SCIENTIFIC AMERICAN

[Entered at the Post Office of New York, N. Y., as Second Class matter. Copyright, 1896, by Munn & Co.]

A WEEKLY JOURNAL OF PRACTICAL INFORMATION, ART, SCIENCE, MECHANICS, CHEMISTRY, AND MANUFACTURES.

Vol. LXXV.—No. 13.
Established 1845.

NEW YORK, SEPTEMBER 26, 1896.

$3.00 A YEAR.
Weekly.

THE RIGID SUSPENSION BRIDGE AT LOSCHWITZ, SAXONY.

BY ROBERT GRIMSHAW.

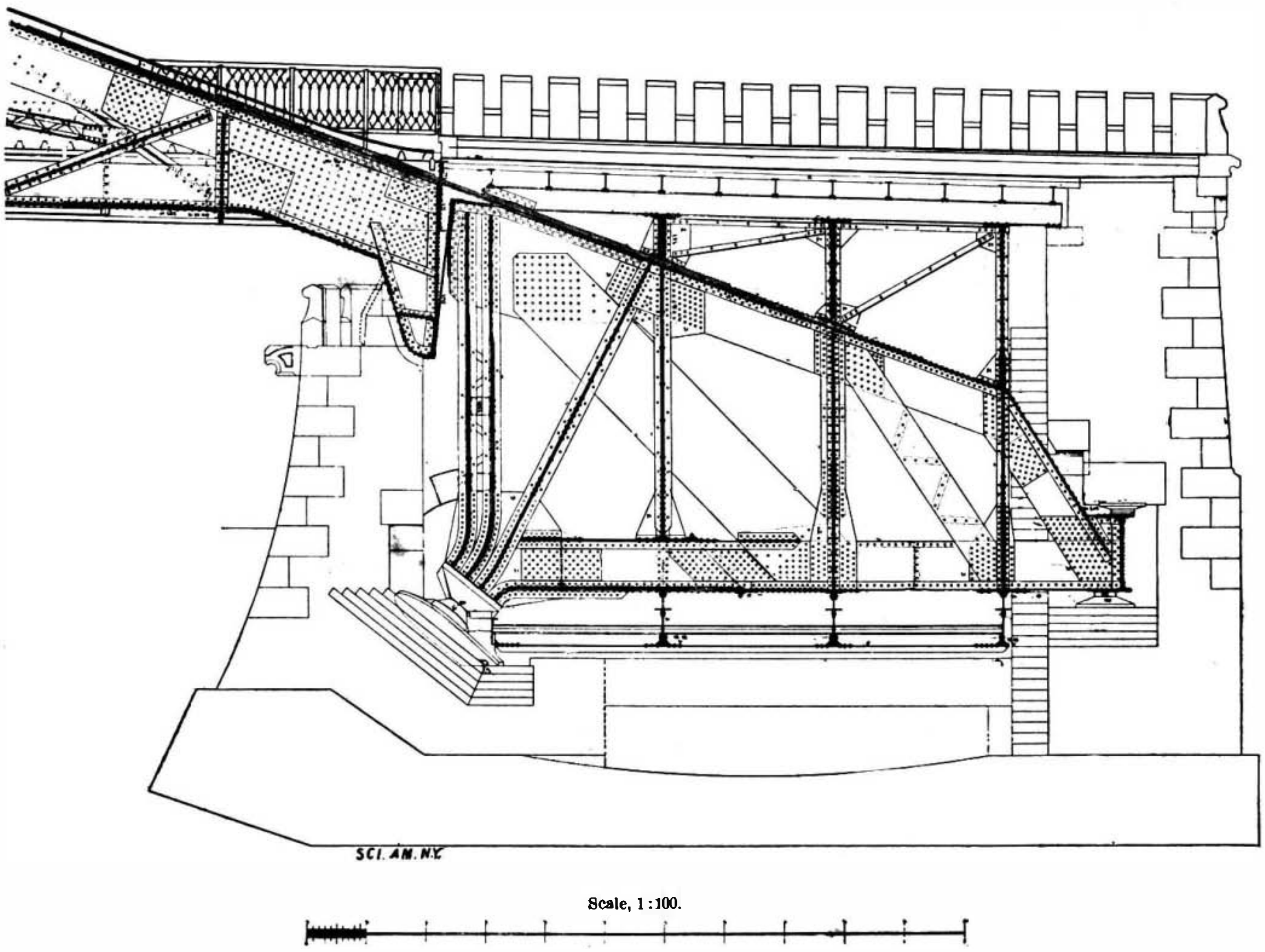
The earliest suspension bridges—suggested probably by the vine trailing across from one tree to another on opposite sides of a stream, was characterized by extreme lateral and vertical flexibility. As in instance after instance this was found to be a source of danger, engineers in successive suspension structures endeavored to give an element of stiffness.

One method employed by Roebling, at the Niagara wire rope bridge, was the addition of a wooden lattice girder; but this did not give sufficient stiffness to permit of the passage of railway trains at any but a slow rate of speed.

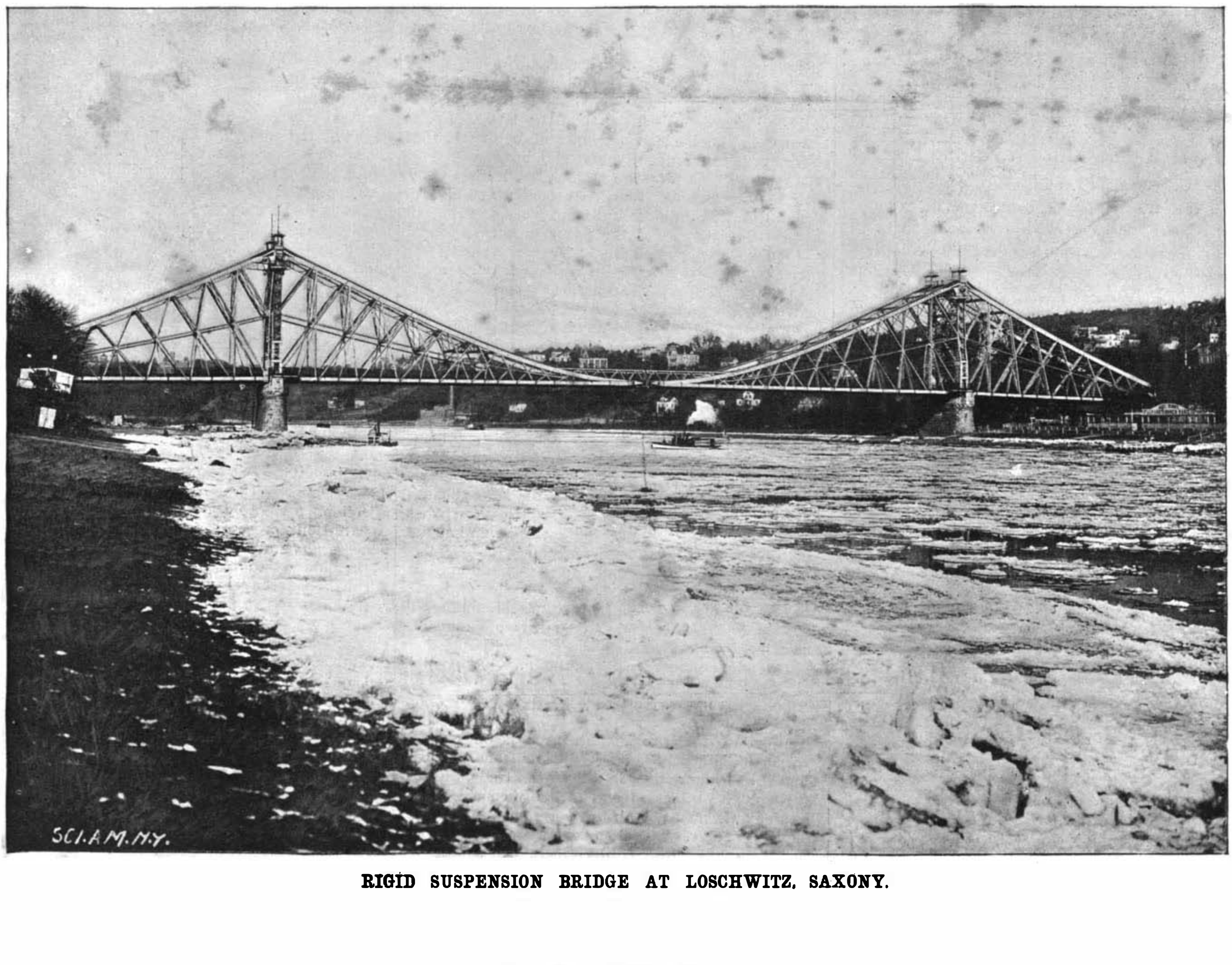
About 1856 a railway was planned between Hamburg and Harburg, crossing the River Elbe twice, with a width near Harburg of about 1,000 feet of deep water and 2,000 feet in all. At that time the erection of piers in deep and rapid rivers with sandy bottom was deemed risky and unsafe, and as the cantilever principle had not yet been introduced, the bridging of the deep portion of 1,000 feet span was planned to be effected by a suspension bridge. (It may be noted that afterward girder bridges have been constructed both at Hamburg and at Harburg, with piers only 100 meters = 328 feet apart.)

For stiffening this proposed structure it was recommended so to connect the chain with the roadway frame that each half formed a rigid beam, hung from one end on a pier and hinged at the center to its mate. As the bending influence of the live load was highest

(Continued on p. 248.)



COUNTERPOISE ANCHORAGE.



RIGID SUSPENSION BRIDGE AT LOSCHWITZ, SAXONY.

THE RIGID SUSPENSION BRIDGE AT LOSCHWITZ, SAXONY.

(Continued from first page.)

in effect near the vertex, the hinge was placed considerably above the roadway frame.

As far back as 1861 * attention was called by Claus Koepcke, the engineer of the Hanoverian Railway, to the fact that the proposed hinge system was applicable to arched bridges, also ; and three-hinged arches were recommended by him. Since then, a number of three-hinged arched iron bridges and roofs have been constructed ; a notable example being the roof of the Manufactures and Liberal Arts building at the Chicago Exposition. The "Flora" horticultural establishment at Charlottenburg, near Berlin, was the first roof example ; and good instances of three-hinged suspension bridges are seen in the 80 meter = 262 foot foot-bridge at Frankfort-on-the-Main, one over the Tiber at Rome, and the 244 meter=800 foot Point bridge over the Monongahela at Pittsburg.

More recently we have the Tower bridge over the Thames at London, the two side spans of which, each 305 feet = 92 meters long, are each composed of two unequal sections, one 188 feet = 57 meters and the other 117 feet = 35 meters, hinged at pillars and at center of length ; and the same system is applied in Koepcke's bridge between Loschwitz and Blasewitz, over the Elbe, just above Dresden.

Although this bridge was designed only for ordinary street traffic, it would safely bear a double track steam railway. There is a carriage road 7 meters = 23 feet wide, and on each side a footway 2·06 meters = 6·75 feet ; the clear distance between railings being 11·12 meters = 36·5 feet. Provision is made to attach brackets to prolongations of the cross beams, outside of the girders, for the support of two additional footways, should these be demanded by increase of traffic.

The center span is 146·68 meters = 481 feet long, with a height of 24 meters = 78·7 feet. The main chain is an inverted arch, the curve of which is an hyperbola having the vertex equation

$$y = 1{\cdot}871 \sqrt{40\,x + x^2}$$

x and y being the vertical and the horizontal co-ordinates respectively.

Each side span is 61·76 meters = 202·6 feet. Their main chains are in circular arcs with 375 meters = 1,230 feet radius. Their bottom flanges are straight, and rise with a gradient of 0·0225. The vertex, with average temperature, rises 0·608 meter or with an inclination of 0·0083.

The side girders are connected at the abutments to loaded levers or anchors, each built in a room 10·5 meters = 34·4 feet long, and transferring the pull of the bridge through four working points to the abutments, which it reaches at a depth of 7·5 meters = 24·6 feet below the roadway.

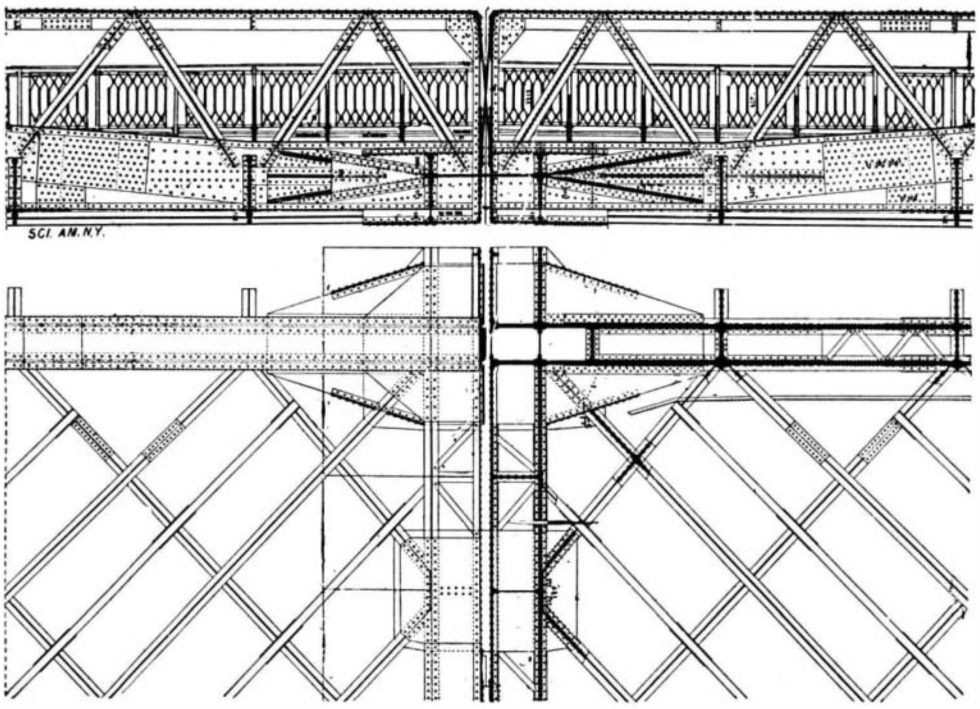
The constructive weight of each anchor is 225 tons ;† its load is in all about 1,535 tons.

As additional anchorage, the lower anchor frames are placed in niches of the abutments, the weight of which latter would effectually aid in holding down the structure, even if the normal bridge load (calculated at 400 kilogrammes per square meter = 82 lb. per square foot) should be trebled.

As two railway trains, occupying the whole distance between girders, would load the bridge only to 480 kilogrammes per square meter, or 100 lb. per square foot ; and as in case of widening the bridge to the extra outside footways 2 meters wide, on brackets, the constructive parts would have a load of only 50 per cent more than at present possible, it may be safely assumed that this bridge is safe beyond all possibility of doubt. The cross beams are laid diagonally, and intersect each other ; one of each crossing pair having a height of 115 cm. = 3·77 feet and the other of 94 cm. = 3·08 feet, so that their flanges are uninterrupted. To counteract the interruption of the webs of the wider beams, there are at each crossing four angle irons. Between every pair of wide cross beams there is placed, to divide the interstice to be bridged by iron sheets of inverted U section, a rolled I beam. To prevent rusting, this I beam rests on bars 2 cm. = 0·787 inch square, laid along the middles of the wide cross beams and of the rolled beams. The gaps in the U shaped flooring are covered by sheet iron, on which there is a sheeting of fir wood filled with asphaltum, which slopes from the center line of the roadway to the footways at each side, and carries an oak pavement in which is laid a double track electric railway.

The footways are formed of two crossing diagonal layers of planks, borne by three lengthwise stringers resting directly on the U irons.

The material of the bridge is chiefly Siemens soft basic steel, with a breaking strength of 51,000 to 64,000 lb. per square inch, having 20 to 30 per cent elongation in 20 cm. = 7·87 inches. The elastic limit comes between 30,000 to 40,000 lb. per square inch, and the area reduction at the breaking point is 40 to 65 per cent.



SPRING HINGE AT VERTEX OF MAIN HINGE.

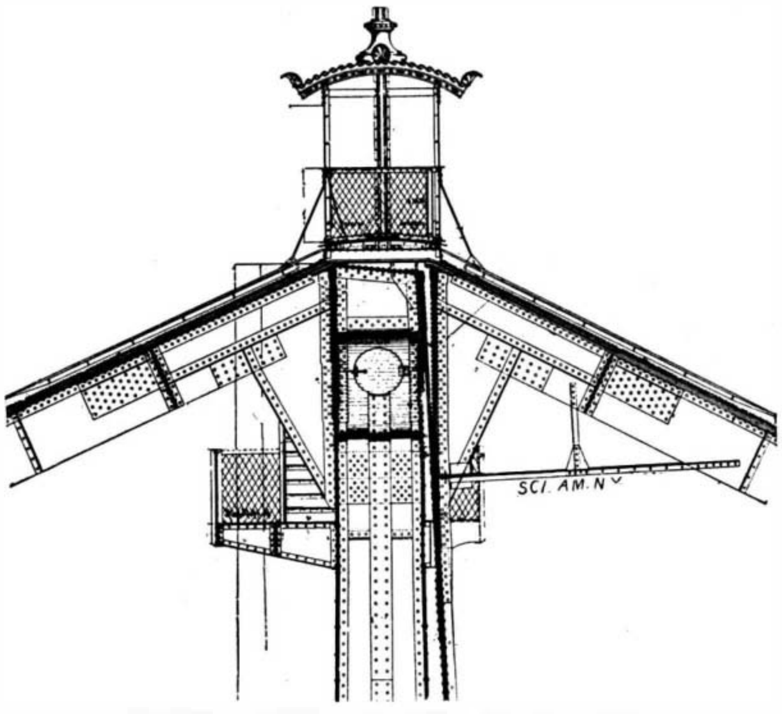
The bed plates on the masonry are cast iron, and the square blocks between them and the anchors, as well as those between the rollers and the pillars, are of cast steel.

The foundation, which rests on solid gravel, has been made within sheet piling, the masonry is cement concrete and quarry stone covered with sandstone.

The total weight of iron and steel in the girders and anchors is 3,800·5 metric tons, which, together with the lead slag, wooden roadway and footways, with two sets of tramway tracks, gives a total weight of 6,708·7 tons.

The total permanent load of the girders is 2,787·2 tons.

This load of 2,787 tons, distributed over 270·2 meters = 886·5 feet, gives 10,316 kilogrammes per meter (= 20,800 lb. per yard) run.



SPRING HINGE AT TOP OF PILLARS.

The movable load is estimated as 736 lb. per square yard, or 8,968 lb. per yard run.

The maximum horizontal strain is 826 tons for each girder.

The minimum stress caused by the bridge weight is 1,158·6 tons, or 579·3 tons per girder.

This bridge was built for the Saxon government, from the designs of Geheimerrath Koepcke and Mr. Manfred Krueger, the latter of whom was resident engineer. The builders were the Marienhuette firm, of Cainsdorf, near Zwickau.

In the construction of the bridge there are introduced many innovations, the principal of which are:

(1) Making the pillars part of the girders.
(2) Using springs in the hinges.
(3) Putting the center hinge at the level of the bottom member.
(4) Using cross beams in net-like arrangement.
(5) Taking the pull of the bridge with loaded levers.
(6) The use of the "bridge brake."

(1) All previous suspension bridges had masonry or iron columns to support the chains or girders ; as at Frankfort, Pittsburg, Wheeling, Brooklyn, Niagara, etc. In some cases (as at Rome, Italy) iron levers were used. But here the pillars form the back frames of the center girders. This gives great stability against wind and centrifugal force (as proved during severe equinoctial storms), and permits expansion and contraction from load and from temperature changes. The pillars are supported by square swing blocks on rollers resting on cast iron bed plates, weighing 7,632 kg. = 16,850 lb. each. The total movement of a pillar between the extremes of minimum load in summer and no load in winter is 7 cm. = 2·8 in.

The stone piers, which get but slight horizontal pressure from rolling friction, have the maximum vertical pressure of 1,090 tons from each of the four pillars. The bottom members of the side spans are kept in position by toes sliding lengthwise in the pillars, and hence are held against lateral pressure, besides being braked against longitudinal vibration as described under (6). Internal spiral stairs give access to summits and bases, and, in fact, to all parts, of the pillars, for the purpose of inspection, painting, or repairs.

(2) The use of springs in the hinges was suggested by the bad performance, in common suspension bridges, of pin joints, which have been in some cases found entirely immovable. An instance of this was discovered at the Tetschen bridge over the Elbe, when Fraenkel found all the deformations of the chains, whether by load or by temperature, to take place only by bending of the links, in consequence of which discovery the permissible traffic had to be reduced.

Now, while the halves of a rigid suspension bridge may not be so flexible as a single chain link of a common suspension bridge, the friction, if pins were used, might cause bending of adjoining parts of the girders ; especially as the pins must be of large diameter.

The spring link principle * consists in producing at the joints pulling resistances in two crossing directions; hence care must be taken that the combination of stresses by direct pull and by bending do not exceed certain limits. The angular motions in three-hinged arches or in three-hinged suspension bridges are caused more by temperature changes than by load variations.

In this bridge the angular motions of each pillar, both sides of the vertical axis (the motionless point being nearly in the center of height of the pillar, or 12 meters = 39·4 feet) is $\frac{0{\cdot}07\text{ m.}}{12\text{ m.}} = 0{\cdot}00583$, or about 20 minutes of arc.

The vertical motion of the vertex is therefore (the half span being 73·34 m. or 240·5 ft.) 73·34 × 0·00583 = 0·42 m. ; or 21 cm. = 8·3 in. above, and the same below, the neutral position. 1° C. = 1·8° F. change of temperature causes 4·5 mm. = $\frac{3}{16}$ inch motion at the vertex.

The stress in a spring of the thickness d or the coefficient θ of change of its length, l, in consequence of bending it to an arc, w, may be found from the equation

$$\theta = \frac{dw}{2\,l}$$

Now the middle horizontal spring is made up of three parts : two side parts each of two plates of 2 cm. = 0·8 in. thick and 100 cm. = 39·4 in. wide by 165 cm. = 68·9 in. long, and a middle part made of four plates of the same thickness, 54 cm. = 21·3 in. wide and 330 cm. = 130 in. long ; the cross sectional area being 1,232 sq. cm. = 191 sq. in. ; the greatest tensile stress is therefore

$$\frac{826000\text{ kg.}}{1232} = 670\text{ kg.}$$

As the angular motion at the vertex is double that at

---

* See Civil Engineer and Architect's Journal of that year.

† All the tons here mentioned are metric, of 2,205 lb. avoirdupois ; the difference between these and our legal tons being unimportant.

* Published in the Zeitschrift of the Hanoverian Engineers' Association, 1889.

the pillars, we have $\theta = \dfrac{2 \times 0{\cdot}00583 \times 8}{2 \times 330} = 0{\cdot}000141$

The coefficient of elasticity being about 2,000,000 kg. per square centimeter = say 28,446,000 lb. per square inch, this θ corresponds to a change of tension of 0·000141 × 2000000 = 282 kg. = 619·6 lb., or to a change of $\frac{282}{2}$ = 141 kg. = 309·8 lb. greater and less than the stress at the middle position. Therefore the tensions in the horizontal spring at the vertex will vary between 670 + 141 and 670 —141; or 811 and 529 kg. per square centimeter or 11663 and 8676 lb. per square inch.

As the spring plates are not riveted together, and hence each one may bend separately, the difference in tensions in the uppermost and the lowermost fibers is only ¼ of that above calculated; the other ¾ of the 141 kg. being manifested as a difference of tensions, common to all constructions. There is, then, nothing risky in using springs or plates for hinges, as the materials will sustain the bending without damage, the more so as the maximum temperature changes occur only at long intervals, and the changes caused by load variations are but a small proportion of those caused by temperature changes.

The double vertical plates in the center withstand the shearing stresses caused by loads passing that point. The springs at the abutments have but slight angular motion—that due to flexure of the side span girder by load variations, temperature changes being here without influence.

Similar spring hinges have been applied to small cantilever bridges in Dresden, to prevent lifting of the girder ends on the four points of support.

(3) The vertex hinge has been put below the roadway surface to get the necessary horizontal stiffness by making the roadway framework a nearly straight girder with uninterrupted flanges, connected by the cross beams, which here form the wind bracing. All other suspension bridges have the vertex considerably above the roadway, to get necessary vertical stiffness. Thus in these others the transmission of stresses through the vertex distorts the connecting members and causes injurious horizontal motions of the whole girder.

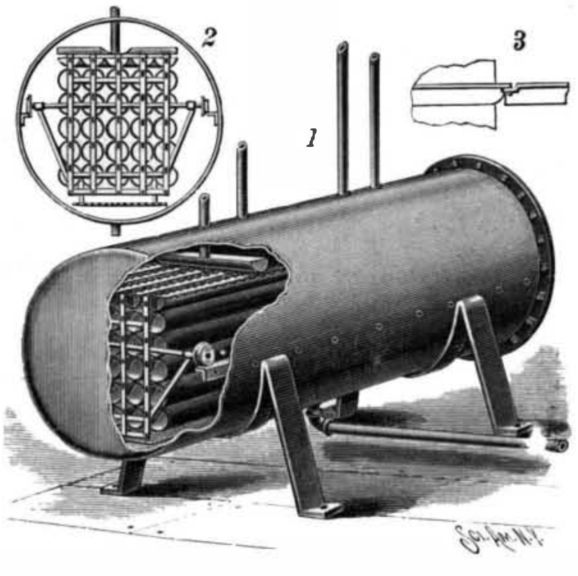
Besides this, there is difficulty in making the hinges as single links (as in the Thames and Monongahela bridges) with pins, for heavy stresses, as the narrowing of the free space between the girders must be avoided. On the contrary, the total breadth of the plates forming the two main springs at the vertex of the Loschwitz bridge is 2·8 m. = 8·5 ft., and besides these, there are also two horizontal plates under the roadway, connecting the hips of the cross beams; and a pair of vertical plates for carrying the vertical stresses caused by moving loads passing the center opening. Thus considerable additional stiffness in the roadway has been obtained. The diagonal cross beams take part of the lengthwise stresses; while they also resist shearing effects, such as those caused by the wind blowing unequally on the different halves of the girder. These connecting springs could only be applied by placing them below the roadway.

(4) Transverse beams crossing each other diagonally so as to make a horizontal lattice which stiffens the bridge against wind and passing loads were recommended as far back as 1860, in the Hannover'sche Zeitschrift; and in 1861 in the Civil Engineer and Architect's Journal of January 1.

The value of this bracing, together with the position of the middle hinge at the level of the lower flanges, in the Loschwitz bridge, may be seen in the fact that its lateral motion during the passage of thirty-six men keeping step was but 0·45 mm. = $\frac{1}{56}$ inch.

Although special diagonal bracing may be strong enough statically, the greater changes of length by tension and compression in such special bracings, which are, of course, weaker than the cross beams, increases the lateral flexure and hence the oscillation period. The matter of oscillation of bridges is more appreciated of late years than formerly, the conviction gaining ground rapidly that horizontal vibrations are as injurious to durability as vertical ones are.

(5) Loaded levers to counteract the push of an arch were applied to the street girder of the bridge over the Elbe at Riesa. The chains or cables of suspension bridges are usually anchored to the natural rock or confined in walled abutments; but there is seldom any precaution taken to permit easy access to all parts of the anchorage system, which last has often been rapidly destroyed by rust. The anchors of the Loschwitz bridge are accessible in every part, so that their coat of coal tar can be readily inspected, and, when necessary, renewed. The anchors bear, in addition to their regular load, the roadway, which covers them, and which is of slag blocks on Monier plate, their ends being inserted into the walls. They cannot give way by any increase of the bridge load within the limits of the bridge strength.



MUNDAY'S FEED WATER HEATER.

(6) The bridge brake consists of clamps which oppose to the sliding or vibratory motion of various parts of a bridge a certain amount of sliding friction, regulatable by springs, by bolts and nuts or otherwise, and thus absorbing much of the vibration or other injurious motion. It is most successfully applied in the bridge here described.

At a trial of the stiffness of this bridge a load of steam and horse road rollers, vehicles, etc., amounting to 150 tons, caused a center deflection of but 9 millimeters, = ⅜ inch, and a company of soldiers marching over it in step caused scarcely perceptible vibration.

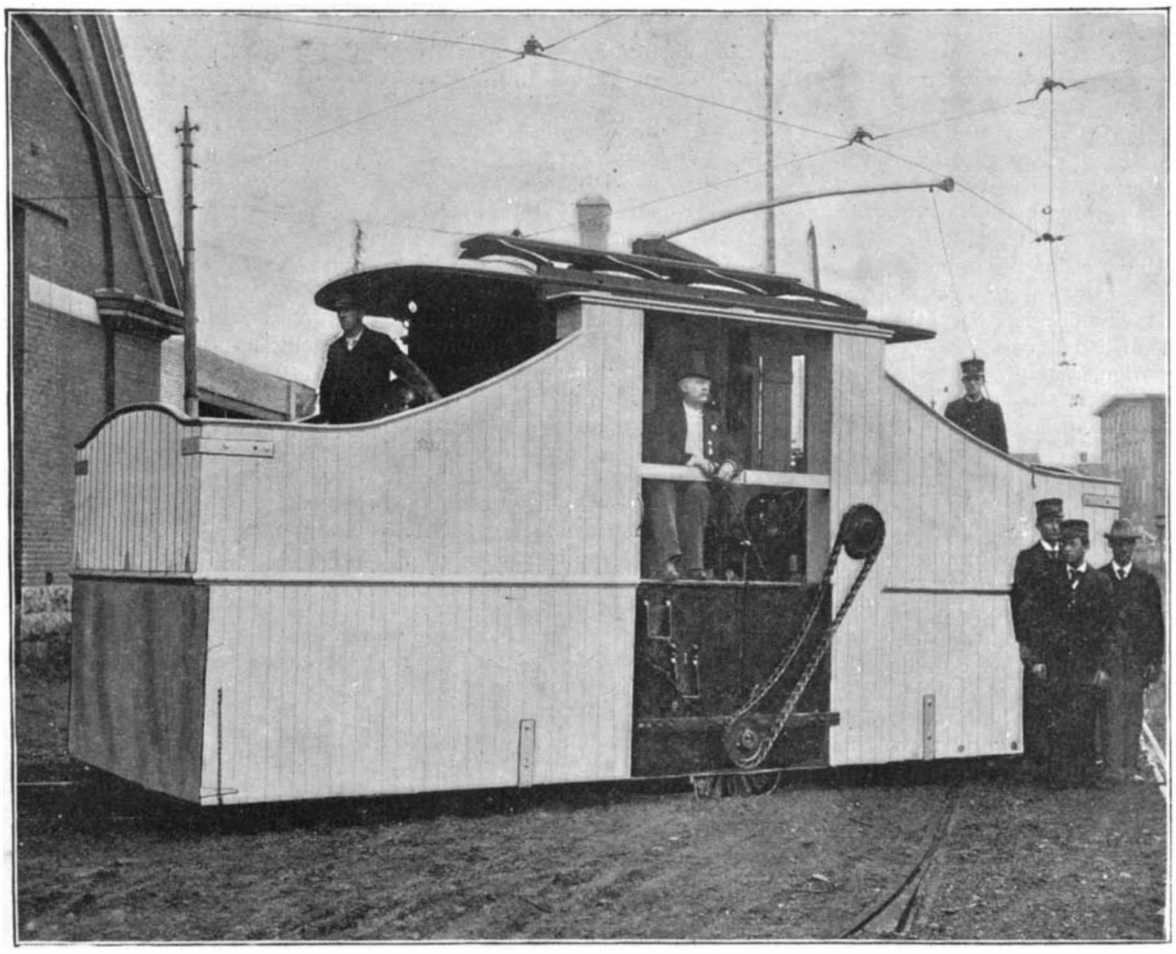
◆

AN ELECTRIC SELF-LOADING CAR FOR STREET CLEANING.

Among the many novel applications of electricity one of the latest is that shown in the accompanying illustration, where it is utilized, through the medium of an electric car, for sweeping up and carrying off the street refuse. The car is 8 feet wide by 25 feet long and 11 feet high. It is carried on two axles, and is fitted with the usual equipment of a trolley car. The brakes and the motor are placed above the wheels. The motor is connected by chain and sprocket gear to the driving wheels and to the brush, the brush making five revolutions to one of the car wheels. The brush runs in a cylindrical case which is open at the top and the bottom, and it is arranged to work both ways, a reversible steel deflector being arranged above the brush. The car consists of an upper platform, in the center of which is a shelter or cab containing the motor, and a lower closed section into which the street rubbish is thrown. Its lower floor is formed in parallel sections, which are hinged transversely to the car, and by the operation of a lever can be opened for dumping out the refuse. The broom, which ordinarily, as shown in the illustration, is the full width of the car, can be extended to cover nearly the full width of the street if so desired.

In operation these cars are used in connection with manual labor, the sweepings of the gutters and sides of the street being thrown toward the center, where they are picked up by the car, which thus sweeps its own section of the road, and also takes the place of the refuse carts.

The car is the invention of A. Jackson Reynolds, of Montreal, who states that when sweeping it travels at the rate of six to eight miles an hour, and that it carries refuse, snow, etc., out of the city at a cost of $2.50 per mile. For removing snow a car specially wide and long is constructed; and it is claimed that by running the car continuously during a snow storm there is no difficulty in keeping a street open. A self-loading car is now being built which will be one of the largest street cars in the world, being 8½ feet wide and 45 feet in length. It will have a capacity for cleaning 25 miles of street without stopping.



ELECTRIC SELF-LOADING CAR FOR STREET SWEEPING.

◆

AN IMPROVED FEED WATER HEATER.

The illustration represents a heater in which troughs connected with the supply pipes distribute the water over tubes in thin streams or a thin sheet, within the shell of the heater, with whose upper portion steam inlet pipes are connected. The improvement has been patented by George T. Munday, Brenham, Texas. On opposite sides of the interior of the shell are secured angle irons forming tracks, on which the tubes are removably supported by means of a supporting frame at each end, as shown in Fig. 1, and in the sectional view, Fig. 2, a transverse shaft of the frame carrying rollers which travel on the tracks. The tubes are open at their ends, to permit the free circulation through them of steam admitted to the heater, and extended above the tubes are troughs supported by the end frames, the edges of the troughs being serrated to cause the breaking up and fine distribution of water flowing from them, each feed pipe discharging into transverse troughs. Below the tubes is a wire cloth screen, also supported by the movable frame, designed to receive falling scale, and in the bottom of the shell is an outlet blow-off pipe. When the tubes and troughs are to be removed from the heater, for cleaning and the removal of scale, the head of the shell is taken off and extensions of the angle iron tracks, as shown in Fig. 3, are connected with the ends of the tracks within the heater, the outer ends of the track extensions being supported in any desired manner, when the whole interior mechanism may be readily drawn out. It is designed with this heater to heat the water as nearly as possible to the temperature corresponding with the boiler pressure, and effect the rapid formation of scale, which may be removed with but little trouble.

◆

PROF. WM. H. BREWER contributes to the Yale Scientific Monthly an account of observations during the past 45 years on earth tremors at Niagara Falls. The heaviest vibrations were on either side of and near the Horseshoe Fall. They disappeared in places in the soft shales below the limestone, although they were evident in the harder limestone and sandstones that occur amid these. Passing down along the gorge, the vibrations decreased in intensity, becoming too faint to be perceived between the suspension bridges, but increasing again on nearing the rapids. Persons living near the falls believe that crystals are more common in the rocks there than elsewhere, the texture having been affected by the jar of the cataract, but Prof. Brewer finds no evidence of this.