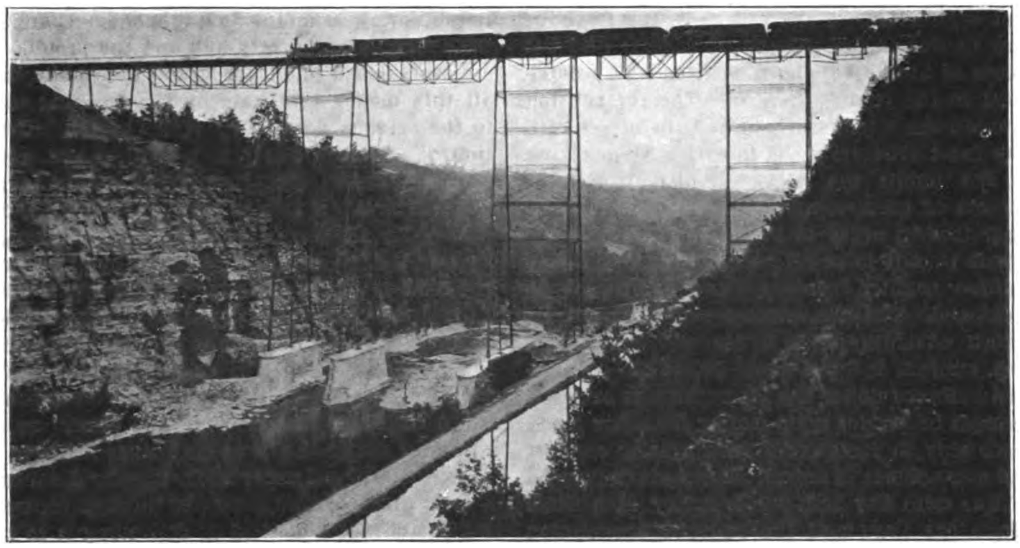


First Iron Viaduct, Built in 1875.

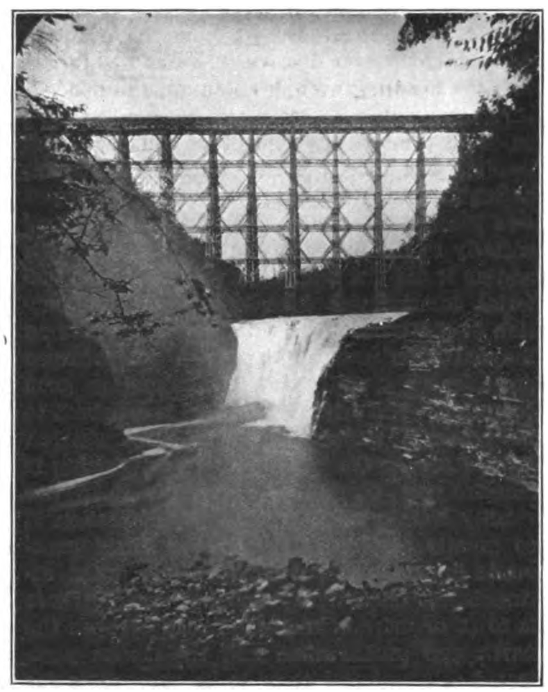
THE NEW SPANS OF THE PORTAGE VIADUCT, ERIE R. R.

DESCRIPTION OF THE THIRD BRIDGE BEARING THIS NAME.

The Portage viaduct, which for many years was famous as one of the highest railroad bridges in the world, is a single-track structure officially known as Bridge No. 16 of the Buffalo Division of the Erie Railroad. It consists of a series of spans connecting towers seated on low-masonry piers built on solid rock in a deep gorge with precipitous sides. It has a total length of 819 ft. between back walls and a height of 235 ft. 2 in. from the bed of the stream to the base of rail. The original structure was a timber trestle built in 1852, and replaced in 1875 by a light wrought-iron structure with pin-connected members, designed by the late G. S. Morison, then bridge engineer for the Erie Railroad. It contained about 639 tons of iron manufactured and erected by the Watson Bridge Co.

As the traffic of the road increased in weight and volume and the iron spans became inadequate, plans were made for replacing them with heavy riveted trusses and plate-girder spans for increasing traffic at a higher speed. They are proportioned for a train load of 4,000 lb. per lin. ft., preceded by two coupled 123½-ton locomotives with 53-ft. wheel bases and 35,000 lb. on each of four pairs of drivers on 4½ ft. centers. This train loading is nominally rather light in comparison with that adopted by some other important roads, but it is compensated for by the low unit stresses allowed, which result in the use of sectional areas about as heavy as are found in any corresponding structure. The train load is considered to be, in reality, a matter of little consequence, since the longest span on the Erie system is only 223 ft., and is therefore nearly covered by the locomotives. There are bridges and viaducts of total lengths up to more than 2,000 ft., but they are all made up of spans shorter than that above mentioned, so that their severest stresses are caused by the locomotives. Longitudinal stresses are assumed at 2 per cent. of the maximum live load, and the wind pressure is assumed at 600 lb. per linear foot.

The old towers and foundations were carefully inspected and found to be in good condition, and as the former structure had been intended ultimately to carry two tracks, the substructure was considered adequate for the increased dead and live loads of a single track. All of the towers and masonry except one abutment were, therefore, retained, and the reconstruction consisted in the replacement of the old track, floor system, girders and trusses by new spans supported on the old towers. The old girders and trusses were seated directly on the caps of the tower columns and were spaced 19 ft. 10 in. apart on centers. The track was carried on 8x16-in. cross-ties 22 ft. long and 14 in. apart on centers which rested directly on the top flanges of the old girders and the top chords of the old trusses. The new structure was designed entirely to facilitate its substitution for



Original Wooden Viaduct; 1852.

the old spans without interrupting the regular train service, and the width of the old span enabled the new one to be erected complete between them and be supported on new transverse girders without adding to the stresses in the old spans or throwing the latter out of service until the new were ready to receive the traffic.

The new trusses and girders are spaced 14 ft. apart on centers, thus clearing the tower columns, and are seated on the top flanges of heavy new transverse girders field-riveted to the inner faces of the columns several feet below their tops, some of which remain projecting above the upper flanges of the girders, while others are cut off even with the new girders.

The three truss spans are seated on special transverse girders 10 ft. deep made with solid web-plates at the end and open center panels X-braced with heavy diagonal members, as shown in the detail. Each end of the girder is seated on a kneebrace bracket with double webs. The depth of the connection is calculated to afford sufficient stiffness to provide all necessary sway-bracing and compensate for the omission of diagonals in the upper panel of the tower. Each end of the girder is connected to the tower column by seventy-four ⅞-in. field rivets at each end, exclusive of those in the brackets. The 50-ft. connecting girder spans are seated on solid-web transverse plate-girders 6 ft. deep, with similar double-web kneebrace brackets at both ends. These girders have forty-four ⅞-in. field rivets at each end in the connections to the columns, and, like the other girders, have vertical web-stiffeners under the loaded points only. The arrangement of field rivets is such that all of them could be easily driven.

The 100 and the 118-ft. spans have pin-connected Pratt deck trusses, respectively 14 and 15 ft. deep on centers. The details are substantially alike, and each of them is designed to carry the track ties directly on the top chord. Both top and bottom chords are connected at panel points by horizontal transverse struts with I-shaped cross-sections built of pairs of angles back-to-back latticed. The lower struts have horizontal connection plates on the bottom flanges, which engage the feet of the vertical posts, and their end web tie-plates project above the top flange angles to form gussets field-riveted to the inner faces of the vertical posts. The upper struts have jaw-plates engaging the flanges of the chords. The upper jaw-plates in the top struts receive the pin connections for the clevis-ended, top-lateral diagonal rods. The lower-lateral struts clear the inner ends of the bottom-chord pins, and the latter are fitted with wing plates in vertical planes which receive the pin connections for the clevis-ended bottom lateral rods. At each panel the top and bottom struts are connected by pairs of X-brace angles riveted together back to back and engaging kneebrace plates between the struts and vertical posts. At the end of the span the lower strut is replaced by a pair of angles back-to-back, and a plate-girder is seated on bracket plates below the upper transverse strut. The top chords are each made in three lengths connected by two field-riveted splices with double-web plates field-riveted to both members and a single cover-plate shop-riveted to one member.

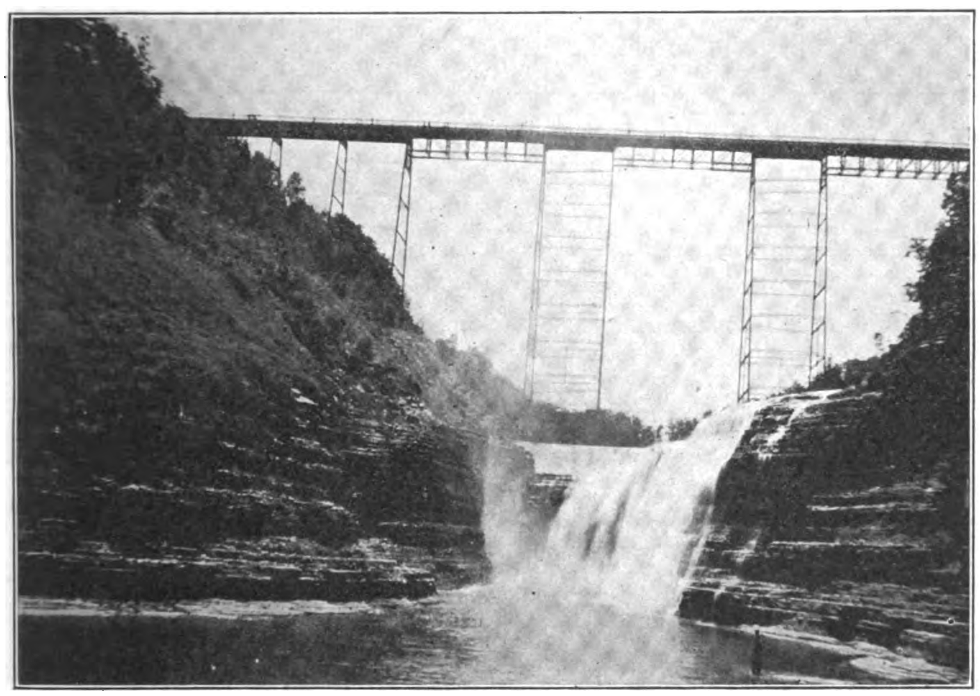
The details of the vertical end posts are special in order to provide for the requirements of erection, which made it necessary to assemble and swing the spans before they were connected to the end posts. These posts in reality served as auxiliary towers united by their transverse bracing, and providing supports for the jacks by which the trusses were lowered from their first positions to their final seat on the upper ends of the posts. On this account the posts do not engage the end top-chord pins, but have horizontal cap-plates on which the lower flanges of the top chords were eventually seated. The top chords are connected by end horizontal transverse struts like those at intermediate panels, and the end posts are connected by transverse sway-brace frames enabling them to act as independent bents before their connection with the trusses. The upper member of these sway-brace frames, instead of being an ordinary strut like the lower member, is a plate-girder which was required to provide support for the jacks by which the trusses were lowered to position after they had been swung and while they were under train service. The feet of the posts have horizontal base-plates and vertical inside web-plates shop-riveted to them and projecting some distance to receive the field-riveted connections to the end lower-chord sections, which are riveted members two panels long. At one end of each 100-ft. span, the connections to the lower chord are made with bolts in 3x1-in. slotted holes. This is considered necessary in order to

allow for temperature movements, because the vertical posts are rigidly attached to the fixed columns and no other adjustment is provided for the trusses.

The longitudinal girders, nominally 50 ft. long, vary in actual length back-to-back of angles from 48 ft. 4½ in. to 50 ft. 2½ in. They have a uniform depth of 6 ft. .04¼ in. back-to back of angles, and the webs are made in four-sections with three field-riveted splices, each having 36 rivets in two vertical rows. The girders are braced at each splice by a vertical transverse frame with two panels of X-brace angles. The panels between these frames are X-braced with the top-lateral system of diagonal rods with screw ends, which pass through 4½-in. slotted holes in the web of the girder just below the top flange. Their nuts take bearing on bent plates riveted to the outsides of the girder webs.

Each girder is divided into panels of about 6 ft. by pairs of vertical web-stiffener angles and fillers. At the ends these angles in adjacent girders are field-riveted together through their outstanding flanges, so as to splice them rigidly and make them form continuous girders except at expansion points, where they are bolted instead of riveted and have slotted holes for the lower flange connections to the cross girders. The ends of the girders adjacent to the trusses are similarly riveted to the end vertical posts of the trusses, and are also seated on solid-web kneebraces, field-riveted to both members. At alternate panels an additional web-stiffener angle is field-riveted to the inside of the girder with clearance from the regular stiffener angle sufficient to receive between their flanges the connection plate for the sway-brace frames. The upper flanges of these frames are field-riveted to horizontal connection plates slotted to clear the stiffener angles and field-riveted to the girder flanges with two rows of rivets.

After the erection of the new spans, it was considered that lateral and transverse stresses would be satisfactorily transmitted to the substructure through the sway-brace frames, and the deep new transverse girders in the tops of the towers. Separate provision was required to transmit the longitudinal stresses to the bracing in the planes of the tower columns, which before had received it directly from the old trusses and girders in the former structure. To accomplish this, the tops of the columns which directly supported the 50-ft. spans are cut off flush with the top flanges of the new transverse girders and capped with horizontal plates, field-riveted to the columns and the girders; these horizontal plates have projecting wings on each side bent downwards to receive the pin-connections for the longitudinal diagonal rods in the battered planes, which were cut down to the required length. At the ends of the truss spans the top chords of the latter are braced to the tops of the tower columns with short inclined struts. The columns are not cut off, but their tops are capped, as previously described, with bent plates that receive the riveted connections of these struts and of another set, which are field-riveted at the opposite end to the webs of the 50-ft. girders. Their points of connection to the girders are connected by horizontal transverse struts formed with pairs of heavy angles. This system of braces provides a balanced framework and transmits the longitudinal stresses from both truss and girder spans through the wing plates on the tops of the columns which engage the upper ends of the longitudinal diagonal brace rods, as already described. This system was designed after the superstructure had been built and has been found to give satisfactory results, the viaduct developing abundant stiffness and rigidity under heavy train traffic.



New Steel Spans on Old Iron Towers.

The weight of new steel in the viaduct is about 500 tons. It was designed by Mr. Mason R. Strong, engineer of bridges, under the direction of Mr. C. W. Buchholz, then chief engineer and now consulting engineer of the Erie Railroad Co. The girders and trusses were built at the McClintick-Marshall bridge shops, and were erected by the railroad company's regular erection force in charge of Mr. W. H. Wilkinson, inspector of bridges.

A VERTICAL BLOWING ENGINE, installed at the North-Eastern Steel Co., at Middlesbrough, England, and having compound steam cylinders 48 and 90 in. in diameter, and two 90-in. air cylinders, showed, according to indicator cards, an efficiency of compression of 92.5 per cent. and a mechanical efficiency of 84.1 per cent., makinga total efficiency, that is, the ratio of the ideal work required to compress the air isothermally to the actual work in the steam cylinders, 77.7 per cent. The engine, which was described in "Engineering," was built by Messrs. Davy Bros., Ltd., Sheffield.

Time Required for the Construction of Large Public Works.

In connection with the studies for the Isthmian Canal and the various schemes proposed within the past year or two for the additional water supply of the city of New York, statements have from time to time been made in the technical and daily press as to the time required for the construction of the works. This time element is frequently a most important consideration, particularly in the case of additional water-works needed to supplement a system already outgrown, or nearly so. In estimating the time which must elapse before a proposed scheme can be carried out, it is often the fact that a sufficient allowance is not made for the inevitable preliminaries of legislation and organization for public works, for delays due to possible strikes or litigations, or to the inefficiency or financial inability of contractors selected by the ancient and honored custom of awarding the work to the lowest bidder. Impractically hopeful estimates of the date at which a project will be completed add to the difficulties and anxieties of the engineers charged with carrying them through and indirectly cast discredit on the profession in general. These facts have led The Engineering Record to present at this time the records of several large and very well known municipal undertakings.

The results of the study are set forth in the form of the following brief partial chronologies of the Massachusetts Metropolitan water-works, the New Croton system for the supply of New York City, the Boston subway, the New York Rapid Transit Railroad, the Massachusetts Metropolitan sewerage systems, and the Philadelphia filtration plants. These works have all been so fully described in this journal that very little explanation of them is necessary. It is merely proposed to point out in a general, approximate way the time consumed in preliminaries and in some of the unexpected and intentional delays, and the total calendar time that passed between the inception and the completion of the works, without going into tiresome details of but limited value. It seems scarcely necessary to suggest caution against the unintelligent and indiscriminate applications of, or deductions from, the facts here presented. Reasons for delays or for rapid progress can be found stated or suggested in the records of the works, to some extent.

In its session of 1892-93, the Massachusetts legislature directed the State Board of Health to investigate and report upon a scheme for supplying the Boston metropolitan district with water to supplement, and in some towns supplant, the then existing sources of supply. On July 6, 1893, the Board instructed its chief engineer, Mr. Frederic P. Stearns, to take immediate charge of the investigations, and he at once began the organization of an engineering force. After nineteen months of diligent labor the Board presented to the legislature in February, 1895, a report, remarkable for its thoroughness and completeness, embodying the results of the studies of the engineers and other experts, and suggesting a well-considered scheme for a system of works, for organizing the district, and for providing the necessary funds, accompanied by a draft of an act for putting the scheme into effect. Surveys, borings and maps were made, and designs for some features of the works were elaborated with no little detail.

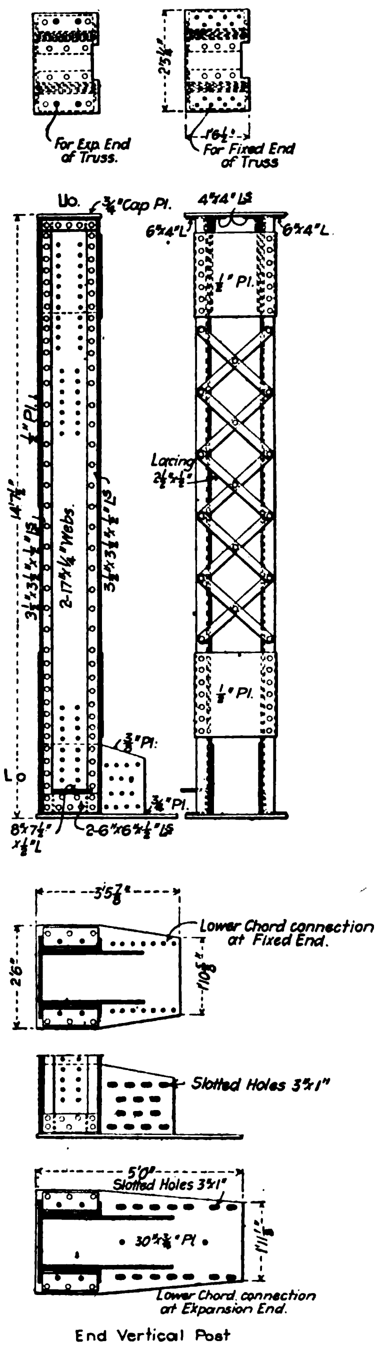
On June 5, 1895, "an Act to provide for a Metropolitan water supply" was approved by the Governor. Members of the Metropolitan Water Board were appointed soon after, met for organization July 19, and appointed a chief engineer July 24. The organization of an engi-

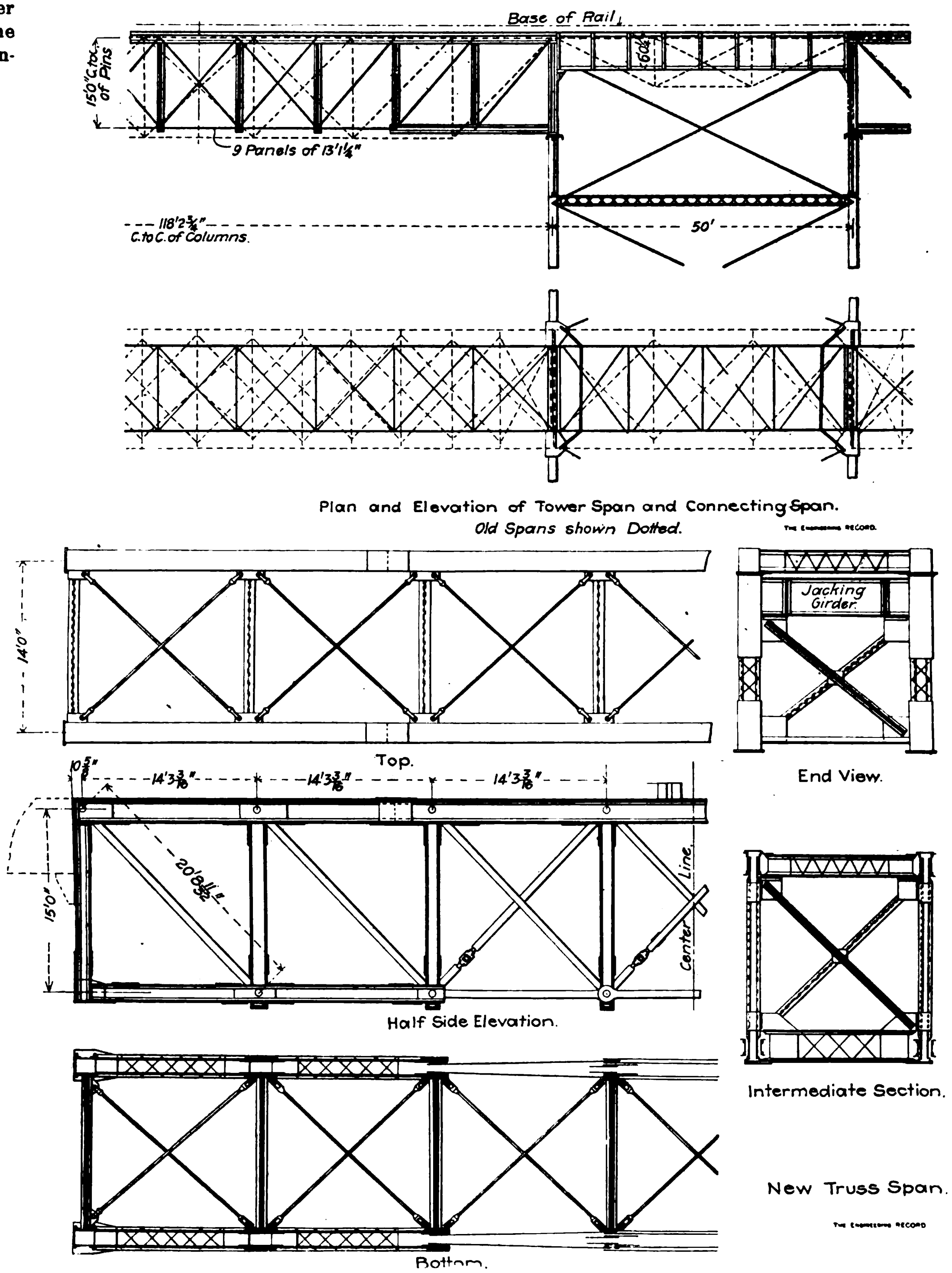
neering force was begun immediately, the chief engineer and most of his principal associates, as well as a number of the subordinates, having been connected with the preliminary investigations. About Aug. 1 the final location surveys for the Wachusett aqueduct were begun, and on Aug. 7 the final borings for the examination of the site of the Wachusett dam. On Feb. 14, 1896, eight months after the approval of the act, the first aqueduct contract was let, for the construction of a tunnel 2 miles long, and the last important contract for the aqueduct, for an open channel 3 miles long, was awarded Sept. 22, 1896, fifteen and a half months after the approval of the act. The tunnel and the 7 miles of cut-and-cover aqueduct were substantially completed by December, 1897, and the open channel by March 7, 1898, on which date water was first conveyed through the aqueduct, two years and nine months having elapsed. This aqueduct has a capacity of 300,000,000 gal. per 24 hours, and its construction was pushed vigorously. Not until Oct. 1, 1900, was the principal contract for the Wachusett dam made, but the early construction of a temporary dam and flume as portions of the works for the control of the river during the building of the main dam rendered possible the partial utilization of the new source at the date given above. It is expected that the dam will be completed during the summer of 1905.

Meanwhile the stripping of the surface soil from the great reservoir, the building of two very large earth dikes, the relocation of highways and railways, the laying of large pipe lines, and the building of reservoirs in the distribution system, the erecting and equipping of pumping stations, and the constructing of other parts of the works were also in active progress. Next fall will, doubtless, see the practical completion of the system, ten years and three months after the approval of the Metropolitan water act, and about twelve and a half years from the date of the beginning of the investigations by the State Board of Health.

Simultaneously with the construction of the Wachusett works, the Metropolitan Water Board built the 300,000,000-gal. Weston aqueduct to supplement the two old aqueducts conveying water to the distribution system from Lake Cochituate and the Sudbury River. In February, 1899, surveys and studies for this aqueduct were begun, but some preliminary studies, including a fairly careful location, had been made by the State Board of Health. On Sept. 24, 1900, the Weston aqueduct department of the engineering force was established to carry on the construction, and on May 9, 1901, the first contracts were let, two years and three months after the beginning of the final surveys. This aqueduct has a total length of 13.4 miles, comprising five tunnels aggregating 2.3 miles, 9.1 miles of cut-and-cover, 1 mile of pipe siphons, and 1 mile of open channel and equalizing reservoir. On Dec. 29, 1903, the first water was delivered into the district through the new aqueduct, four years and eleven months after the beginning of the final surveys, and two years and eight months after the first contract was signed.

From their inception the Metropolitan works were vigorously pushed (except as financial economy required the deferring of certain parts), by an unusually able management in both administrative and engineering branches, from the board and the chief engineer down, almost, if not quite, absolutely free from political influence. Unusual pains were bestowed upon the preparation of the various features of the works before construction was begun, and inspection was intelligent and thorough. Never-

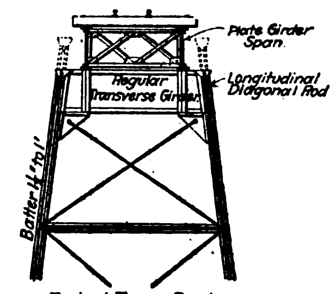




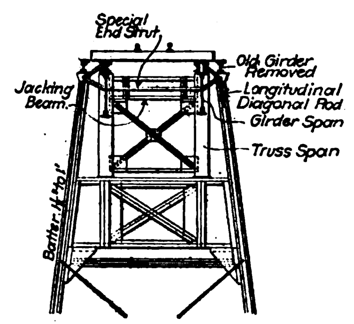
Details of Old and New Spans of Portage Viaduct, Erie Railroad.

theless, a few unforeseen difficulties developed and some trouble and delay were experienced on account of contractors who proved unequal to their tasks. The cost of constructing these works, exclusive of land and damages for water rights and other claims, will be about $26,000,000 in round figures.

Published reports of the new Croton works do not give their history in so much detail, but the principal steps in their progress can be briefly stated. After some preliminary agitation and investigation, the Aqueduct Act, so-called, was passed by the Legislature in June, 1883, and the commissioners met for the first time on Aug. 8. On Dec. 13, 1884, eighteen and a half months later, the contracts for the first sections of the New Croton aqueduct were awarded. On July 15, 1890, this aqueduct was first put into service, although not wholly finished, seven years and two months after the passage of the act; it is about 33 miles long, mostly in tunnel, has a capacity of 300,000,000 gal. per day and cost about $25,000,000 for construction work.



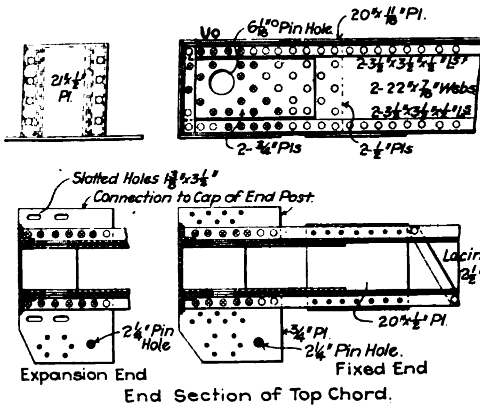
Typical Tower Bent.

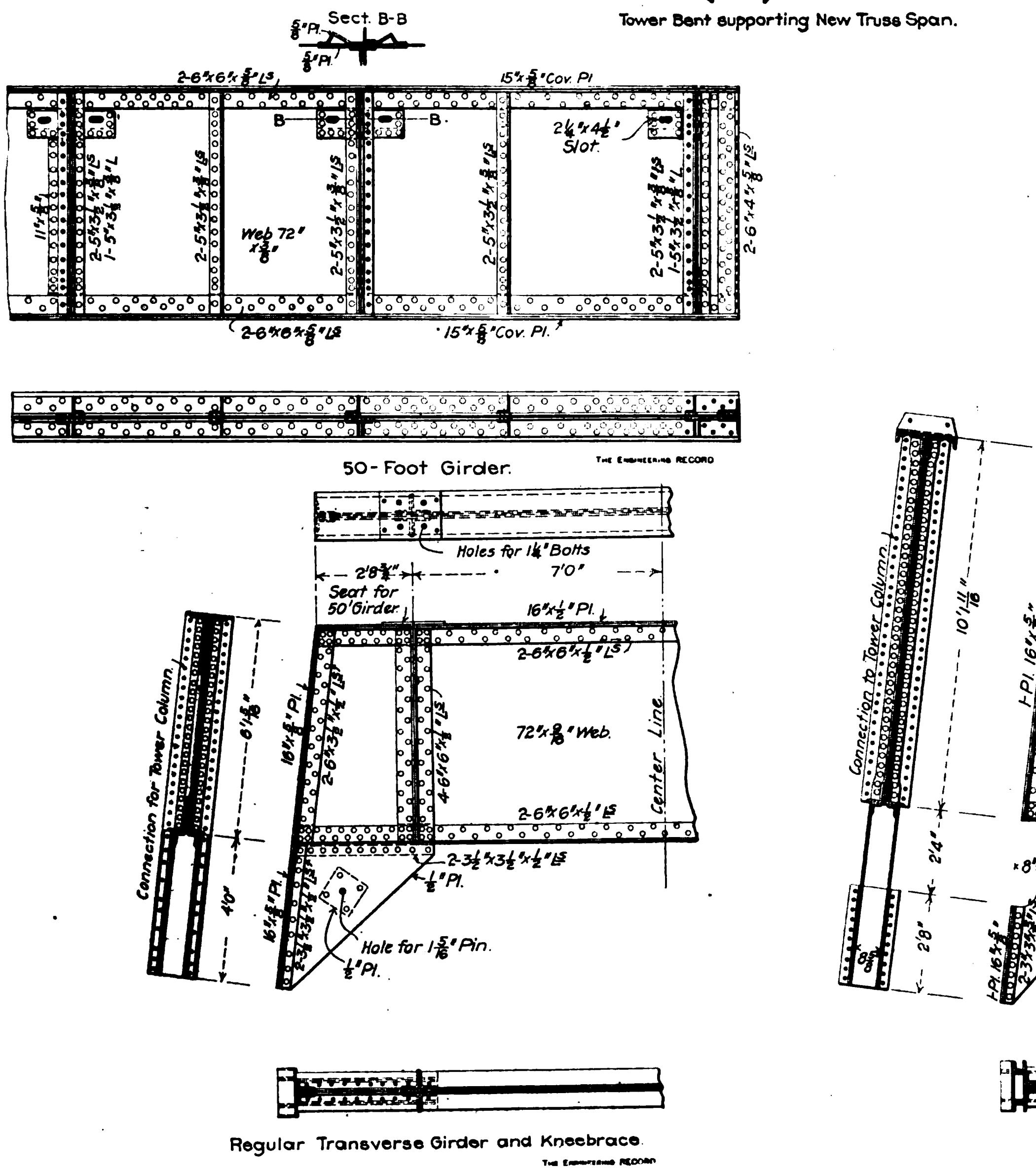


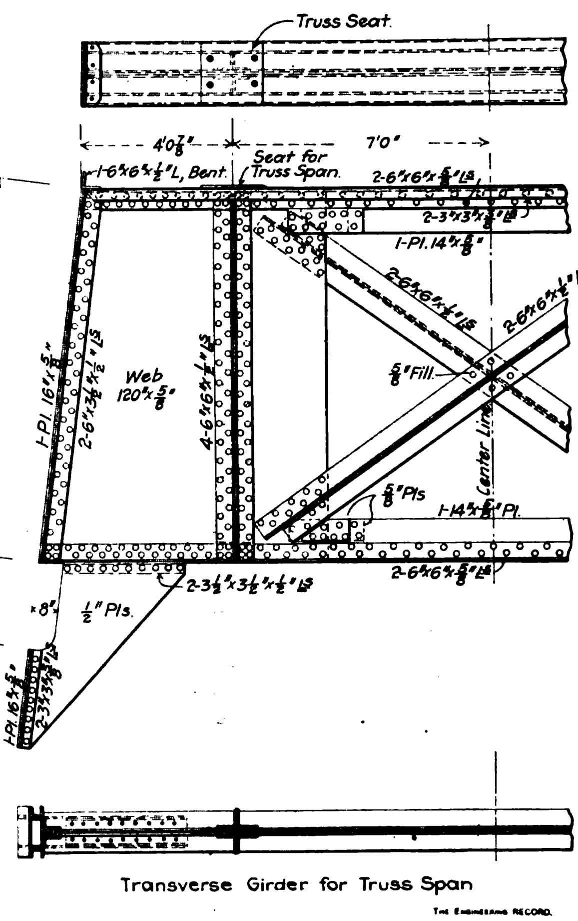
Tower Bent supporting New Truss Span.

amount expended during these years by the Aqueduct Commission for construction, engineering and administration, not including land, is approximately $42,000,000. No little time has been lost by inefficient contractors on some parts of the work, by investigations, by changing the legal working day from ten to eight hours and by strikes, while the progress has been further impeded by the general slowness of municipal methods.

Another example of well managed work is the Boston rapid transit system, but in this case, also, more time has passed between the beginning and the completion than would ordinarily be estimated as required. On June 3, 1891, by act of legislature a commission was created to promote rapid transit for the city of Boston and its suburbs. On April 5, 1892, this com-







Details of New Girders and Top Chord of 100-Foot Span, Portage Viaduct.

On Feb. 7, 1887, the Aqueduct Commissioners adopted a resolution for investigating the design and location of the principal dam, and on March 7, 1888, the board of experts on the Quaker Bridge dam was appointed, four years and nine months after the act was signed. The experts reported Oct. 1, 1888, but it was not until Jan. 22, 1891, that the commissioners adopted a resolution for constructing the New Croton dam at the Cornell site. On Aug. 26, 1892, a contract was made for building the New Croton dam, the Quaker Bridge site having been abandoned. Thus nine years and three months were consumed by investigations, delays and the preparation of drawings and specifications for the principal dam. It is now confidently expected that the New Croton dam and reservoir will be completed by October, 1905, twenty-two and a half years from the date of the act and over thirteen years from the signing of the contract. During the twenty-two years, however, four other impounding reservoirs with their dams and appurtenant works have been completed and Jerome Park reservoir, a very large distributing reservoir, has been about three-quarters completed. The total

mission presented a long report with many detailed studies, maps and drawings. After some other investigations, an act was approved July 2, 1894, under which the Boston Transit Commission was appointed. On March 20, 1895, the first contract was awarded, nearly three years and ten months from the date of the first act and eight and a half months from the final act. During September, 1897, a portion of the subway about 0.8 mile long was put into service. Subsequently other sections were put into service from time to time, and the East Boston tunnel was opened to travel on Dec. 30,

THE RECONSTRUCTION OF THE PORTAGE VIADUCT.

AN EXPLANATION OF THE METHOD OF RECONSTRUCTION WITHOUT INTERRUPTING TRAFFIC.

The Portage viaduct is officially known as bridge No. 16 of the Buffalo Division of the Erie R. R. It is a single-track structure 819 ft. long and about 235 ft. high from the bottom of the river to the base of rail. It consists of six towers supporting plate-girder and truss spans of from about 50 to 118 ft. long. Originally it was built of timber, and for a long time after its completion in 1852, was famous for its height and imposing appearance where it crosses a rocky chasm a short distance above a beautiful waterfall. It was replaced in 1875 by a light pin-connected wrought-iron structure carrying a single track on long and deep ties laid across the top chords of the trusses, which were spaced about 20 ft. apart and were supported directly by the battered columns of the towers. It was originally intended to add at some time a second set of trusses close to the original ones, and from the four lines thus secured support a double track. This plan was never carried out, and when it became necessary to provide for heavier traffic, it was found feasible to support modern trusses and girders on the existing towers and masonry which were in good condition. New spans were, therefore, designed with special care to provide for their erection and the maintenance of traffic without interruption, and the reconstruction was successfully accomplished in 1903.

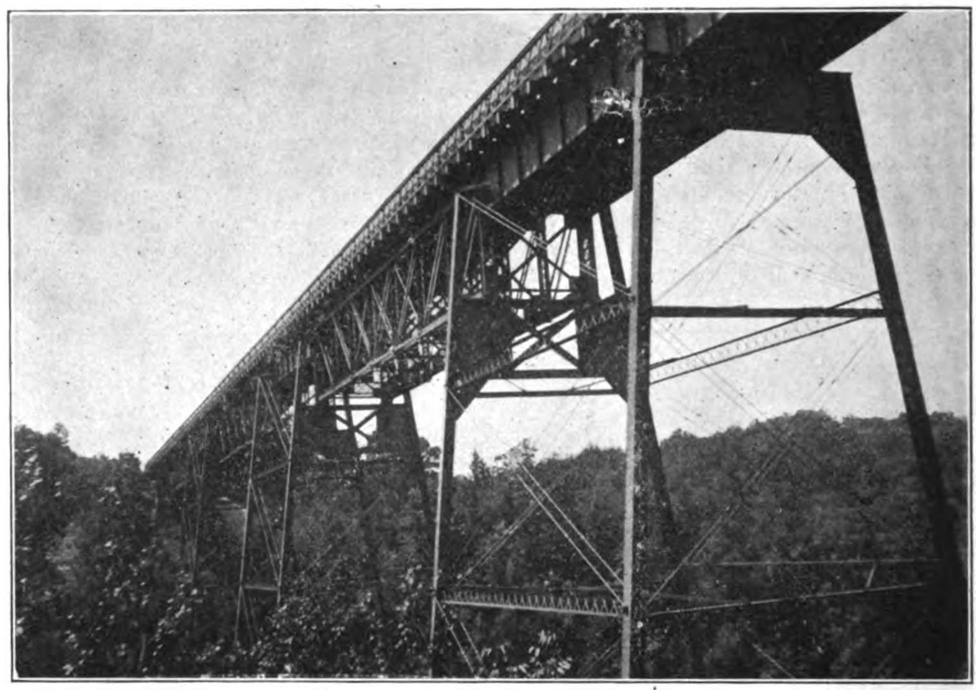
The new work was illustrated and its principal features were described in The Engineering Record of February 4, and consist essentially of 50-ft. deck plate-girders in the tops of the towers and between the shorter towers with two 100-ft. and one 118-ft. pin-connected deck Pratt truss spans between towers over the deepest part of the gorge. All of the spans are carried by new transverse girders riveted to the inner faces of the columns in the upper stories of the towers.

The old spans were all pin-connected trusses with their top chords seated on the column caps 19 ft. 10 in. apart on centers. In order to clear them, the new trusses and girders were made 14 ft. apart on centers, so as to have transverse clearance between the tower columns inside the old trusses. The panel points and transverse bracing were made different from those in the old spans, so that the members of the new structure would clear those of the old structure, as indicated by the accompanying diagram of one tower span and part of the 118-ft. span, which are typical of the whole viaduct. A general plan and elevation of the complete viaduct was published in The Engineering Record of February 4.

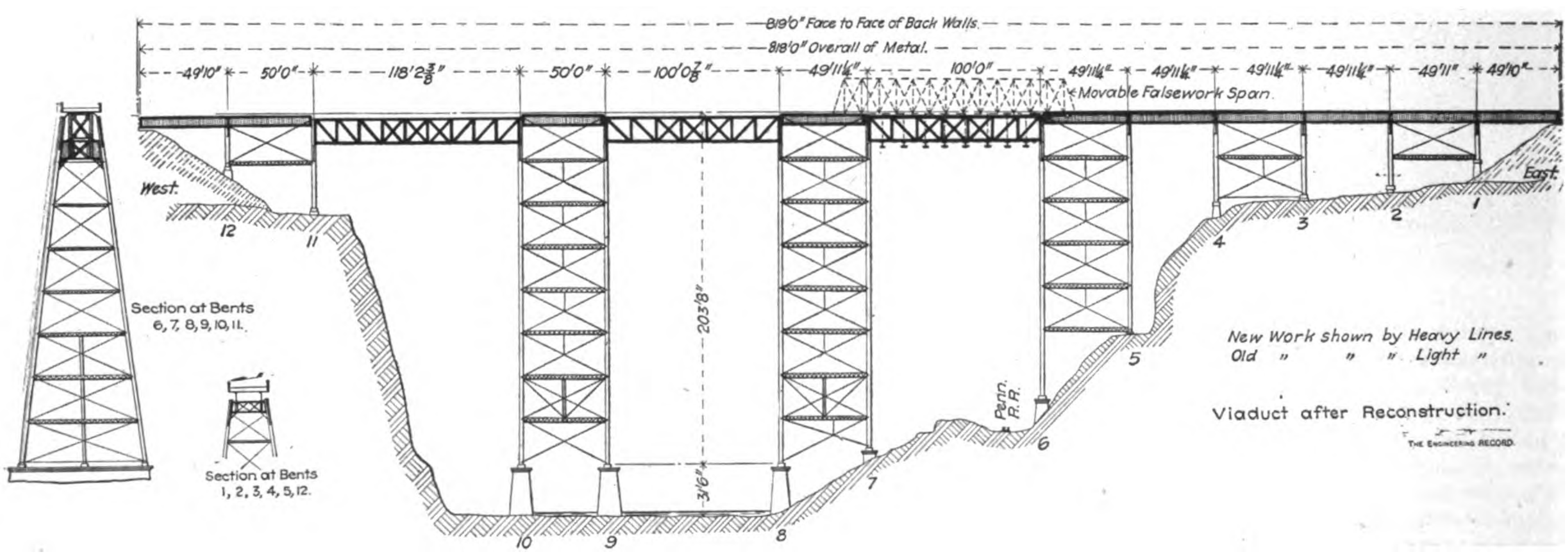
The sequence of operations and the details of the work were carefully determined in advance before the erection was commenced, and the erection was executed in exact conformity to these plans. The principal operations were connecting the new transverse girders to the tops of the tower columns; assembling on them the 50-ft. plate-girder spans and replacing the old track on them; assembling the truss spans above their required position on a platform suspended from falsework trusses; suspending the old track from the new trusses; removing the old trusses; lowering the new trusses to final position and laying the permanent track on them.

Operations were commenced by installing at the end of the viaduct an air compressor driven by a 22-h.p. Fairbanks-Morse gasoline engine. This was equipped with a receiving tank adjacent and an auxiliary tank in the middle of the viaduct, and distributed compressed air to all parts of the structure through a 1½-in. pipe with outlets about 50 ft. apart for flexible connections or manifolds.

Light working platforms in the tops of the towers were suspended from the track ties by 1-in. vertical rods with welded loops at both ends; and workmen on them cut away the lattice-bars on the inner sides of the battered posts and drilled holes for the connections of the new transverse girders. These holes were scribed from cast-iron templates through which the holes in the girders had previously been drilled. The holes in the columns, except in inaccessible positions where they were ratcheted by hand, were drilled by pneumatic tools manufactured by the Chicago Pneumatic Tool Co. There were about 2,200 holes 15/16-in. in diameter, and they were drilled at the rate of ten per hour by the pneumatic tools and four per hour by hand. While this work was in progress a 20-ton derrick was erected in the storage yard for unloading materials. It had a 42-ft. boom and was provided with one stiff-leg and two guys. With it the materials were piled up indiscriminately as received and sorted as delivered for use in the structure. A two-bent wooden gantry traveler was also built to run on rails laid outside of the track on the regular ties of the old bridge. It had sufficient clearance for the train traffic to pass through it, and it could be left in any position where it was required without interrupting trains. It was made with very deep overhead transverse bracing and had two cantilever jigger beams, from which tackles were suspended about 3 ft. clear of the front bent. The rear end of each jigger beam was anchored by



Tops of Old Towers with New Girders and Spans.

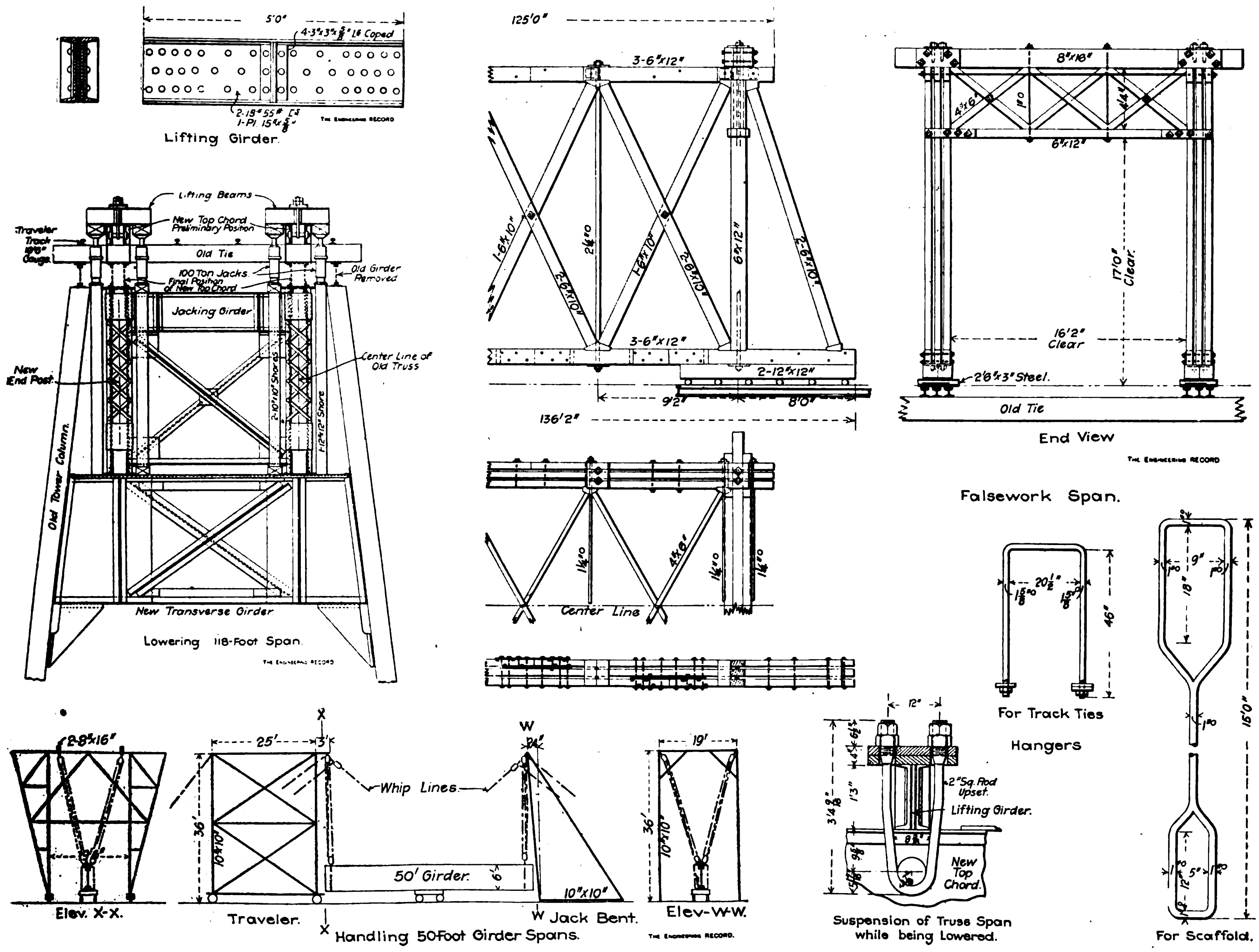


Reconstructed Portage Viaduct, Erection Traveler Shown Dotted.

a ¾-in. steel wire cable made fast to the old trusses.

The 10-ton transverse girders were delivered on trucks to the traveler, which lifted them by a single tackle hitched near one end of the girders and lowered them vertically between the ties of the old bridge floor. When they were clear underneath, a tackle from the other jigger beam was hitched to the opposite end of the girder and both tackles were operated to hoist the girder into a horizontal position and swing it to place between the tower columns, to which it was immediately connected by assembling bolts through all of the field-rivet holes. Riveting gangs closely followed the erectors and replaced the bolts by rivets, most of which were driven by pneumatic hammers. A girder was put in position and bolted up without obstructing the track more than about one hour, ties were removed from the old tower span by two whip lines attached to the traveler, and two attached to the jack bent, and were loaded on trucks and carried a short distance away. The top laterals and sway-bracing were then removed from the old span, leaving the bottom struts and laterals in position. The two new girders were then simultaneously lowered to their seats on the new transverse girders, their sway frames were bolted in place and their lateral rods were put in with the aid of the whip lines, which afterwards replaced the old ties and track on the new girders. The whole operation required about 2½ hr. from the time the old span was out of service until the new span was in service. Afterwards the old trusses and bottom lateral and transverse struts were removed piecemeal by the whip lines and the traveler and jack bent were advanced another were first moved over the 118-ft. span and wedged up at the ends to release the rollers and take bearing over the tops of the tower posts. Thus there was no extra dead load on the old light spans on account of erection. Vertical suspenders were then attached to the lower chords of the trusses and transverse I-beams were connected to them just above the lower chords of the old viaduct trusses.

On them was laid a working platform and the lower chords of the new trusses were assembled on it, supported in the usual manner by blocking and camber wedges. The vertical and diagonal members of the trusses were then put in position and connected to the lower chords, and finally the top-chord pieces were set on the vertical posts completing the trusses. The pins were driven and the trusses were swung from blocking over the new transverse girders, which



Apparatus for Lowering New Spans and Details of Travelers and Movable Falsework Span.

and the work was done at intervals between trains when it occasioned no interruption to traffic.

A sort of braced gallows-frame with longitudinal sills and inclined stiff-legs and having an overhang of 24 in. was built and equipped with two four-part Manila tackles corresponding to those on the traveler. This was called a jack-bent and was seated on one side of the tower, while the traveler was seated on the opposite side of the tower. A sufficient interval between trains was selected and the girders for the tower span were separately delivered and unloaded by the traveler and jack-bent main tackles which landed them alongside the track without releasing them from the tackles. The rails and cross-span and so on. All of the tackles and the whip lines were operated by a two-drum-four-spool Lidgerwood hoisting engine located most of the time near the center of the viaduct, but occasionally moved for convenience.

While the 50-ft. spans were being erected, the falsework Howe trusses were framed in the storage yards, and after the 50-ft. spans were erected they were assembled on the cross-ties outside of the track at the west end of the viaduct. After they were braced together by the overhead struts which afforded clearance for trains to pass between them, each truss was seated on six solid steel rollers at each end and rolled forward on tracks made with three lines of rails spiked to the old ties. The trusses raised them about 3 ft. above their final position. All of the bracing except the top laterals was connected to the trusses and the working platform was removed, the suspenders extended and the platform replaced below the lower chords of the old trusses, where it served to support them during their removal. Before the old trusses were removed, the 8x16-in. cross-ties 22 ft. long, which had rested on their top chords, were suspended from the new top chords which just cleared them, by pairs of U-bolts, and the spans being thus shortened, their strength was increased to carry the traffic from the new trusses and release the old trusses. After the old trusses were removed, transverse lifting girders were connected to the ends of the new

trusses by U-bolts engaging the end top-chord pins and passing between the chord webs where short sections of the cover-plate had been temporarily omitted to give them clearance. The girders were short enough to clear trains on the main track, and were supported at each end clear of the new trusses by 100-ton hydraulic jacks. The two inside jacks were theoretically carried by the plate-girder connecting the tops of the end posts of the new trusses, which were erected independently of the trusses and were braced together so as to virtually form temporary tower bents. The top flanges of the jacking girders were thought to afford too narrow bases for the jacks and 10x10-in. vertical shores were therefore set under the jacks on both sides of the girder to prevent any danger of tipping or displacement and transmit any eccentric load directly to the main transverse girders. Single 12x12-in. vertical shores at the ends of the transverse girders supported the jacks under the outer ends of the lifting girders. By these eight jacks the span was lifted slightly to release the blocking which had supported its top chords on the new transverse girders, and was then gradually lowered to its final position with the ends of the top chords seated on the cap plates of the vertical end posts.

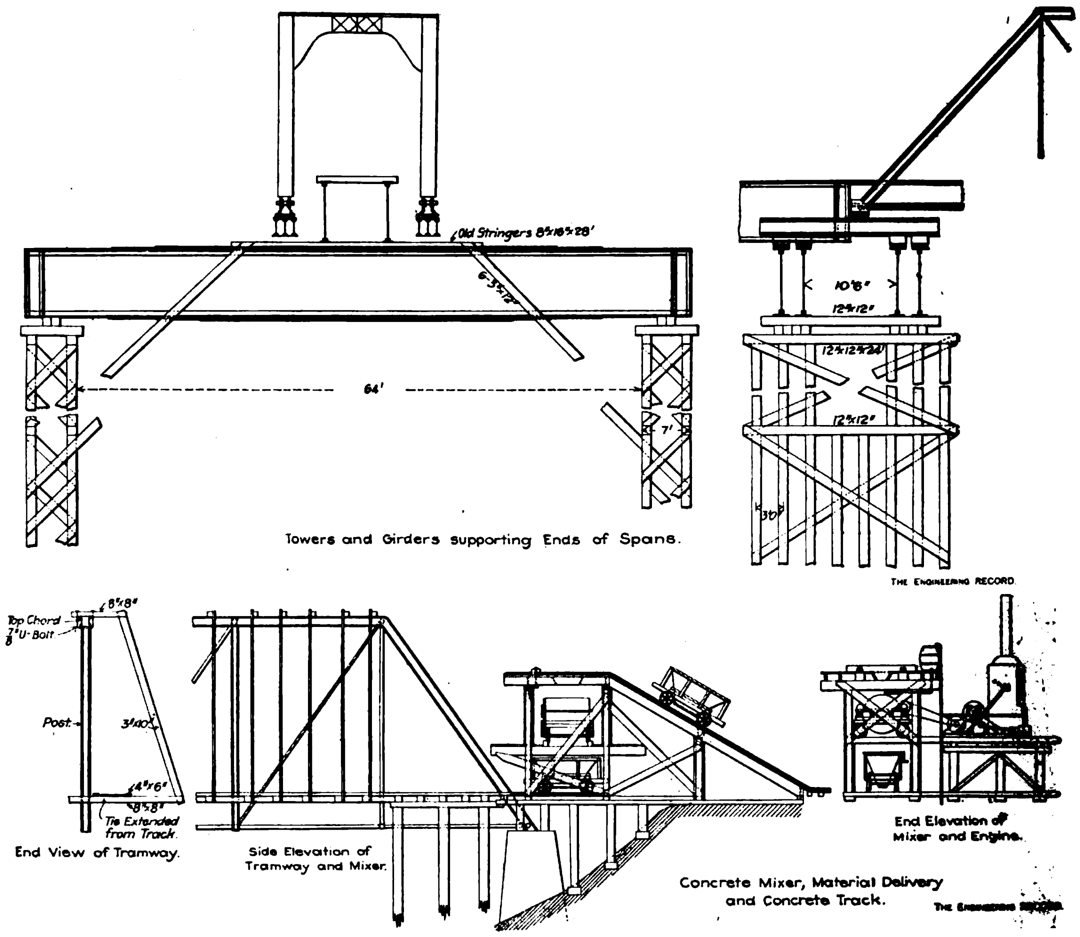
The total displacement was about 3 ft. and the rails were blocked up to maintain the original elevation as the trusses descended. After they had been lowered about 15 in., temporary ties and stringers were connected to them providing for the heaviest traffic, while the original ties were removed and the truss lowering was completed at convenience during intervals between trains, care being taken, of course, to always provide blocking to support the truss in case of any failure of the jacks. When the old ties were removed, the top-lateral system was assembled and the field rivets were driven as soon as possible after connections were made. One new span was put in, riveted up complete and the old span removed in 15 days. The entire work of reconstruction was done by an average party of sixteen men, who were employed for a total period of eleven months, although less than seven months were required to put the new spans in service; but a long time was necessary to complete the bracing in the readjusted upper panels of the towers, to cut off the upper ends of part of the tower columns and to finish various tedious operations. A 6-in. water main in service was carried on the bridge, and its maintenance during the renewal work was rather troublesome. Work was commenced May 25, 1903, and all of the new spans were in service Dec. 15, 1903.

The work was concluded without accident and at a cost materially less than the original estimate. The work was designed and the erection methods planned by Mr. Mason R. Strong, engineer of bridges under the direction of Mr. C. W. Buchholz, then chief engineer of the Erie R. R., and his successor, Mr. W. L. Derr. The 500 tons of steel work were built by the McClintic-Marshall Bridge Co., and were erected by the railroad company's regular erection force in charge of Mr. W. H. Wilkinson, inspector of bridges.

AN UNUSUAL PIER FOUNDATION was prepared some years ago by Sir Guilford Molesworth for a Ceylon bridge. The rock bottom was about 8 ft. below the water surface. He made a small islet of broken rock on this bottom and carried it up about a foot over the water line. The upper surface was then pounded with a heavy ram, after which a shallow pit was excavated in its center. Grout was filled into this pit and penetrated all the interstices of the heap of stone, consolidating it effectively.

Reconstructing Piers of a Railroad Bridge in Service.

A rather unusual piece of substructure work has recently been successfully accomplished in replacing two piers and repairing one abutment of a railroad bridge under traffic where exceptional difficulties were encountered. The bottom of the river was very much obstructed, the river was subject to sudden high floods and to dangerous ice gorges, and one new pier had to be built in the same position as the old one. The work was executed with ordinary plant and involved interesting features in the method of supporting the spans over the replaced pier, and novel devices for supporting the service track, driving the concrete mixer, and handling concrete buckets where there was not sufficient clearance to operate a derrick.



Temporary Erection Structures.

The Wabash River bridge, of the Cleveland, Cincinnati, Chicago & St. Louis Ry., at Terre Haute, Ind., consisted of one curved-chord, 230-ft. span, one 78-ft. girder span, and three 125-ft. Pratt truss spans, resting on limestone masonry piers. From the base of rail to low water is about 40 ft. The old piers were built in 1865, when the road was constructed. They were 22 ft. in length by 6 ft. in width under the coping, and were square ended, with a batter on both ends and sides of ½ in. to a foot. There seems to be no record of the foundations of these piers, but they were supposed to rest simply on timber grillage some distance below low water. The three 125-ft. spans were on the east side of the river and were very much too light for the increased weight of the heavy rolling stock of the Big Four System. It was first decided to replace the three spans with five 74-ft. girders supported on four new concrete piers.

An attempt was made early last spring to build a pier by the open cofferdam process, but after working at it for some months it was found, on account of the quantity of rip-rap stone in the river that this process was practically impossible. The contractor made several attempts to drive sheet piling, and finally did succeed in getting in what appeared to be a fairly tight sheet pile cofferdam, but when he undertook to pump the water out he found that he could not lower it more than a fraction of an inch with one 10-in. and one 6-in. centrifugal pumps. On further investigation it was found that the whole river bottom was filled with rip-rap of sizes running from one-man stones up to 3-ton stones, and, in addition to this, there were two old bridge spans, a locomotive and 40 old freight cars, the remnants of three wrecks on the bridge, besides old falsework piles that had been cut off below low water.

On account of so much debris in the river, and also because the range between high and low water in the Wabash at this point is about 27 ft., and the ice gorges in the spring are very severe, the first plan for replacing the three east spans was abandoned and it was decided to put in two piers resting on pneumatic caisson foundations and two 184-ft. Warren truss spans, thus giving a greater waterway between the piers, and less chance for the ice to gorge than by the other plan.

The Foundation Company, 35 Nassau St., New York, was called in consultation and given a contract to construct these new piers and rebuild the east abutment. They designed the caissons, which were approved by the chief engineer. The caissons were built of 12x12-in. yellow-pine timber, the walls being 24 in. thick and the deck 36 in. thick, with a 4-in. oak shoe on the cutting edge. They were 38 ft. 6 in. in length by 16 ft. 6 in. in width, with a working chamber 6 ft. 4 in. high, with 35 ft. of 12x12-in. beech cribbing on the deck, in which 1:2½:5 concrete was deposited during the process of sinking the caisson. The first caisson was built on shore about 200 ft. below the bridge. Owing to the shallowness of the water in the river it was found necessary to build a false bottom on it in order to successfully launch it. The caisson was launched Oct. 22, 1904, and was