COMPARATIVE ANALYSIS OF THE FINK, MURPHY, BOLLMAN & TRIANGULAR TRUSSES

Published @ 2017 Trieste Publishing Pty Ltd

ISBN 9780649302277

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Edited by Trieste Publishing Pty Ltd.
Cover @ 2017

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TRUSSES,

BY C. SHALER SMITH,

CIVIL ENGINEER.

BALTIMORE:
JOHN W. WOODS, STEAM BOOK AND JOB PRINTER,
No. 202 Baltimore Street.
1865.

Comparison of Four Leading Forms of Bridge Truss,

Viz. those known as the Bollman, Fink, Murphy, and the Triangular; the last called in England the "Warren Girder," (but exhibited here in an improved form) by C. SHALER SMITH, *Civil Engineer.*

THE writer of what follows under the above heading has been engaged almost exclusively for some years in the department of his profession to which it refers, and now submits to his fellow Engineers and the public the results of his inquiries into the principles of bridge trusses and their practical applications, as illustrated by the above forms.

He is aware that the four patterns above enumerated, do not by any means embrace all the modifications of which the several elements of a bridge truss are susceptible. They represent, however, the distinguishing features of the several models which are now most prominently competing for the favor of Engineers and Bridge builders.

The Howe truss, heretofore the favorite form and still so for moderate spans and with wood as a material, is rarely used when the opening exceeds 150 feet without the accompaniment of an arch to which it is in fact but an auxiliary; the lattice, long since abandoned as a wooden structure, and but little employed in iron in America although largely so in Europe; the bow string truss, of which it is believed there is as yet no example with us although claimed in Europe to be, for the weight it will carry, the lightest of all; the tubular or boiler plate girder, used upon a grand scale in England and Canada, but too costly for the United States, except for short spans and usually in the I form; the suspension bridge proper, with its back anchorage and its heavily trussed floor of which there is but the one actual erection, that at Niagara; all of those have either had their day in this country or have not yet been introduced upon our public works, in a form and manner to recommend them to our preference. The writer has therefore, without disparagement to other forms, confined himself to a comparison of the above four trusses which are at this time contending most spiritedly for the prize of professional and popular patronage. In his analysis of the elements of each truss, he has pursued the most simple and practical methods, resorting to mathematical formulæ only so far as was absolutely necessary to exhibit the relations between the several parts of the various combinations, the strains to which they are subjected, and the resistances they are capable of offering. To Engineers well versed in the higher mathematics and accustomed to employ them in the solution of all such questions, his mode may appear too little scientific; but as he is writing more for the less theoretically accomplished members of the profession, and for those practical bridge builders to whom so many of this class of constructions are committed, he prefers to proceed as he has done in this case. The books and journals abound in theories of trusses expressed in algebraic symbols unintelligible to nine-tenths of their readers, and however ingenious, and even sound, the theories reached through their complex equations may be, they are so entirely disregarded by the designers and builders of the structures to which they refer, that they are in effect only an agreeable exercise of the faculties of the learned men who propound them. It is not intended to depreciate high science or the labors of those eminent men who have discovered and developed the elementary principles upon which all correct theory and sound practice are founded, but only to justify the use of simpler processes in demonstrating them to the partially instructed class who apply them in actual construction. In truth, the conditions of the several questions which present themselves in planning a truss, are so many, and so founded upon what the Engineer who experimentally tests the bridge can alone obtain a full knowledge of by noticing the effect of passing trains at various speeds, that it is not to be wondered at, that the skillful algebraist, in framing his equations in his study from only a general idea of the movements which take place, should omit some quantity which ought properly to enter into them.

The writer is aware, that upon this subject many works, some of them of great merit have been published of a practical as well as scientific character, and he by no means expects to render a reference to them unnecessary by the present brief exposition, the object of which, as already stated, is to submit a comparison, based upon established facts, of the forms of truss between which, in view of all the circumstances effecting the question in this country, a choice is most likely to be made.

He may expect his conclusions in favor of the models he prefers to be disputed, and so far from deprecating criticism he invites it, on the simple condition that it be temperate and fair, and free from the personalities and side issues which so often take the place of sound argument upon the true points in controversy.

He has no property in any of the patents involved in the different systems, and no other interest in the adoption of one rather than another, except in so far as his demonstration of its superior economy may cause a structure to be erected, which on a more expensive plan would not be built at all. If his effort should, upon this ground, result in increasing the replacement of temporary and unsafe by permanent and reliable constructions of moderate cost, his field of labor in this branch of his profession will be enlarged, not of course exclusively but in fair competition with others whose interests as well as his own, he will thus have been instrumental in promoting. With these prefatory remarks he will proceed with the comparisons following.

GENERAL PRINCIPLES AND DATA.

In order to prepare the several designs for comparison with each other, it will be necessary to assume first, a certain span, depth, width and weight of truss, and of quiescent load uniformly disposed over its length; secondly, to assign the position of the track and load, whether at the top or bottom of the truss, thirdly, to compute upon the established rules for composition and resolution of mechanical forces, the several tensile and compressive strains upon each part of the framing, under the uniformly distributed load in a state of rest; fourthly, to exhibit the strain to which each part is subjected by the moving load of the locomotive and its train, and the disturbing effect of such strains upon the arrangement of those parts; fifthly, to show the effect of changes of temperature upon that arrangement of parts; sixthly, to consider the means of adjusting the several parts which the principle of framing affords, and by which the truss can be restored to its proper condition after disarrangement from any cause.

The first and second of the preceding conditions being settled as necessary preliminaries to our inquiry, and, under the third and fourth heads, the several strains upon each part having been calculated simply as *lines* of tension or compression, the next step is to determine the sectional dimensions to be given them, and the material best adapted to the duty to be performed, as well as the proportion of strain to ultimate strength, or the limits of *safety* within which the actual stress upon the several parts of the respective systems of framing should be confined. These calculations having been made, the quantities of material of each kind in each form of truss will be determined, and may be compared with each other and their economical relations decided, in this particular, leaving them to be compared finally under the fifth and sixth heads of effects of temperature and adjustability of parts.

Under the first and second heads we will then assume, that the span of the truss is 200 feet, the depth 21 feet, and the width of floor from centre to centre of the trusses 18 feet. These dimensions are taken as a fair average between ordinary spans and those bolder reaches of greater length up to 300 feet, and even beyond, which are coming more into favor of late years. They are also the proportions of the iron bridge over Barren river, on the Louisville and Nashville Railroad, with the details of which the writer is familiar, he having been engaged on that road at the time of its erection.

As computing the strains upon a truss, the weight of the truss itself must be assumed in advance of its actual determination, the bridge just mentioned has been adopted as a standard of weight for the present purpose. This bridge is Fink's suspension truss, of the dimensions above given. The track is at the bottom of the truss, and the bridge contains 122,000 lbs. cast iron, 98,000 lbs. wrought iron, 50,000 lbs. lumber, making a total of 270,000 lbs., which, for convenience of division, will be called 272,000 lbs. The load uniformly distributed will be taken, as usual for railway bridges, at one ton (of 2240 lbs.) per linear foot, or 448,000 lbs., so that the total weight of bridge and load would be 720,000 lbs., of which the weight for each truss will be 360,000 lbs.

The number of panels of 12½ feet in length is 16, each therefore weighing unloaded 8,500 lbs., and with 14,000 lbs. of load added, 22,500 lbs. The position here assumed of the track at bottom of truss making an overgrade or through bridge, is disadvantageous to the Fink truss, as will be explained hereafter, when the effect of a change to the top of truss, making an undergrade bridge upon the several models will be treated of. The rolling weight brought upon the truss by the train, will consist of the heaviest engine used for slow freight transportation, and weighing 84,000 lbs., followed by a tender weighing some 42,000 lbs., and of cars such as are used in carrying coal, weighing so nearly the assumed ton per linear foot, that their falling short of that weight would about be made up by the engine.

This would not, however, be the weight of every train, the ordinary freight, and the passenger trains falling considerably within it. The engine referred to, rests 84,000 lbs. on eight drivers, all connected and with their four centres, all inside of 12½ feet or the length of one panel. The panel supports, then carry the weight of the engine plus the weight of one panel of truss, and must be graduated to resist this strain.

In the Fink and Bollman trusses, the weight of engine borne by each panel system is 42,000 lbs. minus the proportion of the load borne by the adjacent system on each side through the distributing influence of the railjoists. In the present case, taking into consideration the position of the drivers, and leverage of centre of gravity of each half of the load—one-eighth of the weight is carried in each direction, so that the load borne by the panel supports opposite the middle of the engine is 31,500 lbs.—To this add 8,500 lbs. weight of one panel of truss, and we have 40,000 lbs. as the extreme load for one set of panel supports. In the Murphy and Triangular trusses however, if the counter-tie in the panel next the rear of the engine is loose, then the one-eighth of the weight distributed to the rear is transferred back again to the acting system through the main panel tie, and accordingly in this case the weight of engine which can come on the supports of one panel is 42,000 minus one-eighth or 36,750 lbs. To recapitulate, in the Fink and Bollman trusses an engine can bring

upon one panel, ...	31,500 lbs.
In the Murphy and Triangular, ...	36,750 "

excepting in the case of the middle panel, where, as both panel ties must obviously be in adjustment, the weight will be the same as in the other trusses or 31,500 lbs.

The flooring systems will be considered as the same in all four trusses, and for this purpose of equalization the bill of material for the rail track of Barren River Bridge will be taken as common to all. This consists of 17,000 ft. B. M. of lumber, 30 floor truss rods, 1¼ inch section and 4 ft. long, and 30 girder plates weighing 60 lbs. each, and is believed to be fully as economical as any flooring on any of the existing examples of the trusses in question.

The sectional areas of the cast and wrought iron parts as hereafter determined, will be calculated in the computation of the weights, with the net lengths between the points of junction of the lines of compression and extension. To the results thus obtained, there will be added 15 per cent. for the wrought iron and 20 per cent. for the cast; the first being the necessary allowance for bolts, nuts, eyes and pins, and the latter for the joint thickenings and mouldings of the castings. These proportions are based upon the experience of the writer, who uses them habitually in his professional practice.