Observations of the Manufacture and Placement of Prefabricated Bridge Sections and Precast Concrete Riprap

Dave H. Sawyer
Kentucky Highway Materials Research Laboratory

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Memo to: D. V. Terrell  
Director of Research

Among the several interesting and valuable developments with concrete for structural purposes which have been used by the Department during the past year, are the mass production of prefabricated bridge sections and the casting of concrete blocks for rip rap on the fill at a major bridge approach. Neither was absolutely new, but in the uses made this year both had some aspects of newness that led to requests for observations and records by the Research Division. Attached is a report on our observations to date.

In the case of the prefabricated structural members, a particular bridge was selected for construction with half the sections made of the usual type concrete and the other half made of lightweight concrete. Emphasis was placed on the mix design and handling of the lightweight concrete, but some features of transportation and erection were included as a matter of record. There is no doubt that prefabrication offers many advantages in the building of standardized short-span bridges, but whether there is any advantage (other than weight) of lightweight concrete as opposed to regular concrete for this purpose can be judged best by the outcome of the test structure in Boone County. Performance of the structure will be observed at frequent intervals.

The making of concrete blocks for rip rap, which actually started in 1954, entailed mainly problems of handling at the manufacturing plant. You will recall that at the time we visited the plant late in the summer breakage was high, and production schedules for completion this fall could not be met. The question at the time pertained to a request that use of calcium chloride in the mix be permitted, in order to accelerate the set of the concrete and thus reduce breakage and speed up production as well.

Upon investigation by Mr. D. H. Sawyer from our laboratory, it was found that changes in some of the forms and care in selecting the proper time for removal of dividers did much to overcome the problem. It was recognized that the use of calcium chloride would further aid in reducing the breakage, and also overcome delays caused by increasing time of set of the concrete at lower temperatures in the fall. Probably the greatest advantage was gained, however, when production
of blocks on the concrete pavement at the bridge site was undertaken. Because of the fact that it was not necessary to handle these blocks for a period of several days there was no breakage problem, and the conditions were such that the number of blocks made per day was greater at the site than at the manufacturing plant.

Although this report presents only a limited amount of detailed information new to the Department, it should serve as a valuable reference when problems of casting concrete for special purposes arise in the future, and when a final evaluation of lightweight concrete for bridge members is made.

Respectfully submitted,

L. E. Gregg
Assistant Director of Research

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Copies to: Members of Research Committee
J. S. Cobb (3)
The design and equipment necessary in precast concrete operations has progressed in recent years to such an extent that the resulting products are now being used satisfactorily in many types of construction. This report covers two precast concrete products which the Department of Highways authorized in contracts let in 1954 and 1955. These items however, are not the first precast concrete products to be used by the Department. Two concrete bridges are known to have been precast and placed in Scott and Graves County sometime ago. Precast concrete cribbing has also been used for quite some time.

The two items discussed are the precasting of: (1) 60 short-span concrete bridges, and (2) concrete blocks for use as riprap.

The feasibility of using lightweight aggregate concrete in bridge decks was also taken under consideration on this project. A comparison of the performance of lightweight concrete sections as opposed to the regular concrete sections is being made at one installation. In this instance, half the bridge sections were cast of lightweight concrete and alternately spaced on one bridge with the regular concrete sections.
The primary reason for electing to investigate the suitability of lightweight concrete in bridge sections was, of course, due to the substantial reduction in dead weight over regular concrete. Lightweight concrete, for example, is about 30 percent lighter than regular concrete. The reduction in weight of the lightweight sections over the regular concrete sections would be less than 30 percent, however, because of the large quantity of reinforcement steel used.

The second phase of the report deals with the making, handling, and use of precast concrete block as riprap. The necessity for casting these blocks resulted from a shortage of stone in the area where the bridge fill was to be built.

The use of these precast products represent the Department's first major undertaking to include precast concrete material in highway construction. The reasons for interest in the precast field are rather obvious in view of certain advantages of these products over conventional procedures when specific items are involved. For example, the prefabrication of these sections will make it possible to replace a damaged bridge of similar length in the least possible time, and under the most severe conditions. Likewise, the precasting of concrete blocks as riprap alleviated an otherwise impossible situation in an area deficient in natural stone.

Major interest in these two items, which were designed by Department personnel, was in the Maintenance and Construction Divisions, the former requesting the Research Division to make these observations.
PREFABRICATED BRIDGE SECTIONS

In 1954 the Department awarded a contract to the Katterjohn Concrete Products Co. at Owensboro, to precast 60 concrete bridges of 20- and 30-ft. span lengths. The bridges are composed of two curb and gutter sections, each 3 ft. in width. Overall depth of the intermediate sections is 19 in., including the slab depth of 6 in. The total length of the sections is 22 and 32 ft., allowing for 1-ft. bearing at each end.

Fabrication

Class D concrete without air entrainment was used and was supplied to the producer in ready-mix trucks from a nearby location. The concrete was poured with a 1-in. slump, followed with internal vibration. When the concrete had attained 24 hr. of curing, the forms were stripped and the sections stockpiled. Details of the casting, curing and handling operations are shown in Figs. 1 to 10.

This company was able to cast complete one 20-and one 30-ft. bridge every four days during the peak of their operation the past year. Weather conditions were only a limited factor in the production schedule, even though all the work was done outdoors. Steam lines under all the forms insured proper and early curing regardless of the temperature. Tarpaulins were used to protect the concrete from bad weather and also to hold in steam necessary for satisfactory curing.

Permission to cast four lightweight concrete sections, one curb-and-gutter and three intermediate sections, was obtained during the interim of this operation. The lightweight aggregate used, as both the
fine and coarse aggregate, was expanded shale.* The mix design per cubic yard, in accordance with recommendations of the producer (Kentucky Light Aggregate Corporation) was:

- Cement . . . . . . . . 7.5 bags
- Fine Aggregate . . . 1200 lb.
- Coarse Aggregate . . 700 lb.
- Water . . . . . . . . 35 gal. (approx.)
- Protex AEA . . . . . 4.0 oz.
- Slump . . . . . . . . . 1 to 1 1/2 in.

The coarse aggregate, which consists of two separate gradations, was combined prior to delivery in the proportions of 65 percent 3/4-in. aggregate and 35 percent 3/8-in. aggregate. No difficulty was encountered during the casting of these lightweight sections which were made and handled in the same manner as the regular concrete sections. Cylinders cast on the job had an average compressive strength for the above mix of 6000 p.s.i. at 28 days. The corresponding strength requirements for all concrete cylinders was 4500 p.s.i.

The 32-ft. curb-and-gutter section weighs 17,500 lb. as compared to 13,750 lb. for each intermediate section. Thus, a completed 30-ft. bridge weighs a substantial 117,300 lb. The reinforcing bars and the wire mesh used in this bridge accounts for 7,960 lb. and 1000 lb., respectively,

Fig. 1 - General layout of pre-cast operations.

Fig. 2 - Form for 32-ft. curb and gutter section ready for pouring of lightweight concrete.
Fig. 3 - A 32-ft. intermediate section ready for concrete. Vertical pipes through cross-bars provide holes through section to facilitate job fabrication.

Fig. 4 - Placing lightweight concrete in a 32-ft. intermediate section. Because of the low slump required, and lightness of this aggregate, it was necessary to scrape the concrete from the discharge chute.
Fig. 5 - Low slump lightweight concrete in form prior to vibration.

Fig. 6 - Placing lightweight concrete through vibration.
Fig. 7 - Immediately following casting, a tarpaulin was placed over the section to permit steam curing.

Fig. 8 - Arrangement for lifting precast sections from forms. Lift-fork is at center of section.
Fig. 9 - Finished curb and gutter section. Bolts that are on back side are for securing steel guard rail. Holes visible will accommodate lifting apparatus.

Fig. 10 - Sections were transported to stock pile via 10-ton lift fork. Holes seen along lower edge are for transverse tie bolts.
of the total weight. Most bridges are expected to be of the single span type, however, at some locations a center pier has been or will be used in order to utilize this type of construction.

Erection

Responsibility for the erection of these sections went to the Maintenance Division, inasmuch as the sections were intended as replacements for old bridges that had collapsed, were in a bad state of repair, or were too narrow or too weak to accommodate current traffic.

On June 23, 1955, the first precast bridge was erected over Gunpowder Creek in Boone County. The existing steel bridge of 30-ft. span was on Ky. 18, approximately 3 miles from the junction of U.S. 25 and U.S. 42 on the Florence-Burlington-Bellevue Road, and was identified as MP8-130-1.

The prefabricated replacement bridge consisted of eight individual members, four regular concrete sections and four lightweight concrete sections previously mentioned. Four trucks, hauling two sections each, were required to transport the bridge from Owensboro to Boone County. Two cranes of 6- and 10-ton capacity were used to lift the individual sections from the trucks and set them in place. Strips of preformed joint material were placed under the ends of each section as they were lowered into position. The sections were anchored to the abutment at one end, leaving the other end free to expand or contract. Transverse tie bolts were used to fasten the adjacent sections together.
The bridge was set on a 30-degree skew, making it necessary to drill new holes for the transverse tie bolts because the sections used were cast without skew. This situation however, is not expected to re-occur with the regular concrete sections, since half the bridges were cast on right angles, and the remaining bridges were cast equally at 30- and 45-degree skew.

Features involved in the erection of the bridge in Boone County are shown in Figs. 11 to 19.

Fourteen of these precast bridges have been erected to date, in single and continuous spans, and the remaining ones are to be used as time and conditions permit. The bridges completed at this time are listed as follows:

- **Boone Co.**
  - 1 - 30-ft. span

- **Crittenden Co.**
  - 2 - 30-ft. spans

- **Graves Co.**
  - 1 - 30-ft. span

- **Hopkins Co.**
  - 1 - 3 continuous 30-ft. spans

- **Letcher Co.**
  - 4 - 30-ft. spans

- **Webster Co.**
  - 1 - 3 continuous 20-ft. spans

**Summary**

Comparative data on the relative cost of prefabricated bridges as opposed to the conventional type is not available at this time. However, in view of the mass production method used in the casting of these sections and the short time required for erection, it is believed that the prefabricated short span bridge is more economical than the conventional type. In several instances, one or both of the existing bridge abutments has been
Fig. 11 - General view of first bridge replaced by precast sections. Location is at Gunpowder Creek in Boone Co. on Ky. 18, approximately 3-mi. from junction of U.S. 25 and U.S. 42.

Fig. 12 - Four trucks hauling two sections each, were used to transport bridge from Owensboro to Boone County.
Fig. 13 - One of the two cranes used during erection is in position for placing first section. Second crane is at far right. The abutment at left was built entirely of precast concrete cribbing.

Fig. 14 - First curb and gutter section being lowered into place. This section was made of lightweight concrete.
Fig. 15 - View from beneath first three sections of bridge. Spalling in lower foreground resulted from drilling holes for tie bolt. Preformed hole at left could not be used since the right angle sections were set on a 30-degree skew.

Fig. 16 - View of bridge with 7 of the 8 sections in place. Crack and joint sealer material was poured between sections before bridge was opened to traffic.
Fig. 17 - Placing of last section was facilitated by having truck back onto sections placed minutes before. In all cases the sections were lifted just enough to remove the load and permit moving of the truck to a new location. The sections were then lowered to the ground, and the cranes repositioned for final placing.
Fig. 18 - Finished bridge immediately following erection, and prior to sealing of joints and paving of approaches. Beginning with the curb and gutter section at left (looking west), lightweight concrete sections alternate with regular concrete sections across the bridge. The sections were placed in about 4-hr.

Fig. 19 - General view of completed bridge open to traffic. The bridge carries an H-15 rating.
used to support the prefabricated bridge - thus additional reduction in the overall economy of this type construction.

Maintenance cost for this bridge is expected to be a minimum since the only item involved is that of resealing the joints between the sections whenever necessary.

Comparisons between performance of the lightweight concrete and the regular concrete sections will be based upon inspection reports which are to be made at various times.

**PREFABRICATION RIPRAP**

The prefabrication of concrete blocks for use as riprap, in the absence of a suitable and economical source of natural stone, was deemed advisable by the Department at one location this year. Location of the project, which was the fill on the Shawnee town Bridge approach in Union County, and the quantity of material required for the protection of this fill were determining factors in selecting the precast concrete blocks.

The large number of blocks required for this project, and the necessity for completion before spring rains and possible flood conditions early in 1956, required that the blocks be cast simultaneously at two locations. Blocks were cast by the Katterjohn Concrete Products Company at Owensboro, and on the concrete pavement at the Shawnee town project by Ellis and Kelly, prime contractors.

**Fabrication and Laboratory Tests**

The size of the blocks was 6 x 12 x 18 in. and the mix used was Class B concrete without air entrainment. Approximately 0.75 cu. ft.
of concrete was required per block, placing the weight of each block at about 110 lb. A total of 320,000 blocks were required. Details of the operation are seen in Figs. 21 to 25.

Blocks cast at Owensboro contained No. 6 Ohio River Gravel at the coarse aggregate, while No. 6 crushed limestone was used in those cast at the job site. Availability of casting and storage space was no problem for blocks cast on the job, but proved to be a serious handicap at the Owensboro site. Facilities at Owensboro were designed to produce some 3500 blocks per day, assuming favorable weather conditions. Due to a limited casting space at this location, it was necessary to move the blocks to storage as soon as conditions permitted. As the year advanced in the fall cooler weather increased the initial curing time required before handling and thus decreased the production schedule. To offset the effects of weather and to allow early handling of these blocks, permission to add calcium chloride to the mix was requested.

As a result of these conditions, the Research Division was asked to investigate the suitability of using calcium chloride in the mix and to make specific recommendations as to its use. Accordingly, two series of laboratory tests were made using materials obtained directly from the job.

The first investigation was concerned with the possibility of a chemical reaction between this concrete and calcium chloride. The autoclave test was used for this determination since it was believed that any chemical reaction between cement and calcium chloride would be most quickly
Fig. 20 - General view of precast concrete block layout at Owensboro. Completed blocks are on pallets at center and are ready for transportation to the job. Note stockpile of precast bridge sections at extreme right.

Fig. 21 - Placing of low-slump concrete in block molds at Owensboro. Batching equipment is at left. Concrete was hauled to forms by buggies and vibrated in place. Coarse aggregate was Ohio River Gravel.
Fig. 22 - Finished blocks before forms were removed. Wet burlap used in curing is in the background. At the time of this inspection, a portion of the forms at Owensboro had wood dividers. However, the wood dividers were replaced with metal dividers because less damage to the blocks occurred during removal of forms.

Fig. 23 - Condition of blocks as wooden forms were removed.
Fig. 24 - General view of blocks cast at the job site. Blocks were cast on roofing paper over one lane of the pavement for the bridge approach. In this case metal dividers were used and removed before the concrete attained its final set. Approximately 4200 blocks were produced daily.

Fig. 25 - View of precast blocks during placement. Shawneetown bridge is in the background.
ascertained by this method. This test, in general, provides quantitative information on the soundness of neat cement. Unsoundness in cement means excessive expansion of concrete due to hydration of the uncombined lime and magnesia present in cement.

Neat cement bars containing one and two percent calcium chloride solution were tested by ASTM methods and compared to normal cement bars without the admixture. The average increase in length for specimens containing the admixture was 0.05 percent compared to 0.045 percent for the regular cement specimens. The ASTM specification permits a maximum expansion of 0.50 percent before classifying a cement as unsound. The possibility of a chemical reaction then, in this instance, was dismissed on the basis of these results.

The second investigation dealt with the effect of calcium chloride on the resistance of this concrete to alternate cycles of freezing and thawing. Specimens for this test were made with one and two percent calcium chloride added to the mix for comparison with regular Class B concrete without the additive. The average reduction in dynamic modulus of elasticity for the specimens representing the regular mix was 20 percent at 263 cycles of freezing and thawing. In comparison, reductions of 40 percent at 254 cycles, and 40 percent at 200 cycles were sustained by specimens of the mixes containing one and two percent additions of calcium chloride, respectively.

Although performance of the specimens containing the calcium chloride was somewhat inferior to that of the regular concrete, the difference in
indicated durability could be regarded as of little consequence since the overall results with respect to this Class B Concrete (5 bag mix) were comparable to those usually obtained with specimens of concrete containing Ohio River Gravel from this vicinity and having no air entrainment. Thus, it was concluded that calcium chloride in the amounts used was not appreciably detrimental to the resistance of these specimens to alternate cycles of freezing and thawing; and that the early increase in strength derived through its use and consequent resistance to undue damage of blocks during early handling, more than offset the slight sacrifice, if any, in durability of the concrete in its usual sense. Probably ultimate resistance of the blocks to deterioration on the fill would be best under conditions where the initial damage through handling was least.

Placement

The blocks were placed individually on the fill by means of metal tongs. Two men were required to handle each block. Blocks cast at Owensboro were trucked to the job and unloaded along the base of the fill. Blocks cast on the pavement at the job site were simply slid down the fill by means of a wooden chute and set in place. Height on the fill to which the blocks were required for adequate protection was determined on the basis of previous high water marks.

Summary

At the outset of the casting operation at Owensboro, a rather high percentage of the blocks produced were damaged through early handling and storage. Initially, the difficulties leading to this situation were overcome by increasing the time required before handling and in decreasing
the production or casting schedule. Weather, and the use of wood dividers in the forms were conditions largely responsible for the initial delays. These conditions were overcome, however, by replacing the wood dividers with metal strips and through the use of calcium chloride in the concrete mix.

Metal dividers were used from the beginning in the forms as the job site. Moreover, blocks cast on the pavement at the job did not require early handling since a vast amount of casting space was available. Thus, weather conditions accounted for the only handicap in the precast operation at the job site.