Original Demo

Wednesday, 12 October 2022 11:24 pm

EXAMPLE 8–6

Two 25.4 by 101.6 mm 1018 cold-rolled steel bars are butt-spliced with two 12.7 by 101.6 mm 1018 cold-rolled splice plates using four M20 × 1.5 mm grade 5 bolts as depicted in Figure 8–26. For a design factor of $n_d = 1.5$ estimate the static load F that can be carried if the bolts lose preload.

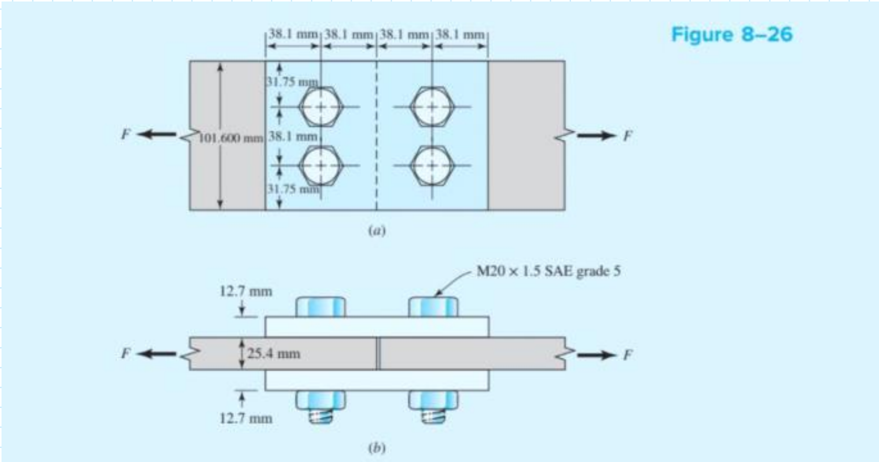
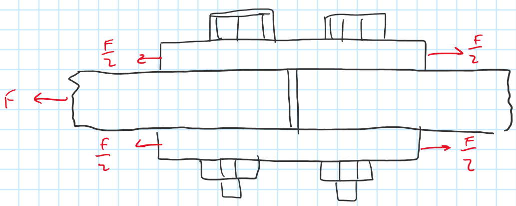


Figure 8–26



Area of splice plates are half more of centre bars

$\sigma_{CB} = \frac{F}{A}$ $\quad \sigma_{sp} = \frac{F/2}{A/2} = \frac{F}{A}$

∴ For forces associated with splice plates, the forces and areas will be those of centre plates

Table A-20 (Members)

1 UNS No.	2 SAE and/or AISI No.	3 Processing	4 Tensile Strength, MPa (kpsi)	5 Yield Strength, MPa (kpsi)	6 Elongation in 2 in, %	7 Reduction in Area, %	8 Brinell Hardness
G10060	1006	HR	300 (43)	170 (24)	30	55	86
		CD	330 (48)	280 (41)	20	45	95
G10100	1010	HR	320 (47)	180 (26)	28	50	95
		CD	370 (53)	300 (44)	20	40	105
G10150	1015	HR	340 (50)	190 (27.5)	28	50	101
		CD	390 (56)	320 (47)	18	40	111
G10180	1018	HR	400 (58)	220 (32)	25	50	116
		CD	440 (64)	370 (54)	15	40	126
G10200	1020	HR	380 (55)	210 (30)	25	50	111
		CD	470 (68)	390 (57)	15	40	131
G10300	1030	HR	470 (68)	260 (37.5)	20	42	137
		CD	520 (76)	440 (64)	12	35	149
G10350	1035	HR	500 (72)	270 (39.5)	18	40	143
		CD	550 (80)	460 (67)	12	35	163
G10400	1040	HR	520 (76)	290 (42)	18	40	149
		CD	590 (85)	490 (71)	12	35	170
G10450	1045	HR	570 (82)	310 (45)	16	40	163
		CD	630 (91)	530 (77)	12	35	179
G10500	1050	HR	620 (90)	340 (49.5)	15	35	179
		CD	690 (100)	580 (84)	10	30	197
G10600	1060	HR	680 (98)	370 (54)	12	30	201
G10800	1080	HR	770 (112)	420 (61.5)	10	25	229
G10950	1095	HR	830 (120)	460 (66)	10	25	248

$S_{ut} = 440$ MPa
$S_y = 370$ MPa

Table 8-11 (Bolts)

Table 8–11
Metric Mechanical-Property Classes for Steel Bolts, Screws, and Studs*

Property Class	Size Range, Inclusive	Minimum Proof Strength,† MPa	Minimum Tensile Strength,† MPa	Minimum Yield Strength,† MPa	Material	Head Marking
4.6	M5–M36	225	400	240	Low or medium carbon	4.6
4.8	M1.6–M16	310	420	340	Low or medium carbon	4.8
5.8	M5–M24	380	520	420	Low or medium carbon	5.8
8.8	M16–M36	600	830	660	Medium carbon, Q&T	8.8
9.8	M1.6–M16	650	900	720	Medium carbon, Q&T	9.8
10.9	M5–M36	830	1040	940	Low-carbon martensite, Q&T	10.9
12.9	M1.6–M36	970	1220	1100	Alloy, Q&T	12.9

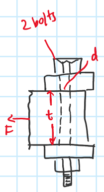
*The thread length for bolts and cap screws is

$$L_T = \begin{cases} 2d + 6 & L \le 125 \\ 2d + 12 & 125 < L \le 200 \\ 2d + 25 & L > 200 \end{cases}$$

where L is the bolt length. The thread length for structural bolts is slightly shorter than given above.
†Minimum strengths are strength exceeded by 99 percent of fasteners.

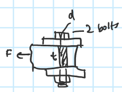
For an M20 bolt:
$S_p = 600$ MPa
$S_{ut} = 830$ MPa
$S_y = 660$ MPa

Case 1: Bearing stress in bolts



Design factor equation

$n_d = \frac{S_y}{\sigma_b}$ → strength / → stress ①



Bearing stress equation

$\sigma_b = \frac{F}{A}$ — because there are 2 bolts $= 2td$

$\therefore \sigma_b = \frac{F}{2td}$ ②

Sub ② in ① and rearrange to get F:

$F = \frac{2td(S_y)}{n_d}$

$= 2(25.4)(20)(660)$

$$F = \frac{2td(S_y)}{n_d}$$

$$= \frac{2(25.4)(20)(660)}{1.5}$$

$$F = 447040\,N$$

$$\therefore \underline{F = 447\,kN}$$

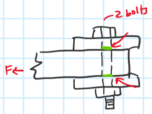
Case 2: Shear stress of Bolts

— will occur at shear plane

All bolts active

* If the bolt threads do not extend into the shear planes

for 4 shanks



Shear stress formula

$$\tau = \frac{F}{A}$$

$$\tau = \frac{F}{\pi d^2} \quad (3)$$

$A = \frac{\pi d^2}{4}$ but

because of 4 shanks

$$A = \frac{\cancel{4}\pi d^2}{\cancel{4}}$$

$$= \pi d^2$$

Shear stress to yield strength relationship (Von Mises Criteria)

$$S_s = \frac{1}{\sqrt{3}} S_y$$

$$n_d = \frac{\text{strength}}{\text{stress}} = \frac{\frac{1}{\sqrt{3}} S_y}{\tau} \Rightarrow \tau = \frac{\frac{1}{\sqrt{3}} S_y}{n_d} = \frac{0.577 S_y}{n_d}$$

Therefore:

$$\tau = \frac{F}{\pi d^2} = \frac{0.577 S_y}{n_d}$$

$$F = \frac{0.577 S_y (\pi d^2)}{n_d}$$

$$= \frac{0.577(660)(\pi \times 20^2)}{1.5}$$

$$= 319035\,N$$

$$\underline{F = 319\,kN}$$

Case 3: Bearing stress in members

Design factor:

$$n_d = \frac{(S_y)_{mem}}{\sigma_{mem}} \Rightarrow \sigma_{mem} = \frac{(S_y)_{mem}}{n_d} \quad (4)$$

Bearing stress equation

$$\sigma_{mem} = \frac{F}{A}$$ — for 2 bolts = 2td

$$\sigma_{mem} = \frac{F}{2td} \quad (5)$$

Equate (4) and (5):

$$\sigma_{mem} = \frac{F}{2td} = \frac{(S_y)_{mem}}{n_d}$$

$$F = \frac{(S_y)_{mem}(2td)}{n_d}$$

$$= \frac{(370)(2)(25.4)(20)}{1.5}$$

$$= 250{,}613\,N$$

$$F = \underline{250.61\,kN}$$

Case 4: Edge shearing of a member at 2 margin bolts

- This failure is avoided by spacing the rivets at least 1.5 diameters away from the edge
- Should be avoided in this case but can be calculated

$$\tau = \frac{F}{A} = \frac{F}{4at} \quad (6)$$

$$n_d = \frac{0.577 S_y}{\tau}$$

$$\tau = \frac{0.577 S_y}{n_d} \quad (7)$$

Equate (6) and (7)

$$\frac{F}{4at} = \frac{0.577 S_y}{n_d}$$

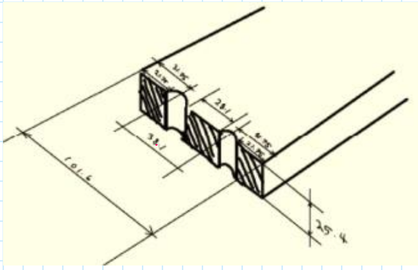
$$F = \frac{4at\,(0.577)S_y}{n_d}$$

$$= \frac{4(28.575)(25.4)(0.577)(370)}{1.5}$$

$$= 413205.625\ N$$

$$F = \underline{413.21\ kN}$$

Case 5: Tensile failure of members



Cross-sectional area

$$A_{total} = 2(21.75)(25.4) + 28.1(25.4)$$

$$= 1818.64\ mm^2$$

$$\sigma = \frac{F}{A} = \frac{(S_y)_{mem}}{n_d}$$

Rearrange for F

$$F = \frac{(S_y)_{mem}}{n_d} A$$

$$= \frac{370}{1.5} \times 1818.64$$

$$= 448597.867\ N$$

$$F = \underline{448.597\ kN}$$

Therefore:

$F_{bear_{bolt}} = 447\ kN$

$F_{shear_{bolt}} = 319\ kN$

$F_{bear_{mem}} = 250.61\ kN$ — minimum force required to exceed allowable stress

$F_{shear_{mem}} = 413.21\ kN$

$F_{tens_{mem}} = 448.597\ kN$