AD 398:
Net area for staggered holes in accordance with Eurocode 3

Determining the net area of a cross section with staggered holes is dealt with in EN 1993-1-1:2005 (+A1:2014) clause 6.2.2.1(4). For those new to this calculation, the illustrative diagram in Figure 6.1 and the presence of the summation sign in equation 6.3 of the Eurocode may be a source of confusion which this AD note attempts to dispel. The following definitions are provided as a starting point: the gross cross sectional area of a plate is its width perpendicular to the longitudinal axis multiplied by its thickness. The net area of the member is the gross area minus the area of holes for fasteners.

Clause 6.2.2.1(4) states that the total area deducted for fasteners should be the greater of:

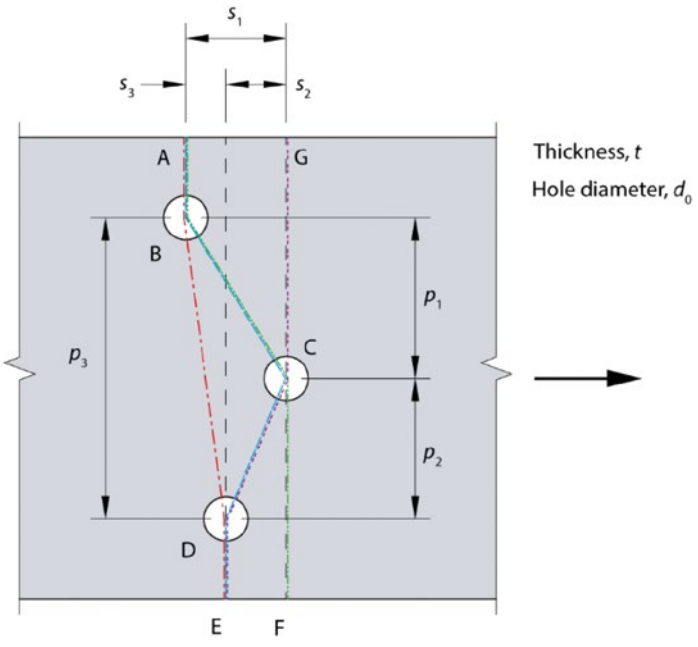
a) the deduction for non-staggered holes, and

b) $t\left(nd_0 - \sum \frac{s^2}{4p}\right)$ (equation 6.3)

where s is the staggered pitch of the holes in the longitudinal direction and p is the spacing of the holes measured perpendicular to the axis of the member. Where a section perpendicular to the longitudinal axis of a member passes through the centre of a number of bolt holes (n say) of diameter d_0, the loss of area is clearly n times the area of one bolt hole. If the bolt holes are staggered along the member (see the figure below), an empirical expression of American origin (eq 6.3 above) reduces the area deducted. Paths are drawn across the member that start and finish perpendicular to the edges of the member and pass in zig-zag lines through the bolt holes, defining all the possible critical sections. A reduction in the area deducted for bolt holes is made for the diagonal line between each pair of holes in a possible critical section given by

$$\frac{s_i^2}{4p_i}$$

for diagonal line i between a pair of holes. If there are several diagonal lines in a possible critical section, a reduction is made for each diagonal line, hence the summation sign in equation 6.3. Obviously, the reduction cannot be such that the total area deducted is less than the area of bolt holes on the worst perpendicular cross section.



Staggered holes in tension member

Because an approach expressed in terms of reducing a deduction for holes is potentially confusing, two examples are presented below. These are based on Owens and Cheal[1] section 7.3.1.

Deduction for holes is the maximum of:

Section ABCF $\quad$ deduction $= 2td_0 - \frac{s_1^2 t}{4p_1}$

Section GCDE $\quad$ deduction $= 2td_0 - \frac{s_2^2 t}{4p_2}$

Section ABDE $\quad$ deduction $= 2td_0 - \frac{s_3^2 t}{4p_3}$

Section ABCDE: $\quad$ deduction $= 3td_0 - \frac{s_1^2 t}{4p_1} - \frac{s_2^2 t}{4p_2} = t\left(3d_0 - \sum_{i=1}^{2} \frac{s_i^2}{4p_i}\right)$

(this is the EC3 formula)

Example 1:

$t = 20$ mm; $d_0 = 22$ mm; $s_1 = 50$ mm; $s_2 = 30$ mm; $s_3 = 20$ mm; $p_1 = 80$ mm; $p_2 = 70$ mm; $p_3 = 150$ mm.

ABCF: deduction = 880 – 156.3 = 724 mm²

GCDE: deduction = 880 – 64.3 = 816 mm²

ABDE: deduction = 880 – 13.3 = 867 mm²

ABCDE: deduction = 1320 – 156.3 – 64.3 = 1099 mm²; **this is the critical section.**

Example 2:

Note: the area of one bolt hole is 440 mm²

Suppose s_1 is increased to 90 mm and s_2 increased to 60 mm; therefore $s_3 = 30$ mm

ABCF: deduction = 880 – 506 = 374 mm² **< 440 mm² therefore not applicable**

GCDE: deduction = 880 – 257 = 623 mm²

ABDE: deduction = 880 – 30 = 850 mm²; **this is the critical section.**

ABCDE: deduction = 1320 – 506 – 257 = 557 mm²

Reference

1 Owens & Cheal, Structural Steelwork Connections, Butterworths 1989

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