APPENDIX NO. 2.

LOADS AND STRAINS OF BRIDGES.

A paper presented by JOHN GRIFFEN and THOS. C. OLARKE, Civil Engineers, members of the American Society of Civil Engineers, at the Fourth Annual Convention of the Society, held at Chicago, June 5 and 6, 1872.

How to obtain uniformity of strength is the problem to be solved by the design of iron railway bridges. The strength of the weakest bridge, and of the weakest part of that bridge, measures the strength of all the bridges on a line of railway. The breaking of a single floor beam may wreck a train, and kill and wound many persons; and it is no consolation to know that all the other floor beams, tie rods, etc., of other bridges of the same line, have a superabundance of strength.

The strength of a bridge results from the following conditions:—

The heaviest loads to which it can be subjected.
The maximum strains resulting from those loads.
The sizes of the tensile and compressive members, and hence their strains per square inch of area.
The available strength of those members depending upon—First. The quality of the iron of which they are made. Second. The cross-section of the struts. Third. The mode of forming the connections.

Errors of design have been made in respect to all these points.

First. A uniform load per lineal foot has been assumed for all spans, short and long alike, while the actual load is greater for short, and less for long, spans, and is always in excess of the general load upon certain parts, such as floor beams.

Second. No distinction has been made between the effects of the dead load of the structure and the moving or live load of trains, suddenly applied and accompanied by shocks and vibrations.

Third. The margin of safety between the allowed strain and the disabling limit of the iron has been overestimated, as the margin of safety of the weakest part measures that of the whole.

Fourth. Sufficient distinction has not been made in specifications between a tough and elastic iron, and a hard and brittle quality, if the ultimate breaking strength of both were alike.

Fifth. The strains allowed upon compressive members are not based upon any definite knowledge of their ultimate powers of resistance.

These points will be considered in turn, and suggestions will be made toward a practice which shall result in uniformity of strength in all lengths of span, in all parts of every span, so that one part shall not give way before another.

The standard of strength must finally be determined by the engineer for each particular case. It would be useless to lay down any rules upon this point. Each man must be free to settle it for himself. But when he has decided it, and says, “I will adopt a margin of safety of three, four, five, or six,” as the case may be, he wishes to feel certain that all his spans, and all their parts, form no exception to this rule. Uniformity of strength will then be attained; how much strength to give will be always an open question.

I. What are the actual loads to which railway bridges are subjected?

In Table No. 1, accompanying this paper, will be found a list of the weights and dimensions of the principal types of locomotives now used upon American railways, divided into three classes.

The first includes those engines of exceptional dimensions and weights which are used for pushing trains up heavy grades. Fortunately, their speed is slow.

The second class includes heavy freight and coal engines, whose average speed is ten to twelve miles an hour.

The third class the common form of four-driver passenger engines, which cross bridges at from twenty to fifty miles an hour.

Class four contains the various kinds of cars,—passenger, freight, and coal.

The following points may be discovered from inspection of this table:

That the weights of engines and loaded tenders average from 2300 to 2700 pounds per foot of track occupied, and that the weights of tenders, separately, are but little less.

That, owing to the concentrated weight of engine over drivers, the loads carried by spans of less than 100 feet will exceed these weights. As there are so many different types of engines we must select one of average dimensions and weight, leaving provision to be made for the passage of exceptionally heavy engines in the margin of safety which is to be fixed by the engineer of the bridge.

Take, therefore, an engine whose total weight with