Worked Example 4: Design of a Rigid Column Bracket (Bolted)

Universiti Teknologi Malaysia	Example 4: Design of a Rigid Column Bracket (Bolted)	
	Design by: Dee Aguindrew Gundeh	
	Checked by: Prof. Dr. Shahrin Mohammad	
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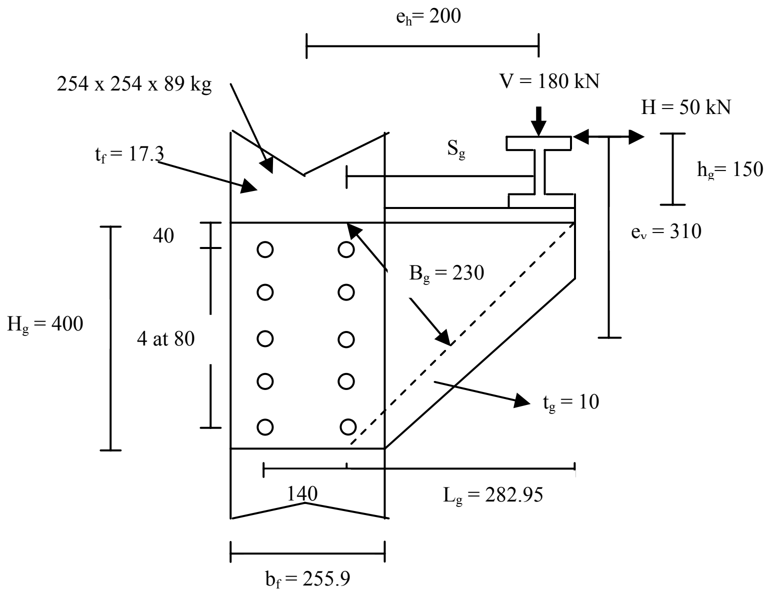
Reference	Calculation	Output

Example 4: Design of a Rigid Column Bracket (Bolted)

Determine the size of the components required to connect the bracket to the column shown in figure below using Grade S355 steel. The forces shown are applied to one gusset plate at ultimate load.



Analysis of bolt group

Second moment of area of the weld group about the centroidal y-y axis

$I_y = 4(80^2 + 160^2) = 128 \times 10^3$ mm^4

Second moment of area of the weld group about the centroidal z-z axis

$I_z = 10(70)^2 = 49 \times 10^3$ mm^4

Second moment of area of the bolt group about the centroidal polar axis (x-x)

$I_x = I_y + I_z = (128 + 49) \times 10^3 = 177 \times 10^3$ mm^4

Reference	Calculation	Output
	Maximum vector force (z-z axis direction)	
	$F_z = (V / n_b) + [(Ve_h + He_v)\ y_n / I_x]$	
	$= (180/10) + \{ [((180 \times 200) + (50 \times 310))\ 70] / 177 \times 10^3) \} = 38.37$ kN	
	Maximum vector force (y-y axis direction)	
	$F_y = (H / n_b) + [(Ve_h + He_v)\ z_n / I_x]$	
	$= (50/10) + \{ [((180 \times 200) + (50 \times 310))\ 160] / 177 \times 10^3) \} = 51.55$ kN	
	Thus, the design force on the bolt	
	$F_{r,\ Ed} = \sqrt{} (F_z^2 + F_y^2) = \sqrt{} (38.37^2) + (51.55^2) = 64.26$ kN	
	Bolt resistance	
	Resistance of M30 Class 4.6 bolts in single shear	
EC3-1-8 T3.4	For Grade 4.6 bolts, $A_t = A_s = 561$ mm^2, $f_{ub} = 400$ N/mm^2 and $\alpha_v = 0.6$	
EC3-1-8 T3.1	$F_{v,\ Rd} = (0.6 A_s f_{ub}) / \gamma_{M2}$	
	$= [(0.6)\ (561)\ (400)] / 1.25 = 107712$ N $= 107.71$ kN	
	$F_{r,\ Ed} = 64.26$ kN $< F_{v,\ Rd} = 107.71$ kN	OK
Annex A4	However the recommended maximum bolt diameter for a column flange width of 254 mm is 24 mm. Use higher class of bolt.	
EC3-1-8 T3.4	Therefore, use M20 Class 8.8 bolts not preloaded, the resistance in single shear	
EC3-1-8 T3.1	For Grade 8.8 bolts, $A_t = A_s = 245$ mm^2, $f_{ub} = 800$ N/mm^2 and $\alpha_v = 0.6$	
	$F_{v,\ Rd} = (0.6 A_s f_{ub}) / \gamma_{M2}$	
	$= [(0.6)\ (245)\ (800)] / 1.25 = 94080$ N $= 94.08$ kN	
	$F_{r,\ Ed} = 64.26$ kN $< F_{v,\ Rd} = 94.08$ kN	OK

Reference	Calculation	Output
EC3-1-8 T3.4	Resistance of M20 Class 8.8 bolts in bearing on the gusset plate	
	$t = 10$ mm	
	$\alpha_d = 40 / (3 \times 22) = 0.61$	
	$f_{ub} / f_u = 800 / 510 = 1.57 > \alpha_d$	
	Therefore, $\alpha_b = 0.61$	
	$2.8e_2 / d_0 - 1.7 = [(2.8 \times 58) / 22] - 1.7 = 5.68 > 2.5$	
EC3-1-8 T3.4	Therefore, $k_1 = 2.5$	
	Thus,	
	$F_{b, Rd} = (k_1 \alpha_b f_u d t) / \gamma_{M2}$	
	$= (2.5 \times 0.61 \times 510 \times 20 \times 10) / 1.25 = 124440$ N $= 124.44$ kN	
	$F_{b, Rd} = 124.44$ kN $> F_{r, Ed} = 64.26$ kN	OK
	Bolt slip resistance	
EC3-1-8 3.9.1(2)	Using pre loaded M22 Class 10.9 bolts	
	$F_{p, C} = 0.7 \times 800 \times 245 = 137200$ N $= 137.20$ kN	
EC3-1-8 T3.6	$k_s = 1.0$	
EC3-1-8 T3.7	$\mu = 0.5$	
EC3-1-8 2.2(2)	$\gamma_{M3} = 1.1$	
EC3-1-8 3.9.1(1)	$F_{s, Rd} = (1.0 \times 0.5 \times 137.20) / 1.1 = 62.36$ kN	
	$F_{s, Rd} = 62.36$ kN $< F_{r, Ed} = 64.26$ kN	NOT OK
	Therefore, try another bolt	

Reference	Calculation	Output
Structural Design of Steelwork to EN 1993 and 1994 Third Edition by Lawrence Martin and John Purkiss	To determine the thickness of the gusset plate for the bolted joint L_g = 225 + [(255.9 – 140) / 2] = 282.95 mm s_g = 150 + [(255.9 – 140) / 2] = 207.95 mm Width of the gusset plate perpendicular to the free edge $B_g = L_g / [(L_g / H_g)^2 + 1]^{0.5} = 282.95 / [(282.95 / 400)^2 + 1]^{0.5} = 231.00$ mm Replace the term $P_u s_g$ with $Vs_g + Hh_g$, the thickness of the gusset plate Grade S355 $t_g = [2(Vs_g + Hh_g) / (f_y B_g^2 / \gamma_{M1})] + (B_g / 80)$ $= [(2((180 \times 207.95) + (50 \times 150))) \times 10^3/((355 \times 230^2) / 1.0)] + (230 / 80)$ = 7.66 mm Therefore, use a 10 mm thick plate of Grade S355 Check for the slenderness ratio of the gusset plate $l_g / i_g = 2(3^{1/2})(B_g / t_g) = 2(3^{1/2})(230/ 10) = 79.67 < 185$, the limit of the slenderness ratio for the application of the theory	 OK

Worked Example 5: Design of a Rigid Column Bracket (Welded)

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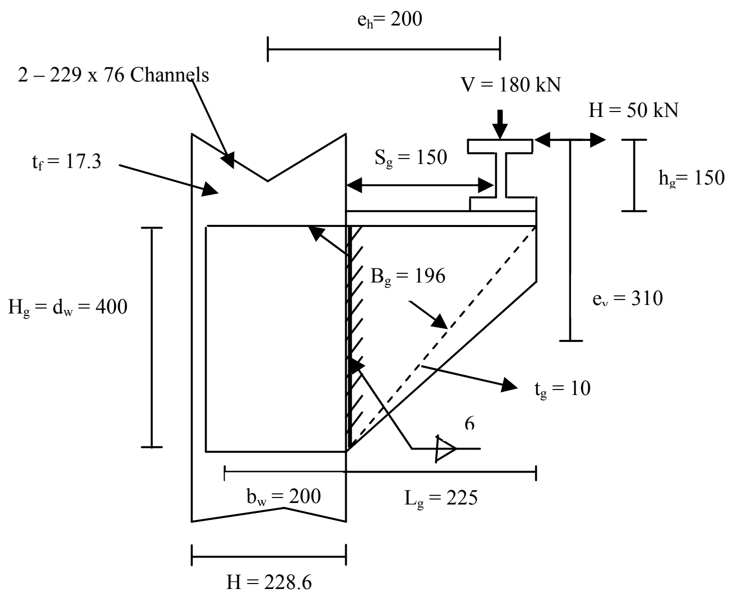
Reference	Calculation	Output

Example 5: Design of a Rigid Column Bracket (Welded)

Determine the size of the components required to connect the bracket to the column shown in figure below using Grade S355 steel. The forces shown are applied to one gusset plate at ultimate load.



Analysis of weld group

The total length of weld

$L_w = 2(d_w + b_w) = 2(400 + 200) = 1200$ mm

Second moment of area of the weld group about the centroidal y-y axis

$I_y = 2[(d_w^3/12) + b_w(d_w/2)^2] = 2[(400^3/12) + 200(400/2)^2] = 26.67 \times 10^6$ mm^4

Second moment of area of the weld group about the centroidal z-z axis

$I_z = 2[(b_w^3/12) + d_w(b_w/2)^2] = 2[(200^3/12) + 400(200/2)^2] = 9.33 \times 10^6$ mm^4

Second moment of area of the bolt group about the centroidal polar axis (x-x)

$I_x = I_y + I_z = (26.67 + 9.33) \times 10^6 = 36 \times 10^6$ mm^4

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Reference	Calculation	Output
	Maximum vector force (z-z axis direction)	
	$F_z = (V / L_w) + [(Ve_h + He_v)\ y_n / I_x]$	
	$= (180/1200)+\{[((180 \times 200)+(50 \times 310))100] / 36 \times 10^6)\} = 0.29$ kN/mm	
	Maximum vector force (y-y axis direction)	
	$F_y = (H / L_w) + [(Ve_h + He_v)\ z_n / I_x]$	
	$= (50/1200)+\{[((180 \times 200)+(50 \times 310))\ 200] / 36 \times 10^6)\} = 0.33$ kN/mm	
	Thus, the design force on the bolt	
	$F_{r, Ed} = \sqrt{}\ (F_z^2 + F_y^2) = \sqrt{}\ (0.29^2) + (0.33^2) = 0.44$ kN/mm	
EC3-1-8 4.5.3.3	**Fillet weld resistance**	
	$F_{w, Rd} = f_u a / (3^{1/2}\ \beta_w\ \gamma_{M2})$	
	$= (430 \times 0.7 \times 6) / (3^{1/2} \times 0.9 \times 1.25) = 926.84$ N/mm $= 0.93$ kN/mm	
	$F_{w, Rd} = 0.93$ kN/mm $> F_{r, Ed} = 0.44$ kN/mm	OK

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Reference	Calculation	Output
Structural Design of Steelwork to EN 1993 and 1994 Third Edition by Lawrence Martin and John Purkiss	To determine the thickness of the gusset plate for the welded joint Width of the gusset plate perpendicular to the free edge $B_g = L_g / [(L_g / H_g)^2 + 1]^{0.5} = 225 / [(225 / 400)^2 + 1]^{0.5} = 196.10$ mm Replace the term $P_u s_g$ with $Vs_g + Hh_g$, the thickness of the gusset plate Grade S355 $t_g = [2(Vs_g + Hh_g) / (f_y B_g^2 / \gamma_{M1})] + (B_g / 80)$ $= [(2((180 \times 150) + (50 \times 150))) \times 10^3/((355 \times 196^2) / 1.0)] + (196 / 80)$ $= 7.51$ mm Therefore, use a 10 mm thick plate of Grade S355 Check for the slenderness ratio of the gusset plate $l_g / i_g = 2(3^{1/2})(B_g / t_g) = 2(3^{1/2})(196/ 10) = 67.90 < 185$, the limit of the slenderness ratio for the application of the theory	OK