Universitatea Politehnica Timişoara
Facultatea de Construcţii
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COMPOSITE STEEL-CONCRETE STRUCTURES

- CURS 6-a-

Composite Connection (2)

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Notele de curs pot fi descărcate de pe pagina de web
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§ 4.4 Classification of Composite Connections

- In Eurocode 3 and Eurocode 4 a connection can be classified by its stiffness, by its strength and by a combination of both its stiffness and strength. Figure *a)* below illustrates the three ways in which a connection can be classified by its stiffness while figure *b)* illustrates the classification by strength. These figures also show the limits given in Eurocode 3 for a braced frame.

- Using its stiffness together with these limits a connection can be classified as pinned, rigid or semi-rigid.
- Similarly a connection can be classified using its strength as pinned, full-strength or partial strength.
- A fuller description of a connection's behaviour can also be obtained by classifying by both stiffness and strength.

Obs: Such a classification leads to connections, which are:

- pinned,
- rigid/partial strength and
- rigid/full-strength,
- semi-rigid/partial strength.

§ 4.4 Classification of Composite Connections

CLASSIFICATION BY STIFFNESS

a) Classification of connections by stiffness

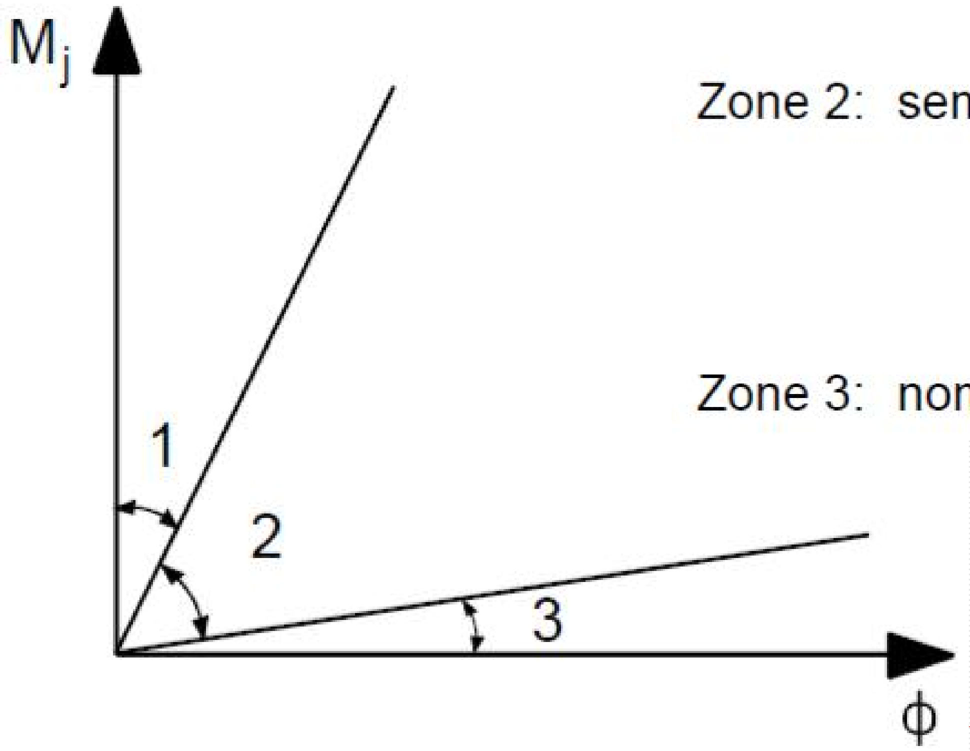
Zone 1: rigid, if $S_{j,ini} \geq k_b E I_b / L_b$

where $k_b = 8$ for frames where the bracing system reduces the horizontal desplacement by at least 80 %

$k_b = 25$ for other frames, provided that in every storey $K_b/K_c \geq 0{,}1$ *)

Zone 2: semi-rigid All joints in zone 2 should be classified as semi-rigid. Joints in zones 1 or 3 may optionally also be treated as semi-rigid.

Zone 3: nominally pinned, if $S_{j,ini} \leq 0{,}5 E I_b / L_b$



§ 4.4 Classification of Composite Connections

CLASSIFICATION BY STIFFNESS

Where:

K_b	is	the mean value of I_b/L_b for all the beams at the top of that storey;
K_c	is	the mean value of I_c/L_c for all the columns in that storey;
I_b	is	the second moment of area of a beam;
I_c	is	the second moment of area of a column;
L_b	is	the span of a beam (centre-to-centre of columns);
L_c	is	the storey height of a column.

CLASSIFICATION BY STRENGTH

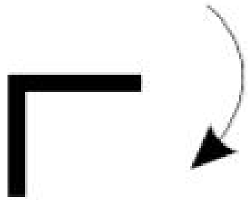
- For classification by strength the resistance of the connection is compared with the capacity of the connected beam.
- The main aim of this parameter is to identify which of the two members will fail first (the connection or the beam).
- The capacity of the composite beam should be taken as its capacity in hogging bending.

§ 4.4 Classification of Composite Connections

CLASSIFICATION BY STRENGTH

b) Classification of connections by strength

a) Top level

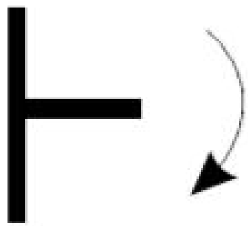


$M_{j,Sd}$

Either $M_{j,Rd} \geq M_{b,p\ell,Rd}$

or $M_{j,Rd} \geq M_{c,p\ell,Rd}$

b) Intermediate level



$M_{j,Sd}$

Either $M_{j,Rd} \geq M_{b,p\ell,Rd}$

or $M_{j,Rd} \geq 2\,M_{c,p\ell,Rd}$

Where:

$M_{b,p\ell,Rd}$ is the plastic moment resistance of a beam;
$M_{c,p\ell,Rd}$ is the plastic moment resistance of a column.

§ 4.4 Classification of Composite Connections

CLASSIFICATION BY STRENGTH

- **Nominally pinned joints** shall be capable of transmitting the internal forces, without developing significant moments which might adversely affect members of the structure.
- A joint may be classified as nominally pinned if its moment resistance $M_{j,Rd}$ is not greater than 0,25 times the moment resistance required for a full-strength joint, provided that it also has sufficient rotation capacity.
- **Full-strength joints.** The design resistance of a full strength joint shall be not less than that of the members connected.
- A joint may be classified as full-strength if it meets the criteria given in figure b) above.
- **Partial-strength joints.** A joint which does not meet the criteria for a full-strength joint or a nominally pinned joint should be classified as a partial-strength joint.

§ 4.4 Classification of Composite Connections

CLASSIFICATION BY STRENGTH

- Where partial-strength joints are used in combination with plastic analysis there is a requirement for rotational capacity. This is needed to permit the redistribution of moments.
- The limits to redistribution are dependent on the local-buckling classification (class 1 plastic, class 2 compact, etc.) of the beam section in hogging bending.

§ 4.5 Capacity of Composite Connections

- The structural action of a composite joint with a steel end-plate connection is shown in figure below:
  - The tensile resistance is provided by the reinforcement in the concrete slab and the upper part of the steel connection;
  - These tensile forces are balanced by compression forces between the lower part of the beam's steel section and the column;
  - Shear resistance is provided by the column web pannel.

§ 4.5 Capacity of Composite Connections

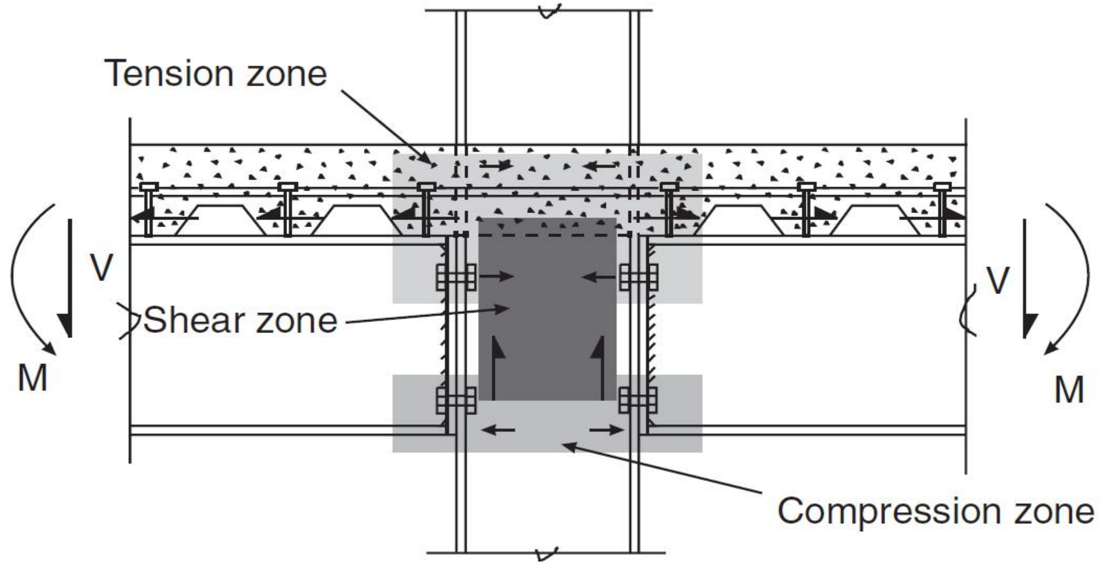


Figure: typical composite connection force transfer by the various component

- By splitting the connection into its tension, compression and shear zones, the resistance of the complete connection can be determined by assembling the resistances of the individual components in such a way that the following three basic requirements are satisfied:
  - The internal forces are in equilibrium with each other and with the external forces applied to the connection;
  - The internal forces never exceed the resistance of the components.
  - The maximum deformation capacity of the components is never exceeded.

§ 4.5 Capacity of Composite Connections

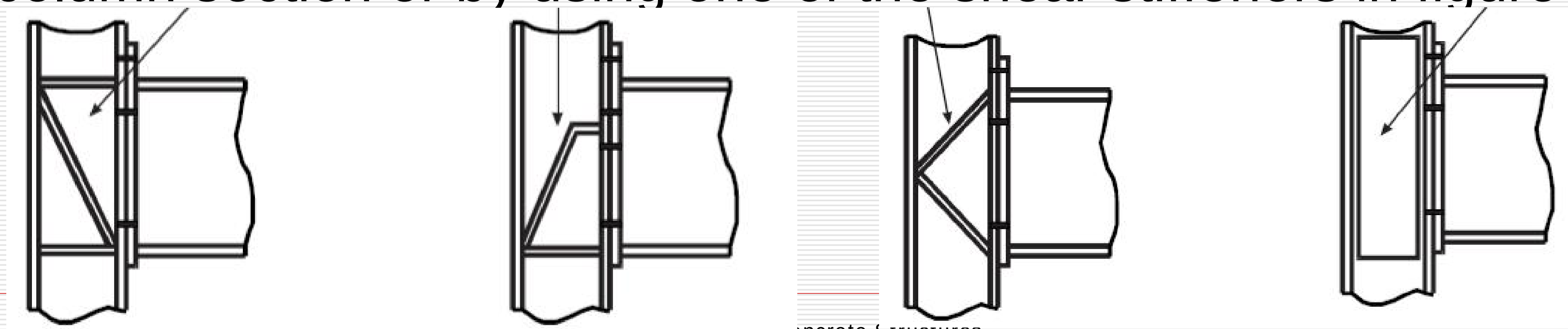
- Researches carried out on composite connections have shown that any of the following four components may control the **tension capacity** of the connection:
  - The tension capacity of the reinforcement.
  - The shear connection between steel beam and concrete.
  - The tension capacity of the steel components.
  - The longitudinal shear force between the slab and the steel beam.

- **The compression resistance** of most of the steel details shown in figure above is based on a consideration of the following modes of failure:
  - The compressive resistance of the beam's lower flange and web.
  - The compressive resistance of the column's web.

Obs: In addition to these modes of failure consideration must be given to bolt slip in the flange cleat connection and lateral–torsional buckling of the fin plate.

§ 4.5 Capacity of Composite Connections

- The column web panel must be designed to resist the resulting **horizontal shear forces**. To calculate these forces the designer must take account of any connection to the opposite column flange.
- In a single sided connection with no axial force the resultant shear force will be equal to the compressive force located at the inferior part of the beam.
  - For a symmetrical two-sided column connection with balanced moments the resulting shear force will be zero.
  - However, in the case of a two sided connection subject to moments acting in the same sense the resultant shears will be additive.
- The strength of a column web can be increased by either choosing a heavier column section or by using one of the shear stiffeners in figure below.



§ 4.6 Stiffness of Composite Connections

- Eurocode 3 Part 1.8 incorporates an alternative method for calculating the stiffness of bare steel connections. This method uses the '*component approach*' in which the rotational response of the joint is determined from the mechanical properties of the different components: end-plate, cleat, column flange, bolts, etc. within the connection.
- The advantage of this approach is that the behaviour of any joint can be calculated by decomposing the connection into its components (end-plate, cleat, column flange, bolts etc).
- The procedure is to derive the rotational stiffness of a connection from the elastic stiffnesses of its component parts. The elastic stiffness of each component is represented by a spring with a force-deformation relationship:

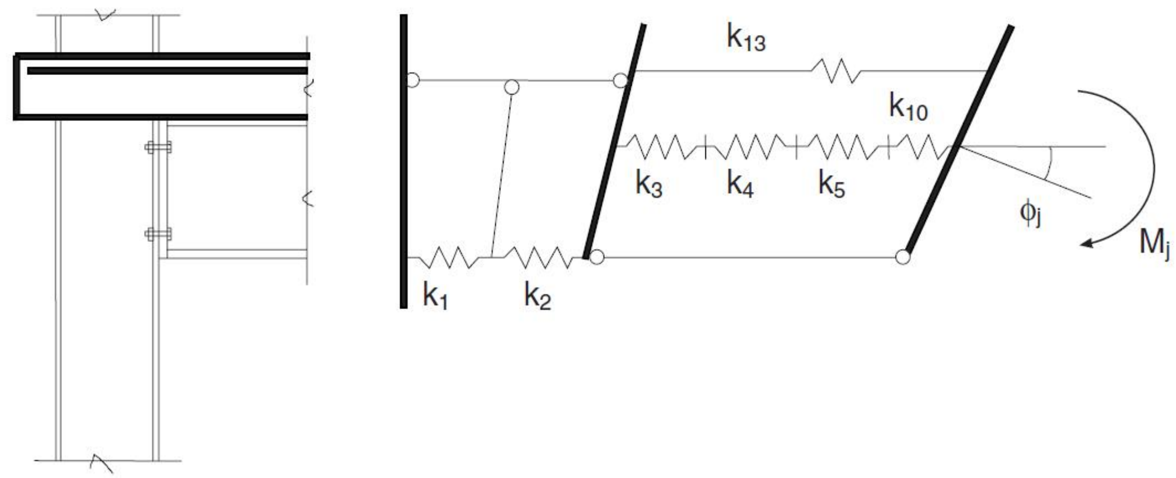
$$F_i = E\, k_i\, w_i$$

Where:

- F_i is the force in component *i*;
- E is the elastic modulus of steel;
- k_i is the stiffness of component *i*;
- w_i is the spring deformation of component *i*.

§ 4.6 Stiffness of Composite Connections

- These components are added together using a simple spring model. The method is best illustrated by a simple example. The figure right shows a simple model for an end-plate connection.



- In this example the stiffness of the connection can be determined from the stiffness of the following components:
  - Unstiffened column web panel in shear (k_1)
  - Unstiffened column web in compression (k_2)
  - Column web in tension (k_3)
  - Column flange in bending (k_4)
  - End plate in bending (k_5)
  - Bolts in tension (k_{10})
  - Reinforcement in tension (k_{13})