Several of the texts on prestressed concrete illustrate the magnitude of the effect of prestressing on the concrete by using a fishing pole as an example. As I recall the fishing pole described, it consists of a length of concrete one inch square in section with a single wire pretensioned through and along its central axis. Not until I was to witness the behavior of the massive precast, post-tensioned girders of the Oneida Lake Bridge, was I completely able to accept the picture of fishing with a concrete pole.

However, after having cast the first girder, and having lifted it from its bed so that it was supported at only two points, the center and one end as it was designed, it was discovered that with a push of the hand on the cantilevered end it was possible to deform and deflect the member to an extent of three inches either side of the center line.

Try to picture a 145-foot-long, 14-foot high concrete girder bending in oscillation through an arc of 6 inches without ever indicating any distress along its length. Some day I will try fishing with a concrete pole.

This is only one of the many new or modified concepts brought to my attention during the performance of the work. This contract was for the State of New York, Department of Public Works with Terry Contracting of New York. Before describing and enumerating some of the concepts it might be well to give a brief description of the structure that was involved.

The structure is actually twin bridges supported on continuous piers and abutments. Each bridge consists of one center span 320 feet long with end spans 70 feet long, all measured between bearings. The roadway width of each bridge is 40 feet between curbs. Each twin consists of 6 cantilevered members 145 feet long which span from the abutment 75 feet, across the pier and extend 70 feet toward midspan. Between the ends of the cantilevered members from either side five so-called drop-in girders are hung. They are hung so that they interlace with the ends of the cantilevered girders, and they are also hung so that the ends of the drop-in girders overlap the ends of the cantilevered girders by 27 feet.

Diaphragms which are post-tensioned are placed approximately 25 feet apart between and connecting each of the cantilevers with its adjacent drop-in girder. In doing this the bridge is actually designed and built to be one continuous concrete member from abutment to abutment 470 feet in length.

All prestressing, both the longitudinal girders' prestressing and the diaphragm post-tensioning, was ac-
Fig. 1—Structure Layout

Fig. 2—Picture of site and bridge in construction

March, 1961
accomplished with the use of the BBR system and supplied by Joseph T. Ryerson and Son, Inc.

Recognizing that the use of prestressed concrete material provides a maintenance-free structure, the owners and the engineers decided to carry that aspect over into all of the materials used in the bridge. They did this by providing for aluminum handrails, stainless steel downspouts for the drainage system and stainless rocker bearings for the bearing supports.

The bearings at each of the piers and abutments are only five in number, where we might normally expect to see six, one under each of the supported bridge members. The engineers in preparing the design for the structure determined that the bearings could more advantageously be placed under the posttensioned transverse diaphragms which connect the cantilevered girders to each other. In order to do this they had to transfer the load of the main bridge members to the diaphragms before reaching the bearings. This was accomplished by developing tendons that look like snakes. We called them S-tendons and they reach from the bottom flange of the cantilevered girders out into the diaphragms and up to the top of the diaphragm just above the bearings.

Although the specifications permitted the use of the cast-in-place method for the cantilevered girders at the site, the contractor agreed with the designers that the hazards to falsework construction due to shipping on the canal would prevent economical construction by the cast-in-place method. The structure spans an active portion of the New York State Barge Canal at the western end of Lake Oneida.

It was this problem of water traffic that led the designers to develop the continuous member in three sections with provisions for splicing during erection.

Although the contractor's forces included seven or eight registered and competent engineers in structural design, the contractor felt almost from the inception of the bid that it would be very well worth while enlisting the services of a consulting firm. The consultant was assigned to review and analyze the contractor's plans and proposals for methods of handling equipment design and temporary structure design. The consultant was to ascertain that the contractor had taken full advantage of the characteristics of either partially or totally prestressed structural members. The consultant was also to see that any incipient hazards to such members through unexpected problems that the contractor had not experienced were avoided.

This concept would undoubtedly apply to any structure whose members could not be yard-fabricated and shipped by truck and handled by readily available lifting devices, such as cranes. The job engineering included the dimension detailing to take care of shrinkage, elastic shortening, and creep. The engineering also consisted of camber control both vertical and horizontal, for the three stages of prestressing.

Form design and tendon location were also engineered to follow the detailed dimensions as mentioned above. The concrete placing methods were also a problem that required specific engineering approaches. The web thickness of the 14-foot-high members in 16 of the members was only 11 inches. The webs were also crowded with...
the normal reinforcing steel, plus the many tendons, 28 per girder, necessary to develop the large forces required in this structure. Engineering was also necessary to determine the proper handling methods, equipment, and temporary structures necessary to move the massive weight of the members from their casting location to their positions in the structure.

The engineering also required feasibility tests on types of forms to answer the above questions. A full-scale section of the girder was formed and poured, including reinforcing and tendon sheaths, in order to test the solutions to these problems with various types of chutes and window openings in the forms.

The concrete used for the testing was exactly the same as that which was used in the job itself.

Further feasibility tests required a full-size slab containing a full-scale length of the post-tensioning tendon described earlier as the S-tendon, in order to determine the friction characteristics of such sharp bends in such short lengths of tendon. These tendons were only 14 feet long.

It was also found necessary to make laboratory tests on totally enclosed sand to determine the economical size and the piston cylinder clearances that could be used in the sand jacks. The sand jacks were required to support the individual cantilevered girders on the piers as they were placed and aligned to proper grade, before casting the diaphragms and including or encasing the stainless steel bearings below the diaphragms and between the girders.

It is quite conceivable that future construction of like magnitude would encounter engineering problems as numerous, and thus require contractors to provide the trained engineering man-hours necessary to control a structure of this type.

A second concept with respect to labor man hours became apparent during the course of the work. This concept was doubly apparent to Terry Contracting, since it contrasted greatly with Terry's many years of experience in structural steel erection. Whereas erection of structural steel would entail approximately a 20 per cent expenditure of contract price for local field labor, the Oneida Lake Bridge local field labor costs were over 70 per cent of bridge costs. Since today's bridges are built primarily by governmental agencies, it would be possible not only to get a long-lasting, relatively maintenance-free structure with prestressed concrete but also a boost to the shaky local economy by distributing a large percentage of its cost through field wages. This concept might also apply to a large proportion of the materials incorporated in such a structure, since they include aggregates and cement which may normally be found relatively close.

A corollary concept seemed to be indicated to this contractor by comparison of work on the Oneida Lake Bridge with bids proposed for posttensioned structures at other locations. In all cases the bids were for prestressed structures as alternates to structural steel designs, and most of these structures involved were in the same order of magnitude as the Oneida Lake Bridge. No specific allowances were made to take full advantage of the character of construction of prestressed concrete. Location, terrain, span lengths and span types were all slanted toward the
steel structure design. The Oneida Lake Bridge indicated a saving of 10 to 12 per cent to the owner and this was during a period in which the economic environment favoring cheaper fabricated steel existed, and also the structure was designed to take full measure of structural steel economies.

It is felt that the full competitive measure of prestressed concrete will not be made for structures of this magnitude until the owner agencies offer truly independent and competitive designs for bidding in lieu of the present process of offering alternates.

It is hoped, of course, that the successful completion of the Oneida Lake Bridge will develop in the owner agencies a greater assurance and desire to tackle larger structures in this material and also to make more frequent use of it.

The consultants made every effort to provide the contractor the opportunity to take full advantage of the environment in the performance of the contract, and it might be of interest to see how this was done.

First, the contract work included a total of 34 precast girders, each weighing approximately 240 tons. This number was divided into four groups of six cantilevered girders each and two groups of five suspended girders each. The specifications stated that all girders of any one group must be cast in relatively the same period of time, and also that one structure must be done, including all diaphragm stressing, in one year—between the dates of April 1 and December 1.

The casting bed areas were utilized completely in the scheduling of the beam fabrication.

A casting bed area was developed behind each abutment and had an area of 180 feet in width and 400 feet in length. The elevation of the bed area was approximately 17 feet below finished grade. These large areas permitted the erection of six casting bed soffits behind each abutment. (Fig. 2)

In order to cast the 24 girders in the contract time available it was decided to provide three sets of forms for the cantilevered girders. Two of them were for the interior type, which was a modified I-section, and one was for the exterior type, which was a rectangular shape. The rectangular fascia beam was included in the design in order to give the appearance of a massive structure.

These three sets of forms required eight uses for each set of forms. This was about the maximum that could be expected without excessive repairs during the course of the job. However, some of this wear and tear may have been incurred in the methods of handling, since they were built and handled in 40-foot lengths, and they were also transported across river by floating them in the river.

A unique feature of the form construction was that they were so matched that all the reinforcing steel and post-tensioning tendons were erected and tied to templates com-
pletely before any form was set. (Fig. 3) This was exclusive of the end bulkheads, which carried the tendon anchorages. After the template frames were removed the four panels along one side were set, aligned, and placed. The matching panels were then set on skids sufficiently far from the steel to permit the passage of carpenters who inserted tie bolts through opposing holes in both walls. (Fig. 4) These extended form bolts were then used as screw jacks to skid the second wall into proper position of alignment. This permitted all operations between the forms to be completed before the forms were actually closed up. (Fig. 5)

A third casting bed area was provided for the fabrication of the suspended girders. Since these girders would be erected from a barge, it was desirable that they be cast on an elevation from which they could be moved out onto the barge with a minimum of vertical movement. In order to achieve this a low area along the northeast bank was filled to proper elevation over a distance that permitted the erection of soffits for the six 231-foot long suspended girders. (Fig. 6) A fill material that could later be removed and used in building up the approach road was used. These forms were not as heavy as for the cantilevered girders, since the girders were only 8 feet high and only 5 reuses were required. It was found that with all operations working normally a girder could be prepared in 15 days from the time the soffit was uncovered until the day of treatment of the succeeding girder.

Since each of the 34 girders took approximately the same amount of concrete, all girders required about the same length of time to cast. This time averaged around six hours. Because of the 14-foot height of the cantilevered girders two horizontal rolls of placing windows in the forms were required, one each on opposite sides of the girder. The windows on one side were used in placing the concrete, and the opposite windows were used to admit internal vibrators. The windows were spaced 4 feet on centers longitudinally. Since the quantity of concrete that any one window would pass at a time was very small, a series of hopper towers were erected along the placing side forms. Concrete was fed to the hoppers in rotation and allowed to dribble slowly through the respective windows. With 19 such hopper towers it was possible to keep the job site batch plant with its two 1-cubic-yard mixers busy to the extent that it would at times be producing at the rate of 35 cubic yards an hour.

Although the specifications called for a 28-day strength concrete of 5,000 psi, it was thought best to take advantage of the permission to apply first-stage stressing as soon as test cylinders indicated a strength of 4,000 psi. This was achieved by providing a design mix that was up to 4,000 psi in four days. Since first-stage stressing required one day, it was possible to move off a soffit on the sixth day after casting. An added advantage was gained in that practically all cylinders tested over 7,000 psi at 28 days, with a goodly number reaching 9,000 psi. In the future it might be possible to lighten up similar structures to take advantage of this available higher strength concrete.

To move these massive girders required the development of some unique methods and tools. Their movement evolved into three phases. First was a movement horizon-
tally over land, then horizontally over water, and last vertically from the water. The cantilevered girders were moved horizontally a maximum distance for any one girder of about 300 feet. Since the cantilever girders were designed for maximum loading at about the center of their length, they also had to be handled at that point. This required the designing of a carrying device capable of handling 200 tons, with a base width limited by the top width of the bridge piers. Since this device had to move over what might be expected to be yielding soil, it had to be designed to follow the supporting soil as it yielded. These requirements resulted in a fully articulated carriage supported on eight endless chain type express rollers running in four channel tracks. (Fig. 7) In order to change directions, which it was necessary to do twice for each girder handled, provision was made to permit jacking the carriage and girder together sufficiently high to permit the 90 degree swing of each of the express rollers.

Moving the cantilever girders from soffit to location on the pier required an average of two days. The same method was used to move the suspended girders from soffit to barge. However, in order to provide a stable platform on which to move the suspended girders from land, it was necessary to build a shoreline bulkhead with a level concrete landing mat at its base a predetermined distance below its freeboard curbs.

The barge used was a compartmented one so that it could be flooded and set solidly on the bottom while loading the girders. (Fig. 8) Figure 9 shows a suspended girder being barged into place under a set of completed cantilever girders.

While a 2500-pound line pull hoist through a 12-part line was used to move the suspended girders onto the barge, the movement over land was achieved by the use of two 10-ton, 5-foot hydraulic jacks kicking between the track base and the rolling carriage. (Fig. 10) The vertical movement of about 15 feet for each of the suspended girders was accomplished by means of continuous threaded rods, jacking beams, and a pair of 200-ton jacks at each end of the suspended girders. (Fig. 11) Safety rods and holding beams were also provided at each end. The girders were lifted vertically in one-foot increments by the jacks acting between a pair of jacking beams with a pair of nuts on each rod above the jacking beams. These nuts were at all times kept finger-tight.
against the members below them in order to avoid any bouncing of the girder in the lifting yoke and holding beam. A single girder could be barge-loaded and erected in this manner in one day.

Although the specifications had limited the maximum travel of grout to fill the voids in the post-tensioning tendon sheaths to 90 feet, it was found entirely feasible and much more desirable to grout even the 231-foot-long tendons of the suspended girders from one end. This was done by prefilling the tendon with water and controlling its discharge from one end by a valve as the grout was forced in by pressure at the opposite end. Apparently this method provided some form of lubrication for the travel of the grout through the long tendon as very little difficulty was encountered.

I would also like to point out that even in such a completely pre-engineered item as the Post-tensioning system itself, it was possible to find needed refinements during the performance of engineering tests. The specifications required a full-scale performance test of the proposed post-tensioning anchorage system to 100 per cent of guaranteed ultimate strength of the tensioning wire. The BBR system used consisted of button-headed wires founded on the face of an anchor head which was made large enough to accept a jacking stressing rod at its center on internal threads for tensioning. This necessarily causes the individual wires—of which there were from 24 to 28 per tendon—to splay out on their emergence from the tendon sheath through an enlarged trumpet end to the anchor head. This splay-out causes each wire to enter the face of the anchor head at a fairly shallow angle, but at an angle. The refinement found necessary in order to achieve the 100 per cent indication of anchor strength of the girder ultimate strength of the wire was that the holes drilled in the anchor head to accept each wire had to have a relieving chamfer placed on the interface, in order to avoid a small indentation in the wire under stress.

This contractor has enjoyed the challenges of construction of this unique bridge, but must admit that here, as elsewhere throughout our land, education is expensive. Recognition of the learning developed through this project was experienced by all concerned, including the owners, designers, and builders. I believe that all are looking forward to the next structure of this magnitude.