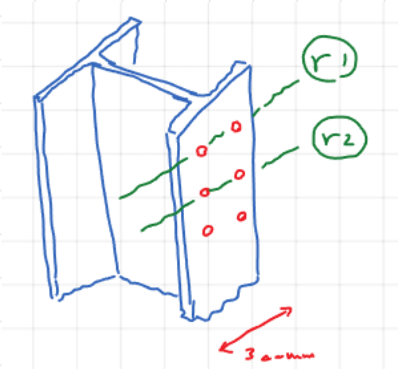
This playlist series focuses on the rigid connection calculation according to EN 1993-1-8. A comparison is made with Ansys at the end of the series after hand calculation. Finally, tips for applying the semi-rigid connection to RFEM are presented.

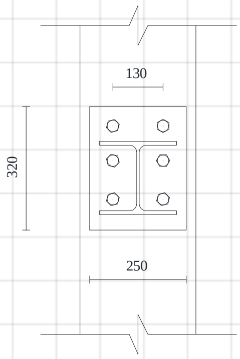
An Endplate welded to a beam, HEA200, is bolted to a HEB300 column with 6M20 class 8.8, as shown in the figures below. Steel material is S355 for all parties.

This video shows the resistance calculation of the equivalent T-Stub of the column flange in bending according to EN 1993-1-8. The contents are as follows:

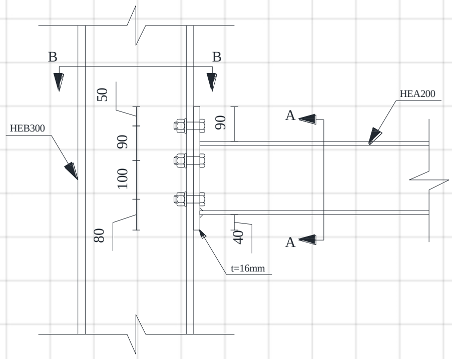
a) Table 6.1 of the code and what needs to be considered in rigid or semi-rigid connection calculation.
b) Column Flange in transverse bending according to 6.2.6.4.
c) Equivalent T-Stub effective length for unstiffened column flange table 6.4.
d) Failure patterns, circular and non-circular, individual and group, and effective length for equivalent T-Stub.
e) The failure mode of the equivalent T-Stub.
f) Tension resistance of the column flange.

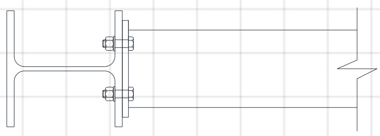
All dimensions are in mm unless otherwise specified.



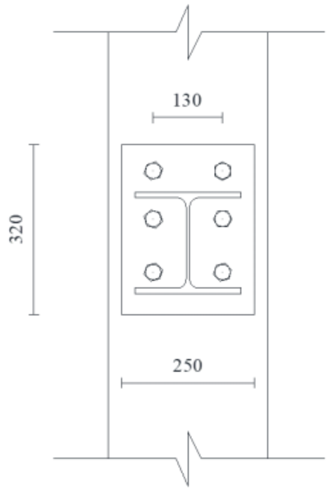


Sec A-A

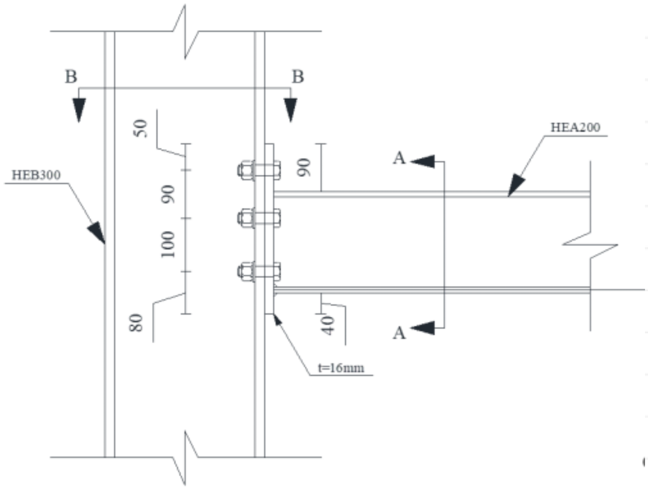




Sec B-B

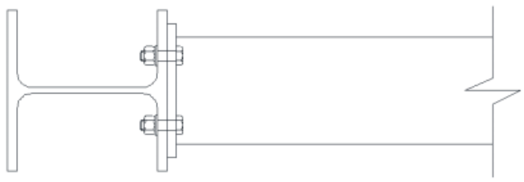


Sec A-A



6T20 → M88

All partie are from S355



Sec B-B

Table 6.1: Basic joint components

	Component		Reference to application rules: Design Resistance	Stiffness coefficient	Rotation capacity
1	Column web panel in shear		6.2.6.1	6.3.2	6.4.2 and 6.4.3
2	Column web In transverse compression		6.2.6.2	6.3.2	6.4.2 and 6.4.3
3	Column web in transverse tension		6.2.6.3	6.3.2	6.4.2 and 6.4.3
4	Column flange in bending		6.2.6.4	6.3.2	6.4.2 and 6.4.3
5	End-plate in bending		6.2.6.5	6.3.2	6.4.2
6	Flange cleat in bending		6.2.6.6	6.3.2	6.4.2
7	Beam or column flange and web in compression		6.2.6.7	6.3.2	*)
8	Beam web in tension		6.2.6.8	6.3.2	*)
9	Plate in tension or compression		in tension: - EN 1993-1-1 in compression: - EN 1993-1-1	6.3.2	*)
10	Bolts in tension		With column flange: - 6.2.6.4 with end-plate: - 6.2.6.5 with flange cleat: - 6.2.6.6	6.3.2	6.4.7
11	Bolts in shear		3.6	6.3.2	6.4.2
12	Bolts in bearing (on beam flange, column flange, end-plate or cleat)		3.6	6.3.2	*)

*) No information available in this part.

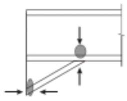
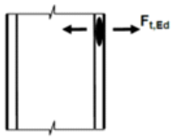
Component			Reference to application rules		
			Design Resistance	Stiffness coefficient	Rotation capacity
13	Concrete in compression including grout		6.2.6.9	6.3.2	*)
14	Base plate in bending under compression		6.2.6.10	6.3.2	*)
15	Base plate in bending under tension		6.2.6.11	6.3.2	*)
16	Anchor bolts in tension		6.2.6.12	6.3.2	*)
17	Anchor bolts in shear		6.2.2	*)	*)
18	Anchor bolts in bearing		6.2.2	*)	*)
19	Welds		4	6.3.2	*)
20	Haunched beam		6.2.6.7	6.3.2	*)
*)	No information available in this part.				

Table 6.1: Basic joint components

Component			Reference to application rules		
			Design Resistance	Stiffness coefficient	Rotation capacity
4	Column flange in bending		6.2.6.4	6.3.2	6.4.2 and 6.4.3

6.2.6.4 Column flange in tranverse bending

6.2.6.4.1 Unstiffened column flange, bolted connection

(1) The design resistance and failure mode of an unstiffened column flange in tranverse bending, together with the associated bolts in tension, should be taken as similar to those of an equivalent T-stub flange, see 6.2.4, for both:

- each individual bolt-row required to resist tension;
- each group of bolt-rows required to resist tension.

(2) The dimensions e_{min} and m for use in 6.2.4 should be determined from Figure 6.8.

(3) The effective length of equivalent T-stub flange should be determined for the individual bolt-rows and the bolt-group in accordance with 6.2.4.2 from the values given for each bolt-row in Table 6.4.

6.2.4 Equivalent T-stub in tension

6.2.4.1 General

(1) In bolted connections an equivalent T-stub in tension may be used to model the design resistance of the following basic components:

- column flange in bending;
- end-plate in bending;
- flange cleat in bending;
- base plate in bending under tension.

(2) Methods for modelling these basic components as equivalent T-stub flanges, including the values to be used for e_{min}, ℓ_{eff} and m, are given in 6.2.6.

(3) The possible modes of failure of the flange of an equivalent T-stub may be assumed to be similar to those expected to occur in the basic component that it represents.

(4) The total effective length $\sum \ell_{eff}$ of an equivalent T-stub, see Figure 6.2, should be such that the design resistance of its flange is equivalent to that of the basic joint component that it represents.

NOTE: The effective length of an equivalent T-stub is a notional length and does not necessarily correspond to the physical length of the basic joint component that it represents.

6.2.4 Equivalent T-stub in tension

6.2.4.1 General

(5) The design tension resistance of a T-stub flange should be determined from Table 6.2.

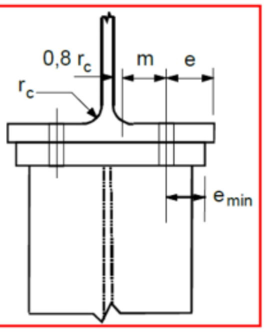
NOTE: Prying effects are implicitly taken into account when determining the design tension resistance according to Table 6.2.

(6) In cases where prying forces may develop, see Table 6.2, the design tension resistance of a T-stub flange $F_{T,Rd}$ should be taken as the smallest value for the three possible failure modes 1, 2 and 3.

(7) In cases where prying forces may not develop the design tension resistance of a T-stub flange $F_{T,Rd}$ should be taken as the smallest value for the two possible failure modes according to Table 6.2.

NOTE 1: In bolted beam-to-column joints or beam splices it may be assumed that prying forces will develop.

6.2.6.4 Column flange in tranverse bending



a) Welded end-plate narrower than column flange.

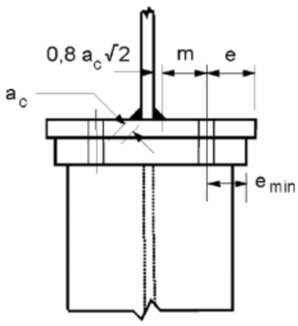
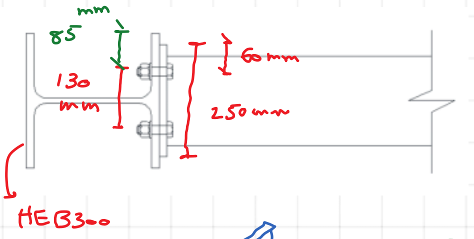


Figure 6.8: Definitions of e, e_{min}, r_c and m



HEB300

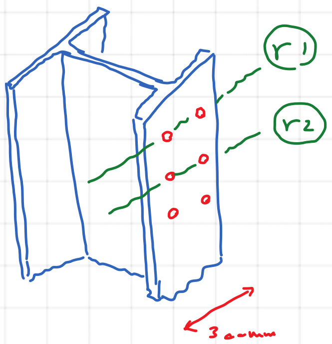
$b_{fc} = 300\,mm$ $A_{cv} = 4743\,mm^2$

$t_{fc} = 19\,mm$

$h_c = 300\,mm$

$t_{wc} = 11\,mm$

$r_c = 27\,mm$



$m = 65\,mm - \frac{11\,mm}{2} - 0.8 \times 27\,mm = 37.9\,mm$

$e = 85\,mm$

$e_{min} = 60\,mm$

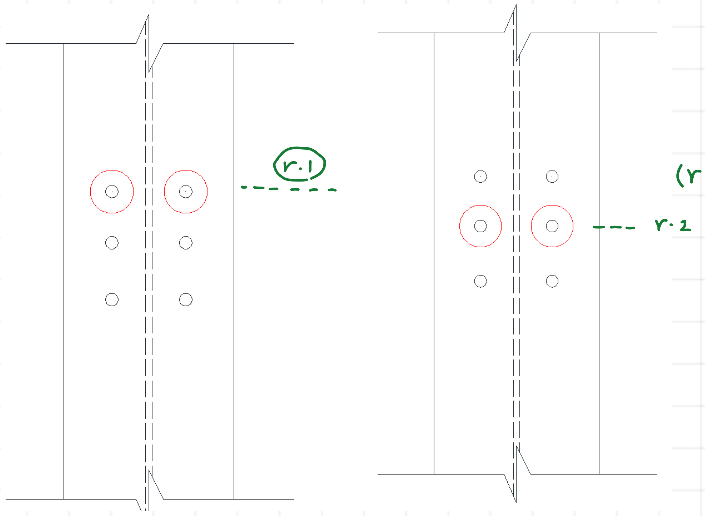
Table 6.4: Effective lengths for an unstiffened column flange

Bolt-row Location	Bolt-row considered individually		Bolt-row considered as part of a group of bolt-rows	
	Circular patterns $\ell_{eff,cp}$	Non-circular patterns $\ell_{eff,nc}$	Circular patterns $\ell_{eff,cp}$	Non-circular patterns $\ell_{eff,nc}$
Inner bolt-row	$2\pi m$	$4m + 1{,}25e$	$2p$	p
End bolt-row	The smaller of: $2\pi m$ $\pi m + 2e_1$	The smaller of: $4m + 1{,}25e$ $2m + 0{,}625e + e_1$	The smaller of: $\pi m + p$ $2e_1 + p$	The smaller of: $2m + 0{,}625e + 0{,}5p$ $e_1 + 0{,}5p$
Mode 1:	$\ell_{eff,1} = \ell_{eff,nc}$ but $\ell_{eff,1} \leq \ell_{eff,cp}$		$\sum\ell_{eff,1} = \sum\ell_{eff,nc}$ but $\sum\ell_{eff,1} \leq \sum\ell_{eff,cp}$	
Mode 2:	$\ell_{eff,2} = \ell_{eff,nc}$		$\sum\ell_{eff,2} = \sum\ell_{eff,nc}$	

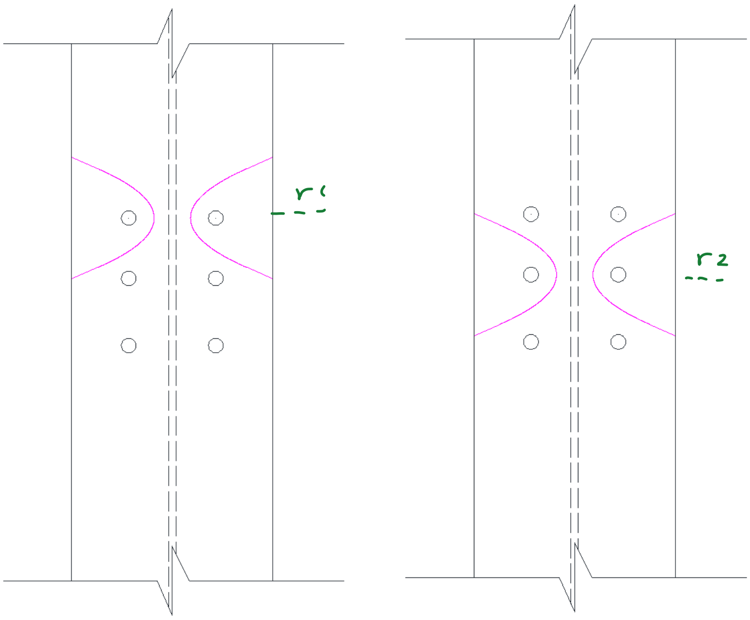
19)Modification to 6.2.6.4.1

Paragraph "(3)", "Table 6.4", add a row at the bottom of the table containing the following paragraph:

"e_1 is the distance from the centre of the fasteners in the end row to the adjacent free end of the column flange measured in the direction of the axis of the column profile (see row 1 and row 2 in Figure 6.9).".



(r1, r2) $l_{eff,cp} = 2\pi m = 238\,mm$ (m = 37.9mm)



(r_1, r_2) $m = 37.9$ mm, $e = 85$ mm

$l_{eff,nc} = 4m + 1.25e = 258$ mm

Individual row → r.1, r.2 →

(Mode 1)

$l_{eff,1} = \min\{l_{eff,cp}, l_{eff,nc}\} = 238$ mm

(Mode 2)

$l_{eff,2} = l_{eff,nc} = 258$ mm

M20 → $A_s = 245\ mm^2$, M8.8 → $f_{ub} = 800$ MPa

$$F_{t,Rd} = \frac{0.9 A_s f_{ub}}{\gamma_{M2}} = \frac{0.9 \times 245\ mm^2 \times 800\ MPa}{1.25} = 141\ kN$$

$$M_{pl,1,Rd} = 0{,}25 \Sigma \ell_{eff,1} t_f^2 f_y / \gamma_{M0} = 0.25 \times 238\ mm \times (19\ mm)^2 \times \frac{355\ MPa}{1} = 7.63\ kN\,m$$

$$M_{pl,2,Rd} = 0{,}25 \Sigma \ell_{eff,2} t_f^2 f_y / \gamma_{M0} = 0.25 \times 258\ mm \times (19\ mm)^2 \times \frac{355\ MPa}{1} = 8.26\ kN.m$$

$$F_{T,1,Rd} = \frac{4 M_{pl,1,Rd}}{m} = \frac{4 \times 7.63\ kN\,m}{37.6\ mm} = 812\ kN$$

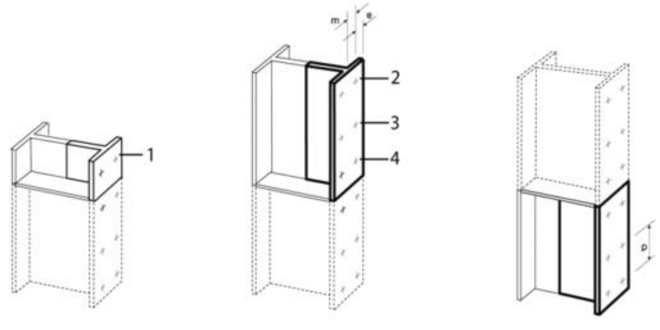
$$F_{T,2,Rd} = \frac{2 M_{pl,2,Rd} + n \Sigma F_{t,Rd}}{m + n} = \frac{2 \times 8.26\ kN\,m + 47.4\ mm \times (2 \times 141\ kN)}{37.9\ mm + 47.4\ mm} = 350\ kN$$

$$n = \min\{\underbrace{e_{min}}_{60\ mm}, \underbrace{1.25\,m}_{47.4\ mm}\} = 47.4\ mm$$

$$F_{T,3,Rd} = \Sigma F_{t,Rd} = 2 \times 141\ kN = 282\ kN$$

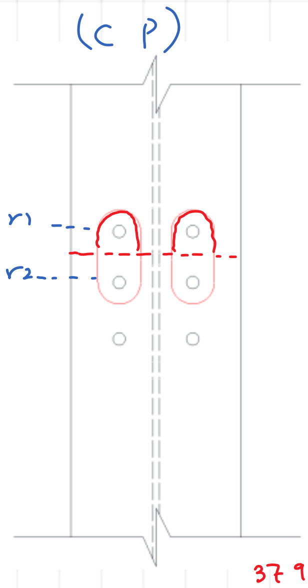
Table 6.4: Effective lengths for an unstiffened column flange

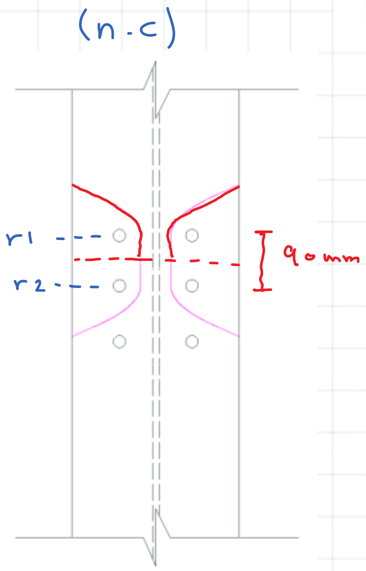
Bolt-row Location	Bolt-row considered individually		Bolt-row considered as part of a group of bolt-rows	
	Circular patterns $\ell_{eff,cp}$	Non-circular patterns $\ell_{eff,nc}$	Circular patterns $\ell_{eff,cp}$	Non-circular patterns $\ell_{eff,nc}$
Inner bolt-row	$2\pi m$	$4m + 1{,}25e$	$2p$	p
End bolt-row	The smaller of: $2\pi m$; $\pi m + 2e_1$	The smaller of: $4m + 1{,}25e$; $2m + 0{,}625e + e_1$	The smaller of: $\pi m + p$; ~~$2e_1 + p$~~	The smaller of: $2m + 0{,}625e + 0{,}5p$; ~~$e_1 + 0{,}5p$~~
Mode 1:	$\ell_{eff,1} = \ell_{eff,nc}$ but $\ell_{eff,1} \leq \ell_{eff,cp}$		$\sum\ell_{eff,1} = \sum\ell_{eff,nc}$ but $\sum\ell_{eff,1} \leq \sum\ell_{eff,cp}$	
Mode 2:	$\ell_{eff,2} = \ell_{eff,nc}$		$\sum\ell_{eff,2} = \sum\ell_{eff,nc}$	

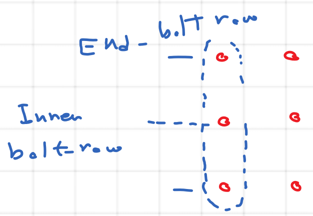


1 End bolt row adjacent to a stiffener
2 End bolt row
3 Inner bolt row
4 Bolt row adjacent to a stiffener

Figure 6.9: Modelling a stiffened column flange as separate T-stubs







$l_{eff,cp,r1} = \pi m + p = 210$ mm (πm: 379 mm; p: 90 mm)

$l_{eff,cp,r2} = 210$ mm

$l_{eff,nc,r1} = 2m + 0.625e + 0.5p = 174$ mm (2m: 37.9 mm; e: 85 mm; p: 90 mm)

$l_{eff,nc,r2} = 174$ mm

$\sum l_{eff,cp} = 420$ mm

$\sum l_{eff,nc} = 348$ mm

Mode 1 → $\sum l_{eff,1} = 348$ mm

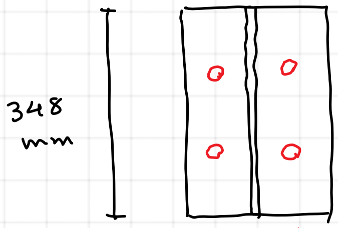
Mode 2 → $\sum l_{eff,2} = 348$ mm

$$M_{p\ell,1,Rd} = 0{,}25\Sigma\ell_{eff,1} t_f^{\,2} f_y / \gamma_{M0}$$

$$M_{p\ell,2,Rd} = 0{,}25\Sigma\ell_{eff,2} t_f^{\,2} f_y / \gamma_{M0}$$

→ $M_{pl,1,Rd} = M_{pl,2,Rd} = 0.25 \times 348\text{ mm} \times (19\text{ mm})^2 \times \frac{355\text{ MPa}}{1}$

$M_{pl,1,2,Rd} = 11.15$ kN m



$M_{pl,1,2,Rd} = 11.15$ kN m

$F_{t,Rd} = 141$ kN

$m = 37.9$ mm

$n = \min\{e_{min}, 1.25m\} = 47.4$ mm

$$F_{T,1,Rd} = \frac{4M_{pl,1,Rd}}{m} = 1177 \text{ kN}$$

$$F_{T,2,Rd} = \frac{2M_{pl,2,Rd} + n\overbrace{\sum F_{t,Rd}}^{4\times 141\text{ kN}}}{m+n} = 575 \text{ kN}$$

$$F_{T,3,Rd} = 4\times 141 \text{ kN} = 564 \text{ kN}$$

(r1) → Mode 3 → $F_T = 282$ kN

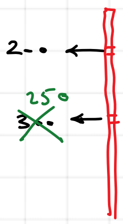
(r2) → Mode 3 → $F_T = 282$ kN

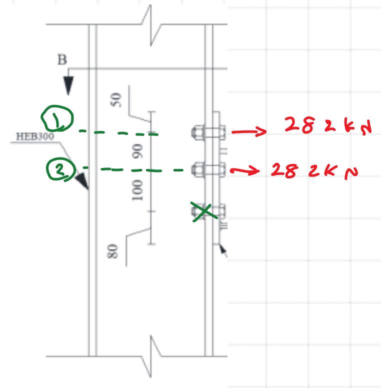
(r1, r2) → Mode 3 → $F_T = 564$ kN

$F_T = 200$

$F_T = 300$

$F_T = 450$ kN





6.2.4.2 Individual bolt-rows, bolt-groups and groups of bolt-rows

(1) Although in an actual T-stub flange the forces at each bolt-row are generally equal, when an equivalent T-stub flange is used to model a basic component listed in 6.2.4.1(1), allowance should be made for the different in forces at each bolt-row.

(2) When using the equivalent T-stub approach to model a group of bolt rows it may be necessary to divide the group into separate bolt-rows and use an equivalent T-stub to model each separate bolt-row.

(3) When using the T-stub approach to model a group of bolt rows the following conditions should be satisfied:

a) the force at each bolt-row should not exceed the design resistance determined considering only that individual bolt-row;

b) the total force on each group of bolt-rows, comprising two or more adjacent bolt-rows within the same bolt-group, should not exceed the design resistance of that group of bolt-rows.

(4) When determining the design tension resistance of a basic component represented by an equivalent T-stub flange, the following parameters should be calculated:

a) the design resistance of an individual bolt-row, determined considering only that bolt-row;

b) the contribution of each bolt-row to the design resistance of two or more adjacent bolt-rows within a bolt-group, determined considering only those bolt-rows.

(5) In the case of an individual bolt-row $\sum \ell_{eff}$ should be taken as equal to the effective length ℓ_{eff} tabulated in 6.2.6 for that bolt-row taken as an individual bolt-row.

(6) In the case of a group of bolt-rows $\sum \ell_{eff}$ should be taken as the sum of the effective lengths ℓ_{eff} tabulated in 6.2.6 for each relevant bolt-row taken as part of a bolt-group.