Project title: Innovative lightweight cold-formed steel-concrete composite floor system Acronym: LWT-FLOOR Project ID: UIP-2020-02-2964 2nd LWT-FLOOR Project Workshop

Numerical investigation of shear connection in cold-formed steel-concrete composite beam

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1. Introduction



- Sustainability of the built environment (construction industry)
 - Energy conservation
 - Conservation of raw material increase value of structural components and building materials through entire lifecycle





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2. Numerical model – Geometry



• Two types of shear connection

Bolted shear connection (embedded nuts)

- Embeded nuts
 - Increased stiffness
 - Easier mounting
 - Direct shear force transmission
 - M12 and M16, grade 8.8
- CFS 2.5 and 3.0 mm (2 grades)
- CW 1.25 mm
- C20/25 + Q524 mesh



Composite dowel rib connector

- Indirect shear force transmission
- CW 0.8 and 1.5 mm
- CFS 2.0 mm
- 3 spot welds per CFS profile
- C20/25 and LC20/22
- Q524 mesh and bars Ø8 mm



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2. Numerical model – Geometry



- Two types of shear connection
 - 12 models

Model	Steel grade	CFS profile	Corrugated web	Bolts	Concrete class				
S1	DX51D		780x120x1.25	M12					
S2	S350GD	20x47x2.5	780x120x1.25	M12	C20/25				
S3	DX51D		780x120x1.25	M16					
S4	S350GD	Ĥ	780x120x1.25	M16		Bolted shear			
D1	DX51D	120x47x3.0	780x120x1.25	M12		connection			
D2	S350GD		780x120x1.25	M12		March Contraction			
D3	DX51D		20x ²	20x ²	20x ⁴	780x120x1.25	M16		and the second sec
D4	S350GD		780x120x1.25	M16					
C1	DX51D	20x47x2.0	780x420x0.8	-	C20/25				
C2	DX51D		780x420x0.8	-	LC20/22	Composite dowel rib			
C3	DX51D		780x420x1.5	-	C20/25	<u>connector</u>			
C4	DX51D	H	780x420x1.5	-	LC20/22				



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2. Numerical model – Constitutive models



Steel

- Bilinear curve
- E_s=210 GPa
- v=0.3
- ρ=7850 kg/m³

Steel	f _{ys} [N/mm ²]	f _{us} [N/mm ²]	ε _{us} [-]				
DX51D	270	325	0,15				
S350GD	350	420	0,15				
8.8	640	800	0,12				
Reinforcement	500	500	-				





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2. Numerical model – Constitutive models

Concrete

- Concrete damage plasticity (CDP) model
- C20/25 ρ=2400 kg/m³
- LC20/22 ρ=1750 kg/m³
- <u>Compression failure</u>
 - Extended EC 2 model
 - Pavlović et. al. [29]

- <u>Tension failure</u>
 - Cornelissen et. al. [30]



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2. Numerical model – Interactions

Interaction

- Surfaces in contact
 - Normal behaviour hard contact
 - Tangential penalty friction (0.3 frictional coefficient) or frictionless

Model name	Nut-CFS profile	Bolt -CFS profile	CFS profile- PSS	Nut-slab PSS	Concrete slab-slab PSS	Bolt- concrete slab
M1	\checkmark	\checkmark	\checkmark	\checkmark	\checkmark	\checkmark
M2	×	×	×	\checkmark	\checkmark	\checkmark
M3	×	×	\checkmark	\checkmark	\checkmark	\checkmark
M4	\checkmark	\checkmark	×	\checkmark	\checkmark	\checkmark
M5	\checkmark	\checkmark	\checkmark	×	×	×
M6	\checkmark	\checkmark	\checkmark	\checkmark	×	\checkmark

• Spot welds

- 3 per CFS profile
- Rigid behaviour (avoid failure)
- Simulation: MPC link (solid-shell) or Point-based fastener (shell-shell)



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2. Numerical model – BC and Load



LOAD

• BC

- Bottom concrete plane
 - All directions
- CFS top
 - Horizontal directions
- CFS free part
 - Constraint Rigid body

• Load

- Bolted SC
 - Dispalcement: 10 mm
 - Time step: 0.1 s
- Composite dowel rib SC
 - Dispalcement: 30 mm
 - Time step: 0.3 s



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3. Results – Bolted SC

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3. Results – Bolted SC







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3. Results – Bolted SC





Model	F _{b,Rk}	N _{Rk}	$\boldsymbol{P}_{\boldsymbol{R}\boldsymbol{k},\boldsymbol{S}}$	$k_t \cdot P_{Rk,S}$	P _{Rk,C}	$k_t \cdot P_{Rk,C}$	
D1	25.4	181	54.4	31.6	32.3	18.7	٦
D2	32.8	235	54.4	31.6	32.3	18.7	
D3	34.4	181	100	58	57.5	33.4	
D4	44.4	235	100	58	57.5	33.4	

single connector or element

	Model	F _{NUM}	Failure mode	F _{CALC}	$\frac{F_{CALC}}{F_{NUM}}$	$k_t \cdot F_{CALC}$	$\frac{k_t \cdot F_{CALC}}{F_{NUM}}$
	D1	296	Concrete	259	0.87	150	0.51
whole model	D2	303	Concrete	259	0.85	150	0.50
	D3	339	Stability	362	1.07	-	-
	D4	358	Concrete	460	1.28	267	0.75



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3. Results – Composite dowel rib SC







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3. Results – Composite dowel rib SC

• C1, C2

- Yielding of CW in shear
- No decrease in F-δ curve steel failure not explicitly defined

• C3, C4

Yielding of CW in shear with concrete failure afterwards



Analytical resistance

Cross-section shear resistance (projected CW length 630 mm)

CW0.8 = 160 kN; CW1.5 = 300 kN

Behaviour

- More ductile, but lower initial stiffness than bolted SC
- No influence of concrete density (similar strength and stiffness parameters)



4. Conclusions



- Specimens with bolted SC show more stiffness and strength, but are less ductile
- Influence of bolt diameter on the shear connection failure in concrete when plate ribs are transverse to the beam should be checked. There is indication that the reduction factor, k_t might be increased or even completely omitted for smaller bolt diameters
- Application of the reduction factor, k_t should be checked for strengths >450 MPa, and bolts with diameter <16 mm
- Behaviour of specimens with composite dowel rib SC is not affected by concrete density when similar concrete classes are used



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