

Ohio River Bridges Substructure Construction

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In discussing any construction project, the subject of "Where did you have your problems and how did you solve them" usually is foremost in the mind of the listener. Since this is usually the most interesting and possibly the most informative area in construction, and since time is limited, this paper will tend in that direction.



NEW ALBANY SUBSTRUCTURE TYPICAL COFFERDAM

With the preceding in mind, the construction of the substructure for the bridge on I-64 at New Albany, Indiana can be dealt with easily and will be discussed first. This substructure was constructed by Roy Ryan Sons Co. of Evansville, Indiana. The area had the almost ideal circumstances of shallow depth (Approx. 30 ft.), good sound shale for keying the cofferdam and founding the pier, and moderate depth of typical river bottom sand and gravel or clay overburden. For the typical cofferdam the bottom wale is used as a template and is located on timber bents which have been located in the river by triangulation from a base line on shore. Steel sheetpiles are then laced around template and driven to refusal in shale to form a cofferdam. Cofferdam wales are made up above water and lowered into position as excavation proceeds. The cofferdam is then dewatered and the remaining excavation to sound shale is made. The cofferdam is flooded and a seal is cast by use of a tremie.

TYPICAL PIER CONSTRUCTION

The cofferdam is again dewatered and pier construction proceeds with the casting of a 20 ft. by 80 ft. distribution block to an elevation 38 ft. above normal pool. A floating concrete batch plant is used to supply all river concrete and materials are supplied by barge. Above the block the configuration of the pier changes to a battered dumbbell section. Columns are cast first with a construction joint at the web and column intersection with dowels out for web. At this stage, centerlines have been permanently established on the block.

The final section of the pier is an 11 ft. wide cap designed to receive the anchorage and load distribution grillages. This anchorage is one of the interesting features of this structure, with all horizontal forces being resisted by a pin or shear key at the centerline of each pier. The anchorage is cast integrally into the cap. Also cast into this cap are the load distribution grillages required to distribute the nearly 2500 ton load from the superstructure.

JEFFERSONVILLE SUBSTRUCTURE TRIANGULATION NETWORK AND RIVER PIER LOCATION

The triangulation network for control of river pier locations of the bridge on I-65 at Jeffersonville, Indiana is typical of our method of control of the various bridges over the Ohio River. Wherever possible it is a distinct advantage to include points in the river itself in the network, as was done here by inclusion of a point on a pier of a railroad bridge 1000 ft. upstream. The Base Line is laid out approximately 1000 ft. long and its length carefully determined, by repeated chaining, with a lovar tape, to within 0.01 ft. Angles are measured to the second with a Wild T2 theodolite and the resulting angular closures can be expected to be within 3 seconds. The locations of all points of the triangulation net are determined and "Cut in Angles" are calculated from each of these points to a predetermined location of the proposed pier. Each pier can then be set by turning the proper "Cut in Angle" from any two triangulation points and can be easily checked from a third point. Actual pier location begins with the construction of a cofferdam compression wale template. Each pier is designed with two, round, separate footings and shafts, and therefore, each shaft can be built in a separate round cofferdam. Since rock excavation is required to key all piers founded directly on rock, cofferdams were designed to be dewatered. The template is located in the river by triangulation to its center point, and sheeting is laced around to form a cofferdam.

PIERS ON OR NEAR SHORE

Piers on this structure are numbered 1 through 6 beginning on the Kentucky shore. One pier is on each shore and 4 piers are in the river. Piers 1 and 2 were both founded on 14BP117 piles to rock. Depth to bedrock in this area is about 100 ft. on the Kentucky shore, and slopes almost uniformly to only 15 ft. below normal pool on the Indiana shore. The two piers on piles offered no particular problems, though at Pier 2 the pile-location and driving was interesting. A 40 ft. diam. cofferdam was set for each footing and excavation was made 35 ft. below pool. 82 14BP117 piles 60 ft. long were driven within each cofferdam. Piles were driven from a platform 30 ft. above their final elevation. To be sure of their final position they were set very carefully in a plumb position to a steel beam template with the tip of pile at a predetermined beginning elevation. From here the piles were leaned to the proper batter and driven 25 ft. below water level to refusal, using a McKiernan Terry S8 marine hammer. A 10 ft. seal was then tremied around these piles.

Both Piers 5 and 6 were founded directly on bedrock by the use of shallow cofferdams with no particular difficulties.

FOUNDING PIER 4

Construction of Pier 4 marked the beginnings of a series of interesting problems and solutions. At this site the water was only 25 ft. deep but there was no overburden, and the rock surface was too hard to seat the sheet piles. The problem here was how to seal the bottom of the cofferdam. Attempts were made using burlap, mud, and concrete in that order, around the bottom of the sheets, but all failed. Contractor then elected to attempt rock excavation by drilling, loading and blasting footing area from a platform built at surface. Rock was drilled with air-impact equipment (Trackdrill). As each hole was completed a skin diver located a loading tube over it and the load was placed and tamped from the surface. When this shot was set off the force of the blast severed the bottom compression wale and collapsed the bottom of the cofferdam. It was then necessary to pull the cofferdam

and start again. The next procedure was to set a double wall cofferdam with the 3 ft. space between sheeting filled with a heavy clay. This worked very well and the contractor was able to dewater, excavate rock, and seal the cofferdams.

FOUNDING PIER 3

Pier 3 was the site of the most difficult problems. Depth to rock here was 60 ft. with 30 ft. of river sand and gravel. Ten to twelve ft. of loose rock and masonry rubble had been dumped at site presumably from lock and dam construction downstream. The contractor elected to drive sheeting through this rubble for the upstream cofferdam. Excavation was begun inside cofferdam but wale template hung on sheeting 15 ft. above its planned elevation. An underwater exploration revealed the sheeting was badly fouled below that point and was binding the template. Pulling, repairing, and redriving more than half the sheets did little good, and this site temporarily abandoned. The downstream cofferdam was attempted by first excavating as much of the rock as possible, and then driving sheeting. This produced only slightly better results. Apparently some rock was missed in the excavation or had worked its way into the overburden, and the sheeting was fouled and this template also refused to be driven into position.

Contractor then proposed, and was given permission, to cast a concrete compression ring 8 ft. high and 2½ ft. wide, in the cofferdam 3 feet above the rock. The forms for this ring were standard 2 ft. by 8 ft. wooden panels bolted to an 8WF35 ring. The form was lowered into the cofferdam and positioned on sand fill 3 feet above rock. Sand was then tremied inside the form to stabilize it and concrete tremied into the annular space between the form and the cofferdam. The work horse of this operation was the full-dress diver who directed the entire operation, via two-way communication, from inside the cofferdam.

With this concrete compression ring in place, cofferdam was successfully dewatered and rock excavation made, and reinforcing dowels to connect the columns with the seal were set to a template. Because of excessive leakage, this cofferdam then flooded and a tremie seal cast.

All efforts failed to dewater the upstream cofferdam, including the casting of a compression ring and grouting outside cofferdam. At one time the water level had been lowered 40 ft. by the efforts of one 10-inch pump and three 6-inch pumps, when a severe blow-in flooded the cell trapping one pump underwater.

It was then proposed that a cofferdam be built inside the existing cofferdam for the sole purpose of excavating a 2 ft. deep 11 ft. diam. Keyway in the rock. Corings at this site indicated a very sound limestone, and with the exception of this keyway, plans called only for leveling the rock if necessary and removing any weathered rock. This interior cofferdam was built around an 18 ft. diam. compression wale template made up of fourteen 6WF20 wales. This template was set inside the existing cofferdam, sheeting laced around it, and the resulting cofferdam dewatered. When keyway excavation complete, this interior cofferdam was removed. Final clean-up, including removal of concrete compression ring forms was done underwater by a diver utilizing a high pressure water jet, and an air lift. Dowel bars out of seal were attached to a template and positioned by diver and tremie seal was cast.

TYPICAL PIER CONSTRUCTION ABOVE FOUNDATION

Twenty foot diameter columns were cast above seals to an elevation 3 ft. below normal pool. At this stage cofferdams were removed since the next 16 feet was designed with an 8 ft. wide connecting web cast homogeneously with the columns.

This required watertight forms for the columns and web set 3 feet into water and pumped dry.

Above this strut the columns step in to 15 ft. diam. Column reinforcing was very heavy and 18 S bars were used in all river piers. Continuous spiral column ties, 5/8 in. round with a 6 in. pitch, were required, and the contractor devised an ingenious method of tying spirals from the top down. The final pour of the pier was an integral casting of the top 15 ft. of the column with a parabolic top strut. The Top Strut forms were supported on 3 steel trusses between columns, which in turn were supported by steel columns resting on sand jacks on the bottom strut.

EVANSVILLE SUBSTRUCTURE

The substructure of the bridge on U. S. Highway 41 at Evansville presented several interesting problems and solutions. The contractor for this substructure was Industrial Construction Division, Allied Structural Steel. A review of two of the five piers in this structure will adequately present the construction difficulties and at the same time show typical construction procedures.

FOUNDING PIER C

Pier C is one of two river piers. Depth to bedrock is approximately 85 ft. below normal pool with approximately 60 ft. of sand and gravel or clay overburden. Bedrock in this area is 4 to 5 ft. of hard grey shale or sandstone underlain by hard blue shale. The contractor elected to construct this pier in an open dredged cofferdam, utilizing underwater cleanup methods and casting a tremie seal. Specifications provided that a regular pattern of 21 cores, a minimum of 10 ft. into sound bedrock be taken to determine a suitable foundation elevation. The specifications also provided that a minimum of 12 cores be made through the seal concrete to sound bedrock to prove the quality of the seal, and the absence or presence of unsuitable material between the seal and bedrock.

Construction began with the location of a 32 ft. by 72 ft. cofferdam template made up of the bottom two wales and bracing and floated into position on a barge. Triangulation control points are on the existing highway bridge 150 ft. upstream. The template is spudded in position, the barge removed and sheeting laced all around. Wale template is set on the bottom and, as excavation proceeds, additional wales are added on top. Wales are 27WF and 36 WF sections, the largest being a 36WF230. When excavation reached rock, 1 5/8 in. round cores were taken and a tentative foundation elevation determined. A 4 ft. c. to c. pattern of 6 in. round holes was drilled 8 ft. into rock, loaded with 10 pounds of Tovex blasting agent, and set off utilizing 25 millisecond delay caps to minimize shock. Blasted material was then excavated and underwater cleanup begun. Final excavation and cleanup was done from the surface using a chipping beam, high pressure jet, and an airlift. The chipping beam was a 100 ft. length of 14BP117 with two 2 ft. sections of 14BP117 welded at the bottom, sharpened and hard surfaced. Rock which couldn't be cut out with 200 psi water jet was chipped out by lifting and dropping this beam. All loose material was siphoned out through an 8 in. air lift. Inspection of the progress was made periodically by divers hired by the contractor, and a final inspection of the bottom was made by a diver hired by the State. This inspection was made 24 hours prior to the seal pour. The seal in this cofferdam was 35 ft. deep, contained 3,000 C.Y. of concrete and required 50 hours of continuous casting. The tremie used had 90 ft. of 10 in. pipe and a 3 C.Y. hopper at the top. The contractor had devised a cone shape plug at the bottom end held in place by a line through the tremie to a supporting crane. Tremie was

lifted completely out of water to charge it at the beginning of the pour, and could be lifted by this plug and moved at will without losing the charge.

The cofferdam was dewatered three days after the seal pour and the specified 2 in. round cores were taken through the seal and into bedrock. Surprisingly, a number of these cores showed a complete lack of recovery in the area immediately below the seal and in some cases extending as much as 2 ft. below the seal. Ten additional cores were then made through seal to recover samples of this missing material. These cores were stopped as nearly as possible to the bottom of the seal concrete, and a split spoon sampler inserted and driven to refusal. Again surprisingly, the spoon would drive in some cases and on recovery contained heavy clay, shale chips, and gravel.

The existence of this material under the seal prompted a series of conferences of officials from the contractor's organization, Bureau of Public Roads, Indiana State Highway Dept., and Hazelet & Erdal. The exact origin of the material was not certain but it must be assumed that it came from a minor blow-in some time after the final inspection and before the seal pour. The contractor was given permission to attempt to consolidate this material with chemical grout, with the understanding that additional cores would be required to prove the results. The Jousten process, using calcium chloride and sodium silicate injected under high pressure, was the means tried. In this process the two ingredients and water are combined under the seal to form calcium silicate particles and salt water. The silicate particles are impacted into any opening through which water will pass. In addition, the 500 psi grouting pressure tends to compact any material in the area. To recover a sample of this grouted material as intact as possible, the contractor drilled a 7 in. diam. hole through all but the last foot of the seal, and took a 6 in. round core from there to bedrock. Recovery with this system was almost 100% and a good representation of existing conditions was obtained. All of these 6 in. cores were carefully examined and several were physically tested. All the available information from these and all previous corings was assembled by Hazelet & Erdal and presented to the State and B.P.R. officials. The consensus of opinion was that the existing foundation conditions were adequate to support the design loads of the structure. It was also agreed that the fixed shoe be moved from Pier C to Pier B as an added safety factor. Construction then proceeded without further mishap.

FOUNDING PIER A

Pier A, on the Kentucky shore, proved to be another trouble spot. Depth to bedrock here was 110 ft. Hard, limestone ledges separated by clay or soft shale existed for 16 ft. above bedrock, and the rest was sand or clay overburden.

Construction began with the blasting of the rock ledges. Eight inch casings were jetted to rock and 6 in. diam. holes drilled on a 6 ft. pattern and loaded with 110 pounds of Tovex blasting agent. The entire area was shot at once (7,200 pounds of Tovex) using 15-25 millisecond delays. A 32 ft. by 66 ft. cofferdam was constructed in a 15 ft. "glory hole." Cofferdam sheeting was driven to refusal on ledge rock 16 ft. above plan footing. Wales refused to follow excavation down almost from the beginning, and a system of 12-200 ton jacks was set up to force wales down. The jacks operated against the top wale which was welded to the sheeting. 10BP42 posts were used to space wales and to jack against.

After over a month of jacking, and when wales were still 30 ft. above their intended final locations, the extreme resistance which had built up finally failed one corner of the bottom wale. It then was necessary to either start all over or try another method. Contractor asked permission to try driving 14BP117 piles through

the blasted ledges (an alternate of concrete caisson piles drilled through these ledges had been included in the original plans). By reinforcing the pile tips and some very hard and persistent driving, contractor was able to drive through ledges to refusal in bedrock. By a liberal use of the 150% construction allowable, enough struts were removed from upper wales to provide necessary pile batter and driving clearances. Prior to casting the seal, the cofferdam was pumped down 25 ft. to an elevation several feet below top of seal, and lugs were welded to sheeting to attach it to the seal. Sheeting was later cut off above the seal and left in place. The cofferdam was flooded and a 10 ft. tremie seal cast. Above the seal, a 20 ft. by 59 ft. distribution block with round ends is cast to a point 6 ft. above normal pool. The next 41 ft. is a dumbbell section composed of two 15 ft. columns and a five ft. web. The top 40 ft. of the pier is an 11 ft. diam. column with a 4 ft. by 12 ft. average, parabolic top strut. Top strut forms are supported from web section below by a system of steel falsework column bents resting on sand jacks. Steel form panels were used throughout the job. The various diam. columns were made with a standard form called a Pi form. Form is a 1/8 in. steel plate, 3.14 ft. wide and of various height with vertical stiffeners only. Any curve from 6 ft. diam. up can be made with this form by attaching an appropriate "Forming Ring" to the top and bottom. Piers were completed with the addition of clearance gauges and temporary pier lights.

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