Universitatea Politehnica Timişoara
Facultatea de Construcţii
Departamentul de Construcţii Metalice şi Mecanica Construcţiilor

COMPOSITE STEEL-CONCRETE STRUCTURES

- CURS 4-a -

Composite Beams (3)

Conf.dr.ing Adrian CIUTINA

Notele de curs pot fi descărcate de pe pagina de web
http://www.ct.upt.ro/users/AdrianCiutina/

§ 2.12 Design of transverse reinforcement

- The transverse reinforcement present in concrete slab must be designed in the ULS such that to prevent premature longitudinal failure of the concrete slab. The principal phenomena that should be prevented are:
  - longitudinal shear;
  - longitudinal splitting.

- The Eurocode 4 requires a minimum percentage of transverse reinforcement for the concrete slab, in order to take over the shear efforts (slip) produced by connecting devices.

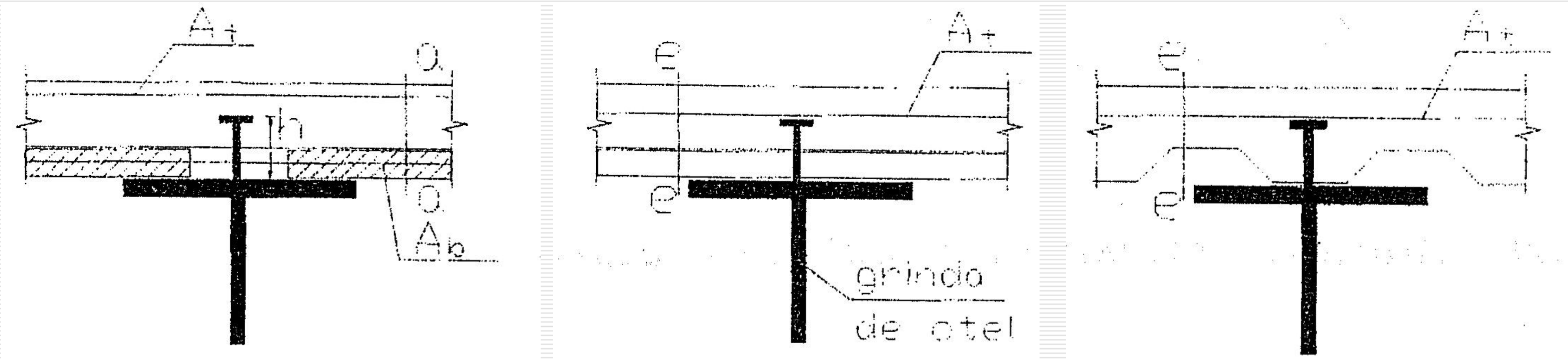
- The check of the transverse reinforcement to longitudinal shear is done by the following formula:

$$v_{Sd} \leq v_{Rd}$$

§ 2.12 Design of transverse reinforcement

- In the above formula:
  - v_{Sd} – the design longitudinal shear per unit length;
  - v_{Rd} – the design resistance to longitudinal shear of the shear surface considered;

- Typical potential surfaces of shear failure are indicated in figure below :



a) Full concrete slab

b) Profiled sheeting slab, with ribs transverse to the steel beam

c) Profiled sheeting slab, with ribs transverse to the steel beam

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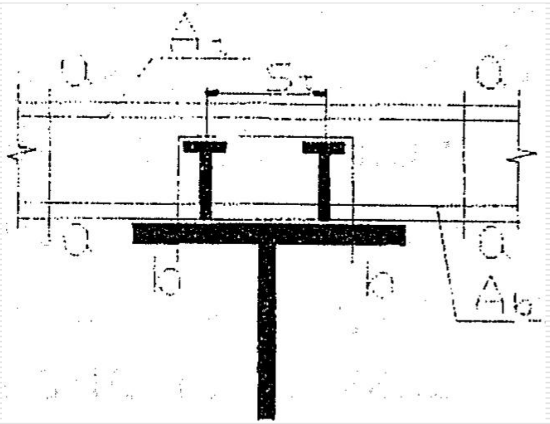
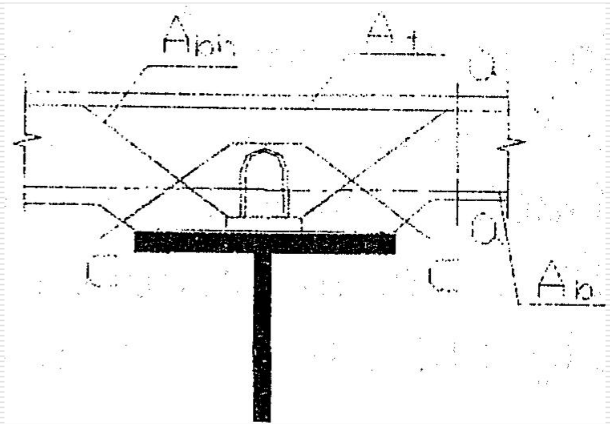
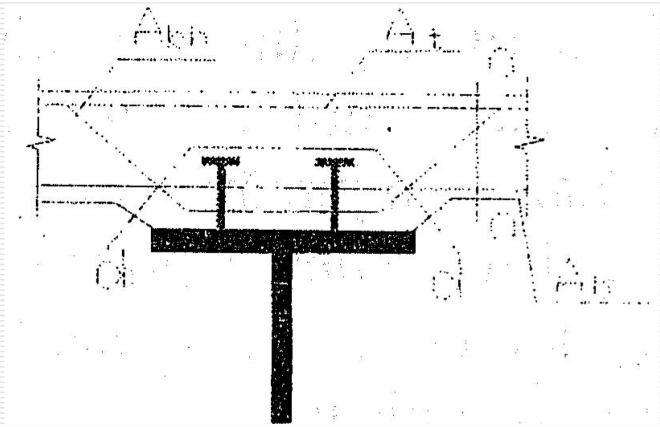


d) Full concrete slab with two rows of connectors



e) Haunched concrete slab with rigid connectors



f) Haunched full concrete slab with headed stud connectors

- Typical potential surfaces of shear failure:

Section type	Failure surface:
a-a	$(A_b + A_t)$
b-b	$2\,A_b$
c-c	$2\,(A_b + A_{bh})$
d-d	A_{bh}
e-e	A_t

§ 2.12 Design of transverse reinforcement

- Notations used in the above figures are:
  - A_b – cross-sectional area of the inferior reinforcing of the concrete slab;
  - A_t – cross-sectional area of the superior reinforcing of the concrete slab;
  - A_{bh} – cross-sectional area of the transversal inclined reinforcement located in concrete haunches;

DESIGN LONGITUDINAL SHEAR FORCE

- The design longitudinal shear v_{Sd} is determined from the resistance of connectors P_{Rd} and computed as a force per unit length of composite beam, by the relations:
  - For a-a section, having the connectors disposed on a single row: $$v_{Sd} = \frac{P_{Rd}}{s}$$
  - For b-b, section, having the connectors disposed on two rows: $$v_{Sd} = \frac{2P_{Rd}}{s}$$

§ 2.12 Design of transverse reinforcement

DESIGN LONGITUDINAL SHEAR FORCE

- In the above formulae:
  - P_{Rd} – is the design bearing resistance of a connector;
  - s – is the longitudinal spacing centre-to-centre of the studs;

LONGITUDINAL SHEAR RESISTANCE

- When computing the longitudinal shear resistance, it should be established the reinforcing areas A_e, computed in accordance of the table given above.

Obs: 1. The b-b shear length given in figure d) is taken as (*h* and *d* are the height and the head diameter of the headed stud respectively):

- $2h + d$ in the case of a single-row of connectors;
- $2h + d + 2s_t$ in the case of connectors disposed on two rows (s_t – represents the is the longitudinal spacing centre-to-centre of the studs);

2. The profiled sheeting with ribs transverse to the steel profile contribute to the longitudinal shear resistance if the sheeting is continuous on the upper steel flange or the stud shear connectors are welded to the steel beam directly through the profiled steel sheets.

§ 2.12 Design of transverse reinforcement

LONGITUDINAL SHEAR RESISTANCE

- The longitudinal shear resistance of all potential shear failure surfaces (in slab or haunches) is computed as the minimum value between:

$$v_{Rd} = 2.5A_{cv} \cdot \eta \cdot \tau_{Rd} + A_e \cdot \frac{f_{sk}}{\gamma_s} + v_{pd}$$

and:

$$v_{Rd} = 0.2A_{cv} \cdot \eta \cdot \frac{f_{ck}}{\gamma_c} + \frac{v_{pd}}{\sqrt{3}}$$

- In the above formulae:
  - τ_{Rd} is the design shear strength of concrete

$$\tau_{Rd} = 0.25\frac{f_{ctk0.05}}{\gamma_c}$$

  - $f_{ctk0,05}$ is the characteristic tensile strength of concrete, computed, 5% fractile;
  - f_{ck} is the characteristic compressive strength of concrete;
  - f_{sk} is the design yield strength of the steel reinforcement;
  - $\eta=1$ for normal-weight concrete;
  - $\eta=0,3+0,7(\rho/2400)$ for light-weight concrete (ρ – density kg/m^3);

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LONGITUDINAL SHEAR RESISTANCE

- A_e represents the sum of cross-sectional areas that passes the considered shear surfaces a-a, b-b, c-c, d-d and/or e-e. These areas are considered transverse on the beam and are evaluated per unit length of the beam. It includes the bending reinforcement present in the concrete slab:
  - For a-a section, the area A_e is:

$$A_e = \frac{A_b + A_t}{s} = \frac{\frac{\pi d_b^2}{4} + \frac{\pi d_t^2}{4}}{s} \quad (\text{mm}^2/\text{mm})$$

    where:
    - A_b and A_t are the cross-sectional areas of the inferior respectively superior reinforcements (of diameters d_b and d_t) of section a-a;
    - s is the center-to-center distance between connectors.
  - For b-b section, aria A_e este:

$$A_e = \frac{2A_b}{s} = 2\frac{\frac{\pi d_b^2}{4}}{s} \quad (\text{mm}^2/\text{mm})$$

  - For c-c section, the area A_e is :

$$A_e = \frac{2(A_b + A_{bh})}{s} = 2\frac{\frac{\pi d_b^2}{4} + \frac{\pi d_{bh}^2}{4}}{s} \quad (\text{mm}^2/\text{mm})$$

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LONGITUDINAL SHEAR RESISTANCE

where:

- A_{bh} cross-sectional area of the transversal inclined reinforcement located in concrete haunches;
- d_{bh} is the diameter of inclined reinforcements;
- A_{cv} represents the transversal cross-sectional area per unit length of the concrete slab in the shear area considered;

- v_{pd} the contribution of the profiled steel sheeting (in case of ribbed slabs) to the longitudinal shear resistance:

$$v_{pd} = A_p \cdot \frac{f_{yp}}{\gamma_{ap}}$$

where:

- V_{pd} is expressed in Newtons per unit length of beam, for each intersection of the beam with the profiled sheeting;
- A_p represents the area of the steel profiled sheeting per unit length of the beam;
- f_{yp} is the yielding strength of the steel of the profiled sheeting;
- γ_{ap} represents the partial safety factor for the profiled sheeting.

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LONGITUDINAL SHEAR RESISTANCE

- When checking the transverse reinforcing, it is chosen a shear stud diameter (between 12 and 20 mm) and the verification is done by:
  - For section a-a:

$$v_{Sd} = \frac{P_{Rd}}{s} \leq v_{Rd}$$

  - For section b-b:

$$v_{Sd} = \frac{2P_{Rd}}{s} \leq v_{Rd}$$

- where:
  - v_{Sd} is the design stress in the reinforcement;
  - v_{Rd} design resistance of shear surfaces.

§ 2.12 Design of transverse reinforcement

REQUIREMENTS FOR TRANSVERSE REINFORCEMENT

- In the case of full concrete slabs, it is recommended a minimum transverse reinforcing area of 0,2% of concrete area.
- In the case of using profiled sheeting, having the ribs parallel or transverse to the steel profile, it is required a minimum transverse reinforcing area of 0.2% from the concrete area, computed above the steel sheeting.
- To prevent longitudinal splitting of the concrete flange caused by the shear connectors, the following additional recommendations should be applied where the distance from the edge of the concrete flange to the centreline of the nearest row of shear connectors is less than 300 mm:
  - transverse reinforcement should be supplied by U-bars passing around the shear connectors;

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REQUIREMENTS FOR TRANSVERSE REINFORCEMENT

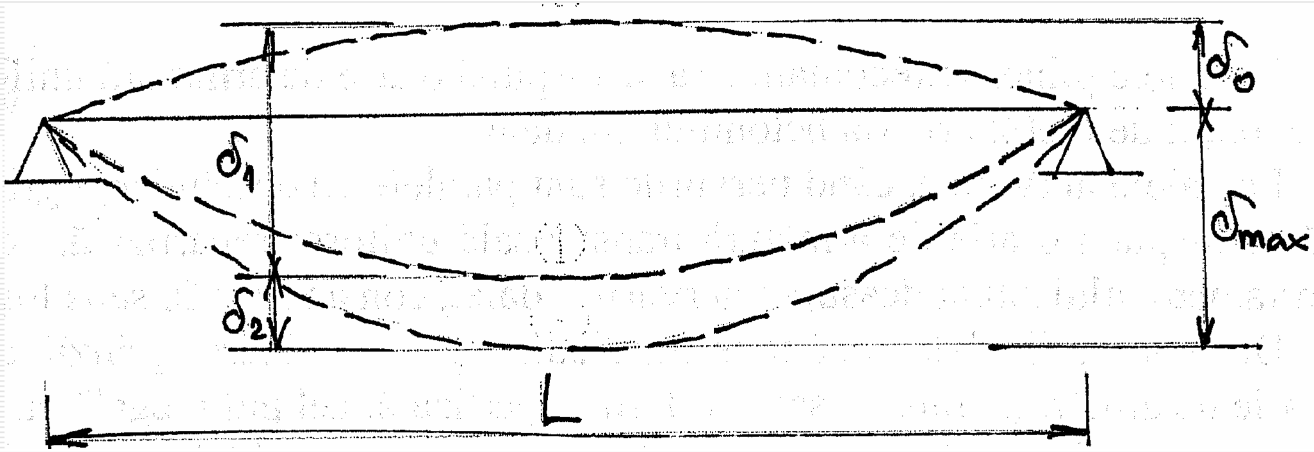
- when headed studs are used as shear connectors, the distance from the edge of the concrete flange to the centre of the nearest stud should not be less than *6d*, where d is the nominal diameter of the stud, and the U-bars should be not less than *0,5d* in diameter;

- the U-bars should be placed as low as possible while still providing sufficient bottom cover.

§ 2.13 Computation and check of deflections

- For composite beams, the deflection check at SLS is performed in accordance to Eurocode 4, Section 5.
- According to this, the total deflection of a beam is computed by the relation:

$$\delta_{max} = \delta_1 + \delta_2 - \delta_0$$



- where:
  - δ_0 is the initial (negative) deflection of the beam;
  - δ_1 is the deflection in the phase 1 (casting of concrete);
  - δ_2 represents the beam deflection due to permanent actions form finishing, variable and technological actions (phase 2).

§ 2.13 Computation and check of deflections

COMPUTATION OF $\boldsymbol{\delta_1}$ DEFLECTION (PHASE 1)

- For the computation of the deflection in phase 1, it must be considered the effects of two loads, δ_1 being:

$$\delta_1 = \delta_{11} + \delta_{12}$$

- where:
  - δ_{11} represents the deflection produced by the weight of the steel profile and that of fresh concrete. This deflection is computed by considering the moment of inertia of the steel profile acting alone.
  - δ_{12} represents the deflection due to the additional loads characteristic to phase 1: weight of workers, weight of casting machines and equipments etc. These loads should be disposed in the most unfavourable positions.

§ 2.13 Computation and check of deflections

COMPUTATION OF δ_2 DEFLECTIONS (PHASE 2)

- In the computation of the deflection in phase 2, there are taken into consideration also two situations, the deflection δ_2 being:

$$\delta_2 = \delta_{21} + \delta_{22}$$

- where:
  - δ_{21} is the deflection produced by the permanent loads applied on hardened concrete (coping, finishing etc.)
  - δ_{22} is the deflection produced by the variable loads: live loads, snow load, technological loads, applied on the composite beams.
- The deflections in the second phase are deduced by considering the moments of inertia of composite sections I_1 and I_2, computed by previous paragraphs. The moments of inertia must be considered in the specific zones, for hogging and sagging bending respectively.

§ 2.13 Computation and check of deflections

DEFLECTION CONTROL

- The total deflection, computed as above is checked by simple comparison to the admissible values of the deflections. For example, in the case of secondary composite beams:

$$\delta_{max} = \delta_1 + \delta_2 - \delta_0 \leq \frac{L}{250}$$

But (supplementary verification)

$$\delta_2 \leq \frac{L}{300}$$

Obs: The principal problem in the case of composite beams is represented by deflections recorded during the casting of concrete - phase 1 (δ_1). In this case, the propping of the beam during this phase could be effective in limiting the final (total) deflection.