Ex. 6.1 - Design Strength<br>• Calculate and check the design strength of the simple<br>connection shown below is the connection adequate for **Ex. 6.1 - Design Strength**<br>• Calculate and check the design strength of the simple<br>connection shown below. Is the connection adequate for<br>carrying the factored load of 300 kN. **x. 6.1 - Design Strength**<br>Calculate and check the design strength of the simple<br>connection shown below. Is the connection adequate for<br>carrying the factored load of 300 kN. **x. 6.1 - Design Strength**<br>Calculate and check the design strength of the simple<br>connection shown below. Is the connection adequate for<br>carrying the factored load of 300 kN.



# Ex. 6.1 - Design Strength<br>• Step I. Shear strength of bolts

- 
- **Ex. 6.1 Design Strength**<br>• Step I. Shear strength of bolts<br>• The design shear strength of one bolt in shear =  $\phi F_n A_b = 0.7$ <br>330 x  $\pi$  x 20<sup>2/4000</sup> = 77.8 kN **4. 6.1 - Design Strength**<br> **Step I.** Shear strength of bolts<br>
• The design shear strength of one bolt in shear =  $\phi F_n A_b = 0.75 \times 330 \times \pi \times 20^2/4000 = 77.8 \text{ kN}$ <br>
•  $\phi F_n A_b = 77.8 \text{ kN per bolt}$  (See Table J3.2) **6.1 - Design Strengt**<br> **330 x**  $\pi$  **x 20<sup>2</sup>/4000 = 77.8 kN<br>
•**  $\phi$  **F<sub>n</sub> A<sub>b</sub> = 77.8 kN per bolt (See Table J3. Design Strength**<br>strength of bolts<br>shear strength of one bolt in shear =  $\phi F_n A_b = 0.74000 = 77.8 kN$ <br>7.8 kN per bolt (See Table J3.2)<br>poth of connection = 4 x 77 8 = 311 2 kN **6.1 - Design Strength**<br> **b.** I. Shear strength of bolts<br>
the design shear strength of one bolt in shear =  $\phi F_n A_b = 0.75 \times$ <br>  $\phi F_n A_b = 77.8 \text{ kN per bolt}$  (See Table J3.2)<br>
• Shear strength of connection = 4 x 77.8 = 311.2 kN **6.1 - Design Strength**<br> **b I.** Shear strength of bolts<br>
the design shear strength of one bolt in shear =  $\phi F_n A_b = 0.75 \times 30 \times \pi \times 20^2/4000 = 77.8$  kN<br> **•**  $\phi F_n A_b = 77.8$  kN per bolt (See Table J3.2)<br>
• Shear strength of
	-
	-

### Ex. 6.1 - Design Strength

- Step II. Minimum edge distance and spacing requirements
	- See Table J3.4M, minimum edge distance = 26 mm for rolled edges of plates
		- The given edge distances (30 mm) > 26 mm. Therefore, minimum edge distance requirements are satisfied.
	- Minimum spacing =  $2.67 d_b = 2.67 \times 20 = 53.4 \text{ mm}.$

(AISC Specifications J3.3)

- Preferred spacing =  $3.0 d_b = 3.0 x 20 = 60$  mm.
- The given spacing (60 mm) = 60 mm. Therefore, spacing requirements are satisfied.

### **Ex. 6.1 - Design Strength<br>
TABLE J 3.4M<br>
Minimum Edge Distance<sup>[a]</sup> from**

### Center of Standard Hole<sup>[b]</sup> to Edge of **Connected Part, mm**



<sup>(a)</sup> If necessary, lesser edge distances are permitted provided the appropriate provisions from Sections J 3.10 and J4 are satisfied, but edge distances less than one bolt diameter are not permitted without approval from the engineer of record.

<sup>[b]</sup> For oversized or slotted holes, see Table | 3.5M.

### Ex. 6.1 - Design Strength<br>Step III. Bearing strength at bolt holes. **6.1 – Design Strength<br>
• III. Bearing strength at bolt holes.**<br>
• At edges, L<sub>c</sub> = 30 – hole diameter/2 = 30 – (20 + 1.6)/2 = 19.2<br>
•  $\phi R_n = 0.75 \times (1.2 L_c t F_u) = 0.75 \times (1.2 \times 19.2 \times 15 \times 400) / 1000 = 103.7 kN$

- Step III. Bearing strength at bolt holes.
- Bearing strength at bolt holes in connected part (120x15 mm plate) **• At other holes, s = 60 mm, L<sub>c</sub> = 60 – (20 + 1.6)<sup>2</sup> = 38.4 mm, and the part (120x15 mm plate)<br>
• At edges, L<sub>c</sub> = 30 – hole diameter/2 = 30 – (20 + 1.6)/2 = 19.2<br>
• \Phi R\_n = 0.75 \times (1.2 L\_c t F\_u) = 0.75 \times (1.2 \times 19.2 \times 15 \times 40** 
	-
	- $\phi$ R<sub>n</sub> = 0.75 x (1.2 L<sub>c</sub> t F<sub>u</sub>) = 0.75 x (1.2 x19.2 x15x400)/1000 = 103.7 kN
	- But,  $\phi R_n \le 0.75$  (2.4 d<sub>b</sub> t F<sub>u</sub>) = 0.75 x (2.4 x 20x15x400)/1000 = 216 kN
	- Therefore,  $\phi R_n$  = 103.7 kN at edge holes.
	-
	- $\phi R_n = 0.75 \times (1.2 L_c t F_u) = 0.75 \times (1.2 \times 38.4 \times 15 \times 400) / 1000 = 207.4 kN$
	- But,  $\phi R_n \le 0.75$  (2.4  $d_b$  t  $F_u$ ) = 216 kN. Therefore  $\phi R_n$  = 207.4 kN

# Ex. 6.1 - Design Strength<br>
Financipal Assembly and the poles<br>
Financipal Assembly at poles = 2 x 403.7 + 2 x 307.4 = 633.2 kM

- Therefore,  $\phi R_n = 216$  kN at other holes
- Therefore, bearing strength at holes =  $2 \times 103.7 + 2 \times 207.4 = 622.2$  kN
- Bearing strength at bolt holes in gusset plate (10 mm plate)
	-
- **6.1 Design Strength American**<br>• Therefore,  $\phi R_n = 216$  kN at other holes<br>• Therefore, bearing strength at holes = 2 x 103.7 + 2 x 207.4 = 622.2 kN<br>earing strength at bolt holes in gusset plate (10 mm plate)<br>• At edges, •  $\phi R_n = 0.75 \times (1.2 L_c t F_u) = 0.75 \times (1.2 \times 19.2 \times 10 \times 400)/1000 = 69.1$ kN and the contract of the con
	- But,  $\phi R_n \le 0.75$  (2.4 d<sub>b</sub> t F<sub>u</sub>) = 0.75 x (2.4 x 20 x 10 x 400)/1000 = 144 kN.
	- Therefore,  $\phi R_n = 69.1$  kN at edge holes.

# Ex. 6.1 - Design Strength<br>
• At other holes, s = 60 mm, L<sub>c</sub> = 60 – (20 + 1.6) = 38.4 mm.

- 
- **6.1 Design Strength**<br>• At other holes, s = 60 mm, L<sub>c</sub> = 60 (20 + 1.6) = 38.4 mm.<br>•  $_{\phi R_n}$  = 0.75 x (1.2 L<sub>c</sub> t F<sub>u</sub>) = 0.75 x (1.2 x 38.4 x 10x 400)/1000 = 138.2 **6.1 - Design Strength**<br>
• At other holes, s = 60 mm, L<sub>c</sub> = 60 – (20 +1.6) = 38.4 mm.<br>
•  $\phi R_n$  = 0.75 x (1.2 L<sub>c</sub> t F<sub>u</sub>) = 0.75 x (1.2 x 38.4 x 10x 400)/1<br>
• But,  $\phi R_n$  ≤ 0.75 (2.4 d<sub>b</sub> t F<sub>u</sub>) = 144 kN **ign Strength**<br>  $\sum_{m,m,L_c=60-(20+1.6)=38.4 \text{ mm}}$ <br>  $\sum_{m,L_u=0.75 \times (1.2 \times 38.4 \times 10 \times 400)/1000}$ <br>  $\sum_{m,L_u=144 \text{ km}}$ **gn Strength**<br>
m, L<sub>c</sub> = 60 – (20 +1.6) = 38.4 mm.<br>  $= 0.75 \times (1.2 \times 38.4 \times 10 \times 400)/1000 = 138.2$ <br>
F<sub>u</sub> $= 144 \text{ kN}$ kN **■ Design Strength**<br>
noles, s = 60 mm, L<sub>c</sub> = 60 – (20 +1.6) = 38.4 mm.<br>
75 x (1.2 L<sub>c</sub> t F<sub>u</sub>) = 0.75 x (1.2 x 38.4 x 10x 400)/100<br>
≤ 0.75 (2.4 d<sub>b</sub> t F<sub>u</sub>) = 144 kN<br>
e, φR<sub>n</sub> = 138.2 kN at other holes<br>
e bearing streng **gn Strength**<br>nm, L<sub>c</sub> = 60 - (20 +1.6) = 38.4 mm.<br>F<sub>u</sub>) = 0.75 x (1.2 x 38.4 x 10x 400)/1000 =<br>t F<sub>u</sub>) = 144 kN<br>kN at other holes<br>noth at holes = 2 x 69 1 + 2 x 138 2 = 414 **n Strength**<br>  $L_c = 60 - (20 + 1.6) = 38.4$  mm.<br>  $= 0.75 \times (1.2 \times 38.4 \times 10 \times 400)/1000 = 138.2$ <br>  $= 144$  kN<br>
at other holes<br>
a at holes = 2 x 69 1 + 2 x 138 2 = 414 6 kN **6.1 - Design Strength**<br>
• At other holes, s = 60 mm, L<sub>c</sub> = 60 – (20 +1.6) = 38.4 mm.<br>
•  $\phi R_n = 0.75 \times (1.2 \text{ L}_c \text{ tr}_u) = 0.75 \times (1.2 \text{ K}) \times 400/1000 = 138.2 \text{ kN}$ <br>
• But,  $\phi R_n \le 0.75$  (2.4 d<sub>b</sub> t F<sub>u</sub>) = 144 kN<br>
• Theref
- But,  $\phi R_n \le 0.75$  (2.4 d<sub>b</sub> t F<sub>u</sub>) = 144 kN
- 
- 
- At other holes, s = 60 mm, L<sub>c</sub> = 60 (20 + 1.6) = 38.4 mm.<br>•  $\phi R_n = 0.75 \times (1.2 L_c t F_u) = 0.75 \times (1.2 \times 38.4 \times 10 \times 400)/1000 = 138.2$ <br>• But,  $\phi R_n \le 0.75$  (2.4 d<sub>b</sub>, t F<sub>u</sub>) = 144 kN<br>• Therefore,  $\phi R_n = 138.2$  kN at other h **1 - Design Strength**<br>
• At other holes, s = 60 mm, L<sub>c</sub> = 60 - (20 + 1.6) = 38.4 mm.<br>
•  ${}_{\phi}R_n$  = 0.75 x (1.2 L<sub>c</sub> t F<sub>u</sub>) = 0.75 x (1.2 x 38.4 x 10x 400)/1000 = 138.2<br>
• But,  ${}_{\phi}R_n$  ≤ 0.75 (2.4 d<sub>b</sub> t F<sub>u</sub>) = 144 k At other holes, s = 60 mm, L<sub>c</sub> = 60 - (20 + 1.6) = 38.4 mm<br>  $\Phi_{R_n} = 0.75 \times (1.2 L_c \text{ t F}_u) = 0.75 \times (1.2 \times 38.4 \times 10 \times 400)$ <br>
kN<br>
But,  $\Phi_{R_n} \le 0.75$  (2.4 d<sub>b</sub> t F<sub>u</sub>) = 144 kN<br>
Therefore,  $\Phi_{R_n} = 138.2$  kN at other holes

# Ex. 6.1 - Design Strength

Connection Strength

Shear strength  $= 311.2$ 

Bearing strength (plate) =  $622.2$  kN

Bearing strength (gusset) =  $414.6$  kN

Connection strength ( $\phi$ R<sub>n</sub>) > applied factored loads ( $\gamma$ Q). 311.2 > 300 Therefore ok.

Only connections is designed here

Need to design tension member and gusset plate

### Eccentrically-Loaded Bolted Connections





### Eccentricity in the plane of the faying surface

Direct Shear + Additional Shear due to moment Pe

### Eccentricity normal to the plane of the faying surface

Direct Shear + Tension and Compression (above and below neutral axis)

### Forces on Eccentrically-Loaded Bolts

Eccentricity in the plane of the faying surface

LRFD Spec. presents values for computing design strengths of individual bolt only. To compute forces on group of bolts that are eccentrically loaded, there are two common methods:

- Elastic Method: Conservative. Connected parts assumed rigid. Slip resistance between connected parts neglected.
- Ultimate Strength Method (or Instantaneous Center of Gravity Method): Most realistic but tedious to apply

### Forces on Eccentrically-Loaded Bolts with Eccentricity on the Faying Surface

● Elastic Method



Assume plates are perfectly rigid and bolts perfectly elastic  $\rightarrow$ rotational displacement at each bolt is proportional to its distance from the  $CG \rightarrow$  stress is greatest at bolt farthest from **CG** and the contract of the c