The Use of Prestressed Concrete and Epoxies to Expedite Construction of Interstate Route 87

by Herbert Goodkind*

INTRODUCTION

The most expensive single highway construction contract, ever awarded by the New York State Department of Public Works, was held by the Slattery Construction Co. of Maspeth, New York. The contract provided for the construction of an 8.16 mile section of Interstate Route 87, from the Cross Westchester Expressway (Interstate Route 287) to a point approximately 2300 ft. north of a proposed interchange with Relocated Route 22 in Armonk, N.Y. The lowest of three bids on this project was $23,529,000.

Among the many unique features of this project is its truly Interstate nature, see Fig. 1. Originating in Westchester County, New York, the road enters Fairfield County, Connecticut, shortly after it underpasses New York State Route 120; continues in Connecticut for approximately 1.4 miles at which point the northbound roadway spans the Byram River in Connecticut while the southbound roadway crosses the river in New York. From this point on, both roadways are in New York.

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The alignment through Connecticut traverses a swamp, which originally was estimated to be approximately 6 to 10 ft. in depth, described as minor. This swamp was the key to the entire job during both the design phase and during its construction. Thanks to complete cooperation between Federal, state and private engineers, a rather unique design was prepared, consisting of combinations of prestressed concrete, epoxies and engineering ingenuity.

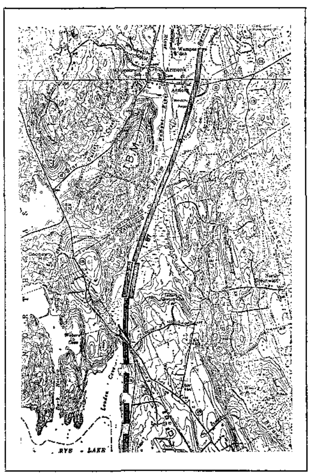


Fig. 1—Portion of I-87 Passing Through a Corner of Connecticut

SCOPE OF WORK

The design of this project was divided into two parts. Part 1, extending from the Cross Westchester Expressway (I-287) to a proposed interchange at the Westchester County Airport, a distance of 4.9 miles, was designed by Madigan-Hyland. Part 2, designed by Goodkind & O'Dea, continues northerly from the Westchester County Airport to Armonk, N.Y., a distance of 3.2 miles.

As originally contemplated, 800,000 cu. yd. of surplus excavation from Part 1 was to be utilized as much as possible in Part 2, which required borrow. This situation was highly desirable, since zoning regulations in this posh suburban area precluded borrow or waste operations close to the project. Imposing long hauls over local streets would be costly and create an undue strain on the highway industry's public relations.

PROPOSED SCHEDULE

On February 19, 1964, Goodkind & O'Dea was asked if they were in a position to complete surveys, contract plans, and right-of-way maps for their section of the route within six months. As described, the job seemed to be relatively simple. The estimated swamp depth appeared to pose no problem, and there were only two grade separation structures plus a multiple pipe or reinforced concrete box culvert required to cross the Byram River. All were concerned that, due to dense swamp vegetation and evergreen trees along most of the route, aerial surveys could not be used. The fact that the work would be subject to the review and approval of two states and two Division Engineers of the Bureau of Public Roads, posed an equally great problem. After being assured by E. Burton Hughes, Deputy Superintendent of Public Works of New York, that this project had top priority for the year and that all submissions would be hand-processed through the New York State Department of Public Works and the Connecticut State Highway Department, the project was undertaken.

ALIGNMENT CONTROLS

In addition to the zoning ordinances and public relations aspect mentioned previously, the alignment was restricted to a relatively narrow corridor. The southern terminus of the section had been set by Madigan-Hyland and any westerly movement was limited by the proximity of Rye Lake, one of the major links in the water supply system of New York City, and by the new multimillion dollar headquarters complex of I.B.M. in Armonk to the north. Any movement to the east was limited by proposed new construction by the F.A.A. at the Westchester County Airport, the Tamarack Country Club, and many historical sites in Connecticut.

SUBSURFACE CONDITIONS

Shortly after receipt of the contract, on March 23, 1964, survey crews began to lay out baselines in the field, and we began to probe the swamp area in hopes of ascertaining its depth and to estimate how much of the 800,000 cu. yd. of surplus material in Part 1 could be used by Part 2. The first indication of possible trouble in the "minor" swamp area came when a 20-ft. probing rod sank out of site under its own weight!

Following a review of the situation with Mr. Sinacori, District Engineer for New York, and Mr. W. Hoffman, Chief Soils Engineer for New York, a crash boring program was undertaken by New York State's

D.P.W. forces in the Connecticut swamp. Early in July, it was apparent that the swamp was consistently much deeper than anticipated.

At a meeting in Albany on July 21, 1964, attended by all interested parties, it was reported that the swamp, instead of being shallow, contained very soft peat and organic silt deposits which might be 60 ft. in depth and 3000 ft. in length. It was estimated that to displace this unsuitable material, approximately 800,000 cu. yd. of rock would be required, and more than 30 acres of land would be needed to store the resulting mudwave. Neither rock nor land was readily available, and a bypass of the deep swamp could not be made. The use of normal construction procedures such as removal and replacement of the unsuitable material or use of sand drains were not practical.

A proposal was made that consideration be given to crossing the swamp on a low-level, modular structure, that could be assembled rapidly and also serve as a work platform for pile driving and erection equipment while it was being built. It might also be capable of supporting the heavy earthmoving equipment required to transport the excess material from south of the swamp to the Route 22 interchange north of the swamp where it was needed. This suggestion was well received and before the meeting adjourned many basic decisions were made:

1. Prestressed concrete box beams would be used, overlain with a 4-in. concrete wearing course, reinforced with ordinary highway mesh, Fig. 2.
2. If feasible, pile caps and abutments were to be precast, and prestressed if necessary.
3. The type of piles to be used and the lengths of spans were left for further study.
4. The possibility of awarding a separate materials contract for prestressed piles and box girders was to be investigated by us.
5. The structure would have no curbs, but would carry full 10-ft. shoulders on the right and 6-ft. shoulders on the left.

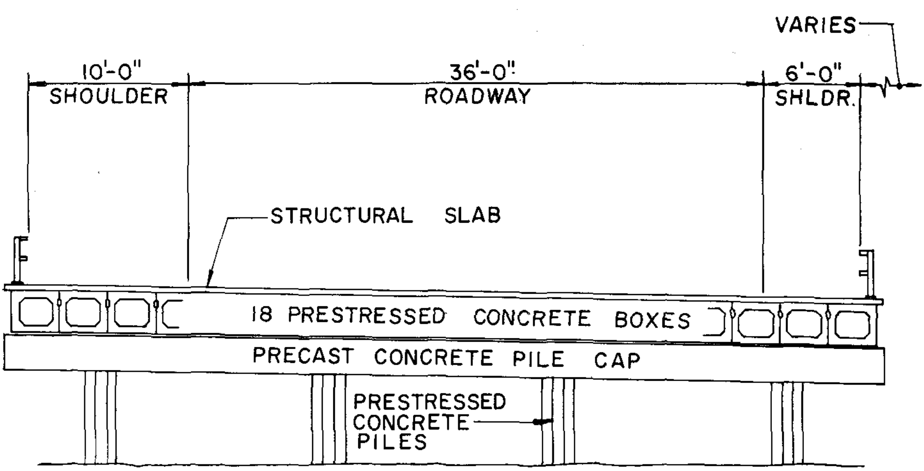


Fig. 2—Typical Half-Section—Northbound Roadway Looking South

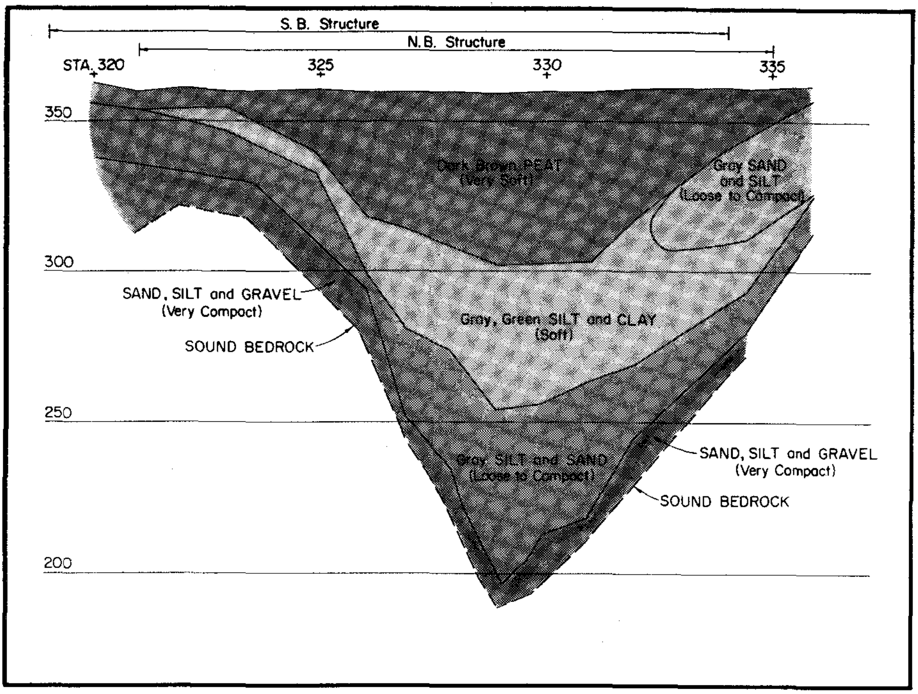


Fig. 3—Soils Profile

PRELIMINARY DESIGNS AND ESTIMATES

During the next three weeks, the subsurface information was studied in detail and additional boring information was received from the field. Both a soils profile, Fig. 3, and a contour map showing the tops of each stratum were prepared to determine the location and direction of the swamp. By shifting the alignment 190 ft. to the east, the length of the swamp crossing was reduced to 1600 ft. It was assumed that depths up to 20 ft. could be economically removed and replaced, thus making the required structure 1300 ft. long.

On August 11, it was estimated that a precast structure 1300 ft. long plus removal and replacement of material for 300 ft. would cost approximately $2,157,000, whereas construction of the same length by displacement methods would cost approximately $4,000,000. Preliminary plans of the proposed structure were submitted for review and approval at the same time.

For study purposes, 60-ft. long, 36-in. cylindrical prestressed concrete piles with 5-in. walls were considered. Each pile weighed 32,000 lb. Prestressed concrete box beams, 30 x 36 in. weighing 595 lb. per ft., were assumed as the pay load to be handled during construction. Span lengths were determined by using the loading diagram for a Manitowac 4600 crane which, with an 80-ft. boom, weighs 434,000 lb. The maximum radius at which this equipment and its payload could safely operate was 65 ft. Allowing 15 ft. as the distance from the end of track to centerline of pin, 50-ft.

spans were established for the structure.

In addition to the economic advantages, it was pointed out that the structural slab provided a much cleaner appearance and would require much less maintenance than on-grade pavement.

It is interesting to note that just prior to the start of our final design, the boring data indicated greater depths of unsuitable material and finally showed that the bottom of the buried valley was 175 ft. deep. This, of course, further indicated the selection of the structural slab construction.

We received prompt review and approval of our plans from the Deputy Chief Engineer (Design) for New York State and were given permission to deal directly with his office and his staff during the development of our final plans. Mr. Robert G. Mitchell, Chief Engineer of Connecticut, by letter of September 11, 1964, approved our preliminary designs, but noted our use of the cylindrical prestressed pile and requested that an alternate design be considered using 24-in. prestressed concrete octagonal piles. This was done and, in light of future events, we were indeed thankful for Mr. Mitchell's foresight. Just two months before our job was scheduled for letting, New York State advertised for bids to construct the foundations for a bridge in Rochester, N.Y. When no bids were received for the Rochester job with circular piles, we used our alternate pile bent design consisting of four 24-in. octagonal piles each carrying 150 tons.

FINAL DESIGN PROCEDURES

Having determined the span

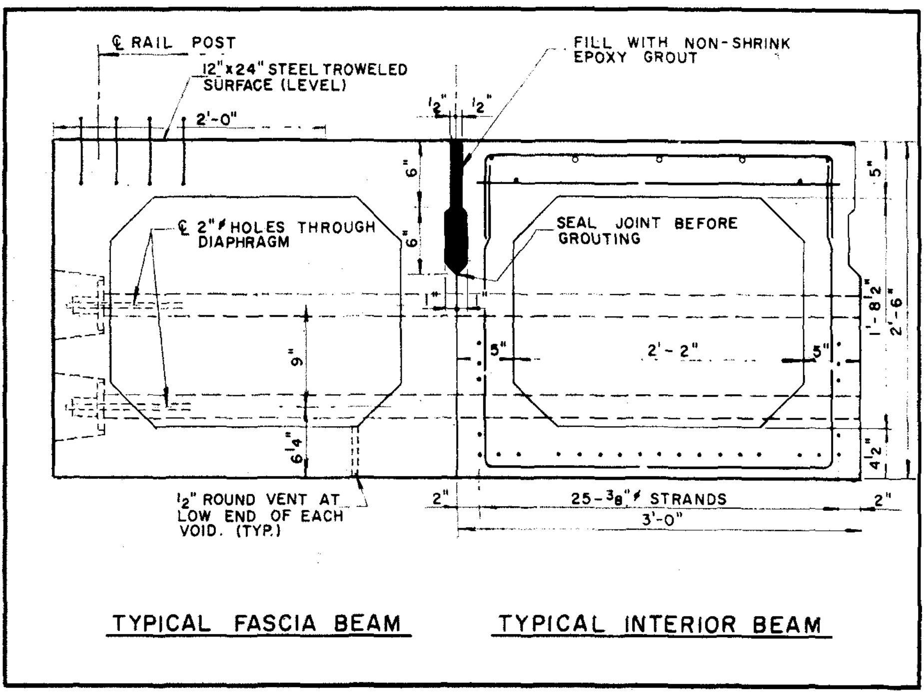


Fig. 4—Prestressed Box Girder Sections

length based on construction equipment sizes and loads, we proceeded with a normal design for HS-20 loading, Fig. 4. This design indicated the need for a deeper box section or a composite section. Since we were already planning a 4-in. concrete wearing course, the addition of reinforcing steel made it a structural slab. However, to achieve composite action by conventional methods, such as keys or stirrups, was not practical. If the box beams were to be used by construction equipment prior to placement of the concrete slab, a new method for shear connection was required. The composite action between prestressed units and 4-in. slab was achieved by using an epoxy-polysulfide bonding compound.

Having completed the design for normal HS-20 loading, the design was checked for anticipated construction loads. In general, a 30% overstress was allowed due to the temporary nature of these loads. The pile driving equipment, weighing 217 tons, was assumed to be distributed over 14 box beams (42 ft.) while moving from one span to the next and a 5% impact was assumed. With the pile driver in position, a trapezoidal load distribution, varying from 14 boxes at the rear, where the deflection in the beams was greatest, to 6 boxes (18 ft.) at the pier, was assumed for a pay load of 47,000 lb. and with the weight of the precast pile caps added.

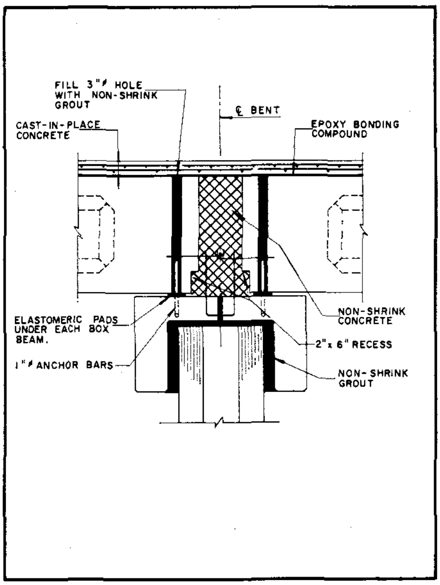


Fig. 5—Typical Fixed Bent Joint

It was not felt that batter piles were necessary for swamp depths up to 60 ft. When the depths of unsuitable material became greater, however, this became a matter for concern. On September 24th, a casing sank 45 ft. under the weight of the hammer, and there were only 12 blows per foot on the sampler at a depth of 153 ft. These increased unsupported lengths made batter piles more desirable, but also less practical. This problem was solved by distributing the horizontal forces over 5 bents by making the superstructure continuous over 4 spans. Continuity was achieved through cast-in-place concrete diaphragms at the fixed piers (Fig. 5) and with the addition of 110 No. 6 mild steel bars 22 ft. 6 in. long in the structural slabs at each fixed pier. Precast pile caps and abutments were not prestressed.

As an added feature to this unusual structure, it was decided to try out a new concept in bridge railing being developed by the New York State Department of Public Works. This railing is designed to permit the posts in the immediate vicinity of impact to break off at the base plate, and the toggle bolts which connect the rail to the posts to shear off on impact, permitting the rails to deflect up to 2 ft. Thus, the railing and not the vehicle absorbs the force of impact. This results in much less damage to the car and may permit it to proceed under its own power. It also reduces the likelihood of chain reaction accidents when a vehicle is thrown back into adjacent lanes.

Based on 36 borings, the last of which was received on December 16, 1964, the structural slab for the northbound roadway was made 1400 ft. long, while the one for the southbound roadway is 1500 ft. in length.

SPECIAL SPECIFICATIONS FOR PRESTRESSED CONCRETE WORKMANSHIP

In drafting the specifications for the prestressed concrete portions of the structure, it was recommended that the prestressed concrete manufacturer also be responsible for the pile driving and erection of the precast caps and prestressed concrete boxes. The reasoning behind this was that the manufacturer would be more careful if he were responsible for putting the pieces together. This suggestion was turned down, but the general contractor was the only other one allowed to do the pile driving and erection work.

To eliminate as many production problems as possible, it was specified that the prestressed concrete piles be plant-produced in one existing fabricating plant. This existing facility was required to be adequate to produce all prestressed concrete piles required for this contract, and to have been regularly engaged in the manufacture of prestressed precast concrete members similar to those indicated on the plans for a minimum of three years. A similar specification was written for the prestressed box beams and the precast abutments and pile caps.

SPECIFICATIONS FOR PILE DRIVING

Piles are to be driven with a template properly and firmly fixed in position. Piles shall be accurately located and driven plumb. Completed piles at the pile cap or abutment cap shall not vary from plan locations by more than 2 in. Maximum deviation from the vertical shall not be more than ¼ in. per foot of length. Piles shall be driven with a steam or pneumatic hammer which shall develop a rated striking energy of not less than 37,500 ft.-lb. per blow, having a ram weight of not less than 14,000 lb. The contractor actually used a Vulcan O16 hammer, which has a 16,250-lb. ram and develops 48,750 ft.-lb. of striking energy.

It was further specified that when the point of the pile is passing through soft material, offering little or no resistance to penetration, the hammer stroke should be reduced so that the energy per blow is not more than 24,000 ft-lb. Disregard of this warning has been the cause of piles breaking.

The contractor was given pile lengths by Deputy Chief Engineer Burns based on borings and confirmed by test piles. The contractor was permitted to use splices to furnish piles of the ordered length, but there was no payment for these splices. He is, however, paid for splices at the price bid if the ordered length of pile, when driven, does not reach a satisfactory resistance.

Longer pile lengths were obtained by adding pretensioned, precast pile sections, with eight No. 10 dowels projecting 24 in. beyond the end. These dowels are placed within the core of the prestressing strands.

The previously driven pile has eight 2-in. diameter holes cast into the top in a pattern identical with that of the eight projecting dowels on the pile build-up. The walls of the holes are roughened to insure a mechanical bond. A ½-in. steel plate is placed on top of the driven section and the build-up section is placed on the driven pile.

A steel splice boot, approximately 4 ft. long, is clamped around the pile and is positioned with 2 ft. above the joint and 2 ft. below. This splice boot makes the two piles collinear and, through pockets on four sides, a heated, quick-setting plasticized cement, trade name Florok, is poured in. It solidifies in a few minutes and reaches a strength of 5000 to 6000 psi in about ten minutes. After 45 minutes the piles are again driven.

SPECIAL SPECIFICATIONS FOR CONNECTIONS

These specifications were developed to circumvent several unfortunate experiences with prestressed concrete structures in the past. The connection between the prestressed concrete piles and the precast concrete pile caps was achieved by pumping a non-shrinking grout through eight 2-in. holes in the cap provided for the purpose. This grout consists of one part cement, two parts sand and a fluidifier meeting the following test requirements as specified by the Corps of Engineers:

Reduction in water requirement	5% min.
Increase in water retentivity	70% min.
Expansion	6 to 15%
Increase in compressive strength	10% min.

The grout used in the longitudinal keys consists of a two-component epoxy resin system mixed with a crushed angular quartzite sand of specified gradation. The proportions are four parts sand to one part epoxy.

The requirements that the longitudinal keys be grouted and the lateral post-tensioning be completed before moving the pile driving equipment on to the structure was necessary to achieve the assumed load distribution. The contractor developed an alternate using steel beam frames supported on the pile caps that speeded up his operations.

Due to allowable tolerances, a sweep of ⅜ in. in a prestressed concrete box of the size being used could be anticipated. The fascia beams might possibly be displaced by as much as 7 in. It was, therefore, specified that the bridge rail anchor bolts be welded to a 7 x 14 x ⅜-in. steel plate, Fig. 6. These plates are to be set to perfect alignment after the boxes are set and the transverse strands tightened. The anchor bolt assemblies are then to be connected to the prestressed boxes with an epoxy-polysulfide bonding compound. Three No. 6 mild steel bars, cast in the prestressed units at the location of the posts, were also provided. It was specified and shown on the plans that an area 2 x 1 ft. in these locations be steel troweled and level.

Due to the unusually large use of epoxies and similar special materials, it was specified that the material suppliers furnish technical assistance on the job whenever their material was being used. This resulted in three employees of one of the major suppliers forming their own company, D.B.M., limiting their work to application of epoxies. We think this is a step in the right direction and it will increase our faith in the many new materials being sold.

CONCLUSION

The 1080 prestressed concrete box beams, 25,400 lineal feet of prestressed concrete piles, 54 precast concrete pile caps and 4 precast

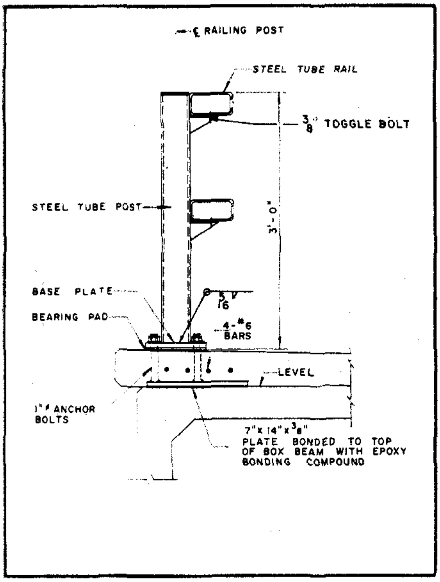


Fig. 6—Railing Post on Box Beam

concrete abutments were manufactured by Blakeslee Prestress in their Hamden, Conn., plants.

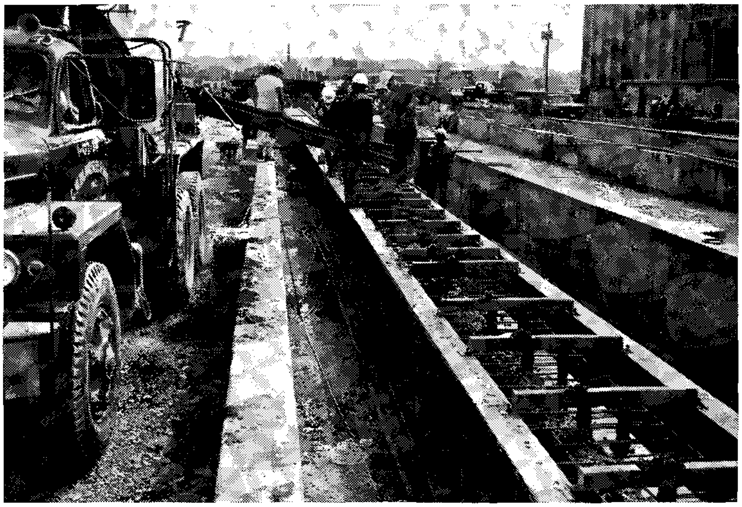
Although we were not involved in the actual construction of this project, personal observations and reports received from Madigan-Hyland, who are handling the technical inspection of the job, indicated that Blakeslee had done a commendable job. Of course, there have been a few slips, such as failure to install the correct number of stirrups in the vicinity of the expansion joints, or failure to box out the ends of some boxes to receive the expansion assembly. This is all a matter of quality control and points out the need for indoctrination of the lowest man in a plant as well as the foremen, salesmen and engineers.

The piles are being driven by the general contractor and the fact that he has chosen to use extra splices is proof of their economy. We understand that he has had no difficulty in setting the precast pile caps and abutments on the previously driven piles. This, too, attests to the quality of his as well as the fabricator's work.

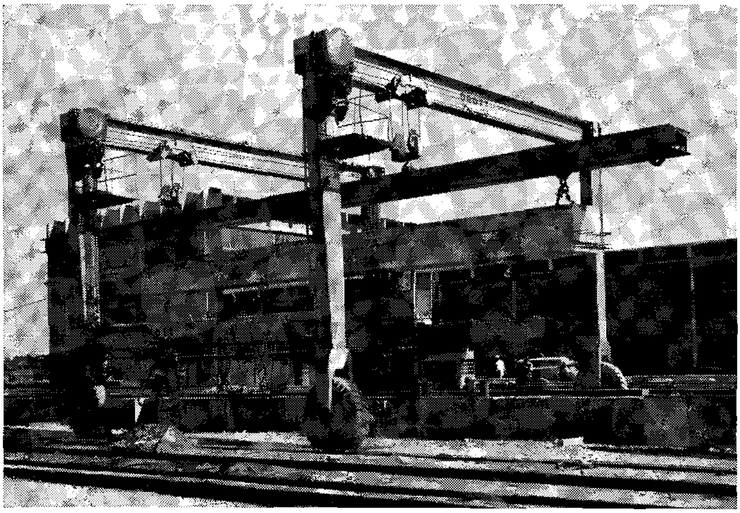
Presented at the Twelfth Annual Convention of the Prestressed Concrete Institute, Houston, Texas, September 1966

Discussion of this paper is invited. Please forward your Discussion to PCI Headquarters before May 1 to permit publication in the August 1967 issue of the PCI JOURNAL.

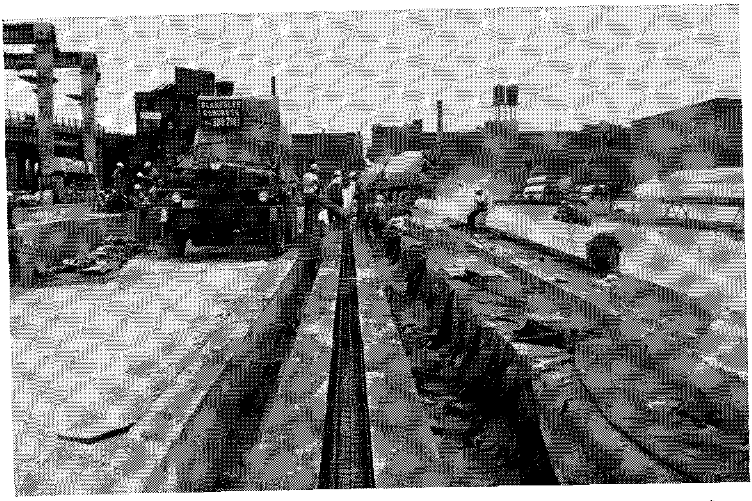
Pictorial Review of Prestressed Concrete Structure on I-87



Plant-cast, hollow, box-girder deck units are 3 ft. wide and 30 in. deep. The cardboard voids are held in position during concrete placement.

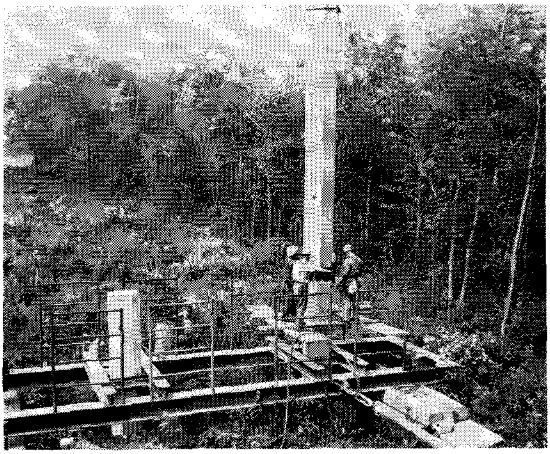


Box-girder units, cast in 50-ft. lengths, were removed from forms as soon as the concrete reached sufficient strength to receive prestressing force.



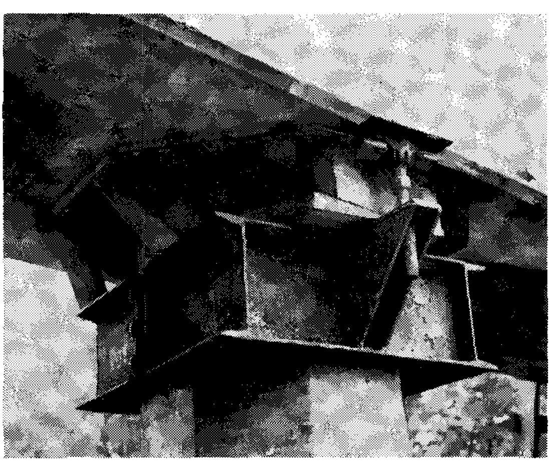
Plant-casting of 24-in. standard prestressed concrete octagonal piles. The solid sections used 5000-psi concrete.

Piles were delivered to the job in lengths up to 80 ft. The contractor elected to set his pile-driving rig on a frame of steel sections spanning between previously placed bents.



Longer piles were developed in the field by splicing a top section. Eight No. 10 bars extended from the top piece into corresponding holes in the bottom unit.

A fast-setting epoxy, that developed 5000 to 6000 psi compressive strength in 10 minutes, completed the splice.



A temporary collar holds the cap to proper elevation while the space above and around the top of pile is filled with an epoxy grout fed through the top.

The 4-pile bents were capped with precast units, 27 in. high, 4 ft. wide and 54 ft. long.

In place, the box girder prestressed units formed a working deck. They acted as simple spans for dead and construction loads; with epoxy-bonded concrete wearing surface and transverse post-tensioning they acted compositely for live and impact loads.