## Sect. II.—OTHER SELECTED PAPERS.

(*Paper No. 2785.*)

# "The Foundations of the Panther Creek Viaduct, Pa., U.S."

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The Panther Creek viaduct, built in 1893, is situated on the line of the Wilkes-Barre and Eastern Railroad, about twenty miles east of Wilkes-Barre, Pennsylvania. The railway ascends from 532 feet at the latter place to an altitude of 1,477 feet at the western end of the viaduct. For several miles near each end of the viaduct, the line winds along picturesque mountain slopes; the purpose of the viaduct was to eliminate crooked distance where it was not needed for development of the gradient; the approaches are through heavy rock cuttings on 8-degree curves, between which the line of the viaduct is straight on a gradient of 47·5 feet per mile, ascending in an easterly direction. The design and erection of the superstructure was entrusted to the Edgemoor Bridge Works, of Wilmington, Del. The total length of the viaduct is 1,650 feet—comprising ten spans 65 feet long, one span 60 feet long, one span 40 feet long, and thirty spans 30 feet long. The spans are supported by twenty towers and one bent. The forty bents composing the towers, and the single bent, vary between 40 feet and 155 feet from the top of the masonry to the rail-level. About 380 feet of the structure exceeds 150 feet in height above the cap-stones of the pedestals, or 161 feet above the bed of Panther Creek.

*Substructure.*—The foundations for the viaduct were prepared by the Wilkes-Barre and Hudson River Improvement Company, of which the Author became the chief engineer in February, 1893. Owing to the absence of good building-stone in the vicinity and the rugged character of the country, it had been decided to form the substructure of concrete pedestals capped with stone blocks, and a few pedestals had been built in the winter. These, however, were unsatisfactory. On the 4th of March, 1893, about one cubic foot of concrete was cut from a pedestal commenced on the 8th of February, and was packed carefully in straw and sent to the Author at New York to be tested for compression. Upon the barrel being opened there was nothing found but loose stone, sand and worthless cement, which, upon trial, did not re-set. For so important a structure only one course was possible; the arrangement with the contractor was rescinded and the work was done by day-work directly under the engineer. The previous pedestal-work was removed in the spring, all the concrete being found worthless. The cement was a natural American cement, doubtless of good quality; as usual in cold weather, brine had been used in its preparation. This experience confirmed the Author's belief that concrete and cement ought not to be used when the temperature is below freezing-point; but in cases where work is then necessary, only an artificial cement should be permitted.

Calculation showed that the weight of the superstructure and load, together with wind-stress at 30 lbs. per square foot of the structure loaded, would result in pressures on the bases of the posts, varying between 233,000 lbs. at the highest bents and longest spans, and 131,000 lbs. at the most favourably conditioned bents. The cap-stones were formed of sound, strong stone, for the lower bents 4 feet by 4 feet by 1½ foot, and for the higher bents 4½ feet by 4½ feet by 1½ foot; the tops of the concrete pedestals being 6 feet square and 7 feet square respectively, and enlarged therefrom as the character of the ground determined, so that the resultants of all the stresses should fall within the "middle third" of the pedestals. Tests of the stone, which was obtained in the vicinity of Wilkes-Barre, gave the following results:—

SINGLE 2-INCH CUBES, HAND-MADE.

| | Compression. lbs. per square inch. |
|---|---|
| Fine conglomerate . . . . . . . . . . | 15,000 |
| Red sand-stone from Laurel Run . . . . | 22,250 |

The latter stone is very fine grained, of regular composition and has well withstood exposure to the weather. The forty large caps were made of the red stone and were obtained by contract. The forty-two smaller caps were of fine conglomerate made by day-work. The trial-pits sunk near to the proposed structure indicated that the eastern precipitous slope was mostly rock, heavily seamed at and near to the surface; the western slope was found satisfactory, being generally hard-pan heavily studded with coarse gravel and broken stone; the bottom of the valley gave equally good indications before deep pits were sunk.

As the concrete was to be subjected to heavy pressures almost immediately, it was composed of one part of German Portland cement, two parts of sand and four parts of broken rock; the cement and sand were mixed dry and placed upon the wetted stones; as the mass was mixed, water was sprinkled upon it, care being taken that the mortar should become only so moist that it would barely "ball" when worked in the hand. The general dimensions of the concrete pedestals where rock was not found, were: 6 feet or 7 feet square at the top, offset at 2-foot courses to a base of 10 feet to 12 feet square at a depth of 6 feet; and from the bottom of the anchoring-spider to the top of the anchor-bolts, 5 feet 10 inches or 7 feet 10 inches, according to the height of the bents. The concrete was thoroughly rammed in layers of 6 inches to 9 inches, in courses 2 feet thick, the first layer of concrete being about 4 inches thick, well rammed into the ground; the bottom of each pedestal was placed at least 7 feet below the surface of ground except at rock foundations, as a precaution against frost. All the materials were carefully selected. No ironwork was placed upon the concrete until thirty days after it had been completed.

Panther Creek lies between bents Nos. 26 and 27, and is provided for by a paved and grouted channel 35 feet wide and 140 feet in length, with side walls 120 feet long averaging 6½ feet in height. The concrete pedestals were begun on the 11th April, and were completed on the 24th June, 1893. The quantity of concrete in a single pedestal varies between 7 and 83 cubic yards; the total quantity in the eighty-two pedestals is 2,353 cubic yards. The bottoms of the foundations are between 5½ feet and 21 feet below the tops of the cap-stones. Of the pedestals, thirty-five are founded on rock, thirty-five are on hard-pan, two are on boulders, eight are on compact gravel, and two are on clay and gravel.

The railway-line did not reach the site of the viaduct from the west until the 10th May, 1893; consequently, most of the cement, tools &c., had to be hauled by wagons over rough roads from the nearest railway station, a distance of about 7 miles, making the cost of cement delivered $3·60 per barrel. Good sand could not be found near to the work, and, after paying a royalty of 25 cents per load, was hauled upwards of 3 miles over heavy mountain roads at a cost of $3 per cubic yard delivered. Circumstances made it advisable to use hand-broken stone, which indeed the Author considers better for concrete than machine-crushed stone, as it is less shattered. The cost of quarrying, hauling and breaking stone averaged $3 per cubic yard.

| | $ | |
|---|---|---|
| Cost of the concrete (not including tools) . . . | 12·60 | per cubic yard. |
| ,, excavating pits . . . . . . . . | 0·95 | ,, ,, |
| ,, pointing and finishing pedestals . . . | 10·00 | each. |
| ,, 4 feet 6 inches by 4 feet 6 inches by 1 foot 6 inches finished cap-stones (red stone) | 45·00 | ,, |
| ,, setting cap-stones . . . . . . . . . . | 11·00 | ,, |

The four $1\frac{1}{4}$-inch anchor-bolts of each pedestal were set in the four corners of a cast-iron spider by adjusting-nuts above and below the casting; a wooden template was placed at the tops of the bolts; and when the concrete had been built approximately to the proper elevation, the spider at the bottom of the bolts and the template at the top were adjusted exactly to line and level. It was considered by the Author that however accurately the measurements might be made, it was yet desirable that a little allowance should be made for adjustment of the iron-work to the substructure; pieces of 2-inch iron pipe were therefore placed temporarily around each anchor-bolt and were wedged concentrically to the bolt; as the concrete was built up, the pipes were lifted; when the pedestal was completed and the pipe had been removed, the bolt was in the centre of a concrete cylinder $2\frac{1}{4}$ inches in diameter, thus allowing the long $1\frac{1}{4}$-inch bolt to be "sprung" considerably. Brass pipes were provided, but it was soon found that by careful manipulation the cement did not adhere to iron pipes. These pipes were moved, to break bond with cement, a couple of hours after the concrete had been rammed around them, but there were cases where ten hours elapsed. This device resulted admirably in the erection of the iron-work. After the erection, the holes were grouted from small channels cut in the tops of the cap-stones so that no grout should go between the sliding- and bed-plates of the columns. The cap-stones were set by means of sleeves of $1\frac{1}{2}$-inch pipe passing through the stones and held on the four anchor-bolts; these were set with great care upon full beds of cement mortar, yet, upon subsequently grouting the anchor bolt-holes, grout which had been poured down one hole frequently came up at other holes.

On the 5th April, quicksand was discovered at a depth of 10 feet in a trial-pit in the lower ground of the valley. This, being under the taller bents, caused much anxiety. Several pits were sunk through the gravel across the valley at distances of 60 feet on each side of the centre-line, and boring appliances were then used, with the idea of enclosing, if necessary, the quicksand with dams above and below the structure, according to a method devised by the Author.[1] These trial-pits showed a compact crust of firm gravelly hard-pan, worked with difficulty, ranging from 12 feet to 21 feet in thickness; beneath which was a body of quicksand 5 feet to 12 feet in depth, extending to a hard bottom at a depth of 21 feet to 35 feet below the proposed cap-

[1] Minutes of Proceedings Inst. C.E., vol. cix. pp. 436 and 437.

stones of the pedestals. The top of the quicksand was uniform in elevation, the longitudinal slope of the valley is slight, and as there was no likelihood of the treacherous material exuding elsewhere, it was decided to build upon the firm stratum; making the bottom of the pedestals as little below ground as possible, and spreading their bases so as to have not more than $\frac{3}{4}$-ton pressure per square foot, upon a strong stratum 6 feet to 14 feet thick. Work had been necessarily suspended on all the lower pedestals. By persistent, careful work, excavations for two of these pedestals, near the edge of the quicksand, were carried through this material to a hard bottom of large boulders and flat stones. It was deemed dangerous to attempt other such excavations. Where one of the pedestals of a bent was founded on boulders and the other on a broad concrete platform, provision was made for remedying any unequal settlement. The bases of the other pedestals were made 16 feet square. Some expense and delay were naturally incurred by these investigations. This understratum of quicksand caused great care to be taken with the design for the new channel, the bed of which was situated above the large footings of the pedestals. As each pedestal was built, a sample of the concrete used in it was placed in a mould, resulting in a complete set of 6-inch test-cubes of various ages. Twenty of the older cubes were sent to the United States Arsenal at Watertown, Mass., and were tested for compression on the 21st July, 1893, with satisfactory results (Appendix). The weight of these cubes was generally $16\frac{1}{2}$ lbs. (132 lbs. per cubic foot). The cost of the substructure was 45 per cent. of the total cost of the viaduct. When the iron-work was erected thereon, no adjustments whatever for line or gradient were necessary. For the satisfactory completion of the work great credit is due to Mr. M. S. Knight, of Dunmore, Pa., who acted as Resident Engineer, and to Mr. Irving A. Hodge, who superintended the construction.

*Superstructure.*—The forty-two plate-iron girder spans are placed apart 7 feet from centre to centre of the girders for straight single track, and are supported by towers 30 feet between bents, which are 7 feet in width at top with a batter of 1 in 6 transversely. The thirty 30-foot girders and the one 40-foot girder are 4 feet 6 inches deep; the ten 65-foot girders and the one 60-foot girder are 6 feet 6 inches in depth. The principal parts of the towers are of medium steel. The columns are of steel Z bars, and the bracing is of non-adjustable angle-bars. The floor is of wood, 14 feet wide, including a foot-walk on its northern side, with provision for a hand-rail. The erection of the viaduct was begun on the 28th June, and was completed on the 3rd August. The actual time occupied in the erection of the iron-work, exclusive of delays occasioned by non-delivery of iron and by wet weather, was twenty-eight days. The average number of men employed was about forty. An overhanging traveller built of Oregon fir was used, its extreme length being 162 feet 4½ inches, and the length of the overhanging portion 101 feet. The weight of the traveller with rigging ready for use was 54 tons. It was designed to handle 7 tons at the extreme point, and 10 tons at a distance of 30 feet from the end. It was carried on eight wheels 20 inches in diameter, four of which were under the main bent of the traveller, two on each side. The counter-weight used was 36,000 lbs., having its centre of gravity 45 feet back from the main bent. All the iron was run out from the top, lowered to the ground by means of a trolley and raised by the overhanging booms into position.

The time that elapsed from the commencement of the foundations to the completion of the structure was six months, and the work was carried out without the occurrence of any accident affecting life or limb.

# APPENDIX.

COMPRESSION TESTS OF CONCRETE CUBES MADE AT THE U.S. ARSENAL, WATERTOWN, MASS., JULY 21, 1893.

*Compressed Surfaces faced with Plaster of Paris to secure level bearings in the testing-machine.*

| Nos. | Age in Days. | Height. | Compressed Surface. | Area. | First Crack. | Ultimate Pressure. | Compression Lbs. per Sq. Inch. |
|---|---|---|---|---|---|---|---|
| | | Inches. | Inches. Inches. | Sq. Inches. | Lbs. | Lbs. | |
| 1 | 88 | 5·98 | 5·93 × 6·03 | 35·76 | 87,860 | 87,860 | 2,457 |
| 2 | 88 | 5·98 | 6·00 × 6·06 | 36·36 | 58,800 | 76,200 | 2,096 |
| 3 | 82 | 5·98 | 6·05 × 6·10 | 36·90 | 99,500 | 99,800 | 2,705 |
| 4 | 82 | 5·95 | 6·04 × 6·11 | 36·90 | 57,500 | 98,450 | 2,668 |
| 5 | 75 | 5·94 | 5·97 × 6·11 | 36·48 | 80,600 | 81,440 | 2,232 |
| 6 | 77 | 5·94 | 5·93 × 6·11 | 36·23 | 97,200 | 98,940 | 2,731 |
| 7 | 65 | 5·94 | 6·07 × 6·02 | 36·54 | 101,800 | 116,100 | 3,177 |
| 8 | 65 | 5·92 | 5·93 × 6·04 | 35·82 | 86,200 | 88,100 | 2,459 |
| 9 | 62 | 5·90 | 5·90 × 6·07 | 35·81 | 80,900 | 82,460 | 2,303 |
| 10 | 60 | 5·90 | 5·85 × 6·05 | 35·39 | 59,100 | 59,100 | 1,670 |
| 11 | 51 | 5·95 | 6·08 × 5·95 | 36·18 | 93,620 | 93,620 | 2,588 |
| 12 | 51 | 5·90 | 6·05 × 5·92 | 35·82 | 81,600 | 84,700 | 2,365 |
| 13 | 46 | 5·93 | 6·10 × 5·92 | 36·11 | 76,990 | 76,990 | 2,132 |
| 14 | 44 | 5·85 | 5·86 × 6·08 | 35·63 | 61,780 | 61,780 | 1,734 |
| 15 | 37 | 5·94 | 6·08 × 6·00 | 36·48 | 68,800 | 73,400 | 2,012 |
| 16 | 36 | 5·85 | 5·91 × 6·09 | 35·99 | 69,200 | 69,200 | 1,923 |
| 17 | 31 | 5·90 | 5·92 × 6·10 | 36·11 | 75,500 | 75,500 | 2,091 |
| 18 | 31 | 5·87 | 5·90 × 6·09 | 35·93 | 62,490 | 62,490 | 1,739 |
| 19 | 27 | 5·80 | 6·11 × 5·90 | 36·05 | 66,100 | 66,140 | 1,835 |
| 20 | 27 | 5·94 | 5·85 × 6·06 | 35·45 | 59,100 | 59,100 | 1,667 |