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CIVIL, MECHANICAL, MINING AND
ELECTRICAL ENGINEERING

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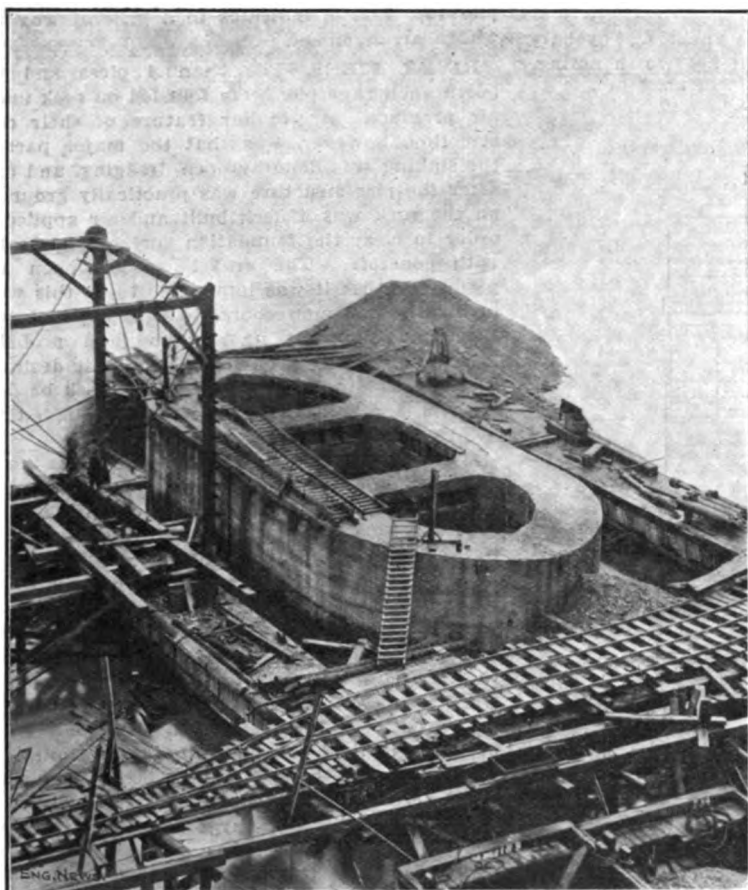
Substructure of Cantilever Bridge Over the Ohio River at Beaver, Pa., Pittsburgh & Lake Erie R. R.

The Pittsburgh & Lake Erie R. R., running northerly from Pittsburgh along the left bank of the Ohio River, crosses the river at the point where the latter bends to the west and south, at Beaver, Pa. The first bridge at this crossing was built in 1878, but later it was reconstructed,

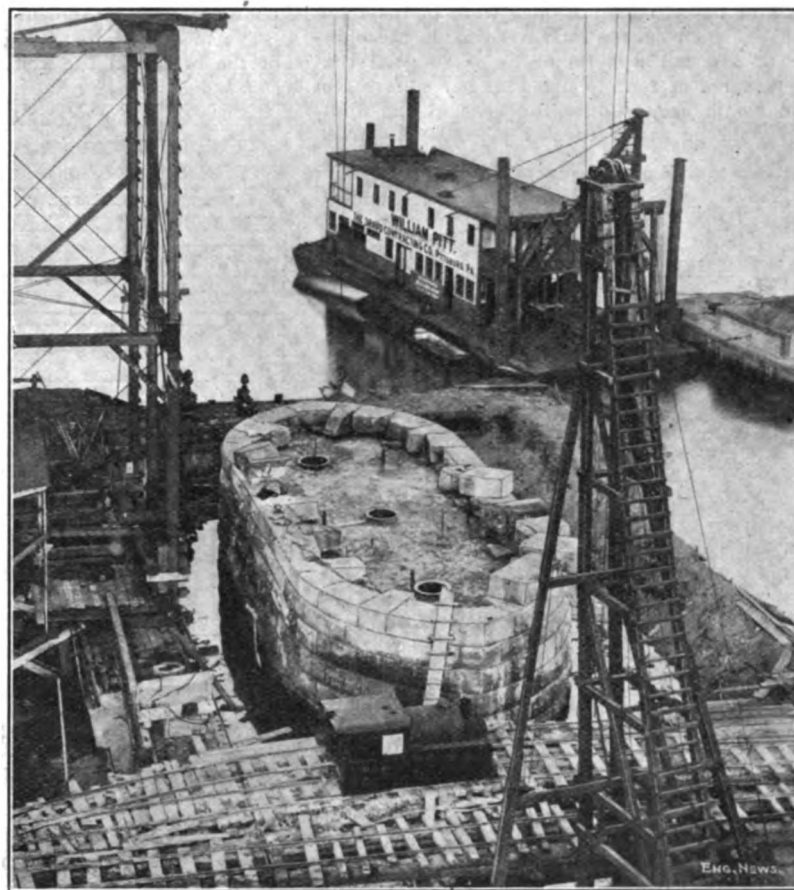
not wide enough to accommodate a double-track bridge, so that no part of the old work needed to be saved, and the span lengths, location, etc., of the old bridge did not limit the design. Moreover, there was opportunity to improve the alignment and increase the track facilities near the bridge by shifting the crossing some distance upstream. Accordingly the new bridge is about 300 ft. upstream of the old one. The spans of the new bridge were determined by the widths of the government bear-trap dams above and below,

cantilever arms of 242 ft. each and a suspended span of 285 ft. The 320-ft. spans are the anchor arms of the structure. The 370-ft. span at the north end is an independent approach span. An outline drawing of the bridge is given in Fig. 1 herewith. The structure is of unusually heavy design, and on this account, as well as of its length, may be said to be the heaviest truss-bridge work yet built in this country.

The substructure of the Beaver Bridge was described in some detail recently by Mr. A. R.



View on Aug. 17, 1908, Showing Shafts for Dredging.



View on Nov. 9, 1908, Showing Air-Lock Wells in Stone-Faced Concrete Shaft of Pier.

TWO VIEWS OF NORTH ANCHORAGE PIER, PITTSBURGH & LAKE ERIE RY. BRIDGE OVER OHIO RIVER AT BEAVER, PA.

again as a single-track structure. The existing bridge is now taxed about to its limit by the train loading, and its single track (or rather two tracks gauntleted, to eliminate the complications of switching) is insufficient to carry the traffic of the road. Several years ago, therefore, it was decided to build a new double-track bridge adjoining the old structure.

The span arrangement of the old bridge is not the most favorable as concerns river navigation, and it was desirable to use better span lengths in the new bridge. It happened that the old piers, being built for a single-track bridge, were

which dams are constructed with a clear channel width of 700 ft.; for the same clear channel width at right angles, the center to center length of channel span on the axis of the bridge as decided upon (slightly skew to the channel) was 769 ft., and this length of span was adopted. Side spans of 320 ft. each and an approach span on the north end of 370 ft., gave a suitable location for abutments.

The bridge is of the strict three-span cantilever type, and is quite similar in its general outlines to the Monongahela Bridge of the Wabash R. R. at Pittsburgh. The channel span is divided into

Raymer, Assistant Chief Engineer of the Pittsburgh & Lake Erie R. R. Co., in a paper read before the Structural Section of the Engineers' Society of Western Pennsylvania. From this paper we abstract the following particulars.

RIVER AND SOIL.—The Ohio River at the site of the bridge has a maximum rise of over 46 ft. above low water. The normal or pool-full stage is 7.1 ft. above low water. The depth at low water is quite shallow.

The river bottom soil is chiefly gravel. To make certain of its character and depth, diamond drill borings were put down, two on the site of

each pier and abutment. These showed that a water-bearing gravel continues all the way to rock, rock being about 30 ft. below low water. Both sandstone and shale were found. The general surface of the rock was practically level.

All piers and abutments are of concrete, with embedded reinforcing bars at some points, and a facing of Beaver Valley sandstone on the visible faces. The bridge seats are not of stone, however, as will be described later.

SOUTH ABUTMENT.—The south abutment not only carries the varying loads or uplifts of the anchor arm, but also serves as retaining wall to a 66-ft. embankment. If this pier were to be carried down to rock, its total height to

under the extreme conditions of this case. The total vertical load on the foundation is 13,400 tons, comprising 6,570 tons masonry load, 1,800 tons superstructure load and 5,030 tons earth load. The pressures per square foot at back and front of base, under different conditions of loading, are given by Mr. Raymer as follows:

	FOUNDATION PRESSURES, SOUTH ABUTMENT.	
	Tons per sq. ft.	
	Back.	Front.
Masonry unloaded, no fills.....	3.1	1.3
Masonry unloaded, fill at back.....	2.5	3.5
Masonry, bridge load, fill at back.....	3.5	3.5
Masonry, bridge load, fill back and front.....	4.2	4.2
Masonry, bridge load, fill back, front and ends.....	4.4	4.4
Masonry, bridge uplift and all fills.....	1.9	4.1

concrete later. The design of the end shoes is such as to maintain a uniform tension in the anchorage eyebars, this tension being that which occurs under maximum uplift conditions; and this is one of the numerous notable details of the bridge.* When the bridge was near its closure point at the center, with the erection traveler at its outer end, producing maximum uplift at the anchorages, wedges provided in the shoes between the upper anchor pin and the shoe base-plate were forced in tight, maintaining the eyebars in their stretched condition. Under all conditions of reduced uplift or even resultant downward load, at the anchorages, the tension of the eyebars is absorbed in part or in whole by

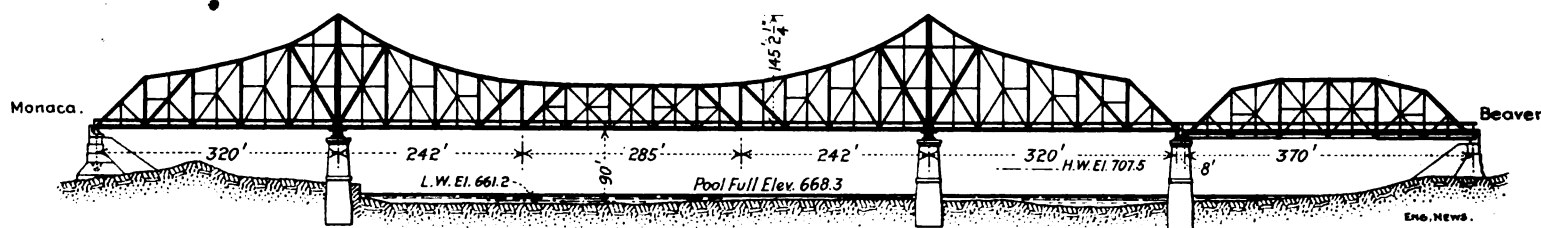


FIG. 1. OUTLINE OF NEW PITTSBURGH & LAKE ERIE RY. BRIDGE OVER OHIO RIVER AT BEAVER, PA.

rail level would be about 110 ft., which seemed out of the question, in view of the heavy lateral earth pressure to be resisted by it. The soil overlying rock was quite firm, and was judged easily able to take moderate foundation pressures, at any rate if assisted by piling. Therefore the decision was reached to found the abutment on a piled foundation a little below ground level. Since this was still some distance above the water plane, concrete piles were planned for. However, when excavations were made the character of the soil was found to be so good that the pressures of four to five tons per square foot which would occur under the base of the abutment could be safely carried by the soil direct.

As this table shows, the design was so worked out that under full dead-load as well as when any one of the earth fills is removed, the foundation reaction would be central to the area of the base, in order to give maximum uniformity of settlement. The slope of the earth faces of the wall is adjusted to accomplish this. It is stated that while the embankment fills were being made the abutment settled $\frac{1}{2}$ in. vertically with no horizontal movement.

The means for receiving the anchorage eyebars of the bridge in the abutment are worth noting.

the masonry of the abutment. This arrangement eliminates all changes of length in the eyebars after the bridge is once completed, and the space around the eyebars can therefore be filled solid without danger that elastic changes of length of the eyebars will cause a separation between eyebars and concrete and so give opportunity for entrance of water and rusting. The outline sketch of the end shoe in position on the pier top, Fig. 3, indicates in a general way the wedge arrangement.

RIVER PIERS.—The channel piers and the north anchorage pier were founded on rock under air pressure. A peculiar feature of their construction, however, was that the major part of the sinking was done by open dredging, and only after the pier structure was practically grounded on the rock was a deck built and air applied in order to clear the foundation surface and seal it with concrete. The gravel was so open and permeable that it was impossible to do this work in the dry without recourse to air. The rock surface had sufficient unevenness (and probably loose or rotten rock on top) to make it desirable that the bedding of concrete on the rock be done with proper assurance of getting a sound, thorough contact.

The open dredging method was adopted as the result of competitive bids, the call for which specified that the concrete laying must be done in the dry, using compressed air for fitting the pier to the rock and sealing with concrete (without specifying the method to be used for the rest of the sinking). The bids received were with one exception for regular pneumatic caisson work; the one bid was for open dredging through shafts in the concrete pier bases, employing compressed air work for only the fitting and sealing operations.

The body of the piers being of concrete, the dredging method was applicable with a minimum of trouble, as the entire pier below low water could be treated as a concrete cylinder with relatively thin walls and large shafts. In the execution of the work two cross walls were constructed across the hollow interior of the pier cylinder, dividing the latter into three chambers or shafts. The outer walls were about 7 ft. thick and their bottom edges were tapered off in steps on the inside to an edge faced with an 8 x 8-in. angle serving as cutting-edge. Bolt anchors extended upward from this angle-iron into the concrete near the inner and outer surfaces. The walls of the cylinder contained some vertical reinforcing rods as a safeguard against possible tensile rupture in the last stages of the sinking, due to excessive friction between cylinder and soil.

Orange peel dredges were used for excavating through the three shafts. No difficulty was experienced in controlling the verticality of the structure while sinking, as it readily followed the

*This will be treated more fully at a later date, when we shall describe the superstructure.

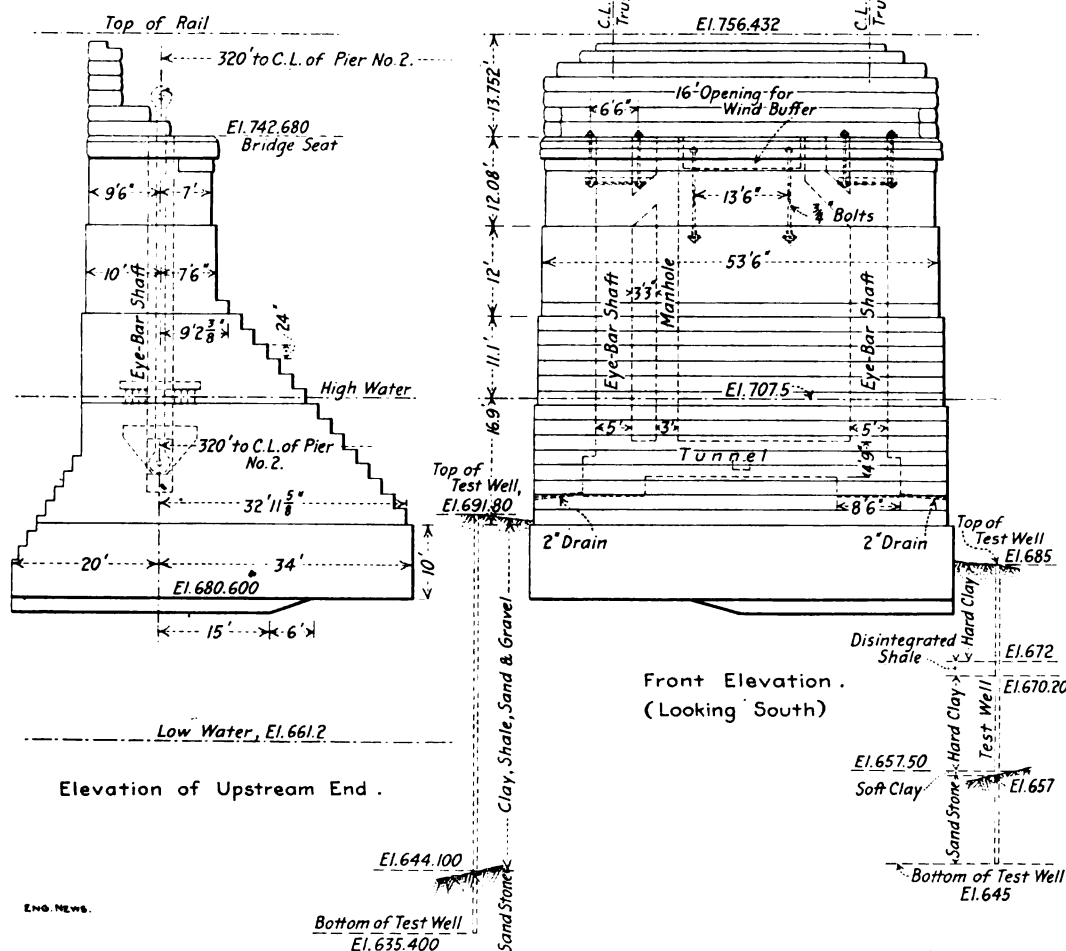


FIG. 2. ELEVATIONS OF SOUTH ANCHORAGE ABUTMENT, P. & L. E. RY. BRIDGE OVER OHIO RIVER, AT BEAVER, PA.

In consequence, the plan of using piles was abandoned, and the abutment was constructed directly on the soil.

The principal elevations of the abutment, Fig. 2, show how the joint service requirements of pier, anchorage and retaining wall were met

Two vertical shafts were cored out in the concrete, connected below by a horizontal passage in which the anchorage girders were set. A third vertical shaft going down to the girder seat was provided as a manhole for use in the work of filling the shafts and passages with

guidance given by dredging deeper at one end or the other.

The final locations of the three river piers varied from their intended location by an average amount of 0.12 ft. longitudinal of the bridge and 0.56 ft. transverse to the bridge.

The soundings having shown that the rock at the site of the piers was not quite level, the

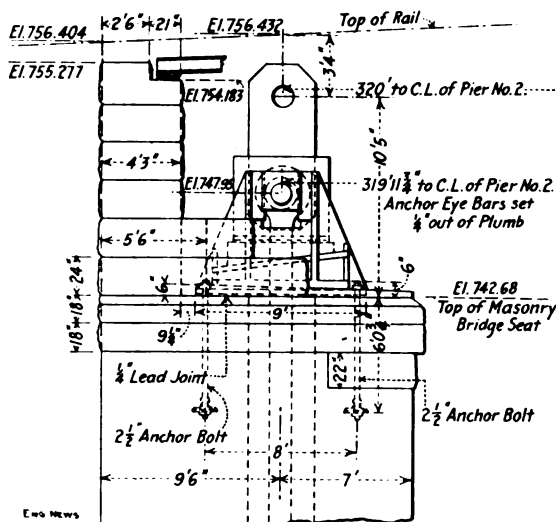


Fig. 3. Top of South Abutment, and Position of Wedge Shoe of Anchor Arm.

caissons were built with the plane of the bottom edge sloped to fit the rock. However, when the piers were grounded (cutting-edge about 16 in. above rock), the water flowed under the cutting-edge freely enough to make it difficult even to pump the water down to a level 10 or 12 ft. above the edge, where forms had to be set for a concrete deck. The walls themselves were watertight, proving the inflow to come under the cutting edge. The deck completed, air pressure was put on, the remaining material over the rock excavated, the caissons sunk through the remaining small depth to a bearing on rock, the

rock surface cleaned off and the whole structure filled with concrete.

The total load on the foundation of each of the channel piers is about 32,000 tons, of which about 12,000 tons is superstructure load. The pressure per square foot on the rock is about 8 tons from masonry and 5 tons from superstructure, or 13 tons total.

The shoes of the main posts resting on the two channel piers are large steel castings with a circular seat for segmental rollers to form a virtual hinge joint—another of the novel features of the superstructure. The bottom face of the casting is 150 sq. ft. in area, so that the post load of 6,000 tons gives a pressure of 40 tons per sq. ft. To distribute this over the pier masonry at a more moderate pressure, an I-beam grillage is set under the shoe. This has an area of 240 sq. ft., making the pressure on the masonry about 25 tons per sq. ft. In the upper 50 ft. of pier below the grillage, 1 1/4-in. rods were placed in alternate layers lengthwise and crosswise in the concrete to assist in distributing the shoe pressure over the full cross-section of the pier.

The concrete forming the body of the piers is a 1:3:5 gravel mixture, used soft enough to puddle. This applies also to the abutments.

The top surface of the piers is not finished with the customary stone capping. The shoe grillage is set upon and surrounded by 1:2:4 concrete (as against 1:3:5 in the body of the piers). The stone outer surfacing of the piers forms only an outer ring on the top face. It was necessary, therefore, to provide a protective surface coat over the pier top. For this purpose a granolithic pavement or roof about 3 ins. thick

was placed over the entire top surface, out to the inner line of the coping, and carefully finished against the edges of the shoe castings to make a water-tight protection. The same kind of top finish was used on the abutments.

The north anchor pier has the same provisions for the anchorage eyebars as the south abutment. The top of the pier carries also the end shoes of the approach span. The relative positions of the two sets of shoes are shown in the sketch, Fig. 4.

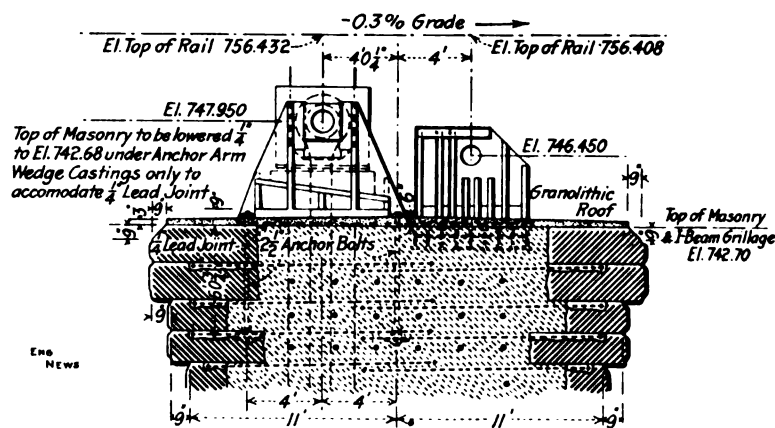


FIG. 4. TOP OF PIER 4 (NORTH ANCHORAGE), SHOWING SHOES OF ANCHOR SPAN AND APPROACH SPAN IN PLACE.

NORTH ABUTMENT.—The construction of the north abutment involved substantially the same problems as the south abutment, except that it carries the fixed reaction of the approach span instead of the reversible reaction of the anchor arm. However, it was not thought safe at this abutment to dispense with piling, the soil not being considered firm enough, creating the risk of excessive compression and settlement. Moreover, the conditions were somewhat different from those at the south abutment inasmuch as the rock was considerably deeper, being about 130 ft. below rail level, or 68 ft. below ground surface. The foundation was therefore designed with piles.

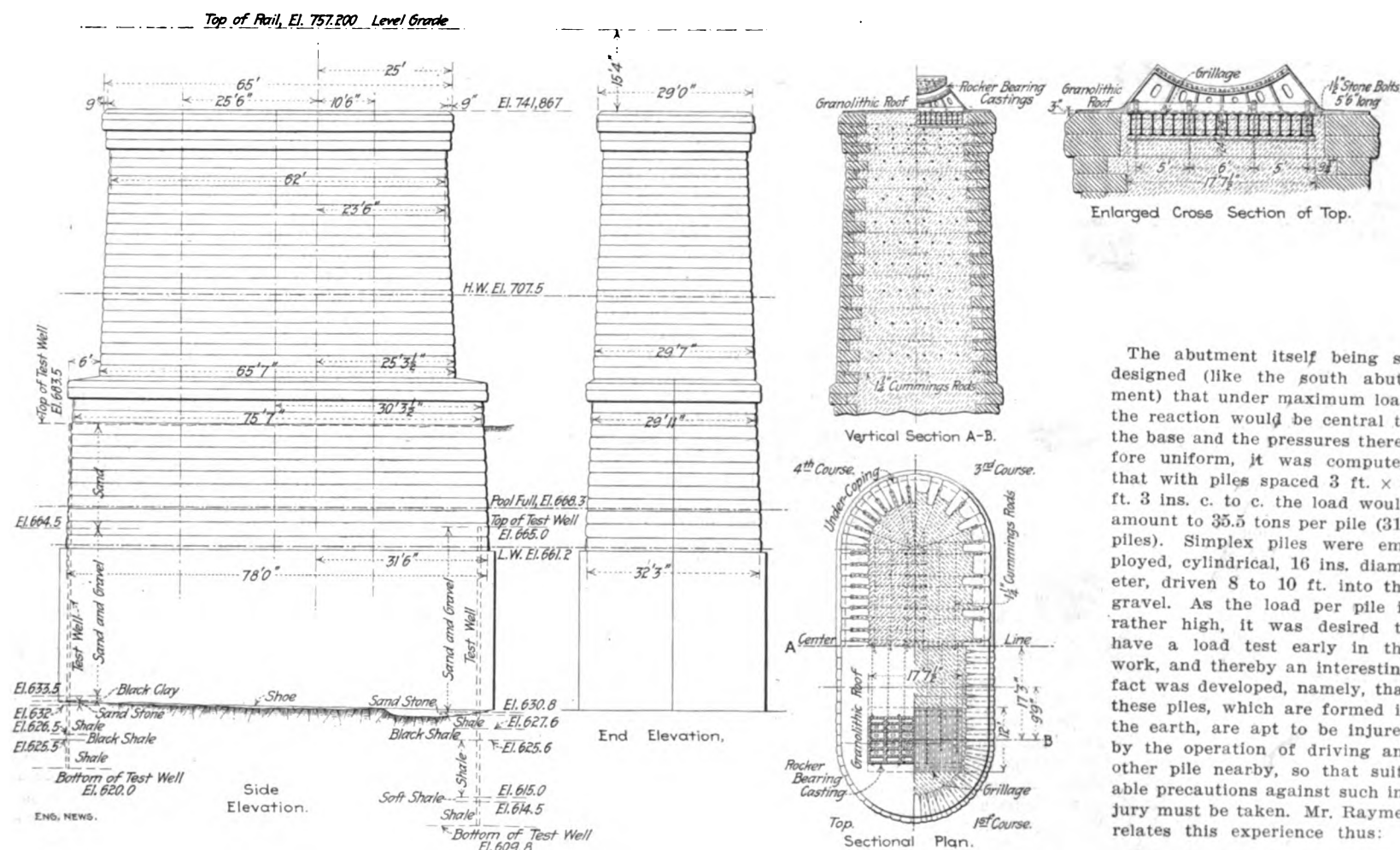


FIG. 5. SOUTH CHANNEL PIER OF BEAVER BRIDGE.

(The cylindrical roller-bearing shoe is a steel casting. It carries the foot of the main post of the cantilever, forming a hinge bearing.)

The abutment itself being so designed (like the south abutment) that under maximum load the reaction would be central to the base and the pressures therefore uniform, it was computed that with piles spaced 3 ft. x 3 ft. 3 ins. c. to c. the load would amount to 35.5 tons per pile (315 piles). Simplex piles were employed, cylindrical, 16 ins. diameter, driven 8 to 10 ft. into the gravel. As the load per pile is rather high, it was desired to have a load test early in the work, and thereby an interesting fact was developed, namely, that these piles, which are formed in the earth, are apt to be injured by the operation of driving another pile nearby, so that suitable precautions against such injury must be taken. Mr. Raymer relates this experience thus:

Before the pile work was commenced it was thought desirable to make some loading tests on piles driven

similarly to those in the proposed foundation work. The first test consisted of a pile driven with four others around it spaced as in the foundation work, the four being driven while this test pile was still soft. The second test differed from the first only by allowing the test pile to partially set before the four piles around it were driven. The working conditions on a large foundation are such that the second test more nearly represents the actual conditions than the first. After both test piles were allowed 30 days to set, the first pile supported a load of 60 tons for 72 hrs., with 9/84-in. of settlement, which settlement it recovered almost wholly after the load was removed, while in the other case the results were, as was to be expected, not good enough for approval.

To meet the difficulty developed by the conditions of the second test, which is simply recognizing the well-known limitations of concrete and applicable to all kinds of concrete piles formed in place, the following specifications were used, it is believed for the first time on such work:

The setting of the concrete in any pile must not under any consideration be disturbed by driving another pile or piles within a radius less than 9 ft. center to center from it, after a minimum interval of 3 hrs. or before the expiration of seven days from the time the concrete was mixed with water for that pile. The contractor may, however, at his own option drive pile forms within the 9-ft. radius to a depth not more than 8 ft. from the total estimated penetration, inside of the 3-hr. limit;

The Most Economical Type of Boat for Operation on Western Rivers with an 8-Ft. Channel Depth.

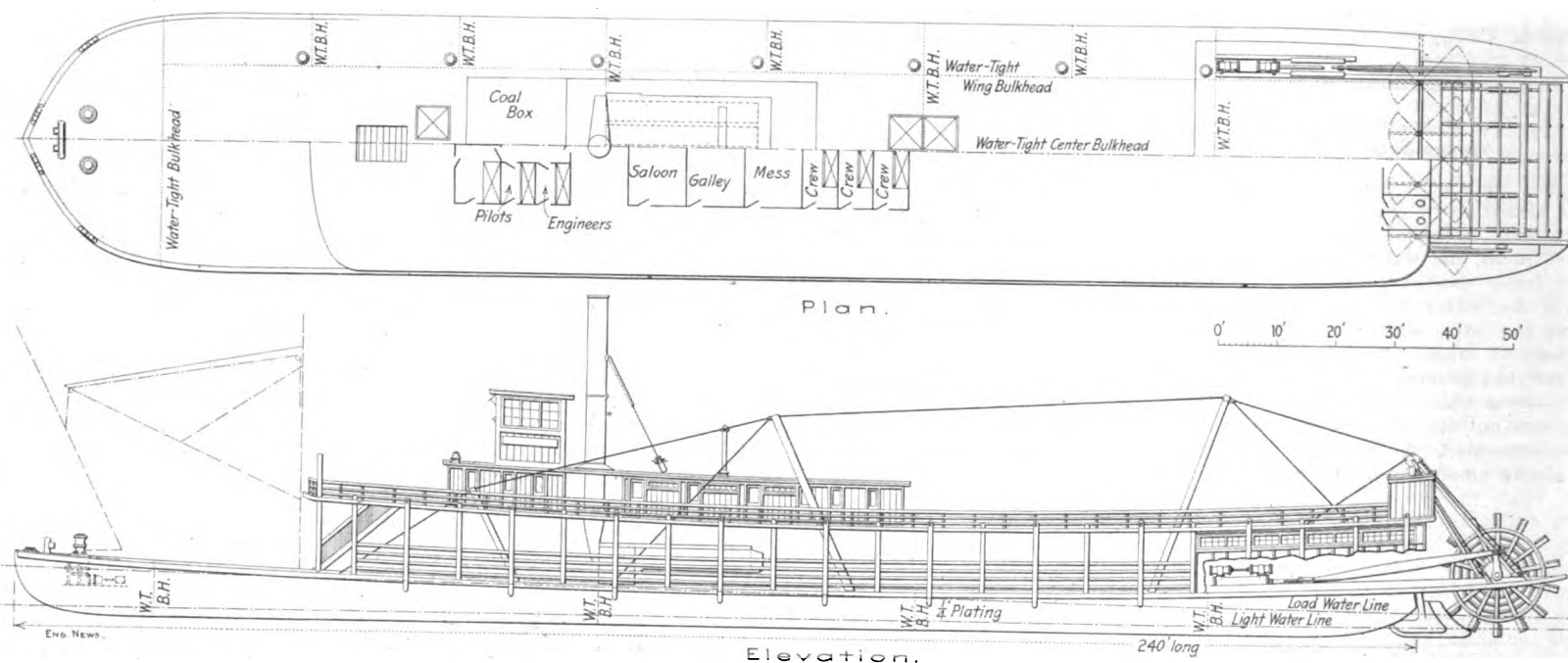
By JOHN M. SWEENEY,* M. Am. Soc. M. E.

The most economical type of boat for freight transportation on the rivers of the Western United States, is the type which will do its work at the smallest total cost. Many items contribute to this total cost. The result is so affected by local conditions that what is the most economical design of boat for one section of a river may not be the most economical for another section. While it is impossible to designate any complete plan as most economical under all conditions, there is one basic requirement of boat design for these rivers, which has been arrived at from the experience of the past ninety years in their steam navigation. This has established the stern paddle wheel as the type of boat best adapted to these rivers, to secure the most economical results. It is the combination of the stern wheel, and the rudders placed between the wheel and the stern of the boat, which gives to this type of boat its commanding place. In Mr. Thos. P.

the usual smart remarks about the "high" steam pressure employed on these boats, the use of hams for fuel, and of course the "nigger" on the safety valve lever! Perhaps some day proper credit will be given to the Western boat designer; and when it is realized how far he was in advance of the profession in the use of high pressure steam, the funny man's remarks of 20 years ago will be properly appreciated.

There is an authentic tale of a manufacturer of marine boilers from the classic Chesapeake, who about this date took passage on an Ohio river boat. Discovering 140 lbs. pressure on the steam gage before the boat had left her dock, he at once cancelled his passage!

EARLY DESIGNS.—The first boats used on Western rivers had side wheels and a single engine with stiff shaft; but this was soon altered so that either or both wheels could be disconnected by clutch from the engine, making it possible to operate either wheel backward or forward, while the opposite wheel was idle. This was a great advantage in the ability to make quicker landings. Indeed the early steamboats avoided landing wherever possible, using a yawl for transfer of passengers and small freight from



GENERAL PLAN AND ELEVATION OF STERN WHEEL PACKET BOAT FOR OPERATION ON THE MISSOURI RIVER.

and then after the 3-hr. limit and before the expiration of the seven-day limit complete the driving and filling of these forms.

This specification was strictly observed; the piles were driven in rows across the foundation in the following order: Rows Nos. 1, 4, 7, 11, 15; then Nos. 2, 5, 8, 12; and 3, 6, 9, 13. After the piles were completed the earth was excavated a couple of feet below the cut-off line, and the concrete was filled in the usual way around and over the pile heads.

It is noted that the construction of the fill behind this abutment caused a vertical settlement of 1 1/4 ins., which is over twice as great as the settlement of the south abutment. In both cases, however, the settlement was uniform and there was no lateral motion.

The construction of these piers and abutments was begun in the Spring of 1908 just after high water, and the work was all completed by December, 1908 (except that the upper part of two of the river piers remained completed until after the 1909 Spring floods). This is an excellent record of speed for work of such magnitude, and this fact no doubt can be credited in large part to the method of sinking adopted. Erection of the superstructure was begun in 1909, and is now practically completed. The piers and abutments were built by the Dravo Contracting Co., of Pittsburgh, Pa. The superstructure is being constructed by the McClintic-Marshall Construction Co., of Pittsburgh. Mr. J. A. Atwood is Chief Engineer of the Pittsburgh & Lake Erie R. R. Co.; Mr. A. R. Raymer, Assistant Chief Engineer.

Roberts' article in Engineering News of Feb. 17, 1910, some of the advantages of the stern-wheel construction were pointed out as applied to tow handling; but there are many additional advantages with respect to the up-stream work of the tow-boat, and with respect to the operation of the so-called packet boat in all classes of work.

The men foremost in the gradual working out of the arrangement of rudders establishing the stern-wheel boat as the best type, were not fully aware of all the advantages, nor the reasons for them; therefore it is hardly a surprise that many prominent engineers fall at first glance, or indeed at second glance, to discover any virtue in the stern-wheel boat.

In 1888 a paper was contributed to the proceedings of the American Society of Mechanical Engineers, at the Nashville Meeting, which was the first to put on permanent record a detailed technical account of the steamboats used on western rivers. The discussion on this paper at that meeting illustrates the hasty way in which the stern-wheel is judged. One prominent engineer brushed the entire propelling plant overboard in a breath, and substituted a number of Westinghouse engines and propeller wheels across the stern, to his entire satisfaction; in blissful ignorance of the fact that in a day's work with usual landings the stern-wheel boat would accomplish easily what with his proposed construction would be impossible.

The discussion on this paper also brought out

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the boat to the shore. When compelled to come to the bank, they cast anchor in the stream, sent a line ashore by the yawl which was secured there and then hauled the boat to the bank on that line, paying out on the anchor cable. This operation was reversed when the boat was started. This no doubt brought about the practice of turning the boats head up-stream in making down-stream landings.

The next change was the use of two independent engines, one for each side-wheel; with this equipment the wheels might be turned in opposite directions at the same time. With this alteration the highest effectiveness of the side wheel boat for western rivers was reached, and this type of boat continued in use without further development until they were finally (with a few isolated exceptions) displaced by the stern-wheel boats.

That the stern wheel did not come more quickly into general use was due to the slowness with which improvements in rudder construction were adopted. As late as 1882, a boat was in service on the Ohio River which frequently was backed ten or twelve miles down stream because of inability to turn herself when an up-stream wind was blowing. Sometime between 1830 and 1840, trial was made of two wheels at the stern capable of independent operation in opposite directions; but this was not productive of betterment, nor was a similar attempt made many years later.

DESIGN OF RUDDERS.—The form and shape of stern construction established also the shape and attachment of the rudders, and for a long