

to the direct *maximum* load that can come upon it for every possible position of the load, and, by the most beautiful and skilful analysis, finds an expression for the total volume of material in the truss containing these variables. The hypothesis of the section of each piece being proportional to the greatest load that comes on it is perfectly just, in spite of Mr. Waddell's opinion. For a truly scientific method must aim at taking in all the conditions of load as actually rolling on many wheels, the speed, and, as we now know, the frequency, as far as can possibly be done, and yet admit of general treatment. Mr. Waddell's uniform load is not a scientific substitute for the actual load, and he is forced into using *different* factors of safety for different members (or factors of ignorance as he calls them, or factors of wilful oversight as I might suggest), hence his 1.5 to 5 tons. Neither is his arithmetical treatment of a few tentative cases at all worthy of scientific recognition. Neither are they of the value they might be as an arithmetical example, because he employs great gaps between the crossbearers to suit his own preconceived ideas, and leaves the wheels to jump across or be carried across by auxiliary trusses, whose volumes for increasing values of the gaps soon swallow up the apparent economy in the main truss. His suggested refinement of adding the positive and negative recurring strains is not demanded, as in large bridges there is sufficient time for the piece to recover itself from one strain before the other is made, which is quite warranted by the practical evidence obtained by the Committee of the British Government, and if Dr. Levy had chosen to do so, it would not make an appreciable difference in the tabulated results. Dr. Levy goes on to prove that the value of the variable for shape (the other circumstances remaining the same) which makes the volume least gives an isosceles triangle, but that the value which makes it rectangular is only 3 per cent. above it. Next he tabulates the ratio of depth to span to make the volume a minimum, keeping to those two shapes and corresponding to a range of value of the number in span including all suitable numbers. Now the ratios of depth to span which give minimum value of material are exactly those employed in England, Germany, and France, and, what is of greater importance, it agrees with the ratio of depth to span which gives the most suitable stiffness to the bridge, a quality of greater importance than strength even. So that, in deliberately taking greater depths in ratio to span, the three following grave scientific errors are made: the loss of economy of material, if each piece were sectioned to resist the direct thrust only; the still greater loss of material in stiffening the long struts which are thereby rendered longer still, and a want of uniform stiffness, there being too much stiffness as a whole and too little stiffness from bay to bay. The last being most serious if the load move swiftly and occasions a series of shocks as the loaded wheels cross each transom, which can be distinctly heard by one standing under any girder as a succession of blows. These blows produce impulsive strains of the braces giving unknown but large stress on them, or more simply tear and wear.

By Mr. Waddell's own allowing, the Americans have thrown over their own complicated inventions, and are now making rectangular trusses, so that it is evident that what Mr. Pownall said is the case, that American