

“The Assimilation of Railway Practice
in respect of Loads on Bridges up to 200 feet Span.”¹

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QUESTIONS of standardization have for some time past been freely discussed by Institutions, and by the public and private press; and it may be admitted that the result of engineers, manufacturers, and consumers, meeting in conference and agreeing to standard sizes of materials required for specific purposes, and to uniformity of practice as regards specifications, tests, and quality of materials, must be increased efficiency and economy of cost and time. The Institution has recently done good service in taking such an active part in the work of standardizing materials, and in having already, amongst other matters, dealt with the various sections of steel used in the construction of bridges. While it is undesirable to carry standardization to such an extent as might tend to arrest advancement in design or construction, it is of the utmost importance that uniformity should be arrived at with regard to the loads to which such structures may be subjected; and the intention in the present Paper is to indicate the anomalies and difficulties that exist, with the view of inviting discussion upon the points raised.

Bridges for railways may be divided into two classes:—

1. Railway bridges, carrying railways over highways, waterways, rivers, etc., over which the loads are guided in their course by a track fixed in position.

2. Highway bridges, carrying highways, etc., over railways, with or without a fixed track to guide the loads.

Railway Bridges.—The general practice has been for the engineer to select the heaviest class of locomotive in use on the line, as a basis for the maximum load for small spans; and to assume a combination of the engines giving the greatest stress for larger spans. The engines are supposed to be marshalled in a continuous train, with no spaces left between them. In order to meet the requirements of traffic, locomotives of increased size, strength, and weight have constantly been designed, with little or no reference to the strength of the bridges which have to carry them: with the result that bridges, which ought to have lasted for a considerable length of time, became early overloaded and over-

¹ *The Engineer*, vol. xcv. p. 616. *Engineering*, vol. lxxv. pp. 820 and 830.

strained, and had to be either strengthened or replaced. Within recent times a decided increase has been made in the weight of locomotives, and also in that of passenger-vehicles and goods-wagons. It is difficult to say whether the maximum has yet been attained; but the fact of the load-gauge being practically taken up to its full capacity indicates that the margin now left is but small. Each of the large railway companies has distinctive classes of locomotives; and as there is so extensive an interchange of traffic between the companies, it appears desirable that all railway bridges in this country should be strong enough to carry the heaviest engines or combination of engines in use on any railway.

In Table I. are shown the equivalent uniformly-distributed live-loads deduced from the maximum bending-moments that are caused by engines running on different British railways; the examples selected are believed to represent the heaviest engines of the several classes that are used throughout the country. A ten-wheels-coupled engine is included, of which as yet there are only a few examples, with a limited range of operations. The figures in the Table include an addition of $2\frac{1}{2}$ per cent. for possible future increase. In some engines not included in the Table the weights are more concentrated than in those tabulated, whereby heavier weights are brought upon the cross-girders. Hence the growing practice of building locomotives with small wheels close together points to the necessity of the cross-girders being placed at shorter distances apart than has hitherto been the custom.

Consideration should also be given to the increased and continuous weights imposed by a train made up of large wagons of 40 tons capacity, or of wagons loaded with boilers, girders, or other heavy materials. In many cases the weight of a train so laden approximates to that of a train of engines.

Highway Bridges.—Dealing with bridges carrying public highways, accommodation-roads, etc., over railways, it will be seen from Table II., which has been compiled from information collected recently, that highway bridges are subjected to very heavy weights; and not infrequently heavier weights than these are drawn along the streets of towns by two and sometimes even three traction-engines. The introduction of tramways with heavy cars, worked by steam and more recently by electricity, and the general increase of loads passing along streets and highways, have raised the standard of weight; and amid such a great variety of loads it is a question for consideration and discussion, what

TABLE I.—EQUIVALENT DISTRIBUTED LIVE-LOADS OF LOCOMOTIVES CROSSING BRITISH RAILWAY BRIDGES,
DEDUCED FROM MAXIMUM BENDING-MOMENTS FOR A SINGLE LINE OF WAY.

Span of Bridge.	Class of Engines.										Diagrams of Engines used in Calculations.
	Single-Driver.		4-Wheels-Coupled.		6-Wheels-Coupled.		8-Wheels-Coupled.		10-Wheels-Coupled.		
Feet.	Tons Distributed.	Tons per Foot Run.	Tons Distributed.	Tons per Foot Run.	Tons Distributed.	Tons per Foot Run.	Tons Distributed.	Tons per Foot Run.	Tons Distributed.	Tons per Foot Run.	
10	36.9	3.69	36.9	3.69	36.9	3.69	34.6	3.46	39.9	3.99	
15	38.1	2.54	46.6	3.11	48.8	3.25	50.3	3.35	55.8	3.72	
20	44.0	2.20	57.6	2.88	56.2	2.81	63.5	3.18	68.9	3.44	
25	51.5	2.06	65.4	2.61	66.3	2.65	73.8	2.95	83.7	3.35	
30	61.2	2.04	73.6	2.45	74.7	2.49	83.2	2.77	98.5	3.28	
35	71.1	2.03	82.6	2.36	84.0	2.40	91.4	2.61	106.9	3.06	
40	80.4	2.01	89.0	2.22	92.4	2.31	98.8	2.47	115.3	2.88	
45	90.0	2.00	95.6	2.12	99.0	2.20	105.6	2.34	120.2	2.67	
50	99.0	1.98	105.3	2.10	104.0	2.08	112.3	2.24	125.0	2.50	
55	107.8	1.93	115.0	2.09	111.1	2.02	119.0	2.16	130.7	2.38	
60	116.0	1.93	124.8	2.08	117.6	1.95	126.0	2.10	136.3	2.27	
65	125.5	1.93	133.9	2.05	124.8	1.92	133.0	2.04	147.6	2.27	
70	135.3	1.93	142.8	2.04	132.3	1.89	140.5	2.01	158.9	2.27	
75	144.0	1.92	151.5	2.02	141.8	1.89	150.0	2.00	169.5	2.27	
80	152.7	1.91	160.4	2.00	150.4	1.88	159.2	1.99	180.8	2.26	
85	162.0	1.91	168.3	1.98	159.8	1.88	168.3	1.98	192.1	2.25	

Total 91½ Tons.

Tender 41¾ Tons. Engine 49½ Tons.

16½^T 12¾^T 12½^T 11¾^T 18^T 19¾^T

5.4' 6.6' 6.6' 7.2' 9.0' 7.9' 6.6' 4.4'

Total Length 53' 1½" over Buffers.

SINGLE-DRIVER.

Total 107 Tons.

Tender 41 Tons. Engine 66 Tons.

15^T 14½^T 11½^T 13^T 18^T 18^T 17^T

5.4' 6.6' 6.6' 9.1' 8.0' 6.10' 5.3' 6.3' 4.0'

Total Length 57' 9" over Buffers.

4-WHEELS-COUPLED

90	172.0	1.91	176.4	1.96	168.3	1.87	176.4	1.96	202.5	2.25
95	180.4	1.90	184.3	1.94	177.7	1.87	184.3	1.94	213.8	2.25
100	188.6	1.88	193.3	1.93	186.0	1.86	192.0	1.92	223.7	2.24
105	197.4	1.88	201.6	1.92	195.3	1.86	201.6	1.92	235.2	2.24
110	206.8	1.88	211.2	1.92	204.6	1.86	211.2	1.92	246.4	2.24
115	216.2	1.88	220.8	1.92	213.9	1.86	220.8	1.92	257.6	2.24
120	224.4	1.87	230.4	1.92	223.2	1.83	230.4	1.92	267.6	2.23
125	233.8	1.87	240.0	1.92	232.5	1.86	240.0	1.92	278.7	2.23
130	243.1	1.87	249.6	1.92	241.8	1.86	249.6	1.92	289.9	2.23
135	251.1	1.86	259.2	1.92	251.1	1.83	259.2	1.92	301.1	2.23
140	260.4	1.86	268.8	1.92	260.4	1.86	267.4	1.91	310.8	2.22
145	268.3	1.85	278.4	1.92	269.7	1.83	277.0	1.91	321.9	2.22
150	277.5	1.85	288.0	1.92	279.0	1.86	286.5	1.91	333.0	2.22
155	285.2	1.84	297.6	1.92	288.3	1.86	296.1	1.91	342.6	2.21
160	294.4	1.84	307.2	1.92	297.6	1.86	305.6	1.91	353.6	2.21
165	302.0	1.83	316.8	1.92	306.9	1.86	315.2	1.91	363.0	2.20
170	309.4	1.82	326.0	1.92	316.2	1.86	323.0	1.90	374.0	2.20
175	316.8	1.81	336.0	1.92	325.5	1.86	332.5	1.90	385.0	2.20
180	324.0	1.80	345.6	1.92	334.8	1.86	342.0	1.90	396.0	2.20
185	331.2	1.79	355.2	1.92	344.1	1.86	351.5	1.90	405.2	2.19
190	338.2	1.78	364.8	1.92	353.4	1.86	361.0	1.90	416.0	2.19
195	345.2	1.77	374.4	1.92	362.7	1.83	370.5	1.90	427.1	2.19
200	352.3	1.76	383.2	1.92	370.0	1.85	378.0	1.89	435.3	2.18

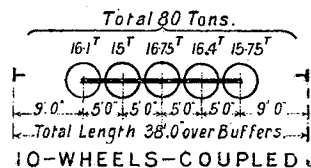
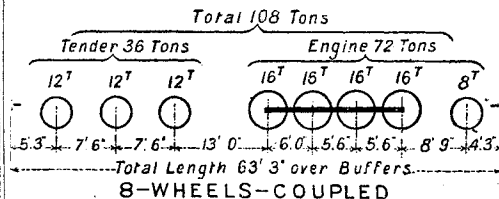
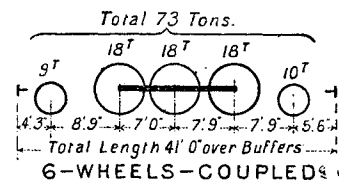


TABLE II.—ROAD-VEHICLES CROSSING HIGHWAY-BRIDGES.

Vehicles.	Length over All.		Width over All.		Length of Wheel-Base.		Weight on Rectangle enclosing Vehicle.	Weight on Rectangle enclosing Wheel-Base.	Number of Axles.	Maximum Weight per Wheel.	Total Weight Loaded.
	Feet.	Inches.	Feet.	Inches.	Feet.	Inches.	Lbs. per Square Foot.	Lbs. per Square Foot.		Tons.	Tons.
Tramway-car, double deck, single truck . . .	27	5	7	0	6	0	137	893	2	3	11 $\frac{3}{4}$
„ „ bogie	33	6	7	1	13	6	139	497	4	2 $\frac{1}{2}$	14 $\frac{3}{4}$
„ „ „	35	0	7	0	16	0	159	496	4	3 $\frac{1}{4}$	17 $\frac{1}{2}$
„ single deck, „	35	0	7	0	17	0	138	380	4	3	15
„ vestibule combination, single truck	30	10	6	9	6	0	103	728	2	2 $\frac{1}{2}$	9 $\frac{1}{2}$
20-ton road-roller	20	3	8	3	11	7 $\frac{1}{2}$	268	482	2	6 $\frac{3}{4}$	20
15-ton „	19	7	7	3	11	6	235	403	2	5	15
Traction engine . . . . .	..		7	2	10	2	..	585	2	7	19
„ „ . . . . .	..		9	7	15	0	..	342	2	8	22
„ „	18	4	7	10	10	7	176	305	2	..	11
Boiler wagon . . . . .	..		..		13	0	..	1,170	2	12	48
„ „ . . . . .	..		..		22	0	..	..	2	9 $\frac{1}{2}$	38
Stone „ . . . . .	..		6	8	9	0	..	600	2	4	16
Steam lorry . . . . .	..		..		11	6	..	392	2	4 $\frac{1}{4}$	10 $\frac{1}{2}$

is a reasonable average to accept as a standard weight per square foot.

The width of highway bridges must depend on the requirements of the district. In large towns, and in the neighbourhood thereof they will most probably have to be wide enough to carry two lines of tramway, with width for a stream of traffic on each side, and with the usual allowances for footpaths. On footpaths of bridges and on foot-bridges it is usual to allow for the weight caused by a crowd of people, which is stated by various authorities to be between 80 lbs. and 140 lbs. per square foot; 120 lbs. per square foot is commonly considered sufficient allowance.

What standard loads, deduced from the data furnished by the Tables, are reasonable to adopt as a basis for calculating the strength of railway- and highway-bridges up to 200 feet span, is the question here raised for discussion. Whether for bridges carrying railways the figures in any of the columns in Table I. should be accepted as a standard—or whether engineers should adopt a hypothetical load, say a series of axles placed 5 feet apart, centre to centre, each bearing a load of 16 to 18 tons, and so should keep well in advance of possible requirements—are subjects for consideration. What is wanted is a standard load which will give some security that a structure may be allowed to live out its natural life; and it should be remembered that the best economy is obtained by providing the full strength of metal when a bridge is being constructed.

Considering the importance of the standardization of loads on bridges, it would seem to be a suitable subject for the Standards Committee to deal with, possibly in conjunction with other authorities and with the aid of the Board of Trade. That would be a step in the right direction; and in order to complete the subject of bridges, the Committee might further consider the relation between dead and live load, the factor of safety to be used, the effect of impact, vibration, etc.

The following speakers took part in the discussion of the subject:—Messrs. F. R. Upcott, F. E. Robertson, A. Fyson, W. J. Cudworth, E. Sauvage, J. Barton, and J. M. Moncrieff; and Mr. R. S. Scholefield, who was unable to be present, communicated his views in writing.