Replacing a High Timber Trestle with a Steel Viaduct

The Fort Dodge, Des Moines & Southern Ry. is an electric road (with about 170 miles of line) formerly operated by steam. In 1906 it adopted on a part of its line, the trolley system with 600-volt direct-current for operating its passenger service (the freight service being still handled by steam locomotives), and in 1912 it adopted 1200-volt direct-current for both passenger and freight service. Its main line is between Des Moines and Fort Dodge, Ia., a distance of 86 miles. About 2½ miles north of Boone, Ia., the line follows the east bank of the Des Moines River, running along the high bluffs at a considerable height. These bluffs rise about 300 ft. above the river and are cut by a series of deep ravines so that the line alternately cuts through a bluff and spans a ravine. There are five ravines in the course of a mile, and these are crossed by timber trestles which range from 40 to 156 ft. in height and from 200 to 800 ft. in length. These were built in 1903. During recent years it has been considered wise to eliminate these trestles, both for the safety of operation and as a permanent improvement to the line. The smaller ones were filled in with solid embankments and the largest has been replaced with a steel viaduct. This trestle was 800 ft. long and 156 ft. high at the deepest point. It was supported on oak piles and built of frame bents with 12x12-in. posts and 12x12-in. caps, and was well braced with 6x8-in. struts and sways. The bents were spaced 16 ft. apart. The trestle contained a total of 860,330 ft. b. m. of timber, 5968 lin.ft. of piling and 22.4 tons of iron. This trestle is shown in Fig. 1. The new steel structure is a plate-girder viaduct, 784 ft. long and 156 ft. high, with spans of 32 and 80 ft. It was designed by W. M. Hughes, of Chicago, as Consulting Engineer for the railway ,and was built and erected by the American Bridge Co. To that company and Mr. Hughes we are indebted for information and plans. The description of the construction work has been furnished us by C. J. Steigleder, Assistant Engineer of the Ft. D., D. M. & S. Ry.

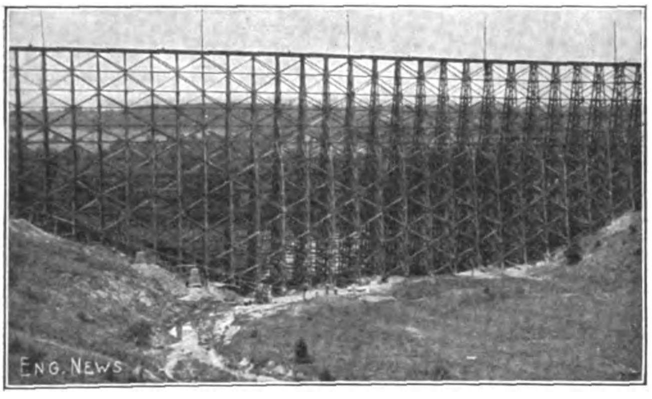


FIG. 1. TIMBER TRESTLE 800 FT. LONG AND 156 FT. HIGH

(Now replaced by a steel viaduct. Fort Dodge, Des Moines & Southern Ry. (electric).)

General Design of Steel Viaduct.

With a regular train service at two-hour intervals it was necessary to plan the reconstruction work so as to avoid interference with traffic. Several preliminary surveys were made to determine the amount of grading necessary on different locations, and it was decided to locate the new structure alongside of the old one (and upon the inner or up-hill side of the latter), with its center line 14 ft. from that of the old structure. This left the deck and track of the trestle undisturbed and open for traffic, atlhough the steel towers encroach upon the lower part of the trestle. This arrangement effected an improvement in alignment, as at the north end it enabled a reverse curve of 2½° to be rectified although at the south end it gave a curve of 5° 15′ instead of 5°. A preliminary design for the viaduct, which apparently overlooked the conditions of erection, included 36-ft. spans. But this would have involved great difficulty in placing the foundations and towers, as some of the steel bents would have been close to or coincident with the positions of the trestle bents. In Mr. Hughes' design the spans are all multiples of 16 ft. (the spacing of the trestle bents) so that the foundations all come in open spaces and the tower legs interfered only with the bracing of the trestle. The tower spans are 32 ft. and the intermediate spans 80 ft., with a 48-ft. span at one end.

The design of the viaduct is shown in Fig. 2, and on this is shown the arrangement of the concreting plant, which is described below. Fig. 3 shows the typical tower design. To the girders are attached bracket frames for the trolley poles, there being a bracket at one end of each 80-ft. girder and the 48-ft. girder. The batter for the sides of the towers is 1 : 6. The girders are spaced 7 ft. c. to c., and the 48-in. girders of the tower spans have end pedestals to bring their tops level with those of the 90-in. girders of the longer intermediate spans. The structure is designed for the live load of Cooper's E-45 classification (two 156-ton engines followed by a train load of 1500 lb. per lin.ft. of track). While this is heavier than would be required for the present equipment, using 40-ton and 70-ton electric locomotives in the freight service, it was considered that the size and weight of such engines is likely to increase, as has been the case with steam locomotives. The dead load is taken as 1400 lb. per lin. ft. of track for the 80-ft. spans, 1000 lb. for the 32-ft. spans and 1200 lb. for the 48-ft. end span. The specifications followed were those of the American Railway Engineering Association, except that the columns are not figured for traction stresses and that the impact allowance is only 50% of that given in those specifications. An interesting feature of the steel structure is the extensive duplication of parts, in the towers as well as in the spans. There are six 80-ft. spans, seven 32-ft. tower spans, and two end spans of 48 ft. (at the south end) and 32 ft. (north end). The 80-ft. girders were riveted up complete in the shops, and the 48-ft. and 32-ft. girders were riveted complete and assembled in pairs with bracing, for shipment as completed spans. The upper sections of the bents (Nos. 5 to 10 inclusive) were all made alike, the difference in height of bent being made in the bottom section. Each column is composed of two 15-in. channels with an 18-in. cover plate over the flanges of the outer face, and a 4-in. reinforcing bar on each of the flanges of the inner face.

The nature of the ground at the side of the bridge is complex, being composed of several formations which range from soft yellow and blue clay to rock. At the bottom of the ravine and in the bed of the stream, it consists of large loose boulders and gravel. Beneath this is a blue joint-clay such as is commonly found over coal measures. The yellow clay, being the upper formation, is very hard when dry, but when water is present, it becomes very slippery and evidences of slip can be seen in several places on the hillside. It was thought at first that it would be necessary to drive piling for the footings of the abutments and pedestals, with the exception of those pedestals at the bottom of the ravine. Upon excavating at the site, it was found that by going deeper with the foundation, a good bearing could be obtained without piles. This was done and the excess concrete used over the original plans only amounted to 211 cu. yd. The piers (with one or two exceptions) were designed with a footing 10 ft. square and 3 ft. deep, and a pedestal 7 ft. high, 4x4 ft. on top, having a batter of 2 in. per ft. on the sides. For the majority of the piers, this gave a bearing area of 100 sq. ft. The safe bearing on hard clay is from 4 to 6 tons per sq. ft., thus giving an allowable pressure of from 400 to 600 tons. The largest pier placed was No. 9 (east), having a footing 12x12 ft., 7 ft. deep and a pedestal 11 ft. high, the total weight being approximately 90 tons.

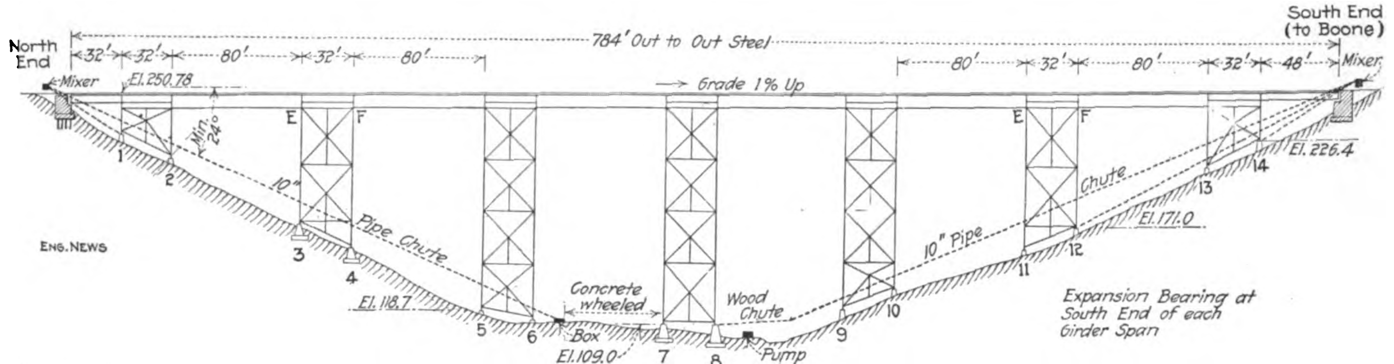


FIG. 2. ELEVATION OF STEEL VIADUCT FOR THE FT. D., D. M. & SO. RY.; SHOWING THE MAXIMUM AND MINIMUM INCLINATION OF PIPE CHUTES FOR DELIVERING CONCRETE TO THE PIER FORMS

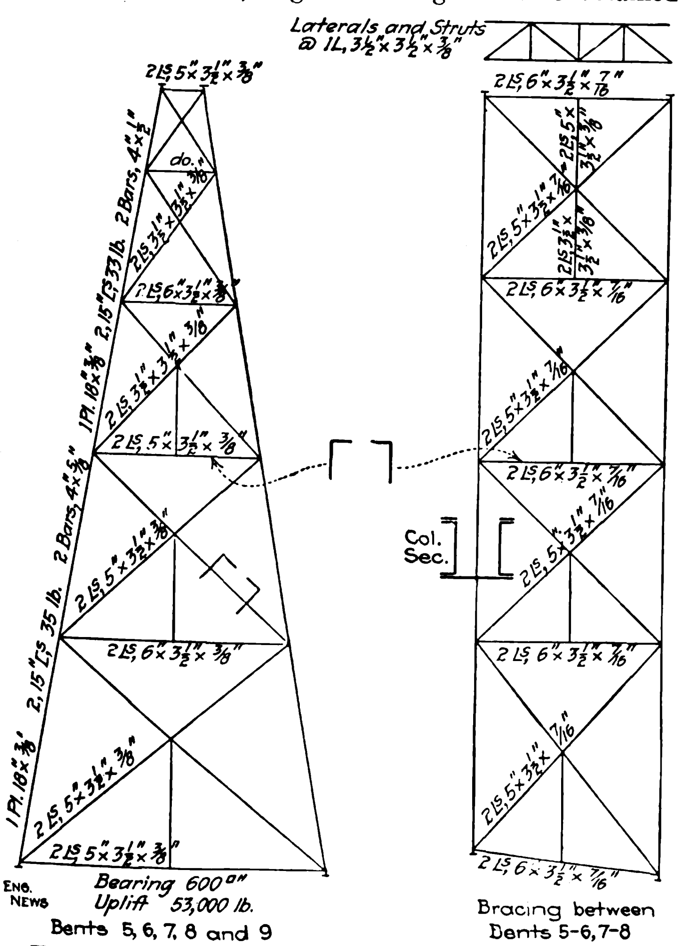


FIG. 3. TOWER BENTS FOR STEEL VIADUCT; FORT D., D. M. & SO. RY.

FORMS AND CONCRETE WORK.

The forms for the pedestals were made of 2x8-in. lumber, dressed on one side. They were built in four sections, each section forming one side of the pedestal. Two sections were cut to the exact dimensions of the pier, while the others were made to overlap the inside section, giving room for a 2x4 in. stop. The upright studding was of 2x4 in. sticks, one placed in the middle of the form section and one at each edge. Where forms higher than 7 ft. were used, they were wired across the inside to keep from bulging. Strap bolts were fastened to the inside corner and the cracks were battened with lath on were bored in the outside section to receive the threaded ends of the bolts, and hand nuts were used to keep the sides in place. A ¼-round molding was placed in each inside corner and the cracks were battered with lath on the outside. Six forms were used on the work, four 7 ft. high and two 9 ft. high. Where forms of other heights were needed, they were made by splicing on or cutting off from those already made. Fig. 4 shows the detail of the forms, including the strap bolts and hand nuts.

The specifications called for 1 : 3 : 6 concrete, except for the coping course, which was considered the top of the pedestal (12 in. thick) and was made 1 : 2 : 4. The stone used with the 1 : 3 : 6 mixture was from 1 to 2 in. in largest dimensions, and for the 1 : 2 : 4 mixture not more than 1 in. in largest dimensions. All stone was screened, no crusher run being used. It was a good grade of limestone rock. The sand was taken from the Des Moines River about five miles up from the site of the bridge, using a standard brand of cement. The water was secured from a creek in the ravine, a 7-hp. gas-engine pump being used to force the water up the hill through a 1½-in. pipe into storage barrels at the mixer. The concrete was made with a batch mixer, driven by a 6-hp. engine mounted on the same frame.

DISTRIBUTING THE CONCRETE.

An interesting feature of this work was the manner of placing the concrete. Owing to the steep slope of the hill, it was impracticable either to move the mixer down the slope, or to wheel the concrete into place. The most efficient way was to spout it and this was the method used. Half of the piers were poured from the north end of the bridge, and the other half from the south end. The mixer was mounted on blocks and a platform, built around it so that the hopper was above the platform, just about the height of a wheelbarrow. The chute used to convey the concrete was of No. 23 sheet steel, circular in form, 10 in. diameter, and in lengths of 10 and 12 ft. The pipe was attached to a small wooden chute at the end of the hopper, and from here run to any desired point. It was supported at joints by wooden cross frames, or by brackets tacked to the batter posts of the trestle. At the end of the pipe, a curved connection was used to turn the concrete down into the forms. The spouting is indicated on Fig. 2, and the concrete mixer and spout are shown in Fig. 5. For bent No. 8, the concrete was delivered through a wooden chute from the end of the pipe chute just beyond bent No. 9. For bent No. 7, the concrete was wheeled into place from a wooden box placed at the end of the pipe chute just beyond bent No. 6 (See Fig. 2). This type of pipe spouting proved satisfactory where the distance was not greater than 250 ft. and the grade not less than 24° with the horizontal (about 1 ft. vertical to 2.3 ft. horizontal). When on a less grade than this, the concrete clogged in the pipe and caused considerable trouble. If it clogged so that any amount of weight would come between supports, the pipe would buckle and break, making it worthless for use again. Mr. Steigleder considers that a better type would be a chute made of similar material, 10 or 12 in. wide, 16 or 18 in. deep, open at the top and with a small angle running along each edge. Occasional spacer angles could be used to stiffen it. This pipe or chute would be easy to handle and it would give access to the concrete flowing in it. Another good type of spouting for this kind of work would be a wooden chute in 12- or 16-ft. sections, lined with sheet iron. The advantage of this chute would be the saving on the investment, as after the job was completed the lumber could be used for some other purpose.

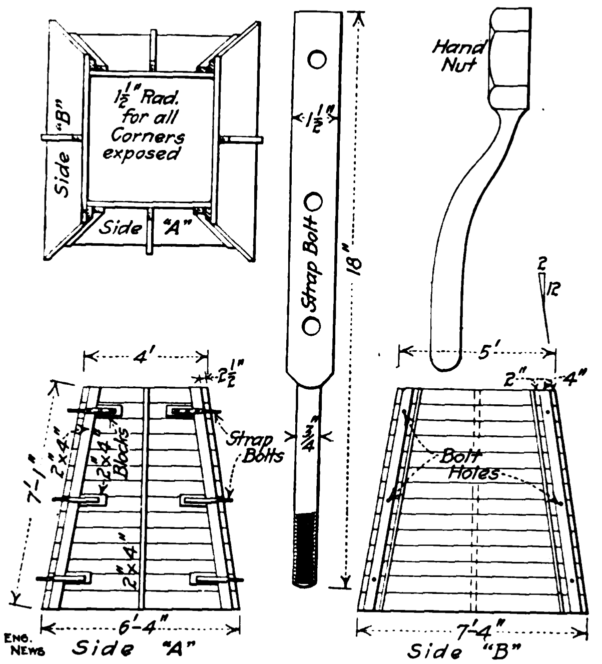


FIG. 4. FORM CONSTRUCTION FOR CONCRETE PEDESTALS OF VIADUCT

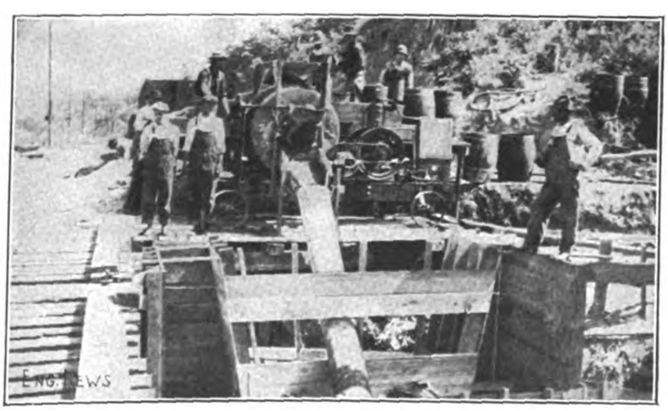


FIG. 5. CONCRETE-MIXING PLANT, WITH STEEL PIPE CHUTE TO FORMS FOR PEDESTALS

The concrete gang was composed of 12 men and a foreman. Two men were used in spading the concrete as it was placed, one on water and dumping cement, one taking care of the mixer, six on sand and rock, and two carpenters. As far as possible, the concreting on a footing or pedestal was continuous, and only in one or two cases were joints made in either. From four to six footings were run at a time. As soon as the first two of these footings had set, the forms for the pedestal were placed and securely braced. After being braced, the template for the anchor bolts was centered and tacked to the top of the pier form. The anchor bolts were then placed in the template, plumbed and wired to the form. The total amount of concrete in the foundations was 932 cu. yd. The time required to place this was 40 days.

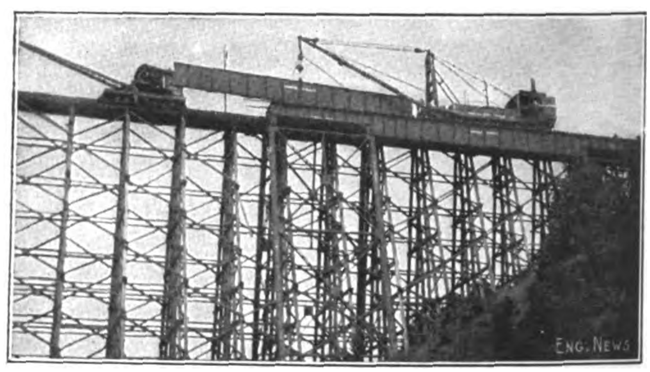


FIG. 6. PLACING AN 80-FT. GIRDER ON THE BOONE VIADUCT FOR THE FT. DODGE, DES MOINES & SOUTHERN RY.

(The erection was done by a derrick car on the viaduct and a locomotive crane on the old trestle alongside the viaduct.)

ERECTION OF STEEL STRUCTURE.

The cut at the north end of the bridge was excavated with a steam shovel, and about 300 ft. of track was laid on the new alignment. This track was used for unloading the steel and for the derrick car during erection, also as a siding when necessary to clear the main line for traffic. The erection was started at the north end and carried through to the south. The first 32-ft. span and the first bent of tower No. 1 were erected by the derrick car, which had a 40-ft. boom. The rest of the towers were erected with a locomotive crane which worked from the old trestle. The tower was first erected and then the girders were placed, the ties and rails being laid as the work progressed. The material for the towers was first lowered through the side of the trestle by the derrick car (the bracing being removed as necessary), and was then picked up by the crane and brought into place. After a tower was completed, the derrick car placed the 80-ft. girders. These girders weighed approximately 16 tons each but no special apparatus was needed to place them, as the boom on the derrick car was kept straight ahead. Fig. 6 shows the derrick car placing an 80-ft. girder on the third span.

No difficulty was experienced in keeping the line open for traffic. The track was cleared ten minutes in advance of all regular trains, and in case of extra trains the foreman on the work was notified of their approach by the dispatcher. In order to protect the locomotive crane from the 1200-volt current on the trolley wire, a breaker was put on the wire and the current was cut off while the crane was working. The only trouble that was encountered during the erection of the steel was that caused by the bracing of the trestle interfering with the columns or braces of the steel towers. At the expense of the railway company, a carpenter gang of six men and a foreman was kept busy cutting away the old woodwork as required. The sway braces and struts that were cut were not replaced. When it was necessary to move a post, the cap was jacked up and the post cut and then moved and blocked into place. The trestle is to be wrecked but the contract for this work has not been let. The best of this timber will be milled and then disposed of, while some of it will be used in repairs to other bridges.

The deck of the viaduct has yellow-pine ties 8x8 in., 10 ft. long, sized to 7½ in. Hook bolts are placed on every other tie and the rails spiked to all ties. The guard rail is 6x8 in., boxed 1 in. over each tie. Three steel guard rails are laid between the track rails. The third guard rail is placed in the center of the track and provides an extra precaution in case a motor casing should drop as a car is crossing the bridge.

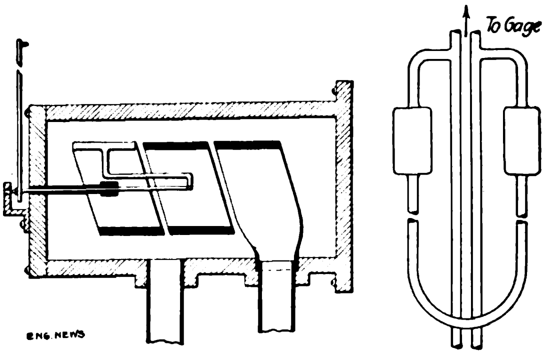
The riveting was done with compressed air, the power for the compressor being supplied part of the time by the engine on the derrick car and the rest of the time by a gas engine. From 12 to 18 men were used during erection, and from 10 to 12 during riveting. The bridge was erected complete before the riveting was started. From three to four gangs were used to drive the rivets, the greatest number driven in one day being 1020, with three gangs working. The time required to unload the steel and erect the bridge complete (including the placing of the ties and rails) was 95 days. The contract for the foundation was let to A. W. Merrick, at Boone, Ia. The excavation was done by the railway company. The painting was included in the contract for the erection.

Painting of the Panama Lock Gates is noted in the "Canal Record." Mar. 6, 1913. At present the work is confined to the interior surfaces of leaves. There is a preliminary washing of the steel to make the paint adhere better. Then there is the application of a "bitumastic enamel" to an average thickness of $\frac{1}{16}$ in. This type of paint has been used on the interior of the sea-going section dredges "Culebra" and "Caribbean" and has worn well during six years of service. This interior painting is being done by the lock-gate contractor under a sub-contract. The exterior paint has not been fixed and will be purchased by the commission but applied by the contractor.

A New Recording Differential Pressure Gage*

Design of a line of recording differential pressure gages has recently been completed by Prof. W. H. Bristol, of Waterbury, Conn., to meet the demand for service with Venturi meters, pitot tubes, orifices, etc., in the measurement of flows of steam, gas and air, as well as water and other liquids.

The mechanism employed is a development of earlier arrangements of hollow springs or diaphragm chambers bearing pressure on the interior and showing pressure changes by changes in shape, which movements are communicated to a pointer or pen arm. With a differential gage, it is desired to measure the difference in pressure between a greater and a lesser pressure. The one is applied to the interior and the other to the exterior of the hollow spring or diaphragm chamber; the corresponding movement of spring or diaphragm is proportional to the difference between the two pressures. Various attempts have previously been made to accomplish this end by inclosing the hollow spring or chamber in a casing and communicating its movement mechanically to the exterior through the casing walls, but the differences in pressures have been small to render negligible the friction of stuffing boxes or equivalent devices. Prof. Bristol has used this type of movement, but has devised for the casing



Diagrammatic Arrangement of Working System and Safety Attachment; Bristol Recording Differential Gage

a practically frictionless sealed bearing for the pointer- or pen-arm shaft. As shown in the accompanying figure, a small shaft bearing the arm passes through a long fixed tube or sleeve and, fitting closely therein, oil or other liquid may be used to fill the annular interstice This supports the shaft and renders the joint very nearly frictionless to rotation while capillary forces make it also pressure tight.

Where there is danger of applying the full pressure to one side or other of the hollow spring or chamber, which might result in wrecking the gage, a safety appliance is attached. As shown in the accompanying figure, the two pressure leads carry outlets which are joined by a U-tube. Near the top of the U-tube are chambers, either of which has sufficient capacity to hold all the liquid contained in the U. When pressure is communicated to one lead and not to the other, the U-tube is cleared of liquid and full pressure is communicated to both sides of the spring or diaphragm chamber.

*From information furnished by the Bristol Co., Waterbury, Conn.