

which since then does regular service on the Stolberg-Wurselen Railway, there are on the Aix la Chapelle-Julich railway two engines of 45,000 kilogs. weight in regular use, which are intended for the service on the St. Gothard Railway. Their construction is illustrated in Figs. 7 and 9, and other data are given in a report by the chief engineer of the Aix la Chapelle-Julich Railway, Herr Pulzner, which runs as follows:

Wurselen, Dec. 23, 1884.

A trial trip was arranged on the line Haaren-Wurselen, the hardest section of the Aix la Chapelle-Julich Railway. This section has a gradient of 1 in 65 on a length of 4 kilos; and two curves of 250 and 300 meters radius and 667 meters length. The goods train consisted of twenty-two goods wagons, sixteen of which were empty and six loaded. The total weight of the wagons was 191,720 kilogs., and this train was drawn by the soda engine with ease and within the regulation time, while the steam pressure was almost constant, viz., five atmospheres. The greatest load admissible for the coal burning engines of 45,000 kilogs. weight on the same section is 180,000 kilogs.

Proof is therefore given that the soda engine has a working capacity which is at least equal to that of the coal burning engine. The heating surface of the soda engine, moreover, is 85 square meters, while that of the

interest which is much greater than that of any railway on the Continent, but there is no sign yet of their having done anything.—*E., in The Engineer.*

### SIMPLE METHODS OF CALCULATING STRESSES IN GIRDERS.

By CHARLES LEAN, M. Inst. C. E.

**Bowstring Girders.**—Having had occasion to get out the stresses in girders of the bowstring form, the author was not satisfied with the common formulae for the diagonal braces, which, owing to the difficulty of apportioning the stresses amongst five members meeting in one point, were to a large extent based on an assumption as to the course taken by the stresses. As far as he could ascertain it, the ordinary method was to assume that one set of diagonals, or those inclined, say, to the right-hand, acted at one time, and those inclined in the opposite direction at another time, and, in making the calculations, the apportionment of the stresses was effected by omitting one set. Calculations made in this way give results which would justify the common method adopted in the construction of bowstring girders, viz., of bracing the verticals and leaving the diagonal unbraced; but an inspection of many

girders. *e.* The maximum horizontal component of the stresses in any bay of the top flange is the same for each bay, and is equal to the maximum stress in the bottom flange. Having taken out the stresses in several forms of bowstring girders, differing from each other in the proportion of depth to span, the number of bays in the girder, and the amounts and ratios of the live and dead loads, similar results were invariably found, and a consideration of the various sets of calculations resulted in the following empirical rule for the stresses in the diagonals: "The horizontal component of the greatest stress in any diagonal, which will be both compressive and tensile, and is the same for every diagonal brace in the girder, is equal to the amount of the live load per bay multiplied by the span of the girder, and divided by sixteen times the depth of girder at center." The following formulae will give all the stresses in the bowstring girder, without the necessity of any diagrams, or basing any calculations on the assumed action of any of the members of the girders:

Let  $S$  = span of girder.  
 $D$  = depth at center.  
 $B$  = length of one bay.  
 $N$  = number of bays.  
 $L$  = length of any bay of top flange.  
 $l$  = length of any diagonal.  
 $w$  = dead load per bay of girder.  
 $w^1$  = live load per bay of girder.  
 $W$  = total load per bay of girder =  $w + w^1$ .

Then:  $\frac{S}{B} = N$ .

**Bottom Flange.**— $\frac{WNS}{8D}$  = maximum stress throughout. (1)

**Top Flange.**—In any bay the maximum stress =  $\frac{WN S}{8D} \times \frac{L}{B} + \frac{WL N^2}{8D}$ . (2)

**Verticals.**—The maximum stress =  $W$ . (3)

**Diagonals.**—The maximum stress is  $\pm \frac{w^1 l S}{16DB} = \pm \frac{w^1 l N}{16D}$ . (4)

These results show that the method generally adopted in the construction of bowstring girders is erroneous; and one consequence of the method is the observed looseness and rattling of the long embraced ties referred to at the commencement of this article during the passage of the live load; the fact being that they have at such times to sustain a compressive stress, which slightly buckles them, and sets them vibrating when they recover their original position.

Another necessity of the common method of construction is the use of an unnecessary quantity of metal in the diagonals; for, by leaving them unbraced, the set of diagonals which does act is subjected to exactly twice the stress which would be caused in it if the bridge was properly constructed. A comparison of the results of a set of calculations on the common plan with those given in this paper, shows at once that this is the case; for the ordinary system of calculating the stresses, in addition to showing compression in the verticals, gives exactly twice the amount of tension in the diagonals which they should have.

FIG. 1B.

Top Flange Stresses.			Stresses in Diagonals.		
	Hor.	Ver.		Hor.	Ver.
$C = 31.5 \times \frac{10}{4.5} = 70.00$	31.50	31.50	$a = 70 - 55 = 15$	15.00	2.25
$D = 25.75 \times \frac{10}{4.5} = 57.22$	25.75	57.22	$b = 57.22 - 55 = 2.22$	2.22	4.00
$E = 24 \times \frac{10}{8} = 30$	24.00	30.00	$c = 55 - 58.33 = -3.33$	-3.33	1.33
$F = 29.75 \times \frac{10}{10.5} = 28.33$	29.75	28.33	$d = 58.33 - 55.83 = 2.50$	2.50	1.75
$G = 23 \times \frac{10}{12} = 19.17$	23.00	19.17	$e = 55.83 - 54.50 = 1.33$	1.33	1.01
$H = 28.75 \times \frac{10}{12.5} = 23.00$	28.75	23.00	$f = 54.50 - 53.67 = 0.83$	0.83	0.59
$I = 27.75 \times \frac{10}{10.5} = 26.43$	27.75	26.43	$g = 53.67 - 53.09 = 0.58$	0.58	0.43
$J = 21 \times \frac{10}{8} = 26.25$	21.00	26.25	$h = 53.09 - 53.09 = 0$	0	0.33
$K = 11.75 \times \frac{10}{4.5} = 26.11$	11.75	26.11	$i = 53.09 - 52.67 = 0.42$	0.42	0.28
$L = 23.5 \times \frac{10}{4.5} = 52.22$	23.50	52.22	$j = 52.67 - 52.36 = 0.31$	0.31	0.24
			$k = 52.36 - 52.06 = 0.30$	0.30	0.18
			$l = 52.06 - 51.75 = 0.31$	0.31	0.16
			$m = 51.75 - 51.44 = 0.31$	0.31	0.13
			$n = 51.44 - 51.13 = 0.31$	0.31	0.11
			$o = 51.13 - 50.82 = 0.31$	0.31	0.06
			$p = 50.82 - 50.51 = 0.31$	0.31	0.06
			$q = 50.51 - 50.20 = 0.31$	0.31	0.06
			$r = 50.20 - 49.89 = 0.31$	0.31	0.06
			$s = 49.89 - 49.58 = 0.31$	0.31	0.06
			$t = 49.58 - 49.27 = 0.31$	0.31	0.06
			$u = 49.27 - 48.96 = 0.31$	0.31	0.06
			$v = 48.96 - 48.65 = 0.31$	0.31	0.06
			$w = 48.65 - 48.34 = 0.31$	0.31	0.06
			$x = 48.34 - 48.03 = 0.31$	0.31	0.06
			$y = 48.03 - 47.72 = 0.31$	0.31	0.06
			$z = 47.72 - 47.41 = 0.31$	0.31	0.06

—The Engineer.

### A SPRING MOTOR.

An exhibition of a spring car motor was given at a recent date at the works of the United States Spring Car Motor Construction Company, Twelfth Street and Montgomery Avenue. As a practical illustration of the operation of the motor a large platform car, containing a number of invited guests and representatives of the press, was propelled on a track the length of the shop. (This was in 1883.) The engine, if such it may be called, was of the size which is intended to be used on elevated railways. As constructed, the motor combines with a stationary shaft a series of drums, carrying springs, and arranged so that they can be brought into use singly or in pairs. Each spring or section has sufficient capacity to run the car, and thus as one spring is used another is applied. There is a series of clutches by which the drums to which the springs are

Fig. 7.

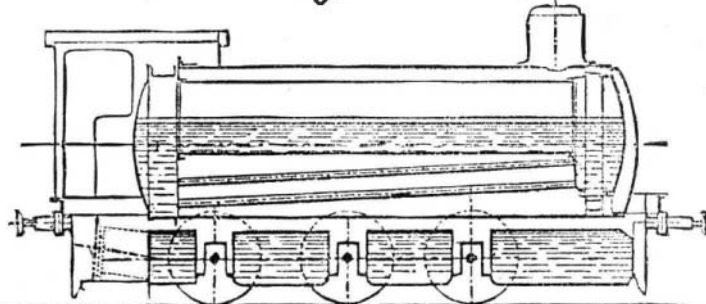
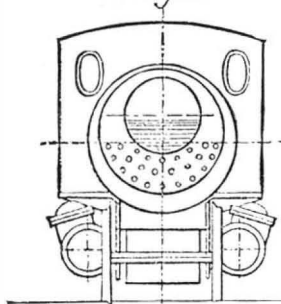


Fig. 8.



corresponding new Henschel engine is 92 square meters. On a former occasion I have already stated that the soda engine is capable not only of performing powerful work and of producing a large quantity of steam during a short time, but also of travelling long distances with the same quantity of soda. Thus, for example, a regular passenger train, with military transport of ten carriages, was conveyed on Nov. 6, 1884, from Aix la Chapelle to Julich and back, i. e., a distance of 45 kilogs, by means of the fireless engine. The gradients on this line are 1 in 100, 1 in 80, and 1 in 65, being a total elevation of about 200 meters. For a performance like this a powerful engine is required, and a proof of it can be recognized in the consumption of steam during the journey, for the quantity of water evaporated and absorbed by  $4\frac{1}{2}$  to 5 cubic meters soda lye was 6,500 liters.

Another certificate concerning the tramway engine illustrated in Figs. 5 and 6 is of equal interest, and runs as follows:

Aix la Chapelle, Jan. 5, 1885.

A fireless soda engine, together with evaporating apparatus, has been at work on the Aix la Chapelle-Burtscheid tramway for the last half year. In order to test the working capacity of this locomotive engine, and the consumption of fuel on a certain day, the Honigmann locomotive engine was put to work this day from 8.45 o'clock a. m. till 8 o'clock p. m., with a pause of three-quarters of an hour for the second quantity of soda lye. The engine was, therefore, at work for fully  $10\frac{1}{2}$  hours, viz.,  $5\frac{1}{2}$  hours with the first quantity, and five with the second. The distance between Heinrichsalle and Wilhelmstrasse, where the engine performed the regular service, is 1 kilo, and there are gradients

Of about 1 in 30 in 400 meter length.

" 1 " 45 " 250 "

" 1 " 72 " 350 "

This distance was traversed sixty-four times, the total distance, including the journeys to the station, being 66 kilogs. The engine gives off fully 15-horse power on the steepest gradient, the total traction weight being  $8\frac{1}{2}$  to 9 tons; it is worked with an average steam pressure of 5 atmospheres, and has cylinders of 180 mm. diameter and 220 mm. stroke, cog wheel-gear of 2 to 3, and driving wheels of 700 mm. diameter. The quantity of water evaporated during the service time of  $10\frac{1}{2}$  hours was found to be about 1,600 kilogs., consequently about 800 kilogs. steam was absorbed by one quantity of soda, the weight of which was ascertained at about 1,100 kilogs. The averaging heating surface is 9.8 square meters; the difference of temperature between soda lye and water was toward the end only 3 deg. Cent.; 234 kilogs. pit-coal were used for boiling down the lye for the  $10\frac{1}{2}$  hours' service, which corresponds to a 6.6 fold evaporation.

(Signed) M. F. GUTERMUTH,

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Here are some unquestionable results. For nearly a year the first railway engine, and for six months the first tramway engine of this new construction, have been introduced into regular public service, and been open to public inspection as well as to the criticism of the scientific world. They are worked with greater ease and simplicity than ordinary locomotive engines; the economy of their working appears, allowing for shortcomings unavoidably attached to small establishments, to be at least equally great: they do not emit either steam or smoke, and their action is as noiseless as that of stationary engines.

In view of these facts it might be expected that railway managers, who are continually told that the smoke of their engines is a serious annoyance to the public, would be eager to make themselves acquainted with them; it might, in particular, be expected that the managers of the underground and suburban railways of this metropolis would lose no time in making experiments on their own lines—if only by converting some of their old engines into those of the fireless system—and assist a little in the development of an invention, in the success of which they have a tangible

existing examples of these bridges during the passing of the live load showed that there was something defective in them. The long unbraced ties vibrated considerably, and evidently got slack during a part of the time that the live load was passing over the bridge. In order to get some definite formulae for these girders free from any assumed conditions as to the course taken by the stresses, or their apportionment amongst the several members meeting at each joint, the author adopted the following method, which, he believes, has not hitherto been used by engineers:

Let Fig. 1 represent a bowstring girder, the stresses in which it is desired to ascertain under the loads shown on it by the circles, the figures in the small circles representing the dead load per bay, and (shown in the large circle the total of live and dead load per bay of the main girders. A girder, Fig. 1A, with parallel flanges, verticals, and diagonals, and depth equal to the length of one bay, was drawn with the same loading as the bowstring. The stresses in the flanges were taken out, as shown in the figure, keeping separate those caused by diagonals inclined to the left from those caused by diagonals inclined to the right. The vertical component of the stress in the end bay of the top flange of the bowstring girder, Fig. 1, was, of course, equal to the pressure on the abutment, and the stress in the first bay of the bottom flange and the horizontal component of the stress in the first bay of the top flange was obtained by multiplying this pressure by the length of the bay and dividing by the length of the first vertical. The horizontal component of the stress in any other bay of the top or bottom flange of the bowstring girder—Fig. 1—was found by adding together the product of the stress in the parallel flanged girder, caused by diagonals inclining to the right, divided by the depth of the bowstring girder at the left of the bay, and multiplied by the depth of the parallel flanged girder; and the product of the stress caused by diagonals inclining to the left divided by the depth of the bowstring girder at the right of the bay, multiplied by the depth of the parallel flanged girder. Thus the horizontal component of the stress in  $D$  =

$$\left( \begin{array}{l} \text{Stress caused by diagonals} \\ \text{leaning to left.} \end{array} \times \begin{array}{l} \text{Length of right} \\ \text{vertical.} \end{array} \times \begin{array}{l} \text{Depth of parallel} \\ \text{flanged girder.} \end{array} \right) + \left( \begin{array}{l} \text{Stress caused by diagonals} \\ \text{inclined to right.} \end{array} \times \begin{array}{l} \text{Length of vertical} \\ \text{to left.} \end{array} \times \begin{array}{l} \text{Depth of parallel} \\ \text{flanged girder.} \end{array} \right)$$

$$= 65; \text{ and the vertical component} = \frac{65}{10} \times \frac{1}{10} \times (8.0 - 4.5) = 22.75.$$

In the same way the horizontal and vertical components of the stresses in each of the other bays of the flanges of the bowstring were found; and the stresses in the verticals and diagonals were found by addition, subtraction, and reduction. These calculations are shown on the table, Fig. 1B. The result of this is a complete set of stresses in all the members of the bowstring girder—see Fig. 2—which produce a state of equilibrium at each point. The fact that this state of equilibrium is produced proves conclusively that the rule above described and thus applied, although possibly it may be considered empirical, results in the correct solution of the question, and that the stresses shown are actually those which the girder would have to sustain under the given position of the live load. Figs. 2 to 10 inclusive show stresses arrived at in this manner for every position of the live load. An inspection of these diagrams shows: *a.* That there is no single instance of compression in a vertical member of the bowstring girder. *b.* That every one of the diagonals is subjected to compression at some point or other in the passage of the live load over the bridge. *c.* That the maximum horizontal component of the stresses in each of the diagonals is a constant quantity, not only for tension and compression, but for all the diagonals. The diagrams also show the following facts, which are, however, recognized in the common formulae: *d.* The maximum stress in any vertical is equal to the sum of the amounts of the live and dead loads per bay of the