Eqs. (6) and (7) are the final working values of the resistance offered by a single stirrup in terms of an increment of moment.

The chart in Fig. 2 is a graph of the above equations when $j = 7/8$, a very common value in rectangular beam design. To use the chart, enter at the left with a given value of d, the depth of the beam; follow across horizontally to the line of the adopted stirrup area; then from this point move up to the fiber stress assigned to the stirrup; and finally passing to the right from this last point, the value of the moment increment for either vertical or inclined rods may be read.

Let us consider the portion of the beam shown in Fig. 3, loaded in such a manner as to produce the moment curve OA. It is desired to reinforce the portion shown with vertical stirrups, keeping in mind the principles just

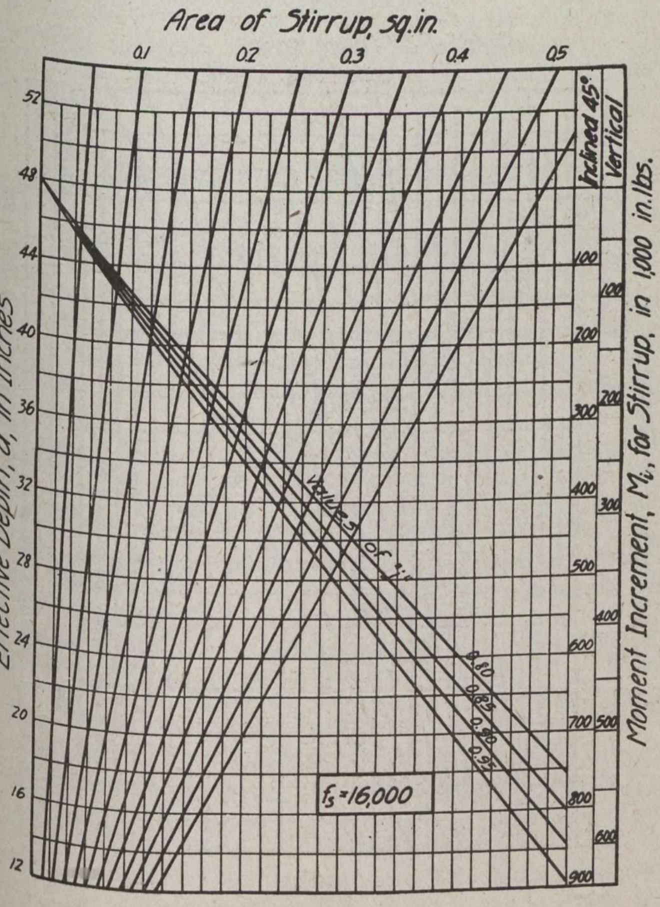

Fig. 2.

laid down. A certain stirrup has been adopted which for this particular beam gives the value of M_1 from eq. (6) equal to the vertical distance shown in Fig. 3*a*. The first increment intercepts the portion *Om* of the curve; the second, *mn*, and so on. Let one of these intercepts, as *mn*, be projected onto the beam, thereby defining an area ABCD on the diagram of the beam. From the preceding discussion this area is the portion of the beam in which the adopted stirrup will exactly carry the shear. The length s of the portion is seen to vary as the shear varies along the beam. Since the stirrup is required to carry the shear for this portion of the beam it will be placed through the centre of the portion. Likewise, each other portion of the beam defined by the projection of the intercept of M_1 will have a stirrup placed at its centre.

To eliminate the feature of dividing each portion of the beam, the following method is suggested: Lay off, as the first value, $\frac{1}{2} M_1$ (Fig. 3*b*). Let all other values equal M_1, as before. These increments have m^1, n^1, and so forth, for points of intersection on the moment curve. Let these points be projected onto the beam. Each projection will thus determine the position of the stirrup. This gives very closely the same results as before, since in this case each increment has been bisected, rather than bisecting the projection of the intercept on the curve. However, if the increment is large, as is sometimes the case with bent-up bars, it is likely to subtend a portion of great curvature, in which case the original method is advised. The second method will be found within practical limits for the spacing of vertical stirrups.

The design of a T-beam will now be followed through in detail. The span will be taken as 24 ft. between centres of supports. The thickness of the flange will be assumed to be limited by a 10-in. floor, and the total depth to approximately 3 ft. The following working stresses will govern the design: f_s = 16,000 lb/in.^{2}; f_c = 650 lb/in.^{2}; u = 80 lb/in.^{2} (at the supports 50% excess allowed, or 120 lb/in.^{2}); v = 35 lb/in.^{2} for concrete and 105 lb/in.^{2} for reinforced concrete. Attention is called to the ratio 1/3 of the two shear values just given. This is in accordance with the developments of eqs. (6) and (7). The total load on the beam will be taken as 4,000 lb/ft.

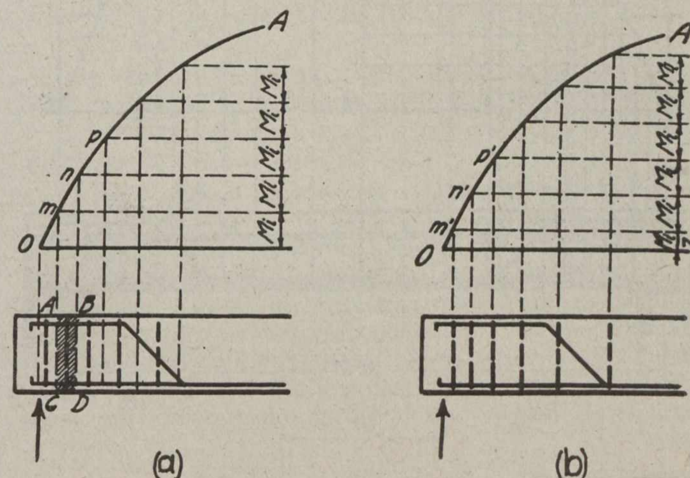

Fig. 3.

The maximum moment is found to be 3,460,000 in. lbs., and the shear at the support, 48,000 lbs. The required web area is 458 in.^{2} or 33 in. deep and 14 in. wide. From Plate X, Turneaure and Maurer, b = 31 in., and jd = 29.2 in. A_s is found to be 7.4 in.^{2} Eight rods 1 in. square will be used. The value in moment of one pair of rods is computed to be 932,000 in. lbs. The arrangement of the rods in cross-section is shown in Fig. 4*c*. The width of the web was changed to 15 in. for clearance between rods. The length of rod necessary to develop its tensile strength in bond is 50 in. At the support four rods are necessary to carry the bond stress.

With the above computations available, the placing of the steel in the beam may be done. Fig. 4*a* shows the bending moment diagram. The resisting moment of each pair of rods is plotted, resulting in the stepped diagram along the exterior of the moment curve. The point of contact of the line with the curve indicates a point of zero stress in the rods corresponding to the zone immediately above the point. This pair of rods may be bent up at this point, therefore, since they are no longer needed to resist moment. It is noted that the four lower rods are required to continue to the end of the beam without being bent up; hence only the upper rods will be bent.

It is proposed to make two arrangements of the steel, —one in which the bent-up rods are intended to carry a