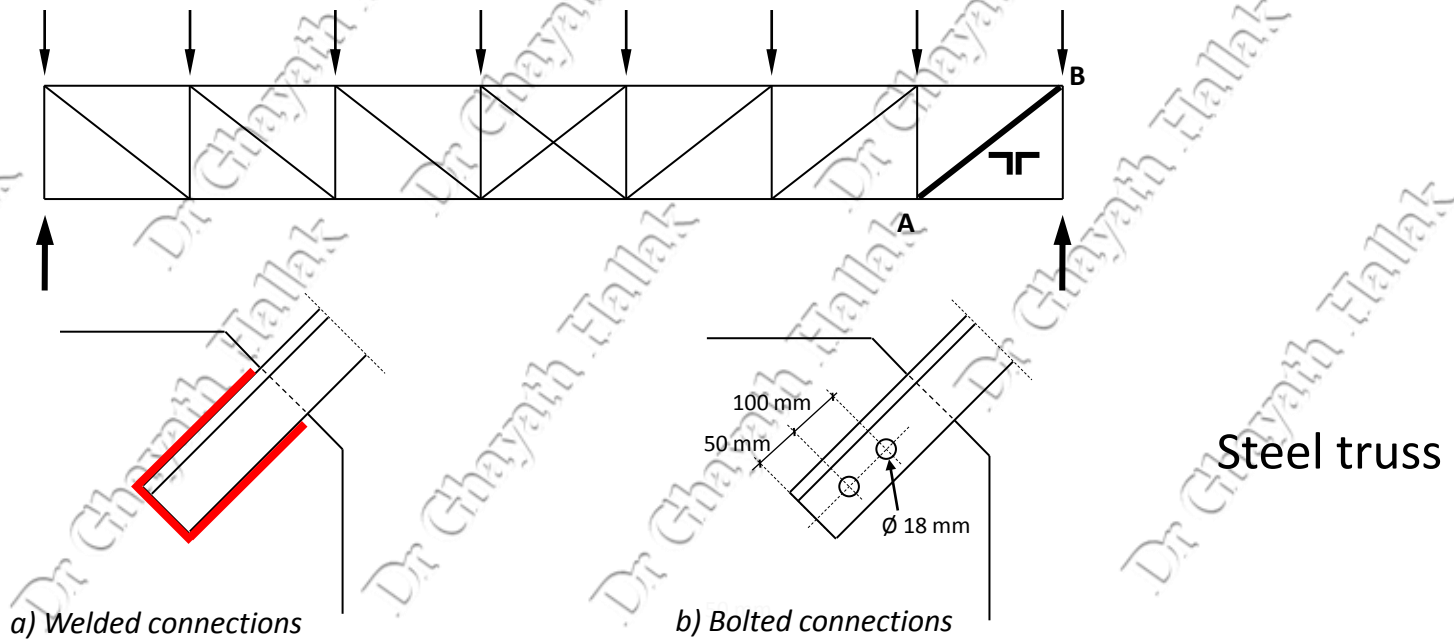


# SIMPLE CONNECTIONS Examples

## Example: 1

Consider the member AB of the steel truss, indicated in Figure, assuming it is subjected to a design tensile axial force of  $N_{Ed} = 220$  kN. The cross section consists of two angles of equal legs, in steel grade S235. Design member AB assuming two distinct possibilities for the connections:

a) Welded connections, b) bolted connections



# SIMPLE CONNECTIONS Examples

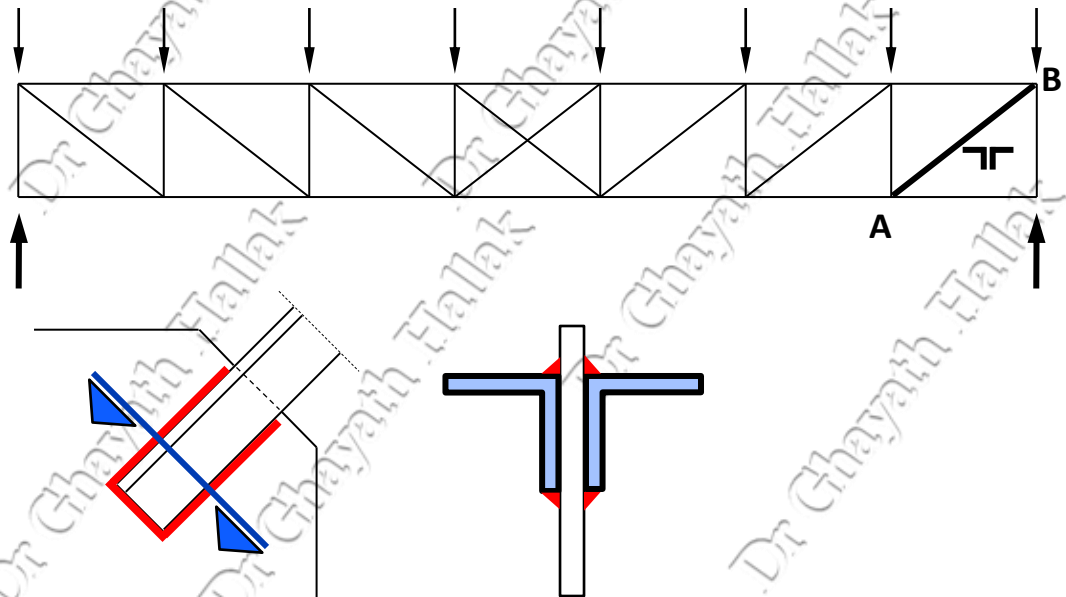
## Example: 1

### a) Welded connections

The member is made up by two angles of equal legs, but the connection is made only in one leg of the angle. Thus, according to clause 4.13 of the EC3-1-8, the effective area can be considered equal to the gross area. Therefore, the following conditions must be satisfied:

$$N_{Ed} \leq N_{t,Rd} = \frac{Af_y}{\gamma_{M0}}$$

Considering the design axial force = 220 kN, then:



a) Welded connections

# SIMPLE CONNECTIONS Examples

## Example: 1

### a) Welded connections

$$220 \leq \frac{A \times 235 \times 10^3}{1.0} \Rightarrow A \geq 9.36 \times 10^{-4} \text{ m}^2 = 9.36 \text{ cm}^2$$

From a table of commercial profiles, a solution with two angles 50×50×5 mm, with a total area of  $2 \times 4.8 = 9.6 \text{ cm}^2$ , satisfies the above safety requirement.

### b) Bolted connections

In this case, the member is made up by two angles of equal legs is connected by two bolts only in one leg. According to clause 3.10.3 of the EC3-1-8, the following design conditions must be ensured:

# SIMPLE CONNECTIONS Examples

## Example: 1

### b) Bolted connections

$$N_{Ed} \leq N_{t,Rd} = \min \left[ N_{pl,Rd} = \frac{A f_y}{\gamma_{M0}}; N_{u,Rd} = \frac{\beta_2 A_{net} f_u}{\gamma_{M2}} \right]$$

$\beta_2$  is a factor obtained from Table 3.8 of EC-1-8.

A **first** check based on the plastic design of the gross section leads to:

$$220 \leq \frac{A \times 235 \times 10^3}{1.0} \Rightarrow A \geq 9.36 \times 10^{-4} \text{ m}^2 = 9.36 \text{ cm}^2$$

Hence, the section obtained in the previous design, two angles 50×50×5 mm, with a total area of  $2 \times 4.8 = 9.6 \text{ cm}^2$ , also satisfies this safety requirement.

# SIMPLE CONNECTIONS Examples

## Example: 1

### b) Bolted connections

The **second condition** (3.12, EC3-1-8), requires the evaluation of the net area  $A_{net}$ , and the factor  $\beta_2$ , both evaluated according to clause 3.10.3 of EC3-1-8.

For  $d_0 = 18$  mm,  $2.5d_0 = 45$  mm and  $5d_0 = 90$  mm.

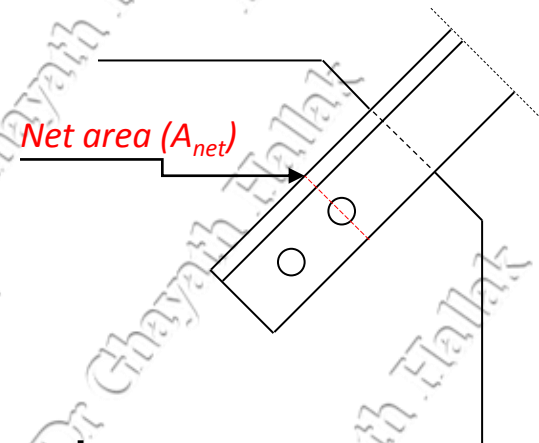
As  $p_1 = 100$  mm  $>$  90 mm, then  $\beta_2 = 0.7$ .

The net area of the bolted section made up of two angles is given by:

$$A_{net} = A - 2td_0 = 9.6 - 2 \times 0.5 \times 1.8 = 7.8 \text{ cm}^2.$$

Thus, the design ultimate resistance is given by:

$$N_{u,Rd} = \frac{0.7 \times 7.8 \times 10^{-4} \times 360 \times 10^3}{1.25} = 157.2 \text{ kN}$$



# SIMPLE CONNECTIONS Examples

## Example: 1

### b) Bolted connections

However,  $N_{Ed} = 220 \text{ kN} > N_{u, Rd} = 157.2 \text{ kN}$ ; therefore, the chosen cross section is not appropriate. By adopting a cross section with enhanced resistance, for example, two angles  $60 \times 60 \times 6 \text{ mm}$  ( $A = 13.82 \text{ cm}^2$  and  $A_{net} = 11.6 \text{ cm}^2$ ), then:

$$N_{pl, Rd} = 13.82 \times 10^{-4} \times 235 \times 10^3 / 1.0 = 324.8 \text{ kN} > N_{Ed} = 220 \text{ kN}$$

$$N_{u, Rd} = \frac{0.7 \times 11.6 \times 10^{-4} \times 360 \times 10^3}{1.25} = 235.1 \text{ kN} > N_{Ed} = 220 \text{ kN}$$

As  $N_{pl, Rd} = 324.8 \text{ kN} > N_{u, Rd} = 235.1 \text{ kN}$ , failure is non-ductile; however, since this is not a design condition, the section defined by two angles  $60 \times 60 \times 6 \text{ mm}$  can be adopted.

# SIMPLE CONNECTIONS Examples

## Example: 2

Check the design of shear connection shown in Figure.

- The connection is

Category A:

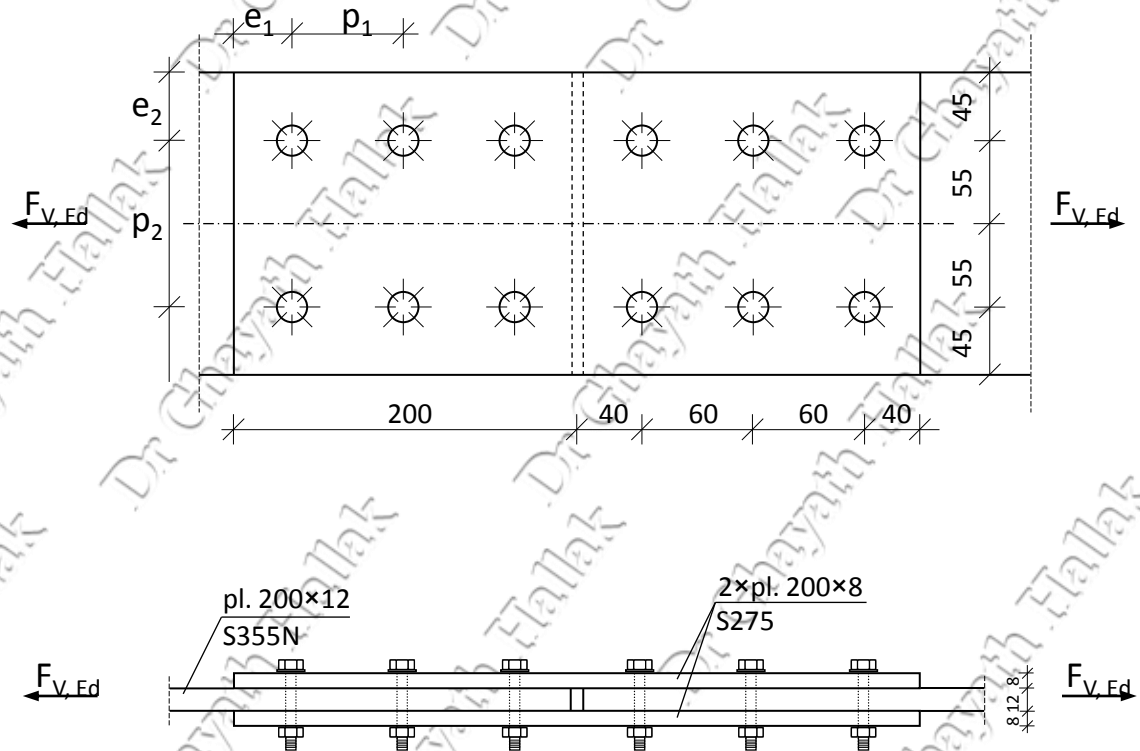
Bearing type

- Bolts 6M20(4.8);

$d = 20 \text{ mm}$ ;  $d_0 = 20 + 2 = 22 \text{ mm}$ ,

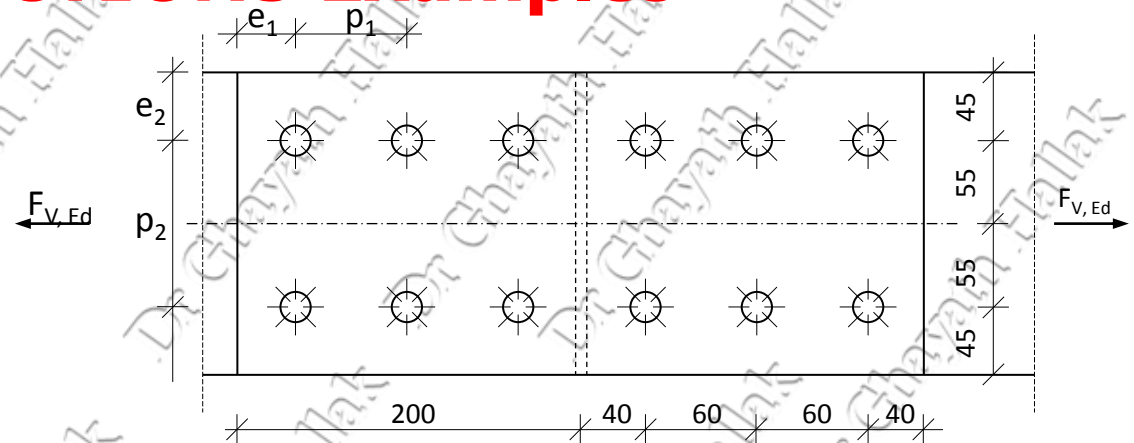
- Used two cover plates  $200 \times 8$  (S275).

- $F_{V,Ed} = 650 \text{ kN}$



# SIMPLE CONNECTIONS Examples

## Example: 2



Minimum and maximum spacing, end and edge distances checking (Table 3-3 EN 1993-1-8 : 2005 (E)):

$$e_{1\min} = 1.2d_0 = 1.2 \times 22 = 26.4 \text{ mm} < 40 \text{ mm /OK/}$$

$$e_{1\max} = 4t + 40 \text{ mm} = 4 \times 8 + 40 = 72 \text{ mm} > 40 \text{ mm /OK/}$$

$$e_{2\min} = 1.2d_0 = 1.2 \times 22 = 26.4 \text{ mm} < 45 \text{ mm /OK/}$$

$$e_{2\max} = 4t + 40 \text{ mm} = 4 \times 8 + 40 = 72 \text{ mm} > 45 \text{ mm /OK/}$$

$$p_{1\min} = 2.2d_0 = 2.2 \times 22 = 48.4 \text{ mm} < 60 \text{ mm /OK/}$$

$$p_{1\max} = \min.(14t = 14 \times 8 = 112; 200) = 112 > 60 \text{ mm /OK/}$$

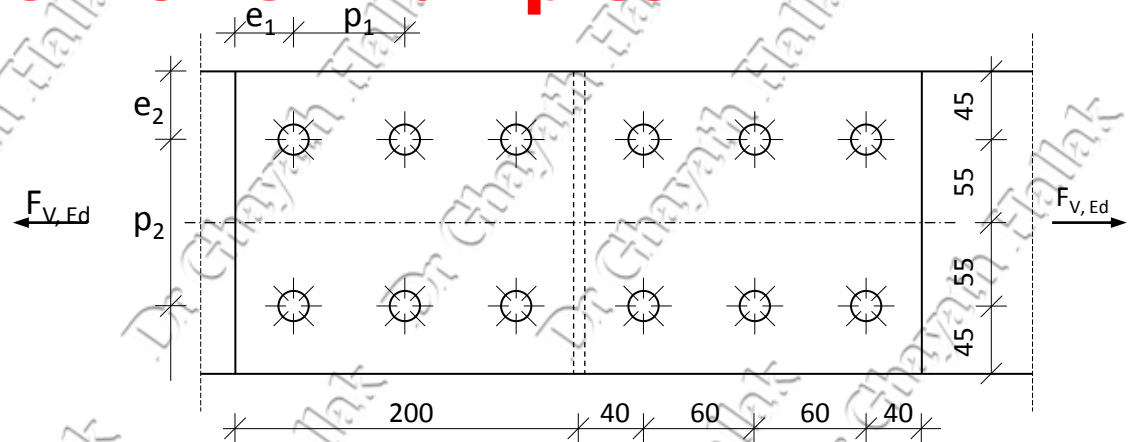
$$p_{2\min} = 2.4d_0 = 2.4 \times 22 = 52.8 \text{ mm} < 110 \text{ mm /OK/}$$

$$p_{2\max} = \min.(14t = 14 \times 8 = 112; 200) = 112 > 110 \text{ mm /OK/}$$



# SIMPLE CONNECTIONS Examples

## Example: 2



Steel S355N (for  $t \leq 40\text{mm}$ )  $\rightarrow f_y = 355 \text{ MPa}$ ,  $f_u = 510 \text{ MPa}$   
(Table 3-1 EN 1993-1-1 : 2005 (E))

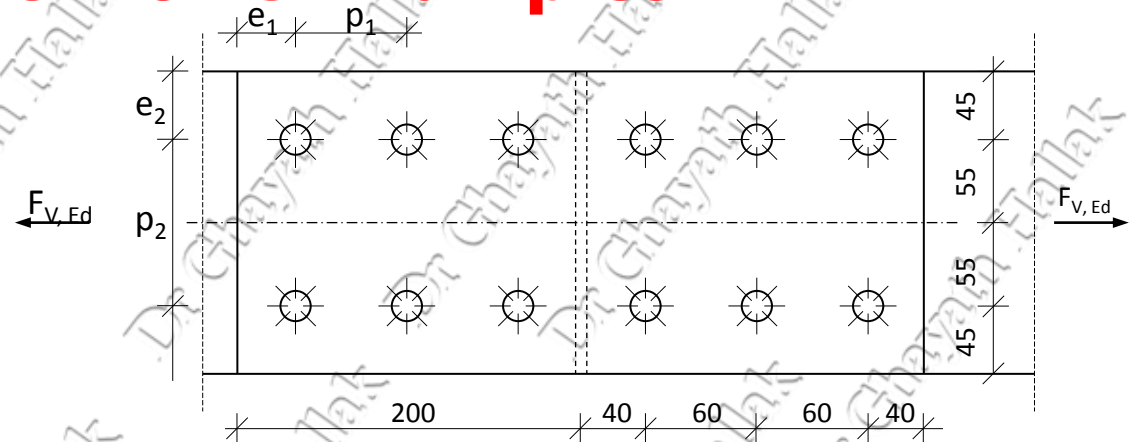
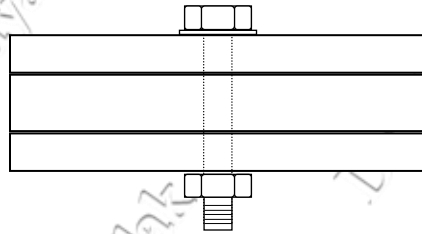
Steel S275 (for  $t \leq 40\text{mm}$ )  $\rightarrow f_y = 275 \text{ MPa}$ ,  $f_u = 430 \text{ MPa}$   
(Table 3-1 EN 1993-1-1 : 2005 (E))

Nominal values of the yield strength  $f_{yb}$  and the ultimate tensile strength  $f_{ub}$  for bolts (Table 3-1 EN 1993-1-8 : 2005 (E)):

Bolts grade 4.8  $\rightarrow f_{yb} = 320 \text{ MPa}$ ,  $f_{ub} = 400 \text{ MPa}$ .

# SIMPLE CONNECTIONS Examples

## Example: 2



The thread of a fit bolt should not be included in the shear plane

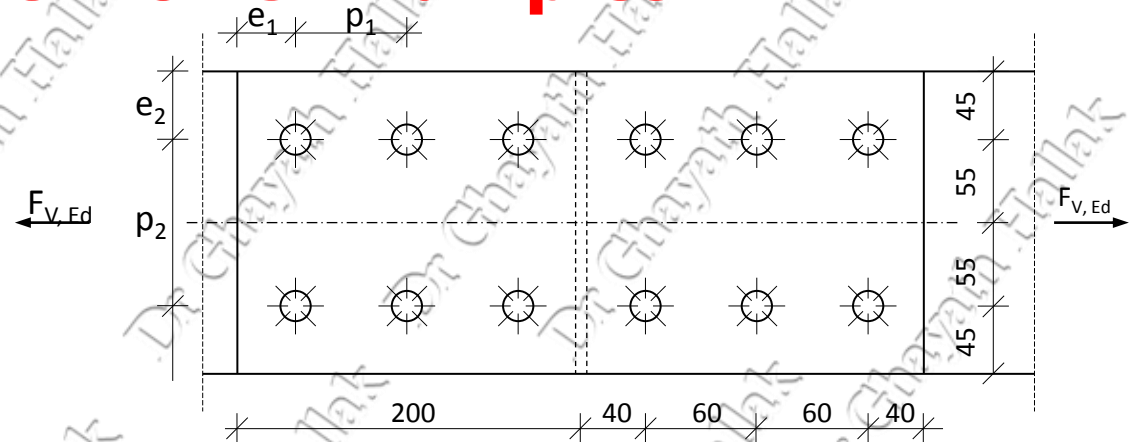
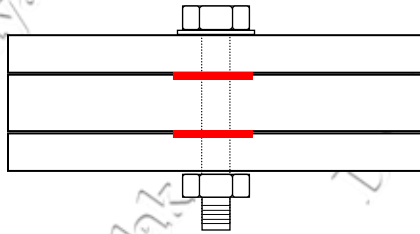
$$A = \pi d^2 / 4 = \pi \times 20^2 / 4 = 314 \text{ mm}^2$$

Design resistance for individual fastener subjected to shear per shear plane (Table 3-4 EN 1993-1-8 : 2005 (E))

$$F_{V,Rd} = \frac{\alpha_V f_{ub} A}{\gamma_{M2}} = \frac{0.6 \times 400 \times 314}{1.25} = 60288 \text{ N} = 60.288 \text{ kN}$$

# SIMPLE CONNECTIONS Examples

## Example: 2



Because bolt is in double shear  $\rightarrow F_{V,Rd} = 2 \times 60.288 = 120.576 \text{ kN}$

**Bearing resistance** (Table 3-4 EN 1993-1-8 : 2005 (E))

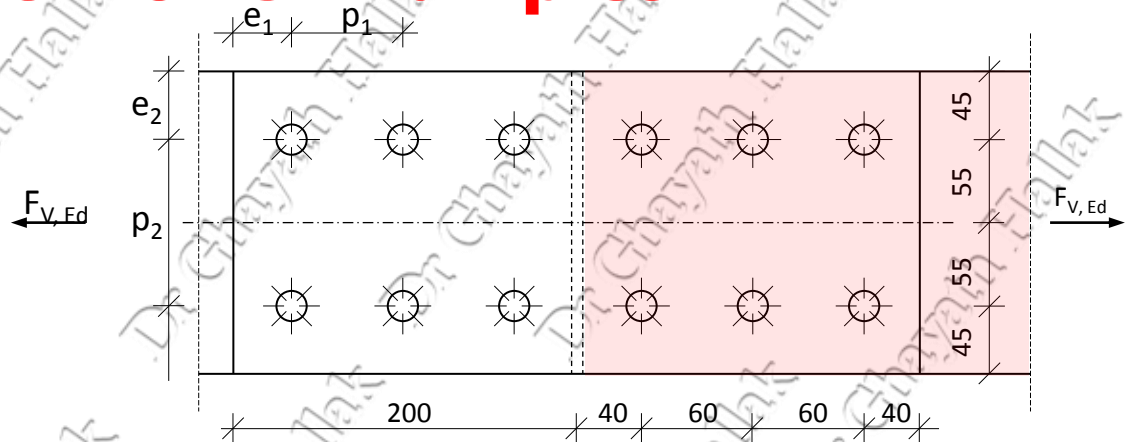
$$F_{b,Rd} = \frac{k_1 a_b f_u d t}{\gamma_{M2}}$$

**Attention:** Steel grade and thickness of tension member and cover plates not the same

# SIMPLE CONNECTIONS Examples

## Example: 2

$$F_{b,Rd} = \frac{k_1 a_b f_u d t}{\gamma_{M2}}$$



1- End bolts bearing on plate of connected part

$t = 12 \text{ mm}$ ,  $f_u = 510 \text{ MPa}$ ,  $d = 20 \text{ mm}$ ,  $\gamma_{M2} = 1.25$

$$\alpha_d = \frac{e_1}{3d_0} = \frac{40}{3 \times 22} = 0.61$$

$$\alpha_b = \min\left(\alpha_d; \frac{f_{ub}}{f_u}; 1.0\right) = \min\left(0.61; \frac{400}{510} = 0.78; 1.0\right) = 0.61$$

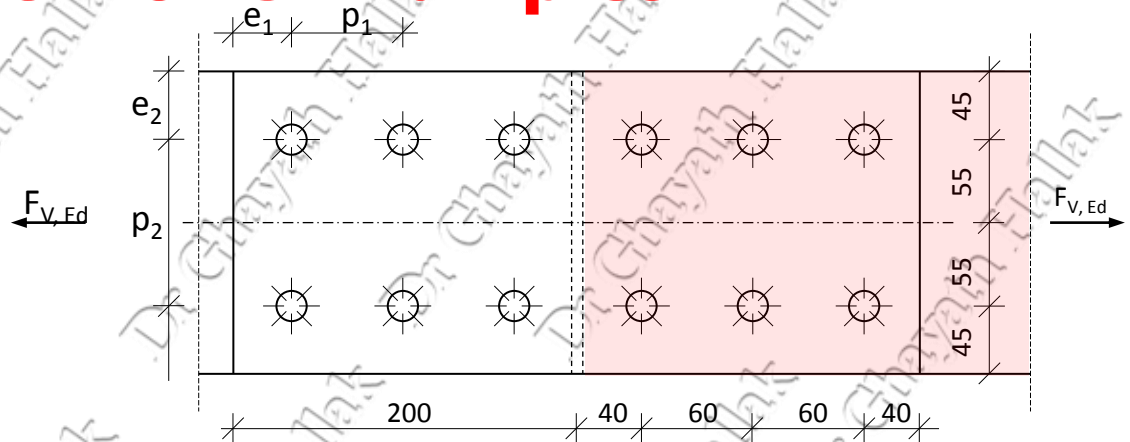
$$k_1 = \min\left(2.8 \frac{e_2}{d_0} - 1.7; 1.4 \frac{p_2}{d_0} - 1.7; 2.5\right)$$

$$= \min\left(2.8 \times \frac{45}{22} - 1.7 = 4.0; 1.4 \times \frac{110}{22} - 1.7 = 5.3; 2.5\right) = 2.5$$

# SIMPLE CONNECTIONS Examples

## Example: 2

$$F_{b,Rd} = \frac{k_1 a_b f_u d t}{\gamma_{M2}}$$



1- End bolts bearing on plate of connected part

$$F_{b,Rd} = \frac{k_1 a_b f_u d t}{\gamma_{M2}} = \frac{2.5 \times 0.61 \times 510 \times 20 \times 12}{1.25} = 149328 \text{ N} = 149.3 \text{ kN}$$

2- Inner bolts bearing on plate of connected part

$$t = 12 \text{ mm}, f_u = 510 \text{ MPa}, d = 20 \text{ mm}, \gamma_{M2} = 1.25$$

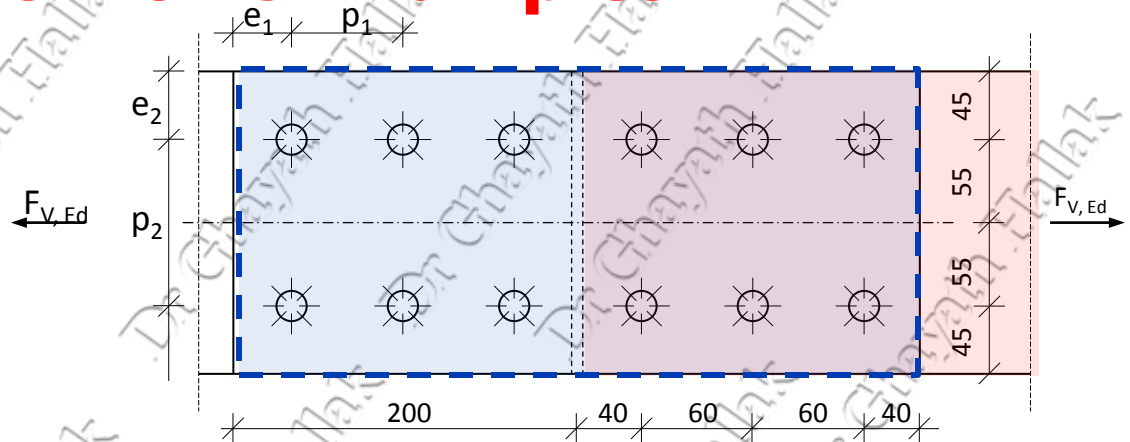
$$\alpha_d = \frac{p_1}{3d_0} - \frac{1}{4} = \frac{60}{3 \times 22} - \frac{1}{4} = 0.66, k_1 = 2.5$$

$$\alpha_b = \min. \left( \alpha_d; \frac{f_{ub}}{f_u}; 1.0 \right) = \min. \left( 0.66; \frac{400}{510}; 1.0 \right) = 0.66$$

# SIMPLE CONNECTIONS Examples

## Example: 2

$$F_{b,Rd} = \frac{k_1 \alpha_b f_u d t}{\gamma_{M2}}$$



### 2- Inner bolts bearing on plate of connected part

$$F_{b,Rd} = \frac{k_1 \alpha_b f_u d t}{\gamma_{M2}} = \frac{2.5 \times 0.66 \times 510 \times 20 \times 12}{1.25} = 161568 \text{ N} = 161.6 \text{ kN}$$

### 3- End bolts bearing on cover plate

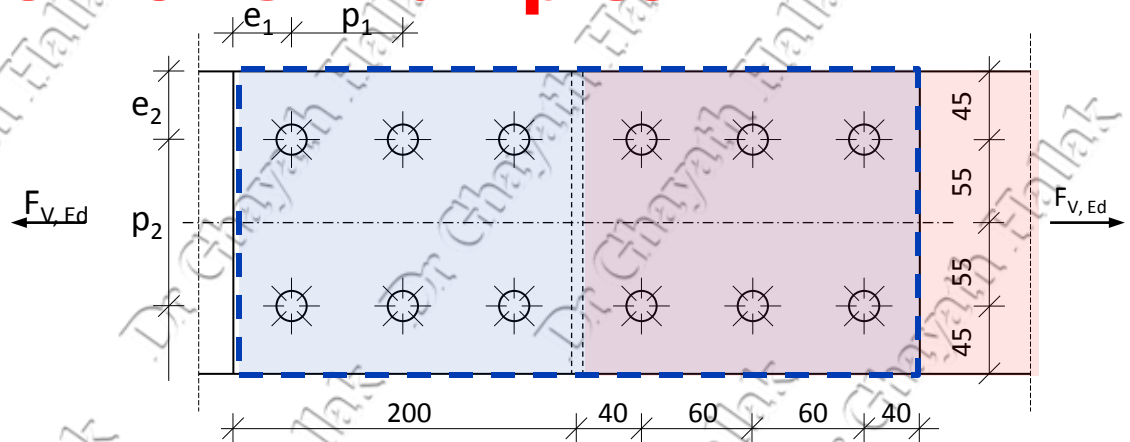
$$t = 2 \times 8 = 16 \text{ mm}, f_u = 430 \text{ MPa}, d = 20 \text{ mm}, \gamma_{M2} = 1.25$$

$$\alpha_a = \frac{e_1}{3d_0} = \frac{40}{3 \times 22} = 0.61$$

# SIMPLE CONNECTIONS Examples

## Example: 2

$$F_{b,Rd} = \frac{k_1 a_b f_u d t}{\gamma_{M2}}$$



### 3- End bolts bearing on cover plate

$$\alpha_b = \min\left(\alpha_d; \frac{f_{ub}}{f_u}; 1.0\right) = \min\left(0.61; \frac{400}{430} = 0.93; 1.0\right) = 0.61$$

$$k_1 = \min\left(2.8 \frac{e_2}{d_0} - 1.7; 1.4 \frac{p_2}{d_0} - 1.7; 2.5\right)$$

$$= \min\left(2.8 \times \frac{45}{22} - 1.7 = 4.0; 1.4 \times \frac{110}{22} - 1.7 = 5.3; 2.5\right) = 2.5$$

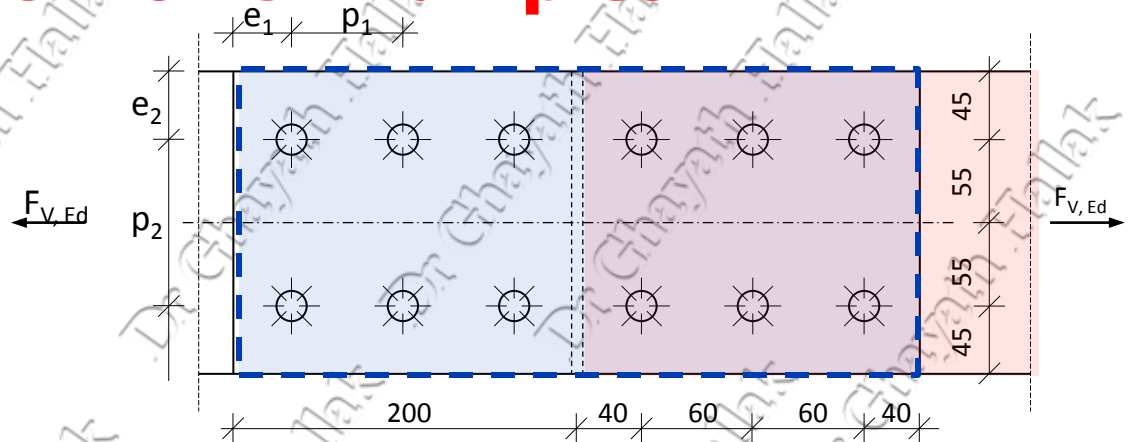
$$F_{b,Rd} = \frac{k_1 \alpha_b f_u d t}{\gamma_{M2}} = \frac{2.5 \times 0.61 \times 430 \times 20 \times 16}{1.25} = 167870 \text{ N}$$

$$= 167.87 \text{ kN}$$

# SIMPLE CONNECTIONS Examples

## Example: 2

$$F_{b,Rd} = \frac{k_1 a_b f_u d t}{\gamma_{M2}}$$



### 4- Inner bolts bearing on cover plate

$$t = 2 \times 8 = 16 \text{ mm}, f_u = 430 \text{ MPa}, d = 20 \text{ mm}, \gamma_{M2} = 1.25$$

$$\alpha_d = \frac{p_1}{3d_0} - \frac{1}{4} = \frac{60}{3 \times 22} - \frac{1}{4} = 0.66, \quad k_1 = 2.5$$

$$\alpha_b = \min\left(\alpha_d; \frac{f_{ub}}{f_u}; 1.0\right) = \min\left(0.66; \frac{400}{430} = 0.93; 1.0\right) = 0.66$$

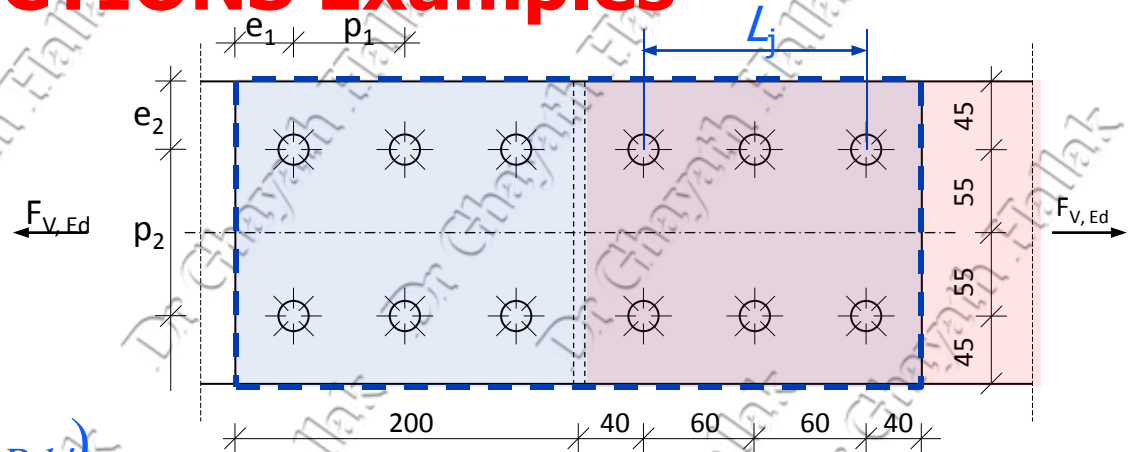
$$F_{b,Rd} = \frac{k_1 \alpha_b f_u d t}{\gamma_{M2}} = \frac{2.5 \times 0.66 \times 430 \times 20 \times 16}{1.25} = 181630 \text{ N}$$

$$= 181.63 \text{ kN}$$



# SIMPLE CONNECTIONS Examples

## Example: 2



$$F_{V,Rd} = n_b F_{Rd,min,i}$$

$$F_{Rd,min,i} = \min.(F_{V,Rd}; F_{b,Rd,i})$$

$$= \min.(120.576; 149.3; 161.6; 167.87; 181.63) = 120.576 \text{ kN}$$

Checking the connection if it is long Joint:

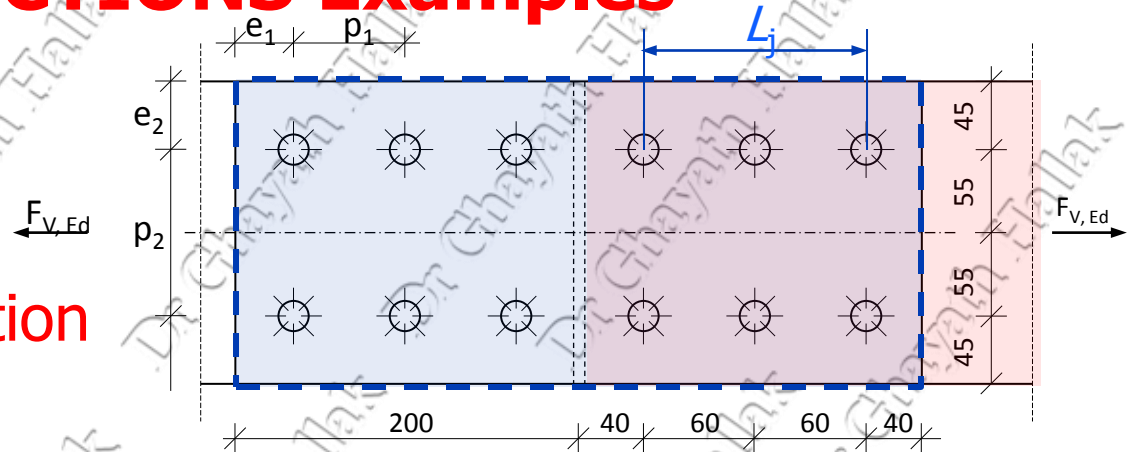
IF  $L_j > 15d$ , Then

The design shear resistance  $F_{V,Rd}$  of all the fasteners calculated according to Table 3.4 should be reduced by multiplying it by a reduction factor  $\beta_{Lf}$

$$1.0 \leq \beta_{Lf} = 1 - \frac{L_j - 15d}{200d} \geq 0,75$$

# SIMPLE CONNECTIONS Examples

## Example: 2



Checking the connection if it is long Joint:

$$L_j = 2 \times 60 = 120 < 15d = 15 \times 20 = 300 \text{ mm} \quad \therefore \text{short Joint, No Reduction to the bolts shear resistance}$$

$$F_{V,Ed} = 650 \text{ kN} < F_{V,Rd} = 6 \times 120.576 = 723.456 \text{ kN} \quad \text{OK/}$$

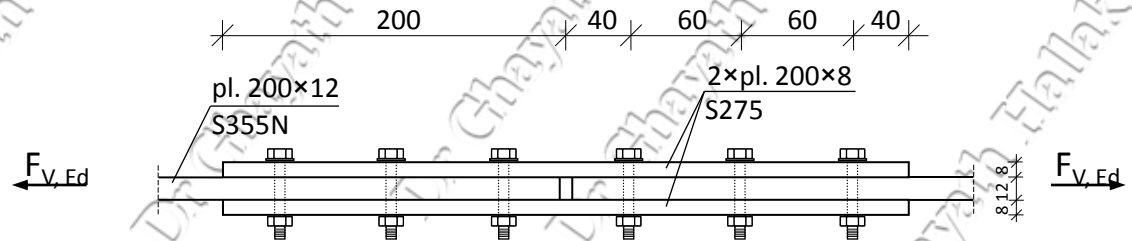
Check design tension resistance for cross section of connected part reduced by holes

$$N_{pl,Rd} = \frac{A f_y}{\gamma_{M0}} = \frac{200 \times 12 \times 355}{1.0} = 852000 \text{ N} = 852 \text{ kN}$$

$$A_{net} = A - n_v d_o t = 200 \times 12 - 2 \times 22 \times 12 = 1872 \text{ mm}^2$$

# SIMPLE CONNECTIONS Examples

## Example: 2



Check design tension resistance for cross section of connected part reduced by holes

$$N_{u,Rd} = \frac{0.9A_{net}f_u}{\gamma_{M2}} = \frac{0.9 \times 1872 \times 510}{1.25} = 687298 \text{ N} = 687.3 \text{ kN} < N_{pl,Rd}$$

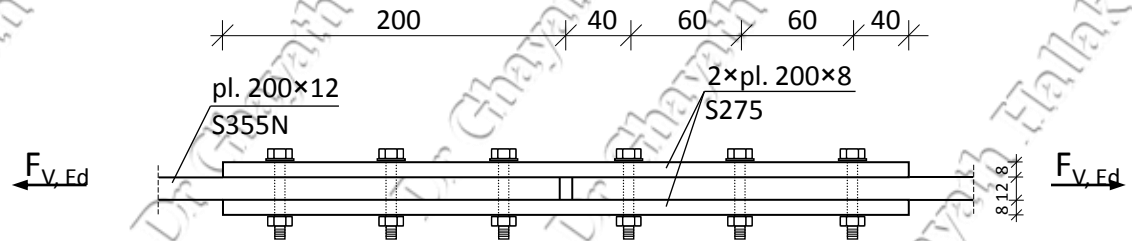
$$F_{V,Ed} = 650 \text{ kN} < N_{u,Rd} = 687.30 \text{ kN} \quad \text{/OK/}$$

Check design tension resistance for cross section of cover plates reduced by holes

$$N_{pl,Rd} = \frac{A f_y}{\gamma_{M0}} = \frac{200 \times 2 \times 8 \times 275}{1.0} = 880000 \text{ N} = 880 \text{ kN}$$

# SIMPLE CONNECTIONS Examples

## Example: 2



Check design tension resistance for cross section of cover plates reduced by holes

$$A_{net} = A - n_v d_0 t = 200 \times 2 \times 8 - 2 \times 22 \times 2 \times 8 = 2496 \text{ mm}^2$$

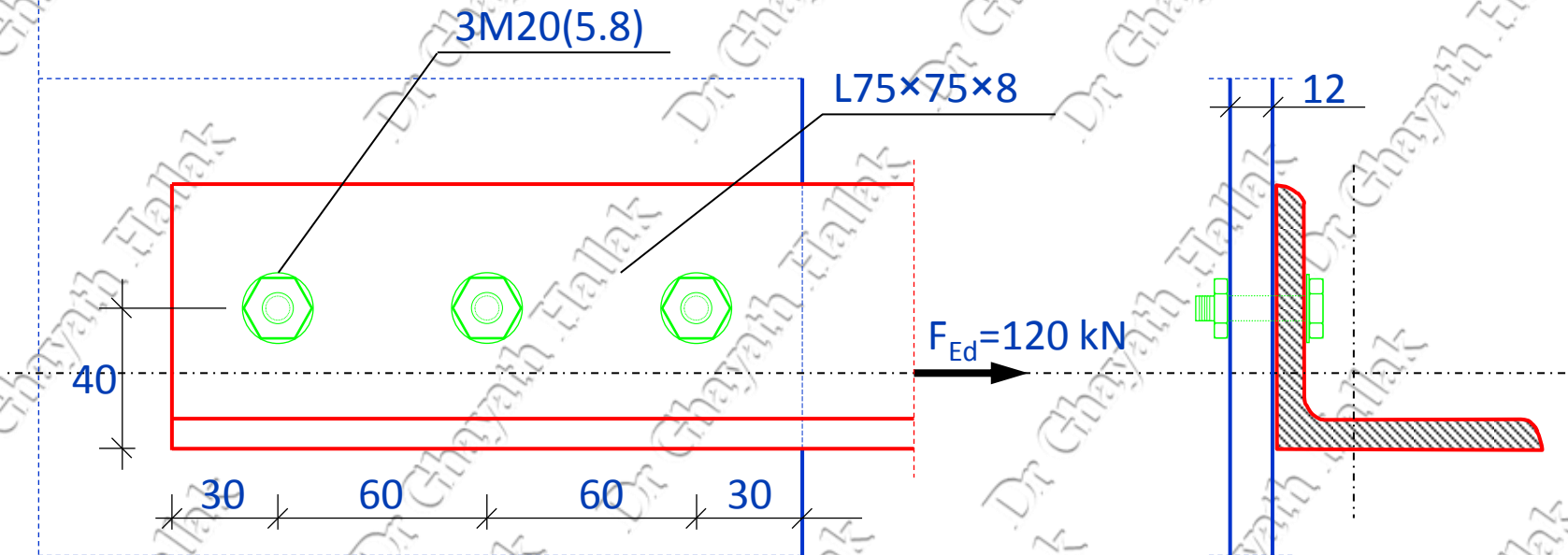
$$N_{u,Rd} = \frac{0.9 A_{net} f_u}{\gamma_{M2}} = \frac{0.9 \times 2496 \times 430}{1.25} = 772700 \text{ N} = 772.7 \text{ kN} < N_{pl,Rd}$$

$$F_{V,Ed} = 650 \text{ kN} < N_{u,Rd} = 772.7 \text{ kN} \quad \text{/OK/}$$

# SIMPLE CONNECTIONS Examples

## Example: 3

Check the design of shear connection shown in Figure.

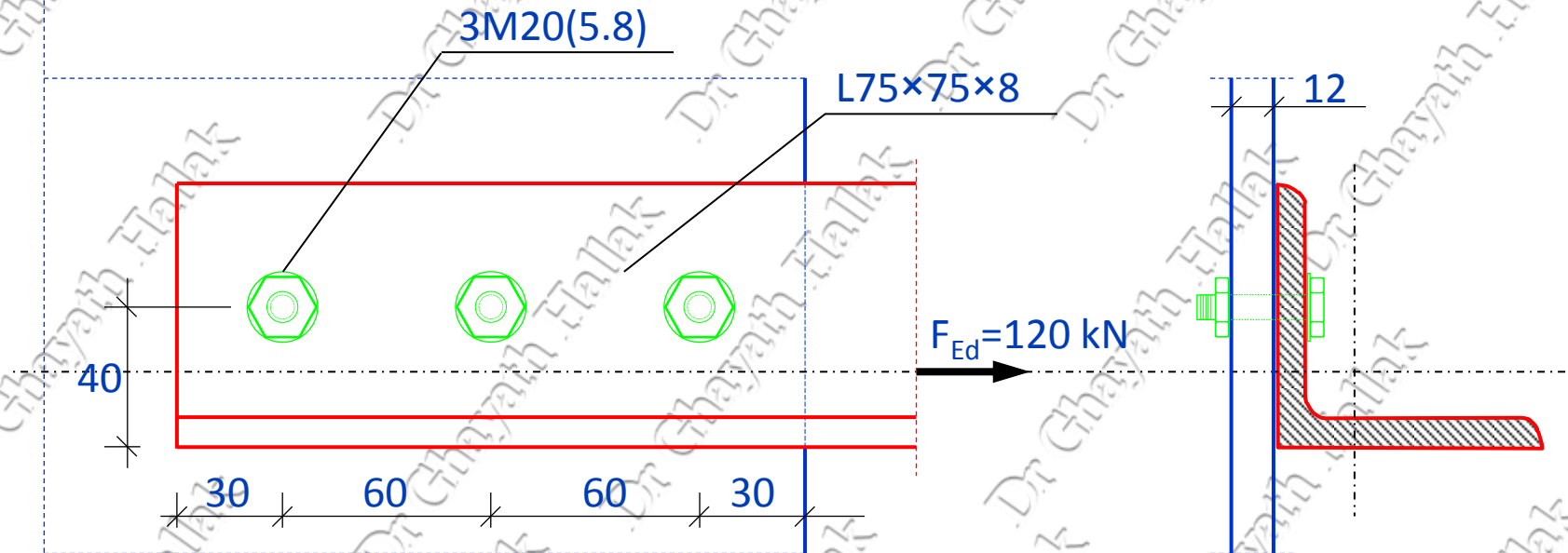


- The connection is Category A: Bearing type
- Steel S355 (for  $t \leq 40\text{mm}$ )  $\rightarrow f_y = 355 \text{ MPa}$ ,  $f_u = 510 \text{ MPa}$ .
- $F_{Ed} = 120 \text{ kN}$

# SIMPLE CONNECTIONS Examples

## Example: 3

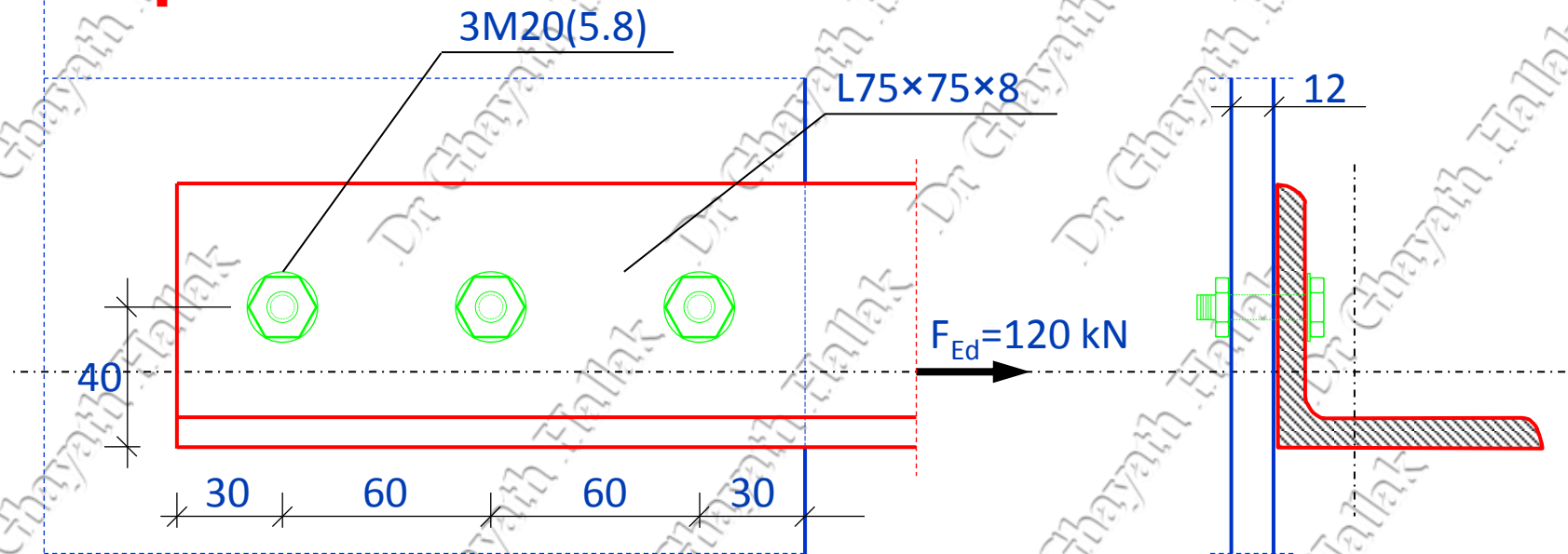
Check the design of shear connection shown in Figure.



- Bolts 3M20(5.8);  $d = 20 \text{ mm}$ ;  $d_0 = 20 + 2 = 22 \text{ mm}$ ,  
 $A_s = 245 \text{ mm}^2$ ,  $f_{yb} = 400 \text{ MPa}$ ,  $f_{ub} = 500 \text{ MPa}$   
 $t = 12 \text{ mm}$  (gusset plate);  $t_1 = 8 \text{ mm}$  (angle)

# SIMPLE CONNECTIONS Examples

## Example: 3



Minimum and maximum spacing, end and edge distances checking (Table 3-3 EN 1993-1-8 : 2005 (E)):

$$e_{1\min} = 1.2d_0 = 1.2 \times 22 = 26.4 \text{ mm} < 30 \text{ mm /OK/}$$

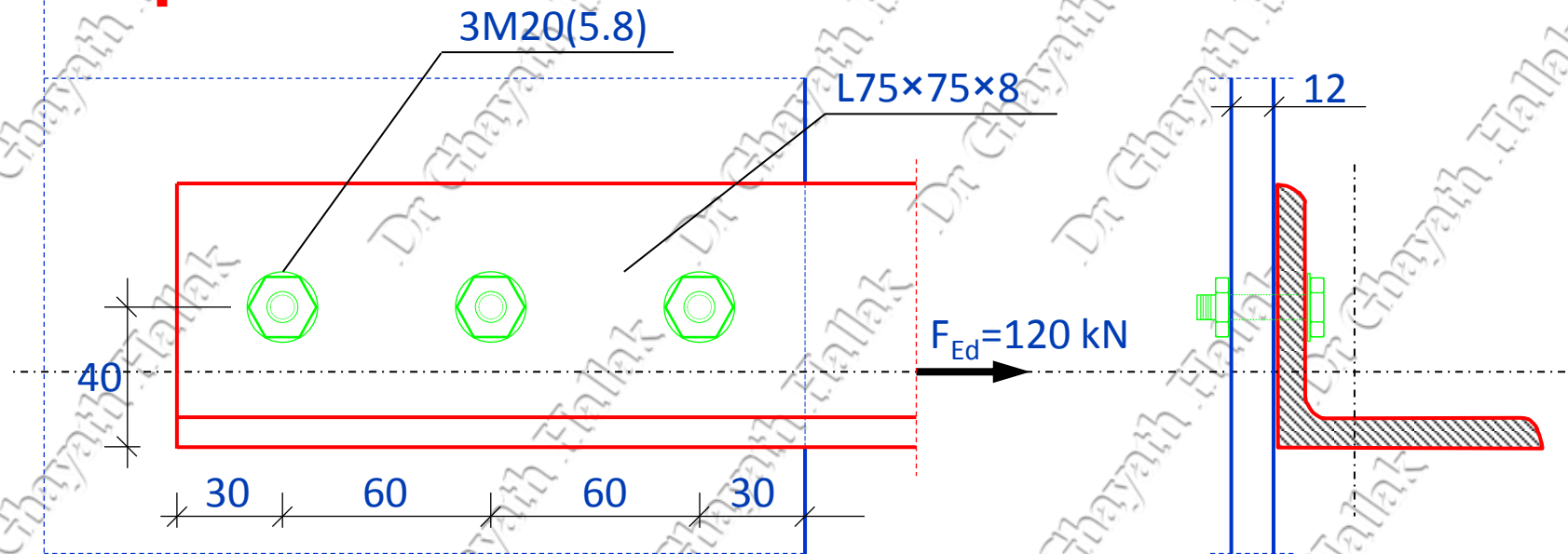
$$e_{1\max} = 4t + 40 \text{ mm} = 4 \times 8 + 40 = 72 \text{ mm} > 30 \text{ mm /OK/}$$

$$e_{2\min} = 1.2d_0 = 1.2 \times 22 = 26.4 \text{ mm} < 35 \text{ mm /OK/}$$

$$e_{2\max} = 4t + 40 \text{ mm} = 4 \times 8 + 40 = 72 \text{ mm} > 35 \text{ mm /OK/}$$

# SIMPLE CONNECTIONS Examples

## Example: 3



Minimum and maximum spacing, end and edge distances checking (Table 3-3 EN 1993-1-8 : 2005 (E)):

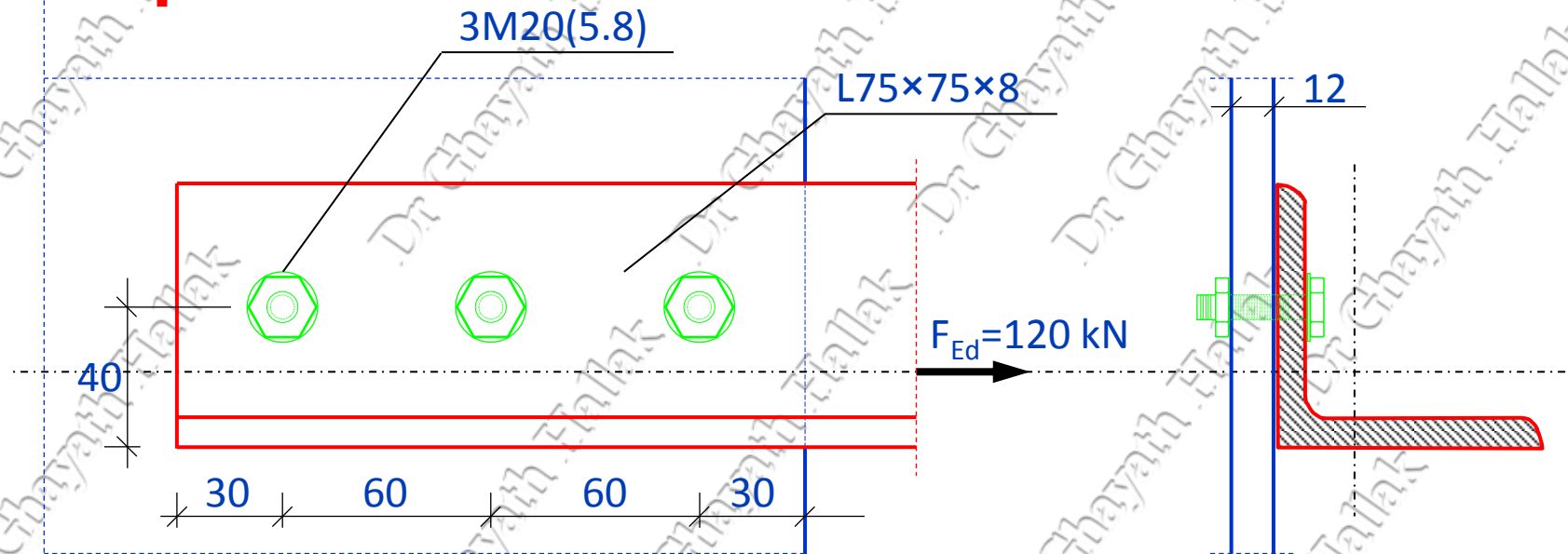
$$p_{1\min} = 2.2d_0 = 2.2 \times 22 = 48.4 \text{ mm} < 60 \text{ mm /OK/}$$

$$p_{1\max} = \min.(14t = 14 \times 8 = 112; 200) = 112 > 60 \text{ mm /OK/}$$



# SIMPLE CONNECTIONS Examples

## Example: 3



The thread of a fit bolt should be included in the shear plane

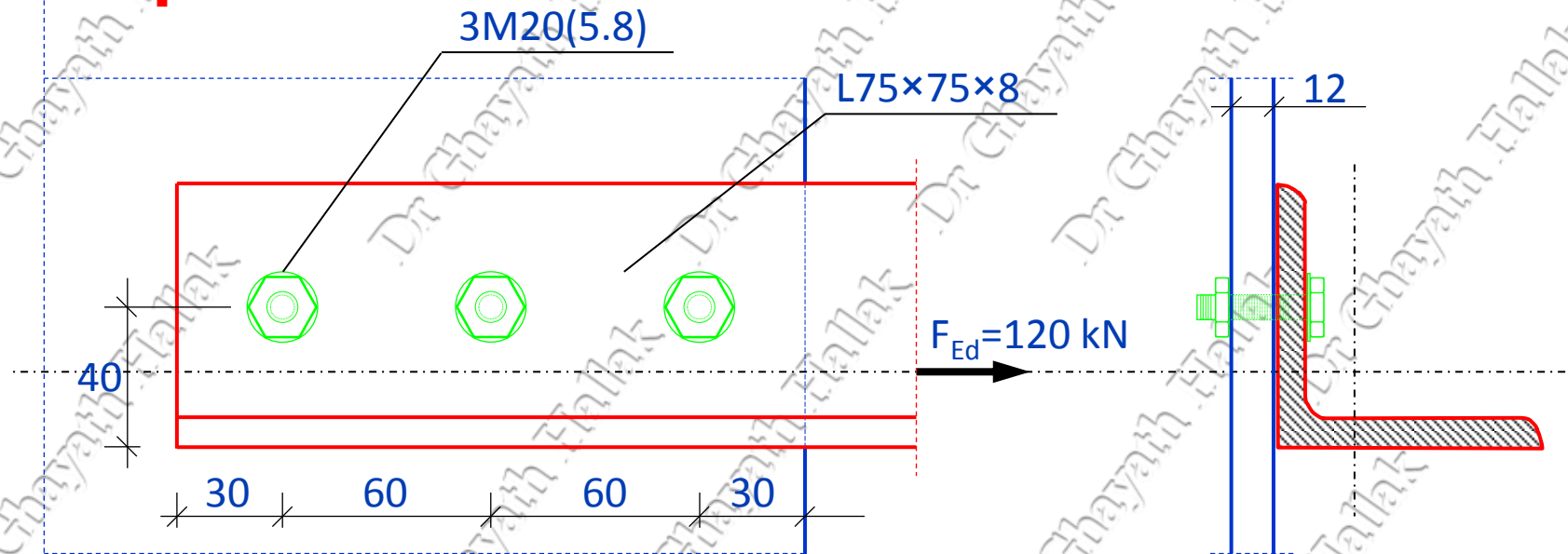
Design resistance for individual fastener subjected to shear per shear plane (Table 3-4 EN 1993-1-8 : 2005 (E)):

$$F_{v,Rd} = \frac{\alpha_v f_{ub} A_s}{\gamma_{M2}} = \frac{0.5 \times 500 \times 245}{1.25} = 49000 \text{ N} = 49 \text{ kN}$$

$\alpha_v = 0.5$  for strength grades 4.8, 5.8, 6.8 and 10.9

# SIMPLE CONNECTIONS Examples

## Example: 3



Bearing resistance (Table 3-4 EN 1993-1-8 : 2005 (E))

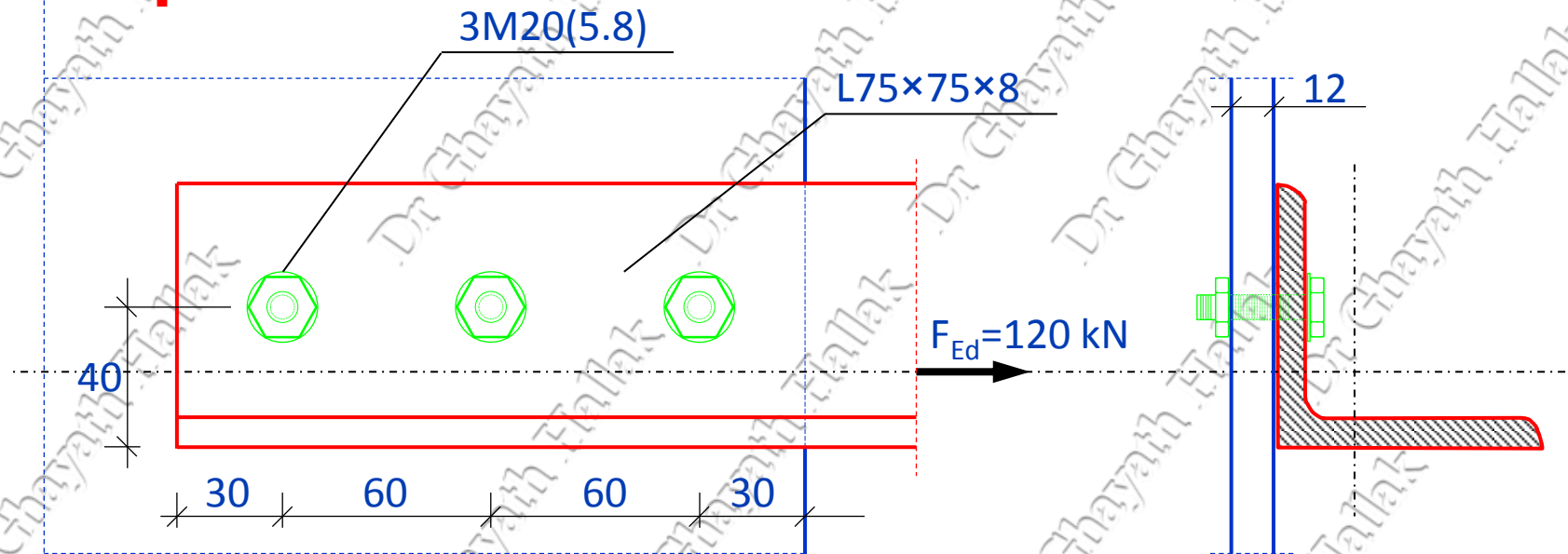
$$F_{b,Rd} = \frac{k_1 \alpha_b f_u d t}{\gamma_{M2}}$$

1- End bolts bearing on angle

$$t_1 = 8 \text{ mm}, f_u = 510 \text{ MPa}, d = 20 \text{ mm}, \gamma_{M2} = 1.25$$

# SIMPLE CONNECTIONS Examples

## Example: 3



Bearing resistance (Table 3-4 EN 1993-1-8 : 2005 (E))

1- End bolts bearing on angle

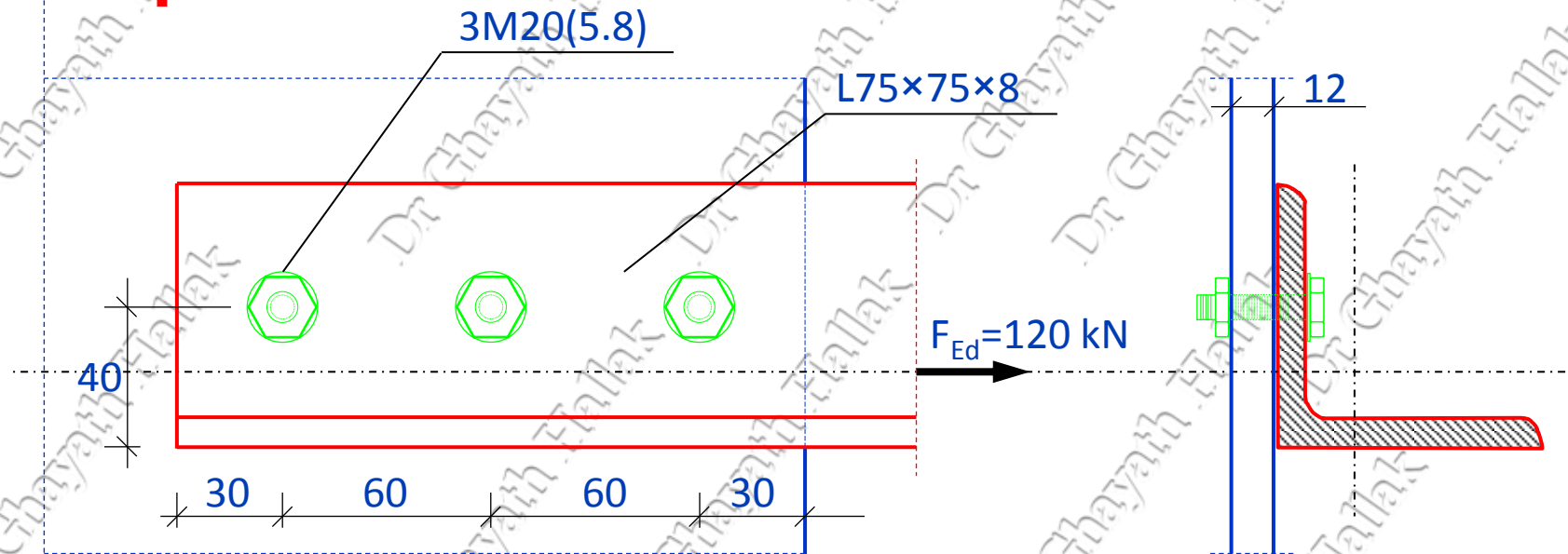
$$\alpha_d = \frac{e_1}{3d_0} = \frac{30}{3 \times 22} = 0.455$$

$$F_{b,Rd} = \frac{k_1 \alpha_b f_u d t}{\gamma_{M2}}$$

$$\alpha_b = \min. \left( \alpha_d; \frac{f_{ub}}{f_u}; 1.0 \right) = \min. \left( 0.455; \frac{500}{510} = 0.98; 1.0 \right) = 0.455$$

# SIMPLE CONNECTIONS Examples

## Example: 3



Bearing resistance (Table 3-4 EN 1993-1-8 : 2005 (E))

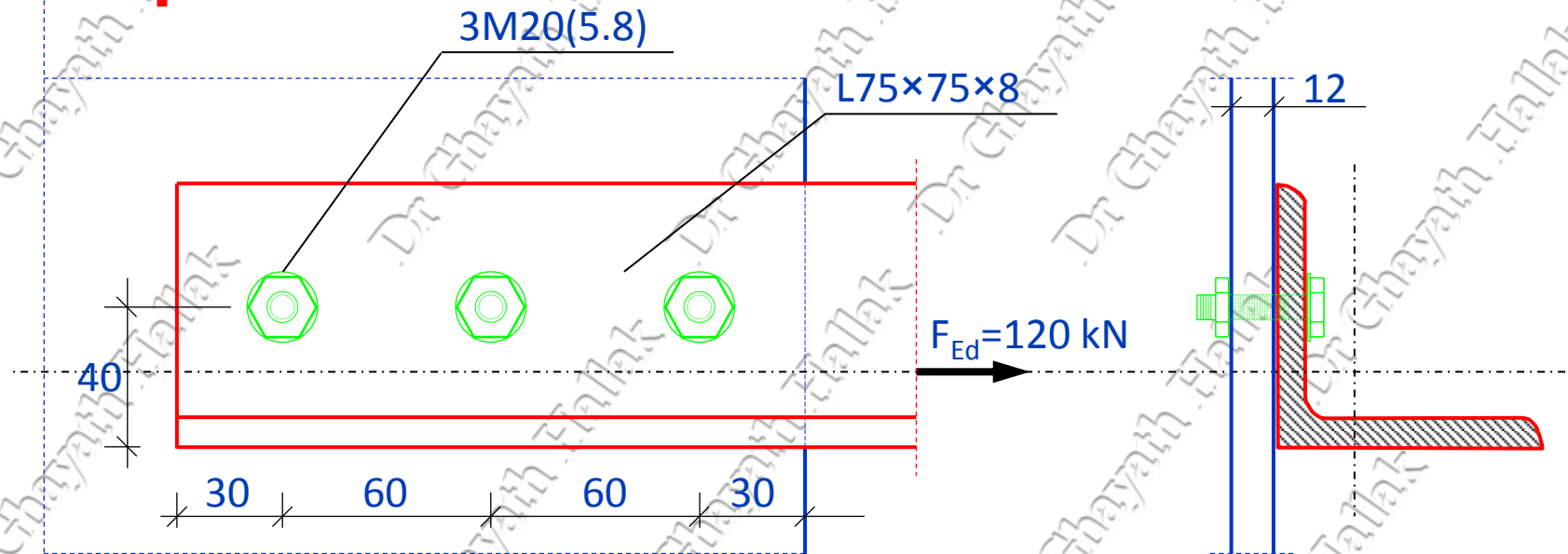
1- End bolts bearing on angle

$$k_1 = \min. \left( 2.8 \frac{e_2}{d_0} - 1.7; 2.5 \right) = \min. \left( 2.8 \times \frac{35}{22} - 1.7 = 2.75; 2.5 \right) = 2.5$$

$$F_{b,Rd} = \frac{k_1 \alpha_b f_u d t}{\gamma_{M2}} = \frac{2.5 \times 0.455 \times 510 \times 20 \times 8}{1.25} = 74256 \text{ N} = 74.256 \text{ kN}$$

# SIMPLE CONNECTIONS Examples

## Example: 3



Bearing resistance (Table 3-4 EN 1993-1-8 : 2005 (E))

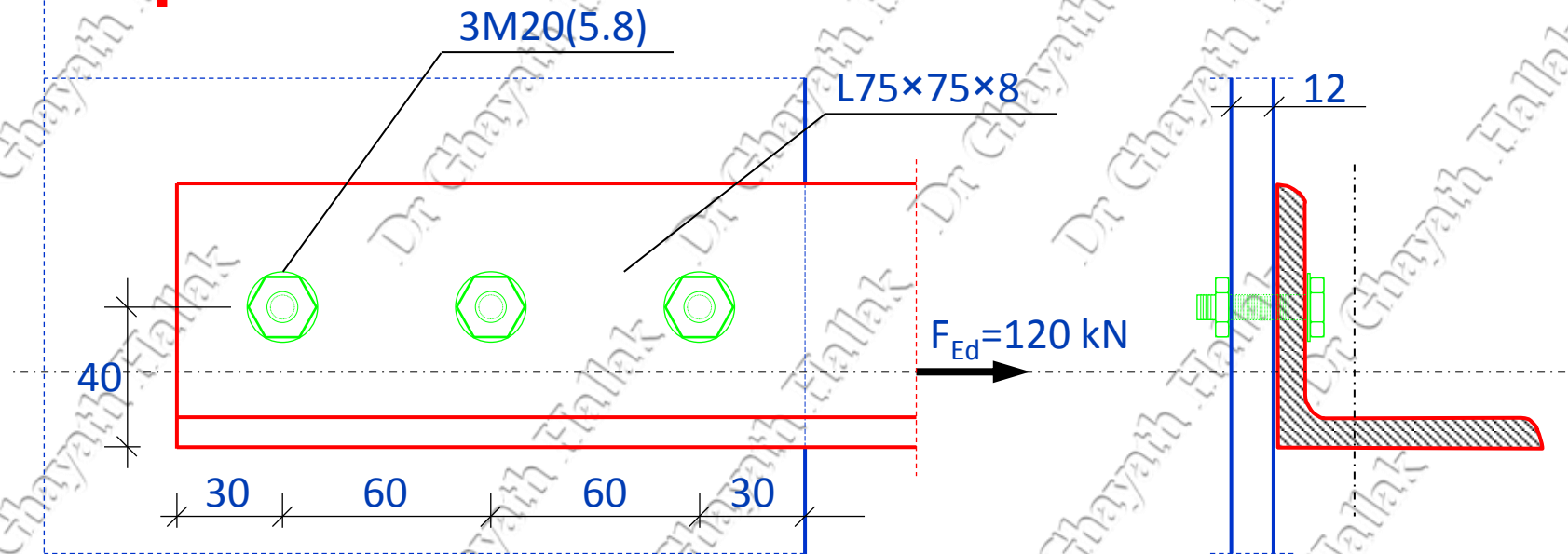
1- Inner bolts bearing on angle

$$t_1 = 8 \text{ mm}, f_u = 510 \text{ MPa}, d = 20 \text{ mm}, \gamma_{M2} = 1.25$$

$$\alpha_d = \frac{p_1}{3d_0} - \frac{1}{4} = \frac{60}{3 \times 22} - \frac{1}{4} = 0.66$$

# SIMPLE CONNECTIONS Examples

## Example: 3



Bearing resistance (Table 3-4 EN 1993-1-8 : 2005 (E))

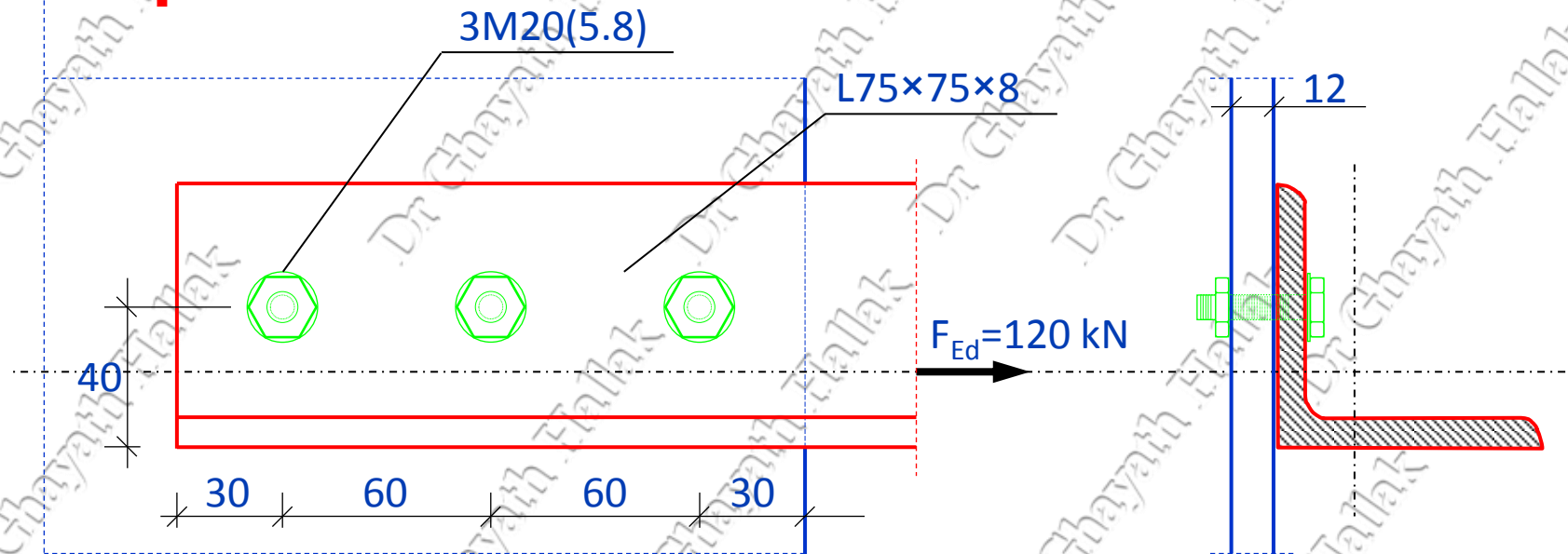
1- Inner bolts bearing on angle

$$\alpha_b = \min\left(\alpha_d; \frac{f_{ub}}{f_u}; 1.0\right) = \min\left(0.66; \frac{500}{510} = 0.980; 1.0\right) = 0.66$$

$$F_{b,Rd} = \frac{k_1 \alpha_b f_u d t}{\gamma_{M2}} = \frac{2.5 \times 0.66 \times 510 \times 20 \times 8}{1.25} = 107712 \text{ N} = 107.712 \text{ kN}$$

# SIMPLE CONNECTIONS Examples

## Example: 3



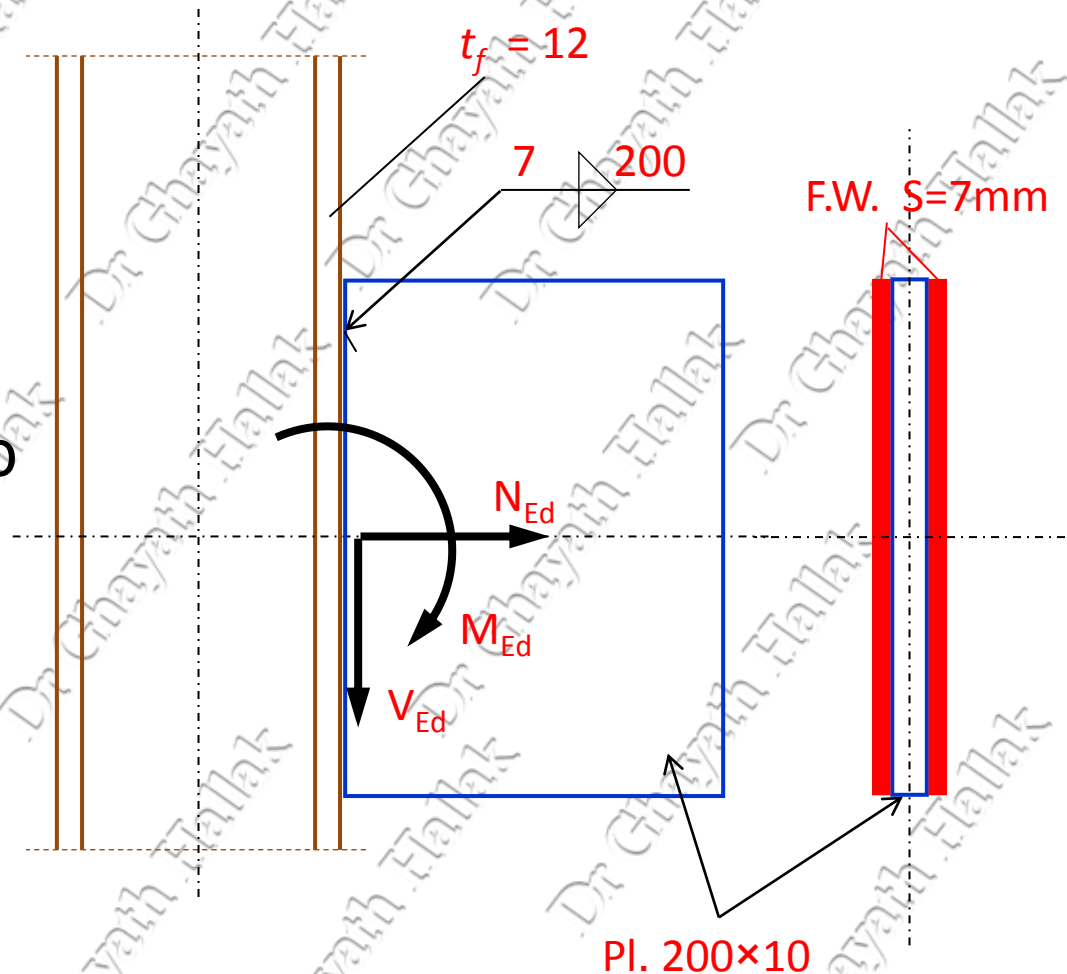
$$F_{V,Rd} = n_b F_{Rd,mini}$$

$$F_{Rd,min} = \min.(F_{V,Rd}, F_{b,Rdi}) = \min.(49; 74.256; 107.712) = 49 \text{ kN}$$

# SIMPLE CONNECTIONS Examples

## Example: 4

The Fig. shows a fillet weld connection of a Gusset Plate (200x10) into steel column. The connection subjected to  $N_{Ed} = 100\text{kN}$ ,  $V_{Ed} = 100\text{kN}$ ,  $M_{Ed} = 10\text{kN.m}$ . Check the fillet welds needed to connect the gusset plate to the column using Grade S275 steel. (poor weld)





# SIMPLE CONNECTIONS Examples

Steel S275 ( $t < 40$ ) →

$f_y = 275 \text{ MPa}$ ;  $f_u = 430 \text{ MPa}$

Directional method:

$$\sqrt{\sigma_{\perp}^2 + 3(\tau_{\perp}^2 + \tau_{\parallel}^2)} \leq \frac{f_u}{\beta_w \gamma_{M2}} \quad \text{and} \quad \sigma_{\perp} \leq \frac{0.9 f_u}{\gamma_{M2}}$$

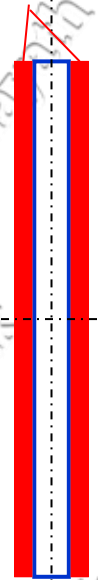
Check  $a_w = 0.7 S = 0.7(7) = 4.9 \text{ mm}$

$0.2 t_{\max} \leq a_w \leq 0.7 t_{\min}$  but  $a_w \geq 3 \text{ mm}$

$0.2 \times 12 = \mathbf{2.4} \leq a_w \leq 0.7 \times 10 = \mathbf{7.0} > a_{w,\min} = \mathbf{3} \text{ mm}$  (4.5.2-2)

$a_w = 4.9 \text{ mm}$  /OK/

F.W.  $S=7\text{mm}$



# SIMPLE CONNECTIONS Examples

Directional method:

$$\sqrt{\sigma_{\perp}^2 + 3(\tau_{\perp}^2 + \tau_{\parallel}^2)} \leq \frac{f_u}{\beta_w \gamma_{M2}} \text{ and } \sigma_{\perp} \leq \frac{0.9 f_u}{\gamma_{M2}}$$

$$A_w = 2a L_{\text{eff}} = 2 \times 4.9 \times (200 - 2 \times 4.9) = 1864 \text{ mm}^2$$

$$W_w = 2a L_{\text{eff}}^2 / 6 = 2 \times 4.9 \times (200 - 2 \times 4.9)^2 / 6 = 59087.5 \text{ mm}^3$$

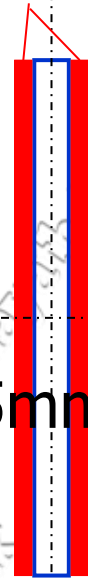
$$\sigma_w = \frac{N_{Ed}}{A_w} + \frac{M_{Ed}}{W_w} = \frac{100 \times 10^3}{1864} + \frac{10 \times 10^6}{59087.5} = 223 \text{ MPa}$$

$$\sigma_{\perp} = \tau_{\perp} = \frac{\sigma_w}{\sqrt{2}} = \frac{223}{\sqrt{2}} = 157.7 \text{ MPa} < \frac{0.9 \times 430}{1.25} = 309.6 \text{ MPa}$$

$$\tau_x = \frac{V_{Ed}}{A_w} = \frac{100 \times 10^3}{1864} = 53.6 \text{ MPa}$$

$$\sqrt{157.7^2 + 3(157.7^2 + 53.6^2)} = 328.8 \text{ MPa} < \begin{cases} \frac{f_u}{\beta_w \gamma_{M2}} = \frac{430}{0.85 \times 1.25} \\ = 404.7 \text{ MPa} \quad \text{OK} \end{cases}$$

F.W. S=7mm



# SIMPLE CONNECTIONS Examples

Simplified method

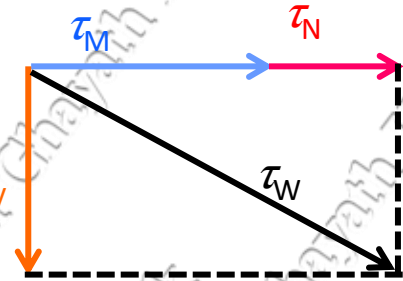
$$\tau_M = \frac{M_{Ed}}{W_w} = \frac{10 \times 10^6}{59087.5} = 169.2 \text{ MPa}$$

$$\tau_N = \frac{N_{Ed}}{A_w} = \frac{100 \times 10^3}{1864} = 53.6 \text{ MPa}$$

$$\tau_V = \frac{V_{Ed}}{A_w} = \frac{100 \times 10^3}{1864} = 53.6 \text{ MPa}$$

$$\tau_w = \sqrt{(\tau_M + \tau_N)^2 + \tau_V^2} = \sqrt{(169.2 + 53.6)^2 + 53.6^2} = 229.2 \text{ MPa} <$$

$$\left\{ \frac{f_u}{\sqrt{3} \beta_w \gamma_{M2}} = \frac{430}{\sqrt{3} \times 0.85 \times 1.25} = 233.65 \text{ MPa} \quad \text{OK} \right.$$

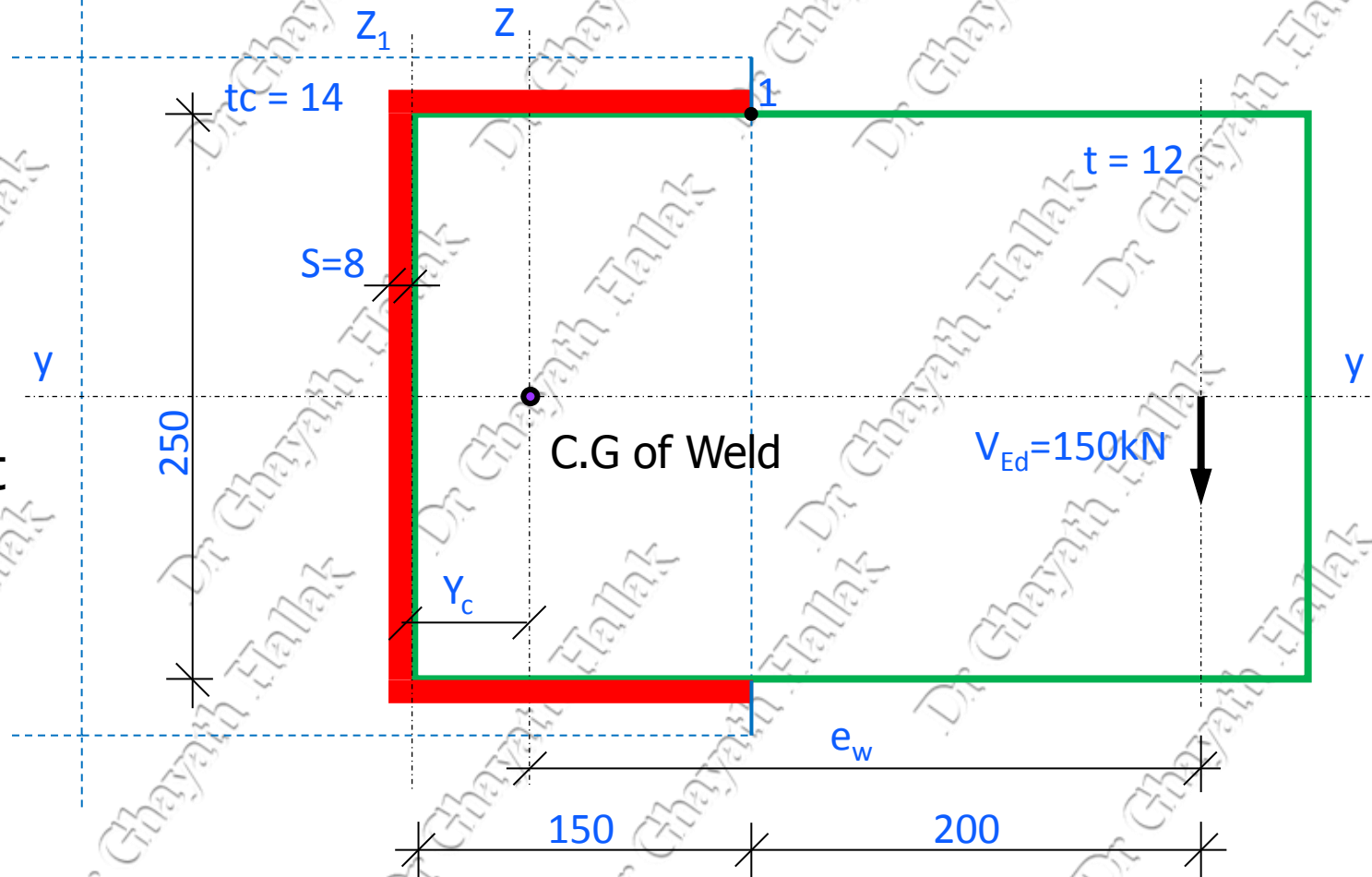


## SIMPLE CONNECTIONS Example: 5

The Fig. shows a fillet weld connection of a Gusset Plate into steel column. The connection subjected to  $V_{Ed} = 100\text{kN}$ .

Check the fillet welds needed to connect the gusset plate to the column

using Grade S275 (poor weld)



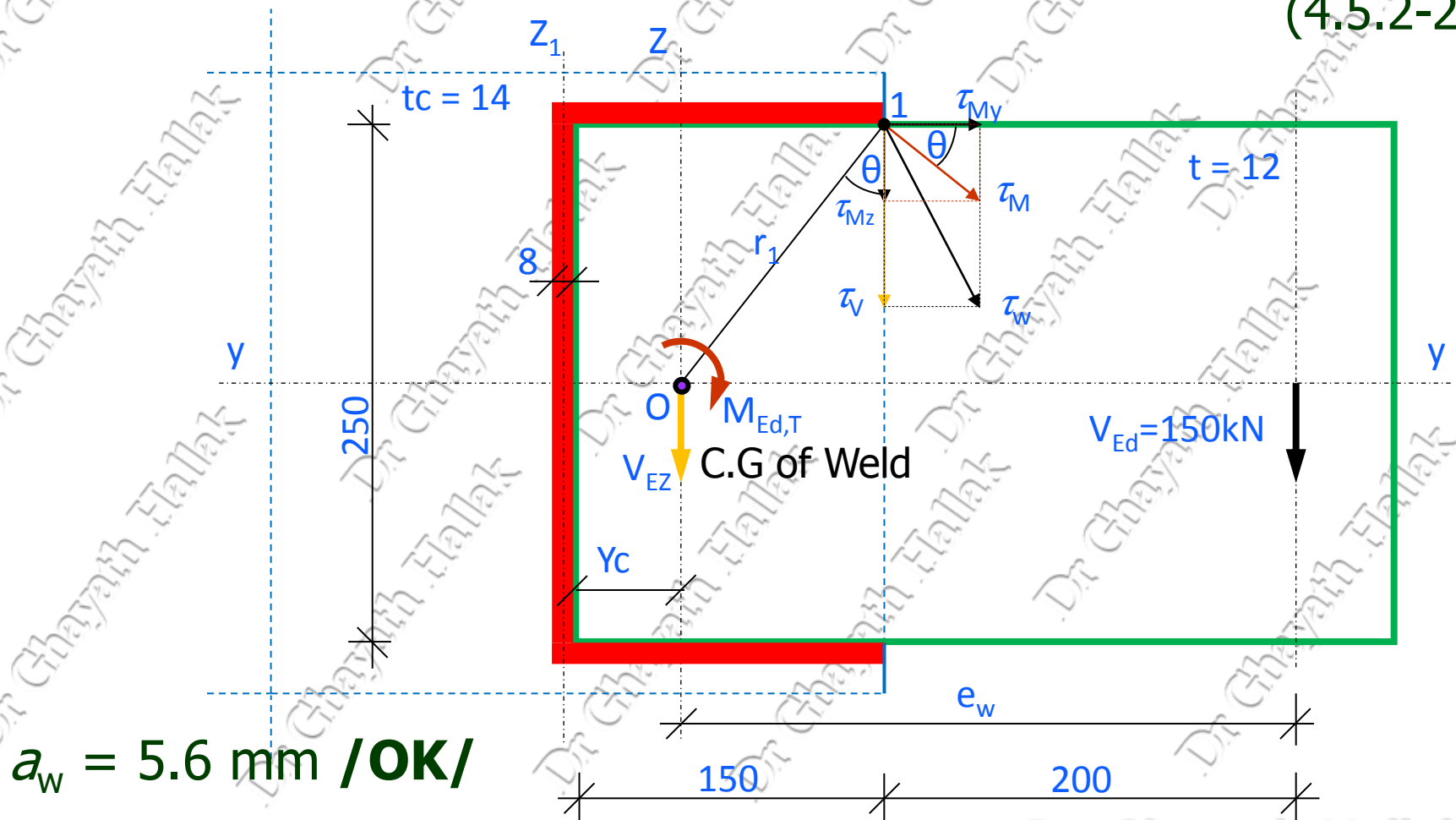
# SIMPLE CONNECTIONS Example: 5

Steel S275 ( $t < 40$ )  $\rightarrow f_y = 275 \text{ MPa}; f_u = 430 \text{ MPa}, a_w = 0.7S = 5.6 \text{ mm}$

Check  $a_w$ :  $0.2t_{\max} \leq a_w \leq 0.7t_{\min}$  but  $a_w \geq 3 \text{ mm}$

$$0.2 \times 14 = \mathbf{2.8} \leq a_w \leq 0.7 \times 12 = \mathbf{8.4} > a_{w,\min} = \mathbf{3} \text{ mm}$$

(4.5.2-2)

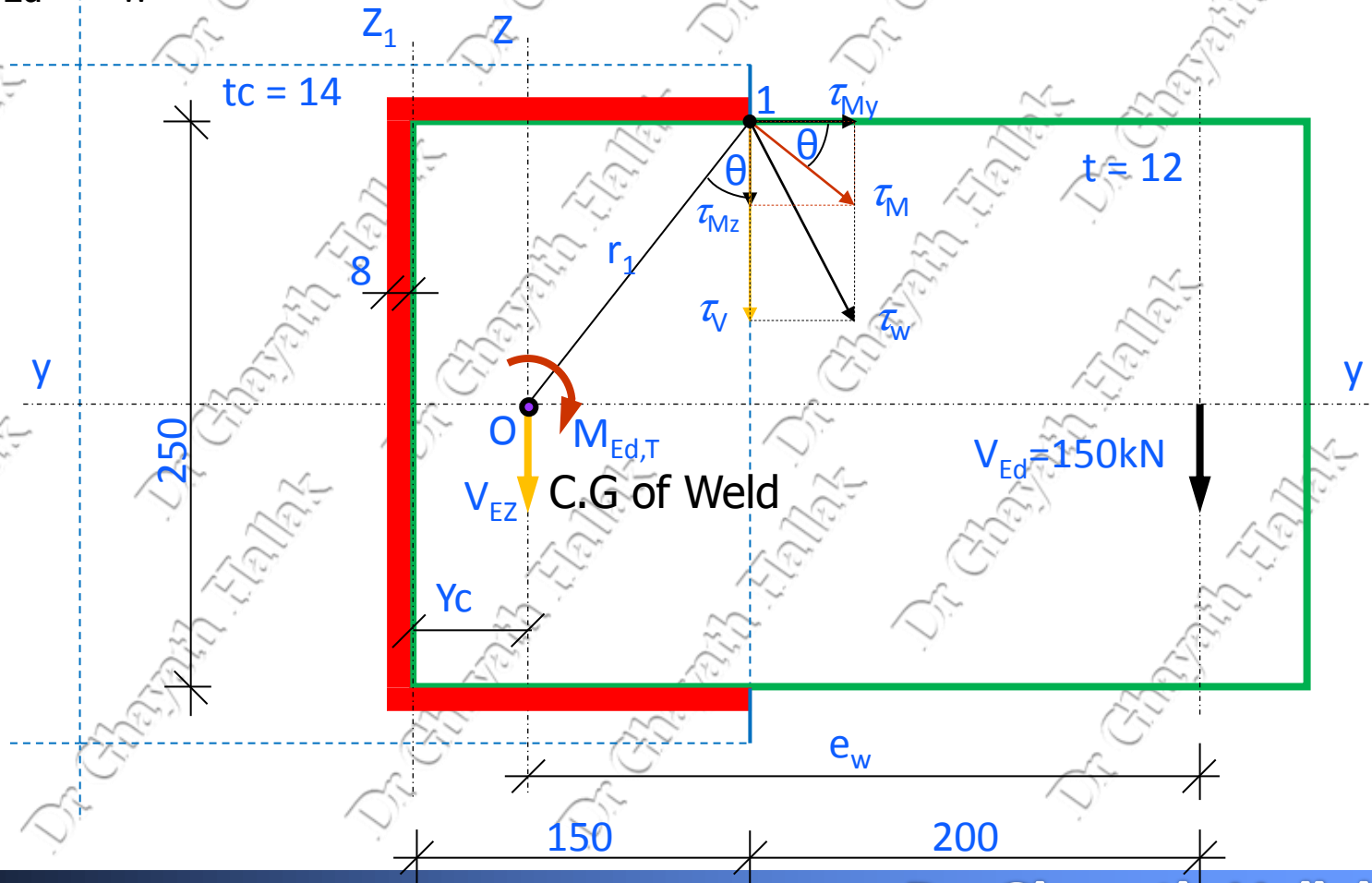


# SIMPLE CONNECTIONS Example: 5

$$Y_c = \frac{\sum L_i Y_i}{\sum L_i} = \frac{(250 \times 0 + 150 \times 75 \times 2)}{(250 + 150 \times 2)} = 40.91 \text{ mm}$$

$$e_w = 200 + 150 - 40.91 = 309.1 \text{ mm}, \quad V_{Ez} = V_{Ed} = 150 \text{ kN}$$

$$M_{Ed,T} = V_{Ed} \cdot e_w = 150 \times 309.1 = 46365 \text{ KN.mm} = 46.365 \text{ kN.m}$$



# SIMPLE CONNECTIONS Example: 5

$$r_1 = \sqrt{y_1^2 + z_1^2} = \sqrt{(109.09)^2 + (125)^2} = 165.91 \text{ mm}$$

$$I_{wy} = 250^3 \times 5.6 / 12 + 2 \times 150 \times 5.6 \times 125^2 = 33.54 \times 10^6 \text{ mm}^4$$

$$I_{wz} = 2[150^3 \times 5.6 / 12 + 150 \times 5.6 \times (109.09 - 75)^2] + 250 \times 5.6 \times 40.91^2 = 7.45 \times 10^6 \text{ mm}^4$$

$$A_w = (2 \times 150 + 250) \times 5.6$$

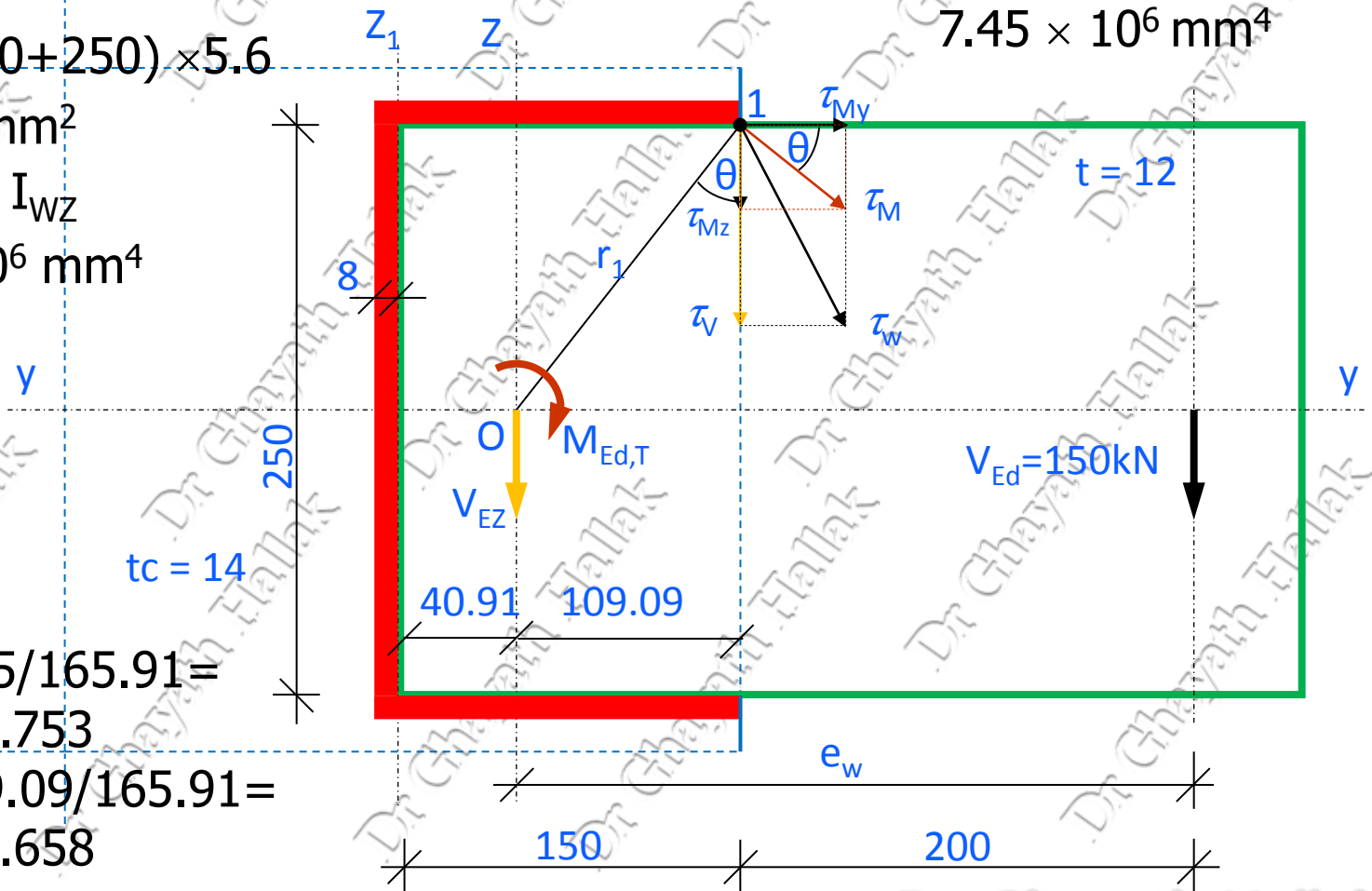
$$A_w = 3080 \text{ mm}^2$$

$$I_{wo} = I_{wy} + I_{wz}$$

$$I_{wo} = 41 \times 10^6 \text{ mm}^4$$

$$\cos \theta = 125 / 165.91 = 0.753$$

$$\sin \theta = 109.09 / 165.91 = 0.658$$



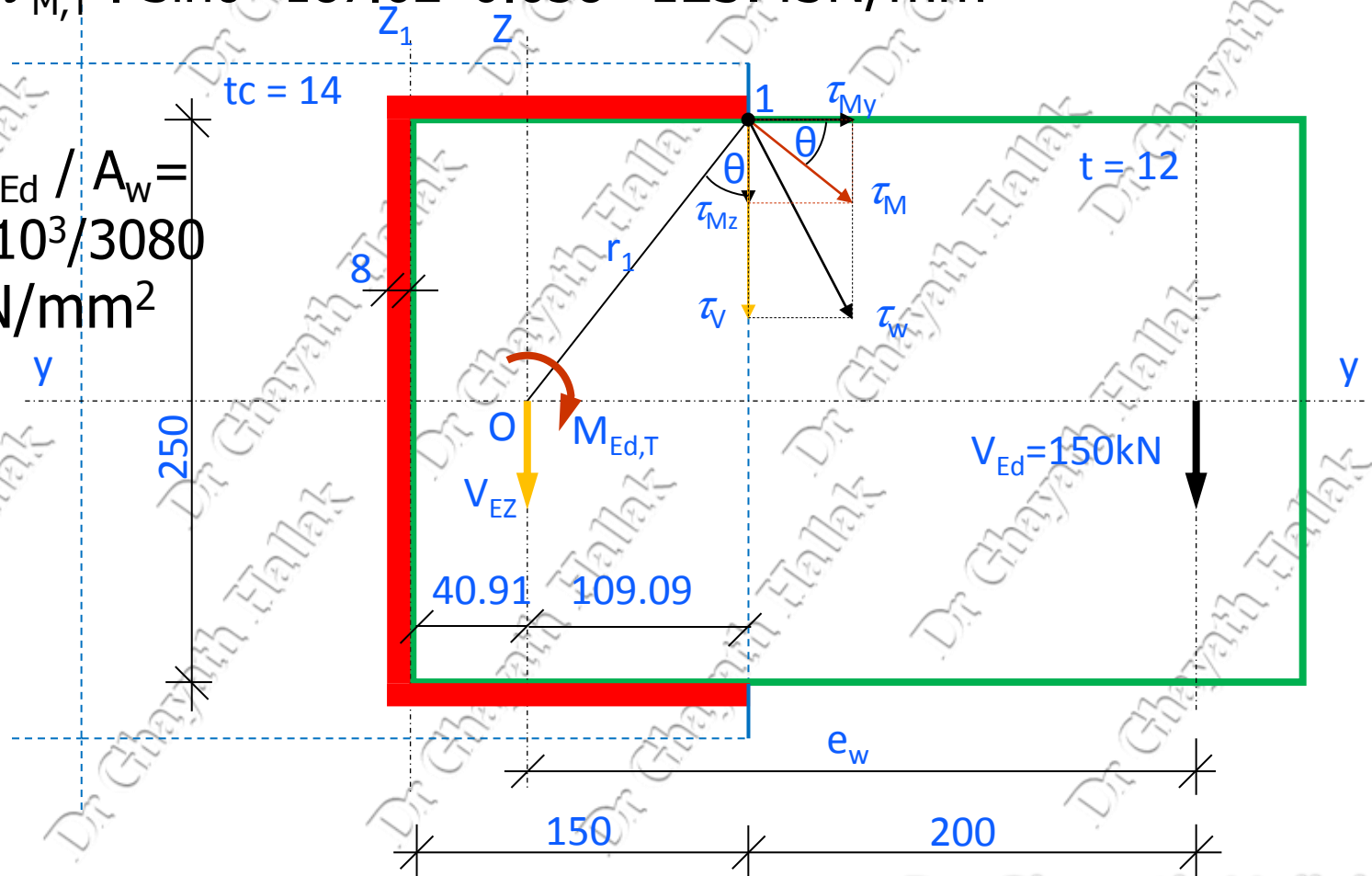
# SIMPLE CONNECTIONS Example: 5

$$\tau_{M,T} = M_{Ed,T} \cdot r_1 / I_{wo} = 46.365 \times 10^6 \times 165.91 / 41 \times 10^6 = 187.62 \text{ N/mm}^2$$

$$\tau_{M,T,y} = \tau_{M,T} \cdot \cos\theta = 187.62 \times 0.753 = 141.28 \text{ N/mm}^2$$

$$\tau_{M,T,z} = \tau_{M,T} \cdot \sin\theta = 187.62 \times 0.658 = 123.45 \text{ N/mm}^2$$

$$\begin{aligned} \tau_{v,z} &= V_{Ed} / A_w = \\ &= 150 \times 10^3 / 3080 \\ &= 48.7 \text{ N/mm}^2 \end{aligned}$$





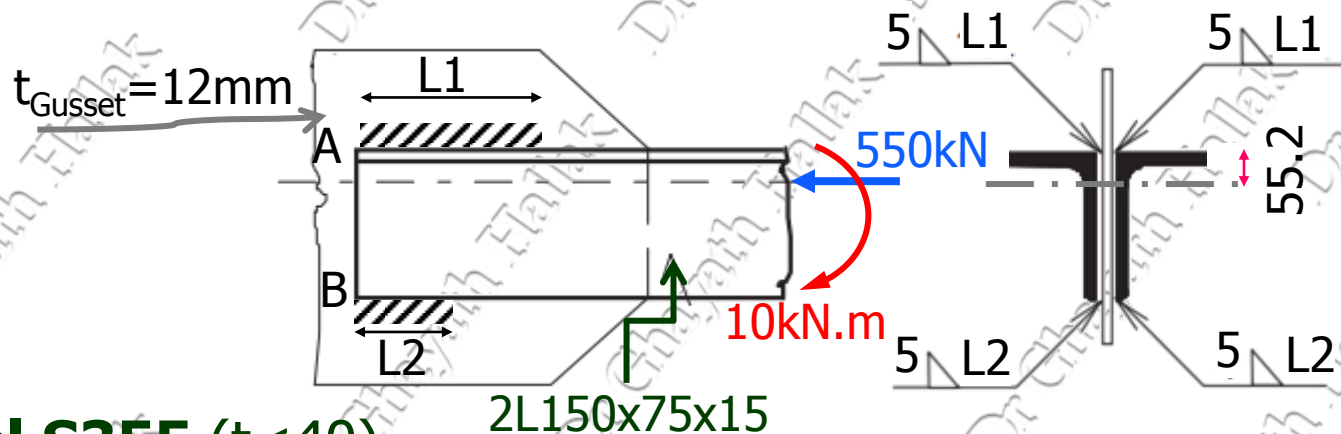
## SIMPLE CONNECTIONS Example: 5

$$\tau_w = \sqrt{(\tau_{M,T,y})^2 + (\tau_{M,T,z} + \tau_{v,z})^2} = \sqrt{(141.28)^2 + (123.45 + 48.7)^2}$$
$$= 222.7 \text{ N/mm}^2 < f_{vw,d} \quad \text{OK}$$

$$f_{vw,d} = \frac{F_u}{\sqrt{3} \beta_w \gamma_{M2}} = \frac{430}{\sqrt{3} \times 0.85 \times 1.25} = 233.66 \text{ MPa}$$

## SIMPLE CONNECTIONS Example: 6

The connection shown in the Fig is subjected to factored compressive force of 550kN and a factored moment of 10kN.m. Find the length L1 and L2 of the weld. S355 and the size of the weld is 5mm. (*poor weld at the start and the stop*)



**Steel S355** ( $t < 40$ )

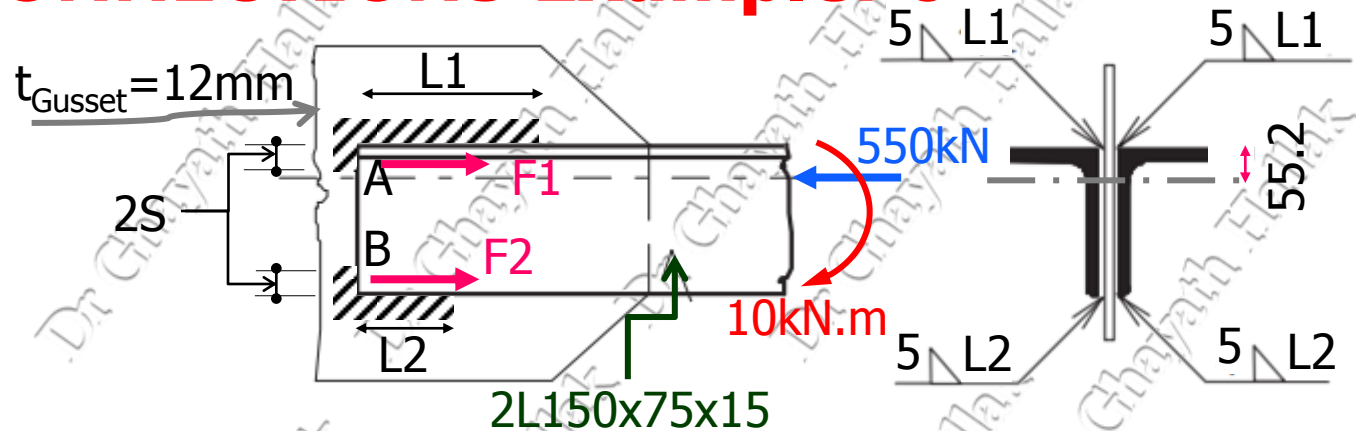
$$\rightarrow f_y = 355 \text{ MPa}; f_u = 510 \text{ MPa}, a_w = 0.7S = 3.5 \text{ mm}$$

**Check  $a_w$ :**  $0.2t_{\text{max}} \leq a_w \leq 0.7t_{\text{min}}$  but  $a_w \geq 3\text{mm}$

$$0.2 \times 15 = 3 \leq a_w \leq 0.7 \times 12 = 8.4 > a_{w,\text{min}} = 3 \quad (4.5.2-2) \quad / \text{OK}/$$

**Steel Section Properties**  $L150 \times 75 \times 15 \rightarrow C_y = 55.2\text{mm}$ ,  
 $C_z = 18.1\text{mm}$ ,  $A = 3170\text{mm}^2$

# SIMPLE CONNECTIONS Example: 6



$$\sum MB=0 \rightarrow 550 \times (150 - 55.2) = F1 \times 150 + 10 \times 10^3 \rightarrow F1 = 280.94 \text{ kN}$$

$$F1/2 = \mathbf{140.47 \text{ kN}} \text{ at each face.}$$

$$F1 + F2 = F \rightarrow F2 = 550 - 280.94 = 269.06 \text{ kN} \rightarrow F2/2 = \mathbf{134.53 \text{ kN}}$$

at each face.

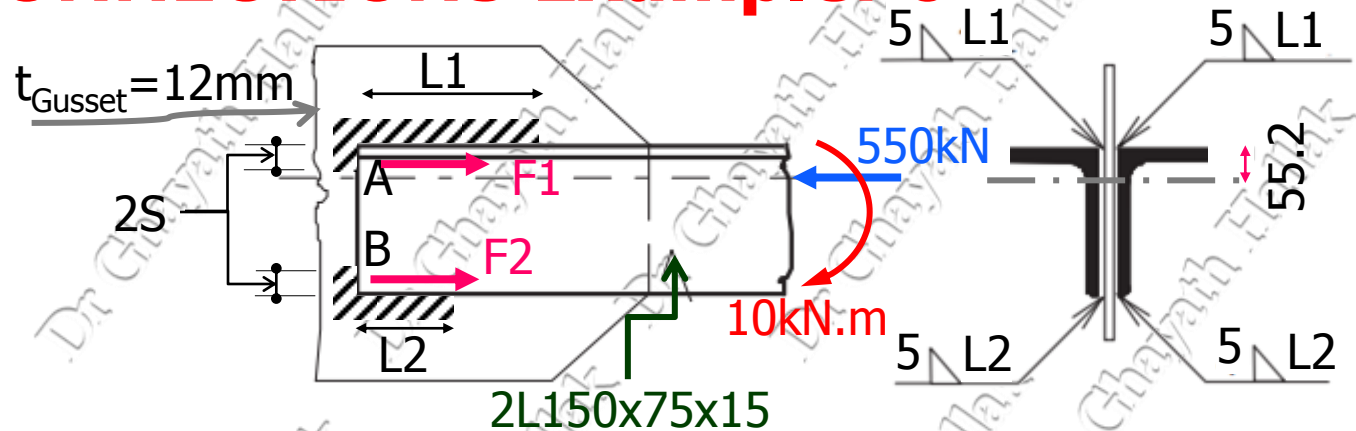
$$f_{vw,d} = \frac{F_u}{\sqrt{3} \beta_w \gamma_{M2}} = \frac{510}{\sqrt{3} \times 0.9 \times 1.25} = 261.73 \text{ N/mm}^2$$

$$A_{1,w} = (L_{1\text{eff}}) \times a \rightarrow \tau_1 = (0.5F1) / A_{1,w} = f_{vw,d} \rightarrow 261.73 = 140.47 \times 10^3 / (a \times L_{1\text{eff}})$$

$$\rightarrow L_{1\text{eff}} = 153.34 \text{ mm} \rightarrow L_{1\text{eff}} = L_1 - 2a \rightarrow L_1 = 153.34 + 7 = 160.34 \text{ mm}$$

→ as recommended by the code, a continuous return weld of length 2S at edge A has to be provided then  $L_1 = 160.34 + 2 \times 5 = 170.34 \text{ mm} \therefore$  use 175mm

# SIMPLE CONNECTIONS Example: 6



$A_{2,w} = (L_{2eff}) \times a \rightarrow \tau_2 = (0.5F_2) / A_{2,w} = f_{vw,d} \rightarrow 261.73 = 134.53 \times 10^3 / (a \times L_{2eff})$   
 $\rightarrow L_{2eff} = 146.86 \text{mm} \rightarrow L_{2eff} = L_2 - 2a \rightarrow L_2 = 146.56 + 7 = 153.56 \text{mm}$   
 $\rightarrow$  as recommended by the code, a continuous return weld of length 2S at edge B has to be provided then  $L_2 = 153.56 + 2 \times 5 = 163.56 \text{mm} \therefore$  use 165mm