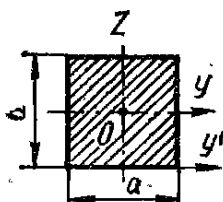
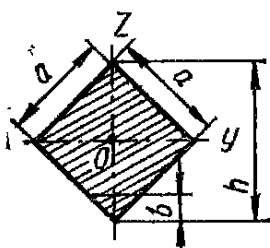
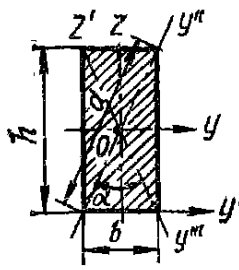
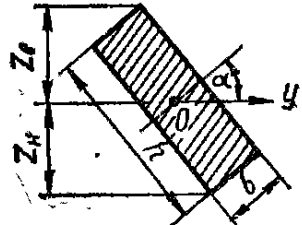
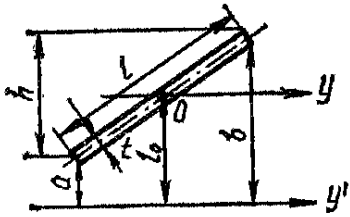


Приложение 1

ГЕОМЕТРИЧЕСКИЕ ХАРАКТЕРИСТИКИ ПРИ РАСТЯЖЕНИИ — СЖАТИИ И ИЗГИБЕ

Таблица 1. Сплошные сечения

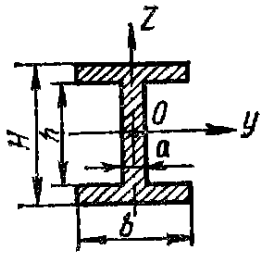
	<p>Квадрат</p> $F = a^2; J_y = J_z = \frac{a^4}{12}; J_{y'} = \frac{a^4}{3} = \frac{a^2 F}{3};$ $J_{\rho o} = \frac{a^4}{6}; W_y = \frac{a^3}{6}; i_y = i_z = \frac{a}{\sqrt{12}} = 0,289a$
	<p>Квадрат на ребро</p> $F = a^2; h = a\sqrt{2}; J_y = J_z = \frac{a^4}{12}; W_y = 0,118a^3,$ <p>При срезке верхнего и нижнего углов W_y увеличивается. Наибольший момент сопротивления при срезке углов</p> $W_{y\text{ср}} = 0,124h^3 \text{ при } b = \frac{h}{18}$
	<p>Прямоугольник</p> $F = bh; J_y = \frac{bh^3}{12}; J_z = \frac{hb^3}{12}; J_{y'} = \frac{bh^3}{3}; J_{z'} =$ $= \frac{b^3h}{3}; J_{y'z'} = \frac{h^2b^2}{4}; J_{y''} = J_{y'''} = \frac{d^4 \sin \alpha}{48};$ $J_{\rho o} = \frac{bh}{12} (b^2 + h^2); W_y = \frac{bh^2}{6}; W_z = \frac{b^2h}{6};$ $i_y = 0,289h; i_z = 0,289b$
	<p>Прямоугольник, повернутый на угол α</p> $F = bh; z_B = z_H = \frac{1}{2} (h \cos \alpha + b \sin \alpha);$ $J_y = \frac{bh}{12} (h^2 \cos^2 \alpha + b^2 \sin^2 \alpha);$ $W_y = \frac{bh}{6} \cdot \frac{h^2 \cos^2 \alpha + b^2 \sin^2 \alpha}{h \cos \alpha + b \sin \alpha};$ $i_y = 0,289 \sqrt{h^2 \cos^2 \alpha + b^2 \sin^2 \alpha}$



Узкая прямоугольная полоса

$$F = tl; z_0 = \frac{a+b}{2}; J_y = \frac{tlh^2}{12};$$

$$J_{y'} = \frac{tl}{3} (a^2 + ab + b^2)$$



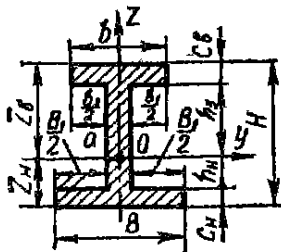
Симметричный двутавр, составленный из прямоугольников

$$F = ah + b(H - h);$$

$$J_y = \frac{ah^3}{12} + \frac{b}{12} (H^3 - h^3); J_z = \frac{a^3h}{12} + \frac{b^3}{12} (H - h);$$

$$W_y = \frac{b}{6H} (H^3 - h^3) + \frac{ah^3}{6H};$$

$$W_z = \frac{a^3h}{6b} + \frac{b^2}{6} (H - h)$$

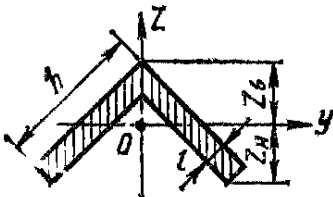


Несимметричный двутавр, составленный из прямоугольников

$$F = bc_B + a(h_H + h_B) + Bc_H; b_1 = b - a; B_1 = B - a;$$

$$z_H = \frac{aH^2 + B_1c_H^2 + b_1c_B(2H - c_B)}{2(aH + B_1c_H + b_1c_B)}; z_B = H - z_H;$$

$$J_y = \frac{1}{3} (Bz_H^3 - B_1h_H^3 + bz_B^3 - b_1h_B^3)$$



Равнобокий уголок

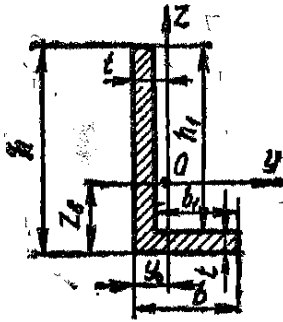
$$F = t(2h - t);$$

$$z_b = \frac{h^2 + ht + t^2}{2(2h - t) \cos 45^\circ}; z_H = \frac{h + t - 2c}{\sqrt{2}};$$

$$J_y = \frac{1}{2} \left[2c^4 - 2(c - t)^4 + t \left(h - 2c + \frac{t}{2} \right)^2 \right],$$

где $c = z_B \cos 45^\circ$

Неравнобокий угол

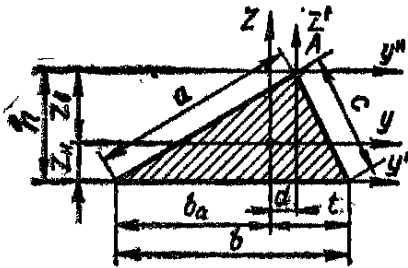


$$F = t(b + h_1) = t(h + b_1); y_0 = \frac{b^2 + h_1 t}{2(b + h_1)}$$

$$z_0 = \frac{h^2 + b_1 t}{2(h + b_1)}; J_y = \frac{1}{3} [t(h - z_0)^3 + b z_0^3 - b_1(z_0 - t)^3]; J_z = \frac{1}{3} [t(b - y_0)^3 + h y_0^3 - b_1(y_0 - t)^3];$$

$$J_{yz} = -\frac{b b_1 h h_1 t}{4(b + h_1)} = -\frac{b b_1 h h_1 t}{4(h + b_1)}$$

Треугольник



$$F = \frac{1}{2} h b; z_H = \frac{2}{3} h; \alpha = \frac{1}{3} (b_a - b_c);$$

$$J_y = \frac{b h^3}{36}; J_{y'} = \frac{b h^3}{12}; J_{y''} = \frac{b h^3}{4};$$

$$J_z = \frac{h b (b^2 - b_a b_c)}{36}; J_{z'} = \frac{h (b_a^3 + b_c^3)}{12};$$

$$J_{\rho_0} = \frac{b h (h^2 + b_a^2 + b_a b_c + b_c^2)}{36};$$

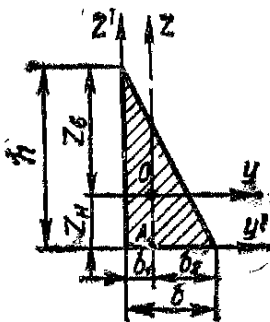
$$J_{\rho A} = \frac{h}{12} (3b h^2 + b_a^3 + b_c^3); W_{y_H} = \frac{b h^2}{12}$$

(для нижних волокон);

$$W_{y_B} = \frac{b h^2}{24} \text{ (для верхних волокон);}$$

$$i_y = 0,2357h$$

Прямоугольный треугольник



$$F = \frac{1}{2} b h; z_H = \frac{h}{3}; z_B = \frac{2}{3} h; b_1 = \frac{b}{3};$$

$$b_2 = \frac{2}{3} b; J_y = \frac{b h^3}{36}; J_z = \frac{b^3 h}{36}; J_{yz} = -\frac{b^2 h^2}{72};$$

$$J_{y'} = \frac{b h^3}{12}; J_{z'} = \frac{b^3 h}{12}; J_{y'z'} = \frac{b^2 h^2}{24};$$

$$J_{\rho_0} = \frac{b h}{36} (h^2 + b^2) = \frac{b h c^2}{36}, \text{ где } c^2 = h^2 + b^2;$$

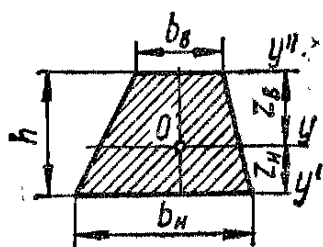
$$J_{\rho A} = \frac{b h}{36} (h^2 + b^2) = \frac{b h c^2}{12}; W_{y_H} = \frac{b h^2}{12}$$

(для нижних волокон)

$$W_{y_B} = \frac{b h^2}{24} \text{ (для верхних волокон);}$$

$$i_y = 0,2357h$$

Трапеция



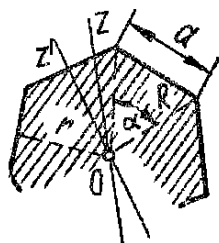
$$F = \frac{1}{2} (b_B + b_H) h; z_H = \frac{b_H + 2b_B}{3 (h_H + h_B)} h;$$

$$z_B = \frac{2b_H + b_B}{3 (b_H + b_B)} h; J_y = \frac{h^3 (b_H^2 + 4b_H b_B + b_B^2)}{36 (b_H + b_B)}$$

$$J_{y'} = \frac{h^3 (b_H + 3b_B)}{12}; J_{y''} = \frac{h (3b_H + b_B)}{12}$$

$$W_{y_H} = \frac{J_y}{z_H}; W_{y_B} = \frac{J_y}{z_B};$$

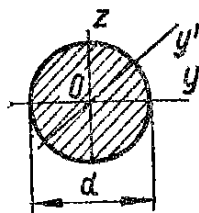
$$i_y = \frac{h \sqrt{2 (b_H^2 + 4b_H b_B + b_B^2)}}{6 (b_H + b_B)}$$



Правильный многоугольник с n сторонами

$$F = \frac{1}{4} n a^2 \operatorname{ctg} \alpha; R = \frac{a}{2 \sin \alpha}; r = \frac{a}{2 \operatorname{tg} \alpha};$$

$$J_y = J_{y'} = \frac{n a r}{96} (12 r^2 + a^2)$$

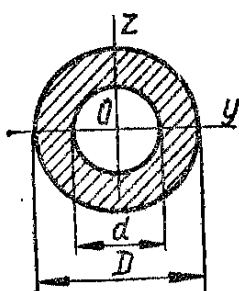


Круг

$$F = \frac{\pi d^2}{4} \approx 0,785 d^2; J_y = J_z = J_{y'} = \frac{\pi d^4}{64}$$

$$\approx 0,05 d^4; J_{p_0} = 2 J_y = \frac{\pi d^4}{32}; W_y = W_{z'} = W_{y'} =$$

$$= \frac{\pi d^3}{32} \approx 0,1 d^3; i_y = i_z = \frac{d}{4}$$



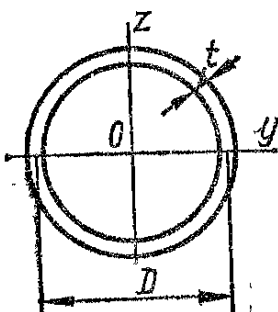
Кольцо

$$F = \frac{\pi D^2}{4} (1 - \alpha^2); \alpha = \frac{d}{D};$$

$$J_y = J_z = \frac{\pi D^4}{64} (1 - \alpha^4) \approx 0,05 D^4 (1 - \alpha^4);$$

$$W_y = \frac{\pi D^3}{32} (1 - \alpha^4) \approx 0,1 D^3 (1 - \alpha^4);$$

$$i_y = i_z = \frac{D}{4} \sqrt{1 + \alpha^2}$$

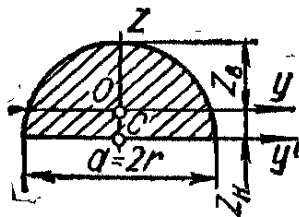


Тонкое кольцо ($t \ll D$)

$$F = \pi D t; J_y = J_z = \frac{\pi D^3 t}{4} \approx 0,3926 D^3 t;$$

$$W_y = W_z = \frac{\pi D^2 t}{4} \approx 0,7853 D^2 t;$$

$$i_y = i_z = 0,353 D$$



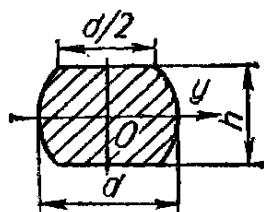
Полукруг

$$F = \frac{\pi d^2}{8} \approx 0,392d^2;$$

$$z_H = 0,2122d; \quad z_B = 0,2878d; \quad J_y = 0,00686d^4;$$

$$J_z = J_{y'} = \frac{\pi d^4}{128} = 0,025d^4;$$

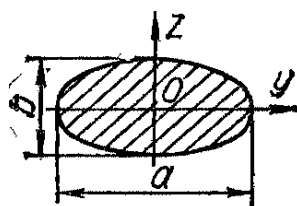
$$W_{y_H} = 0,2587r^3; \quad W_{y_B} = 0,1908r^3$$



Сечение бревна, стесанного сверху и снизу

$$h = 0,866d; \quad J_y = 0,039d^4; \quad W_y = 0,088d^3;$$

$$i_y = 0,223d$$

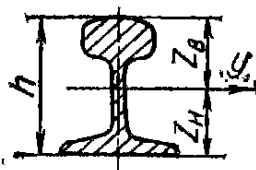


Эллипс

$$F = \frac{\pi}{4} ab; \quad J_y = \frac{\pi ab^3}{64}; \quad J_z = \frac{\pi a^3 b}{64};$$

$$W_y = \frac{\pi ab^2}{32}; \quad W_z = \frac{\pi a^2 b}{32}; \quad i_y = \frac{b}{4};$$

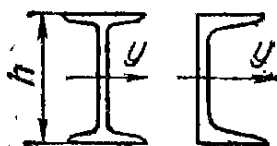
$$i_z = \frac{a}{4}$$



Сечение железнодорожного рельса (формулы приближенные)

$$F \approx 0,238h^2; \quad z_H \approx 0,5h; \quad J_y \approx 0,032h^4;$$

$$W_y \approx 0,064h^3; \quad i_y = 0,37h$$



Сечения стандартных прокатных профилей (формулы приближенные):

двутавр $W_y \approx \frac{(h+2)^3}{51};$

швеллер $W_y \approx \frac{(h+5)^3}{81}$