Civil and Mechanical Engineering.

OHIO RIVER BRIDGE AT STEUBENVILLE.

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A PORTION of the masonry for a bridge to connect the Pittsburgh and Steubenville Railroad with the Steubenville and Indiana Railroad, was erected in 1856, when the work was suspended. In 1862, the Western Transportation Company having arranged to complete the Pittsburgh and Steubenville Railroad to Steubenville, a lease of the franchises of the Holiday's Cove Railroad Company, with authority to erect the bridge over the Ohio River, was effected, and the work was executed under the auspices of the Trustees.

To the writer was assigned the duty of designing and superintending the erection of the iron superstructure.

By a revised location of some of the piers, the spans were reduced to four equal spans of 235 feet each, on the eastern side, between centres of piers, and three equal spans of 210 feet between centres of piers on the western side of the channel. The piers for the channel span are 90 feet in height above low water. They are 16 feet at the top, with a batter of 1 in 24. The adjacent undergrade spans are supported in a recessed chamber, four feet deep, in the sides of the piers, leaving an available thickness of 12 feet of masonry to support the channel span. The distance between the centres of these bearings is 320 feet.

An act of Congress required the channel span to be constructed so as to afford a clear opening of 300 feet between the piers and a clear height of 90 feet above low water.

These requirements rendered it necessary to support the track of the channel span on the lower chords; an arrangement which impairs in some measure the beauty and symmetry of the entire structure.

The bridge company desiring the completion of the structure in 1863, without in any manner obstructing the channel, no system of wrought iron construction then in use appeared available.

A selection had consequently to be made from the plans of composite structures in use, none of which had been extended to spans

of so great extent. The "Linville and Piper" patent truss was modified to meet the requirements of this particular locality, and adopted by the bridge company.

The description will be limited to an explanation of the peculiarities in the construction of the span over the channel.

The trusses are divided into 24 equal subdivisions 12 feet 3 ins. each, with two end panels 12 feet $6\frac{3}{8}$ ins., making the entire length from centre to centre of bearings 319 feet $0\frac{3}{4}$ in.

The height from centre of the lower chord to the top of the upper chord, at extremities is 28 feet, the upper chord having a camber of 9 inches, the posts radiating so as to render their bearing surfaces normal to the curve of the upper chord.

The lower chords consist of 8 lines of "Linville and Piper" patent upset eye bars, graduated in section to resist the maximum effects of the dead load, and of an uniformly distributed travelling load of 3000 pounds per lineal foot of superstructure, together with the transverse strain from the floor timbers, without producing a tensile strain in these bars, exceeding 10,000 pounds per square inch of sectional area.

The lower chords and the looped ends of the suspension diagonals are combined by means of connecting pins $4\frac{1}{2}$ inches in diameter, the suspension diagonals being so disposed between the chord bars and ribs on the bases of the posts as to produce a shearing strain only in the connecting pin.

The upper chords consist of two similar tubes of cast iron, having an external diameter of 15 inches at centre of each section, and slightly tapering towards the ends. These two sections are combined by intermediate cast iron ribs and webs, and terminate at the abutting surfaces in two double rectangular tubes with vertical ribs, between which pass the suspension bars.

By combining these tubes, greater width of abutting surface and consequently greater lateral stiffness was obtained. Under a maximum load the strain per square inch on upper chords does not exceed 10,000 pounds. The posts are also twin tubes of cast iron, 8 inches in diameter, combined by intermediate webs and ribs, and made in two sections, with flanged ends, through which and the intermediate parting plate, pass 16 bolts $1\frac{1}{4}$ inches to 1 inch diameter, securely combining the two sections of the posts to the parting plates and to each other. The parting plate has four projecting pieces, with concave bearings, to receive the truss rods, which are

secured near the top of the posts, and deflecting eighteen inches, bear against the parting plate at the centre of the posts, and passing through shoulders near the bases of the posts, are adjustable by screws and nuts at their lower extremity. The posts are graduated in thickness by Hodgkinson's formulæ, the factor of safety being assumed at one-eighth of the breaking weight. The suspension diagonals consist of four square bars, varying in section in proportion to the strains, and were rolled in one piece, without welds. The lower ends have loops or eyes, $4\frac{1}{2}$ inches in diameter, which receive the connecting pins.

At the upper ends, the section of the bar is circular, formed by upsetting the iron in moulds, under immense pressure, and then swaging the ends. Screws are then cut, the available section of the bar at this point, after deducting screw-threads, being equal to the sectional area of the square bar. The upper and lower lateral rods are graduated in size, decreasing from $1\frac{5}{8}$ inches diameter at the extremities of the span, to $1\frac{1}{8}$ inches diameter at the centre. The lower lateral rods have welded loops passing through eyes in the wide eye plates, secured on the ends of the connecting pins. They meet in a ring at their intersection, and are adjustable by screws and nuts. The upper lateral rods pass through the cast iron chords, and are adjustable by nuts bearing against angle bosses cast on the chords. A system of diagonals is also introduced between the posts and upper chords, the strut being placed at sufficient height to clear the traffic.

Heavy cellular pier plates of cast iron are interposed between the bases of the end columns and the masonry.

At one end provision is made for variations in length arising from changes in temperature by means of a series of rollers secured in a frame of wrought iron. The track is supported on longitudinal timbers of white oak, resting on the transverse white pine floor timbers, which are sustained by the wide thin eye bars that constitute the lower flange or chord. In consequence of the heavy Government contracts incident to the late civil war, and the scarcity of skilled labor, great delay was experienced in procuring the requisite materials; and the progress of the work was frequently interrupted. The erection of the shorter spans was begun in 1863. The channel span not being completed ready for erection during the stage of low water in 1864, its erection was deferred until the summer of 1865. To keep the channel open, and avoid risks from sum-

mer freshets, a wooden pier and two trestle abutments 40 feet in height, were erected to support two spans of wooden Howe truss bridge, on which were placed wooden trestles 25 feet in height, to carry the iron superstructure of the channel span. The erection of the channel span occupied about three weeks. The entire work was completed in August, 1865, without accident.

The general design of the deck spans is similar to that of the channel span. The end posts are vertical. The upper chords consist of cast iron tubes to resist the compressive strains, with two lines of rolled I beams, one at each side of each tube, to sustain the floor timbers supporting the track.

The channel span was fitted in the shops of the Pennsylvania Railroad Company, Altoona.

The Keystone Bridge Company of Pittsburgh were the contractors for the manufacture and erection of the seven deck spans, and the erection of the channel span; also, at the same time, for the manufacture and erection of the great double track iron span of 265 feet over the Monongahela River at Pittsburgh, the long line of plate bridge in South Pittsburgh, and the iron bridge at Saw Mill Run, all for the same line of road. The channel span over the Monongahela was constructed from the patterns of the channel span at Steubenville, such modifications being made as were necessary to adapt the bridge for a double line of rails.

All these bridges have been constructed by the aid of the most approved machinery; the bearings being actually planned and the eyes in the eye bars of chords being drilled with so great accuracy that no variation exceeding 100th part of an inch was allowed. To test the strength of the large tubes, and the wrought iron bars, chords, &c., a hydrostatic testing machine was provided, capable of exerting a compressive force of 675 tons on columns 3 feet diameter and 30 feet in length, and a tensile strain of 130 tons on bars 40 feet in length, or on any intermediate size; thus enabling the engineer to test to the proof strain, all the materials used in these structures.

Owing to unavoidable delays in the preparation of this machine, it was possible to test only a few of the posts, chords, bars, &c., but the results demonstrated conclusively the accuracy of the data from which the proportions of the tubes had been determined.

The completed structure was tested by passing a train of engines and cars loaded to their utmost capacity with railway bars, the load

entirely covering the channel span, and amounting to about $1\frac{1}{4}$ tons per lineal foot. The deflection being carefully indicated by a pencil point on a rod fixed to the scaffolding, free from the structure, did not exceed five-eighths of an inch. The weight of cast iron in the channel span is greatly increased by the material consumed in the webs and ribs combining the twin chord tubes and posts, also in the additional system of transverse struts to resist the effects of the diagonal bracing. By combining the posts and chords in this manner, the effective width of each truss was increased to 45 inches, thus adding to the lateral stiffness of the posts and chords, and ensuring the lateral stability of the bridge. This system of combining and trussing the posts was new and untried. This span was the pioneer of long spans of iron truss bridges on this continent, and to ensure success it was deemed prudent to allow considerable margin on the side of safety.

The weight of cast iron consumed in the construction of the channel span was 2136 pounds per lineal foot, and of best refined wrought iron 1423 pounds per lineal foot.

The line was opened in September, 1865, and since that time the bridge has sustained the constant heavy traffic without developing any defects, or requiring adjustment.

Since the completion of this bridge, arrangements have been effected with the "Union Iron Mills" of Pittsburgh, to furnish the "Linville and Piper" patent wrought iron tubular columns, "Upset Chord Bars," and wrought iron beams for the patent upper chords, which are now generally adopted in the construction of long spans. They would have been employed in the Ohio River Bridge in preference to cast iron upper chords and columns, if delays in the preparation required to manufacture these shapes had not been apprehended.

Self-Registering Compass.—An instrument of this description, devised by Captain Albini, of the Italian Navy, and constructed by Messrs. Elliot Bros., of London, was exhibited at the late *Conversazione* of the Institute of Civil Engineers. It consists essentially of a compass, with a card carrying types at its periphery in such a way that, by an attached clockwork, an impression may be made at stated intervals on a band of paper, from whatever type is over a certain point at these times. Thus clearly an almost continuous record of the ship's course may be automatically produced.