# Tubo non dim

$$\frac{Eh^3}{12(1-\nu^2)} \nabla^4 w + h \frac{\partial}{\partial x_\alpha}\left(\sigma_{\alpha\beta} \frac{\partial w}{\partial x_\beta}\right) = p$$

$$\frac{\partial \sigma_{\alpha\beta}}{\partial x_\alpha} = 0$$

$$\varepsilon_{\alpha\beta}^{(m)} = \frac{1}{2}\left(\frac{\partial u_\alpha}{\partial x_\beta} + \frac{\partial u_\beta}{\partial x_\alpha}\right) + \frac{1}{2}\frac{\partial w}{\partial x_\alpha}\frac{\partial w}{\partial x_\beta}$$

$$\underset{\sim}{\sigma} = \frac{E}{1-\nu^2}\left(\quad\right)\underset{\sim}{\varepsilon}^{(m)}$$

$$\sigma_{\alpha\beta} = E^{\alpha\beta\gamma\delta}\varepsilon_{\gamma\delta}^{(m)} \qquad t_\alpha = \sigma_{\alpha\beta} n_\beta$$

$$w^* = h w$$

$$x_\alpha^* = l x_\alpha$$

$$u_\alpha^* = h\left(\frac{h}{l}\right) u_\alpha$$

$$\sigma_{\alpha\beta}^* = \frac{E}{(1-\nu^2)}\left(\frac{h}{l}\right)^2 \sigma_{\alpha\beta}$$

$$p^* = \frac{E}{12(1-\nu^2)}\left(\frac{h}{l}\right)^4 p$$

$$\varepsilon_{\alpha\beta}^{(m)} = \left(\frac{h}{l}\right)^2\left[\frac{1}{2}\left(\frac{\partial u_\alpha}{\partial x_\beta} + \dots\right) + \frac{1}{2}\frac{\partial w}{\partial x_\alpha}\frac{\partial w}{\partial x_\beta}\right] = \frac{h^2}{l^2}\varepsilon_{\alpha\beta}$$

$$t_\alpha^* = \frac{E}{(1-\nu^2)}\left(\frac{h}{l}\right)^2 t_\alpha$$

$$\frac{Eh^3}{12(1-\nu^2)}\frac{h}{\ell^4}\nabla^4\omega - \frac{h}{\ell^2}\frac{E}{(1-\nu^2)}\left(\frac{h}{\ell}\right)^2 h\frac{\partial}{\partial x}\left(\sigma\frac{\partial\omega}{\partial x}\right) = \frac{E}{12(1-\nu^2)}\left(\frac{h}{\ell}\right)^4 p$$

$$\boxed{\nabla^4\omega - 12\frac{\partial}{\partial x_\alpha}\left(\sigma_{\alpha\beta}\frac{\partial\omega}{\partial x_\beta}\right) = p}$$

$$\frac{E}{(1-\nu^2)}\frac{h^2}{\ell^2}\sigma_{\alpha\beta} = \frac{E}{(1-\nu^2)}E^{\alpha\beta\gamma\delta}\frac{h^3}{\ell^2}\varepsilon_{\gamma\delta}$$

$$\boxed{\sigma_{\alpha\beta} = E^{\alpha\beta\gamma\delta}\varepsilon_{\gamma\delta}}$$

$f(\nu)$ only

$$\frac{E}{(1-\nu^2)}\left(\frac{h}{\ell}\right)^2\sigma_{\alpha\beta}n_\beta = \frac{E}{(1-\nu^2)}\left(\frac{h}{\ell}\right)^2 t_\alpha$$

$$\boxed{\sigma_{\alpha\beta}n_\beta = t_\alpha}$$