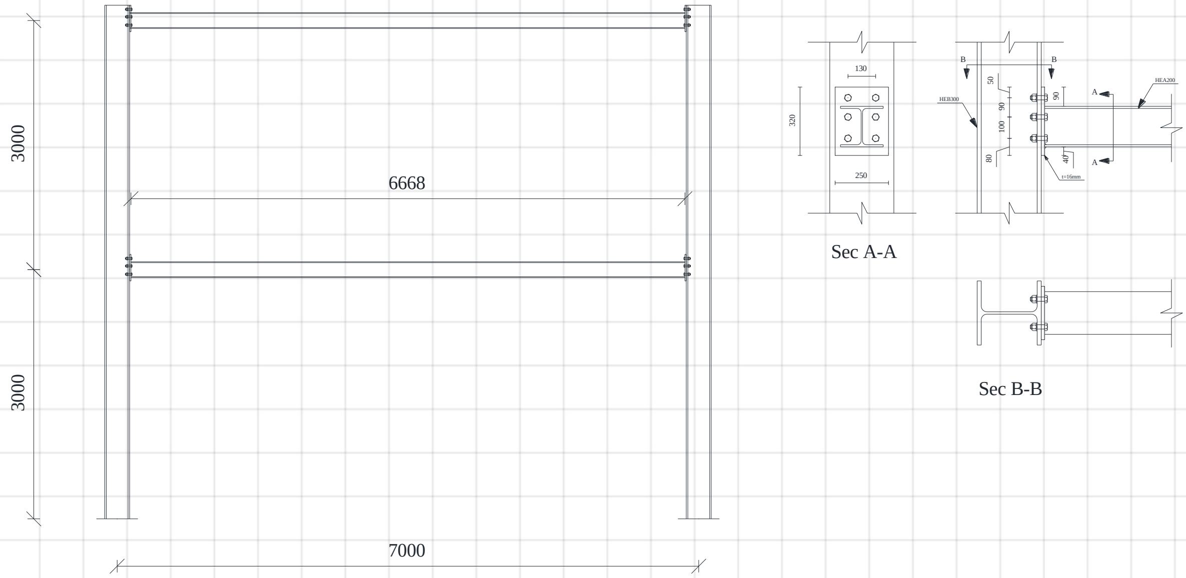
This playlist series focuses on the rigid connection calculation according to EN 1993-1-8. A comparison is made with Ansys at the end of the series after hand calculation. Finally, tips for applying the semi-rigid connection to RFEM are presented.

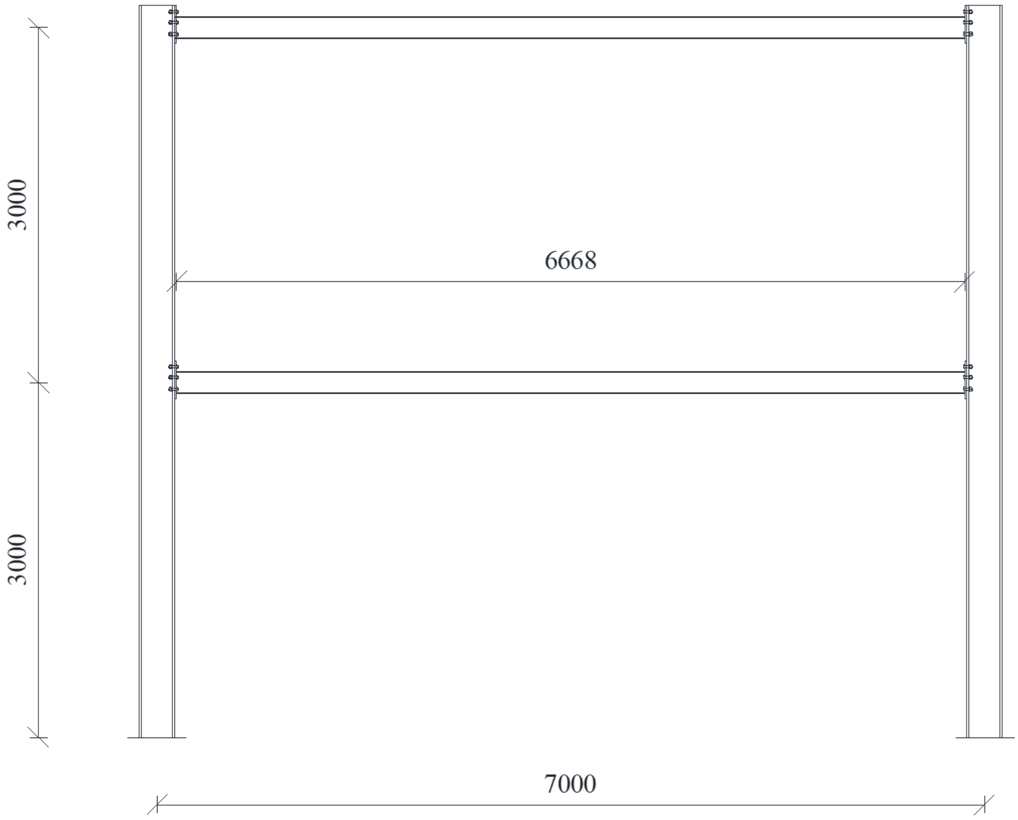
A portal frame with two levels is presented, as shown in the figure below. We went through the connections in this playlist for both ends and beams. The Endplate welded to the HEA200 beam is bolted to a HEB300 column with 6M20 class 8.8, as shown in the figures below. Steel material is S355 for all parties.

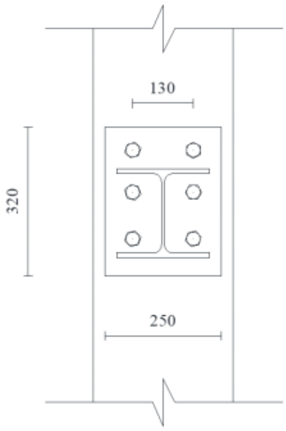
This video shows the rotational stuffiness of rigid and semi-rigid connections according to EN 1993-1-8. The contents are as follows:

a) Introduction to clause 6.3.
b) Different components' stiffness coefficients according to Table 6.11.
c) Required stiffness coefficient to be considered in the calculation according to table 6.10.
d) Equivalent stiffness for Endplate according to 6.3.3.1.
e) Equivalent lever arm according to 6.3.3.1(3)
f) Rotational stiffness of the connection.

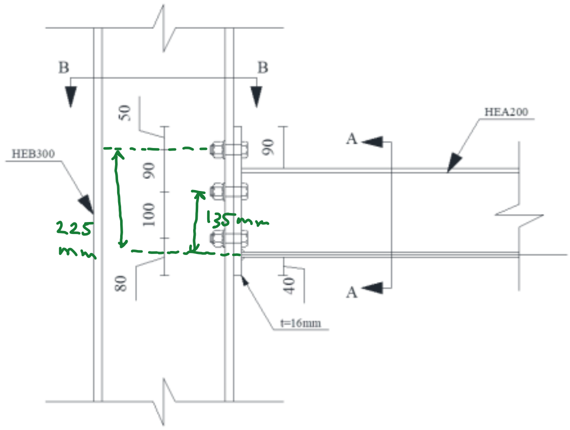
All dimensions are in mm unless otherwise specified.

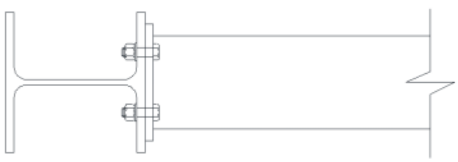



3000
3000
6668
7000


130
320
250

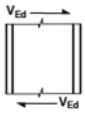
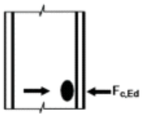
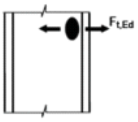
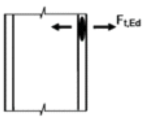
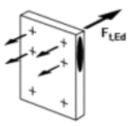
Sec A-A


B
B
50
90
100
80
HEB300
225 mm
135mm
90
40
A
A
HEA200
t=16mm



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

6.3 Rotational stiffness

6.3.1 Basic model

(1) The rotational stiffness of a joint should be determined from the flexibilities of its basic components, each represented by an elastic stiffness coefficient k_i obtained from 6.3.2.

NOTE: These elastic stiffness coefficients are for general application.

(2) For a bolted end-plate joint with more than one row of bolts in tension, the stiffness coefficients k_i for the related basic components should be combined. For beam-to-column joints and beam splices a method is given in 6.3.3 and for column bases a method is given in 6.3.4.

(3) In a bolted end plate joint with more than one bolt-row in tension, as a simplification the contribution of any bolt-row may be neglected, provided that the contributions of all other bolt-rows closer to the centre of compression are also neglected. The number of bolt-rows retained need not necessarily be the same as for the determination of the design moment resistance.

6.3 Rotational stiffness

6.3.1 Basic model

(4) Provided that the axial force N_{Ed} in the connected member does not exceed 5% of the design resistance $N_{pl,Rd}$ of its cross-section, the rotational stiffness S_j of a beam-to-column joint or beam splice, for a moment $M_{j,Ed}$ less than the design moment resistance $M_{j,Rd}$ of the joint, may be obtained with sufficient accuracy from:

$$S_j = \frac{Ez^2}{\mu \sum_i \frac{1}{k_i}} = \frac{E z^2}{\mu\left(\frac{1}{k_1} + \frac{1}{k_2} + \frac{1}{k_{eq}}\right)} \qquad \text{... (6.27)}$$

where:

k_i is the stiffness coefficient for basic joint component i;

z is the lever arm, see 6.2.7; → 180mm

μ is the stiffness ratio $S_{j,ini} / S_j$, see 6.3.1(6).

NOTE: The initial rotational stiffness $S_{j,ini}$ of the joint is given by expression (6.27) with $\mu = 1,0$.

6.3 Rotational stiffness

6.3.1 Basic model

(6) The stiffness ratio μ should be determined from the following:

- if $M_{j,Ed} \leq 2/3\ M_{j,Rd}$:
  $\mu = 1$ ... (6.28a)

- if $2/3\ M_{j,Rd} < M_{j,Ed} \leq M_{j,Rd}$:
  $\mu = (1{,}5 M_{j,Ed} / M_{j,Rd})^{\Psi}$ ... (6.28b)

in which the coefficient ψ is obtained from Table 6.8.

Table 6.8: Value of the coefficient ψ

Type of connection	ψ
Welded	2,7
Bolted end-plate	2,7
Bolted angle flange cleats	3,1
Base plate connections	2,7

Table 6.10: Joints with bolted end-plate connections and base plate connections

Beam-to-column joint with bolted end-plate connections	Number of bolt-rows in tension	Stiffness coefficients k_i to be taken into account
Single-sided	One	k_1; k_2; k_3; k_4; k_5; k_{10}
	Two or more	k_1; k_2; k_{eq}

6.3.3 End-plate joints with two or more bolt-rows in tension

6.3.3.1 General method

(4) In the case of a beam-to-column joint with an end-plate connection, k_{eq} should be based upon (and replace) the stiffness coefficients k_i for:

- the column web in tension (k_3);
- the column flange in bending (k_4);
- the end-plate in bending (k_5);
- the bolts in tension (k_{10}).

Table 6.11: Stiffness coefficients for basic joint components

Component	Stiffness coefficient k_i	
Column web panel in shear	Unstiffened, single-sided joint, or a double-sided joint in which the beam depths are similar	stiffened
	$k_1 = \frac{0{,}38 A_{VC}}{\beta z}$ (→ 4743 mm²)	$k_1 = \infty$
	z is the lever arm from Figure 6.15; (180 mm) β is the transformation parameter from 5.3(7). (1)	
Column web in compression	unstiffened	stiffened
	$k_2 = \frac{0{,}7 b_{eff,c,wc} t_{wc}}{d_c}$ (272 mm; 11 mm; 208 mm)	$k_2 = \infty$
	$b_{eff,c,wc}$ is the effective width from 6.2.6.2	
Column web in tension	stiffened or unstiffened bolted connection with a single bolt-row in tension or unstiffened welded connection	stiffened welded connection
	$k_3 = \frac{0{,}7 b_{eff,t,wc} t_{wc}}{d_c}$ (11 mm; 208 mm)	$k_3 = \infty$
	$b_{eff,t,wc}$ is the effective width of the column web in tension from 6.2.6.3. For a joint with a single bolt-row in tension, $b_{eff,t,wc}$ should be taken as equal to the smallest of the effective lengths ℓ_{eff} (individually or as part of a group of bolt-rows) given for this bolt-row in Table 6.4 (for an unstiffened column flange) or Table 6.5 (for a stiffened column flange).	

$K_1 = \frac{0.38 \times 4743\,mm^2}{1 \times 180\,mm} = 10\,mm$

$K_2 = \frac{0.7 \times 272\,mm \times 11\,mm}{208\,mm} = 10\,mm$

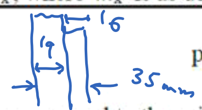
$K_{31} = \frac{0.7 \times 238\,mm \times 11\,mm}{208\,mm} = 8.8\,mm$

$K_{32} = \frac{0.7 \times 238\,mm \times 11\,mm}{208\,mm} = 8.8\,mm$

Basic Component					Bolt Row #1	l(eff)	m or mx	Bolt Row #2	l(eff)	m
Column Web in Shear	k1	Video#7			-	-	-	-	-	-
Column Web in Transverse Compression	k2	Video#5	b(eff.c.wc)	272	-	-	-	-	-	-
Column Web in Transverse Tension	k3	Video#2	b(eff.t.wc)		k3.1	238	-	k3.2	238	-
Column Flange In Bending	k4	Video#1	l(eff)		k4.1	238	37.9	k4.2	238	37.9
End Plate in Bending	k5	Video#3	l(eff)		k5.1	125	33.6	k5.2	368	58.6
Bolts In Tension	k10	-	-		k10.1	-	-	k10.2	-	-
Beam Flange and Web in Compression	k7	Video#6	Infinity							

Table 6.11: Stiffness coefficients for basic joint components

Component	Stiffness coefficient k_i
Column flange in bending (for a single bolt-row in tension)	$k_4 = \dfrac{0{,}9\ell_{eff}\, t_{fc}^{\ 3}}{m^3}$ ℓ_{eff} is the smallest of the effective lengths (individually or as part of a bolt group) for this bolt-row given in Table 6.4 for an unstiffened column flange or Table 6.5 for a stiffened column flange; m is as defined in Figure 6.8.
End-plate in bending (for a single bolt-row in tension)	$k_5 = \dfrac{0{,}9\ell_{eff}\, t_p^{\ 3}}{m^3}$ ℓ_{eff} is the smallest of the effective lengths (individually or as part of a group of bolt-rows) given for this bolt-row in Table 6.6; m is generally as defined in Figure 6.11, but for a bolt-row located in the extended part of an extended end-plate $m = m_x$, where m_x is as defined in Figure 6.10.
Bolts in tension (for a single bolt-row)	$k_{10} = 1{,}6A_s / L_b$ preloaded or non-preloaded L_b is the bolt elongation length, taken as equal to the grip length (total thickness of material and washers), plus half the sum of the height of the bolt head and the height of the nut.



NOTE 4: For *beam flange and web in compression* (k_7), *beam web in tension* (k_8), *plate in tension or compression* (k_9), *haunched beams* (k_{20}), the stiffness coefficients should be taken as equal to infinity. These components need not be taken into account when calculating the rotational stiffness S_j.

238mm
19mm
37.9mm
245 (M20)

$k_{41} = k_{42} = \dfrac{0.9 \times 238\,mm \times (19\,mm)^3}{(37.9\,mm)^3}$
$k_{41} = 27\,mm$
$k_{42} = 27\,mm$
$k_{51} = \dfrac{0.9 \times 125\,mm \times (16\,mm)^3}{(33.6\,mm)^3} = 12.15\,mm$
$k_{52} = \dfrac{0.9 \times 368\,mm \times (16\,mm)^3}{(58.6\,mm)^3} = 6.75\,mm$
$L_b = 10\,mm + 35\,mm = 45\,mm$
$k_{10,1} = k_{10,2} = \dfrac{1.6 \times 245\,mm^2}{45\,mm} = 8.7\,mm$
$8.7\,mm$

6.3.3 End-plate joints with two or more bolt-rows in tension

6.3.3.1 General method

(1) For end-plate joints with two or more bolt-rows in tension, the basic components related to all of these bolt-rows should be represented by a single equivalent stiffness coefficient k_{eq} determined from:

$h_1 = 225mm$

$h_2 = 135mm$

$$k_{eq} = \frac{\sum_r k_{eff,r} h_r}{z_{eq}} \quad \text{... (6.29)}$$

where:

h_r is the distance between bolt-row r and the centre of compression;

$k_{eff,r}$ is the effective stiffness coefficient for bolt-row r taking into account the stiffness coefficients k_i for the basic components listed in 6.3.3.1(4) or 6.3.3.1(5) as appropriate;

z_{eq} is the equivalent lever arm, see 6.3.3.1(3).

(2) The effective stiffness coefficient $k_{eff,r}$ for bolt-row r should be determined from:

$$k_{eff,r} = \frac{1}{\sum_i \frac{1}{k_{i,r}}} \quad \text{... (6.30)}$$

$\Rightarrow k_{eff,1} = \frac{1}{\frac{1}{k_{3r}} + \frac{1}{k_{4r}} + \frac{1}{k_{5r}} + \frac{1}{k_{10r}}}$

k_3, k_4, k_5, k_{10}

where:

$k_{i,r}$ is the stiffness coefficient representing component i relative to bolt-row r.

(3) The equivalent lever arm z_{eq} should be determined from:

$$z_{eq} = \frac{\sum_r k_{eff,r} h_r^2}{\sum_r k_{eff,r} h_r} \quad \text{... (6.31)}$$

$k_1 := 10\ mm$ $k_2 := 10\ mm$ $k_{3.1} := 8.8\ mm$ $k_{3.2} := 8.8\ mm$ $h_1 := 225\ mm$ $E := 210\ GPa$

$k_{4.1} := 27\ mm$ $k_{4.2} := 27\ mm$ $h_2 := 135\ mm$ $z := 180\ mm$

$k_{5.1} := 12.15\ mm$ $k_{5.2} := 6.75\ mm$

$\mu := 1$

$k_{10.1} := 8.7\ mm$ $k_{10.2} := 8.7\ mm$

$$k_{eff.1} := \frac{1}{\frac{1}{k_{3.1}} + \frac{1}{k_{4.1}} + \frac{1}{k_{5.1}} + \frac{1}{k_{10.1}}} = 2.874\ mm \qquad k_{eff.2} := \frac{1}{\frac{1}{k_{3.2}} + \frac{1}{k_{4.2}} + \frac{1}{k_{5.2}} + \frac{1}{k_{10.2}}} = 2.417\ mm$$

$$z_{eq} := \frac{k_{eff.1} \cdot h_1^2 + k_{eff.2} \cdot h_2^2}{k_{eff.1} \cdot h_1 + k_{eff.2} \cdot h_2} = 194.82\ mm \qquad k_{eq} := \frac{k_{eff.1} \cdot h_1 + k_{eff.2} \cdot h_2}{z_{eq}} = 4.994\ mm$$

$$S_j := \frac{E \cdot z^2}{\mu \cdot \left(\frac{1}{k_1} + \frac{1}{k_2} + \frac{1}{k_{eq}}\right)} = \left(1.7 \cdot 10^4\right)\ kN \cdot m$$