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Joint Configuration of Composite Beams to Reinforced Concrete Wall

Maria Pop[a,]*, Zoltan Kiss[a], Paul Pernes[a]

[c]*Faculty of Civil Engineering, Technical University of Cluj-Napoca, 15 C. Daicoviciu Street, RO-400020, Cluj-Napoca, Romania*

Abstract

Multi Storied structures are used worldwide and have outstanding advantages in the use of composite materials in structural application. This study heads to an experimental and to a numerical study to reproduce the behavior on a composite joint configuration.
The experimental and numerical calibration and validation of the behavior is treated, for the simulation of the composite beam to reinforced concrete wall configuration subjected to a monotonic loading, to determine deformation capacity of the joint.

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Keywords: composite beams; concrete wall; joint components; numerical model; interaction.

1. Introduction

Due to the lack of knowledge, during the last few years a lot of studies are based on the semi-rigid composite joints that can provide useful data about the behaviour and the resistance of these connections. [2]

The study aims to an experimental and a numerical study, to reproduce the behavior of a joint configuration between a composite beams to a reinforced concrete wall. The advantages of these joints are to reduce costs and to minimize onsite construction durations of the structure. The complex method is to approach the design of steel and composite joints with proven efficiency.

* Corresponding author. Tel.:+40-745.262.072.
E-mail address: maria.pop@dst.utcluj.ro

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A number of two tests were performed and a numerical study was carried out to obtain a better development of the joint behavior.

Classification criteria of the joints are: rigid, semi-rigid and pined connection which take account of the rotation capacity, by comparing with the stiffness of the initial rotation capacity $S_{j.ini,}$ where the joints can be determinate on the structure:

$$S_{j,ini} \leq 0{,}5\frac{EI_b}{L_b} \tag{1}$$

According to the joint configuration, [7] it is assumed that the moment resisting condition is calculated to be:

$$Mj,Rd < Mpl,Rd,b \tag{2}$$

Nomenclature

$M_{pl,Rd,b}$	Value of the plastic moment resistance of composite section
M_j,R_d	Value of the computation moment resistance of composite section
M_j,R_d	reference state (started state)
$V_{pl,Rd}$	Value of the shear force
I_b	Inertia moment of the beam joint
L_b	Beam opening

2. Description of the proposed joint

In this study, a design of a full-scale composite joint that is composed of a concrete wall to a composite beam, is proposed and tested. The data from the tests was also used to calibrate the three-dimensional model with the finite element program.

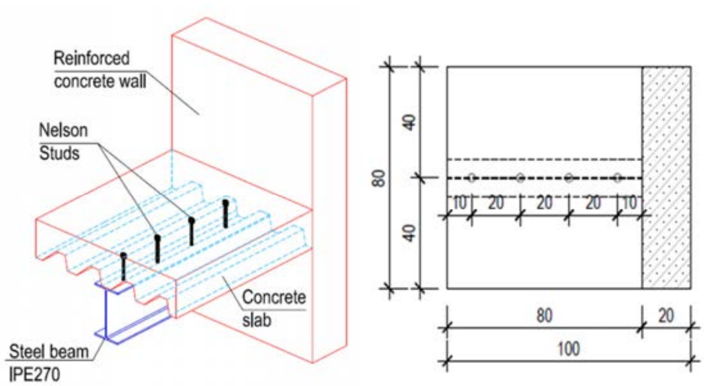

Fig. 1. Test specimen configuration

The experimental program consisted in testing until failure of four composite joints are showed in Fig. 1, the specimens were tested at the Civil Engineering Faculty from Technical University of Cluj-Napoca (TUCN). The joint was loaded at the mid span of the beam with a concentrated load.

The joint has the configuration of: a steel profile IPE 270, concrete class C25/30 (for the concrete wall and beam) that are showed in Table 1.

Table 1 Performed models to experimental testing procedure

MODEL ID	Position	Concrete beam C25/30 (cm)	Steel beam (S275)	End plate (mm)	Wall Concrete Rebars (B500S)	Beam Concrete Rebars	Multideck Steel floor
PM 1	Monotonic	15	IPE 270	10	Ø12	Ø10	S250
PM 2	Monotonic	15	IPE 270	10	Ø12	Ø10	S250

3. Experimental program

The design model of the composite joints is to determine the behaviour of the joints under bending moment. Experimental tests on concrete and steel materials are made to validate the numerical model against the experimental data. For each element samples were taken to determine compressive strength for the concrete wall and the concrete slab.

Fig. 2 Compressive strength tested

Concrete strength was determined on three specimens showed in Fig. 2: cube 150mm dimensions, samples were taken at the site were the concrete casting was made and tested after 28 days and at the experimental date.

Table 2 Characteristic values for the concrete materials

Testing	f_{cmcube}	E	Unit
28 days	31,31	31385	N/mm2
Experimental date	33,5	32264	N/mm2

Due to the testing of the concrete materials (see Table 2), the results showed similar behaviour and the concrete, the proper class was achieved in all specimens.

The steel materials were tested also according to the tensile testing procedure [9].The specimens were tested to determine the characteristics physical and mechanical. All the tested specimens had the same material properties.

The results of the tensile test on the tree specimens tested for the steel beams are given in Fig. 3, the ultimate elongation shows the steel elements have a good ductility.

The experimental program for the composite joints was conducted by using a pattern for monotonic loads [11]. The force was induce with the help of a hydraulic press of 1200kN, and an extension of 40cm.

The basic set-up includes a reaction frame and a loading system, Fig. 4 shows the reaction frame used in the experimental testing procedure. The supports provided for the joints was hinge at the bottom part of the wall and at the upper side was simply supported. The composite beam had one side free edge and at the joint interface was embaded in the concrete wall.

A vertical load was applied at the free edge of the composite beam up to failure. The tests were performed using in control of displacements showed in Fig. 5.

In all test failure was obtained by the rupture of the longitudinal steel reinforcement bars in tension, also the steel decking suffered major deformation.

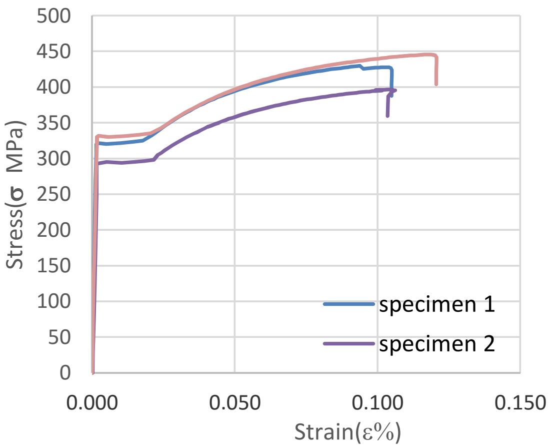

Fig. 3 Stress–Strain curve determined for the steel beam

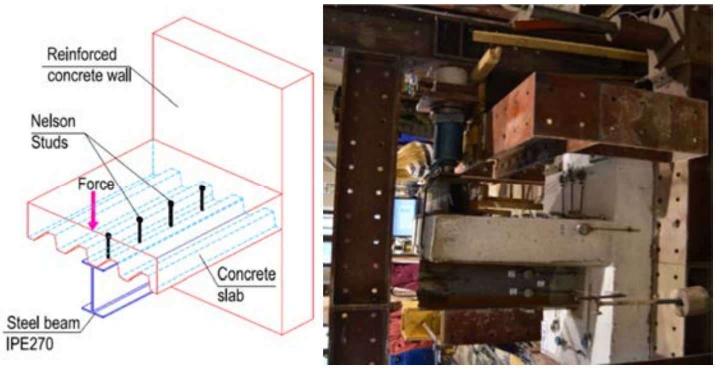

Fig. 4 Instrumentation of the experimental set-up

Fig. 5 Failure of the specimens in Experimental and Numerical model

4. Identification of joint components in FEM

This study is carried out with the finite element program Abaqus v.6.10 [4] and involves simulating the composite connection on a composite beam to a concrete wall with the purpose to determine the rotation capacity, rigidity and the strength of the joint configuration.

Numerical model consists of three-dimensional elements, the geometry and nonlinearity of the material are taken into account.

The calibration and validation of the model is based on the convergence of the results and in comparison with the experimental program. For the finite element calibration of the joints are modelled is used the first order element with reduce integration (C3D8R).

For the main elements: concrete wall, concrete beam, end plate and anchor plates are defined as “Solid deformable”, the decking flooring is defined as “Shell deformable”, the reinforcement in the concrete wall and the concrete beam are defined as “wire” (B31), shear conectors are modeled as “solid deformable” elements.

The material properties used for concrete and steel profiles is the curve obtained on the material according to the tests specimens. The studs, and the end plate were modelate with a standard steel S250. For the flooring deck a standard steel curve of S235 was defined.

The Contact between steel pieces: ‘‘hard’’ contact with on the tangential direction, on the surface 2D of the surface was used the contact with friction (μ= 0.45).

The value of the parameters defining Concrete damage plasticity (CDP) are showed in Table 3.

Table 3 Additional parameters to define CDP constitutive model

Parameter	Ψ	ε	f_{t0}/f_{c0}	k
Preset Value	-	0,1	1,16	0,667
Considered Value	36	0	5	6

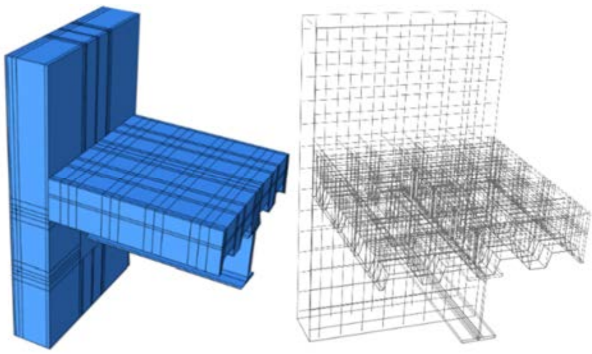

Fig. 6 Finite element model of the composite joint configuration

The numerical joint configuration was developed in Fig. 6 in the FEM model using all the results obtained in the experimental part. The FE model was developed to obtain an accurate behaviour of the model by validation of the comparison of results in terms of Moment - rotation (M_j,R_d - ϕ) also von misses stress are showed in Fig. 7.

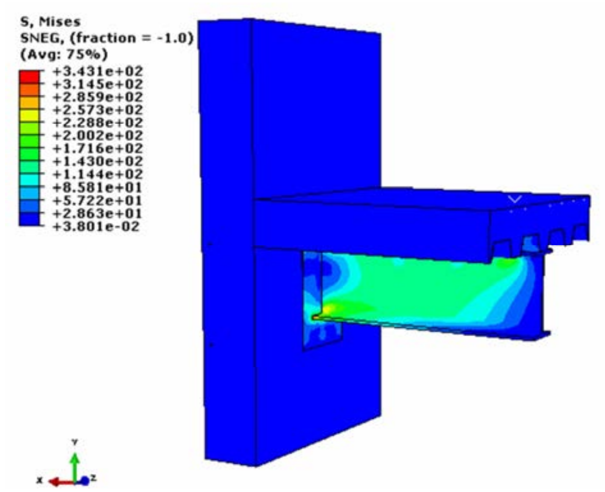

Fig. 7 von Misses stresses

The main results obtained for the Moment–rotation curve M_j,R_d showed in Fig. 8, corresponding to the joints in experimental and also in the numerical part. The results of the FE model are also included. The results shows a good rotation at the maximum bending moment, with a percentage difference between the numerical and experimental part of 7%.

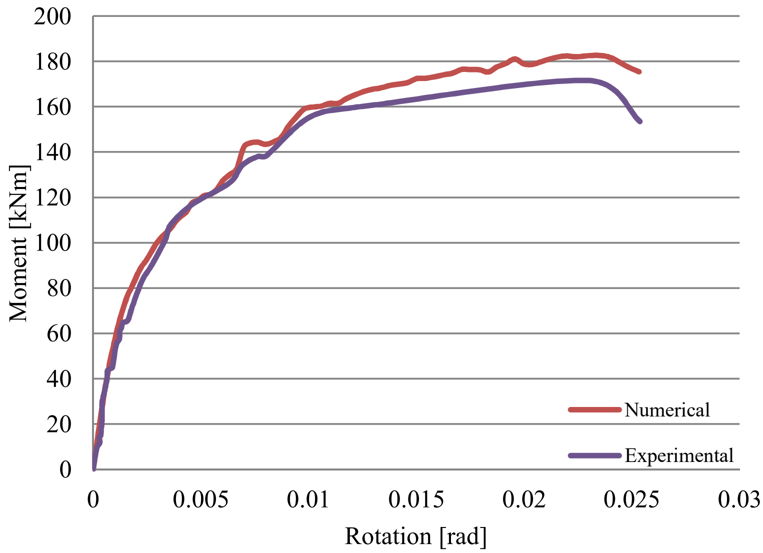

Fig. 8 Results of FE and Experimental Analysis

5. Conclusions

The paper makes a short description of the composite joint configuration that is to be investigated through experimental tests on a concrete wall to a composite beam. The purpose is to assess the joint characteristics in terms of resistance and rotation capacity. Each components of the joints were identified and designed according to current design codes.

The joint connection between the concrete wall and composite beam is also numerical simulated in the FE modelling. Based on the obtained results, the numerical simulation prove a good configuration and design of the joint.

At the tension zone the longitudinal reinforcement bar reached the resistance of the tension zone and the anchor plate showed tension over the limit.

The Moment-Rotation curve shows a good rotation capacity of the joint configuration. Further research activities will be developed to the calibration of the numerical models based on joint test.

Acknowledgements

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