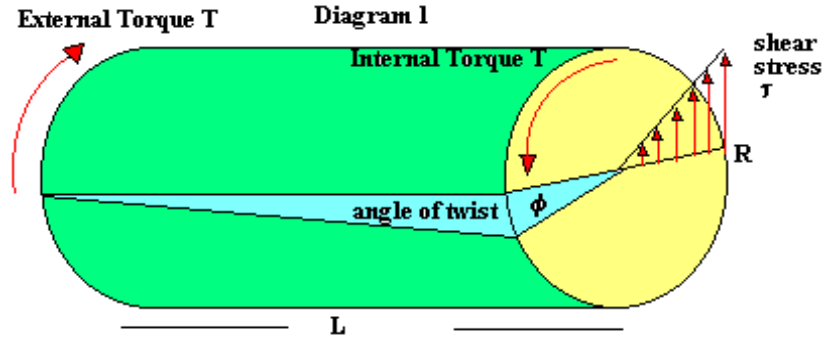


## STATİK - MUKAVEMET

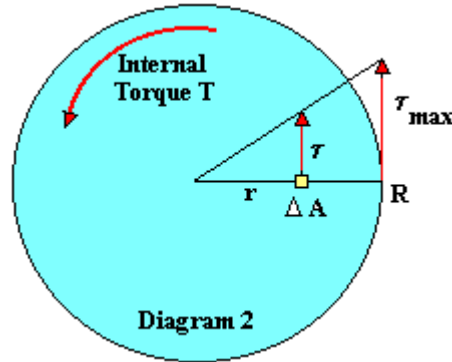
### 12. HAFTA

### BURULMA

L uzunluğunda R yarıçapında burulma çubuğu,

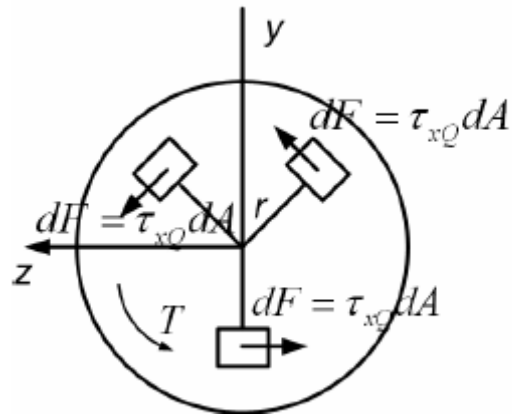


merkezden r kadar uzaklıktaki, diferansiyel eleman kesit alanı  $\Delta A$ ,



Kayma gerilmesi:

$$\tau = \left(\frac{r}{R}\right) \tau_{\max}$$



$$d\vec{F} = \tau_{x\theta} dA$$

$$dT = dF \times r = \sigma_{x\theta} r dA$$

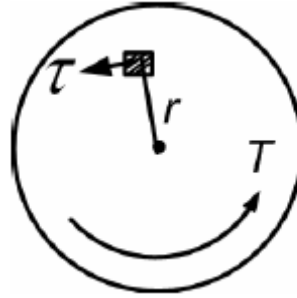
$$T = \int_A \tau_{x\theta} r dA$$

$$T = T_0$$

$$T = \int_A \tau r dA$$

$$T = \int Gr \frac{d\phi}{dx} r dA$$

$$T = G \frac{d\phi}{dx} \int_A r^2 dA$$



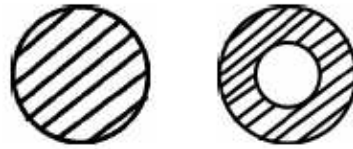
$$I_P = \int_A r^2 dA$$

$$I_P = \frac{\pi}{32} D^4$$

$$I_P = \frac{\pi}{2} R^4$$

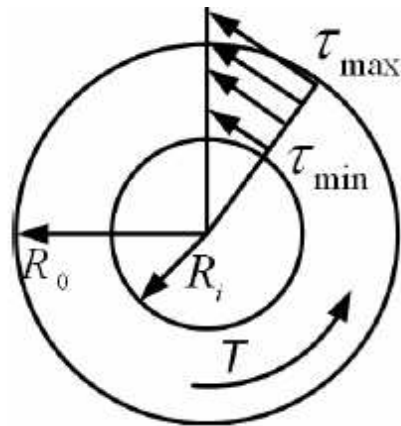
$$I_P = \frac{\pi}{32} D^4 - \text{Solid}$$

$$I_P = \frac{\pi}{32} (D_o^4 - D_i^4) - \text{hollow}$$



$$\tau_{max} = \frac{TR_o}{I_P}$$

$$\tau_{min} = \frac{TR_i}{I_P}$$

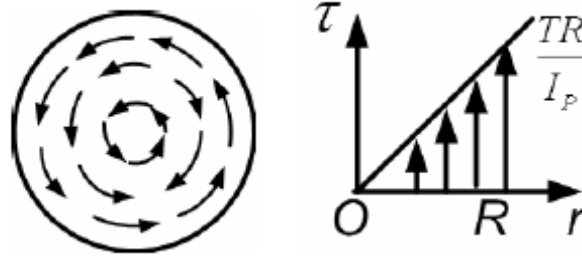


$$T = GI_P \frac{d\phi}{dx}$$

$$\frac{d\phi}{dx} = \ominus = \frac{T}{GI_P}$$

$$\frac{\tau}{Gr} = \frac{T}{GI_P}$$

$$\tau = Gr \frac{d\phi}{dx} \quad \tau = \frac{Tr}{I_P}$$



$$\tau_{max} = \tau_{xQ_{max}} = \frac{TR}{I_P}$$

Diferansiyel Kuvvet

$$\Delta F = \gamma \Delta A = (r/R) \tau_{max} \Delta A$$

**Diferansiyel burulma momenti**

$$\Delta T = r \Delta F = r \tau \Delta A = (r^2/R) \tau_{max} \Delta A$$

$$T = \sum \Delta T = \sum (r \Delta F) = \sum (r \tau \Delta A) = \sum (r^2/R) \tau_{max} \Delta A$$

$$T = (\tau_{max}/R) \sum r^2 \Delta A = (\tau_{max}/R) J$$

$$\gamma = T r / J$$

## Örnek 1

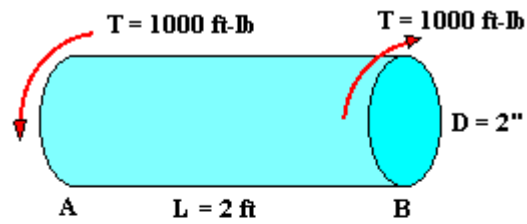


Diagram 1a

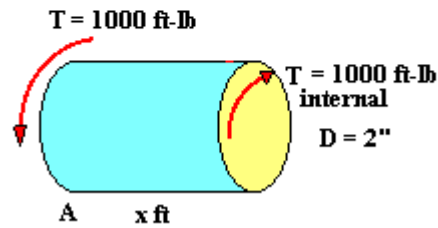


Diagram 1b

$$\tau = T r / J;$$

$$T = 1000 \text{ ft-lb} = 12,000 \text{ in-lb.}$$

$$r = 1 \text{ in.}$$

$$J = \left( \frac{\pi}{32} \right) d^4 \text{ for a solid shaft} = \left( \frac{3.1416}{32} \right) (2^4 \text{ in}^4) = 1.57 \text{ in}^4.$$

$$\tau = T r / J = 12,000 \text{ in-lb.} \cdot 1 \text{ in.} / 1.57 \text{ in}^4 = 7,640 \text{ lb/in}^2.$$

### Halka Kesit

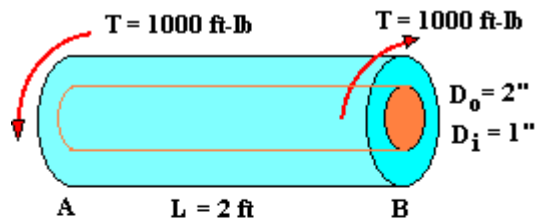


Diagram 2a

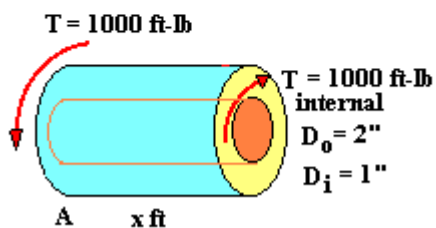


Diagram 2b

$$\tau = T r / J$$

$$T = 1000 \text{ ft-lb} = 12,000 \text{ in-lb.}$$

$$J = \left( \frac{3.1416}{32} \right) [d_o^4 - d_i^4] \text{ for a hollow shaft} = \left( \frac{3.1416}{32} \right) [(2^4 \text{ in}^4) - (1.0^4 \text{ in}^4)] = 1.47 \text{ in}^4.$$

$$= T r / J = 12,000 \text{ in-lb.} \cdot 1 \text{ in.} / 1.47 \text{ in}^4 = 8,150 \text{ lb/in}^2.$$

## Örnek 2

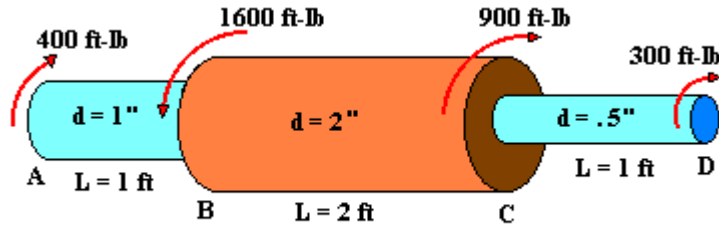
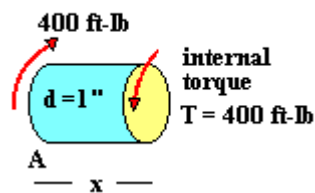


Diagram 1

Diagram 2



$$\tau = T r / J;$$

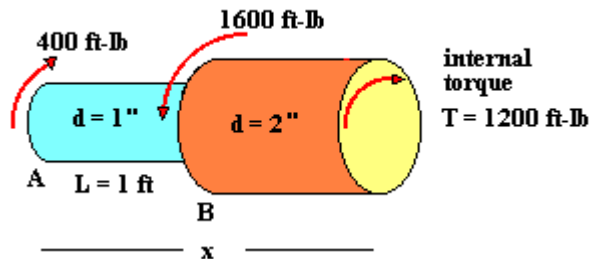
$$T = 400 \text{ ft-lb.} = 4,800 \text{ in-lb.}$$

$$r = .5 \text{ in.}$$

$$J = (\pi/32) d^4 \text{ for a solid shaft} = (3.1416/32) (1^4 \text{in}^4) = .098 \text{ in}^4.$$

$$\tau = T r / J = 4,800 \text{ in-lb.} \cdot .5 \text{ in.} / .098 \text{ in}^4 = 24,500 \text{ lb./in}^2.$$

Diagram 3



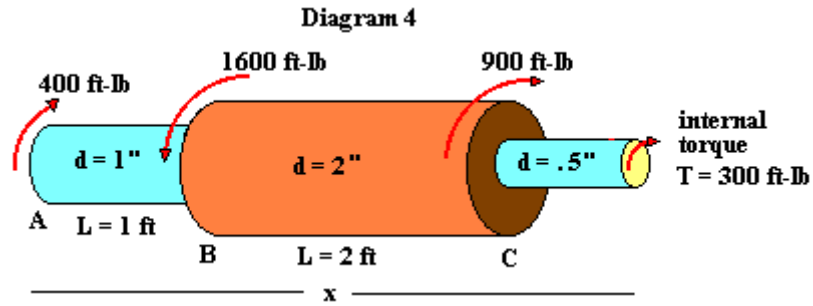
$$\tau = T r / J;$$

$$T = 1,200 \text{ ft-lb.} = 14,400 \text{ in-lb.}$$

$$r = 1 \text{ in.}$$

$$J = (\pi/32) d^4 \text{ for a solid shaft} = (3.1416/32) (2^4 \text{in}^4) = 1.57 \text{ in}^4.$$

$$\tau = T r / J = 14,400 \text{ in-lb.} \cdot 1 \text{ in.} / 1.57 \text{ in}^4 = 9,170 \text{ lb./in}^2.$$



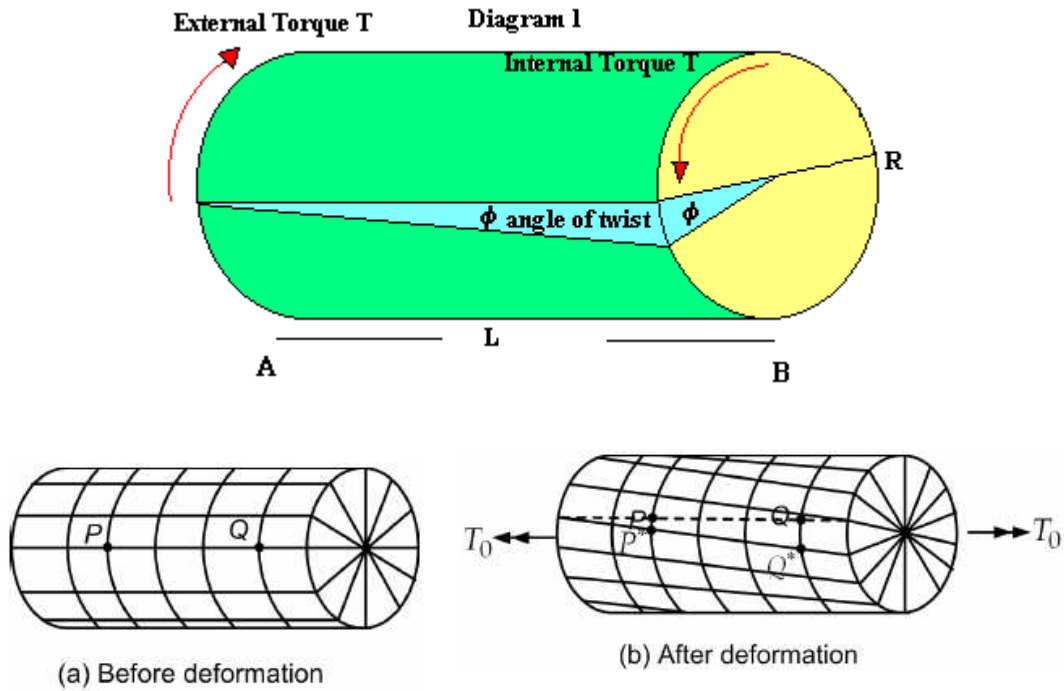
$$T = 300 \text{ ft-lb.} = 3,600 \text{ in-lb.}$$

$$r = .25 \text{ in.}$$

$$J = \left( \frac{\pi}{32} \right) d^4 \text{ for a solid shaft} = \left( \frac{3.1416}{32} \right) (.5^4 \text{ in}^4) = .0061 \text{ in}^4.$$

$$\tau = T r / J = 3,600 \text{ in-lb.} * .25 \text{ in.} / .0061 \text{ in}^4 = 147,500 \text{ lb/in}^2.$$

## AÇISAL DÖNME

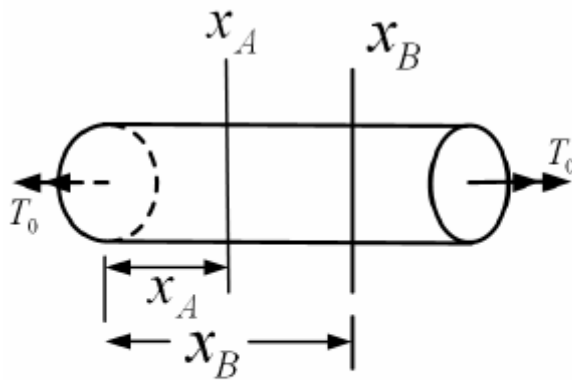
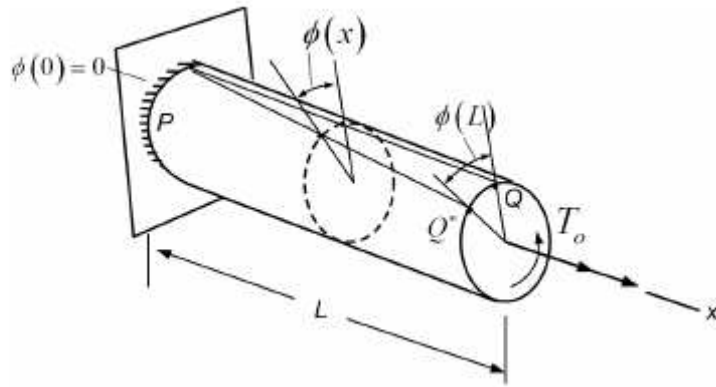


$$\phi = T L / J G$$

G = Kayma Modülü

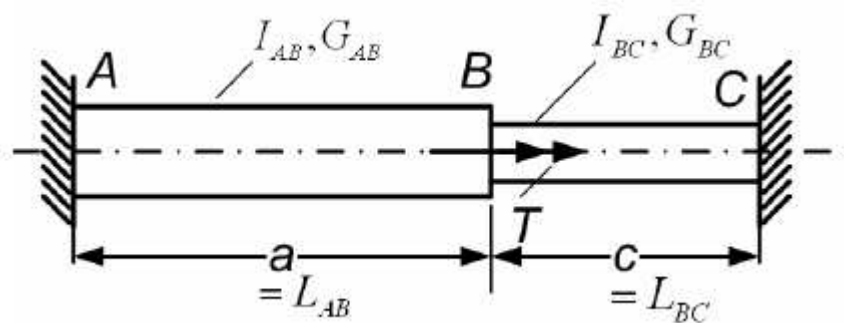
$$G_{\text{steel}} = 12 \times 10^6 \text{ lb/in}^2,$$

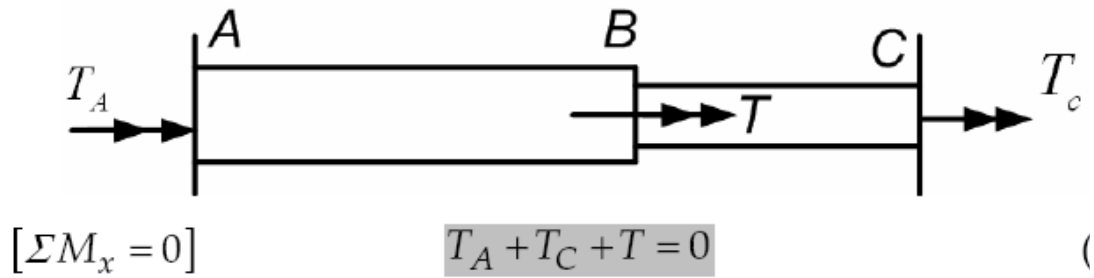
$$G_{\text{brass}} = 6 \times 10^6 \text{ lb/in}^2.$$



$$\odot = \frac{d\phi}{dx} = \frac{T}{GI_P}$$

$$\phi_{B/A} = \phi_B - \phi_A = \int_{x_A}^{x_B} \frac{T}{GI_P} dx$$



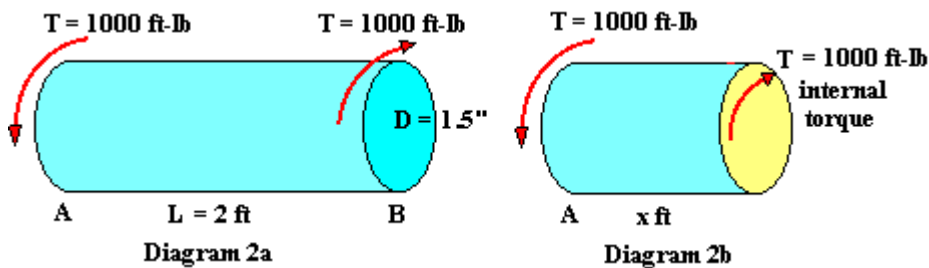


$$\phi_{B/A} = \phi_{B/C}$$

Compatibility equation

$$\phi_{B/A} = \frac{T_A L_{AB}}{G_{AB} I_{P_{AB}}} ; \phi_{B/C} = \frac{T_C L_{BC}}{G_{BC} I_{P_{BC}}}$$

$$\frac{T_A L_{AB}}{G_{AB} I_{P_{AB}}} = \frac{T_C L_{BC}}{G_{BC} I_{P_{BC}}}$$



$$\phi = \frac{TL}{JG}$$

$$T = 1000 \text{ ft-lb.} = 12,000 \text{ in-lb.}$$

$$L = 2 \text{ ft.} = 24 \text{ inches}$$

$$J = \left(\frac{\pi}{32}\right) d^4 \text{ for a solid shaft} = \left(\frac{3.1416}{32}\right) (1.5^4 \text{ in}^4) = .5 \text{ in}^4.$$

$$G_{\text{steel}} = 12 \times 10^6 \text{ lb/in}^2$$

$$\phi = \frac{TL}{JG} = \frac{(12,000 \text{ in-lb.} \cdot 24 \text{ in})}{(.5 \text{ in}^4 \cdot 12 \times 10^6 \text{ lb/in}^2)} = .048 \text{ radians} = 2.75^\circ.$$

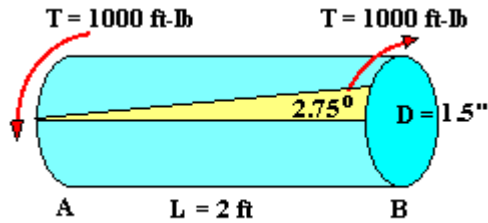


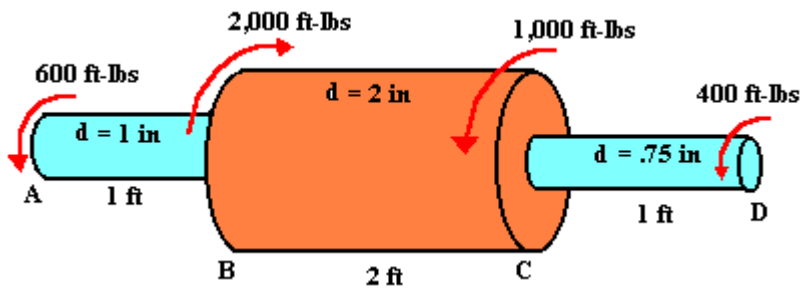
Diagram 3

$$\gamma = T r / J = 12,000 \text{ in-lb.} \cdot .75 \text{ in.} / .5 \text{ in}^4 = 18,000 \text{ lb/in}^2.$$

### Örnek

Çeliğin kayma modülü =  $12 \times 10^6 \text{ lb/in}^2$ .

Pirincin kayma modülü =  $6 \times 10^6 \text{ lb/in}^2$ .



#### I. Kesit:

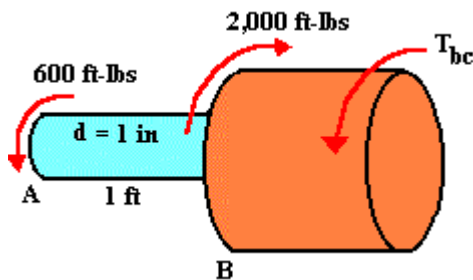
$$T = 600 \text{ ft-lb} - T_{AB} = 0; \text{ So } T_{AB} = 600 \text{ ft-lb}$$

$$\tau_{AB} = T r / J = (600 \text{ ft-lb})(12 \text{ in/ft})(.5 \text{ in}) / [3.1416 \cdot (1 \text{ in})^4 / 32] = 36,700 \text{ psi}$$

#### II. kesit:

$$T = 600 \text{ ft-lb} - 2000 \text{ ft-lb} + T_{BC} = 0; \text{ So } T_{BC} = 1400 \text{ ft-lb}$$

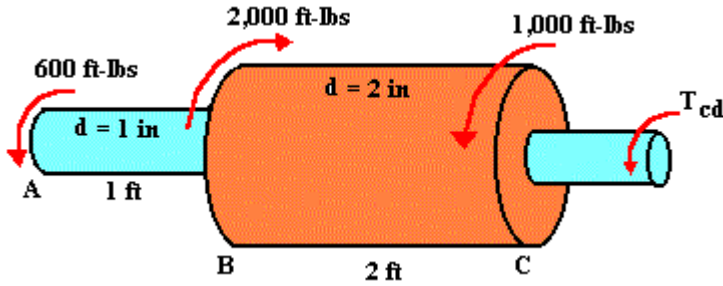
$$\tau_{BC} = T r / J = (1400 \text{ ft-lb})(12 \text{ in/ft})(1 \text{ in}) / [3.1416 \cdot (2 \text{ in})^4 / 32] = 10,700 \text{ psi}$$



#### III. kesit:

$$T = 600 \text{ ft-lb} - 2000 \text{ ft-lb} + 1000 \text{ ft-lb} + T_{CD} = 0; \text{ So } T_{CD} = 400 \text{ ft-lb}$$

$$\tau_{CD} = T r / J = (400 \text{ ft-lb}) (12 \text{ in/ft})(.375 \text{ in}) / [3.1416 \cdot (.75 \text{ in})^4 / 32] = 57,900 \text{ psi}$$



$$\phi_{AB} = TL/JG = (600 \text{ ft-lb})(12 \text{ in./ft})(1 \text{ ft})(12 \text{ in./ft}) / [(3.1416 * (1 \text{ in})^4 / 32)(12 \times 10^6 \text{ lb/in}^2)] = .0733 \text{ radians (cw)}$$

$$\phi_{BC} = TL/JG = (1,400 \text{ ft-lb})(12 \text{ in./ft})(2 \text{ ft})(12 \text{ in./ft}) / [(3.1416 * (2 \text{ in})^4 / 32)(6 \times 10^6 \text{ lb/in}^2)] = .0428 \text{ radians (ccw)}$$

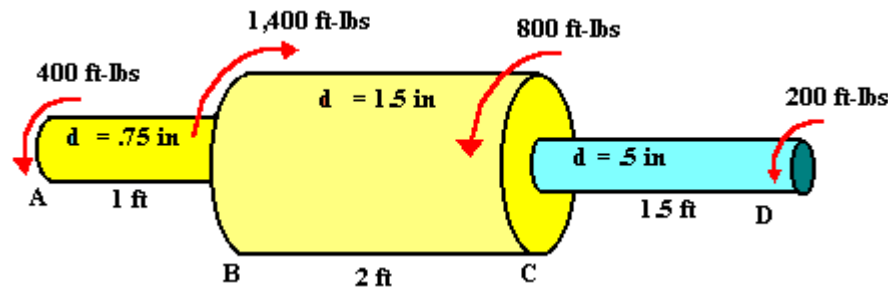
$$\phi_{CD} = TL/JG = (400 \text{ ft-lb})(12 \text{ in./ft})(1 \text{ ft})(12 \text{ in./ft}) / [(3.1416 * (.75 \text{ in})^4 / 32)(12 \times 10^6 \text{ lb/in}^2)] = .155 \text{ radians (ccw)}$$

$$\phi_{\text{Total}} = -\phi_{AB} + \phi_{BC} + \phi_{CD} = .1245 \text{ radians (ccw)}$$

### Örnek

Çeliğin kayma modülü =  $12 \times 10^6 \text{ lb/in}^2$ .

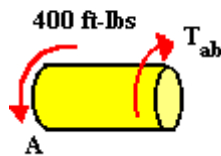
Pirincin kayma modülü =  $6 \times 10^6 \text{ lb/in}^2$ .



#### I. kesit:

$$T = 400 \text{ ft-lb} - T_{AB} = 0; \text{ So } T_{AB} = 400 \text{ ft-lb}$$

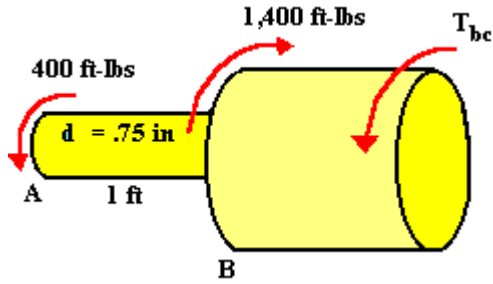
$$\tau_{AB} = Tr / J = (400 \text{ ft-lb})(12 \text{ in./ft})(.375 \text{ in}) / [3.1416 * (.75 \text{ in})^4 / 32] = 57,900 \text{ psi}$$



#### II.kesit:

$$T = 400 \text{ ft-lb} - 1,400 \text{ ft-lb} + T_{BC} = 0; \text{ So } T_{BC} = 1,000 \text{ ft-lb}$$

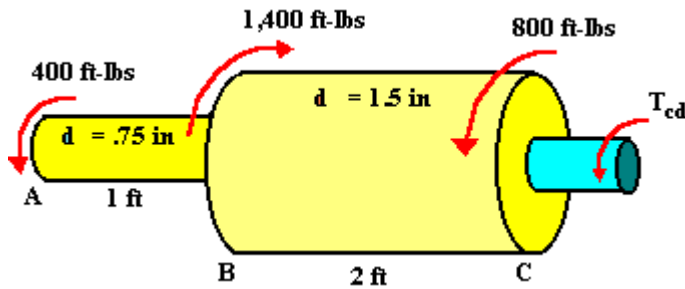
$$\tau_{BC} = Tr / J = (1,000 \text{ ft-lb})(12 \text{ in./ft})(.75 \text{ in}) / [3.1416 * (1.5 \text{ in})^4 / 32] = 18,100 \text{ psi}$$



III.kesit:

$T = 400 \text{ ft-lb} - 1,400 \text{ ft-lb} + 800 \text{ ft-lb} + T_{CD} = 0$ ; So  $T_{CD} = 200 \text{ ft-lb}$

$\tau_{CD} = Tr / J = (200 \text{ ft-lb})(12 \text{ in/ft})(.25 \text{ in}) / [3.1416 * (.5 \text{ in})^4 / 32] = 97,800 \text{ psi}$



$\phi_{AB} = TL/JG = (400 \text{ ft-lb})(12 \text{ in./ft})(1 \text{ ft})(12 \text{ in/ft}) / [(3.1416 * (.75 \text{ in})^4 / 32)(6 \times 10^6 \text{ lb/in}^2)] = .309 \text{ radians (cw)}$

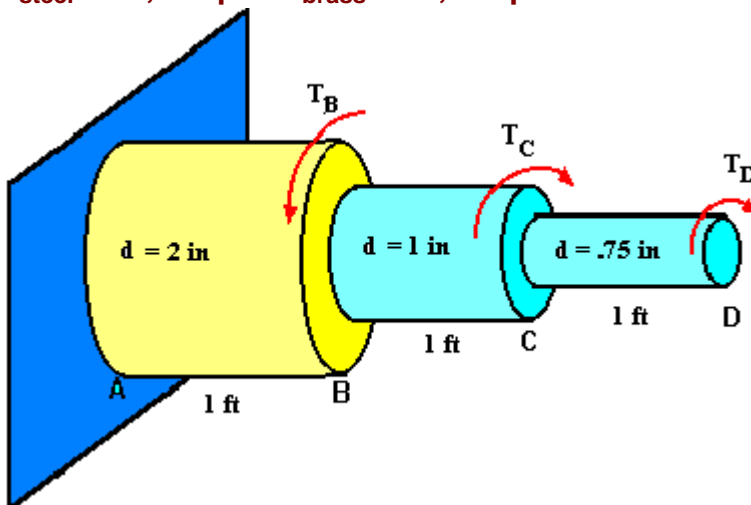
$\phi_{BC} = TL/JG = (1,000 \text{ ft-lb})(12 \text{ in./ft})(2 \text{ ft})(12 \text{ in/ft}) / [(3.1416 * (1.5 \text{ in})^4 / 32)(6 \times 10^6 \text{ lb/in}^2)] = .0966 \text{ radians (ccw)}$

$\phi_{CD} = TL/JG = (200 \text{ ft-lb})(12 \text{ in./ft})(1.5 \text{ ft})(12 \text{ in/ft}) / [(3.1416 * (.5 \text{ in})^4 / 32)(12 \times 10^6 \text{ lb/in}^2)] = .587 \text{ radians (ccw)}$

$\phi_{\text{Total}} = -\phi_{AB} + \phi_{BC} + \phi_{CD} = .375 \text{ radians (ccw)}$

Örnek

$\tau_{\text{steel}} = 18,000 \text{ psi}$   $\tau_{\text{brass}} = 12,000 \text{ psi}$



**Çeliğin kayma modülü =  $12 \times 10^6 \text{ lb/in}^2$ .**

**Pirincin kayma modülü =  $6 \times 10^6 \text{ lb/in}^2$ .**

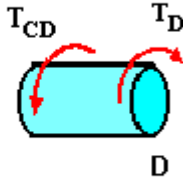
**I:**

$$T = T_{CD} - T_D = 0; \text{ So } T_D = T_{CD}$$

$$\tau_{\text{steel}} = T_{CD} r / J$$

$$18,000 \text{ lb/in}^2 = T_{CD} (.375 \text{ in}) / [3.1416 * (.75 \text{ in})^4 / 32]$$

$$T_{CD} = T_D = 1491 \text{ in-lb} = 124 \text{ ft-lb}$$



**II:**

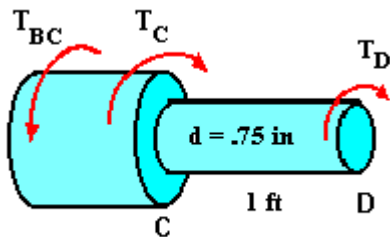
$$T = T_{BC} - T_{CD} - 124 \text{ ft-lb} = 0; \text{ So } T_C = (T_{BC} - 124 \text{ ft-lb})$$

$$\tau_{\text{steel}} = T_{BC} r / J$$

$$18,000 \text{ lb/in}^2 = T_{BC} (.5 \text{ in}) / [3.1416 * (1 \text{ in})^4 / 32]$$

$$T_{BC} = 3534 \text{ in-lb} = 295 \text{ ft-lb}$$

$$T_C = (295 \text{ ft-lb} - 124 \text{ ft-lb}) = 171 \text{ ft-lb}$$



**III:**

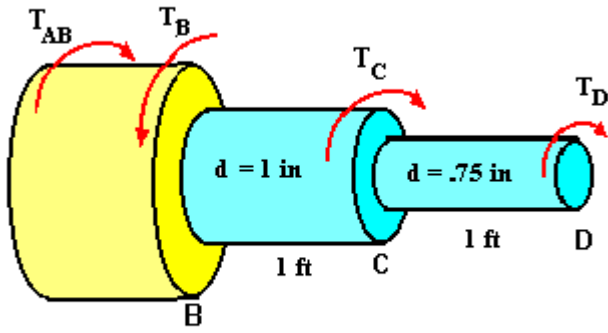
$$T = -T_{AB} + T_B - 171 \text{ ft-lb} - 124 \text{ ft-lb} = 0; \text{ So } T_B = (T_{AB} + 171 \text{ ft-lb} + 124 \text{ ft-lb})$$

$$\tau_{\text{brass}} = T_{AB} r / J$$

$$12,000 \text{ lb/in}^2 = T_{AB} (1 \text{ in}) / [3.1416 * (2 \text{ in})^4 / 32]$$

$$T_{AB} = 18,850 \text{ in-lb} = 1570 \text{ ft-lb.}$$

$$T_B = (1570 \text{ ft-lb} + 171 \text{ ft-lb} + 124 \text{ ft-lb}) = 1865 \text{ ft-lb}$$



$$\phi_{AB} = TL/JG = (1,570 \text{ ft-lb})(12 \text{ in./ft})(1 \text{ ft})(12 \text{ in./ft}) / [(3.1416 * (2 \text{ in})^4 / 32)(6 \times 10^6 \text{ lb/in}^2)] = .024 \text{ radians (ccw)}$$

$$\phi_{BC} = TL/JG = (245 \text{ ft-lb})(12 \text{ in./ft})(1 \text{ ft})(12 \text{ in./ft}) / [(3.1416 * (1 \text{ in})^4 / 32)(12 \times 10^6 \text{ lb/in}^2)] = .0361 \text{ radians (cw)}$$

$$\phi_{CD} = TL/JG = (124 \text{ ft-lb})(12 \text{ in./ft})(1 \text{ ft})(12 \text{ in./ft}) / [(3.1416 * (.75 \text{ in})^4 / 32)(12 \times 10^6 \text{ lb/in}^2)] = .0479 \text{ radians (cw)}$$

$$\phi_{\text{Total}} = +\phi_{AB} - \phi_{BC} - \phi_{CD} = .06 \text{ radians (cw)}$$

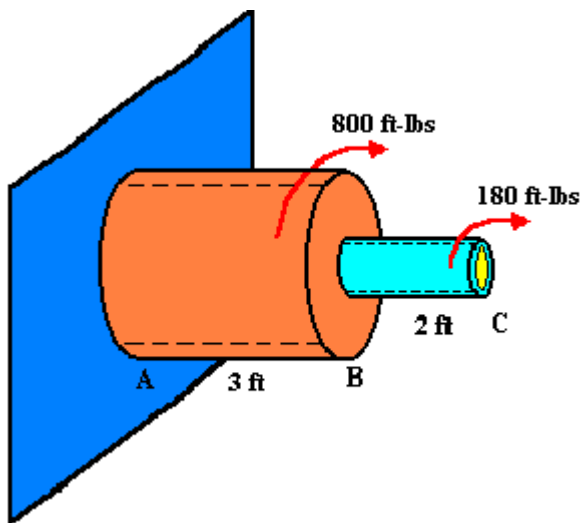
### Örnek

**Çeliğin kayma modülü =  $12 \times 10^6 \text{ lb/in}^2$ .**

**Pirincin kayma modülü =  $6 \times 10^6 \text{ lb/in}^2$ .**

Dışçap AB = 2.5 in, iç çap AB = 2 in

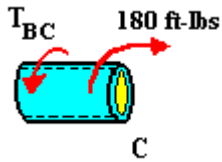
dışçap BC = 1 in, iççap BC = .8 in



I:

$$T = T_{BC} - 180 \text{ ft-lb} = 0; \text{ So } T_{BC} = 180 \text{ ft-lb}$$

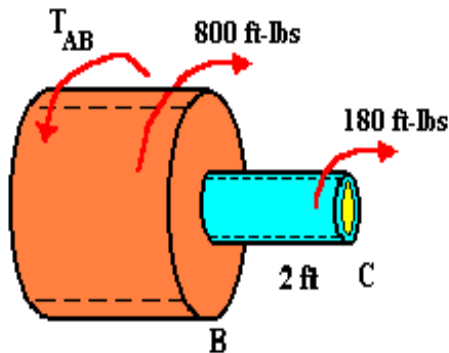
$$\tau_{AB} = Tr / J = (180 \text{ ft-lb})(12 \text{ in/ft})(.5 \text{ in}) / [3.1416 * [(1 \text{ in})^4 - (.8 \text{ in})^4] / 32] = 18,600 \text{ psi}$$



II:

$$T = T_{AB} - 800 \text{ ft-lb} - 180 \text{ ft-lb} = 0; \text{ So } T_{AB} = 980 \text{ ft-lb}$$

$$\tau_{AB} = Tr / J = (980 \text{ ft-lb})(12 \text{ in/ft})(1.25 \text{ in}) / [3.1416 * [(2.5 \text{ in})^4 - (2 \text{ in})^4] / 32] = 6,490 \text{ psi}$$



$$\phi_{AB} = TL/JG = (980 \text{ ft-lb})(12 \text{ in./ft})(3 \text{ ft})(12 \text{ in/ft}) / [(3.1416 * [(2.5 \text{ in})^4 - (2 \text{ in})^4] / 32)(6 \times 10^6 \text{ lb/in}^2)] = .0312 \text{ radians (cw)}$$

$$\phi_{BC} = TL/JG = (180 \text{ ft-lb})(12 \text{ in./ft})(2 \text{ ft})(12 \text{ in/ft}) / [(3.1416 * [(1 \text{ in})^4 - (.8 \text{ in})^4] / 32)(6 \times 10^6 \text{ lb/in}^2)] = .0149 \text{ radians (cw)}$$

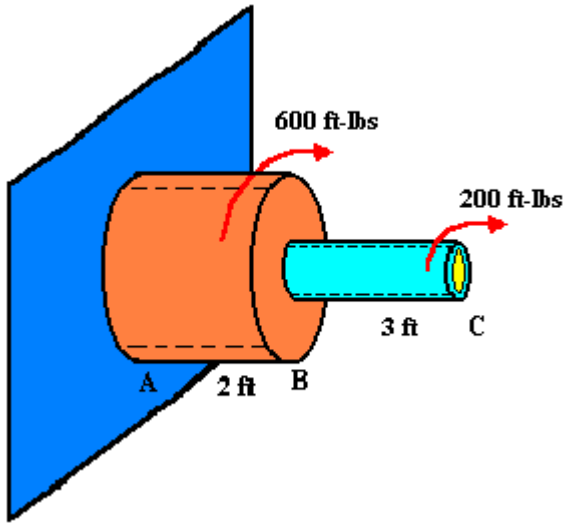
$$\phi_{\text{Total}} = -\phi_{AB} - \phi_{BC} = -.0461 \text{ radians (cw)}$$

### Örnek

**Çeliğin kayma modülü =  $12 \times 10^6 \text{ lb/in}^2$ .**

**Pirincin kayma modülü =  $6 \times 10^6 \text{ lb/in}^2$ .**

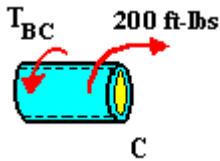
Dışçap AB = 3.5 in, iç çap AB = 2.8 in  
 dışçap BC = 2 in , iççap BC = 1.6 in



I:

$T = T_{BC} - 200 \text{ ft-lb} = 0$ ; So  $T_{BC} = 200 \text{ ft-lb}$

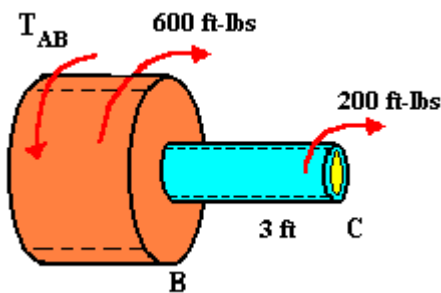
$\tau_{AB} = Tr / J = (200 \text{ ft-lb})(12 \text{ in/ft})(1 \text{ in}) / [3.1416 * [(2 \text{ in})^4 - (1.6 \text{ in})^4] / 32] = 2,600 \text{ psi}$



II:

$T = T_{AB} - 600 \text{ ft-lb} - 200 \text{ ft-lb} = 0$ ; So  $T_{AB} = 800 \text{ ft-lb}$

$\tau_{AB} = Tr / J = (800 \text{ ft-lb})(12 \text{ in/ft})(1.75 \text{ in}) / [3.1416 * [(3.5 \text{ in})^4 - (2.8 \text{ in})^4] / 32] = 1,150 \text{ psi}$



$\phi_{AB} = TL/JG = (800 \text{ ft-lb})(12 \text{ in./ft})(2 \text{ ft})(12 \text{ in/ft}) / [(3.1416 * [(3.5 \text{ in})^4 - (2.8 \text{ in})^4] / 32)(6 \times 10^6 \text{ lb/in}^2)] = .0044 \text{ radians (cw)}$

$\phi_{BC} = TL/JG = (200 \text{ ft-lb})(12 \text{ in./ft})(3 \text{ ft})(12 \text{ in/ft}) / [(3.1416 * [(2 \text{ in})^4 - (1.6 \text{ in})^4] / 32)(6 \times 10^6 \text{ lb/in}^2)] = .0155 \text{ radians (cw)}$

$\phi_{\text{Total}} = -\phi_{AB} - \phi_{BC} = -.0199 \text{ radians (cw)}$

Çapı 2D Çapı D

A B C

60cm 40cm

2Mb Mb

AB iki malzemeli BC tek malzemeli

1 2

Şekildeki burulma çubuğunda AB arasında iç çap D, dış çap 2D olmak üzere iki malzemeli, BC arasının çapı D ve tek malzemeli olduğuna göre emniyetle taşınabilecek  $M_b$  burulma momentini bulunuz.  $D=4\text{cm}$ ,  $\tau_{em}=8\text{kN/cm}^2$ ,  $G_1=800\text{kN/cm}^2$ ,  $R=D/2$ ,  $G_2=2*G_1$ ,  $\varphi=w*L$

$$I_0 = \frac{\pi D^4}{32}, \tau_{\max} = \frac{M_b}{I_0} R, \varphi = \frac{M_b L}{GI_0}$$

Çapı 2D Çapı D

A B C

60cm 40cm

2Mb Mb

Şekildeki burulma çubuğunda AB arasının çapı 2D, BC arasının çapı D olduğuna göre emniyetle taşınabilecek  $M_b$  burulma momentini bulunuz.  $D=4\text{cm}$ ,  $\tau_{em}=8\text{kN/cm}^2$ ,  $G=800\text{kN/cm}^2$ ,  $R=D/2$

$$I_0 = \frac{\pi D^4}{32}, \tau_{\max} = \frac{M_b}{I_0} R, \varphi = \frac{M_b L}{GI_0}$$

Şekildeki burulma çubuğunun moment diyagramı hangisidir.

8Nm 4Nm 6Nm

A B C D

A) 4 6

B) 8 10 6

C) 2 10 6

D) 8 4 6

1 2

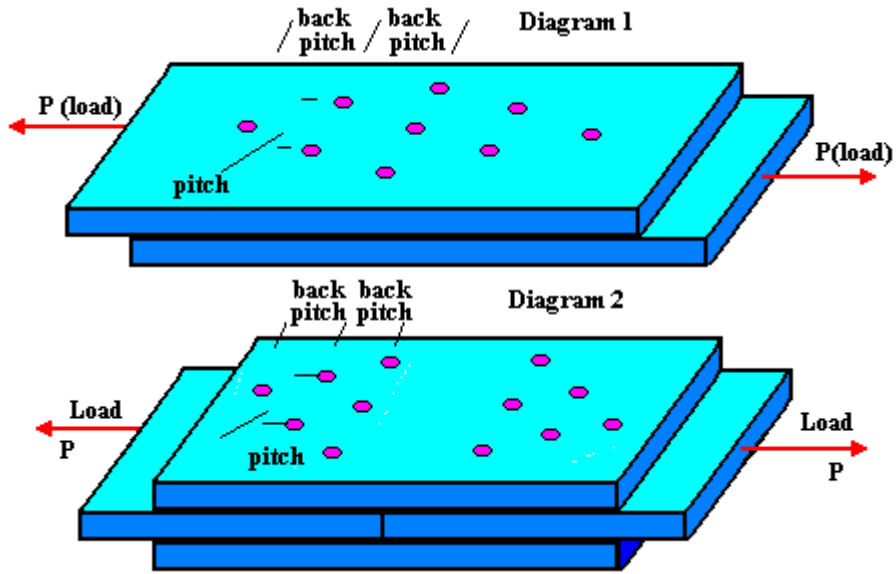
Şekildeki iki malzemeden yapılmış olan burulma çubuğuna  $M_b$  burulma momentini etkimektedir. İç çap D, dış çap 2D olmak üzere bu iki malzemenin taşıyabilecekleri momentler arasındaki ilişki nedir.  $G_1=G_2$

$$I_0 = \frac{\pi D^4}{32}, \tau_{\max} = \frac{M_b}{I_0} R, \varphi = \frac{M_b L}{GI_0}$$

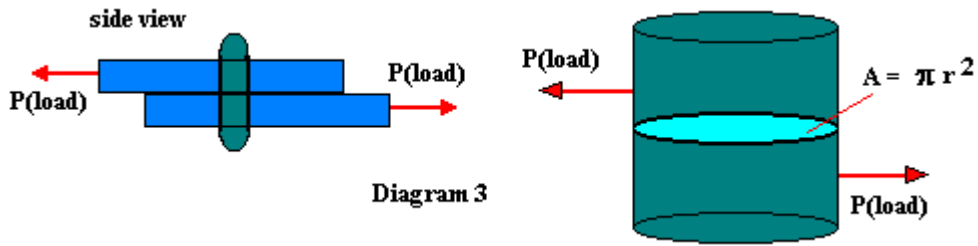
A)  $M_1=M_2$ , B)  $M_1=I_1*M_2/I_2$  C)  $M_1=2M_2$  D)  $M_1= M_2/2$

## KESME KUVVETİ

2.



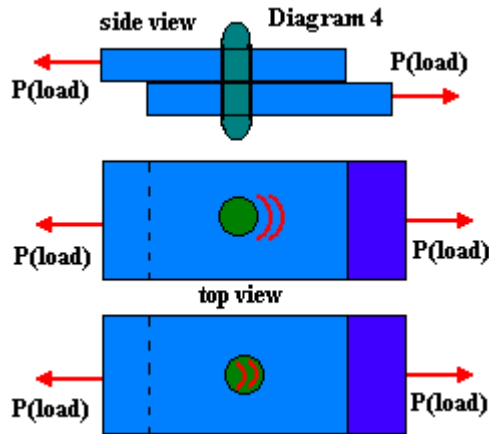
**1. Perçin Kesme kuvveti:**



$P_{\text{rivet shear}} = N (\pi \cdot d^2/4) \tau_{\text{all}}$   
 $N = \text{perçin sayısı}$

$A = \pi \cdot d^2/4$  (or  $\pi \cdot r^2$ )

**2. Perçin /levha kontrolu**



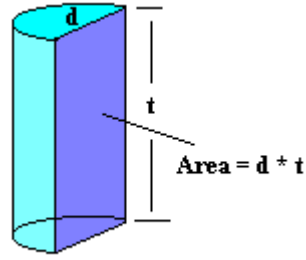


Diagram 5

$$P_{\text{bearing}} = N (d \cdot t) \sigma_{\text{all}}$$

**N** = Perçin sayısı

**d** = perçin çapı

**t** = plak kalınlığı

### 3. Plak:

$$A = w \cdot t$$

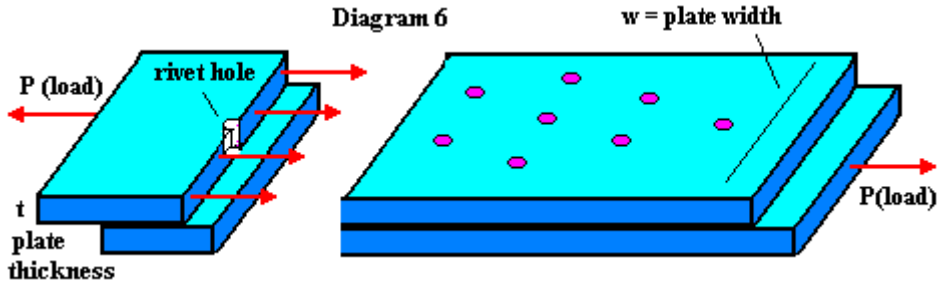


Diagram 6

$w = \text{plate width}$

$$P_{\text{row1}} = (w - n d) t \sigma_{\text{all}}$$

**w** = plak genişliği

**n** = bir sıradaki perçin sayısı (örneğin 1. sırada 1 perçin)

## Örnek 1

$d = 5/8$  inch.

genişlik 6 inch ve kalınlık 1/2 inch. Emniyet gerilmeler:

perçinde:  $\sigma = 16,000 \text{ lb/in}^2$ ,  $\sigma_t = 22,000 \text{ lb/in}^2$ ,  $\sigma_c = 24,000 \text{ lb/in}^2$

Plakta:  $\sigma = 14,000 \text{ lb/in}^2$ ,  $\sigma_t = 20,000 \text{ lb/in}^2$ ,  $\sigma_c = 23,000 \text{ lb/in}^2$

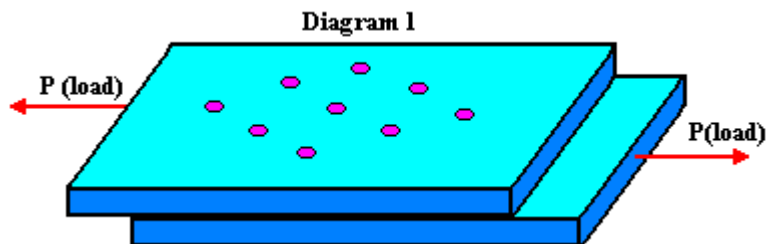


Diagram 1

$$P = N (\pi * d^2/4) \tau = (9 \text{ rivet areas}) * [3.1416 * (5/8)^2/4] * 16,000 \text{ lb/in}^2 = 44,200 \text{ lb.}$$

$$P_{\text{bearing}} = N (d * t) \sigma_{\text{all}} = (9 \text{ rivets}) * (5/8" * 1/2") * (23,000 \text{ lb/in}^2) = 64,700 \text{ lb.}$$

**Plak 1. sıra:**

$$P_{\text{row1}} = (w - n d) t \sigma_{\text{all}} = (6" - 1 * 5/8") * (1/2") * (20,000 \text{ lb/in}^2) = 53,750 \text{ lb.}$$

**Plak 2.sıra**

$$(8/9)P_{\text{row2}} = (w - n d) t \sigma_{\text{all}} = (6" - 2 * 5/8") * (1/2") * (20,000 \text{ lb/in}^2) = 47,500 \text{ lb.,}$$

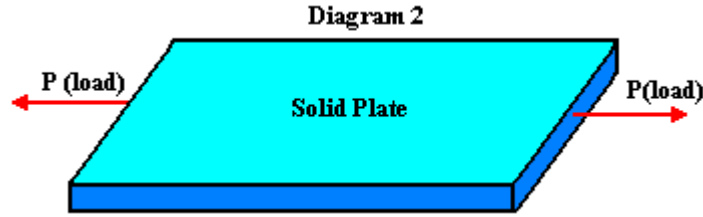
$$P_{\text{row2}} = (9/8) * 47,500 \text{ lb.} = 53,400 \text{ lb.}$$

**Plak 3 sıra:**

$$(6/9)P_{\text{row3}} = (w - n d) t \sigma_{\text{all}} = (6" - 3 * 5/8") * (1/2") * (20,000 \text{ lb/in}^2) = 41,250 \text{ lb.,}$$

$$P_{\text{row3}} = (9/6) * 41,250 \text{ lb.} = 61,900 \text{ lb.}$$

$$P_{\text{plate}} = (w * t) * \sigma_{\text{all}} = (6" * 1/2") * 20,000 \text{ lb/in}^2 = 60,000 \text{ lb.}$$



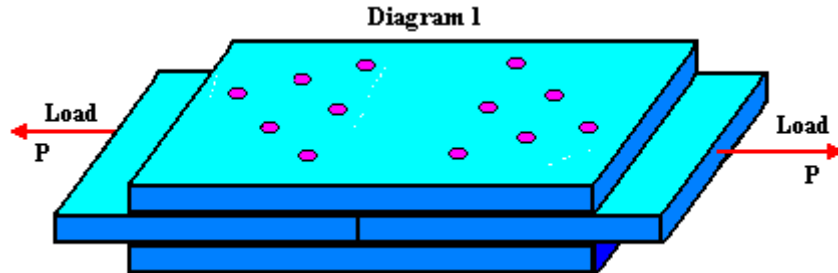
$$\text{Efficiency} = \text{Joint Strength} / \text{Plate Strength} = 44,200 \text{ lb.} / 60,000 \text{ lb.} = .737 = 73.7 \%$$

## Örnek 2

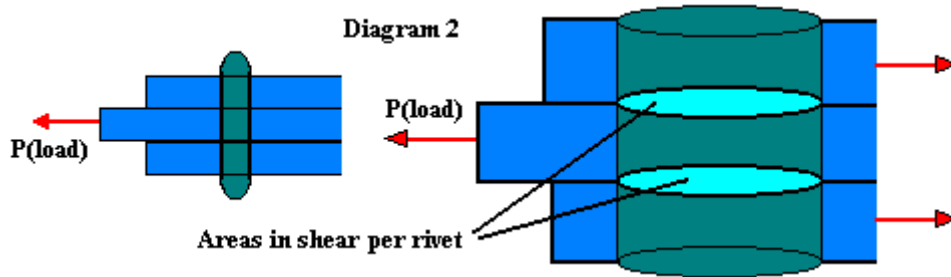
D= 3/4 inch. genişlik 6 inch ve kalınlık 1/2 inch. Emniyet gerilmeleri:

Perçinde:  $\tau = 18,000 \text{ lb/in}^2$ ,  $\sigma_t = 22,000 \text{ lb/in}^2$ ,  $\sigma_c = 24,000 \text{ lb/in}^2$

Plakta:  $\tau = 16,000 \text{ lb/in}^2$ ,  $\sigma_t = 21,000 \text{ lb/in}^2$ ,  $\sigma_c = 22,000 \text{ lb/in}^2$



$$P = N (\pi * d^2/4) \tau = (12 \text{ rivet areas}) * [3.1416 * (3/4)^2/4] * 18,000 \text{ lb/in}^2 = 95,400 \text{ lb.}$$



$$P_{\text{bearing}} = N (d \cdot t) \sigma_{\text{all}} = (6 \text{ rivets}) * (3/4" * 1/2") * (22,000 \text{ lb/in}^2) = 49,500 \text{ lb.}$$

1. SIRA:

$$P_{\text{row1}} = (w - n d) t \sigma_{\text{all}} = (6" - 1 * 3/4") * (1/2") * (21,000 \text{ lb/in}^2) = 55,100 \text{ lb.}$$

2 sira:

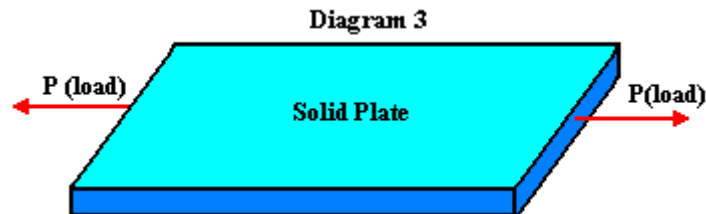
$$(5/6)P_{\text{row2}} = (w - n d) t \sigma_{\text{all}} = (6" - 2 * 3/4") * (1/2") * (21,000 \text{ lb/in}^2) = 47,250 \text{ lb.,}$$

$$P_{\text{row2}} = (6/5) * 47,500 \text{ lb.} = 56,700 \text{ lb.}$$

3. SIRA:

$$(3/6)P_{\text{row2}} = (w - n d) t \sigma_{\text{all}} = (6" - 3 * 3/4") * (1/2") * (21,000 \text{ lb/in}^2) = 39,400 \text{ lb.,}$$

$$P_{\text{row2}} = (6/3) * 39,400 \text{ lb.} = 78,800 \text{ lb.}$$

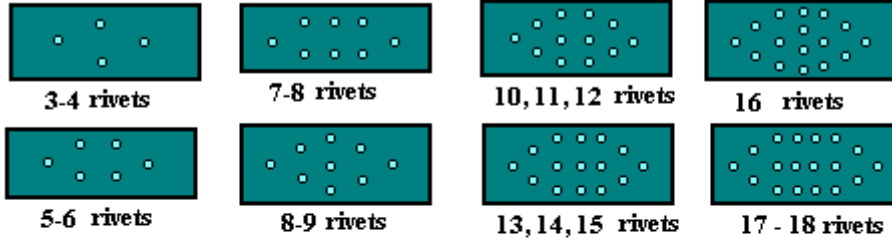


$$P_{\text{plate}} = (w * t) * \sigma_{\text{all}} = (6" * 1/2") * 21,000 \text{ lb/in}^2 = 63,000 \text{ lb.}$$

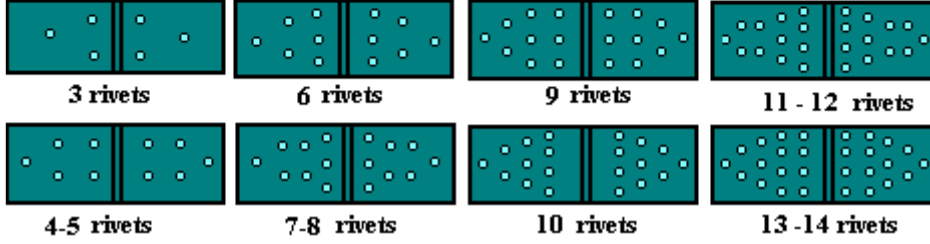
This is the plate  
**Efficiency = Joint Strength / Plate Strength = 49,500 lb. / 63,000 lb. = .786**  
**= 78.6 %.**

## Perçin düzenekleri

Diagram 1 Lap Joint Patterns



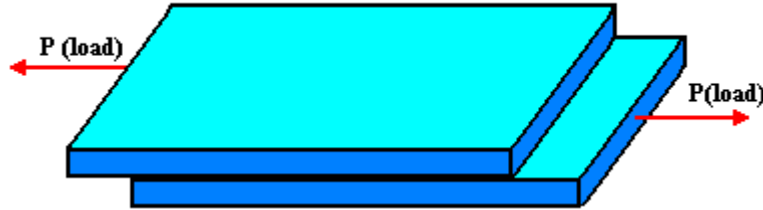
Butt Joint Patterns



### Örnek

Genişlik 6 inch, kalınlık 1/2 inch. çap 3/4 inch.

Diagram 2



Perçinde:  $\tau = 16,000 \text{ lb./in}^2$ ,  $\sigma_t = 22,000 \text{ lb./in}^2$ ,  $\sigma_c = 25,000 \text{ lb./in}^2$

Plakta:  $\tau = 17,000 \text{ lb./in}^2$ ,  $\sigma_t = 20,000 \text{ lb./in}^2$ ,  $\sigma_c = 24,000 \text{ lb./in}^2$

$$P_{\text{row1}} = (w - n d)t \sigma_{\text{all}}$$

$$w = 6$$

$n$  = perçin sayısı (bir sırada , 1 perçin)

$$d = 3/4 \text{ inch}$$

$$t = 1/2 \text{ inch}$$

$$\sigma_{\text{all}} = 20,000 \text{ lb./in}^2$$

$$P_{\text{row1}} = (6" - 1 * 3/4") * (1/2") * 20,000 \text{ lb./in}^2 = 52,500 \text{ lb.}$$

$$P_{\text{rivet shear}} = N (\pi * d^2/4) \tau_{\text{all}}$$

$$N = 1$$

$$d = 3/4 \text{ inch}$$

$$\tau_{\text{all}} = 16,000 \text{ lb./in}^2$$

$$P_{\text{rivet shear}} = 1 [3.1416 * (3/4")^2/4] * 16,000 \text{ lb./in}^2 = 7070 \text{ lb./rivet}$$

$$P_{\text{bearing}} = N (d \cdot t) \sigma_{\text{all}}$$

$$N = 1$$

$$d = 3/4 \text{ inch}$$

$$t = 1/2 \text{ inch}$$

$$\sigma_{\text{all}} = 24,000 \text{ lb./in}^2$$

$$P_{\text{bearing}} = 1 * [(3/4") * (1/2")] * 24,000 \text{ lb./in}^2 = 9000 \text{ lb./rivet}$$

# Perçinler = 52,500 lb. / 7070 lb./perçin = 7.43 ; # 8 perçin seçilir

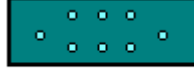


Diagram 3

$$P_{\text{shear}} = 8 * 7070 \text{ lb./rivet} = 56,560 \text{ lb.}$$

$$P_{\text{bearing}} = 8 * 9000 \text{ lb./rivet} = 72,000 \text{ lb.}$$

$$P_{\text{row1}} = (6" - 1 * 3/4") * (1/2") * 20,000 \text{ lb./in}^2 = 52,500 \text{ lb.}$$

$$(7/8)P_{\text{row2}} = (6" - 2 * 3/4") * (1/2") * 20,000 \text{ lb./in}^2 = 45,000 \text{ lb.}, \text{ and then}$$

$$P_{\text{row2}} = (8/7) 45,000 \text{ lb.} = 51,400 \text{ lb.}$$

$$(5/8)P_{\text{row3}} = (6" - 2 * 3/4") * (1/2") * 20,000 \text{ lb./in}^2 = 45,000 \text{ lb.}, \text{ and then}$$

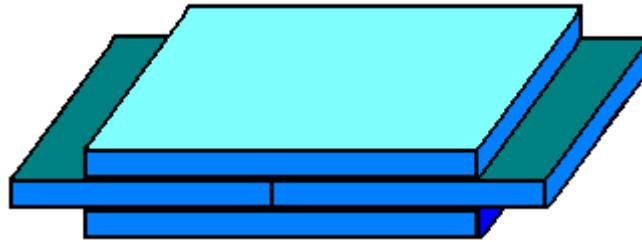
$$P_{\text{row3}} = (8/5) 45,000 \text{ lb.} = 72,000 \text{ lb.}$$

Strength of the Joint is 51,400 lb. (plate tearing row 2)

Efficiency = Joint Strength / Plate Strength = 51,400 lb./((6"\*1/2")\*20,000 lb./in<sup>2</sup>) = .86 =86%

## Örnek perçin seçimi

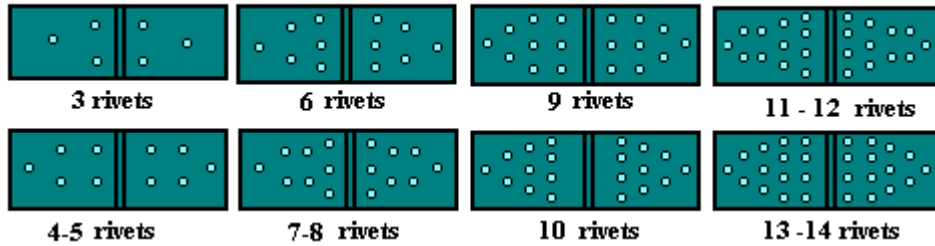
Diagram 1



$$\text{perçin: } \tau = 15,000 \text{ lb/in}^2, \sigma_t = 24,000 \text{ lb/in}^2, \sigma_c = 26,000 \text{ lb/in}^2$$

$$\text{Plak: } \tau = 16,000 \text{ lb/in}^2, \sigma_t = 22,000 \text{ lb/in}^2, \sigma_c = 24,000 \text{ lb/in}^2$$

Diagram 2 Butt Joint Patterns



$$P_{\text{row1}} = (w - n d)t \sigma_{\text{all}} ,$$

$$w = 7 \text{ inches}$$

$$n = \text{bir sıradaki perçin sayısı}$$

$$d = 5/8 \text{ inch}$$

$$t = 3/4$$

$$\sigma_{\text{all}} = 22,000 \text{ lb/in}^2,$$

$$P_{\text{row1}} = (7" - 1 * 5/8") * (3/4") * 22,000 \text{ lb/in}^2 = 105,200 \text{ lb.}$$

$$P_{\text{rivet shear}} = N (\pi * d^2/4) \tau_{\text{all}}$$

$$N = 2$$

$$d = 5/8 \text{ inch}$$

$$\tau_{\text{all}} = 15,000 \text{ lb/in}^2$$

$$P_{\text{rivet shear}} = 2 [3.1416 * (5/8")^2/4] * 15,000 \text{ lb/in}^2 = 9200 \text{ lb./rivet}$$

$$P_{\text{bearing}} = N (d*t) \sigma_{\text{all}} , \text{ where}$$

$$N = 1$$

$$d = 5/8 \text{ inch}$$

$$t = 3/4 \text{ inch}$$

$$\sigma_{\text{all}} = 24,000 \text{ lb/in}^2$$

$$P_{\text{bearing}} = 1 * [(5/8") * (3/4")] * 24,000 \text{ lb/in}^2 = 11,250 \text{ lb./rivet}$$

$$\# \text{ Perçin} = 105,200 \text{ lb.} / 9200 \text{ lb./perçin} = 11.43 ; \# \text{ seçilen} = 12$$

Diagram 3



11 - 12 rivets

$$P_{\text{shear}} = 12 * 9200 \text{ lb./rivet} = 110,400 \text{ lb.}$$

$$P_{\text{bearing}} = 12 * 11,250 \text{ lb./rivet} = 135,000 \text{ lb.}$$

$$P_{\text{row1}} = (7" - 1 * 5/8") * (3/4") * 22,000 \text{ lb/in}^2 = 105,200 \text{ lb.}$$

$$(11/12)P_{\text{row2}} = (7" - 2 * 5/8") * (3/4") * 22,000 \text{ lb/in}^2 = 94,875 \text{ lb.}, \text{ and then}$$

$$P_{\text{row2}} = (12/11) 94,875 \text{ lb.} = 103,500 \text{ lb.}$$

$$(9/12)P_{\text{row3}} = (7" - 2 * 5/8") * (3/4") * 22,000 \text{ lb/in}^2 = 94,875 \text{ lb.}, \text{ and then}$$

$$P_{\text{row3}} = (12/9) 94,875 \text{ lb.} = 126,500 \text{ lb.}$$

## Kaynaklı birleşimler

Diagram 1a

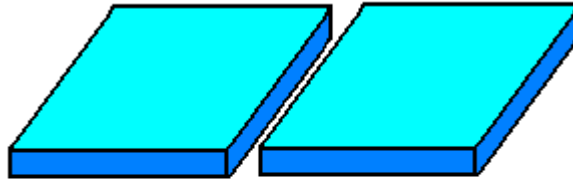
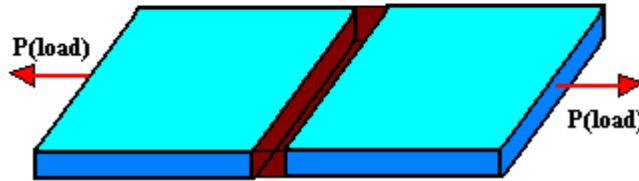


Diagram 1b



$$P_{\text{weld}} = (w * t) * \sigma_{\text{tension}}$$

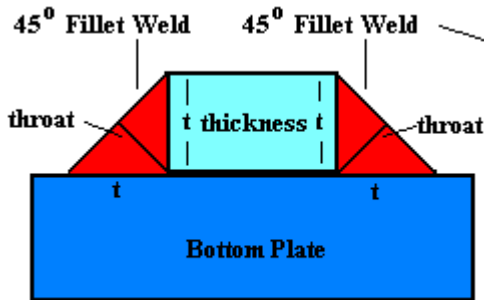


Diagram 2a

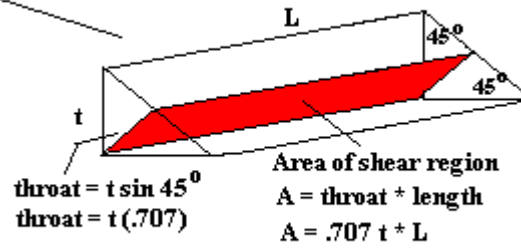


Diagram 2b

$$P_{\text{weld}} = \text{Area} * \tau_{\text{all}} = (\text{throat} * \text{length}) * \tau_{\text{all}} = (t \sin 45^\circ * L) * \tau_{\text{all}}$$

$$P_{\text{weld}} = (.707 t * L) * \tau_{\text{all}}$$

t = plak kalınlığı

L = kaynak uzunluğu

$\tau_{\text{all}}$  = kaynak malzemesinin kayma gerilmesi

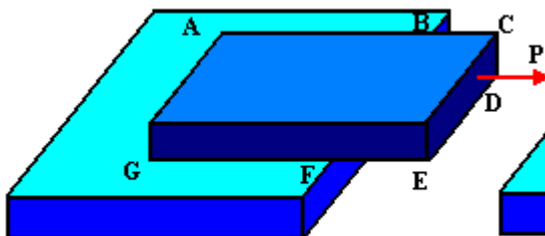


Diagram 3a

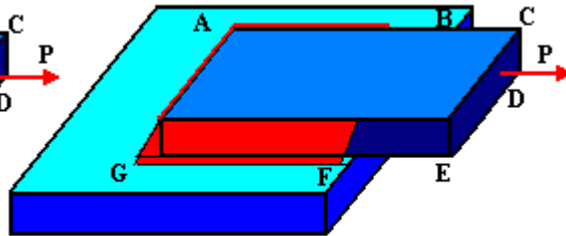
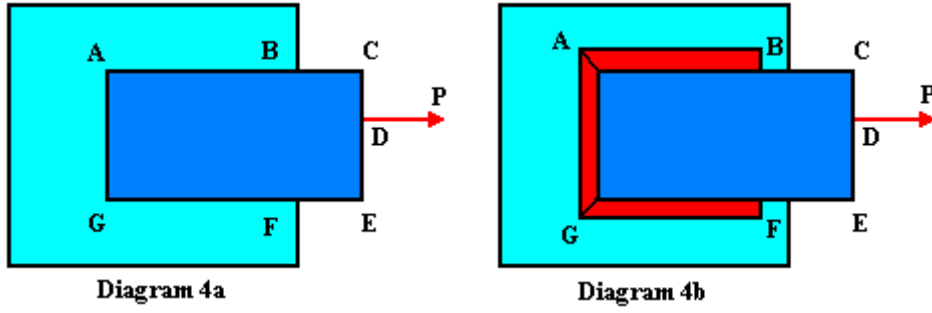
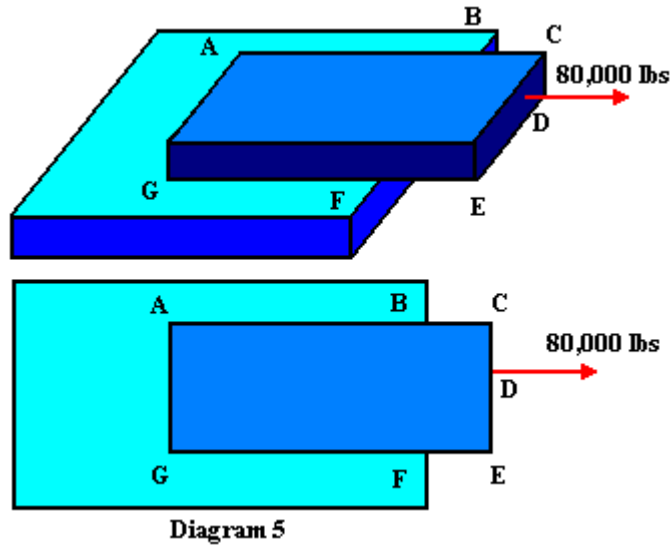


Diagram 3b



Örnek



Kaynak malzemesi:  $\tau = 14,000 \text{ lb/in}^2$  ;  $\sigma_t = 24,000 \text{ lb/in}^2$

Plak:  $\tau = 15,000 \text{ lb/in}^2$  ;  $\sigma_t = 30,000 \text{ lb/in}^2$

Boyutlar: AB = GF = 20 inches; CD = 3 inc; DE = 5 inc

**Çözüm:**

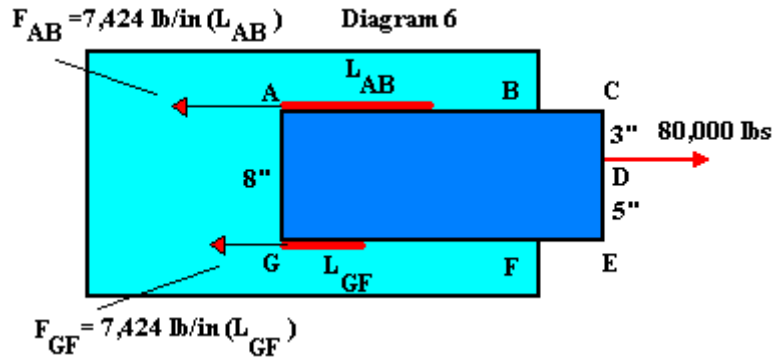
$$P_{\text{weld}} = (.707 t * L) * \tau_{\text{all}}$$

$$80,000 \text{ lb} = (.707 * 3/4" * L) * 14,000 \text{ lb/in}^2 = (7,424 \text{ lb./in.})L;$$

$$L = 80,000 \text{ lb.}/(7,424 \text{ lb./in.}) = 10.78 \text{ inches.}$$

$$F_{AB} = (7,424 \text{ lb./in.}) * L_{AB}$$

$$F_{GF} = (7,424 \text{ lb./in.}) * L_{GF}$$



Toplam kuvvet  $80,000 \text{ lb.} - (7,424 \text{ lb./in.}) * L_{AB} - (7,424 \text{ lb./in.}) * L_{GF} = 0$   
 Toplam moment about G:  $-80,000 \text{ lb.} * (5") + (7,424 \text{ lb./in.}) * L_{AB} * (8") = 0$   
 $L_{AB} = 6.73 \text{ inches,}$

$L_{GF} = 10.78" - 6.73" = 4.05"$

$P_{\text{plate}} = (w * t) \sigma t.$

$P_{\text{weld}} = (.707 t * L) * \tau_{\text{all}} = P_{\text{plate}} = (w * t) \sigma t, \text{ or}$   
 $(.707 t * L) * \tau_{\text{all}} = (w * t) \sigma t, \text{ and then}$   
 $(.707 * 3/4" * L) * 14,000 \text{ lb/in}^2 = (8" * 3/4") 30,000 \text{ lb/in}^2,$   
 $L = 24.25 \text{ inches}$

## Örnek 2

$T = .5 \text{ inch, } w = 10 \text{ inches}$

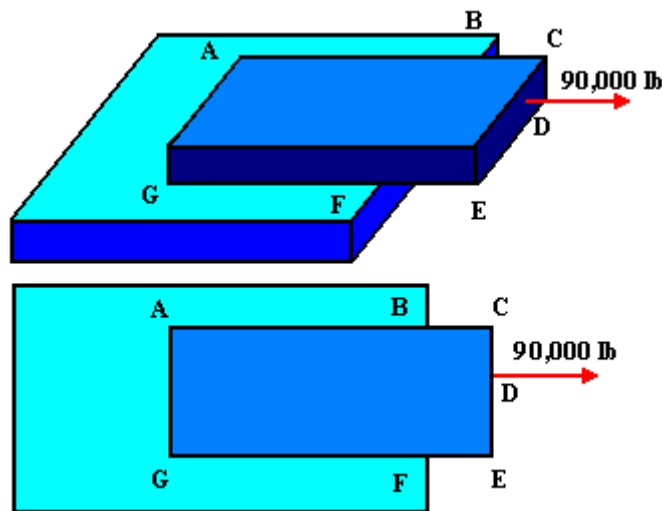


Diagram 1

Kaynakta:  $\tau = 15,000 \text{ lb/in}^2 ; \sigma t = 24,000 \text{ lb/in}^2$   
 Plakta:  $\tau = 14,000 \text{ lb/in}^2 ; \sigma t = 28,000 \text{ lb/in}^2$   
 $AB = GF = 20 \text{ inches; } CD = 4 \text{ inches; } DE = 6 \text{ inches}$

**Çözüm:**

$$P_{\text{weld}} = (.707 t * L) * \tau_{\text{all}}, \text{ or}$$

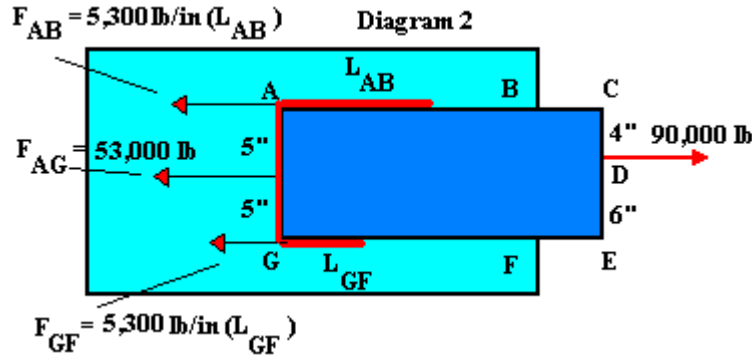
$$90,000 \text{ lb} = (.707 * .5" * L) * 15,000 \text{ lb/in}^2 = (5,300 \text{ lb./in.}) * L;$$

$$L = 90,000 \text{ lb.} / (5,300 \text{ lb./in.}) = 16.98 \text{ inches.}$$

$$F_{AB} = (5,300 \text{ lb./in.}) * L_{AB},$$

$$F_{GF} = (5,300 \text{ lb./in.}) * L_{GF},$$

$$F_{AG} = 5,300 \text{ lb/in} * 10" = 53,000 \text{ lb.}$$



$$\text{Toplam kuvvet: } 90,000 \text{ lb.} - (5,300 \text{ lb./in.}) * L_{AB} - (5,300 \text{ lb./in.}) * L_{GF} - 53,000 \text{ lb.} = 0$$

$$\text{Toplam moment about G: } -90,000 \text{ lb.} * (6") + (5,300 \text{ lb./in.}) * L_{AB} * (10") + 53,000 \text{ lb.} * 5" = 0$$

$$L_{AB} = 5.19 \text{ inches,}$$

$$L_{AB} + L_{GF} + 10" = 16.98 \text{ inches.}$$

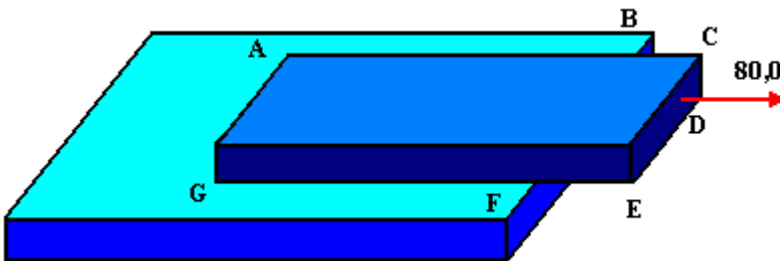
$$L_{GF} = 16.98" - 5.19" - 10" = 1.79"$$

$$P_{\text{plate}} = (w * t) * \sigma_t.$$

$$P_{\text{weld}} = (.707 t * L) * \tau_{\text{all}} = P_{\text{plate}} = (w * t) * \sigma_t, \text{ or}$$

$$(.707 t * L) * \tau_{\text{all}} = (w * t) * \sigma_t, \text{ and then}$$

$$\begin{aligned} & (.707 * .5" * L) * 15,000 \text{ lb/in}^2 \\ & = (10" * .5") * 28,000 \text{ lb/in}^2, \\ & L = 26.4 \text{ inches} \end{aligned}$$



**Örnek**

Üst plaka  $t = .5 \text{ inch}, w = 8$

inc

Kaynak:  $\tau = 12,000 \text{ psi}, \sigma_t = 24,000 \text{ psi}$

Plaka:  $\tau = 15,000 \text{ psi}, \sigma_t = 30,000 \text{ psi}$

AB = GF = 20 inches:

CD = 3 inches: DE = 5 inches

**Çözüm:**

$$P_{\text{weld}} = (.707 t * L) * \tau_{\text{all}}, \text{ or}$$

$$80,000 \text{ lb} = (.707 * .5" * L) * 12,000 \text{ lb/in}^2 = (4,242 \text{ lb./in.}) * L; \text{ then solving for } L$$

$$L = 80,000 \text{ lb.} / (4,242 \text{ lb./in.}) = 18.86 \text{ inches.}$$

$$F_{AB} = (4,242 \text{ lb./in.}) * L_{AB}, F_{GF} = (4,242 \text{ lb./in.}) * L_{GF}, \text{ and } F_{AG} = 4,242 \text{ lb/in} * 8" = 33,936 \text{ lb. as shown in Diagram 2. We now apply static equilibrium}$$

conditions to the top plate:

$$\text{Sum of Forces: } 80,000 \text{ lb.} - (4,242 \text{ lb./in.}) * L_{AB} - (4,242 \text{ lb./in.}) * L_{GF} - 33,936 \text{ lb.} = 0$$

$$\text{Sum of Torque about G: } -80,000 \text{ lb.} * (5") + (4,242 \text{ lb./in.}) * L_{AB} * (8") + 33,936 \text{ lb.} * 4" = 0$$

$$L_{AB} = 7.79 \text{ inches,}$$

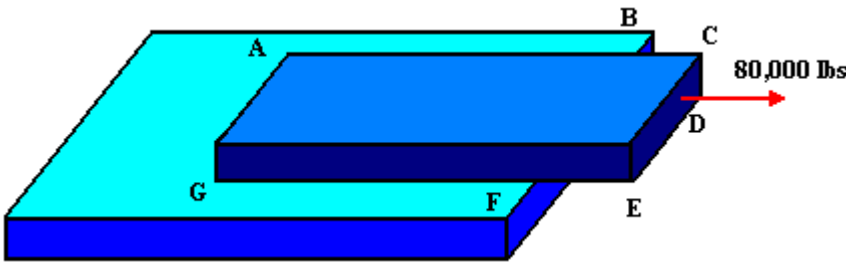
$$L_{GF} = 18.86" - 7.79" - 8" = 3.07"$$

$$P_{\text{weld}} = (.707 t * L) * \tau_{\text{all}} = P_{\text{plate}} = (w * t) * \sigma_t, \text{ or}$$

$$(.707 t * L) * \tau_{\text{all}} = (w * t) * \sigma_t, \text{ and then}$$

$$(.707 * .5" * L) * 12,000 \text{ lb/in}^2 = (8" * .5") 30,000 \text{ lb/in}^2,$$

$$L = 28.29 \text{ inches}$$



### Örnek

Üstteki plaka kalınlığı .7 inch genişliği 6 inch, 45° açı ile kaynaklanıyor.

Kaynak uzunluğunu bulunuz:

kaynak malzemesi:  $\tau = 16,000$  psi,  $\sigma_t = 30,000$  psi

Plak Malzemesi:  $\tau = 14,000$  psi,  $\sigma_t = 28,000$  psi

Boyutlar:

AB = GF = 30 inches:

CD = 2 inches: DE = 4 inches

**Çözüm:**

$$P_{\text{weld}} = (.707 t * L) * \tau_{\text{all}},$$

$$80,000 \text{ lb} = (.707 * .7" * L) * 16,000 \text{ lb/in}^2 = (7,918 \text{ lb./in.}) * L;$$

$$L = 80,000 \text{ lb.} / (7,918 \text{ lb./in.}) = 10.1 \text{ inches.}$$

$$F_{AB} = (7,918 \text{ lb./in.}) * L_{AB},$$

$$F_{GF} = (7,918 \text{ lb./in.}) * L_{GF},$$

$$F_{AG} = 7,918 \text{ lb/in} * 6" = 47,510 \text{ lb.}$$

$$\text{Kuvvet dengesi: } 80,000 \text{ lb.} - (7,918 \text{ lb./in.}) * L_{AB} - (7,918 \text{ lb./in.}) * L_{GF} -$$

$$47,510 \text{ lb.} = 0$$

$$\text{Moment dengesi about G: } -80,000 \text{ lb.} * (4") + (7,918 \text{ lb./in.}) * L_{AB} * (6") + 47,510$$

$$\text{lb.} * 3" = 0$$

$$L_{AB} = 3.74 \text{ inches,}$$

$$L_{GF} = 10.1" - 3.74" - 6" = .36"$$

$$P_{\text{weld}} = (.707 t * L) * \tau_{\text{all}} = P_{\text{plate}} = (w * t) * \sigma_t, \text{ or}$$

$$(.707 t * L) * \tau_{\text{all}} = (w * t) * \sigma_t,$$

$$(.707 \cdot .7" \cdot L) \cdot 16,000 \text{ lb/in}^2 = (6" \cdot .7" ) 28,000 \text{ lb/in}^2 ,$$

$$L = 14.85 \text{ inches}$$

