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Influence of Parameters Reinforced Concrete Floor to Stiffness of Beam – Columns Connector in Composite Structures

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***Abstract*: In this paper, the author introduces the beam – column connections, steel – concrete composite beams and floor element in the frame structures, and shows how to determine the stiffness connections of the typical beam - column according to European standards. Survey parameters affecting, including: slab thickness; section area and module elasticity of reinforcing bars; distance anchor, in order to clarify the influence of the parameters on the stiffness of the connections beam - column in composite steel – concrete structures.**

***Keywords*: Composite joints, Connections, Steel.**

I. INTRODUCTION

Bearing structure, using steel-concrete composite components is widely used in construction works, and recently made bearing structures for multi-storey houses. The beam and column components are linked together through the link button, they include components such as bolts, flanges, steel angles, supports etc., when bearing, these parts and themselves The cross section of the beam and the column there is deformed [1]. Studies show that the connection between beams and columns has a certain hardness, not absolute stiffness or ideal joints, they affect the working of the frame structure. The studies of the influence of parameters and the form of linkage to the stiffness of the beam-column link, concentrating mainly on steel frames, and the steel-concrete composite frame are quite few. Seeing that the study influences the parameters associated with the stiffness of the link node, it can be done by experiments or numerical simulation by specialized software, these studies account for calculation time and The cost is quite large. However, in a simpler way, by using component component method, it has been mentioned in European steel structure design and steel - concrete composite structure. (EC3 and EC4) [5, 7], to calculate the stiffness of the bond through component stiffness, including the stiffness of the components of the column, beams, bonding elements and reinforced concrete slab . Therefore, the content of this paper will use the European standard to investigate the influence of slab parameters on the stiffness of the beam - column link in the steel - concrete composite frame structure to assess the level of The effect of this parameter on rigidity and recommendation of experts to adjust the stiffness of the beam-column link node by adjusting the slab parameter.

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II. THEORY

A. Beam link button - conjugate column

Due to beam-column alignment in steel frame structure in general and steel-concrete composite frame structure in particular, they are very diverse, the classification depends on many criteria, can be based on the stiffness of the link or in the form, associated position or type of bearing structure, etc. As shown in Fig. 1, some common beam-column types are shown in the steel-concrete composite frame structure, using flanges and bolts (Fig. 1a); direct welding type with beams (Fig. 1b); type using angle steel and bolts (Fig. 1c); models using flanges and bolts, combination bearings (Fig. 1d).

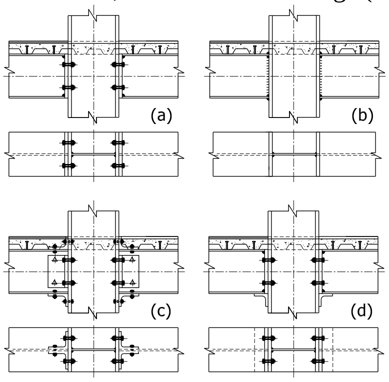

Fig. 1. Several types of beam-column links

B. Beams and combined floor

- Integrated beams, including parts: steel beams (shaped steel or composite steel); Reinforced concrete floors (with corrugated or non-corrugated iron) and beam links with concrete floors (anchor or corner steel), the composite beam construction is illustrated in Fig. 1 [1, 7].

- Integrated floor, including parts: cold-rolled corrugated sheet placed below; reinforced concrete floor slabs; and corrugated iron sheets with concrete floors (anchor pins).

Detailed construction of composite floor parts [1, 7]:

- Floor thickness, thickness h = (80-400) mm, thickness of concrete part is on corrugated iron, , hcs $\geq$ 40mm;

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- Cold-pressed corrugated iron sheet, thickness from (0.75-1.5) mm, for corrosion resistance, galvanized sheets are galvanized on both sides, elastic limit of corrugated steel material is about 300 N / mm2 ;

- Anchor bonding, often using pegs, with round section with caps. Height of latch hch ≥ 3d, where d is the stem diameter. The hat section has a diameter of hcd ≥ 1,5d, and the hat height hh ≥ 0,4d; the distance between the pins in the direction perpendicular to the shear force acs ≥ 5d, the distance in the direction of the cutting force acs ≥ 2,5d with the solid slab and acs ≥ 4d for the other slabs. Maximum distance of pegs acs ≤ 6h or acs ≤ 800mm.

- Reinforcement or wire mesh, arranged within the working thickness (hcs) of the slab. The distance between the steel bars a = min {2h, 350mm} and the steel content according to the whole direction must not be less than 80mm2 / meter long. Elastic modulus of steel material in the range of Es = (190 - 200) kN / mm2. For simplicity of calculation in the conjugate structure, the value Es is the value of Ea = 210kN / mm2 of structural steel.

However, due to the characteristics of working at the girder, and this is also the link beam-column, bending moment in pull beam for slab, and it is often assumed that steel corrugated iron does not calculate joining force but instead It is the steel floor to withstand traction. Therefore, the parameters of the slab affect the working of the structure, including: concrete part thickness (hcs); area of tensile reinforcement (As), reinforcing elastic modulus (Es) and distance of shear anchors (a).

C. Determination of stiffness of beam links - conjugated columns [3, 7, 9]

1) Determine the component stiffness of the beam link - non-conjugated column

In the case of unconnected beams and columns (in normal steel frame without composite structure), the determination of component stiffness such as the hardness of the abdomen column of the compressive column (K_{cwc}), hardness of abdomen of the tensile column (K_{cwt}), hardness of bending column (K_{cfb}), hardness of bending bearing (K_{epb}), hardness of tensile bearing bolt (K_{br}), hardness of upper angle steel wing bending (K_{tab}), determined according to European structural design standards, Eurocode 3 (EC3). This issue has been presented in the article [2].

2) Determine the component stiffness of the beam link - conjugated column

When there is a joint button with a steel-concrete composite floor, in addition to the component hardness mentioned above, at this time there is more component hardness value of the conjugated floor ($K_{long.sr}$) and the hardness value of abutment abutment column (Kcws), this value changes due to the arm swing of the link button changes.

- Hardness ($K_{long.sr}$) of tensile steel in conjugated floor:

When considering only deformation of tensile longitudinal steel in conjugated slab, the hardness $K_{long.sr} = K_{s,r}$ is determined as follows:

$K_{s,r}$ - hardness coefficient of vertical steel in the tensile slab, as follows:

+ with beams only one side of the column, determined by the formula***:***

$$K_{s,r} = A_s/(3{,}6h_c) \qquad (1)$$

+ with beams on either side of the column, and the two-sided bending moment equal ($M_{Rd.l} = M_{Rd.r}$), determined by the formula:

$$K_{s,r} = A_s/(0{,}5h_c) \qquad (2)$$

+ with beams on either side of the column, the bending moment on the side has a larger value (eg the side with $M_{Rd.l}$ when $M_{Rd.l} < M_{Rd.r}$), determined by the formula:

$$K_{s,r} = \frac{A_{s,r}}{h_c\left[(1+\beta)/2+K_\beta\right]}\frac{E_s}{E_a} \qquad (3)$$

with:

$$K_\beta = \beta\left(4{,}3\beta^2 - 8{,}9\beta + 7{,}2\right)$$

β - coefficient, determined as follows:

+ with boundary button, with beams on one side of the column: β = 1;

+ with the middle button, there are beams on both sides of the column, load and symmetry moment: β = 0;

+ with the middle button, there are beams on either side of the column, load asymmetry:

on the large load side: β = 1;

on the small load side: β = 0 and Kst = 0;

As - tensile steel cross section area in the slab, determined by the formula:

$$A_s = \mu.d_{eff}(b_{eff.b} - b_c) \qquad (4)$$

According to structural requirements:

$$A_s^{min} \le A_s \le A_s^{max};$$

with:

$$A_s^{min} = 0{,}004d_{eff}(b_{eff.b} - b_c), \text{ and}$$

$$A_s^{max} = \frac{1{,}1(0{,}85f_{ck.s}/\gamma_c)b_c d_{eff}}{\beta(f_{sk}/\gamma_s)} \qquad (5)$$

Here:

b_c - width of column cross section;

$b_{eff.b}$ - effective width of the slab, determined by the formula:

$$b_{eff.b} = 3h_b \qquad (6)$$

d_{eff} - the effective thickness of the slab, deff = hcs;

f_{sk} - standard strength of tensile steel in concrete;

f_{ck}. - standard strength of concrete materials;

γ_c, γ_s - reliability coefficient of concrete and steel materials:

μ - reinforcement content in the slab, determined by the formula:

$$\mu = \frac{A_s}{(b_{eff} - b_c)d_{eff}} \qquad (7)$$

Condition, 0,3% ≤ μ ≤ 0,9%

- The hardness ($K_{long.sr}$) of vertical steel is pulled in the conjugated floor when considering the deformation of the anchor anchor:

$$K_{long.sr} = K_{s.r}K_{slip} \qquad (8)$$

Inside:

K_{slip} – reduction factor, determined by the formula:

$$K_{slip} = \frac{1}{1+\frac{E_sK_{st}}{K_{sc}}} \qquad (9)$$

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With:

E_s - elastic modulus of vertical steel material of slab;

K_{sc} – stiffness coefficient of shear anchors, determined by the formula:

$$K_{sc} = \frac{Nk_{sc}}{\nu - \dfrac{\nu - 1}{1+\xi}\dfrac{h_1}{d_s}} \quad (10)$$

d_s - the distance from the neutral axis of the steel beam to the center of the tensile steel section in the slab, determined by the formula:

$$d_s = 0{,}5h_b + h_{cs} + h_{ps} - a_{cs} \quad (11)$$

h_{fs} - vertical steel arm in the joint slab for the center of rotation, determined by the formula:

$$h_{fs} = h_b - 0{,}5t_{fb} + h_{cs} + h_{ps} - a_{cs} \quad (12)$$

Here:

h_b - beam section height;

a_{cs} - distance from the center to the reinforcement section to the floor on the slab;

h_{cs} - working thickness of concrete slab, $h_{cs} = d_{eff}$;

h_{ps} - corrugated wave height;

ξ - coefficient, determined by the formula:

$$\xi = \frac{E_a I_a}{d_s^2 E_s A_s} \quad (13)$$

ν – coefficient, determined by the formula:

$$\nu = \sqrt{\frac{(1+\xi)\, Nk_{sc} L_{eff.b} d_s^2}{E_a I_a}} \quad (14)$$

With:

$L_{eff.b}$ - effective length of slab, determined by the formula:

$$L_{eff.b} = 4h_b \quad (15)$$

N - the number of anchors cut on the effective width of the slab, determined by the formula:

$$N = (L_{eff.b}/ \text{Anchor distance} +1) \quad (16)$$

I_a - second-inertia moment of steel beam section;

k_{sc} - second-inertia moment of steel beam section;

- Hardness of the abutment plate abutment (K_{cws}) when working on the joint floor:

When the conjugation works, then the arm of the joint changes so that the stiffness of the abutment plate is cut (K_{cws}), determined by the formula:

$$K_{cws} = 0{,}38\frac{A_{vc}}{\beta h_{eq}} \quad (17)$$

3) Determine the stiffness of the beam link node - conjugate column

With the column link beams using flanges - bolts and tie beam columns using angle steel - bolts, at this time Keq is the equivalent stiffness of the longitudinal steel in the slab and of the bolt rows for the center, according to the formula:

$$K_{eq} = \frac{K_{long.sr}h_1 + \sum_{i=2}^{n_b} K_i^* h_i}{h_{eq}} \quad (18)$$

b) Hardness of the beam-column link

$$K_\varphi = \frac{E_a h_{eq}^2}{\dfrac{1}{K_{wcs}} + \dfrac{1}{K_{cwc}} + \dfrac{1}{K_{eq}}} \quad (19)$$

Inside:

h_{eq} - equivalent arm for the center of rotation, determined according to the following cases:

+ With the link beam column using direct welding, determined by the formula:

$$h_{eq} = \frac{K_{long.sr}h_1^2 + K_2^* h_2^2}{K_{long.sr}h_1 + K_2^* h_2} \quad (20)$$

Inside

ht - torque arm for rotating center.

+ With the link of the column girder using the bolt flange and the connecting column of the column beam using angle steel - bolt, at this time heq is the equivalent arm arm of the longitudinal steel in the slab and of the bolt rows for the turning center determined by the formula:

$$h_{eq} = \frac{K_{long.sr}h_{fs}^2 + \sum_{i=1}^{n_b} K_i h_i^2}{K_{long.sr}h_{fs} + \sum_{i=1}^{n_b} K_i h_i} \quad (21)$$

Other symbols are explained and identified as in the document [3].

III. SURVEYING THE INFLUENCE OF SLAB PARAMETERS ON BEAM-COLUMN STIFFNESS

A. Calculation parameters and survey requirements

1) Parameter calculation

Girder-column link in steel-concrete composite structure, using flanges and bolts (as shown in Fig. 2), the material and geometry parameters are as follows:

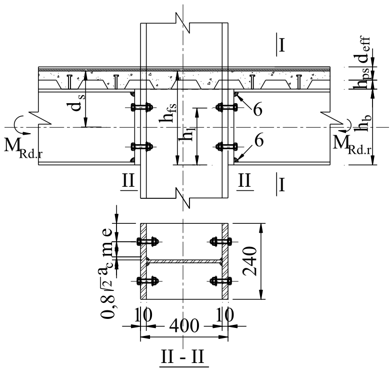

Fig. 2. Beam - column link button using flanges and bolts

Materials of beam and column steel have elastic modulus, $E_a = 210.10^3 N/mm^2$. Bearing steel material is pulled in a slab of standard tensile strength, $f_{sk} = 460 N/mm^2$ and elastic modulus, $E_s = 210.10^3$ N/mm. Standard compressive strength of concrete in slab, $f_{ck.s} = 20 N/mm^2$. The reliability coefficient of concrete and steel materials is: $\gamma_c = 1{,}5$; $\gamma_s = 1{,}15$.

* Geometric-sized beams:

Height of girder section, $h_b = 350$ mm

Thickness of girder plate, $t_{wb} = 6$ mm

Width of beam plate, $b_{fb} = 170$ mm

Thickness of beam plate, $t_{fb} = 8$ mm

The height of the weld seam with the girder belly, $a_{fb} = 6$ mm

* Joint floor:

Working thickness of slab, $h_{cs} = 80$mm

The effective thickness of the slab, $d_{eff} = 80$mm

Floor reinforcement area, $A_s = 402$ mm2

The distance from reinforcement is to pull the floor to the floor, $a_{cs} = 40$mm

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Corrugated wave height, h_{ps} = 50mm
Anchor resistant to steel beams, anchor type with anchor head diameter of 19mm, stiffness, k_{sc} = 100.10^3N/mm^2, distance of anchorage points in floor, a = 100mm
* Columns with geometric shapes:
Height of column section, h_c = 400 mm
Stomach plate thickness, t_{wc} = 8mm
Width of the column plate section, b_{fc} = 240 mm
Column thickness of the column, t_{fc} = 10 mm
Height of welding seam with wing column, a_{fc} = 6mm
* Flange:
Flange width, b_{ep} = 200 mm
Flange thickness, t_{ep} = 20mm
Distance of beam edge to flange, L_{ep} = 70mm
The distance of the first row of bolts to the flange edge, e_{ep} = 40mm
Distance of two bolts in a row, w = 60mm
Distance of end bolts to flange edge, e_{pl} = 70mm
The distance from the top bolt center to the middle of the wing on the beam, p = 48mm
* Bolts:
Bolt diameter, d_b = 20mm
Distance between two rows of bolts, p_p = 220mm
Distance of bolts to flange edge, p_1 = 100mm
* Height of welding line:
Flange welding line - girder, a_{ep} = 6mm
Flange welding line - belly girder, $a_{ep.w}$ = 6mm
Flange welding line - wing under beam, a_{pf} = 6mm

2) Request survey

Survey the parameters of the conjugate floor, affecting the beam-column link stiffness, the case of linking using flanges and bolts, including: (1) the working thickness of the slab, h_{cs}; (2) area of reinforced reinforcement, A_s; (3) elastic modulus of tensile reinforcement, E_s; and (4) the distance between shear-anchored anchors, a.

- Case 1: Change the working thickness of the combined floor, corresponding to the following cases: h_{cs} = 70 mm, h_{cs} = 80 mm, h_{cs} = 90 mm, h_{cs} = 100 mm.
- Case 2: Change the area of tensile reinforcement in the conjugate floor, in the following cases: A_s = 226 mm2 (equivalent to 8ϕ8 a150) and A_s = 402 mm2 (equivalent to 10ϕ8 a100).
- Case 3: Change the elastic module of tensile reinforcement in the conjugate floor, in the following cases: E_s = 190000 N / mm2, E_s = 200000 N / mm2, E_s = 210000 N / mm2.
- Case 4: Change the distance of the shear-anchored anchor in the conjugated floor, corresponding to the cases: a = 100 mm, a = 200 mm, a = 300 mm, a = 400 mm.

3) Survey results

(1) Case 1:
From the process of calculating the stiffness of the tie beam column using flanges and bolts, the working thickness value of the slab corresponds to the following cases: h_{cs} = 70 mm, h_{cs} = 80 mm, h_{cs} = 90 mm, h_{cs} = 100 mm, the survey results influence the working thickness of the conjugated floor to the beam link stiffness - column using the flange and bolt shown in Tab. 1 and the graph illustrated as Fig. 3.

Tab. 1. Effect of combined floor thickness

No	h_{cs} (mm)	K_φ (kNm/rad)	Difference (%)
1	-	11682	-
2	70	15542	33,04
3	80	15797	35,23
4	90	16061	37,49
5	100	16332	39,80

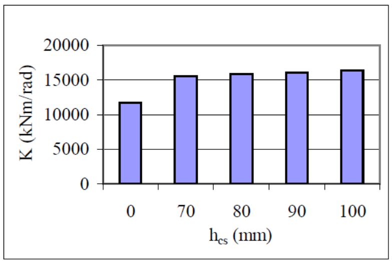

Fig. 3. Illustration of the effect of floor thickness

(2) Case 2:
From the calculation of column beam link stiffness using flanges and bolts, the value of the tensile reinforcement area in the conjugate floor corresponds to the following cases: A_s = 226 mm^2 (equivalent to 8ϕ6a150) and A_s = 402 mm^2 (equivalent to 8ϕ8 a100), the results of surveying the effect of the tensile reinforcement area in the conjugated floor to the stiffness of the beam link-column using flanges and bolts in Tab. 2 and graph illustrated as Fig. 4.

Tab. 2. Influence of tensile reinforcement area in the floor

No	A_s (mm)	K_φ (kNm/rad)	Difference (%)
Floor thickness h_{cs} = 70mm			
1	-	11682	-
2	226	14048	20,25
3	402	15542	33,04
Floor thickness h_{cs} = 80mm			
1	-	11682	-
2	226	14204	21,59
3	402	15797	35,23

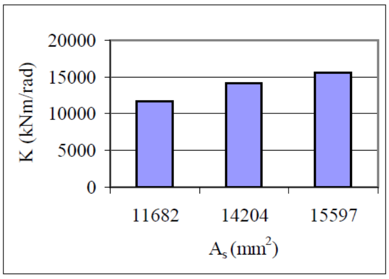

Fig. 4. Illustration of the effect of the area of reinforcing steel in the floor

(3) Case 3:
From the calculation of column beam link stiffness using flanges and bolts, the modulus of elastic modulus of tensile reinforcement in the conjugated floor corresponds to the following cases: E_s = 190000 N/mm^2, E_s = 200000 N/mm^2, E_s = 210000 N/mm^2, the results of surveying the effect of the elastic tensile reinforcement module in the conjugated floor to the beam link stiffness - column using flange and bolts link in Tab. 3 and graph illustrated as Fig. 5.

Tab. 3. Effect of tensile reinforced elastic module in the conjugate floor

No	E_s (N/mm^2)	K_φ (kNm/rad)	Difference (%)
1	-	11682	-

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2	190000	15499	32,67
3	200000	15650	33,97
4	210000	15797	35,23

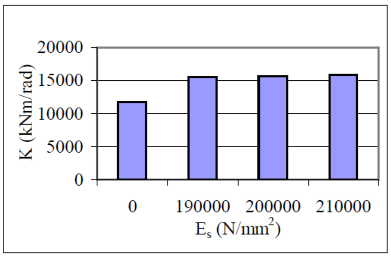

Fig. 5. Illustration of the effect of the reinforced reinforcement elastic module in the floor

(4) Case 4:

From the process of calculating the column girder stiffness link using flanges and bolts, the value of the shear-resistant anchor gap in the conjugated floor corresponds to the cases: a = 100 mm, a = 200 mm, a = 300 mm, a = 400 mm, the survey results influence the distance of the shear in the conjugated floor to the stiffness of the beam - column using flanges and bolts shown in Tab. 4 and illustrated graphs as Fig. 6.

Tab. 4. Influence of shear anchor distance in floor

Stt	a (mm)	K_φ (kNm/rad)	Chênh (%)
1	-	11682	-
2	100	15797	35,23
3	200	15550	33,11
4	300	15386	31,71
5	400	15265	30,67

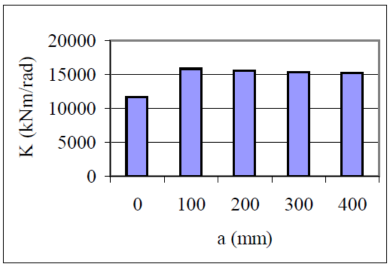

Fig. 6. Illustration of the effect of shear anchor distance in the floor

B. Review results

- When there is a combined slab version, the stiffness of the column tie link using flanges - bolts increase (22.00-39.80)%. Thus, the combined slab has increased the stiffness of the column girder bonding node.

- In the above survey cases, the case of increasing the tensile bearing area in the conjugate floor is the case of increasing the stiffness of the column beam link significantly. Next is the case of increasing the working thickness of the conjugate floor, the other two cases include increasing the elastic modulus of the tensile reinforcement and the distance of the anchor in the composite floor, which increases the stiffness of the bonding node but does not significant.

Therefore, in order to increase the stiffness of the column-link knot structure in the steel-concrete composite frame structure, the author recommended consideration of the influence of the tensile reinforcement area in the floor and the floor thickness.

IV. CONCLUSION

Above, the author has analyzed the basis of selecting parameters of the slab and developed a calculation and survey process that affects those parameters to the stiffness of the beam-column link in the steel frame structure. - concrete.

Through the survey showed that the slab also affects the stiffness of the beam-column link, and often increases the hardness value compared to not considering the impact of the slab. Increasing the stiffness of the beam-column link, due to the impact of tensile steel is the main and will be effective when increasing the reinforcement area around the link button.

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