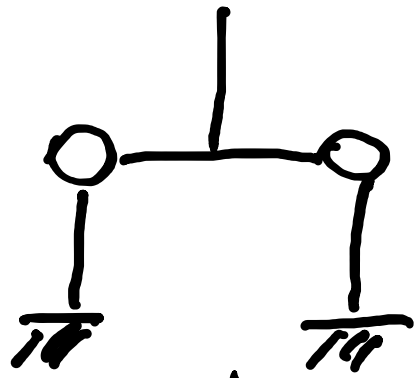
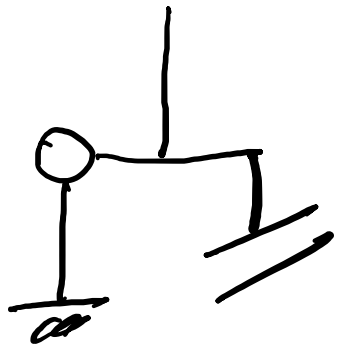
$\varepsilon_{osso\,sano} = \varepsilon_{osso\,residuo+protesi}$

omogenizzazione $\quad E_{osso\,sano} = E_{osso\,residuo+protesi}$

puntuale > 1 g.d.l.

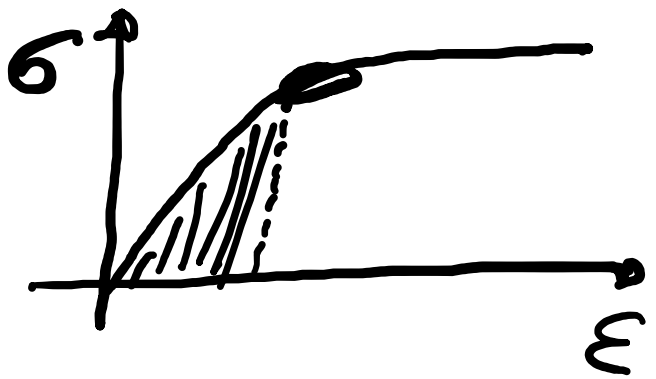


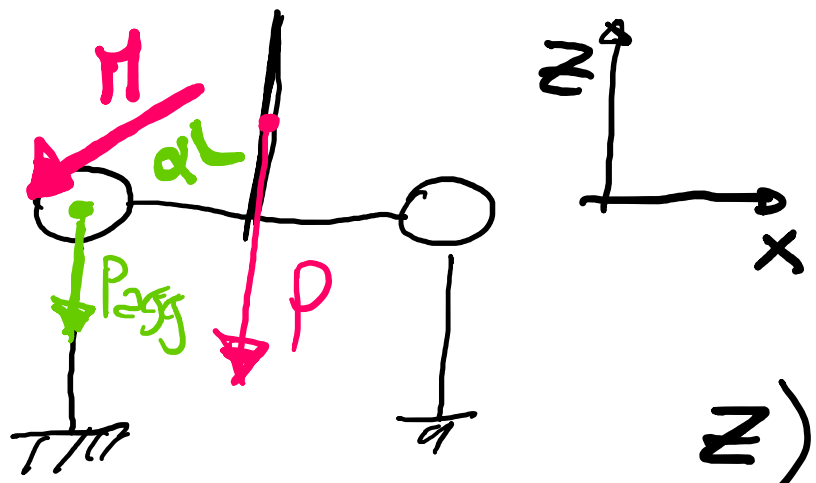
bipodalica



monopodalica

worst case



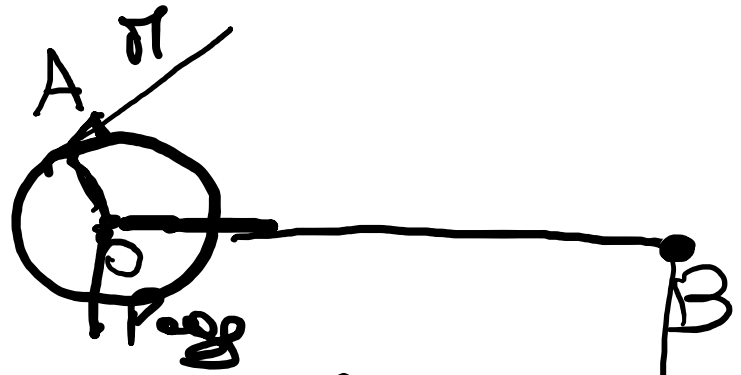


$m_{agg} = 10\ Kg$ $\quad P_{agg} = 100\ N$

$\alpha = 16°$

z) $R_z = -\frac{P}{2} - P_{agg} - \Pi \cos\alpha$

x) $R_x = -\Pi \sin\alpha$



z) $R_z = -\frac{P}{2} - P_{agg} - KP\frac{P}{2}\cos\alpha$

x) $R_x = -KP\frac{P}{2}\sin\alpha$

$\frac{P}{2} \cdot OB = \Pi \cdot OA$

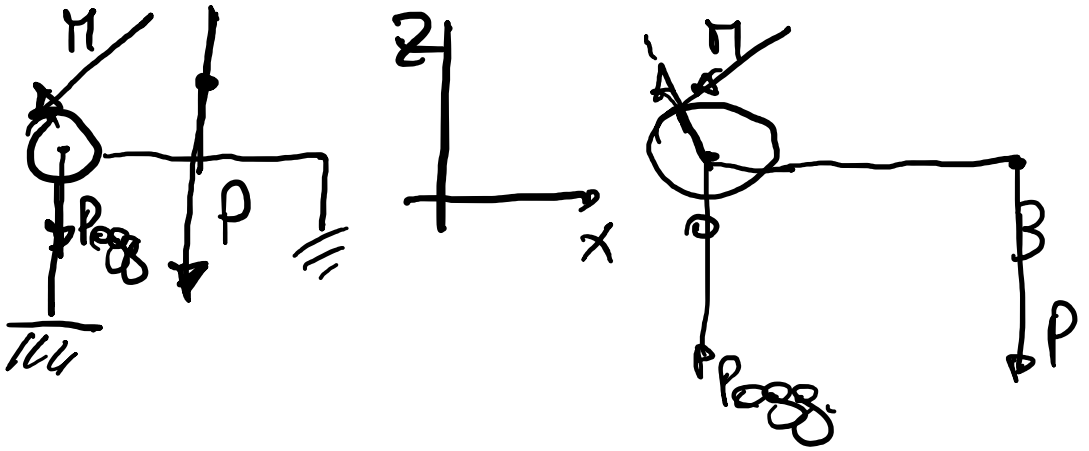
$\Pi = \frac{P}{2}\frac{OB}{OA}$ $\qquad \frac{OB}{OA} = K \simeq 10$

$$R = \sqrt{R_x^2 + R_z^2} = \sqrt{K^2 \frac{P}{4}^2 \sin^2\alpha + \left(K\frac{P}{2}\cos\alpha + P_{osg} + \frac{P}{2}\right)^2} =$$

$$= \sqrt{K^2\frac{P^2}{4}\sin^2\alpha + K^2\frac{P^2}{4}\cos^2\alpha + P^{*2} + 2\cdot\frac{KP}{2}\cos\alpha P^*} =$$

$$P_{osg} + \frac{P}{2} = P^*$$

$$= \sqrt{\frac{K^2P^2}{4} + P^{*2} + KP\cos\alpha P^*}$$



$$P \cdot OB = M \cdot OA$$

$$M = P \cdot \frac{OB}{OA} = P \cdot K$$

$$R_z = -P - P_{ogg} - M \sin\alpha = -\underbrace{P - P_{ogg}}_{P^*} - PK\sin\alpha$$

$$R_{xy} = -M\cos\alpha = -PK\cos\alpha$$

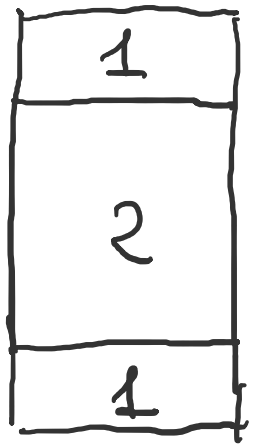
$$R = \sqrt{R_z^2 + R_{xy}^2} = \sqrt{(P^* + PK\sin\alpha)^2 + P^2K^2\cos^2\alpha} =$$

$$\sqrt{P^{*2} + P^2K^2\sin^2\alpha + 2P^*PK\sin\alpha + P^2K^2\cos^2\alpha} =$$

$$\sqrt{P^{*2} + P^2K^2 + 2P^*PK\sin\alpha}$$

$$\alpha = 45^\circ$$

Omogenizzazione



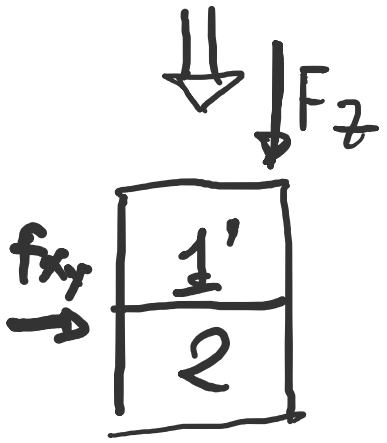
$f_1 = 15\%$ $\quad f_1' = 2f_1 = 30\%$

$f_1 = 70\%$

$E_1 = 0.5\ GPa$

$E_2^z = 17\ GPa$

$E_2^{xy} = 12\ GPa$



$$E_2^{O.S.} = \frac{E_1' \cdot E_2^z}{f_1' E_2^z + f_2 E_1} = \frac{0.5 \cdot 17}{0.3 \cdot 17 + 0.7 \cdot 0.5} =$$

$$= \frac{8.5}{5.1 + 0.35} = \frac{8.5}{5.45} = 1.56\ GPa.$$

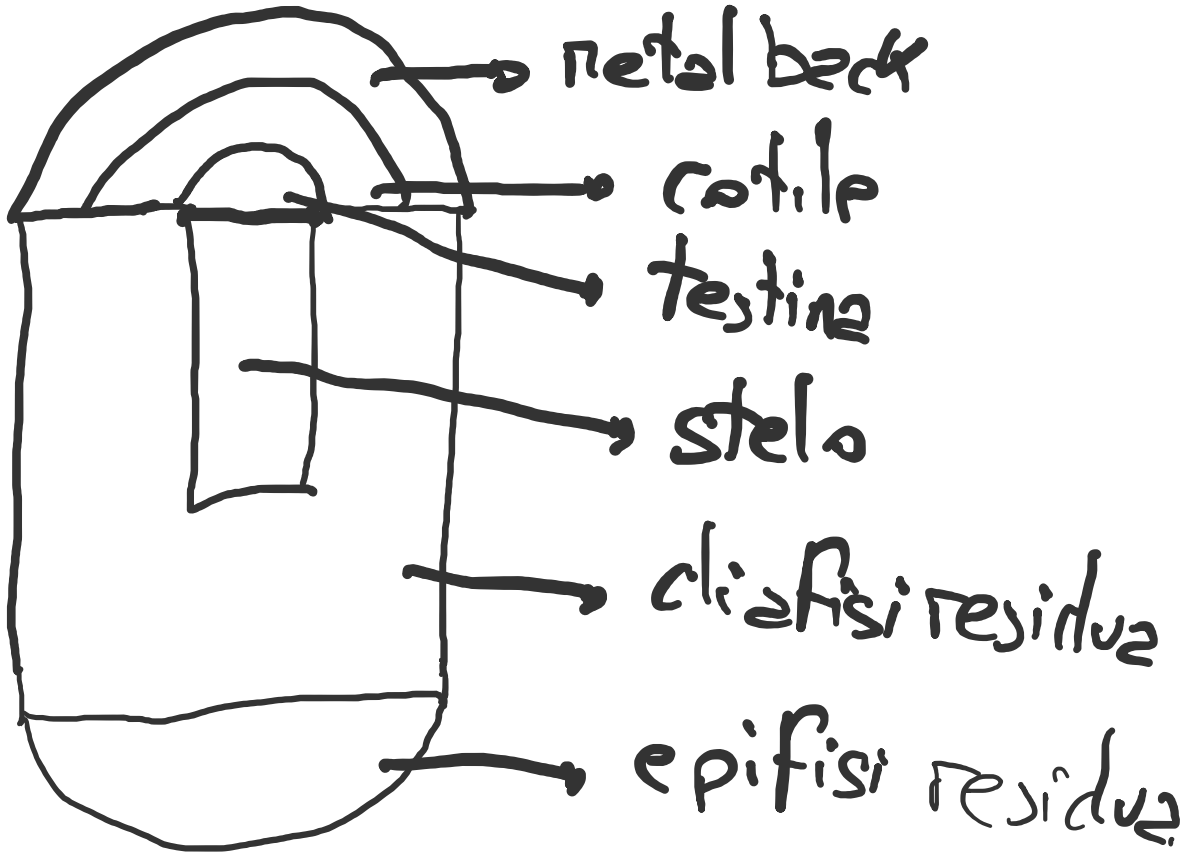
$$E_{xy}^{O.S.} = f_1' E_1 + f_2 E_2^{xy} = 0.3 \cdot 0.5 + 0.7 \cdot 12 = 0.15 + 8.4 = 8.55\ GPa$$

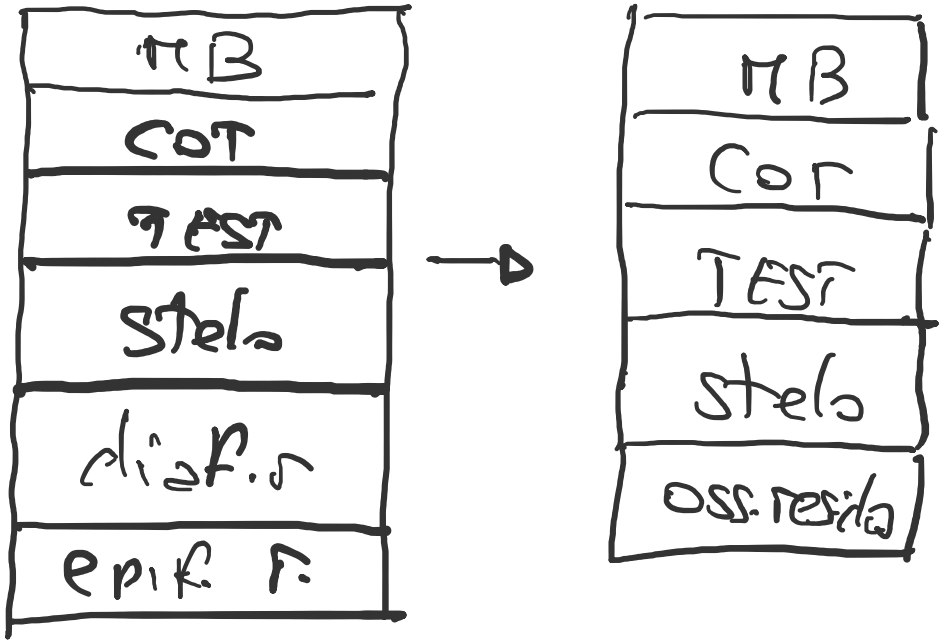
$E_0^z = 1.56$ GPa

$E_0^{xy} = 8.55$ GPa

Parente.

$$E = E_0 (1-p)^\alpha A^\beta \delta^\gamma \dot{\varepsilon}$$



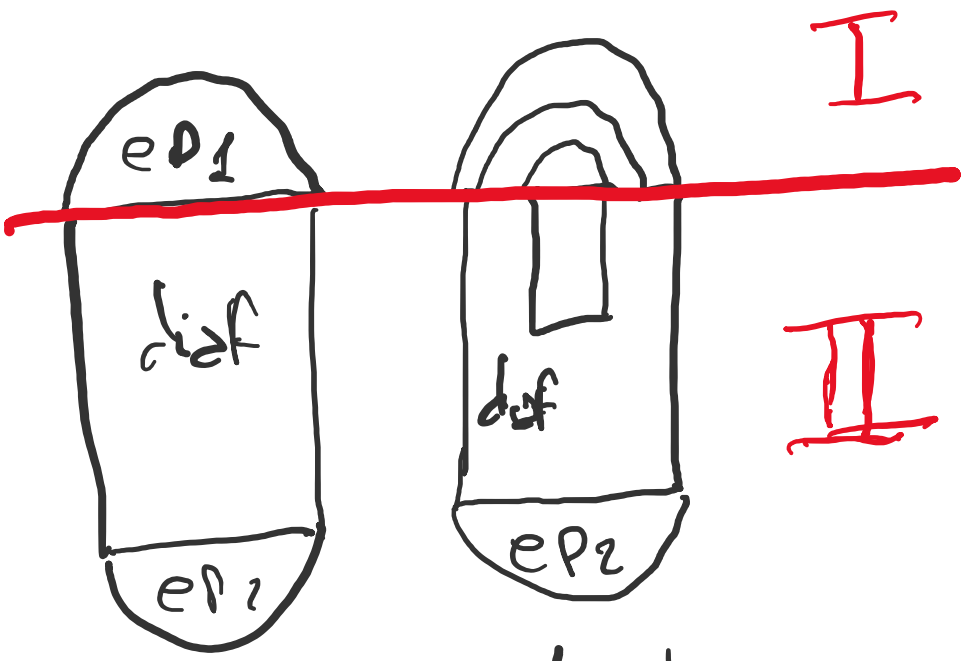


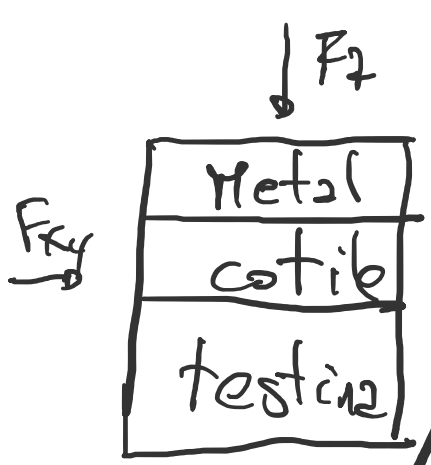
$$E_{osso\,sano} = E_{osso\,residuo + protesi}$$

Omogeneizzazione parziale

Omogeneizzazione totale

$E^{I}_{oss.sano} = 0.5\ GPa$



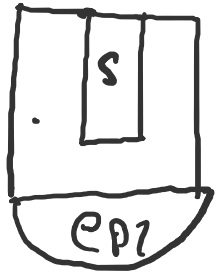


$$\begin{cases} \dfrac{1}{E_z} = \dfrac{f_{MB}}{E_{MB}} + \dfrac{f_{COT}}{E_{COT}} + \dfrac{f_T}{E_T} \\ E_{xy} = f_{MB} E_{MB} + f_{COT} E_{COT} + f_T \cdot E_T \\ f_{MB} + f_{COT} + f_T = 1 \end{cases}$$

$r_{testina}$ $r_{int.\,met.}$

$r_{int.\,cotile}$ $r_{est.\,met.\,back}$

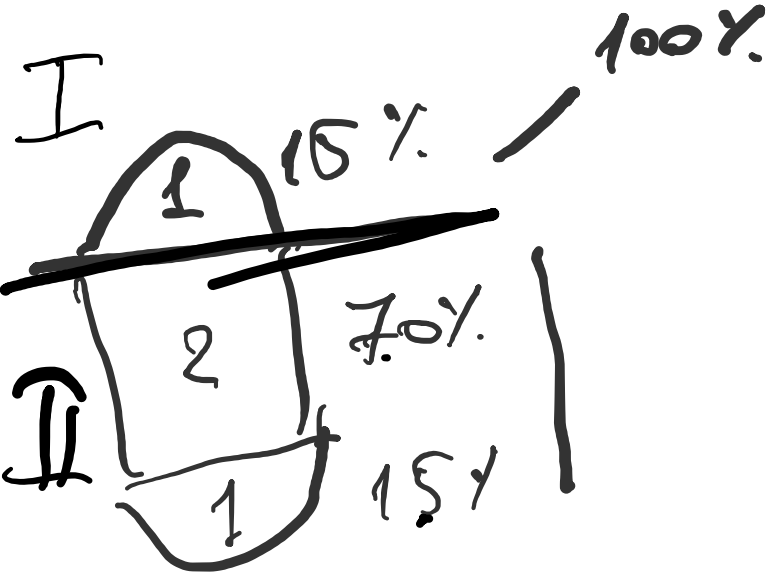
$r_{est.\,cotile}$



(a) (b)

$$\frac{1}{E_{0.\delta}^{z}} = \frac{f_{dist}}{E_0^{z}} + \frac{f_{ep}}{E_0^{ep}} = \frac{1}{E_1}$$

$$E_{0.\delta}^{xy} = f_{dist} E_0^{xy} + f_{ep} E_0^{ep} = E_2$$



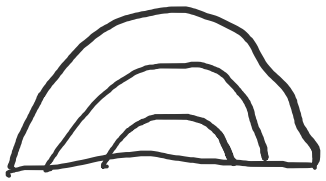
$$E_{1z}^{res\,reab} = E_1 (1-p)^{\alpha} A^{\beta} \varepsilon \delta^{\gamma}$$

$$E_{2y}^{res\,reab} = E_2 (1-p)^{\alpha} A^{\beta} \varepsilon \delta^{\gamma}$$

$f_2 : 100 = 70 : 85$

$f_1 : 100 = 15 : 85$

$$\begin{cases} \dfrac{1}{E_z^T} = \dfrac{f_s}{E_s} + \dfrac{f_{osres}}{E_{1z}} \\ E_{xy}^T = f_s E_s + f_{osres} \cdot E_{2xy} \\ f_s + f_{osres} = 1 \end{cases}$$



r_{est}

$r_{int.cotile}$

$r_{est.cotile} = d_{cotile}$

$r_{int.met.b} = r_{est.cotile}$

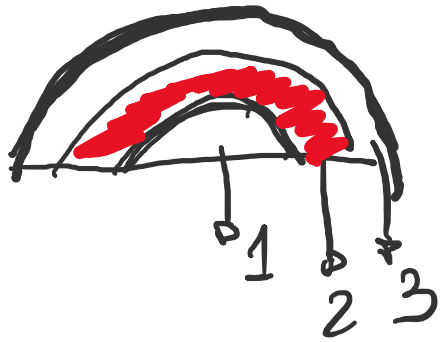
$r_{est.met.b} = r_{raggio\ .\ coppa\ acetabolare}$

tasso usura UHMWPE $= 10\ \mu m / anno$ 10 anni

$\delta_{consumo} = 100\ \mu m$

$\delta_{consumo\ totale} = 200\ \mu m.$

$\delta_{mm} = 1\ cm = 10\ mm$

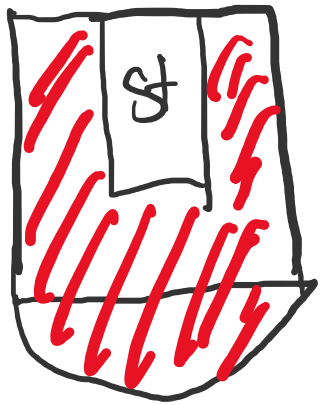


$$f_1 = \frac{V_T}{V_{TOT}} = \frac{2}{3}\pi r^3 t \cdot \frac{1}{\frac{2}{3}\pi r_{e.c}^3} = \frac{r^3 t}{r_{e.c}^3}$$

$$f_2 = \frac{V_{COT}}{V_{TOT}} = \frac{\frac{2}{3}\pi r_{e.c}^3 - \frac{2}{3}\pi r^3 t}{\frac{2}{3}\pi r_{e.c}^3} =$$

$$f_2 = \frac{r_{ec}^3 - r^3 t}{r_{ec}^3} = \frac{r_{e.c}^3}{r_{ec}^3} - f_1$$

$$f_3 = \frac{\frac{2}{3}\pi r_{ec}^3 - \frac{2}{3}\pi r_{i.m}^3}{\frac{2}{3}\pi r_{ec}^3} = \frac{r_{ec}^3 - r_{i.m}^3}{r_{ec}^3} = 1 - \frac{r_{i.m}^3}{r_{ec}^3}$$



h_{stelo}

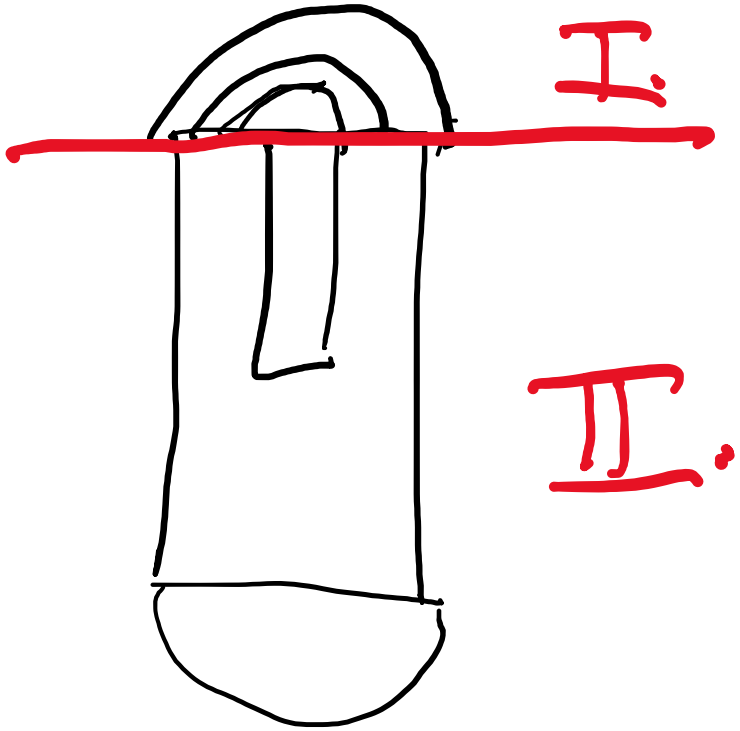
r_{stelo}

$$f_{st} = \frac{\pi r_{st}^2 h_{st}}{\pi r_F^2 \cdot h_{diaf} + \frac{2}{3}\pi r_{ep}^3}$$

$$f_{oss.residuo} = \frac{\pi r^2 f\, h_{diaf} + \frac{2}{3}\pi r_{ep}^3 - \pi r_{st}^2 h_{st}}{\pi r_F^2 h_{diaf} + \frac{2}{3}\pi r_{ep}^3}$$

$E_{0\,sen\alpha}^{z} \rightarrow$ $E_{0\,residuo}^{z} = E_{0\,sen\alpha}^{z}\left(1 - f_{st}\right)^{d}$

$E_{0\,sen\alpha}^{xy} \rightarrow$ $E_{0\,residuo}^{xy} = E_{0\,sen\alpha}^{xy}\left(1 - f_{st}\right)^{d}$



I. ep

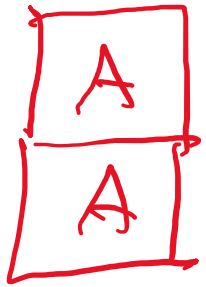
II. diaf+ep

osso compleso

osso compleso

E_0^z

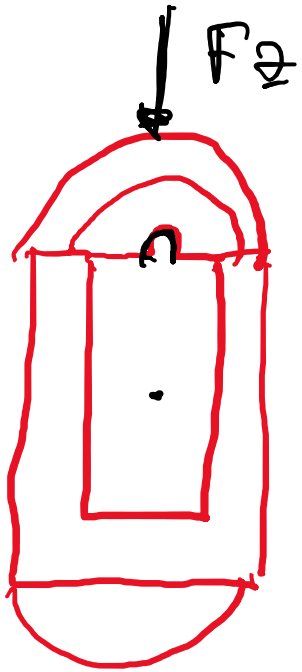
E_0^{xy}

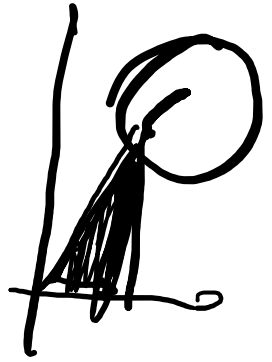


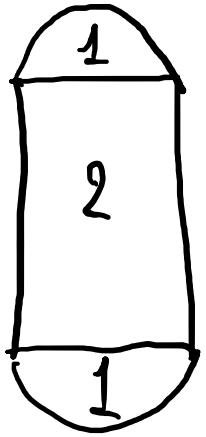
E_A

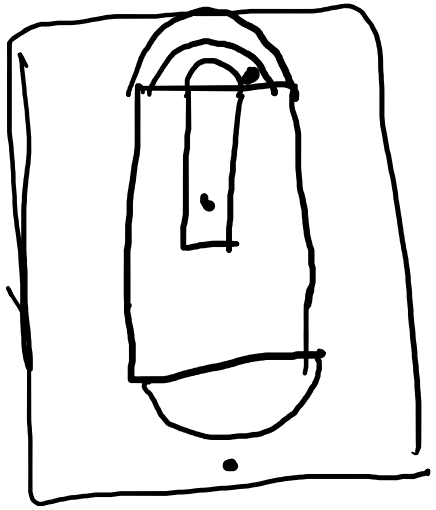
E_A

$\rightarrow E_A$



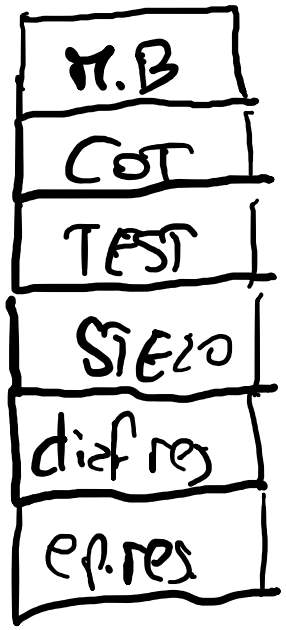




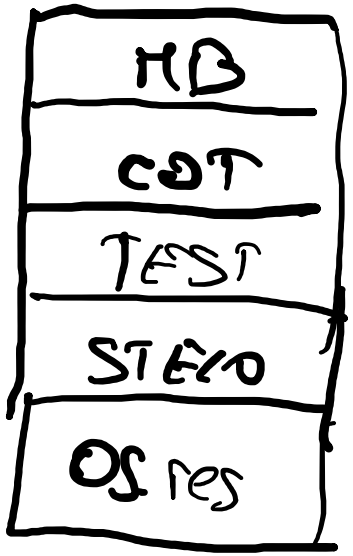


$$\frac{1}{E_z^{Servo}} = \frac{2f_1}{E_{os.sp}} + \frac{f_2}{E_{o.c}^{z}}$$

$$E_{xy}^{Servo} = 2f_1 \cdot E_{os.sp} + f_2 E_{o.c}^{xy}$$



→ $15 \pm \varepsilon$



$r_{test\,ue}$

$r_{int.cot.}$

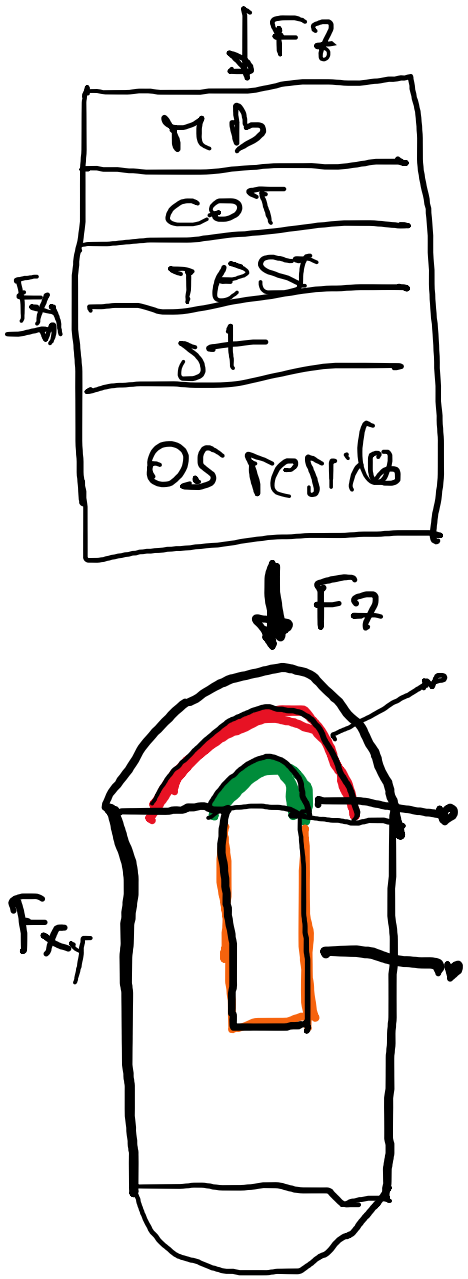
$r_{est.\,cot}$] $\delta_{cot.b} = 10.2.\ mm$

$r_{int.met}$

$r_{est.\,met} = r_{acc.}$

r_{stelo}

n_{stelo}



$$\frac{1}{E^{z}_{Sem}} = \frac{f_{MB}}{E_{MB}} + \frac{f_{COT}}{E_{COT}} + \frac{f_{TEST}}{E_{TEST}} + \frac{f_{ST}}{E_{ST}} + \frac{f_{OS.RES}}{E_{OS.RES.}}$$

$$E^{xy}_{Sem} = f_{MB}\, E_{MB} + f_{COT}\, E_{COT} + f_{TEST}\, E_{TEST} + f_{ST}\, E_{ST} + f_{OS.RES.}\, E_{OS.RES}$$

$$f_{MB} + f_{COT} + f_{TEST} + f_{ST} + f_{OS.RES} = 1$$

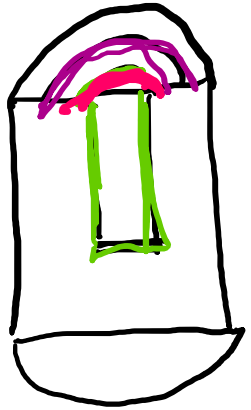
Isostress

$$\sigma_z = \sigma_{xy}$$

(1) $$\frac{F_z}{A^1_z} = \frac{F_{xy}}{A^1_{xy}}$$

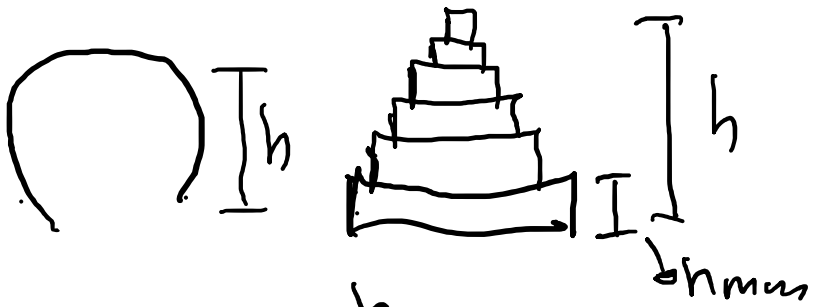
(2) $$\frac{F_z}{A^2_z} = \frac{F_{xy}}{A^2_{xy}}$$

(3) $$\frac{F_z}{A^3_z} = \frac{F_{xy}}{A^3_{xy}}$$



③ $\frac{R_z}{\pi z^2 st} = \frac{R_{xy}}{2\pi z st\, h st} \rightarrow 2st = \frac{R_z}{R_{xy}} \cdot 2h st$

② $\frac{R_t}{2\pi z^2 t} = \frac{R_{xy}}{A_{xy}}$



$$A = \int_{h_{min}}^{h} 2\pi z \, dz \qquad z = \sqrt{x^2+y^2+z^2}$$

$$A = \int_{h_{min}}^{h} 2\pi (x^2+y^2+z^2)^{\frac{1}{2}} dz = \cancel{2\pi} \cdot \frac{2}{3} \frac{(x^2+y^2+z^2)^{\frac{3}{2}}}{\cancel{2z}} \Big|_{h_{min}}^{h} = \frac{2}{3}\pi (x^2+y^2+z^2)^{\frac{3}{2}} \Big|_{h_{min}}^{h}$$

$$A_{xy} = \frac{2}{3}\pi \left[\frac{(x^2+y^2+h^2)^{\frac{3}{2}}}{h} - \frac{(x^2+y^2+h_{min})^{\frac{3}{2}}}{h_{min}} \right]$$

$h_{min} = h_{est} = 100\,nm$ $\quad \simeq \phi$

$$A_{xy} \simeq \frac{2}{3}\pi \frac{(r^2)^{\frac{3}{2}}}{h} = \frac{2}{3}\pi \frac{r^3}{h}$$

$$\frac{R_z}{2\pi r^2 t} = \frac{R_{xy}}{\frac{2}{3}\pi \frac{r^3 t}{ht}} \Rightarrow \frac{2}{3}\pi \frac{r^3 t}{ht} R_z = R_{xy} 2\pi r^2 t.$$

$$\underline{\underline{rt = \frac{R_{xy}}{R_z} 3.ht}}$$

(1)

$$\frac{R_z}{A_z^1} = \frac{R_{xy}}{A_y^1}$$

$$\frac{R_z}{2\pi z_{est}^2 c_{ot}} = \frac{R_{x-1}}{\frac{2}{3}\pi \frac{z^3 c_{st} c_{ot}}{h_{ot}}}$$

$$z_{est\,cot} = \frac{R_{xy}}{R_z} \cdot \frac{3 h_{cot}}{} = \left(z_t + \delta_{cot}\right)$$

$$h_{ep} = h_{test} + \delta_{cot} + \delta_{TGT.B.}$$

$$V_{TOT} = V_{ep_1} + V_{ep_2} + V_{diaFisi} = \frac{2}{3}\pi 2_{1ep}^3 + \frac{2}{3}\pi 2_{2ep}^3 + \pi 2^2 h_f$$

$$2_{1ep} = 2_{ep_2} \qquad V_{TOT} = \frac{4}{3}\pi 2_{ep}^3 + \pi 2_2^2 h_f$$

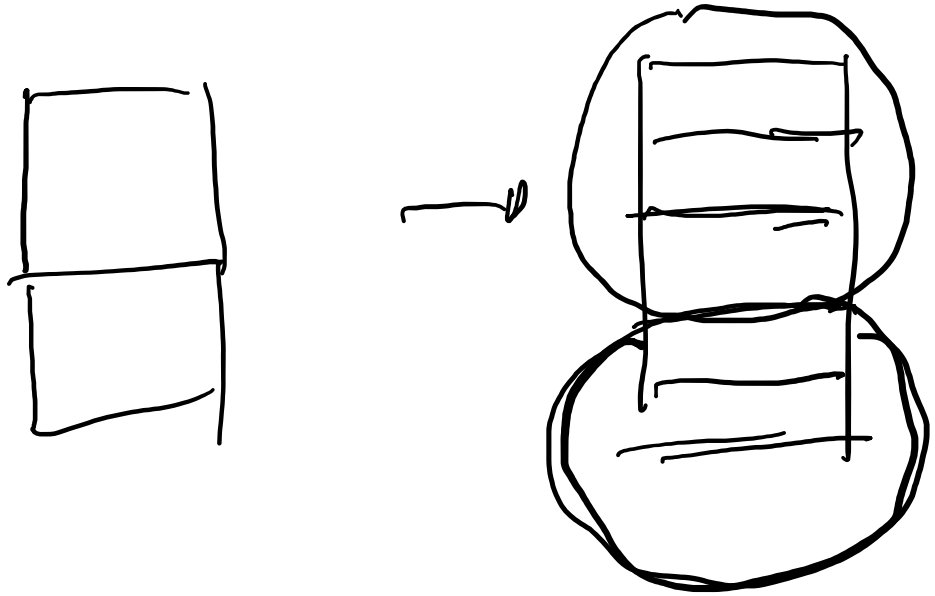
$$f_{MB} = \frac{\frac{2}{3}\pi 2_c^3 - \frac{2}{3}\pi 2_{in.m.b}^3}{V_{TOT}} \qquad f_{ST} = \frac{\pi 2_{st}^2 \cdot h_{st}}{V_{TOT}}$$

$$f_{COT} = \frac{\frac{2}{3}\pi 2_{in\ mb}^3 - \frac{2}{3}\pi 2_f^3}{V_{OT}} \qquad f_{OST} = \frac{\frac{2}{3}\pi 2_{ep}^3 + \pi(2_f^2 - 2_{st}^2) h_{fem}}{V_{TOT}}$$

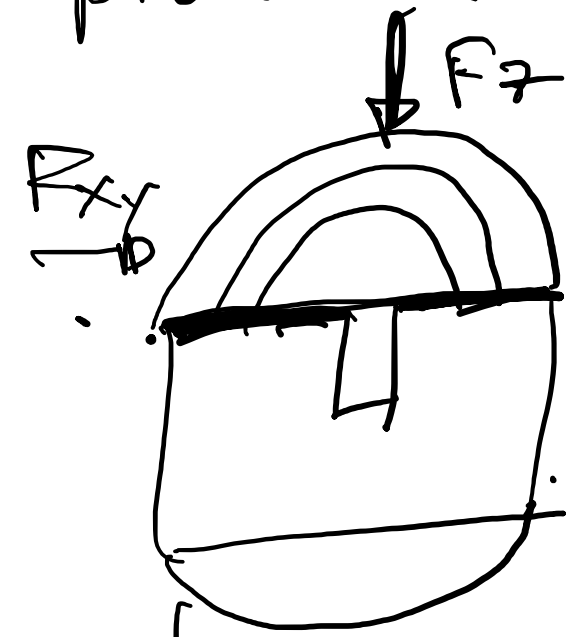
$$f_T = \frac{\frac{2}{3}\pi 2^3 t}{V_{TOT}}$$

Problemi

1) più g.d.l.
2) equazioni di isostress non sono più valide.
3) perdita di ortotropia.



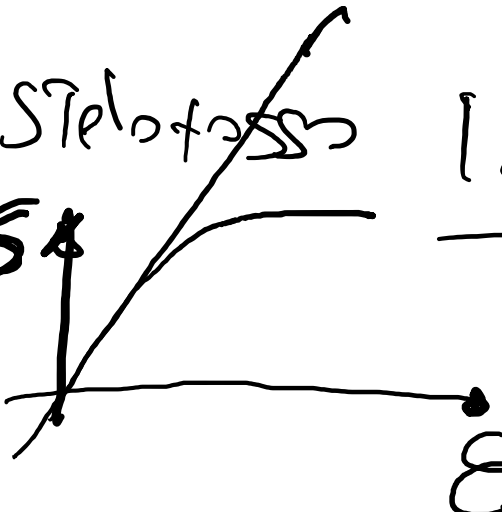
TEST



$\varepsilon_{osso\,sano}$

Stelo stesso

Isotropo



$\varepsilon_{osso\,sano} = \varepsilon_{osso\,rest\,protesi}$