HIGHWAY RESEARCH BOARD

Bulletin No. 39

Precasting Highway Bridges and Structures

1951

HIGHWAY RESEARCH BOARD

1951

OFFICERS

PUBLICATION OFFICES

2101 Constitution Avenue Washington 25, D. C.

HIGHWAY RESEARCH BOARD

Bulletin No. 39

PRECASTING HIGHWAY BRIDGES AND STRUCTURES

PRESENTED AT THE THIRTIETH ANNUAL MEETING
1951

HIGHWAY RESEARCH BOARD
DIVISION OF ENGINEERING AND INDUSTRIAL RESEARCH
NATIONAL RESEARCH COUNCIL

Washington 25, D. C. August 1951

DEPARTMENT OF HIGHWAY DESIGN

C. N. Conner, *Chairman*
Principal Highway Engineer,
Bureau of Public Roads

COMMITTEE ON BRIDGES

G. S. Paxson, *Chairman*
Bridge Engineer,
Oregon State Highway Commission

Raymond Archibald, Bureau of Public Roads

E. L. Erickson, Bureau of Public Roads

James P. Exum, Howard, Needles, Tammen and Bergendoff, New York City

George M. Foster, Bridge Engineer, Michigan State Highway Department

T. B. Gunter, Jr., Bridge Engineer, North Carolina State Highway and Public Works Commission

T. R. Higgins, Director of Engineering, American Institute of Steel Construction, New York City

R. Robinson Rowe, Supervising Bridge Engineer, California Division of Highways

Professor C. P. Siess, Department of Civil Engineering, University of Illinois

RECENT DEVELOPMENTS IN PRECASTING OF HIGHWAY BRIDGES AND STRUCTURES

R. B. McMinn, Senior Highway Bridge Engineer,
Bureau of Public Roads, Portland, Oregon

SYNOPSIS

The importance of precasting, as an advance in bridge construction, is set forth in this paper, together with its advantages and possible use in the future. A plea is also made for its ready acceptance by engineers and those in the construction industry.

This report points out that prior to 1948 the precasting of highway bridges consisted principally of precasting units, complete in themselves, which when placed or assembled constituted a complete span. The writer describes later developments with respect to bridges as consisting of two different systems of precasting.

The first system consists of combining precast stringers with cast-in-place floor slabs, thus resulting in Tee beam spans. This system is illustrated in the Turnagain Arm Project, Alaska, discussed at length in the paper. This system has also been employed in bridges constructed at Lowell, Mass., with spans up to 55 ft.; and in 800 linear ft. of trestle approach to the South Yamhill River Bridge in Oregon.

The second system is described as consisting of the field assembly of precast beams or stringers and floor slab panels separately, which, when assembled, are welded together with concrete to form an integral structure. This system is illustrated in the Baker River Bridge which was constructed in the State of Washington by the Bureau of Public Roads.

Interesting applications of precasting of highway structures are presented in this study, such as the precasting of the roofs of two snow-sheds now being constructed by the Department of Highways, State of Washington. The use of precast members in culverts and tunnel lining is also discussed in this paper.

Recommendations regarding precasting and a discussion of the important advantages of precasting highway bridges and structures are included in this paper.

In this report the common acceptance and use of precast members for building construction is contrasted with the somewhat slight interest and only occasional usage of the precasting method for bridges and highway structures. The writer points out that experience in precasting bridges has proven that this method is satisfactory, and that it results in saving of time, labor, and money. Only by actual use of precasting can enthusiastic interest be engendered. Active participation in such projects by more state highway departments, and greater interest on the part of consulting engineers would lend impetus to this method of bridge construction.

The writer concludes that if precasting is to take its proper place in the highway industry it will be necessary for bridge engineers to initiate projects, develop the details, and actually construct some precast structures. The situation appears a challenge to the ingenuity and progressive instincts of those in the engineering profession. Contractors and concrete products' manufacturers should also cooperate, for their own benefit as well as for the good of the highway industry as a whole.

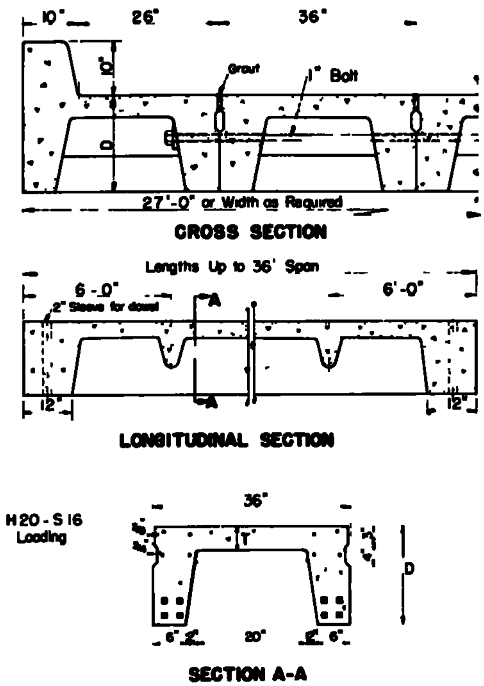
Centennial celebrations commemorating the birth of reinforced concrete were observed in Europe in 1949. During that century great strides were made in reinforced concrete design; however, notwithstanding the great amount of concrete placed, only a microscopic part has been precast. In recent years there have been rapid advances in the use of precast members for building construction, and it seems that there is some new development in the building field each week; however, comparatively little interest has been exhibited in the precasting of bridges and highway structures.

In 1949 the Highway Research Board published Bibliography No. 7 on "Prestressing and Precasting Reinforced Concrete for Use in Highway Bridges and Structures," (1)[1] which called

[1]Figures in parentheses refer to list of references at the end of the paper.

attention to Precast Bridges Highway Practice followed up to the time that material for the bibliography was assembled.

Examination of the bibliography reveals that the system of precasting of bridges covered therein consisted principally of precasting units, complete in themselves, which when placed or assembled constituted a complete span.



Top Steel	Bottom Steel	D	T	Clear Span	Weight#/ft
2 ⅝"φ	8-1"φ	16"	4"	18	356
"	8 1"φ	18"	"	24	394
"	"	20"	"	26	428
"	8-1⅛"φ	20"	"	28	433
"	8-1"φ	22"	6"	30	491
"	"	24"	"	32	522
"	"	26"	"	34	547
"	8-1⅛"φ	26"	"	36	553
For Curb Section Add 90#/ft					

Figure 1. Type of Precast Deck Used in Pennsylvania - Main Reinforcement Only is Shown

The following are quite representative of this type of precast:

1. The State of Pennsylvania practice as illustrated in Figure 1 and as described in *Concrete* (9).

2. The type now in use in the State of Florida as illustrated in Figure 2.

3. The plain slab span in which an entire span is precast in half or full width.

4. The T-beam type as discussed in this paper in the Brunswick-St. Simons Causeway and as utilized in the Mattiponi River Bridge at West Point, Va., which consisted of a complete T-beam span 40 feet long, having a 26-ft. roadway and five beams. The complete unit weighed 110 tons. The Mattiponi River Bridge was described in the *Engineering News Record* (10).

Later developments are discussed in this paper. With respect to bridges, they consist of two different systems of precasting.

The first system consists of combining precast beams or stringers with cast-in-place floor slabs, thus resulting in Tee beam spans. This system is illustrated in the Turnagain Arm Project and Kenai River Bridge in Alaska; Bridges at Lowell, Mass.; and in trestle construction now under way in the State of Oregon.

The second system consists of precasting beams or stringers and floor slab panels separately, which when assembled are welded together with concrete to form an integral structure. This system is illustrated in the Baker River Bridge, State of Washington.

An interesting application of precasting of highway structures is the precasting of the roof of a snow-shed on Primary State Highway No. 2, State of Washington, in which precast T beams are assembled to form the roof. Precasting of box culverts has also been initiated during the past year.

The developments referred to are discussed in detail as follows:

THE TURNAGAIN ARM PROJECT
Seward-Anchorage Highway
Alaska

There were a number of trestles on this project, aggregating 180 spans, each 25 ft. in length, or a total of 4,500 linear ft., which were placed under contract in the summer of 1948. The piles and caps were creosote-treated. The stringers were precast, and the concrete floor was poured in place. The roadway width was 24 ft.

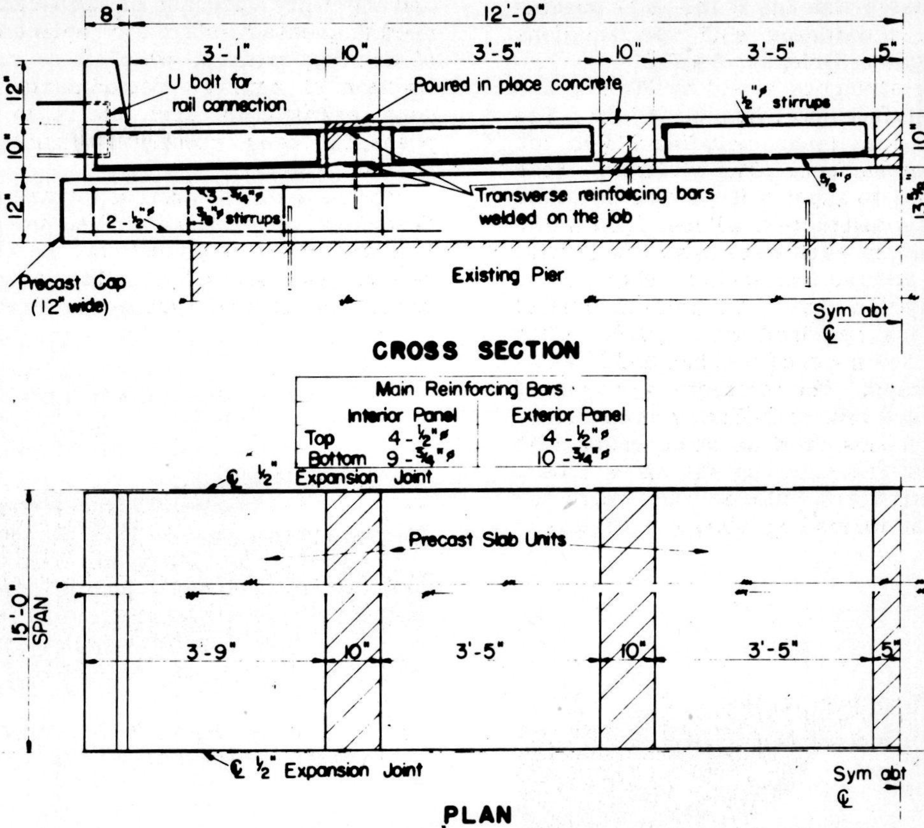


Figure 2. Type of Precast Slab Used in Florida

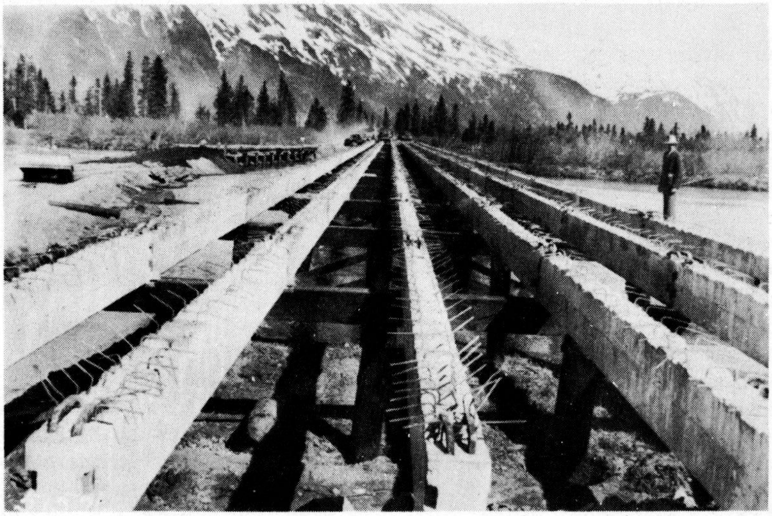


Figure 3. Placer River Bridge, Alaska - Precast Stringers in Position Ready for Forms

The design was for H 15 - S 12 loading and in accordance with specifications for Highway Bridges, AASHO.

The stringers are 8 by 20 in., and each stringer weighed 5,000 lb. The slab is 6 in. thick, including 1/2-in. for wearing surface. The stringers were designed to support the entire floorload during construction without falsework.

The stringers were cast at a central plant, and the maximum number cast in one day was forty. The total number of stringers required was 1,080. They were steam-cured and handled in about three days. The stringers were placed with truck cranes operating on construction trestles, and in some cases with shovels traveling on the stream bed. The stringers, placed and ready for the slab forms are shown in Figure 3.

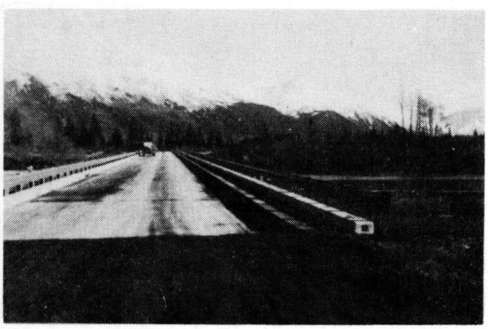


Figure 4. Placer River Bridge, Alaska - View of Completed Trestle

The floor slab was placed by conventional methods. A completed trestle is shown in Figures 4 and 5.

The use of the precast stringers proved to be very satisfactory, and there were no construction difficulties. None of the stringers was damaged during handling. The cost of the completed trestles was practically the same as that for treated timber stringers with concrete deck, as determined by bids received for the project.

The trestles were designed by the Bureau of Public Roads, and the project was constructed by contract under the jurisdiction of that Agency.

BRIDGES AT LOWELL, MASS.

Through the exercise of initiative and ingenuity, precast bridges can be used to great advantage for replacement of existing bridges, which is a major function of highway departments. A good example of such use is in five precast bridges recently constructed at Lowell, Mass.

The design and construction are well described in the *Journal of the American Concrete Institute* (2) and in the *Engineering News Record* (3). The precast decks are of two types: 1. Precast

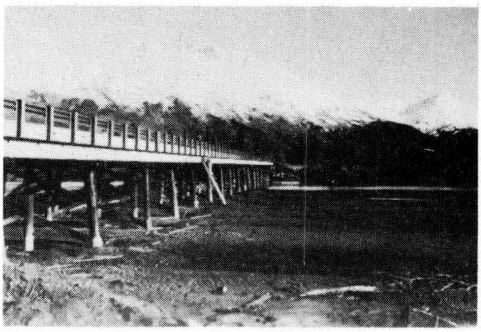


Figure 5. Placer River Bridge, Alaska - Perspective of Completed Trestle

Figure 6. View of Kenai River Bridge, Kenai Peninsula, Alaska - Stringers for Deck Precast

sections (inverted U shape), which when assembled form the completed deck, used for spans of 20 ft. or less. 2. Having precast stringers with cast-in-place floor slabs, used for spans up to 55 ft. in length. The use of precast spans for these bridges proved to be very successful. The savings were

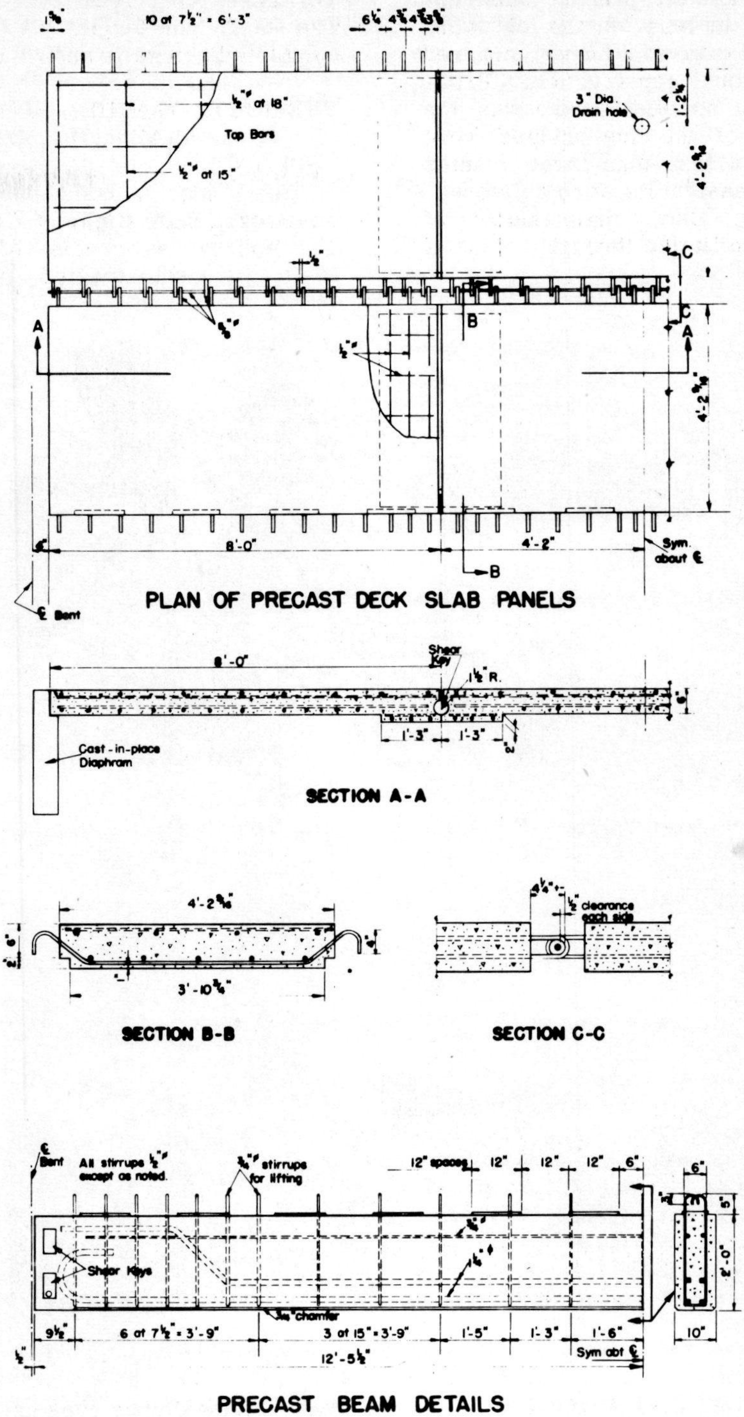


Figure 7. Baker River Bridge, State of Washington - Details of Precast Deck

appreciable, and the precast construction resulted in less "on the job" work and confusion than would have occurred with conventional construction. Probably the most notable feature was the fact that all of the five bridges were constructed in less than three months after the precast units were delivered. In this case, also, maintenance of traffic was facilitated through the use of precast units.

Turnagain Arm trestles. The trestle was 400 ft. in length. A view of the completed bridge is shown in Figure 6.

THE SOUTH YAMHILL RIVER BRIDGE
Near McMinnville, Oregon

This bridge is being constructed by the Oregon State Highway Commission. The approaches consist of thirty-two 25-ft. creosote-treated pile trestle

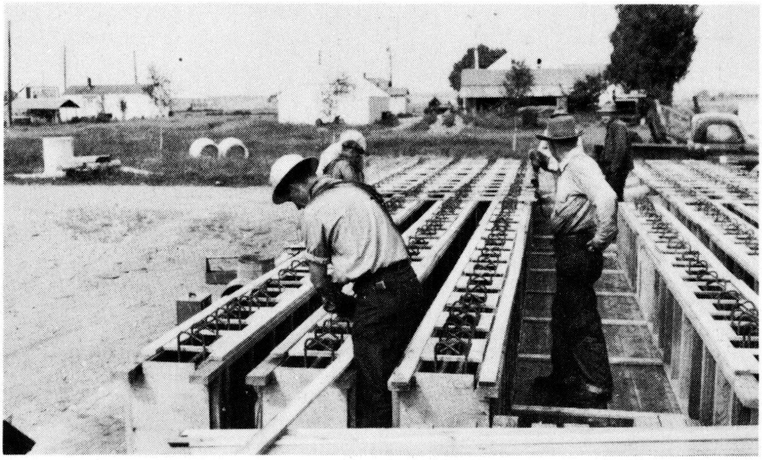


Figure 8. Baker River Bridge - Forms for Stringers About Ready for Placing of Concrete

Figure 9. Placing Concrete in Stringers

THE KENAI RIVER BRIDGE
Kenai Peninsula, Alaska

This bridge was completed in 1950. It is of trestle type, identical with the

spans having timber caps and a concrete deck. The specifications stipulated that the deck be either conventional cast-in-place T-beam construction or with precast beams and cast-in-place floor slabs. Bids were not taken on the alternate schemes, the type being left to the option of the contractor. The contractor elected to precast the beams, principally in order to eliminate falsework and save on the cost of formwork. There is no certain method of estimating the saving to the State through the use of the precast stringers, but it is believed to be substantial.

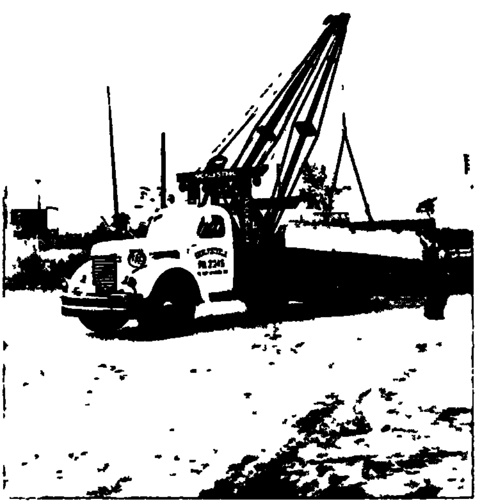


Figure 10. Baker River Bridge - Handling Precast Stringers with Towing Truck

The bridge has a roadway width of 26 ft., and two sidewalks are provided. The live loading is H 15 - S 12. The beams are 9 in. by 1-ft. -11-in., spaced 5-ft. -4-in. center-to-center. Each beam weighs 5,600 lb. The slab is 6 in. thick. The precast beams were designed to carry the entire dead load, as rectangular beams, and with the slab placed, they constitute conventional T-beams. Shear keys are provided between the stem and the slab. Holes are left in the beams for insertion of bolts to support the slab forms.

This is the first bridge in the State of Oregon involving the use of precast beams.

THE BAKER RIVER BRIDGE
Baker River Road - State of Washington

The Baker River Bridge was constructed in 1949 by contract, under the jurisdiction of the Bureau of Public Roads, and the design was made by that Agency. (4)

The Bridge consists of eight 25-ft. reinforced concrete T-beam spans supported by treated timber piles. The roadway width is 26 ft. The stringers and floor panels were precast separately and welded together with concrete.

Design - The bridge was designed for H 20 - S 16 live loading and in accordance with Specifications for Highway Bridges, AASHO. The slab units were designed as simple spans for both dead and live loads. This assumption is on the side of safety, as some continuity of the slab will be developed by the welded joint. In order to distribute wheel loads at the ends of slab units the edges are thickened, and to make the slabs act in unison under live load a transverse shear key is provided.

The beams are designed as simple rectangular beams for dead load, and as T-beams for live load. Shear keys are provided, as is customary when slabs are placed separately from the stems in T-beam construction. The details are shown in Figure 7. The stringers are 10-by 24-in., 25 ft. long. The typical slab panel is 8-ft. 4-in. by 4-ft. 2-in., 6-in. thick.

Construction - The precast stringers and slab panels were made at Burlington, Washington, which is 50 miles from the site of the bridge and four miles from a transit mix concrete plant. The site was located to take advantage of labor supply and of the concrete plant. These factors are important with respect to cost, and they outweigh hauling costs. The forms for the beams and reinforcing steel are shown in Figure 8, and the pouring in Figure 9. The forms were lined with plywood.

Excellent aggregates were available, and 4,000-lb. strength was secured in 28 days with a cement content of 6-1/2 sacks per cubic yard. The concrete was vibrated. The curing was done by ordinary methods. If rapid production were required, steam curing would be employed. The beams weighed 6,300 lb. each, and the maximum weight of a slab panel was 3,100 lb. The precast members were handled readily with a towing truck, as shown in Figure 10. The precast members, stockpiled ready to haul, are shown in Figures 11 and 12. The concrete beams were placed with a pile-driver which was equipped with a swinging boom. The beams were hauled to the pile-driver on the tram, shown in Figure 13, operated on timber stringers. The forming and pouring of diaphragms was the next operation. Placing of the slab panels is shown in Figure 14. An eight-ton truck, gross load, is allowed on the deck for placing of the precast units. The interlocking of reinforcing steel in the longitudinal joint is shown in Figure 15. The bars from opposite slabs are staggered. Hooks extending up from the beams secure the slab to the beams.

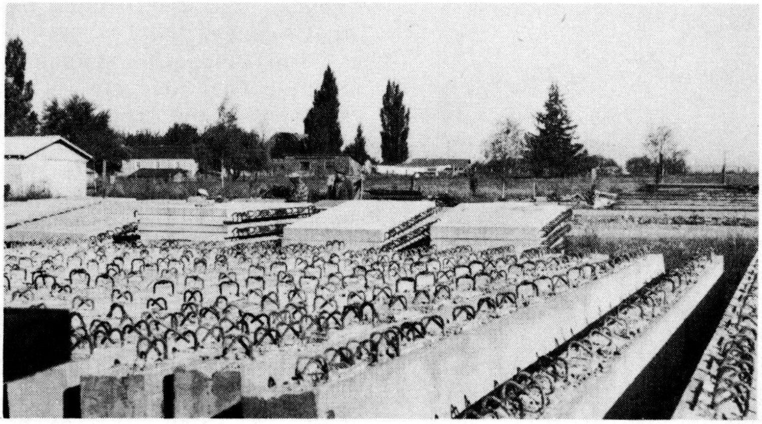


Figure 11. Baker River Bridge - Stringer and Slab Precasts Stockpiled

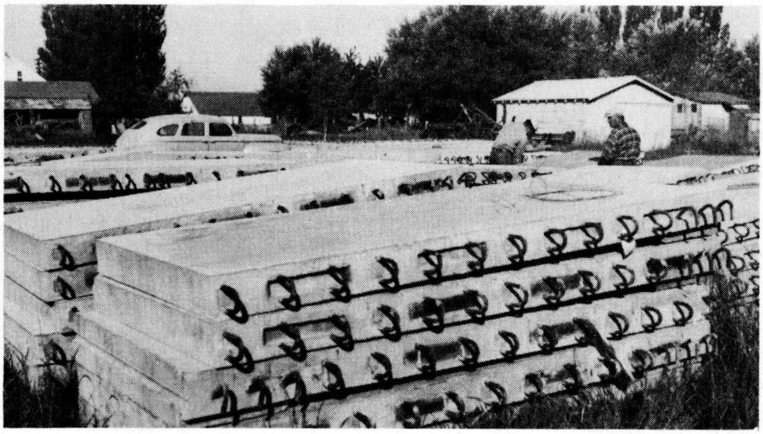


Figure 12. Baker River Bridge - A Close-Up View of Precast Slab Panels

The precasting was done very accurately, and most of the slabs had uniform bearing on the beams. Slight irregularities were not important, as openings were filled when the concrete was placed to weld the sections together. The greatest wind, or warp observed in a panel of the floor slab was 1/4-in. When completed, the floor had a very smooth riding surface, comparable to that on many cast-in-place bridges. A workable tolerance

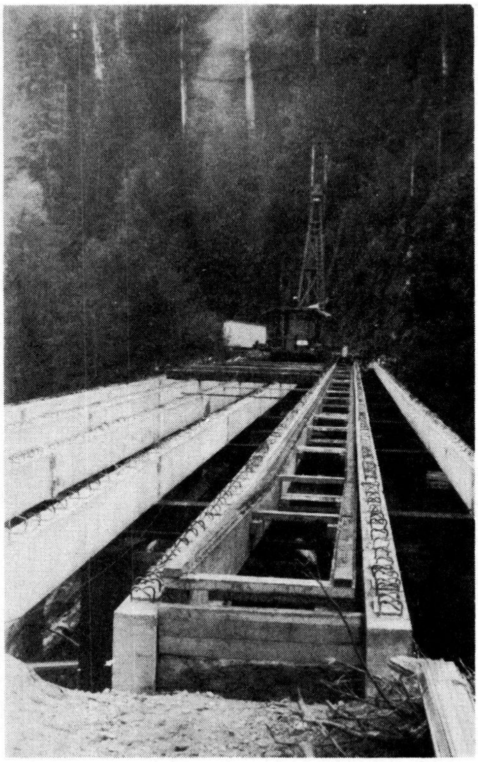


Figure 13. Baker River Bridge - Placing Precast Stringers with Pile Driver - Tram Used for Hauling Stringers

for precast members of the size used on this project appears to be about 1/8-in. A view of all of the precast members in position is shown in Figure 16.

When all of the precast stringers and slabs were placed and lined up, the longitudinal joints over the beams were filled with concrete. In order to avoid shrinkage cracks, this concrete was reworked just prior to initial set. The transverse joints were then filled with grout.

The actual time required for the erection of the deck after delivery of the precast units was as follows: Placing of beams, 4 days; forming and placing concrete in diaphragms, 4 days; placing of deck slabs, 4 days; forming curbs and pouring of concrete in curbs and joints, and pouring of grout, 4 days, or about one month for the operation. No attempt was made to rush the work.

The completed bridge is shown in Figures 17, 18, and 19.

Remarks - The precasting of the Baker River Bridge proved to be very satisfactory. The construction demonstrated that stringers and slabs could be cast with precision and that they could be assembled and welded together with concrete and grout.

The principal criticism of the Baker River Bridge design is that the cast-in-place diaphragms involve: 1. Formwork on the job. 2. Considerable time for form construction and the placing of concrete. 3. Complication of erection procedure.

The third item is the most serious. As designed, the first operation is placing of beams; the second, placing of diaphragms; and the third, placing of floor panels; which procedure required special equipment for placing the stringers and prevents completion of each span, successively, across the bridge. The details of the Baker River Bridge (Fig. 7) have been modified to avoid the use of cast-in-place diaphragms (as shown in Fig. 20), and also to eliminate cast-in-place curbs, thus doing away with all form work and cast-in-place concrete except that required to weld or tie the various units together. The result is that a light mobile crane can erect the first span complete, and then operate on the deck to erect additional spans progressively for the entire length of the bridge. This procedure speeds up erection to such an extent that one span of superstructure can be erected each day with a small crew on single shift.

The spans can be increased considerably above 25 ft. if desired. Where light weight aggregates are available, their use would be advantageous for the beams of the longer spans. It is to be noted that bars can be added over the

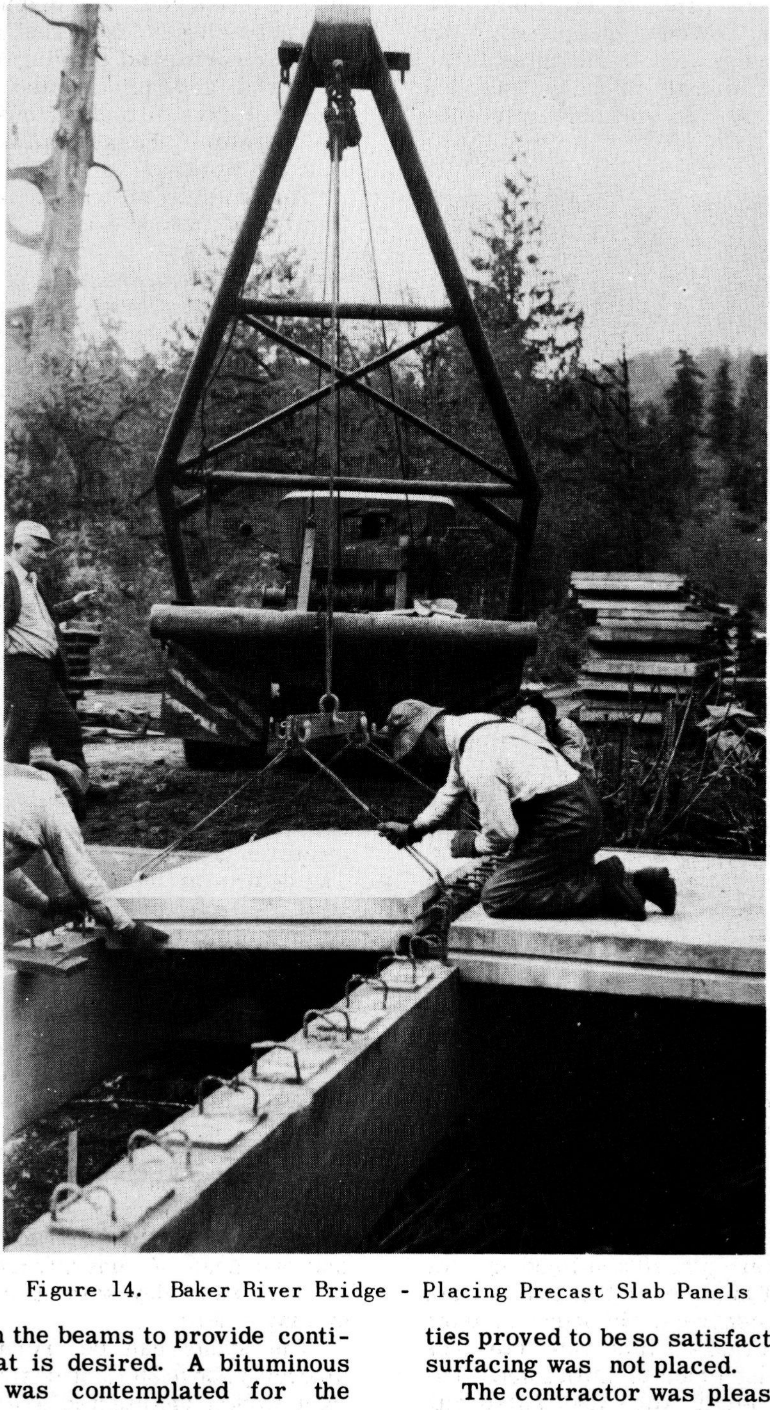


Figure 14. Baker River Bridge - Placing Precast Slab Panels

supports in the beams to provide continuity if that is desired. A bituminous surfacing was contemplated for the Baker River Bridge because of the possibility of there being some rough joints in the deck, but the riding qualities proved to be so satisfactory that the surfacing was not placed.

The contractor was pleased with the

precast construction, and he is definitely interested in future work of this character.

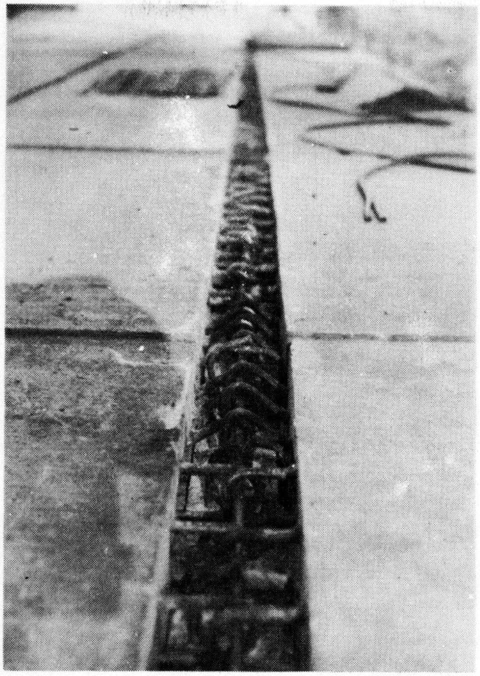


Figure 15. Baker River Bridge - Note interlocking steel in longitudinal joint.

Figure 16. Baker River Bridge - All Precast Stringers and Panels in Position Ready for Filling of Joints

THE BRUNSWICK ST. SIMONS CAUSEWAY

This causeway, connecting Brunswick and St. Simons Island in Georgia was dedicated on June 9, 1950. The causeway has five bridges, with a total length of one mile, connected by 3.2 miles of paved highway. The cost of the causeway was $2,500,000.00.

The construction has created wide interest among engineers and contractors because of the precast reinforced

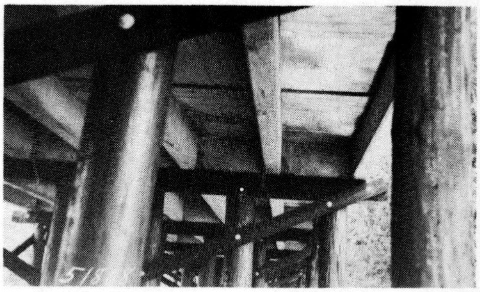


Figure 17. Baker River Bridge - View Looking Up Under the Deck

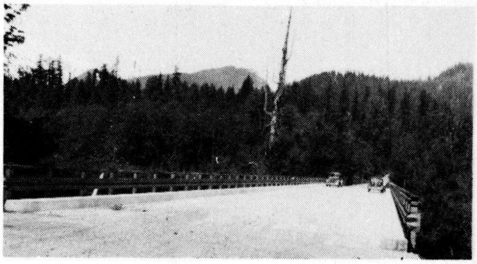


Figure 18. Baker River Bridge - View of Deck, Complete

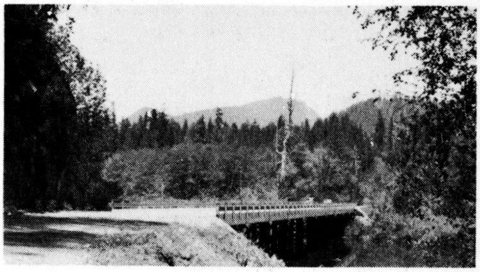


Figure 19. Baker River Bridge - Perspective of Completed Trestle

concrete deck involved in the long trestles. Briefly, the details are as follows:

The roadway is 24 ft. wide, and two sidewalks are provided. Each span is composed of two precast units having a 36-ft. span length, laid parallel with a longitudinal joint on the center line of the highway. Each unit is composed of the 36-ft. beams and deck slab, which is conventional T-beam construction. Each unit weighed 50 tons. The precast units were made at a central plant in Brunswick and barged to the bridge sites, where they were placed with floating derricks.

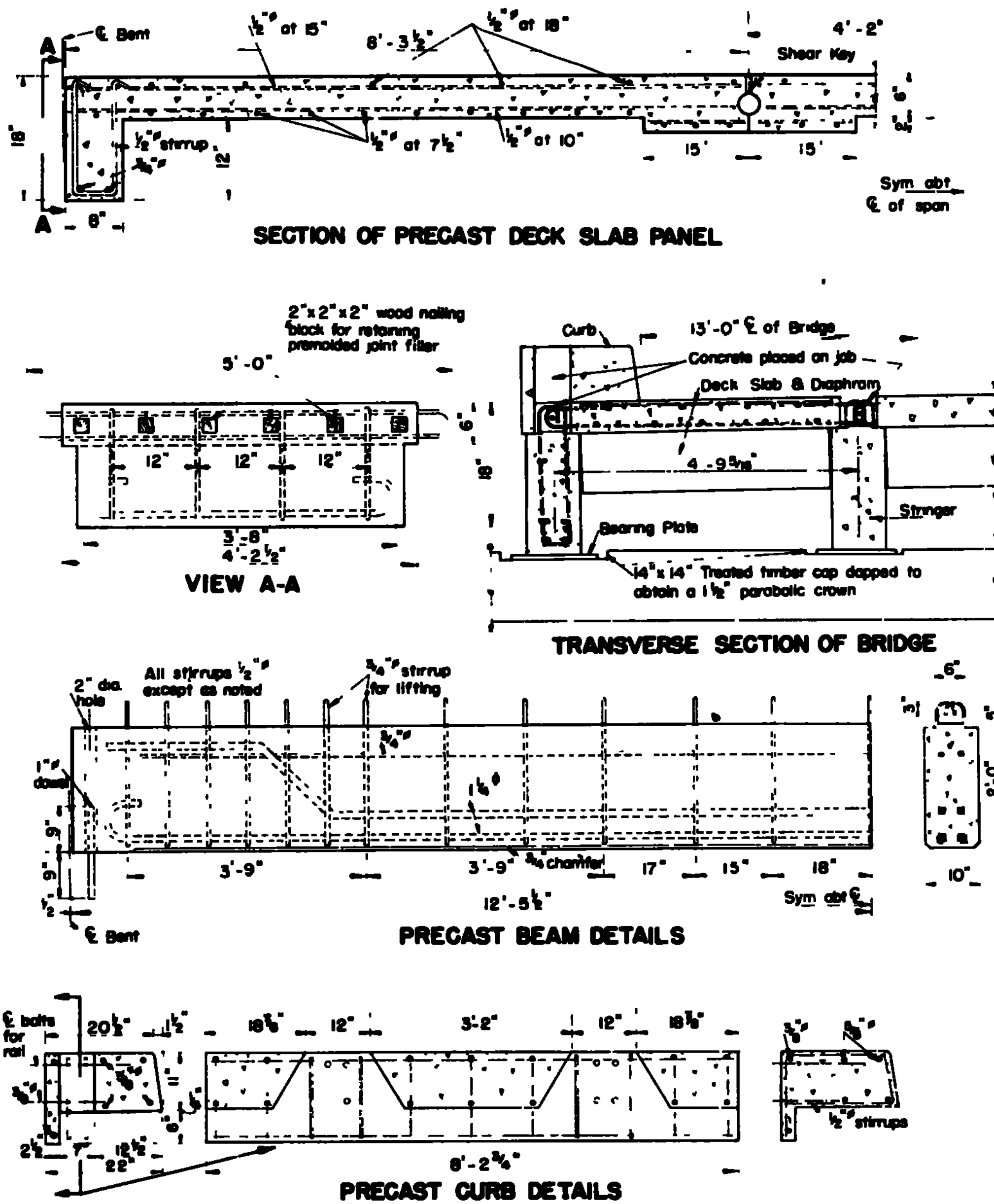


Figure 20. Proposed Precast Deck Details - Eliminating All "On the Job" Formwork - Details not shown are similar to those in Figure 7.

The construction required a little more than one year after actual work was commenced. The rapid progress is attributed directly to the use of precast units. Other benefits derived from precasting were the saving in cost of the work and better construction possible because of close control of mixing and placing of concrete at the central plant.

snow-sheds involving 3,120 cu. yd. of precast concrete. The Lake Keechelus shed is 500 ft. long, and the Airplane Curve shed is 1,300 ft. long. The roofs are precast and the other concrete is cast-in-place. The highway is four-

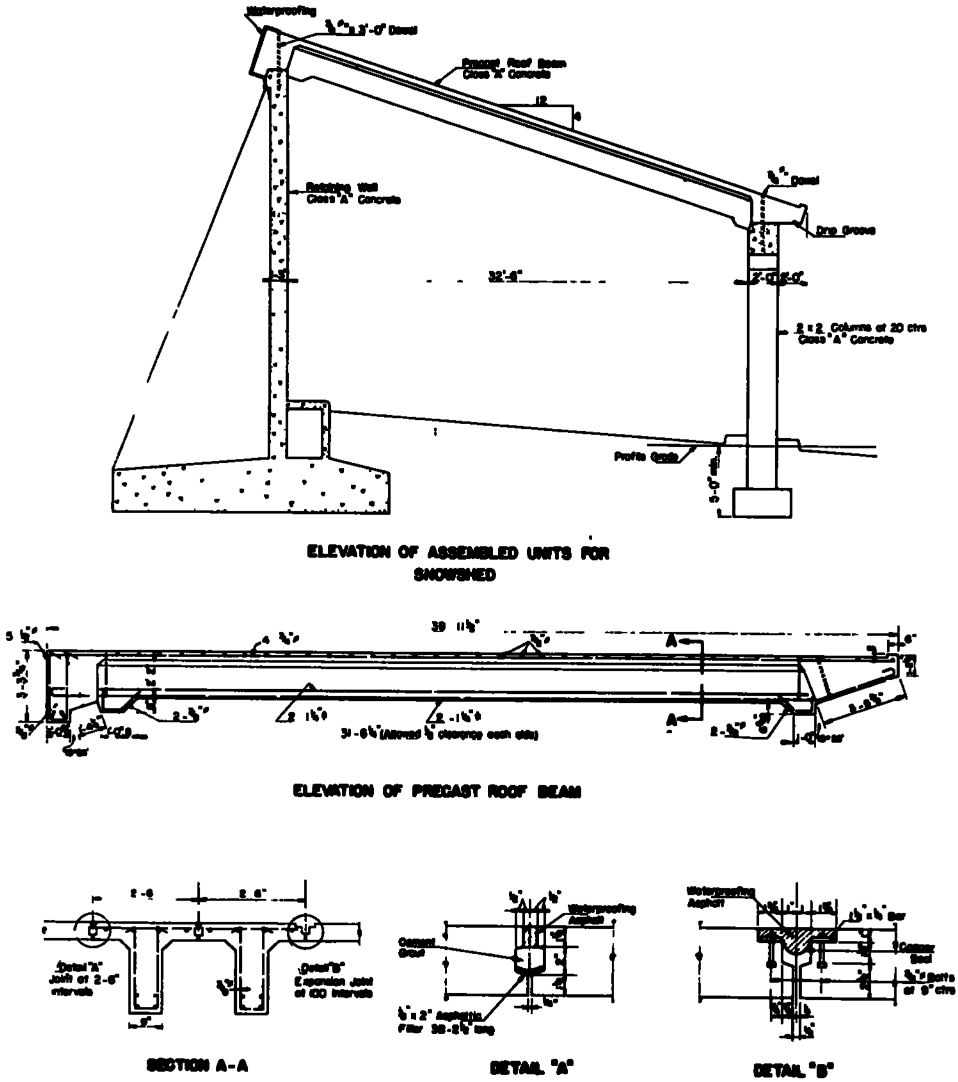


Figure 21. Details of Precast Roof of 1800 Linear Feet of Snow-Sheds in the State of Washington

SNOW-SHEDS
State of Washington - Snoqualmie Pass
Primary State Highway No. 2

The Department of Highways has designed and placed under contract two

lane; however, the snow-sheds cover two lanes only, which are sufficient for winter traffic.

The details of the snow-sheds are shown in Figure 21. Seven hundred and twenty of the T-precasts are required for the two snow-sheds. They are being fabricated at a Seattle Concrete Pipe plant which is 55 miles from the project. A number of the precast beams have been erected without any difficulty. The time required is only ten minutes for each member.

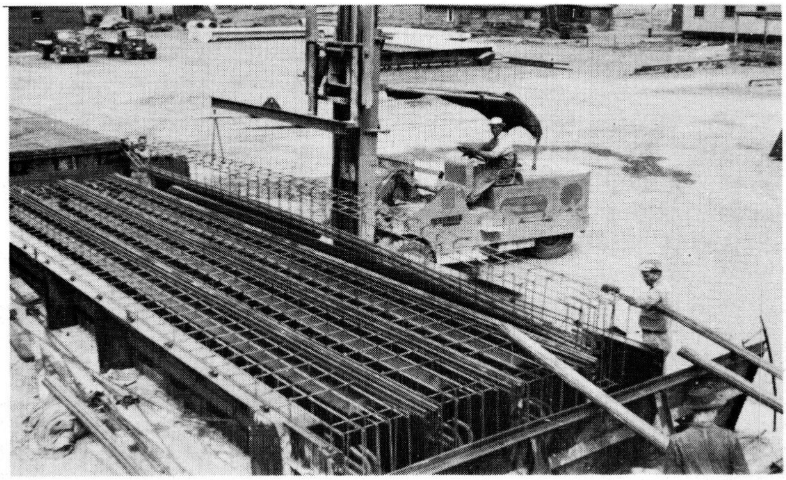


Figure 22. Snow-Sheds - State of Washington - Steel Forms for Battery of Five Precast Units - Reinforcing Being Placed - After forms are removed the battery of beams is covered with tarpaulin and the beams are steam-cured.

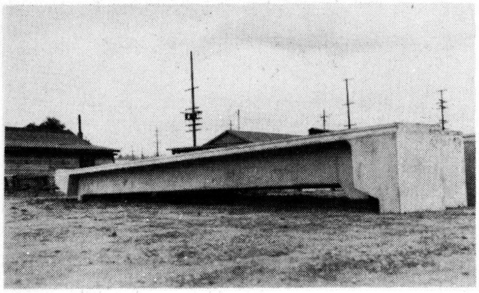


Figure 23. Snow-Sheds, State of Washington - Precast Beams Ready for Hauling

Steel forms are being used. The plates are 3/16-in. thick, and they are welded throughout. The forms are constructed with the sides and bottoms in separate pieces, and are assembled in batteries of five beams. With this assembly, five bottom sections, two exterior sections and four interior sections are required. After the sections are assembled they are fastened together with transverse bolts extended through the whole battery in the base of the bottom sections. Hardwood pieces are attached to the steel forms to shape the keyway in the flanges of the T-section. The reinforcing steel for each beam is assembled in a jig, tack-welded to the stirrups, and when fabricated hoisted into the forms. Figure 22 shows the form layout and reinforcing steel being placed.

The beams are steam-cured for a period of not less than 48 hours under a portable canvas cover, which covers a battery of five beams, thus providing a practical and economical means of steam-curing. With 20 forms available, the plant capacity is 10 per day. A completed beam is shown in Figure 23.

The beams weigh approximately 8 tons each. Two eye bolts are inserted in special anchors for handling the beams. Hauling will be done with logging trucks fitted with special carriages. The project will be completed in 1951.

The bids on concrete for this project are interesting, in that they show the divergence of opinion among contractors in respect to the relative costs of precast and cast-in-place concrete. The bids are listed, per cu. yd., with the low bid (considering entire project, including grading and surfacing,) at the top, and successively to the high bid at the bottom.

Bids Entire Project	Class A Concrete Precast (Roof Sections)	Class A Concrete (Retaining Walls and Columns)
$ 1,016,000	$ 49 80	$ 39.00
1,091,000	42.00	52 00
1,231,000	65 00	70 00
1,245,000	46 00	55 00
1,249,000	60 00	60 00
1,291,000	44 00	56 00
1,334,000	60 00	60 00
1,337,000	53 00	69 00
1,435,000	65 00	70 00
1,452,000	43 00	57 50
1,594,000	80 00	80 00

The low bidder was the only one who bid less on cast-in-place concrete than on precast concrete, the difference being $10.80 per cu. yd. At the other extreme, one bid $16.00 per cu. yd. less for precast than for cast-in-place concrete.

These snow-sheds presented an ideal situation for the use of precast members, and their use is very appropriate for the following reasons:

1. Elimination of falsework and formwork.
2. Obviates interference to traffic during construction.
3. Saving in cost.
4. Eliminates much on-the-job labor.

PRECAST, PRESTRESSED-REINFORCED CONCRETE BRIDGE PLANK

The most recent development in West Virginia in the replacement of the wooden floors of old steel bridges consisted of the use of precast, prestressed reinforced concrete bridge plank. This new type floor has been in place for about two years on one bridge and to date has proven satisfactory.

With the exception of the prestressed steel and the length of the plank, standard forms are used for various loadings and stringer spacing. The thickness is 6 in. and the width 12 in. The concrete used was 1:2:3, using 4 gallons of water per bag of cement. This type of floor weighs 75 lb. per sq. ft. It could be reduced to possibly 40 lb. by using light-weight aggregate. The cost of the concrete plank delivered to the bridge site was $1.75 per sq. ft. Unloading and placing costs totaled $281.10. The crack filling job cost $48.30. Over-all cost was $1.97 per sq. ft.

To prevent movement the planks are bolted in 20 ft. sections with 3 galvanized bolts, 5/8-in. diameter. The bolts run parallel with the bridge centerline. Provision is made for curb or wheel guard. Quarter-inch bituminous premoulded expansion joint material was placed on top of the existing steel floor beams and stringers to provide even bearing and reduce impact. The bridge (93 ft. long) refloored with this plank is located at Bruceton Mills, West Virginia. The work was done by State forces. No detour was possible near the bridge site and speed was essential. After the old wooden floor was removed, the placing of the 93 pieces of prestressed concrete planks required only three hours. It appears that this new type of floor might prove to be very useful in helping to solve the problem of replacing old wooden floors and in many instances be advantageous in new bridges.

BOX CULVERTS

It appears that little has been done in the direction of precasting reinforced concrete box culverts. The Texas Highway Department, in cooperation with County forces, constructed one as an experimental installation in 1950. The design and installation are described in *Roads and Streets*, (5). The size was 3-ft.-10-in. by-5-ft., and the length 30 ft. The top and bottom slabs were 6 by-6-ft., and the wall slabs were 4 by-6-ft. The slabs were 6-in. thick. The joints of the wall and top and bottom slabs were staggered. The slabs were set in mortar, and the grooved transverse joints were filled with mortar. The old bridge was removed, excavation made and the culvert assembled and backfilled, all within one day. The heaviest precast slab weighed 2,700 lb. The precast slabs were set with a truck crane, and the crew consisted of six men.

Precast culverts, cattle passes and pedestrian underpasses, under the trade name "Universal Flat-Base Pipe," are being manufactured by the Universal Concrete Pipe Company (6) at several of their plants. The type is illustrated in Figure 24.

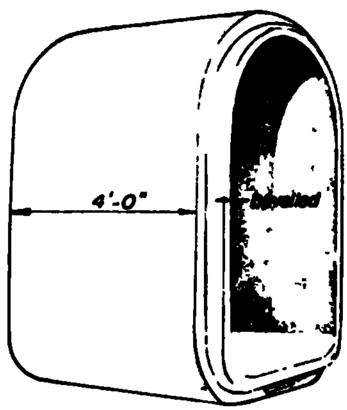


Figure 24. Precast Culverts and Cattle Passes Now in Production

A FEW RECOMMENDATIONS

1. Valuable technical information regarding design of precast members for building construction has been developed, and bridge engineers should take advantage of it to the extent that it is applicable to bridges. The same is true of construction details. For example references (11), (12), (13), and (14).

2. The precision required for casting should be specified, with definite tolerance set for variations in straightness, size and length.

3. For rectangular beams, it should be specified that they be kept in an upright position from the time they are cast until they are placed (unless handling stresses are satisfied for other positions).

4. It is recommended that eyebolts or methods for handling with slings be provided on the plans or in the specifications. Preferably, more longitudinal steel should be placed in the top of beams than required for temperature or spacer bars, in order to provide for handling stresses.

5. Precast members should be designed to:

   A. Simplify form work so that it can be readily removed and reused.

   B. To facilitate the placing and finishing of the concrete.

   C. To provide for ease and safety in handling.

6. The use of an air-entraining agent is recommended for all concrete in precast members for the following reasons:

   A. To improve the workability of the concrete.

   B. To increase the resistance of the concrete to freezing and thawing.

An air-entraining agent was used with beneficial results in the precast members for the following projects which have been described in this paper: The Turnagain Arm Project, the Kenai River Bridge, the Baker River Bridge, the snow-sheds, and one is specified for the South Yamhill River Bridge.

Vibration of the concrete in precast members is considered to be essential, and it is believed to be common practice.

7. Consideration should be given to the use of lightweight aggregate for beams, in order to:

   A. Reduce the dead load, thus effecting a saving in steel and concrete.

   B. By reducing the dead load, increase the length of spans considered feasible to precast.

   C. Reduce the load, so that the beams can be more easily handled, transported and placed.

CONCLUSIONS

The specific developments discussed in this paper are believed to constitute an important advance in the precasting of highway structures; however, the fact remains that at present there is little interest in the subject. A recent survey indicates that only a few state highway departments are taking any interest. Those who have done precasting are satisfied that there is a real advantage in it. It appears that only by actual use of precasting can enthusiastic interest be developed.

Considering the extensive use of precasting in the building industry and its successful use on a number of bridge projects, it is evident to the writer that precasting of bridges and highway structures is just in its infancy and that it presents an excellent opportunity for promotion. Active participation toward this end by all of the state highway departments and more evidence of interest on the part of consulting engineers would soon produce good results. There are innumerable ideas in use for precasting in building construction, and improvements are constantly being made, but the surface has just been scratched in the development of precasting members for bridges and highway structures.

Some of the possibilities which merit further discussion are:

1. The application to floors of steel spans. The West Virginia installation has been discussed. The writer is cognizant only of other applications on the Connecticut River Bridge (7), and on the decks of bascule bridges in Chicago.

The Connecticut River Bridge has a span length of 160 ft. The precast panels were 8 by-20-ft., being 13 in. thick at the end and 6 in. thick at the arched crown. Each precast panel weighed 8-1/2 tons. The work was done in 1922. The precast slabs were used in order to maintain traffic (7).

The details of the precast slabs used on the bascule spans in Chicago are included in the References (1) referred to above and also in *Concrete* (8).

The use of precast members on steel spans should be particularly advantageous for deck renewal and repair where there is heavy traffic or where speed of construction is important.

2. The application to tunnel lining. Precast tunnel lining has been used in England for a number of years, but as far as is known none has been used in this country. Steel plates and prefabricated timber are available, but nothing in concrete, which would prove to be desirable material in many locations.

3. More general application to box culverts and application to retaining walls, pier shafts and ventilation shafts.

4. The use of precast decks for replacement of old trestles should be very profitable. They can be installed with little delay to traffic, which is an important consideration in many locations. For such purpose the precast elements would be stockpiled.

More attention seems to be given at present to prestressing than to simple precasting. It is the writer's opinion that it would be far better to stress precasting instead of prestressing until such time as precasting comes into more general use.

One of the most important advantages of precasting bridge decks and of box culverts is the speed of construction. With a single shift and a very small crew of men, a trestle span can be completed in one day if the stringers and slabs are cast in advance. In case of emergency projects the time required could be greatly reduced. This factor, combined with the fact that precast members can be placed on one half of the roadway at a time, is particularly important where traffic must be maintained. A precast culvert can be placed in two to three days, whereas a cast-in-place culvert would require 30 days or more.

The elimination of a large percentage of "on the job" labor through the use of precasting should not be overlooked. The precast members can be made a considerable distance from the site of the bridge where there is a good labor supply and where a readymix plant or material supply is available. This is particularly important on isolated jobs, inasmuch as it is difficult to get men to go to such jobs, and if they do go out the cost of labor may be increased as much as 50 percent because of additional travel, subsistence and bonus costs.

Advantages from the use of precast members are summarized as follows:

1. Savings in forms, falsework and placing of concrete.

2. Elimination of a large amount of "on-the-job labor."
3. Speed of erection.
4. Facilitates maintenance of traffic.
5. A central plant operation permits closer control of concrete mixture, placing and curing, resulting in a better construction job.
6. In regions where the construction season is short, precasting can be done during the winter season under cover and thus expedite construction.

It does not follow that precast members are intended to replace all cast-in-place concrete, but, as with other means of construction available to engineers, they should be used when such use is indicated by sound engineering judgment.

It is to be noted that in the timber industry and in the steel industry there are firms which are very aggressive in promoting their products. They will supply innumerable items and also handle the engineering. To illustrate, trusses of timber or steel can be obtained on short notice for particular needs almost like packaged goods from a grocery store. Such firms have had a vital influence in promotion. There is no counterpart for such firms in the concrete industry, and this situation has without doubt retarded the use of precasts. Concrete products' manufacturers confine their activities largely to blocks, pipe, etc., and are not equipped in general to undertake precasting for other highway structures.

Though some general contractors are willing to undertake precasting, many of them would prefer to buy precast members from firms who are specially-equipped for their manufacture. It is difficult to obtain such quotations at present. Furthermore, if concrete products' firms take an active interest in precasting for highway construction their experience and cooperation should be of value in perfecting details and in reducing costs.

There has been so little precasting done in connection with highway structures that it is new to contractors, and it is only natural that they bid initial projects rather high. However, such high prices on a few installations should not unduly influence the use of precast structures, as fair prices cannot be expected until contractors have some experience in this kind of work. It is obvious that better prices can be obtained where a large number of precast units is required.

If precasting is to take its proper place in the highway industry it will be necessary for bridge engineers to initiate projects, develop the details and actually construct some precast structures. It is a challenge to their ingenuity and progressive instincts. Contractors and concrete products' manufacturers should also cooperate, for their own benefit as well as for the benefit of the highway industry as a whole.

REFERENCES

Pertaining to Precast Highway Structures

1. Bibliography No. 7, "Prestressing and Precasting Reinforced Concrete for Use in Highway Bridges and Structures," Highway Research Board, Compiled by the Bridge Department of the California Division of Highways, 1949.
2. Hanckel, Robert C., "Precast Units for Short-Span Bridges," *Journal, American Concrete Institute*, Vol. 21, No. 5, January 1950.
3. Kearney, Stephen, "Municipal Bridge Maintenance Cut by Precasting Techniques," *Engineering News-Record*, Vol. 144, No. 5, February 2, 1950.
4. "Precast Concrete Bridge Deck Slabs," *Western Construction News*, Vol. 25, No. 3, March 15, 1950.
5. "Precast Culvert Built in Texas by State and County Forces," *Roads and Streets*, Vol. 93, No. 8, August 1950.
6. Precast Cattle Passes, Pedestrian Underpasses, Culverts, (Advertisement, *Engineering News-Record*, p. 89, June 15, 1950.)
7. "Precast Concrete Slabs Replace

Wood-Block Bridge Floor," *Engineering News-Record*, Vol. 90, No. 19, May 10, 1923,

8. "Precast Light-Weight Concrete Slabs Bridge Floor Problem," *Concrete*, Vol. 38, No. 1, pp. 15-17,
9. "Precast Units Speed Bridge Building and Repair," *Concrete*, Vol. 58, No. 6, p. 28, June 1950.
10. "Deck Bridge Built of Precast T-Beam Units," *Engineering News-Record*, Vol. 135, No. 16, pp. 96-99, October 18, 1945.
11. Amirikian, Arsham, "Extent and Acceptability of Cracking in Precast Concrete Framing Members," *Journal of the American Concrete Institute*, Vol. 21, No. 9, May 1950.
12. Menefee, F. N. and Kinnier, H. L., "Spacing of Moment Bars in Precast Joists," *Journal of the American Concrete Institute*, Vol. 21, No. 8, April 1950.
13. Amirikian, Arsham, "Proposed Specifications for Minimum Bar Spacing and Protective Cover in Precast Concrete Framing Members," *Journal of the American Concrete Institute*, Vol. 21, No. 8, April 1950.
14. Pletta, D. H., Massie, E. F., and Robins, H. S., "Corrosion Protection of Thin Precast Concrete Sections," *Journal of the American Concrete Institute*, Vol. 21, No. 7, March 1950.

HIGHWAY RESEARCH BOARD BULLETINS *

No. 1 Silicate of Soda as a Soil Stabilizing Agent, by W. Derby Laws and J. B. Page (1946) 21 pp. 15

No. 3 Report of Committee on Highway Organization and Administration (1947) 23 pp . .30

No. 4 Report of Committee on Land Acquisition and Control of Highway Access and Adjacent Areas (1947) 42 pp. 45

No. 5 Report of Committee on Compaction of Subgrades and Embankments (1947) 23 pp . .30

No. 6 Report of Committee on Uses of Highway Planning Survey Data (1947) 40 pp . . .45

No. 7 An Analysis of State Enabling Legislation of Special and Local Character Dealing with Automobile Parking Facilities, by David R. Levin (1947) 30 pp. . .30

No. 8 Design of Flexible Pavements Using the Triaxial Compression Test - Kansas Method (1947) 63 pp. 75

No. 9 Salary and Wage Practices of State Highway Departments (1947) 51 pp 60

No. 10 Report of Committee on Land Acquisition and Control of Highway Access and Adjacent Areas (1948) 46 pp 60

No. 11 The Polarized Headlight System (1948) 40 pp 60

No. 12 Highway Finance (1948) 69 pp. 75

No. 13 The Appraisal of Terrain Conditions for Highway Engineering Purposes (1948) 99 pp. 1.50

No. 14 Soil Committee Reports and Special Papers (1948) 42 pp. 60

No. 15 Parking, Committee Report and Three Papers (1948) 31 pp 60

No. 16 Expressways, Committee Report and Three Papers (1948) 21 pp 45

No. 17 Highway Planning (1948) 45 pp 60

No. 18 Land Acquisition and Control of Highway Access and Adjacent Areas, Report of Committee and Four Papers, (1949) 44 pp 60

No. 19 Parking (1949) 78 pp 90

No. 20 Pavement Performance (1949) 74 pp 90

No. 21 Maintenance Costs (1949) 20 pp 15

No. 22 Engineering Use of Agricultural Soil Maps (1949) 128 pp 1.80

No. 23 Compaction of Soils, Two Papers (1949) 17 pp 15

No. 24 Zoning for Parking Facilities, by David R. Levin (in two sections) (1950) 161 pp 3.00

No. 25 Controlled Access Expressways in Urban Areas (1950) 45 pp 60

No. 26 The Truck Weight Problem in Highway Transportation (1950) 130 pp. 1.20

No. 27 Road Surface Properties, Report of Committee and Paper on Rubber in Bituminous Pavements (1950) 27 pp 45

No. 28 Soil Exploration and Mapping (1950) 124 pp. 1.50

No. 29 Maintenance Costs (1950) 23 pp. 30

No. 30 Progress in Roadside Protection (1951) 54 pp. 75

No. 31 Highway Planning (1950) 26 pp 45

No. 32 One-Way Streets (1950) 39 pp. 60

No. 33 Use of Parking Meter Revenues (1951) 30 pp. 60

No. 34 Reflectors and Night Visibility (1951) 57 pp. 90

No. 35 Highways with a Narrow Median (1951) 98 pp. 1.50

No. 36 Pavement Marking (1951) 32 pp 45

No. 37 Roughness and Skid Resistance (1951) 59 pp. 90

No. 38 Land Acquisition and Control of Adjacent Areas (1951) 82 pp 1.20

No. 39 Precasting Highway Bridges and Structures (1951) 20 pp. 45

*Publications in this series not listed here are out of print and not available.

NATIONAL RESEARCH COUNCIL

The National Academy of Sciences is a private organization of eminent American Scientists, chartered under a special act of Congress in 1863 to "investigate, examine, experiment, and report on any subject of science or art." The Academy maintains the National Research Council as its operating agency.

The Council, organized with the cooperation of the scientific and technical societies of America, enjoys the voluntary services of more than 2600 scientists making up over 400 standing committees, boards, and panels in all fields of the natural sciences; its membership includes representatives of business and industry. The Council provides advisory and administrative services for research, and attempts to stimulate and coordinate research effort.

DIVISION OF ENGINEERING AND INDUSTRIAL RESEARCH

The National Research Council operates through eight divisions covering fundamental and applied natural sciences, as well as matters of international relations in scientific research. The Division of Engineering and Industrial Research is concerned with the stimulation and correlation of research in a wide variety of fields in engineering and the applied sciences.

HIGHWAY RESEARCH BOARD

The Highway Research Board is organized under the auspices of the Division of Engineering and Industrial Research of the National Research Council. Its purpose is to provide a national clearing house for highway research activities and information. The membership consists of 42 technical, educational, industrial, and governmental organizations of national scope. Associates of the Board are firms, corporations, and individuals who are interested in highway research and who desire to further its work.

The purposes of the Board are: "To encourage research and to provide a national clearing house and correlation service for research activities and information on highway administration and technology, by means of: (1) a forum for presentation and discussion of research papers and reports; (2) committees to suggest and plan research work and to correlate and evaluate results; (3) dissemination of useful information and (4) liaison and cooperative services."