AD 534: Anchorage length of horizontal stiffeners in steel and composite beams with large web openings

In SCI publication P355 Design of composite beams with large web openings, some typographical mistakes have been found in the equations for the anchorage length of horizontal stiffeners. The corrected equations are given below. Given the age of the publication, and that rules will shortly appear in the second-generation Eurocodes for beams with large web openings, it is timely to also provide some background information on the design of horizontal stiffeners at large web openings.

In steel and composite beams with large web openings, horizontal stiffeners are formed from rectangular plates, welded to the top and/or the bottom edges of the openings, and they may be welded on one or both sides subject to certain geometric limits. They have the effect of:

- Increasing the local resistance to Vierendeel bending.
- Preventing local buckling of the web of the Tee.

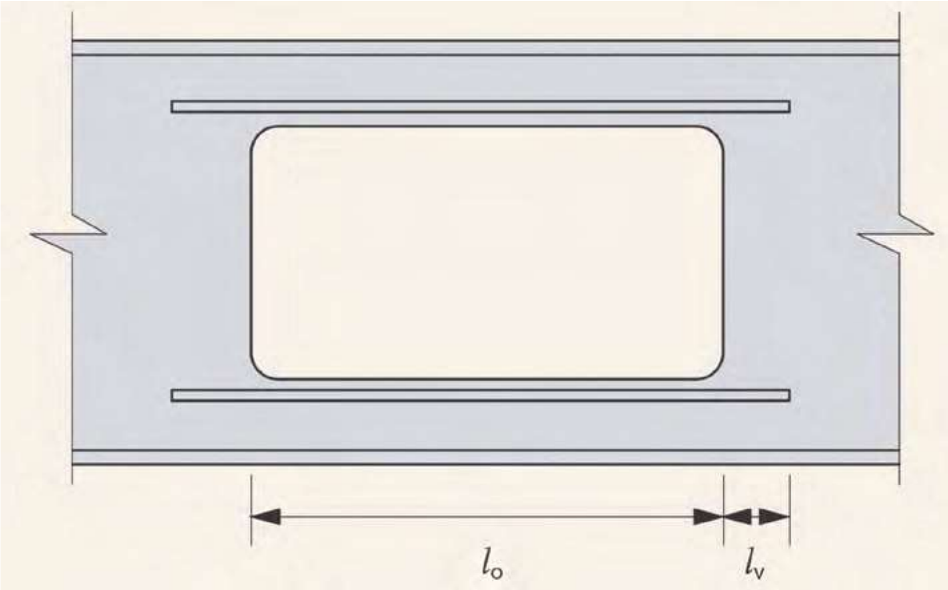

Figure 1: Anchorage length, l_v of horizontal stiffeners beyond each end of the opening

The maximum size of stiffener is generally controlled by the ability of the web to resist the local anchorage forces, which are transferred by the welds between the stiffener and the web at the ends of the opening. A suitable anchorage length is required in order to develop the full axial resistance of the stiffener. Although not explicably stated in P355, for non-rectangular openings, such as elongated circular openings, the anchorage length is taken from the end of the equivalent rectangular opening.

Clause 5.2.2 of P355 provides equations to calculate the anchorage length, l_v (as shown in Figure 1). Unfortunately, there are some typographical mistakes in the shear resistance of the web (equation c) and the design force in the stiffeners, F_r, both of which are corrected below.

In addition to the calculated values, SCI P355 states that the anchorage length, lv of the stiffener beyond each end of the opening should generally be taken as not less than 0.25lo or 2br, with a minimum of 150 mm. These minimum values are good practice but should not be used in the absence of suitable calculations. The minimum offset distance from the edge of the opening should be at least 8 mm, to allow for at least a 5 mm leg length fillet weld.

Where:

l_o is the length of a rectangular opening (or may be taken as le = lo − 0.55 ho for an elongated circular opening)

h_o is the depth of the opening

b_r is the width of the stiffener

The anchorage length of the stiffener should satisfy the following criteria (the corresponding correct equations from P355 are identified for information only):

a) For the design resistance of the longitudinal fillet welds (P355 no different):

$$l_v \geq \frac{F_r}{2naf_{vw,d}}$$

b) For the shear resistance of the stiffeners (P355 no different):

$$l_v \geq \frac{F_r}{nt_rf_y/(\gamma_{M0}\sqrt{3})}$$

c) For the shear resistance of the web (P355 incorrectly included n in the denominator and assumed the web material was the same steel grade as the stiffeners):

$$l_v \geq \frac{F_r}{2t_wf_y/(\gamma_{M0}\sqrt{3})}$$

where:

F_r is the design axial force in the stiffener(s), which may be taken as:

$$F_r = F_{r,Rd} = \frac{nA_rf_{yr}}{\gamma_{M0}}$$

n is 1 for a single-sided stiffener; and 2 for double-sided stiffeners (P355 did not include the variable n)

A_r is the cross-sectional area of a stiffener, or effective area of a Class 3 stiffener

f_{yr} is the yield strength of the stiffener

M_0 is the partial factor for resistance of steel cross sections

a is the throat thickness of the fillet weld

$f_{vw,d}$ is the design shear strength of a fillet weld, given in clause 4.5.3.3 (3) of BS EN 1993-1-8

t_r is the thickness of the stiffener

t_w is the thickness of the web

f_y is the yield strength of steel beam

In addition, P355 gives limits for the relative thickness of the stiffener and web to avoid transverse shear and bending effects in the web. For stiffeners on one side of the web, the web should be relatively stocky so that minor-axis bending of the web due to the eccentric stiffener force can be resisted. This applies for webs with depth, $h_w \leq 70t_w$, where $\varepsilon = (235/f_{yr})0.5$. Double sided stiffeners should be used for more slender webs.

For stiffeners on both sides of the web, the thickness of the stiffeners should satisfy the following limit:

$$\frac{t_r}{t_w} \leq 1.2\left(\frac{l_v}{2b_r}\right)$$

Therefore, for the minimum case of $l_v = 2b_r$, $t_r \leq 1.2\ t_w$.

For single-sided stiffeners the thickness of the stiffener should satisfy the following limit:

$$\frac{t_r}{t_w} \leq 0.96\left(\frac{l_v}{2b_r}\right) \text{ but } \leq 1.0$$

Therefore, for the minimum case of $l_v = 2b_r$, $t_r \leq t_w$ is a reasonable limit.

The rules given in BS EN 1993-1-13:2024 are not as explicit as SCI P355 and therefore the designer should refer to P355 for comprehensive guidance.

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