Please read and send in as full discussion as possible at earliest date

The Canadian Society of Civil Engineers
INCORPORATED 1887

ADVANCE PROOF—*(Subject to revision)*

TRACTION STRESSES.

By S. Blumenthal, A. M. Can. Soc. C. E.

(To be read at the first meeting of the General Section, Oct., 1910.)

In the design of bridge piers, trestle towers, and other similar structures, the effect of traction is an important consideration. Traction may be defined as the force parallel to the centre line of track produced by the live load, and acts at the level of the top of rail. Hence, in order to get structures that will be safe for the forces they have to resist, and that will be at the same time economically designed, it is essential that the actual conditions producing these forces be considered.

There are two conditions where stresses due to traction would occur:

(1) When a train is being hauled over the structure by a locomotive, with brakes off. In this case there would be a pull on the rails from the driving wheels of the locomotive, and an equal and opposite force due to the rolling and journal frictions and atmospheric resistance in the rest of the train. On a structure of any length these would tend to neutralize one another, and on a span long enough to take the whole train, would obviously produce no traction stresses in the piers.

(2) The second and most important case is the one where the brakes are applied to the wheels of a moving train. In this case, as long as the wheels revolve, the pull of the rails on the wheels =

the pull exerted by the brakes on the wheels = pressure of the brakeshoes, multiplied by the coefficient of brakeshoe friction. When this latter force becomes equal to the pull of the rail, the wheel will slide on the rail.

In nearly all of the existing specifications the traction force is taken as 20 per cent. of the total live load on the span considered. This condition assumes that enough pressure is applied by the brakes to skid all the wheels of a loaded train, with a coefficient of friction between wheel and rail of .20.

The standard American practice is to make the efficiencies of the brakes on the various classes of equipment as follows:

Passenger Cars..	..90 per cent. of light weight.
Freight Cars	..70 per cent. of light weight.
Tenders..	..100 per cent. of light weight.
Locomotive Driving Wheels..	..75 per cent. of the loaded weight.
Locomotive Truck Wheels	..75 per cent. of the loaded weight.

By efficiency of the brakes is meant the ratio of the total maximum pressure exerted by the brake shoes on the wheels to the vertical pressure of the wheels on the rails.

These percentages have been determined and adopted by the American Air Brake Association as best suited to actual service conditions, and are designed to prevent skidding and consequent flattening of wheels when the brakes are applied.

The comparatively high ratio of 90 per cent. of the light weight is used on passenger cars because there is small variation between the light and loaded weights, and it has been found that at the comparatively high speeds at which these cars run, the coefficient of brakeshoe friction is lower than that of freight cars which run at lower speeds.

The experiments of Captain Douglas Galton and Mr. George Westinghouse, Jr., made in 1878, show that the coefficient of friction between the cast-iron brakeshoes and steel-tired wheels varies from 5 per cent., at a speed of 60 miles per hour, to 25 per cent., at zero speed.

The coefficients for locomotive driving wheels and trucks are based on the loaded weights, since for these the loaded weight is the working weight, which does not vary much.

Assuming the value of 25 per cent. and Cooper's E/50 loading, a formula giving the coefficient of traction on spans of various lengths may be obtained.

A Locomotive of this size would carry 12½ Tons of Coal, say.. .. .. 25,000 lbs.
And 5,000 Gallons of Water.. .. .. 50,000 lbs.

75,000 lbs.

Working Weight of Tender.. .. .. 130,000 lbs.
Light Weight of Tender.. .. .. 55,000 lbs.
Per Axle.. .. .. 13,750 lbs.

Taking a span of 109 ft., the distance covered by two locomotives, the sum of the pressures exerted by the brakes on the wheels would be as follows:

75 per cent. of Working Load on 2 Trucks = 2 × .75 × 25,000 lbs. = ... 37,500 lbs.
75 per cent. of Working Load on 8 Driving Axles = 8 × .75 × 50,000 lbs. = ... 300,000 lbs.
100 per cent. of Light Load on 8 Tender Axles = 8 × 1 × 13,750 lbs. = ... 110,000 lbs.

Total Brake Pressure.. .. .. 447,500 lbs.

Total Longitudinal Force or Traction = 447,500 × .25 = 111,875 lbs.

Total Vertical Force = Weight of 2 Locomotives with Tenders at 355,000 lbs. = 710,000 lbs.

Coefficient of Traction for this Span (109 ft.) =

$$\frac{111,875}{710,000} = 15.75 \text{ per cent.}$$

The heaviest class of steel freight car in use at the present day, the short base 50-ton steel ore car, has an unloaded weight of about 1,500 lbs. per lin. ft., and a loaded weight of 5,000 lbs. per lin. ft., corresponding to the uniform load of 5,000 lbs. per lin. ft. behind the engines for Cooper's E/50 loading.

For every foot of train load there would be added a vertical force of 5,000 lbs., and a horizontal force of 1,500 × .70 (the efficiency of the brakes) × .25 (the coefficient of the brakeshoe friction) = 262.5 lbs.

From this the following formula has been derived:

Where T = the coefficient of traction or the ratio between the horizontal and vertical forces.
L = length of span covered by the live load.

$$T = \frac{111,875 + 262.5\ (L - 109)}{710,000 + 5,000\ (L - 109)}$$

simplified:

$$T = \frac{82{,}263 + 262.5\ L}{165{,}000 + 5{,}000\ L}$$

Or, in round figures:

$$T = \frac{82{,}000 + 265\ L}{165{,}000 + 5{,}000\ L}$$

From consideration of the above it will be seen that the coefficient of traction varies from a maximum of $.75 \times .25 = 18.75$ per cent. for spans of from 0 to 32 ft. to $.7 \times .25 \times \frac{1{,}500}{5{,}000} = 5.25$ per cent. for a span of infinite length.

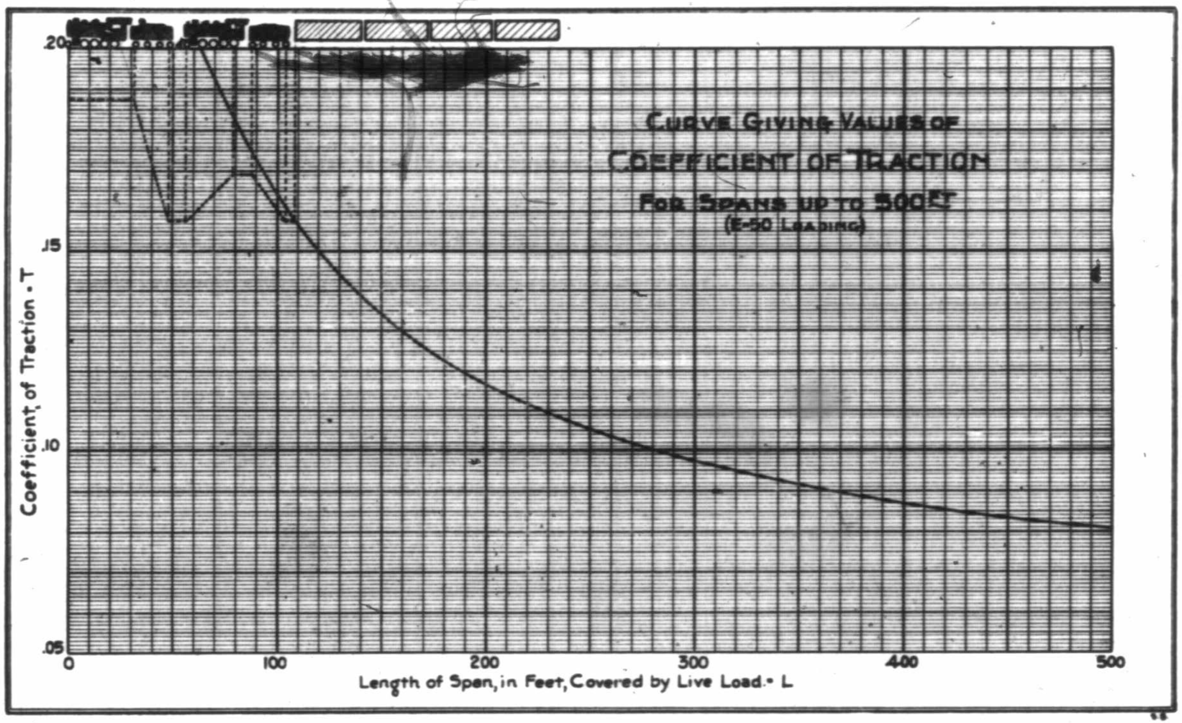
There is a possibility of the driving wheels of a locomotive skidding when the brakes are applied and the engine reversed. This would increase the coefficient slightly, and the effect would, of course, be greatest on the shorter spans. It would therefore seem reasonable to take a coefficient of 20 per cent. for spans up to about 60 ft., reduced for spans above this in accordance with the formula given above and as shown on Plate 1.

The assumed maximum value of 25 per cent. for the coefficient of brakeshoe friction was obtained in the experiments of Westinghouse and Galton for very low speeds (about 1½ miles per hour) immediately after the application of the brakes. The value decreased to about .17 five seconds after the brakes were applied, and to about .12 fifteen seconds afterwards.

The values given by the formula are therefore maximum values, and would only be obtained for an instant after the maximum brake pressure had suddenly been applied to a train which is moving very slowly, a condition which seldom occurs in actual practice.

Since the efficiency of the brakes is based on the unloaded or tare weight of the car, with a given tare weight per lin. ft. of car, it follows that the total tractive force on any given span will be the same, whether the cars are unloaded or loaded.

The full line on the attached diagram shows the coefficients for spans from 60 to 500 ft., computed from the formula derived above, the dotted lines representing values for spans under 109 ft., calculated from the brake efficiencies and weights given in the beginning of the paper.


Curve Giving Values of
Coefficient of Traction
For Spans up to 500 Ft
(E-50 Loading)
Coefficient of Traction - T
.20
.15
.10
.05
0
100
200
300
400
500
Length of Span, in Feet, Covered by Live Load - L