CHAPTER III.

TRUSSES FOR FLAT ROOFS.

25. **Trapezoidal Truss; Equal Loads.**—A consideration of the trapezoidal, or queen-post, truss, represented by Fig. 14, will bring out two or three points which will be of use in the analysis of other trusses. In this case, let us suppose the load to be on the lower part, or bottom chord, of the truss. In order to separate the supporting forces from the small weights on the ends of the truss, and to permit them to come consecutively with the other weights in the load line, let us draw the supporting forces above the tie, instead of below as before. The rectangle formed by the two vertical and two horizontal pieces might become distorted; we will therefore introduce the brace H I, represented by the full line. The rectangle is thus divided into two triangles and movement prevented. The dotted line shows a piece which might have been introduced in place of the other.

If the truss is symmetrically loaded, or C D = D E, we shall get the first stress diagram. The stress in each vertical is here seen to be the load at its foot. The stress in the piece H I proves to be zero. If the load had been on the upper joints, no stress would have been found in the verticals also. (See § 17.) It is evident that a trapezoidal truss, when symmetrically loaded, requires no interior bracing. This fact might readily be seen if we considered the form assumed by a cord, suspended from two points on a level, and carrying two equal weights symmetrically placed.

26. **Trapezoidal Truss; Unequal Loads.**—The second stress diagram will be drawn when the weight C D is less than D E. Let us suppose that bc and ef are of the same

magnitude as in the first diagram, and let the span of the truss, or distance between supports, which we shall denote by l, be divided by the joints into three equal parts. The first step is to find the supporting forces. If each external force be multiplied by the perpendicular distance of its line of action from any one assumed point, which distance may be called its leverage, and all the products added together, those which tend to produce rotation about this point in one direction being called plus, and those tending the other way minus, it is necessary for equilibrium that the sum of these products shall be zero; otherwise the rotation can take place. A convenient point to which to measure the distances will be one of the points of support, for instance the right-hand one. Then we shall have

$$AF \,.\, l - FE \,.\, l - ED \,.\, \tfrac{2}{3}l - DC \,.\, \tfrac{1}{3}l - CB \,.\, 0 + BA \,.\, 0 = 0,$$

or

$$AF \,.\, l = FE \,.\, l + ED \,.\, \tfrac{2}{3}l + DC \,.\, \tfrac{1}{3}l;$$

therefore

$$AF = FE + \tfrac{2}{3}ED + \tfrac{1}{3}DC.$$

If E D be taken as 3 D C,

$$AF = FE + \tfrac{7}{9}ED.$$

It will be seen that the object in taking the point or axis at B is to eliminate B A, and have only one unknown quantity, A F. This method of determination is called *taking moments*, and is at once the simplest and most generally applicable. Lay off the above reaction at fa; ab will be the reaction at the right support. One cause of a diagram's failure to *close*, when drawn by a beginner, is carelessness in placing the reactions on the load line in the wrong order.

The point a being now located, we can proceed to draw the second diagram. The construction requires no explanation; but we will call attention to the fact that a compressive stress here exists in H I. If, in place of the diagonal represented by the full line, the one shown by the dotted line is now supplied, the reader can without difficulty trace out for himself the change in the diagram, which is denoted by the dotted lines and the letters marked by accents. The stress in this diagonal will be seen to be tensile. Changing the diagonal reverses its stress.

It is also worthy of notice that the only pieces affected by the substitution of one diagonal for the other are those which form the quadrilateral enclosing the diagonals. This fact will be of service later.

27. **Use of Two Diagonals.**—If, at another time, this excess of load might fall on C D in place of D E, the stress on either diagonal would be reversed: that is, if it sloped down to the right it would be a tie; if to the left, a strut. As a tension diagonal is likely to be a slender iron rod, which is of no practical value to resist a thrust, while the compression member, unless made fast at its extremities, will not transmit tension, a weight or force which may be shifted from one joint to another may require the designer to introduce two diagonals in the same rectangle or trapezium, or else to so proportion and fasten one diagonal as to withstand either kind of stress.

Where both diagonals occur the diagram can still be drawn. Determine which kind of stress, tension or compression, the two shall be designed to resist, and then, when drawing the diagram, upon arriving at a particular panel or quadrilateral, try to proceed as if only one of the diagonals existed. If a contrary kind of stress to the one desired is found to be needed, erase the lines for this panel only, and take the other diagonal. In the treatment for wind pressure, this method becomes serviceable, since the wind may blow on either side of the roof.

This truss can be used for a bridge of short span.

28. **Trusses for Halls.**—It is sometimes the case that, in covering a large building, it is desired to have the interior clear from columns or partitions, while a roof of very slight pitch is all that is needed. As it is not expedient to have a truss of much depth, since the space occupied by it is not generally available for other purposes, one of several types of

parallel-chord bridge trusses may be employed, for instance the "Warren Girder," of Fig. 15, which is an assemblage of isosceles triangles. In a public hall, galleries may be suspended from the roof, and the weight of a heavy panelled or otherwise ornamented ceiling may be added to what the truss is ordinarily expected to carry. The depth may be less than here drawn, but, for clearness of figure, we have not made the truss shallow.

If the roof pitches both ways from the middle of the span, the top chord may conform to the slope, making the truss deeper at the middle than at the ends; but a light frame may be placed above, as shown by the dotted lines, and supported at each joint of the top chord. The straight-chord truss is more easily framed. If the roof pitches slightly transversely to the trusses, it will be convenient to make them all of the same depth and put on some upper works to give the proper slope. The ends of the truss could readily be adapted to a mansard roof.

29. **Warren Girder.**—In Fig. 15, each top joint is supposed to be loaded with the weight of its share of roof, in which case the joint L M or P Q will have three-quarters of the weight on N O or O P, if the roof is carried out to the eaves as marked on the left; or practically the same as N O, if the roof follows the line I L. The bottom joints are supposed to carry the weight of the ceiling, and in addition the tension of a suspending rod to a gallery on each side. The load line will be equal to the weight on the upper part of the truss, and the polygon of external forces will overlap, as in Fig. 12, previously explained, § 22. We go from *k* to *r*, for the loads on the exterior in sequence, then up to *s* for the left-hand reaction, then down to *w* for the loads on the interior, and finally close on *k* with the right-hand reaction.

Upon drawing the diagram it will be seen that the stress is compression in the top chord and tension in the bottom chord; that the stresses in the chords increase from the supports to the middle; that the stresses in the braces decrease from the ends of the truss to the middle, and that alternate ones are in compression and in tension, those which slant up from the abutment towards the centre being compressed, and those which incline in the other direction being in tension. The tie-braces are, therefore, A B, C D, F G, and H I. A decrease of depth in the truss will increase the stresses in the chords.

30. **Howe Truss; Determination of Diagonals.**—A truss with parallel chords may be employed, in which the braces are alternately vertical and inclined. The designer will choose whether the verticals shall be ties and the diagonals struts, in which case the type is called the "Howe Truss," Fig. 16, or the verticals struts and the diagonals ties, when it is known as the "Pratt Truss." There is an advantage in having the struts as short as possible, but, if one desires to use but little iron, the Howe is a good form.

To decide which diagonal of the rectangle shall be occupied by the piece:—Start from the wall as a fixed point; it is evident that, to keep the load C D from sinking, C Q must be a strut. If we wish to put a tie in this panel, it must lie in the other diagonal, shown by the dotted line. C D now being held in place, P O as a strut will uphold D E. We thus may work out from each wall until we have passed as much load as equals the amount supported, or the reaction, at that wall. If the last load passed exactly completes the amount required to equal the reaction, no diagonal will be required in the next panel. We might draw diagonals, one in each panel, sloping in either direction as we pleased, and then construct the stress diagram. If we found a stress in any diagonal opposite to the stress we desired, § 27, we could then erase that diagonal and substitute the other, erasing also so much of the diagram as referred to the pieces in that panel. Were the chords not parallel, this method might be necessary (see Fig. 20), but in the present case it is better to draw the load line first, find the dividing point *a*, Fig. 16, for the two reactions, see what load it cuts, and then incline the diagonals from each wall either up or down, as preferred, towards that loaded joint.

31. **Howe Truss; Diagram.**—In the present example C D is supposed to be four times D E, etc. A tower on that end of the truss or some suspended load will account for the difference. Recalling the manner in which the supporting forces were found when the load was unsymmetrical, § 26, use a panel as a unit of distance, call a panel length p and the ordinary weight on a joint w. Then we shall have, taking moments about H,

$$w \,.\, p\,(1 + 2 + 3) + 4w \,.\, 4p + \tfrac{1}{2}w \,.\, 5p = \mathrm{R} \,.\, 5p, \quad \text{or} \quad \mathrm{R} = 4.9\,w,$$

the reaction at B, or ab. The two supporting forces will then be ha and ab. Draw the stress diagram as usual; the diagonals will all come in compression as intended, and the verticals will be ties. There will plainly be no stress in the dotted vertical O N. The stress in the chords is inversely proportional to the depth of the truss, and economy of material in the chords will be served by making the depth as much as possible, within reasonable limits. In bridge trusses this depth is seldom less than from one-sixth to one-eighth of the span.

32. **Moving Load.**—If the joint D E also might become heavily loaded, we could draw another diagram for that case, and, as the joints in succession had their loads increased, we might make as many diagrams. From a collection of diagrams for all positions of a moving load, we could select the maximum stress for each piece. A truss designed to resist such stresses would answer for a bridge. We should find that the greatest stresses in the chords occurred in all panels when the bridge was heavily loaded throughout, and that the greatest stress in a diagonal was found when the bridge was heavily loaded from this piece to one end only, that end generally being the more distant one. As we have more expeditious methods of analyzing a bridge truss, this one is not used. The graphical treatment of bridge trusses is found in Part II. of this work.