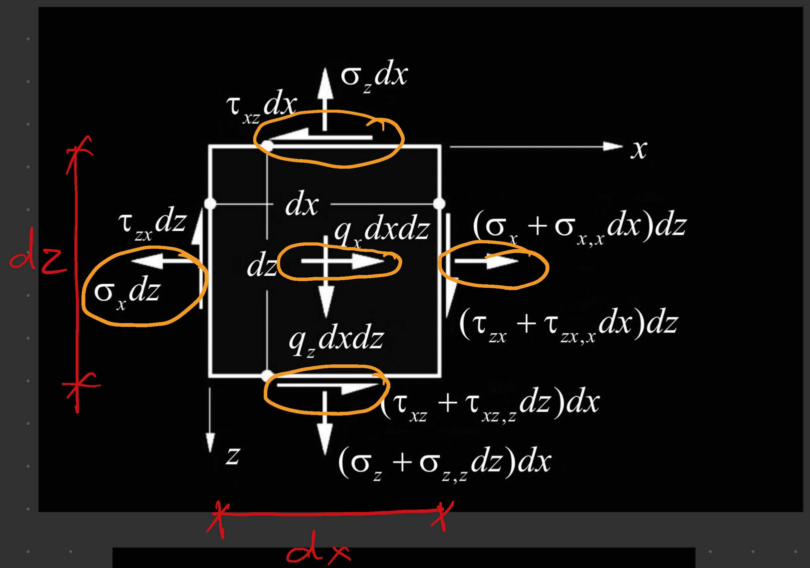


$$\frac{\partial \sigma_x}{\partial x} + \frac{\partial \tau_{xz}}{\partial z} + q_x = 0$$

$$\Sigma u_x: \; -\cancel{\sigma_x dz} + q_x\, dz\, dx + \Big(\cancel{\sigma_x} + \underbrace{\frac{d\sigma_x}{dx}\cdot dx}_{\text{variation of } \sigma_x}\Big)\cdot dz - \cancel{\tau_{xz} dx} + \Big(\cancel{\tau_{xz}} + \frac{d\tau_{xz}}{dz} dz\Big) dx$$

$$= 0$$

$$q_x \cancel{dz}\cancel{dx} + \frac{d\sigma_x}{dx}\cdot \cancel{dx}\cancel{dz} + \frac{d\tau_{xz}}{dz} \cancel{dz}\cancel{dx} = 0$$

$\sigma_x = -2\ \mathrm{MPa}$

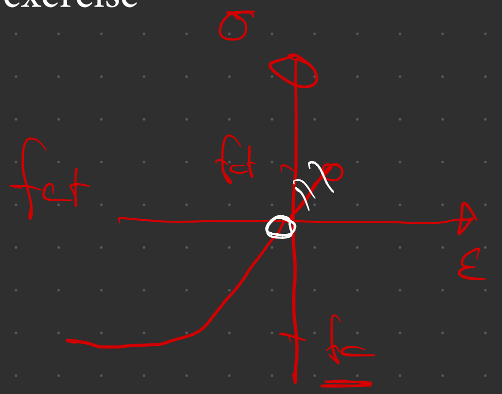
$\sigma_z = 5\ \mathrm{MPa}$

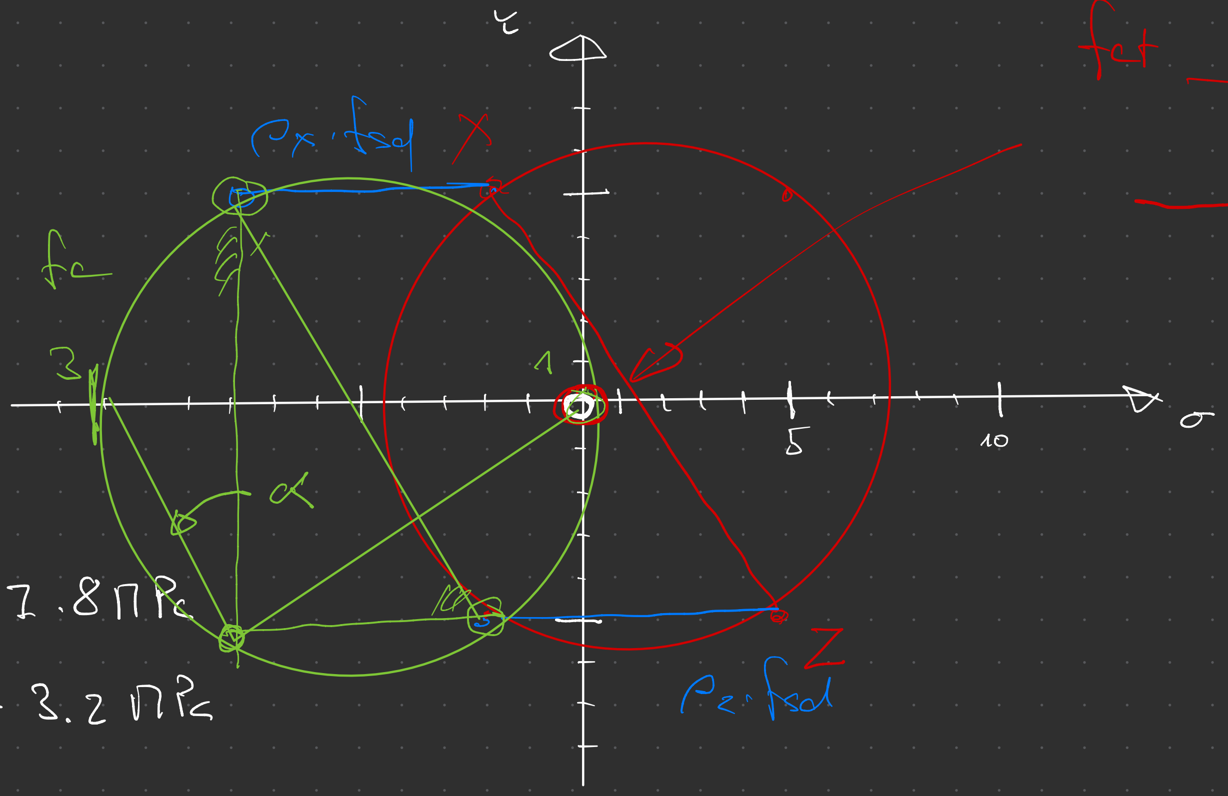
$\tau_{xz} = 5\ \mathrm{MPa}$

$f_{sd} = 435\ \mathrm{MPa}$

$\rho_x = 1.3\ \%$

$\rho_z = 1.9\ \%$





$$\sigma_x = \sigma_{xs} + \sigma_{xc}$$

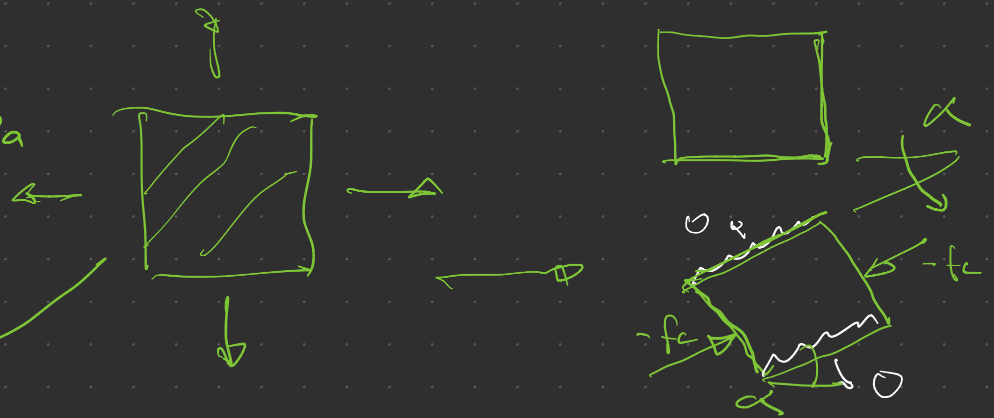
$$\sigma_{xc} = -2 - 1.3\ \% \cdot 435 = -7.8\ \mathrm{MPa}$$

$$\sigma_{zc} = 5 - 1.9\ \% \cdot 435 = -3.2\ \mathrm{MPa}$$

$$f_c \cong 11\ \mathrm{MPa}$$

$$f_c = k_c \cdot f_{cd} \Rightarrow f_{cd} = 20\ \mathrm{MPa}$$

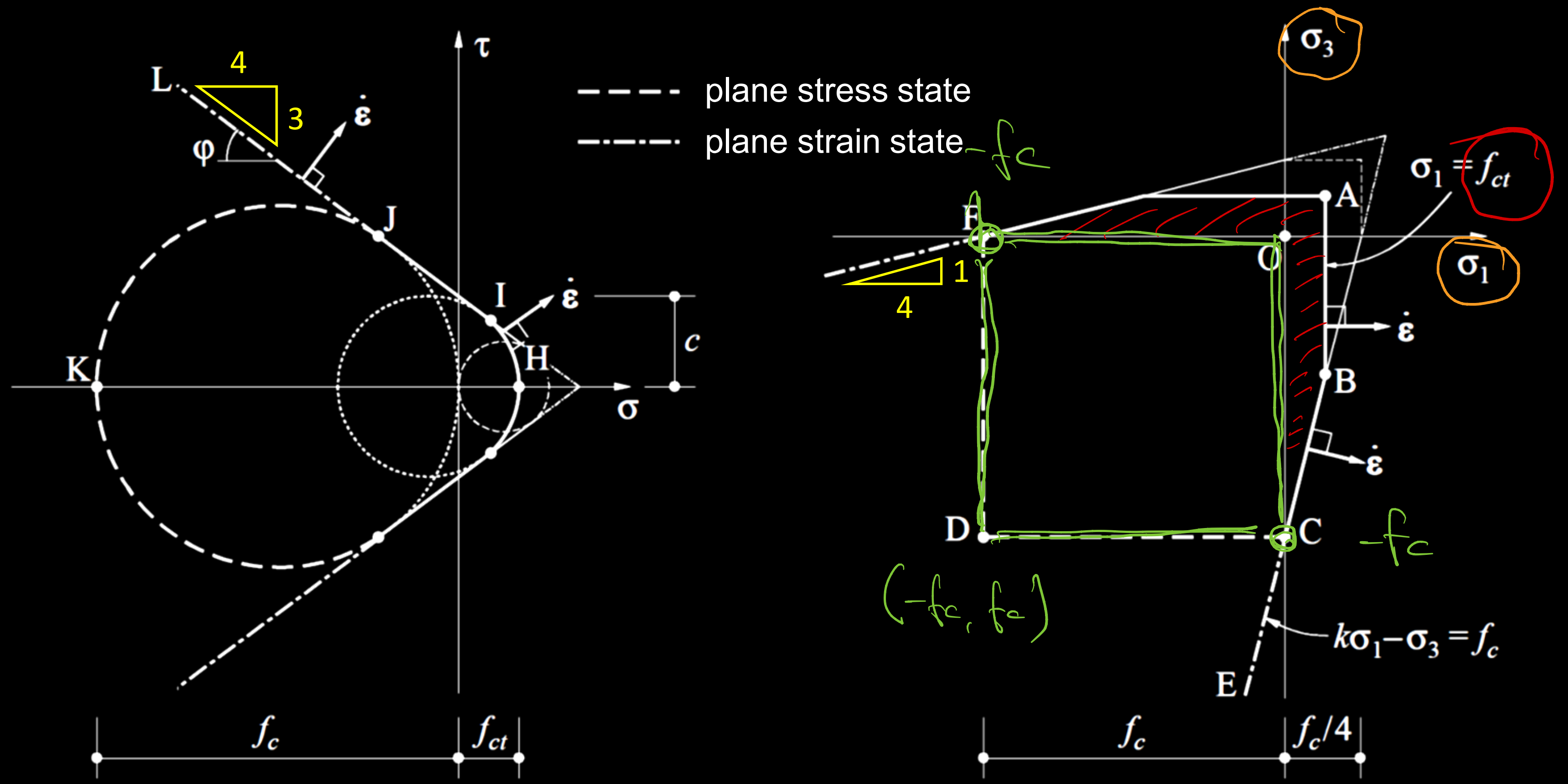
$\quad \hookrightarrow 0.55$



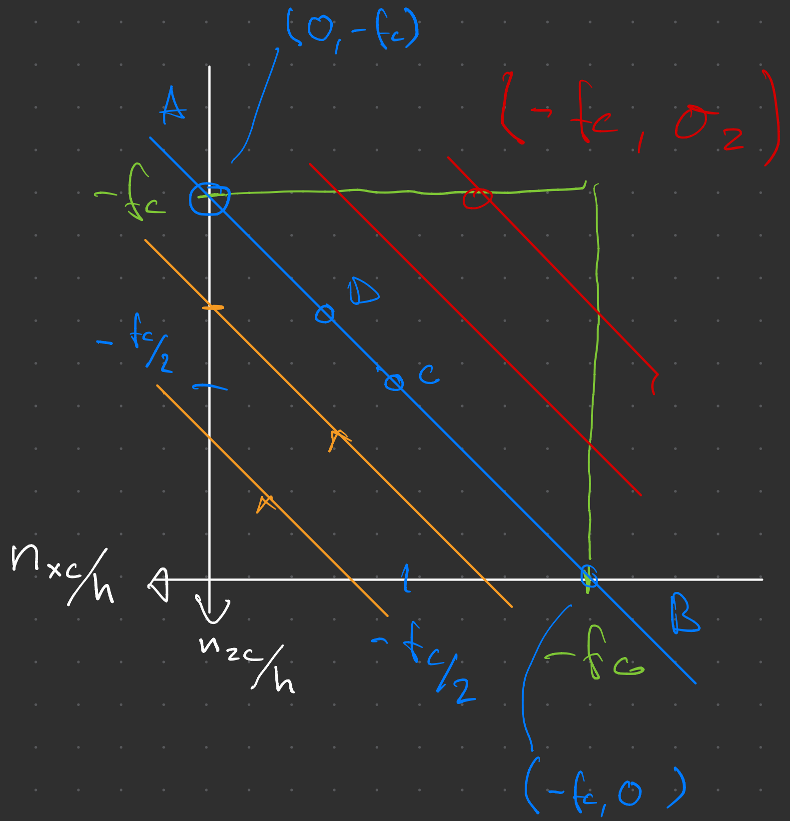
Theory of plasticity – Limit analysis – see 1. Introduction

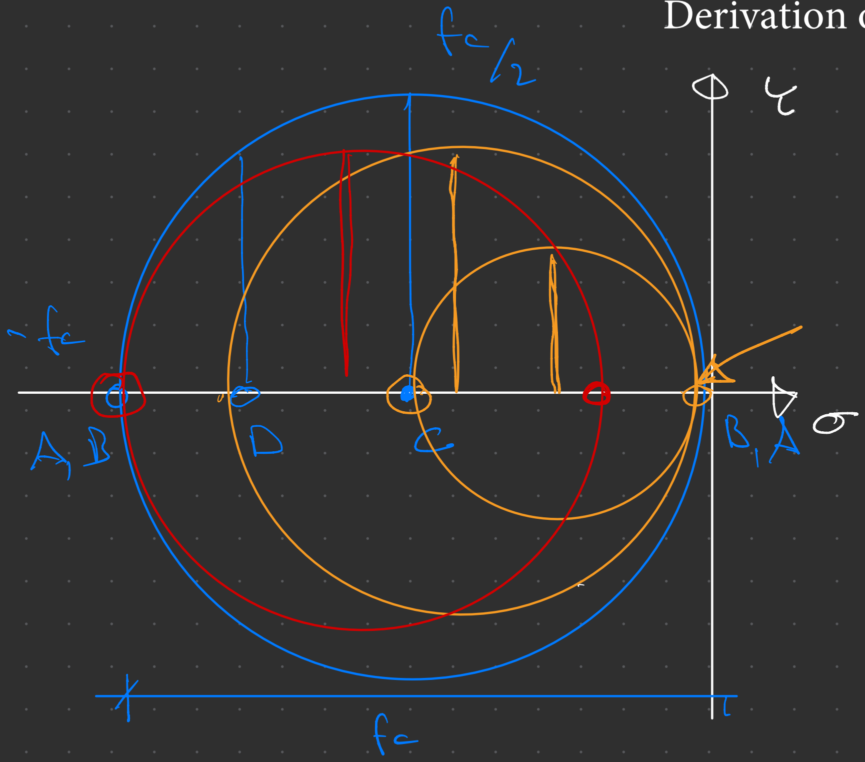
Concrete - Modified Coulomb yield surface

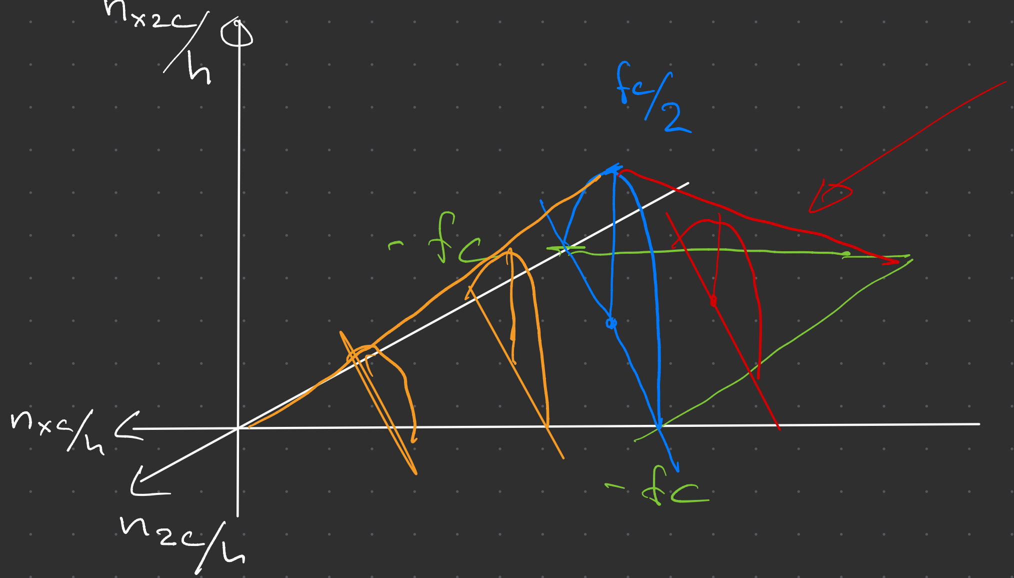
Normal concrete: tan(φ) = 0.75 → $c = f_c/4$, φ = approx. 37°



Derivation of concrete yield surface







Derivation of yield conditions for first two yield regimes

hs/09.11.2023

1) $Y_1 = n_{xz}^2 - (a_{sx} f_{sx} - n_x)(a_{sz} f_{sz} - n_z) \qquad = 0$

2) $Y_2 = n_{xz}^2 - (h f_c - a_{sz} f_{sz} + n_z)(a_{sz} f_{sz} - n_z) \qquad = 0$

$a_{sx} \cdot f_{sd} \qquad a_{sz} \cdot f_{sd}$

$$Y_c = 0: \quad n_{xz}^2 - n_{xc} \cdot n_{zc} = n_{xz}^2 - (n_{xs} - n_x)(n_{zs} - n_z)$$

$$n_x = n_{xc} + n_{xs} \Rightarrow n_{xc} = n_{xs} - n_x$$

"negative": $-n_{xc}$

2) $Y_c = 0: \quad n_{xz}^2 - n_{xc} \cdot n_{zc}$

$\quad \rightarrow a_{sz} \cdot f_{sd} - n_z$

$$a_s \sigma_{sx} - n_x < a_{sx} f_{sd} - n_x$$

$$= (f_c - a_{sz} \cdot f_{sd})$$