BRIDGES.

Fig. 1. LONDON OLD BRIDGE

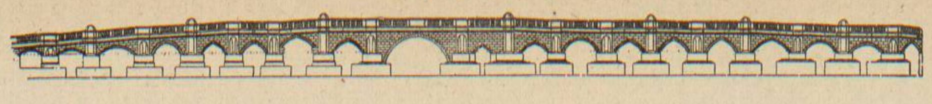


Fig. 2. LONDON NEW BRIDGE.

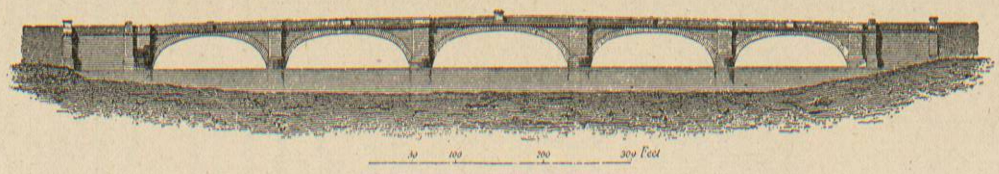


Fig. 3. WATERLOO BRIDGE

Fig. 4. SOUTHWARK BRIDGE

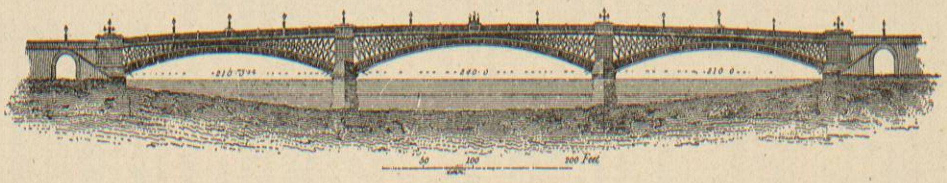
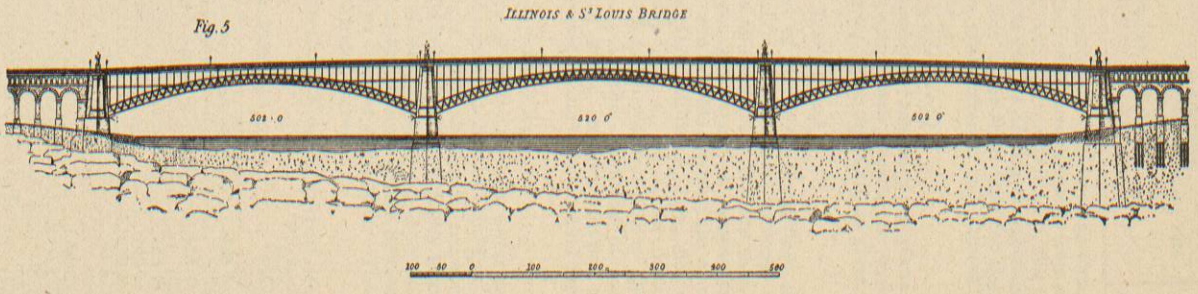


Fig. 5. ILLINOIS & ST LOUIS BRIDGE



BRIDGES.

Fig. 1. BRITANNIA TUBULAR BRIDGE.

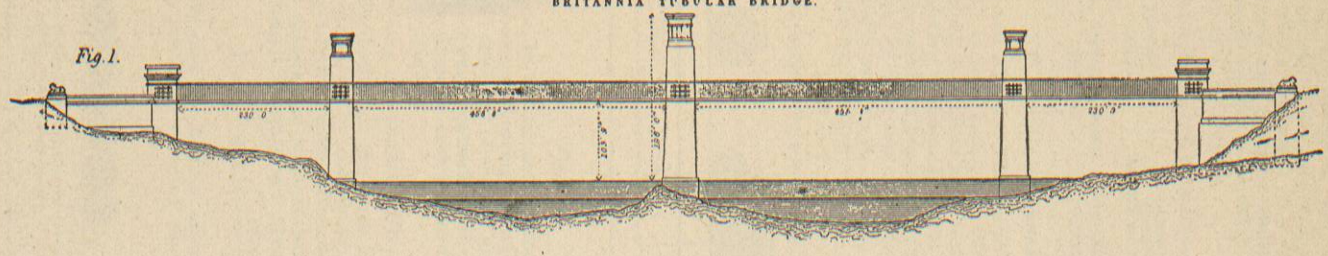


Fig. 2. MENAI SUSPENSION BRIDGE.

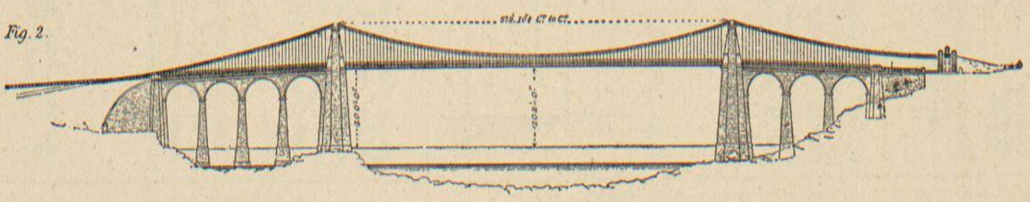


Fig. 3. HIGH LEVEL BRIDGE NEWCASTLE.

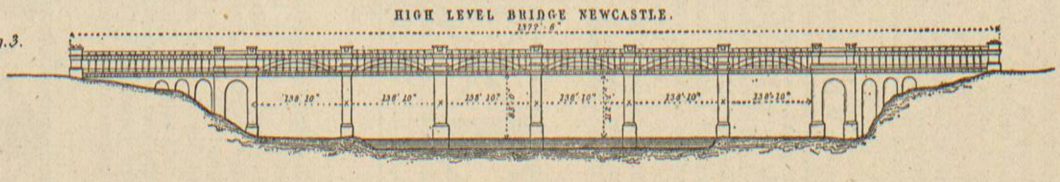


Fig. 4. CRUMLIN VIADUCT. South Wales.

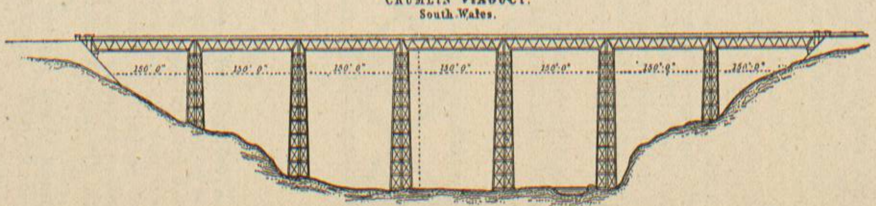
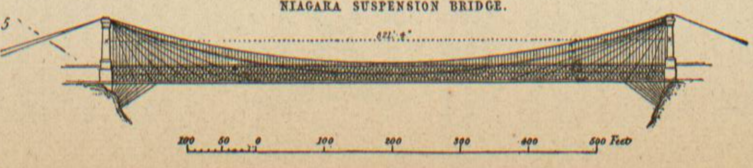


Fig. 5. NIAGARA SUSPENSION BRIDGE.



§ 11. *Change of Length due to Change of Temperature.*—The change in the dimensions of structures due to a change of temperature exercises a material influence on the durability and strength of structures, and must not be lost sight of in the design of any bridge of more than common dimensions. The following short table gives the coefficient by which the length of a bar of each material measured in any unit must be multiplied to obtain the increase in length (in the same unit) resulting from a rise of temperature of 1° centigrade.

TABLE VII.—*Coefficient of Linear Expansion per degree cent.*

Cast-iron.	Wrought Iron.	Stone (paving or granite.)	Sandstone (Craigleith).
0·000011	·000012	·000008 to ·000009	·000012
Slate (Penryn).	Brick (best Stock).	Brick (Fire).	Dry Deal, in direction of grain.
·00001	·0000055	·000005	·0000043

II. BEAMS OR GIRDERS.

§ 12. *External Forces.*—The beams or girders of bridges are subject to vertical loads, and they are supported by vertical reactions at piers or abutments. The sum of the loads is, therefore, necessarily equal to the sum of the reactions at the points of support; or calling P and P_1 the weights borne by two abutments (when the girder has no other support), and w_1, w_2, w_3, &c., the loads on various parts of the girder, we have—

1. . . . . . $P + P_1 = \Sigma w$.

Let L be the distance between the points of support, fig. 7,

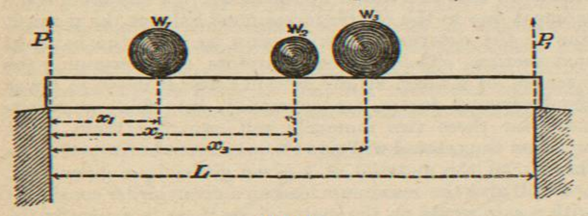


Fig. 7.

and let x_1, x_2, x_3 be the distances of the several loads w_1, w_2, w_3 from the abutment bearing the weight P; then, taking moments round the point of support at the above abutment, we have the upward reaction at the pier × span = the sum of the products of each weight into its distance from the point of support, or

2. . $P_1L = \Sigma wx$, and similarly $PL = \Sigma w\,(L - x)$.

When the distribution of the loads is known, equation 2 gives the weight borne by each abutment. Applied to the case of a single load W rolling from end to end of a beam, calling x the distance of the load from the abutment supporting the weight P, equation 2 gives

3. . . . $P_1 = \frac{Wx}{L}$ and $P = \frac{W(L-x)}{L}$.

Applied to the case of a uniform advancing load, such as a railway train gradually covering the whole beam (fig. 8),

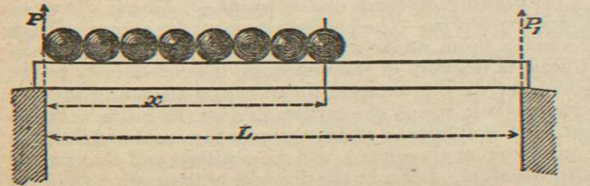


Fig. 8.

calling x the distance covered by the train measured from the pier bearing load P, and w the weight of the load per unit of length, equation 2 gives

4. . . . $P_1 = \frac{wx^2}{2L}$ and $P = wx\,\frac{2L-x}{2L}$.

These equations express the fact that the beam, as used in a bridge, is as a whole in equilibrium under a system of parallel vertical forces which may be called the *external forces*, and which are all determinate so soon as the distribution of load and the span are given.

§ 13. *Internal Forces.*—The external forces call into play certain internal forces. A beam of given design will be properly *proportioned* if each part has just those dimensions which are suitable to bear the maximum *internal* stress which any distribution of load can bring to bear upon it; and the beam will be properly *designed* if its form is such as to enable it to bear the load with the least possible quantity of material. A complete analysis of the internal forces in a loaded beam would in any case be exceedingly difficult and with most designs impossible, but it is found by experiment that a beam will bear a given load if we provide strength enough to resist the *horizontal* components of those internal forces which tend to extend or compress the beam in the direction of its length, and if we also provide against the *vertical* components which tend to shear the beam across in planes perpendicular to the longitudinal axis of the beam. The nature of the horizontal and vertical forces due to the elastic reaction of the material will be understood by reference to figs. 9, 10, 11.

Let a model be made of four stiff light frames of wood A, A_1, A_2, A_3, each say 18 inches deep, 18 inches long, and 6 inches wide (fig. 9). Let these be connected with one

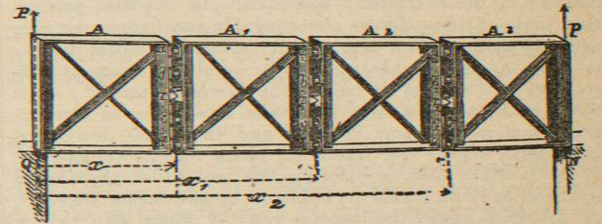


Fig. 9.

another by smallcylinders of india-rubber, $a\ b\ c\ d$, $a_1\ b_1\ c_1\ d_1$, and $a_2\ b_2\ c_2\ d_2$. These cylinders must be so attached to the frames as to be capable of resisting both extension and compression. The whole structure will now have somewhat the appearance of a beam, but if it is placed between two supports Q, N, it will be found unsuited to carry even its own weight, because the middle frames will tend to slip down between the two others.

This tendency will be still better seen when a load is placed on the imperfect beam. Fig. 10 shows the tendency

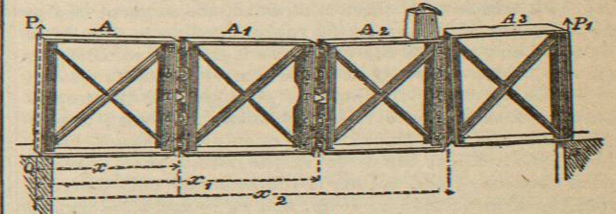


Fig. 10.

to shear off the loaded from the unloaded part of the beam. The frame A_2 is forced down below the frame A_3 by a shearing stress resisted by the india-rubber in a very