* has been widely accepted in bridge construction as giving full interaction in the positive moment areas. The deck, poured in place on top of the girders, acts as the top flange in resisting the compressive stress at the center of the span.

Over the supports, in the negative moment areas, the deck may be utilized, together with prestressing tendons on top of the girders, as the tension flange. The tendons in this case can be either post-tensioned cables in ducts or pretensioned strands, stressed against lugs in the top of the girders, and encased in the deck concrete. This system was employed on a bridge in Czechoslovakia.

Where the segment that is to be placed over the support requires haunching, and thus may be excessively heavy for erection, upside-down composite action also can be employed, pouring the bottom compressive flange after erection, in forms suspended from the precast segment.

D. *External tendons* eliminate many of the problems of post-tensioning of segments, such as maintaining the continuity of the duct across the joints and friction and grouting. Of even greater importance is the physical problem of making the web thick enough to accommodate the ducts. Thus, the thickness of the web is determined by the necessity of providing room for the ducts.

By placing the tendons external to the web, friction may be minimized. Relatively thin webs of high strength concrete can be used, since quality and accuracy can be assured in the plant manufacture of the precast segments.

The shear from the tendons is transferred by stirrups extending from the web. Encasement after tensioning is provided by poured concrete or by fitting a metal

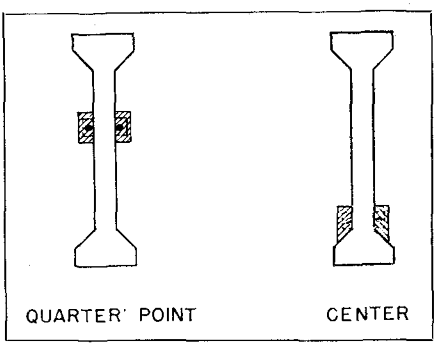

Fig. 5—EXTERNAL PRESTRESSING

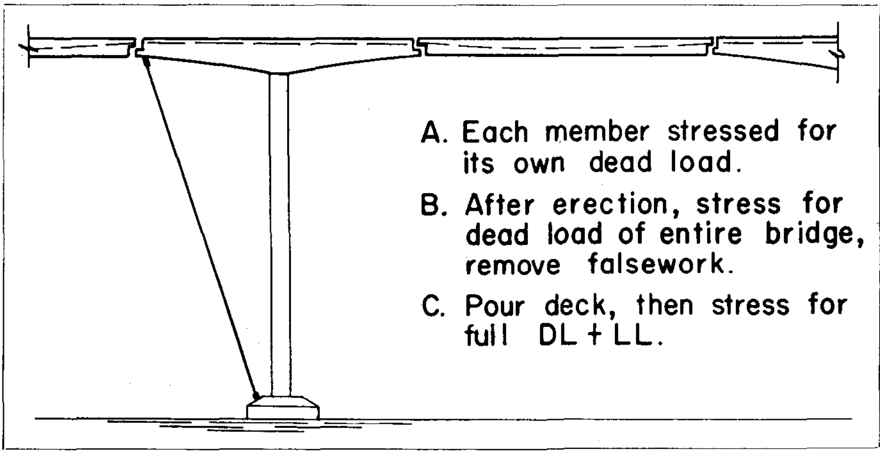

Fig. 6—STAGE STRESSING

cable cover which is filled with injected grout and then itself encased in poured concrete. It is, of course, essential to insure that corrosion cannot attack these external tendons. The concrete encasement, while not prestressed, will have minimum shrinkage because of the high percentage of steel, the ability to use a very dry mix, and it may pick up some prestress from the creep or plastic flow of the girder.

The use of external tendons offers so many advantages that every possible means should be taken to assure positive protection against corrosion. The use of bitumastic or epoxy coatings over the concrete encasement would help. In Australia, recent tests with epoxy-coated tendons show much better resistance to corrosion as well as better bond to the encasing concrete.

External tendons, encased in poured concrete, were used on the west approaches of the Bay Bridge reconstruction project.

E. Lightweight concrete can be employed effectively in long span bridges. Some cantilever-suspended span bridges in Europe use lightweight for the suspended span, and normal weight concrete for the anchor arms.

Precast lightweight segments can be regularly manufactured in plants in California and other parts of the U.S. with a 28-day cylinder strength of 5000 psi.

F. *Stage stressing* is often necessary to prevent over-stressing during erection phases before the full dead load is on the members.

This problem is of particular importance in cantilever-suspended span structures being built by segmental methods. The full negative moment prestress in the segments over the support may produce excessive tensile stresses in the bottom fibers, until the suspended span is erected, or even until the deck is poured.

Post-tensioning in stages is widely employed in Europe, stressing being alternated with erection of subsequent segments and with cast-in-place deck pours.

Another solution to this problem is to provide unstressed steel, either as embedded reinforcement, or as external steel beams temporarily affixed to the top of the girder segment.

G. *Varying the cross-section* is a means of locating the heavier segments in the area where they may be most easily erected. For example, deeper and heavier segments than normal can be used adjacent to the pier, where they may be partially supported by the pier itself. This in turn redistributes the maximum moment to the pier and reduces the size of the segments in the center of the span.

Inclined V-shaped piers have been used at Lake Maracaibo and on a number of English and German bridges to achieve the same purpose.

H. *Concentrated tendons* are being extensively employed in order to concentrate large forces in a small space. This permits the design of the most efficient cross-section. Local stresses and details must be given careful consideration when employing concentrated tendons.

II. BRIDGE SYSTEMS

Almost every standard bridge system has been utilized in constructing prestressed concrete bridges of precast segments; including simple span, cantilever-suspended span, continuous girder, truss, tied arch, simple arch, double cantilever, and arch-cantilever. In actual structures, a combination of these systems may be employed, making it difficult to specify an exact classification.

Some of them appear to be especially adaptable to long-span prestressed concrete bridges constructed of precast segments.

Continuous girders are generally employed in the 100 to 150 foot range, with the use of mild steel or prestressing applied over the negative moment areas after erection.

The cantilever-suspended span system appears extremely favorable in the American economy for spans in the range of 200 feet. One such bridge to be built in California uses anchor arm girders of 144 feet in length, cantilievering 24 feet out beyond each main pier. These in turn support a suspended span of 140 feet, giving a central span of 188 feet.

Two bridges planned for Florida are similar in spans, but constructed with a different segmental arrangement. An over-support segment 65

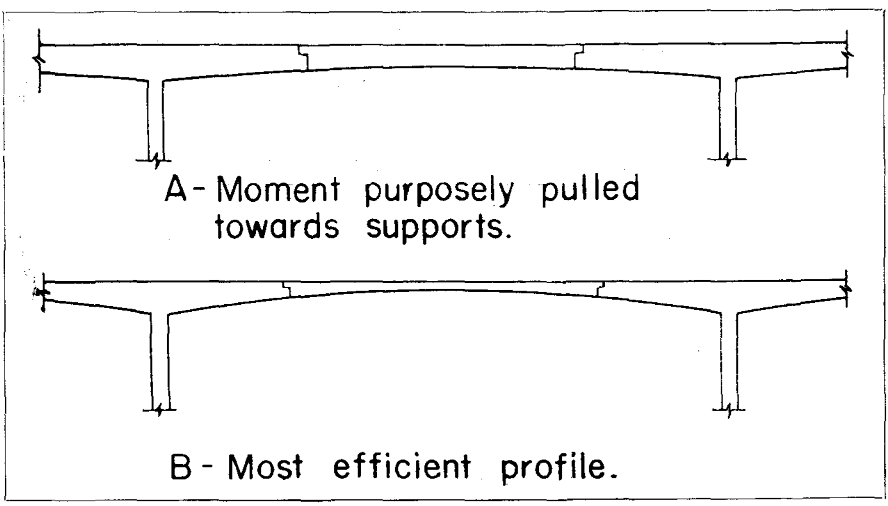

Fig. 7—VARYING CROSS-SECTION TO SIMPLIFY ERECTION

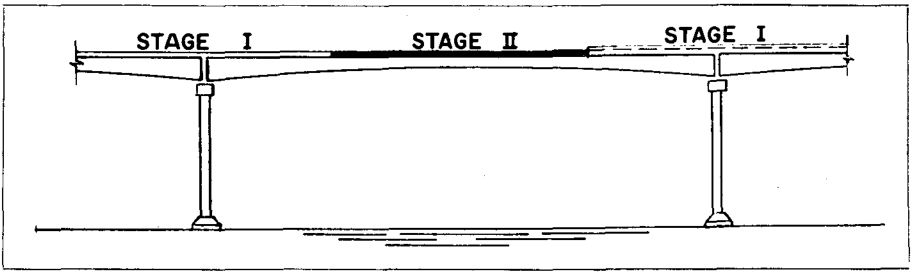

Fig. 8—SIMPLE BEAMS MADE CONTINUOUS AFTER ERECTION

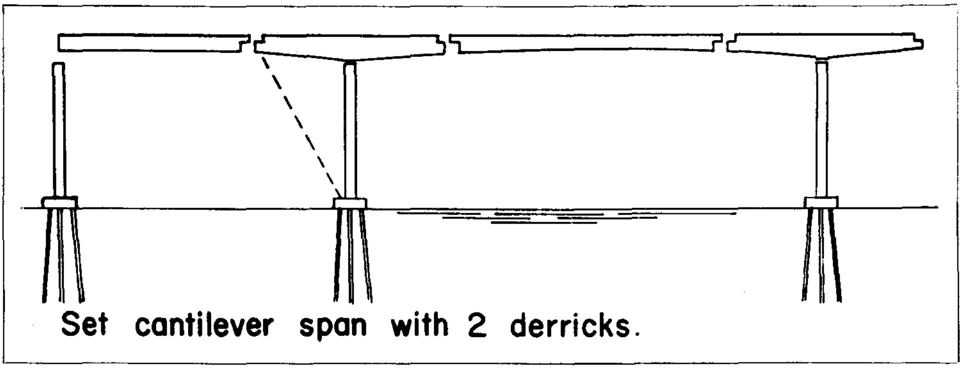

Fig. 9—CANTILEVER-SUSPENDED SPAN

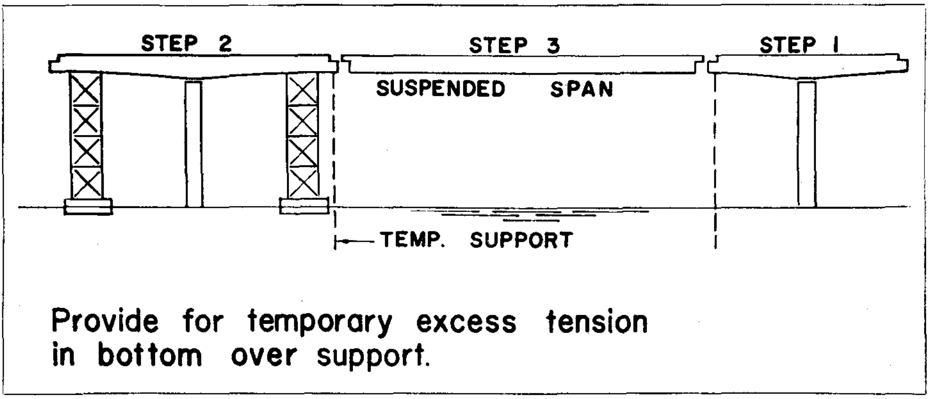

Fig. 10—CANTILEVER-SUSPENDED SPAN

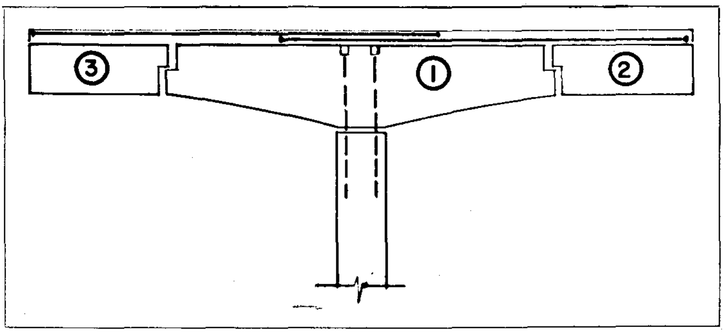

Fig. 11—FRAMED OR DOUBLE CANTILEVER METHOD

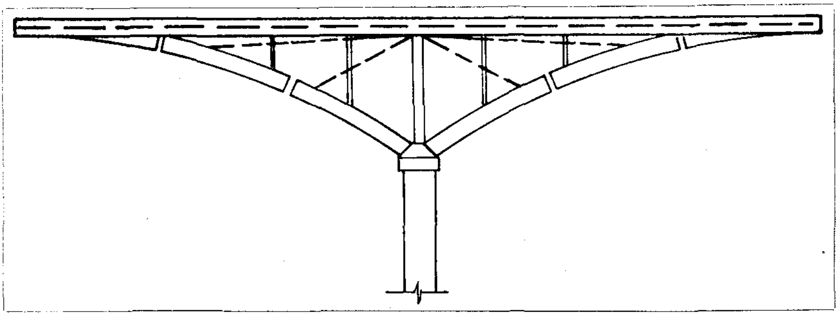

Fig. 12—ARCH CANTILEVER METHOD

feet long is first erected on a main pier, supported by temporary falsework in the anchor span. Then the anchor arm segment is set, and the joint between it and the over-support segment is concreted. Lastly, the central suspended span is erected, giving a span arrangement of 100, 180, and 100 feet.

The double cantilever system is also well adapted to the use of precast segments. This is similar to the cantilever method utilizing cast-in-place segments which has been employed extensively in Germany, Japan, and on the Medway Bridge in England, except that it is much faster, and more efficient sections can be utilized. Construction proceeds out simultaneously in both directions from each main pier.

The arch cantilever system produces a series of deck arch spans. The segments are cantilevered out simultaneously from each main pier with the prestressed deck acting as a tie between the arms of the arch. This system is being extensively employed in the U.S.S.R. with very favorable results.

In most of these bridge schemes, precasting enables the section and profile to be constructed and maintained to a high degree of accuracy. When segments are erected on falsework, the dead weight deflections occur before final positioning. Each element or segment can then be raised to its exact position, the joint completed, and the stressing performed.

Typical systems are shown diagrammatically in figures accompanying 7, 8, 9, 10, & 11.

III. ERECTION METHODS

The erection method is obviously

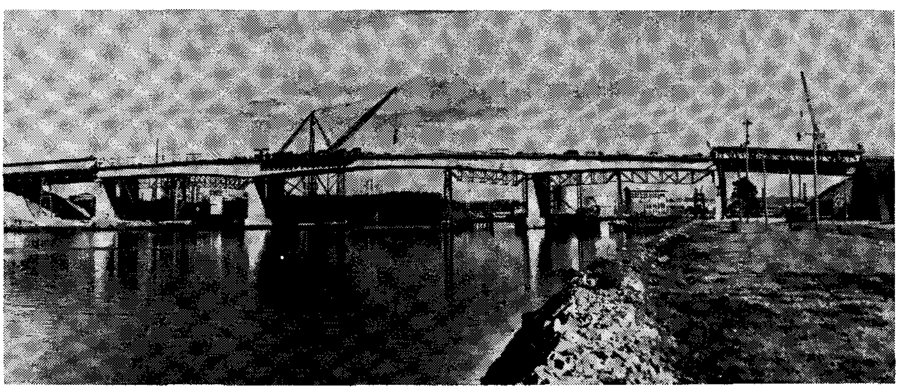

Fig. 13—Silverwater Bridge, Sydney, Australia

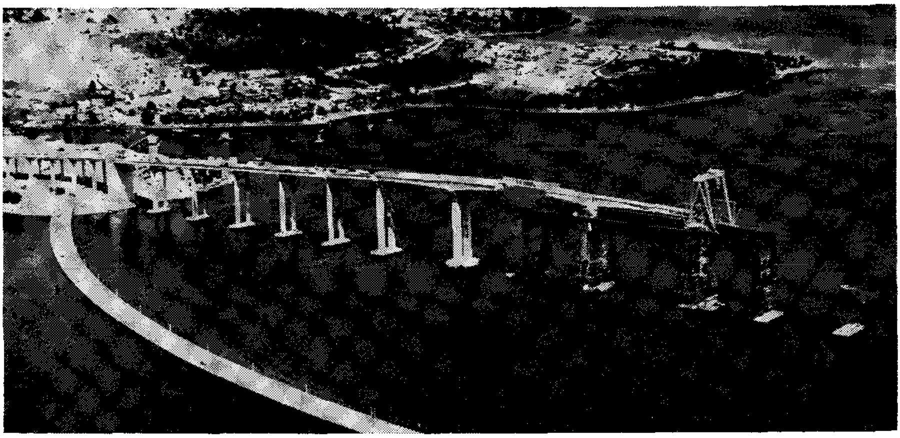

Fig. 14—Main Span Construction on Tasman Bridge, Hobart, Tasmania

dependent on the bridge system employed. It is also determined by the topography and special site conditions. Proper techniques must be employed as part of the erection and assembly.

Movable falsework trusses have been sucessfully employed on a number of bridges, of which some of the Australian bridges offer excellent examples.

A. In the case of the Silverwater Bridge in Sydney, Australia, a falsework truss was supported on ledges on the piers. The segments were assembled on it, the 3 in. wide joints provided between the segments were then concreted. External cables placed inside the box girder section were stressed, and then encased in concrete. The falsework truss was then jacked down, and moved sideways to support the next box girder.

   The bridge was so designed that the anchor arms followed the same profile as the main span, thus permitting most of the precast segments to be repeated, with a maximum re-use of forms.

B. In the case of the Tasman Bridge, across the Derwent River in Hobart, Tasmania, a temporary pier was constructed in the center of the main navigation span. This temporary pier and the adjoining main pier supported one of the standard falsework trusses which had been previously employed in the approach spans. Precast segments were then erected on this truss to form the 106 foot long cantilever portion of the main arm. At the same time, precast segments were erected on an extended falsework truss to form the anchor arm. After assembly and joint concreting, the complete anchor arm—cantilever girder was tensioned. These trusses also supported a 100 ton gantry crane which was used to lift and position the segments.

   The 98 foot long suspended span girder segments were assembled, and their joints concreted, on top of the eastern cantilever while the western cantilever was being completed. They were then post-tensioned, and lifted and moved forward into position by the gantry crane.

   External cables were used for all stressing. They were placed on the outside of the relatively thin webs of the girders, and, after stressing, were encased in

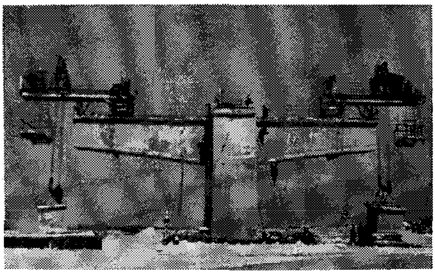

Fig. 15—Bridge across River Oyat near Leningrad

concrete. The joints between the segments were 3 in. thick and the girder segments were up to 40 feet long.

Temporary piers are frequently constructed to support cantilever overhangs during erection of cantilever suspended span bridges. Temporary inclined supports from a permanent pier can serve the same purpose. Jacks are employed to release the temporary supports.

C. A number of major Russian bridges have been constructed by assembling precast segments on falsework along and parallel to the shore. The segments can be erected in winter, then the joints are concreted and the entire span or half span is stressed. During the summer, a floating barge assembly, consisting of two or more barges connected with a heavy steel truss, is floated in under the span, the span is picked up and floated into position. By ballasting, the span is then lowered into position on the piers. This method was employed on the Yenisei River Bridge at Krasnoyarsk. It was also earlier employed on the Moscow River Bridge at Moscow.

D. A unique method of launching is employed on a bridge in Venezuela. The precast segments were assembled on one bank, joints concreted, and the several spans of girders were stressed in a first stage. Then with a launching nose attached, the bridge was jacked out over the piers. Following launching, the cables were jacked up or down into their final profile.

E. The cantilever method is particularly well adapted to precast segments. The bridge across the River Oyat, east of Leningrad, was constructed in the winter, as a double cantilever, with erection cranes working on top of the completed sections. Dry joints were employed.

F. For the Likhachev Bridge across the Moscow River, the anchor arm adjacent to the shore was constructed of segments erected on falsework. The main span was then constructed by means of erection derricks cantilevering out from on top of the previously erected segments. The precast segments were made up on the shore from factory-made precast slabs. The precast flat slabs were assembled to form 18 foot long box girder segments weighing from 80 to 165 tons. The segments were then set on a pontoon barge, towed under the boom of the erection derrick and hoisted

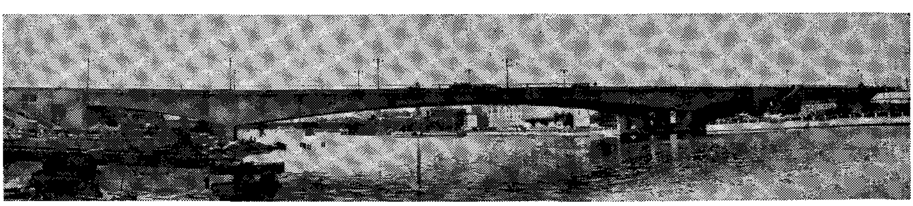

Fig. 16—Likhachev Bridge across Moscow River

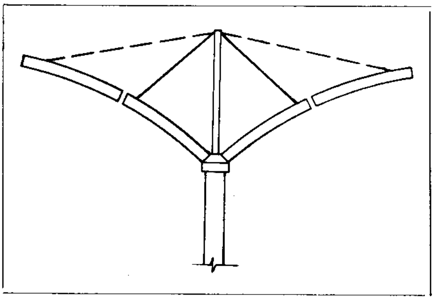

Fig. 17—SUSPENSION METHOD

into place. Two forks extending from the erection derrick pulled the unit into position where the reinforcing bars were welded and the 8 in. wide joints were concreted. Strength gain was accelerated by steam curing. In two days the joint concrete had reached a strength of 4500 psi cylinder strength and the first stage stressing was applied.

As a result of experience on this bridge the following recommendations were made:

1. Longer sections be used in mid-span where the weight per foot is less.
2. Use of a step or offset in the joint so the segment when hoisted could be more easily positioned by being set on the step.
3. Dry joints would reduce erection time per segment from the 4 days of the present method to 1 or 2 days.

It is believed that the cantilevering method is particularly well adapted to use for over-water bridges in this country. Large precast segments could be transported by barge and raised either by erection derricks on top or by heavy-lift floating shear legs or derricks.

G. Suspended erection is an extension of the cantilevering process. A temporary tower is built above each main pier. As each segment is erected, it is suspended by cables back to the tower.

Fig. 19—Bridge across the Yenesei River near Krasnoyarsk, Siberia. The 492 ft. span was erected by floating preassembled sections to the site.

This system was employed in erecting the 690 foot main arch span of the bridge across the Danube River in Yugoslavia.

This method is frequently employed for the arch-cantilever system of construction employed on a number of major bridges in the U.S.S.R. with spans up to 400 feet, including two across the Moscow River and the projected Dnieper River Bridge at Kiev. In these cases, the bridge pier tower acts as the support for horizontal tendons which suspend the segments as they are erected. Later

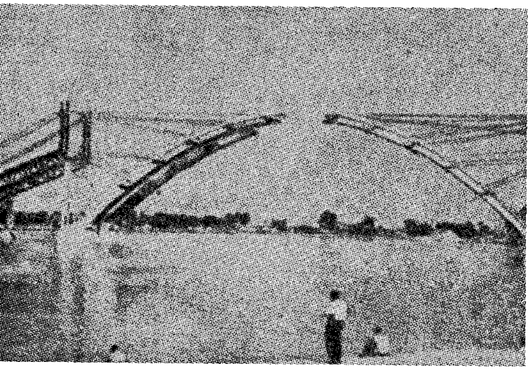

Fig. 18—Bridge across Danube River, Yugoslavia

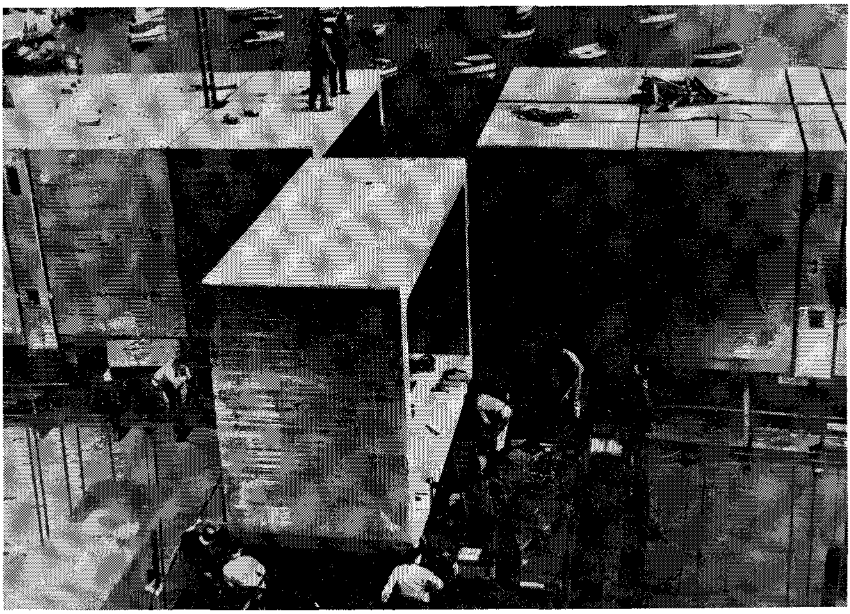

Fig. 20—Gladesville Bridge, Sydney, Australia. Placing a closing precast rib section.

the tendons are encased in the deck concrete, which acts as a permanent prestressed tie. Additional prestressing is then added as a second stage.

H. The Gladesville Bridge consists of a 4 ribbed concrete arch having a clear span of 1000 feet, the longest concrete span in the world. The midspan height clearance will be 135 feet. The arch ribs are made up of precast box sections, cast vertically in a nearby casting yard, and transported by barge to the site. Meanwhile, temporary piers were constructed and a steel falsework bridge erected to the profile of the arch. At midspan, a huge tower was constructed, with a gantry crane running transversely to the ribs.

A box section, weighing about 50 tons, is hoisted from the barge

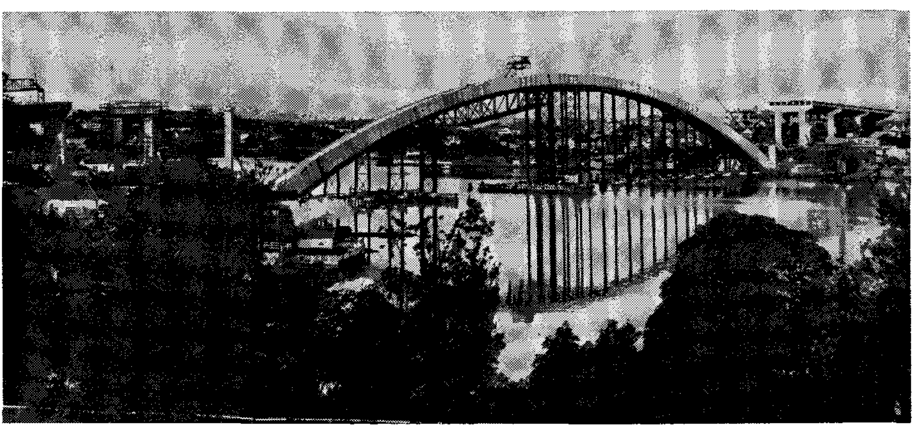

Fig. 21—Gladesville Bridge, Sydney, Australia. One 1,000 ft. arch rib completed.

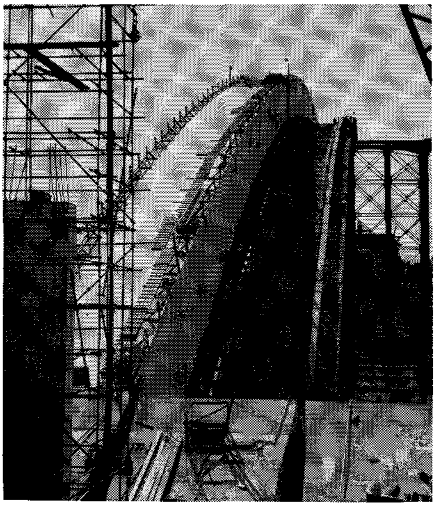

Fig. 22—Gladesville Bridge, Sydney, Australia. View of the steel falsework upon which the precast box sections are placed.

to the top. Then it is moved sideways by the gantry and set on a carriage. The carriage runs on rails affixed to the steel falsework. With this system, each block is run along and down the arch profile to its position in the arch rib. Final positioning is by a series of hydraulic jacks. After all the box sections for a rib are in place, the joints are concreted, except for two joints at the third points. Flat jack assemblies are inserted, each assembly consisting of 48 flat jacks with a total capacity of 2000 tons. The 48 jacks are operated through a manifold; at each of the 4 box corners is a manually operated jack for balancing.

After jacking, the flat jacks are grouted. It was found that there was a small loss. To compensate for this loss the flat jacks were re-pressurized after the first stage grout had set. They were then given a second injection of grout.

The completed rib is lifted clear of the falsework by the jacking. The steel falsework bridge is now moved sidewise for the next rib.

Two of the four ribs were completed and decentered by the fall of 1963. Actual deviation of the first rib was less than 1 in. from true position, well within the allowable limits.

The columns and deck girders are all composed of precast and

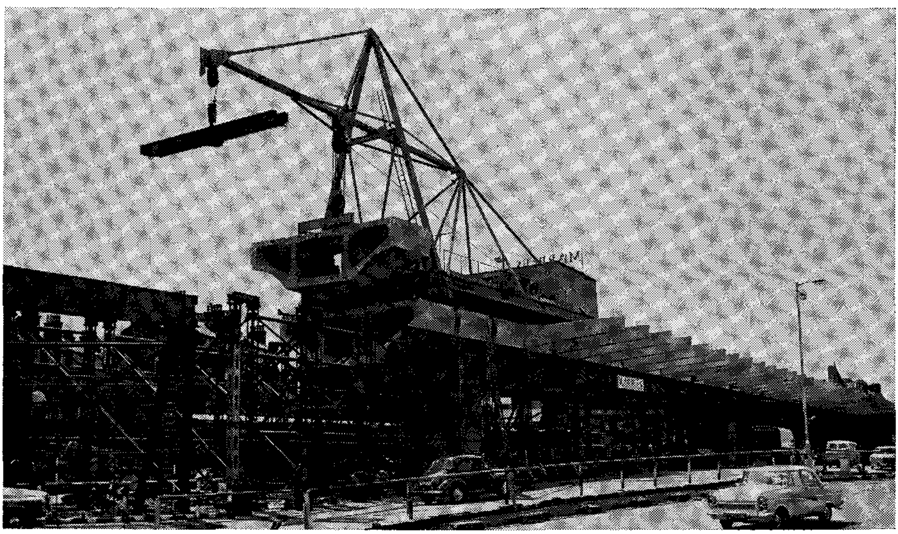

Fig. 23—Hammersmith Flyover, London

prestressed units, cast on each side of the river and launched progressively into position by means of a launching gantry cantilevering one span ahead.

I. The Haringvliet Sluice Bridge, Netherlands—These huge "Nabla" girders, named for the Greek word symbolizing a triangle pointing downwards, act as support for the roadway bridge and for the 450 ton sluice gates. There are 17 spans of 200 feet. Each leg of the triangular Nabla girder cross-section is 73 feet.

Each girder is assembled from 22 transverse segments, each weighing 250 tons. A segment is cast face down on the sluice floor. Steam curing is used to accelerate hardening. Then the segment is post-tensioned transversely. A huge gantry crane lifts the section in a horizontal plane and places its nose or point in a tilting frame. By picking at the other two corners, the segment is tilted up to vertical position. The segment is then lifted into position on steel falsework centering.

Jointing was described earlier in this paper. Each girder is then post-tensioned longitudinally with a total force of 28,000 tons.

J. The Hammersmith Flyover—This notable segmental bridge in London is chiefly interesting because of the clever system of transverse segments. Cantilever arm segments alternate with box girder sections. All segments were cast in a plant 9 miles away. They were cast flat, then turned upright for transportation to the site by truck. They were erected on falsework by a gantry crane riding on rails on top of previously placed segments. Final adjustment of each segment was by jacks on the falsework.

The 3 in. thick joints were filled with concrete. After the joint concrete reached its design strength, the girders were longitudinally stressed in an overlapping pattern to form a continuous girder bridge.

IV. CONCLUSION

The successful completion of these and other major bridges indicate the tremendous potentialities for economical construction of long span bridges of prestressed concrete. Precast segments, of very high quality and close tolerances, are readily obtainable from existing precasting plants. They can be transported by barge or truck, erected by standard erection derricks, by cranes or floating derricks, or by special gantries. They can be joined by techniques already proven on major structures in the United States, Europe, the U.S.S.R., and Australia. Careful attention to all details and full integration of all phases of the project, from design through manufacture, erection, jointing, and prestressing, are essential.

These matters are similar to those previously encountered and successfully met in long span steel bridges; in steel the techniques and procedures have become well known, but engineering skills, vigilance, and attention to detail are still essential, just as in the newer field of concrete.

Precast segmental construction makes long span prestressed concrete bridges practicable and economical and should open the door to their widespread use.