the underside of the flange of the rails, where a species of permanent layer of corrosive liquid is formed between the surface of the rails and that of the chairs.

Various instances of this are given in detail. On one of the rails (Vignoles type) on the descending line in the long Ronco tunnel, the corrosion of the flange in two-and-a-half years amounted, in various places, to 0.086 in. On the ascending line in the same tunnel the maximum flange corrosion after three-and-a-half years was, in some cases, as much as 0.22 in. to 0.26 in.; and after four years' wear 0.28 in. to 0.3 in. The corrosion had honeycombed the entire under-surface of the flange. Other examples are illustrated—from the Frejus tunnel, on the Turin and Modane line; from the Sella tunnel, on the San Giuseppe & Savona line; and from the Belbo tunnel, between San Giuseppe and Bra. In the Laveno tunnel, between Novaro and Pino, where transverse fractures necessitated the removal of various rail-lengths, a most extraordinary degree of corrosion was noted, amounting to 0.39 in. on the underside of the flange, while the abrasion of the head amounted (in the worst case) to 0.49 in., the rails having been laid eleven-and-a-half years.

Action of Sea Air on Coast Lines.—This source of corrosion has been chiefly observed on the Ligurian Riviera, where the line is not merely exposed to the salt air, but is frequently subject to drifts of spray from the waves. In such cases the rail frequently reaches its limit of safety long before the normal wear has been attained. For instance, on the Celle and Cogoleto section of the line from Genoa to Ventimiglia, the Vignoles rails, after fifteen years' service, showed a reduction of only 0.118 in. to 0.158 in. on the head, but were much corroded in the flange, frequently to the extent of 0.158 in. to 0.236 in.; while the width of the flange was correspondingly reduced by 0.39 in. to 0.6 in., and in some cases even 0.79 in.

Permanent Elongation and Deflection of Rails.—In addition to abrasion and corrosion, other destructive agencies may be noted.

On the Mont Cenis approach line, between Meana and Chiamonte, on a gradient of 1 in 34½, laid with Vignoles rails, it was found in several cases that the original clearance between the rail ends had entirely disappeared, and that one or both of the rails had extended longitudinally, pressing together, causing the head to bulge out—in one case to the extent of 0.39 in.—correspondingly decreasing in height and tightening the gauge by fully $\frac{3}{16}$ in. Between the points of support the rails were also conspicuously deflected, so that the number of supports could be counted by the successive curvatures or undulations of the rail. This was evidently due to the defective quality of the steel.

Methods Adopted for Diminishing the Wear or Deterioration.—During the past three years a harder steel has generally been specified than was formerly adopted. The old specification was, tensile strength 35 tons per sq. in. (sometimes even less), with minimum elongation 18 per cent. to 20 per cent. Except in special cases the normal tensile strength now required is from 41 tons to 44½ tons per sq. in., with minimum elongation 14 per cent. Experiments were also made with a view to the adoption of a rail not greatly exceeding in weight the old type, but with larger bearing surfaces. The width of the head is increased from 2.36 in. to 2.83 in., and the weight is 90¾ lbs. per lin. yd. The area of abrasion allowable is 2.23 sq. in., as against 0.72 in. in the old type.

Since the adoption of the new section, no instance of elongation or undue deflection has been noted, and the extent of abrasion has been considerably diminished. The new rails laid in the Ronco tunnel, for instance, in October, 1894, were examined in February, 1897, i. e., after two years and four months, and the reduction of the head amounted to only 0.118 in.

The results of the methods adopted for securing a diminution of chemical or corrosive action have not yet been demonstrated on a sufficiently reliable basis.

On the Celle and Cogoleto section of the Genoa & Ventimiglia line, some of the rails relaid in 1891 were coated with tar and with other ironwork varnishes. When examined in 1896 the results varied in different parts of the rail. The friction of the portions bedded in the ballast or in contact with the chairs and fastenings had naturally worn away the coating; but though rust was slightly formed, very little trace of corrosive action was observable. In the exposed portions the protective coating stood remarkably well.

Concurrently with this, a similar experiment was being made in the Frejus tunnel, and the rails were examined after an average wear of three years and eight months. The Bessemer varnish was found to have been the most effective coating; next to this being tar, two coats. Although the period was too short for the establishment of conclusive data, it appears to be distinctly proved that the small outlay for a protective coating is amply justified by the additional life and soundness of the rails.

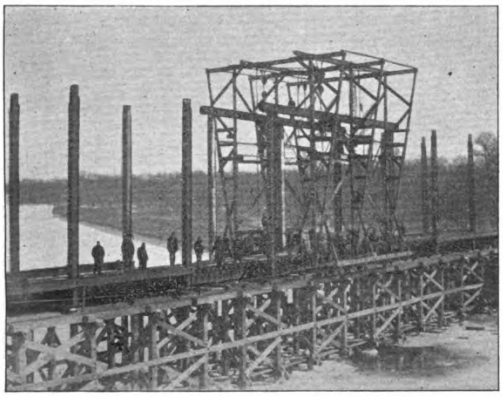


Fig. 4.

Fig. 5.

Span No. 1, Chicago & Northwestern Bridge, Clinton, Ia.

Reconstruction of the Chicago & Northwestern Bridge, Clinton, Iowa.

The Chicago & Northwestern Railway, as previously noted, has, during the past winter, replaced a number of important bridges at various points, and the accompanying engravings show the main features of the reconstruction of four fixed spans of the single track bridge over the Mississippi River at Clinton, Iowa. This bridge, at present, consists of one draw and twelve fixed spans, and, like most of the Mississippi River railroad bridges, has been rebuilt a number of times.

The river at this crossing is divided into an east and west channel by Little Rock Island. In 1860 the east channel was bridged by seven 200-foot spans of the McCullum patent truss. These spans were furnished by the patentee, Mr. D. E. McCullum, and the foundations and masonry were put in by Harper & Cross of Chicago, under the supervision of Mr. Milo Smith, Superintendent and Chief Engineer of the Chicago, Iowa & Nebraska Railway. The railroad traffic was carried over the west channel by a ferry until 1865. During 1864 and 1865 the west channel was bridged by three Howe truss spans and one 300-ft. draw span of the Bollman type of truss; the draw was furnished by the Detroit Bridge & Iron Works. These Howe truss spans were replaced in 1874 by iron spans of the Whipple type, made by the American Bridge Works, and the draw was replaced by a pin-connected Pratt truss draw span in 1887, furnished by the Detroit Bridge & Iron Works.

The reconstruction of this draw involved a rather novel piece of engineering work. Owing to the difficulty and danger of placing falsework in the river at this point, it was decided to erect the new draw up and down stream on the protection pier, leaving the old draw intact to carry the railroad traffic. When the new draw was completed, the two arms of the old draw were coupled together across the new draw and the latter was then swung in line with the railroad, thus bringing the old draw span in the position over the protection which the new draw occupied while being erected. This work was done under the direction of Mr. E. C. Carter, now Principal Assistant Engineer of the Chicago & Northwestern, but at that time Engineer for the Detroit Bridge Works.

The present work carried on during the past winter consisted in replacing with pin-connected Pratt in by the American Bridge Works. In 1870 the remaining six 200-foot spans in the east channel were removed and new piers built for eight 150-foot spans. These, with the exception of two spans, were pin-connected Pratt trusses, and the following bridge companies furnished two spans each: Detroit Bridge & Iron Works, Phoenix Bridge Co., and Keystone Bridge Co. The two exceptions were Post trusses and were furnished by the American Bridge Works. The first 200-foot span in the east channel was replaced in 1880 by Rust & Coolidge, with a Whipple truss, and during the years 1882 to 1885, the Lassig Bridge & Iron Works replaced the remaining eight 150-foot spans in the east channel, using pin-connected Pratt trusses. All this reconstruction was under the direction of Mr. John E. Blunt, the present Chief Engineer of the Chicago & Northwestern.

The present work carried on during the winter of 1898 consisted in replacing with pin-connected Pratt trusses the first span of the east channel, formerly a 200-foot Whipple truss, and the three fixed Whipple truss spans in the west channel. This last work was done under the direction of Mr. John E. Blunt, Chief Engineer; Mr. W. H. Finley, Engineer of Bridges, had charge of the designing of the bridges, and the plans for the falsework, while Mr. H. J. Slifer, Division Engineer, superintended the work in the field. The Detroit Bridge & Iron Works furnished the spans and erected them and the railroad company put in the falsework.

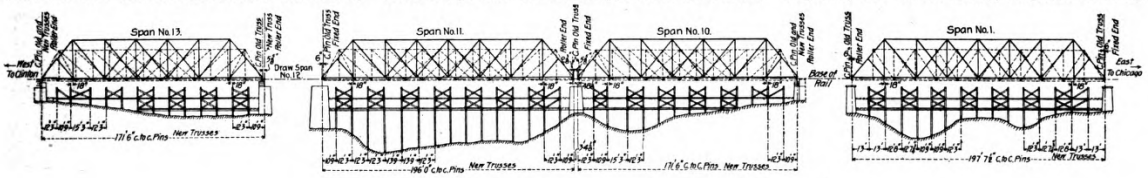


Fig. 1.—The Chicago & Northwestern Bridge at Clinton, Ia.

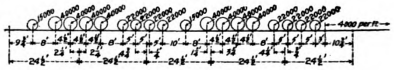
The old spans are shown in dotted lines.

Fig. 1 shows the general outline of the old and new trusses, and the arrangement of the falsework, the old masonry piers and abutments being used for the new superstructure. It will be seen that there are two spans, 171 ft. 6 in. long, consisting of 7 panels each, one 196-foot span of 8 panels, and one 8-panel span 197 ft. 7½ in. long. All trusses are pin-connected. The strain sheet, Fig. 2, gives the stresses in the different members arising from the combined live and dead loads, the area of the cross-sections, and indicates how the various members are built up. The small diagram gives the arrangement of the

wheel loads for two standard consolidation locomotives at the head of a train. The material used for the riveted members was soft steel, while medium steel was used for eyebars, and all holes were reamed in the bottom chord, floor system and their connections.

corbels were sawed off close to the main posts so as to allow room for the new floor beams to be dropped into place. In this way the erection progressed rapidly, as shown by the following record:

The new spans were erected without mishap and with little delay to traffic. During this time the aver-



Wheel Loads.

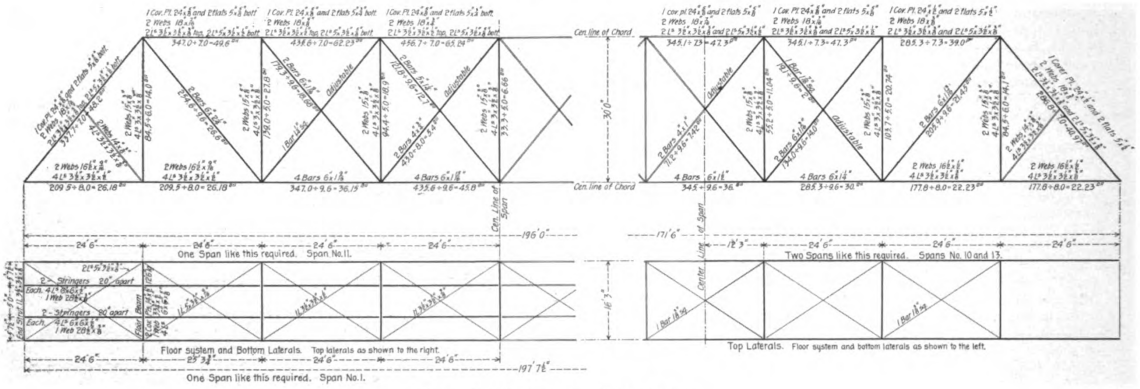


Fig. 2.—Strain Sheet, Clinton Bridge.

The assumed loading per lineal foot of track was as follows:

		Live load, lbs.	Dead load, lbs.
Floor system	Stringers	9,600	500
	Floor beams	5,610	500
Trusses	196-ft. span		2,150
	171-ft "		2,160
Floorbeam reaction			81,500 lbs.
Stringer "			30,950 lbs.

The unit stresses, in lbs. per sq. in., used in calculating the cross-section of the various members, were as follows:

		Live load.	Dead load.
Plates and shapes		8,000	16,000
Eyebars		9,600	19,200
		Shear.	Bearing.
Rivets. In floor system	Shop	6,000	12,000
	Field	5,100	10,200
In trusses	Shop	7,500	15,000
	Field	6,000	12,000
Pins		6,000	12,000

Owing to the danger from the breaking up of ice and other uncertainties connected with the erection of a bridge on falsework in the Mississippi River, especial care was taken in designing the falsework to permit of rapid progress after the old iron spans were removed. The falsework is shown in detail by Fig. 3, and it will be noted that it consisted of framed trestles resting on piles. Each bent under the new iron truss spans was accurately spaced, as shown by Fig. 1, so as to be not less than 18 in. to one side of the panel points. After the old iron work had been removed, the track was carried on stringers by the falsework. In erecting the new spans, the floor was put in, a panel at a time, by removing the blocking and temporary floor, and the old stringers and their

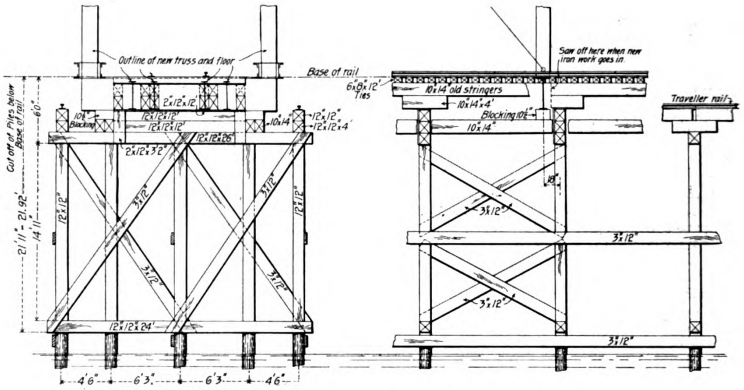


Fig. 3—Details of False Work; Clinton Bridge.

age daily number of trains passing over the bridge was 33, while the maximum number for a single day was 44, and the minimum 25 trains.

Figs. 4 and 5 are views of span No. 1. Fig. 4 shows the progress of the work on February 24, when the new floor was resting on the falsework; the lower panel chords and intermediate posts were in position, while the center panel top chord was just being placed. Fig. 5 shows the same span, on February 26, completed and ready for the removal of the falsework. This view also gives a good idea of the appearance of the truss.

Statement Showing Renewal of Four Spans of the Mississippi River Bridge, Chicago & Northwestern Ry., at Clinton, Iowa.

Span No.	Date.	Taking down old iron.	Erecting new iron.	Remarks.
13	Jan. 19, 1898	6 panels at east and 2 at west ends		Stringer seats at east end in place.
	20	All iron down at noon		Truss seats east end and stringer seats west end.
	21		All floor beams in and all stringers except west panel	Masonry complete.
	22		Floor sytem in. 10 intermediate posts up. 2 panels west end bottom chord and center panel top chord, with laterals, counters and struts.	
	23		All iron west of center panel in place	
	24		All iron except center bottom chord bars in place	
	25		Span coupled at noon	
10	Jan. 31, 1898	All iron remov'd except 4 west pan'ls		Stringer seats at east end set.
	Feb. 1	All iron removed	East panel floor system in place	Masonry east end complete
	2		All stringers in place, except two west panels	Masonry west end half completed.
	3		Floor system in at noon, 10 intermediate posts, 2 panels bottom chord at east end in place.	Masonry complete.
	4		All iron east of center panel in place, 2 panels bottom chord at each end and top chord all up.	
	5		All iron in place except pins and center panel bottom chord	
	6		Span coupled at noon	
11	Feb. 7 1898	West end posts taken down		
	8	All iron remov'd except 5 east pan'ls		All masonry in place.
	9	All iron removed	3 panels floor system at west end in place	
	10		Floor system in. 5 intermediate posts, 4 panels bottom chord in place.	
	11		All iron west of double center panels in place	Worked 15 hours.
	12		All iron in place, last pin driven at 3 p. m	
1	Feb. 18, 1898	4 east panels iron removed		Feb 19 and 20 storm, no work.
	21	All iron down except 2 panels		Masonry at east end complete.
	22	All iron removed	3 panels floor system in place	Masonry complete.
	23		Floor system in. 6 intermediate posts all up, 4 end panels bottom chord in	
	24		4 panels iron complete, intermediate posts all up	
	25		All iron in place except 4 panels bottom chord bars	
	26		Last pin driven at 3 p. m	

Summary.

Span No.	Old span.		New spans.		Time taking down old spans.	Time erecting new spans.	Remarks.
	Length.	No. panels.	Length.	No. panels.			
13	171 ft. 0¾ in.	13	171 ft. 6 in.	7	14 hours.	45 hours.	
10	171 ft. 0¾ in.	13	171 ft. 6 in.	7	15 hours.	46 hours.	
11	195 ft 7¼ in.	15	196 ft.	8	25 hours.	37 hours.	
1	197 ft. 7½ in.	12	197 ft. 7½ in.	8	25 hours.	47 hours.	

Average time taking out 4 panels of old floor and putting in 2 panels of new floor, 1 hour and 30 minutes. Average time taking out 2 panels of old floor and putting in 1 panel of new floor, 50 min.