Metal structures, selected chapters

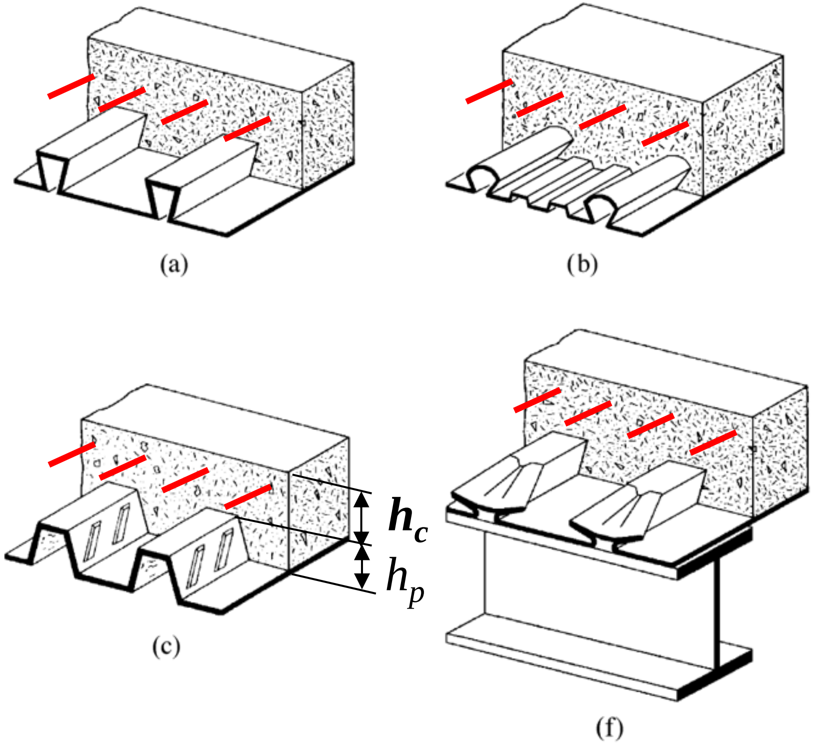
Intro. to composite slabs

Ref: SIA 264 § 5.4 and § 6

Prof. A. Nussbaumer

Introduction, special features of composite slabs

- Sheet metal t_{nom} = 0.75 to 1.50 mm
- h_p = 38 to 80 mm
- Mixed effect of profiled sheet metal and concrete:
  - re-entrant shape ribs (frictional connection), case (a)(b)
  - bosses in webs or wings, case (c)
  - slab end anchors (studs, brackets, deformation of ribs) (d)
- If part of a composite beam or used as a diaphragm: $h \geq 90$ mm and $\boldsymbol{h_c} \geq 50$ mm
- Reinforcement in slab, lower/upper counted in resistance



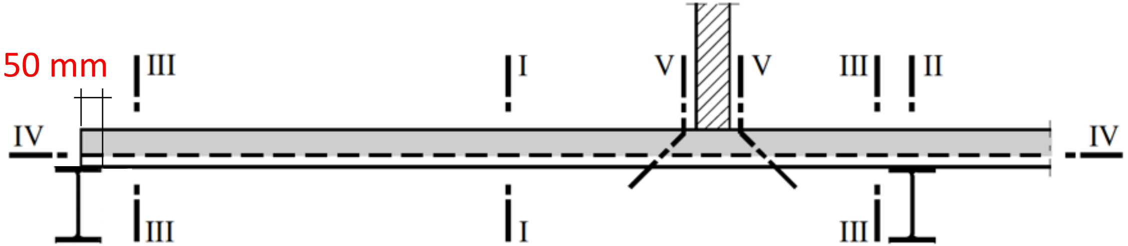
EPFL

What makes composite beams different?

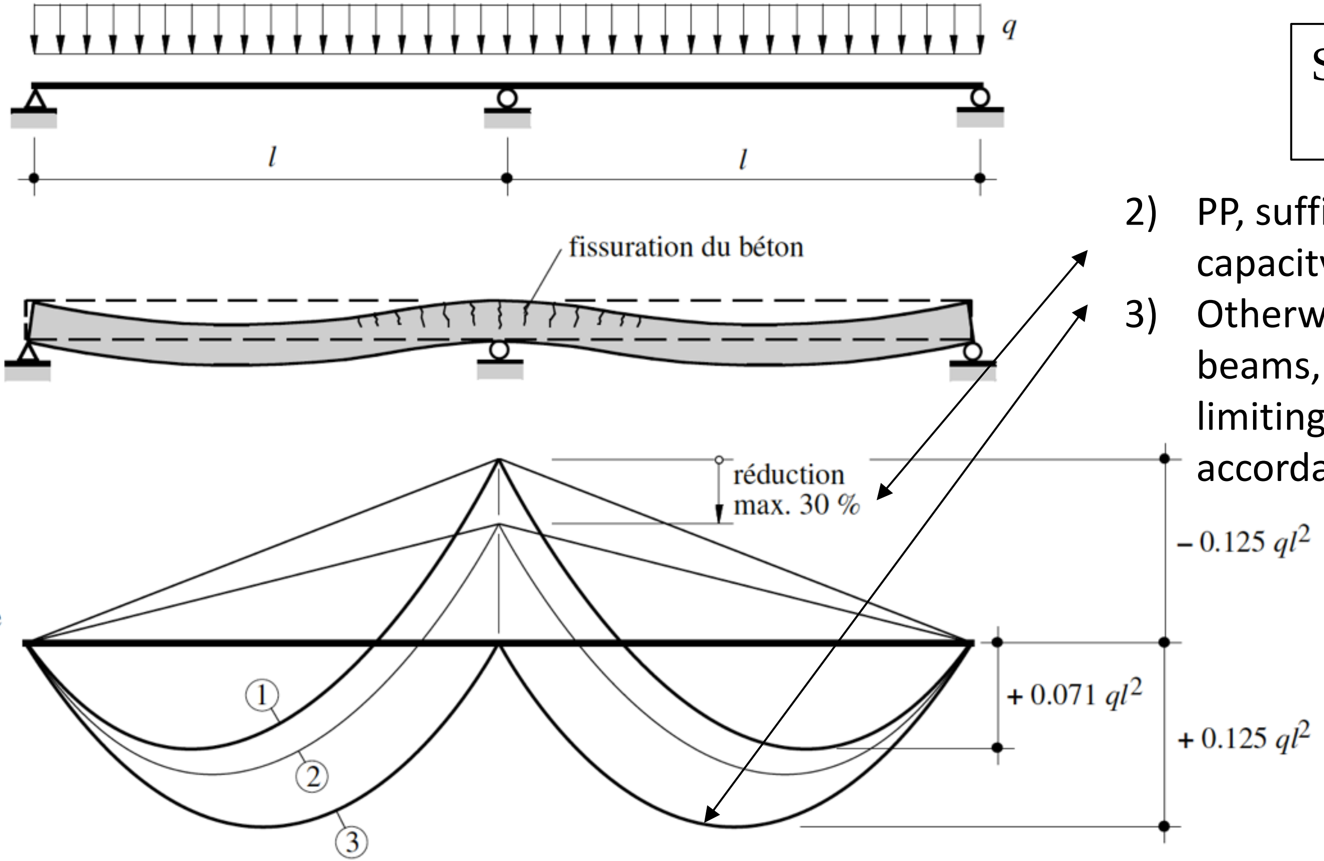
- Sheet metal usually section class 4: effective cross-sections (by calculation or manufacturer's values). And mixed slabs, no more buckling problems.
- Mixed behaviour between total and partial connection (failure by bending or longitudinal shear)
- Resistance factor values (SIA $\gamma_a = \gamma_{ap} = 1.05$, EN $\gamma_{M0} = \gamma_{M1} = 1.00$)
- Calculation of deflections at construction stage (under fresh concrete), average inertia of effective sections: $w_{c,Cd}$ (without construction load) ≤ L/180

  (if $w_g > h/10$, take into account the concrete surplus in $w_{c,Cd}$)
- Final stage calculation, EE, EP or PP calculation (if PP, check required rotation capacity)
- Sections to be checked: min 50 mm

(no connection check)



Effect of concrete cracking on the calculation of internal forces

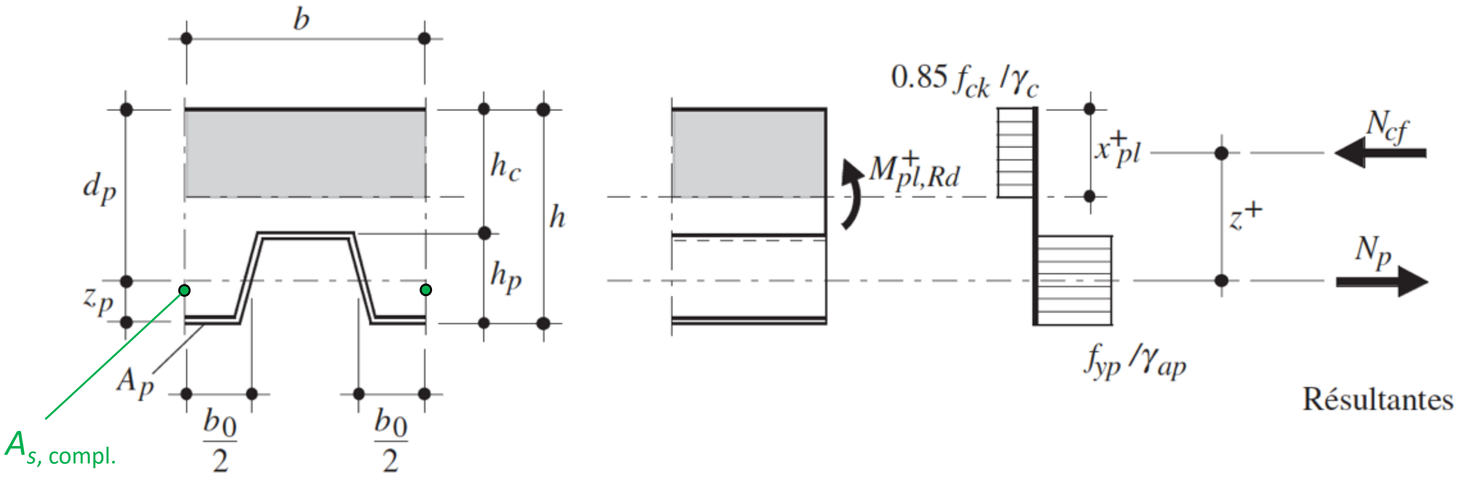


SIA 264
§ 5.4.2

2) PP, sufficient rotation capacity
3) Otherwise, for simple beams, minimum crack-limiting reinforcement (in accordance with SIA 262)

I) Flexural strength of slab under M+, common case

- As a composite beam section, and 100% efficient sheet metal



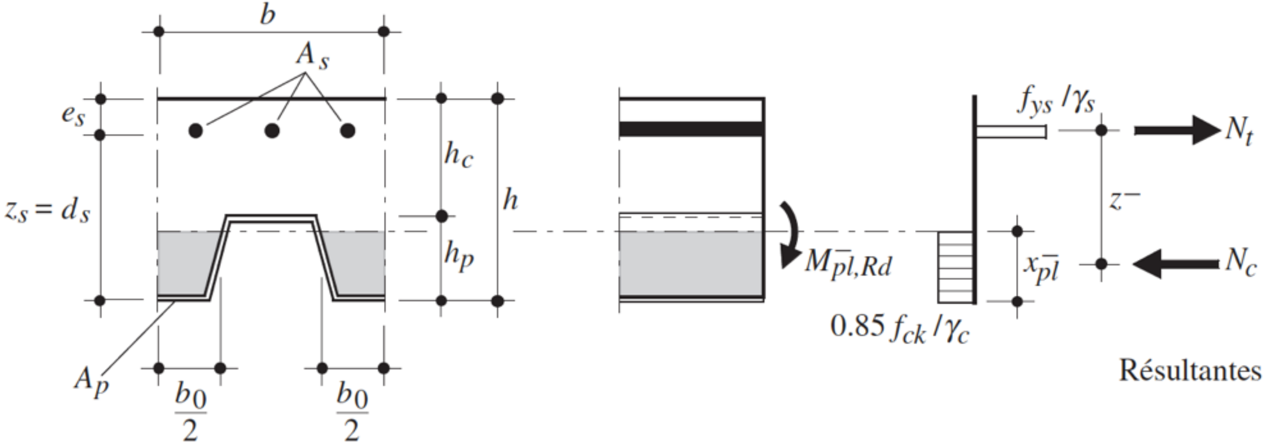
$$x^+_{pl} = \frac{f_{yp}\,A_p}{\gamma_{ap}} \cdot \frac{\gamma_c}{0.85\,f_{ck}\,b}$$

$$M^+_{pl,Rd} = \frac{f_{yp}}{\gamma_{ap}} A_p \left(d_p - \frac{x^+_{pl}}{2}\right)$$

d_p : Useful height for positive bending moment $(d_p = h - z_p)$

II) Flexural strength of slab under M-.

- As reinforced concrete section (sheet metal neglected ⬄? sheet metal)



$$x^-_{pl} = \frac{f_{ys}\, A_s}{\gamma_s} \cdot \frac{\gamma_c}{0.85\, f_{ck}\, b_c} \qquad M^-_{pl,Rd} = \frac{f_{sk}}{\gamma_s} A_s\, z^-$$

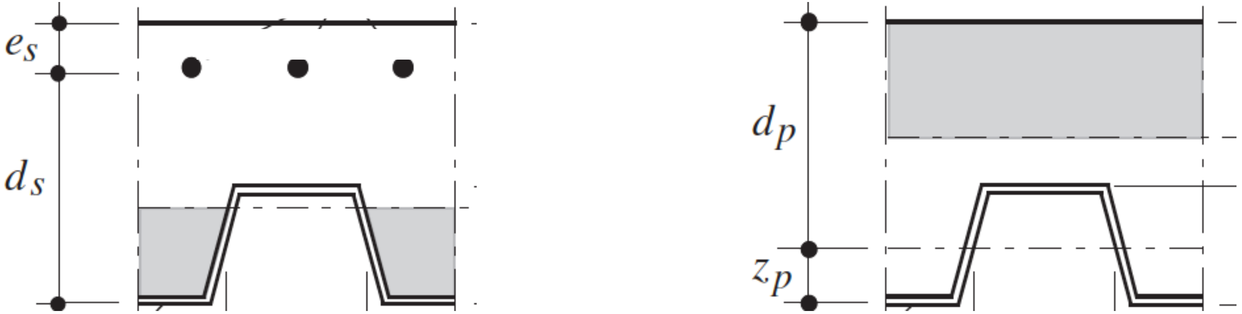
b_c : width of concrete in compression = average width of ribs over 1 m ($b_c \cong \sum b\,)_0$

b_0 : average width of a rib filled with concrete

III) Slab shear strength

SIA 264
§ 5.4.3.3

- Data per concrete section (sheet metal neglected ⇔ stiffness diff.)



- Per 1 m width: $$V_{v,Rd} = k_d \, \tau_{cd} \, d \, b_c$$

d: useful height (support d_s , span d_p)
k_d : reduction factor for mixed slabs ($d \leq 150$ mm, $k_d = 0.8$, see SIA 262)
τ_{cd} : limit shear stress concrete, SIA 262

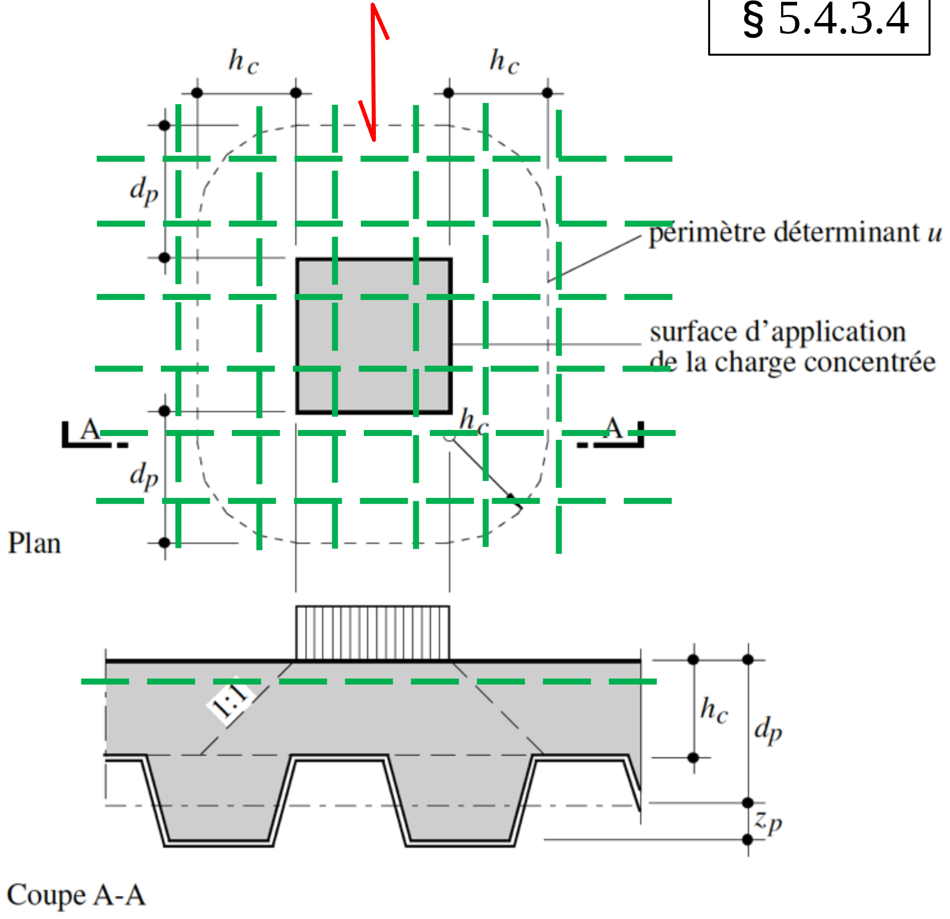
EPFL

IV) Slab resistance to punching

SIA 264
§ 5.4.3.4

- Reinforcing mesh to distribute concentrated load
- Calculation value:

$$V_{v,Rd} = k_d \, \tau_{cd} \, u \, h_c$$



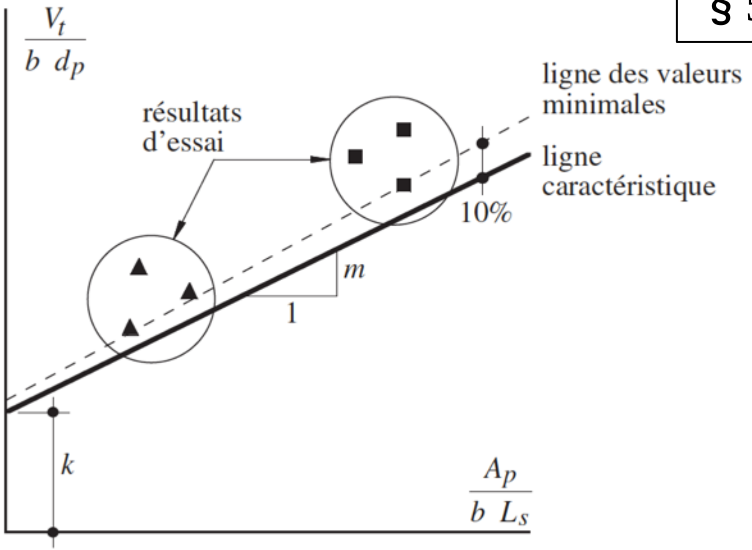
EPFL

V) Longitudinal shear

SIA 264
§ 5.4.3.5

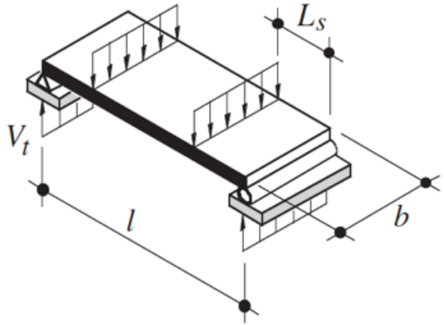
- Steel-concrete bond strength at the interface
- Comes from friction, bosses + connectors in general
- Can only be determined by testing, method ***m - k***
- Calculation value: — données fabricant

$\gamma_v = 1.25$



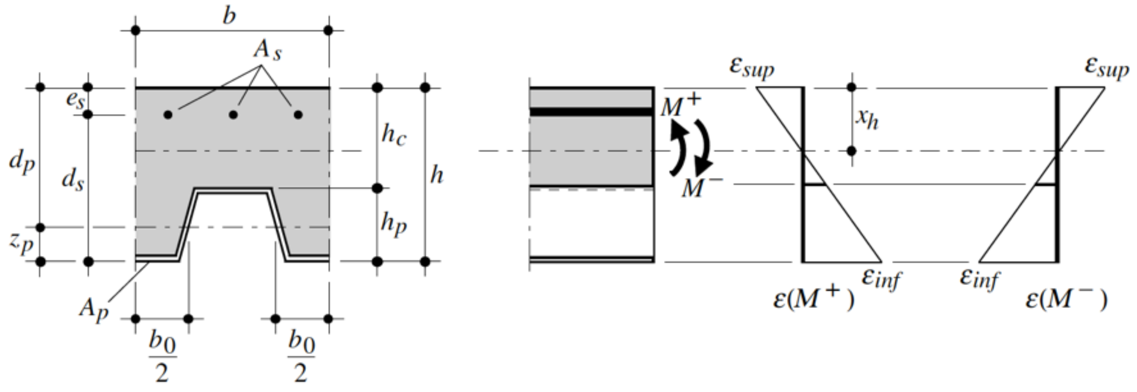
$$V_{l,Rd} = \frac{b\,d_p}{\gamma_v}\left[m\frac{A_p}{b\,L_s} + k\right]$$

$$V_{l,tot,Rd} = V_{l,Rd} + V_{anc,Rd} + V_{l,s,Rd}$$

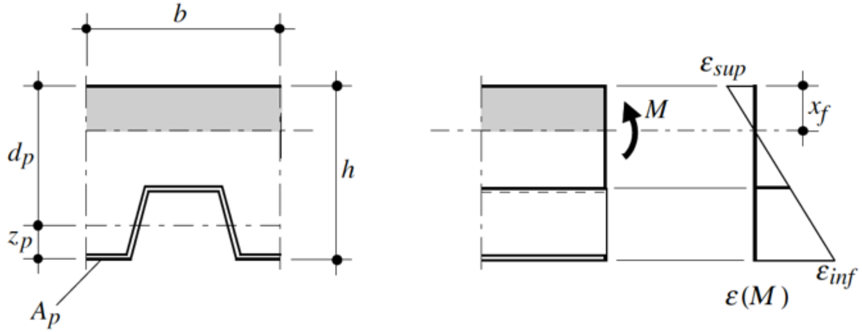


L_s sheared span:
= L/4 under q
L = 0.8L continuous
L = 0.9L on board

ELS, section characteristics



(a) Section non fissurée (homogène)



(b) Section fissurée en travée

- For example, in cracked sections:

$$I_{bf} = \frac{b\,x_f^3}{3n} + A_p(d_p - x_f)^2 + I_p$$

$$x_f = \frac{n\,A_p}{b}\left(\sqrt{1 + \frac{2\,b\,d_p}{n\,A_p}} - 1\right)$$

Rigidity & rotational capacity

SIA 264
§ 5.4 and § 6.2

- Global plastic analysis without rotation capacity check :
  - Class B or C reinforcement
  - span L < 3 m
- Otherwise, to ensure rotation capacity, class C an $\rho_s = A_s / b_{eff}\, h_c = 1{,}0\%$
- Continuous but dimensioned as a series of singles, limiting cracking of intermediate supports by reinforcement (upper layer):
  - $A_{s,min} \geq 0.2\%$ (unsupported slabs)
  - $A_{s,min} \geq 0.4\%$ (underpinned slabs)
- Jointed beam-column assembly:
  - to avoid creating M in column
  - interrupted slab (joint)
  - no contact with column flanges