Research Goals

- Influence of cracking (ε_1) on the web compressive strength (factor η_ε)

- Influence of the presence of prestressing cables (factor η_D)

- Interaction between both effects

- Contribution of the compression flange to shear strength of beams (V_{sup})

- Contribution of inclined prestressing cables to shear strength of beams (V_P)
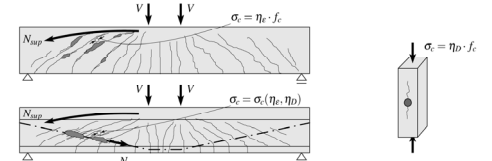
Shear strength of RC and PC girders η_D in prism tests

Experimental Program

Full-scale beam testing

Capolago TI (1967)   Structures Lab
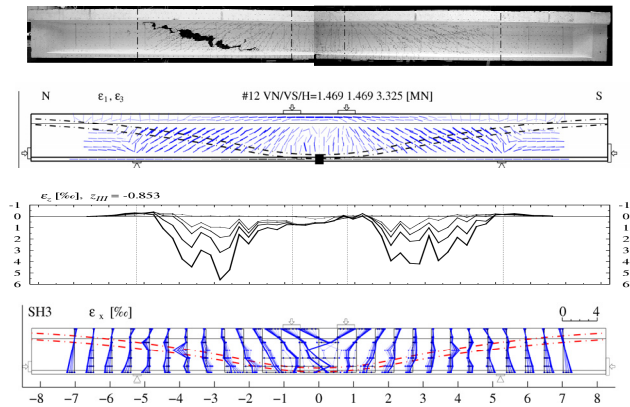
Construction in 1967 of the A2 motorway bridge "Sopra le Cantine" at Capolago (Ticino). Replacement in 2003. Five beams of ℓ = 16.5 m and h = 1.3 m have been extracted, transported to EPFL and tested there. Failure of all beam by web crushing along the prestressing cables.
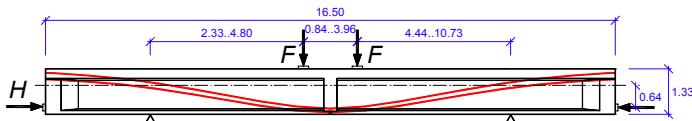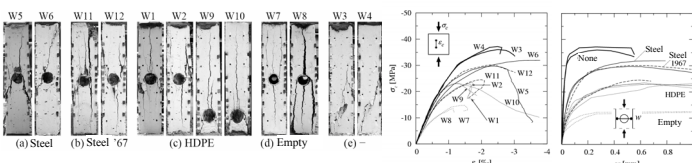

Example beam: SH3 (failure load: $V = F$ = 1.54 MN, H = 3.76 MN)

Panel testing

Panels of 0.6 x 0.6 x 0.125 m. Isolation of η_D-effect. Influence of prestressing duct type: empty duct, injected plastic (HDPE) and steel duct. The duct diameter to thickness ratio δ was constant. 16 panels have been tested.
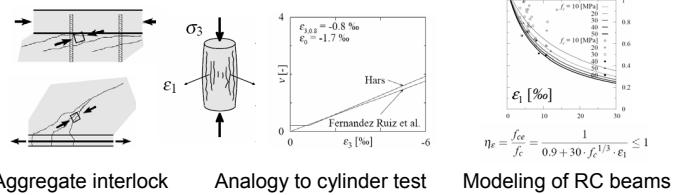

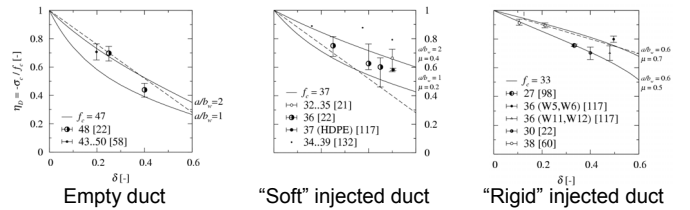(a) Steel   (b) Steel '67   (c) HDPE   (d) Empty   (e) –

Theoretical Modelling

Influence of cracking η_ε

Aggregate interlock   Analogy to cylinder test   Modeling of RC beams

$$\eta_\varepsilon = \frac{f_{ce}}{f_c} = \frac{1}{0.9 + 30 \cdot f_c^{1/3} \cdot \varepsilon_1} \le 1$$

Influence of presence of prestressing cable η_D on prism tests

Empty duct   "Soft" injected duct   "Rigid" injected duct

Interaction between η_ε and η_D

Empty cable   Injected cable, HDPE duct   Injected cable, steel duct

Contribution of the compression flange V_{sup}

$$d_v(x) = d - \left(h_C - \frac{x_{pl}}{2} \right) \cdot \left(\frac{x}{x_0} \right)^2 - \frac{x_{pl}}{2}$$

Contribution of inclined prestressing cables V_p

$$\frac{d\Delta N_p}{dx_p} = \frac{dN_p}{dx_p} = N'_p = k_{\eta_D} \cdot \pi \cdot \varnothing_{p,id} \cdot \tau_{bp}$$

Conclusions

- Criterion for η_ε includes effect of ε_1 and of f_c. Good agreement with RC beams of literature (use of compatible stress field model to this aim)

- Criterion for η_D includes effect of duct diameter to thickness ratio δ and f_c. Good agreement with prism tests. Plastic ducts are less good than steel

- Combined failure criterion (η_ε and η_D) for web of PC beams may be simplified by a linear approach of the form $f_{ce} = \eta_\varepsilon (1 - k \delta) f_c$, k = const.

- Model based on compatibility gives V_{sup} = 10% V for the own PC beams; FEM calculations give comparable values for RC beams with N<0

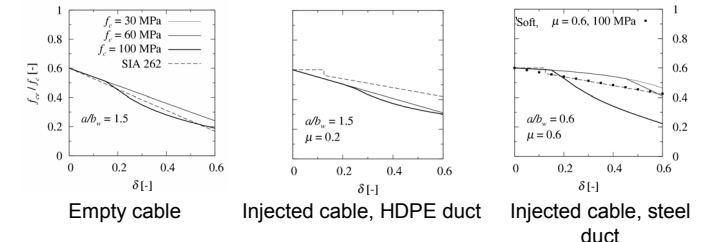- Model using a bond condition for the prestressing cables gives ΔV_p = 10 % V for the own PC beams