NUMERICAL MODELING OF PUSH-OUT TEST FOR STUD SHEAR CONNECTORS

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Summary: *An accurate nonlinear finite element (FE) model of the push-out specimen has been developed to investigate the capacity of stud shear connectors in composite structures. The material nonlinearities were adequately considered in the FE model. The capacity and ductility of the connection, the load- slip behaviour were presented. The results obtained from the FE analysis were verified against experimental results. It provided a strong tool for investigating the performances of this kind of push- out test.*

Keywords: *Composite beams, connectors, stud shear, push-out test, finite element method, steel structures*

I. INTRODUCTION

Push-out tests are commonly used to determine the capacity of the shear connection and load-slip behaviour of the shear connectors. Several works performed push-out tests to investigate the behaviour of small headed studs in a composite beam with a solid slab and profile steel sheeting [1][3][7]. Although the experimental approach can provide reliable results of the behavior of the connections, it is expensive and time consuming. Since FE analysis is a useful alternative, it has been performed by numerous researches [4][8] to investigate connection behavior. The FE analysis might be an appropriate and efficient solution when considering the experimental method cannot be applied to large real size of connections.

In this paper an accurate nonlinear three-dimensional FE model to study the behaviour of headed stud shear connectors in composite beams using the program Atena is presented. The material nonlinearities are considered in the models. The results obtained from the FE analysis were verified against the experimental results obtained by [3].

II. PUSH-OUT TEST

When studs are used in design, one must be able to predict their ability to resist the longitudinal forces that arise between the steel and concrete. There are two ways two to develop stud strength prediction: push-out tests and full-scale beam tests. Because of the large size and expense of beam tests, push-out tests can be used to make this evaluation if the deck and stud details of the push-out specimen match those of the composite beam.

The push-out specimen consists of a short piece of steel beam that is connected on both sides to concrete slab by means of shear connectors, as shown in Figure 1. The slabs are bedded down on mortar directly onto the reaction floor with load being applied to the upper end of the member. Slip between the two slabs and the steel beam is measured at displacement or load increments.

The push-out test specimen in the experiment study of Michelle Deanna Rambo-Roddenberry [3] was investigated in this study. The test specimen is composed by a short piece of steel beam of W10x49 and two rectangular slabs of concrete of 650 mm x 650 mm x 150 mm (length x width x thickness) dimension, that located at each side of the steel beam in contact with the flange. The connection between the slab and the profile is obtained by means of a stud connector with dimension of 19 mm x 100 mm. Diameter of reinforcement in the concrete slabs is 10mm.

Compressive strength of concrete slabs is 55 MPa. Yield strength of steel beam and stud connector is 501 MPa and maximum strength is 596 MPa. The strength of reinforcement is 576MPa and 675MPa.

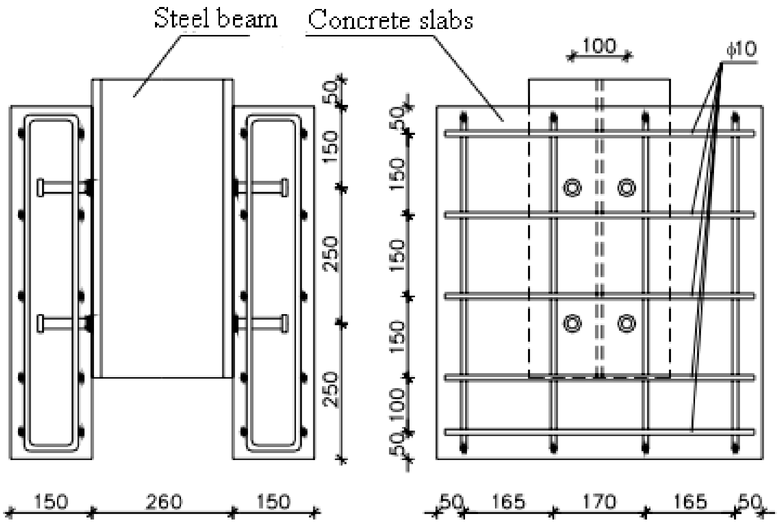


Figure 1. *Push-out test specimen*

III. FINITE ELEMENT ANALYSIS

A numerical investigation using the FE in ATENA software presented in this section. The model is capable of simulating the non linear behavior of concrete structures including concrete cracking, crushing and connector yielding.

3.1. Element types and meshes

The three-dimensional linear four-node tetrahedral isoparametric element (IsoTetra4_3D) was used to model the slab concrete and steel beam. The head and the stud of the connectors are approximated by a hexagon. Modeling of steel-concrete interaction is interface element.

3.2. Material modeling

a. Concrete

To describe the behavior of the concrete slab in the push-out specimen, concrete is treated as an elastic-plastic material that is offered by ATENA software with compressive strength is 55MPa.

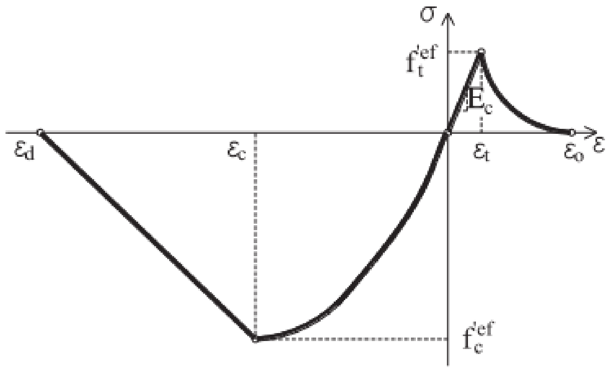


Figure 2. *Stress-strain law for concrete*

b. Shear stud behavior, steel beam and reinforcement

The stress-strain curve of the headed stud and steel beam is shown in figure 3a. The steel stud model behaves like linear elastic material with Young's modulus Es = 200000 MPa up to the yield stress fy =501 MPa. After reaching this value, the steel becomes fully plastic. For the steel of reinforcement, as input data were used: nominal values of yield stress fy = 576 MPa, ultimate stress fu = 675 MPa and Young's modulus Es = 200000 MPa. Therefore, the material behavior was considered as bilinear stress-strain diagram as shown in figure 3b. Reinforcement was modeled by discrete bars loaded in tension and also in compression.

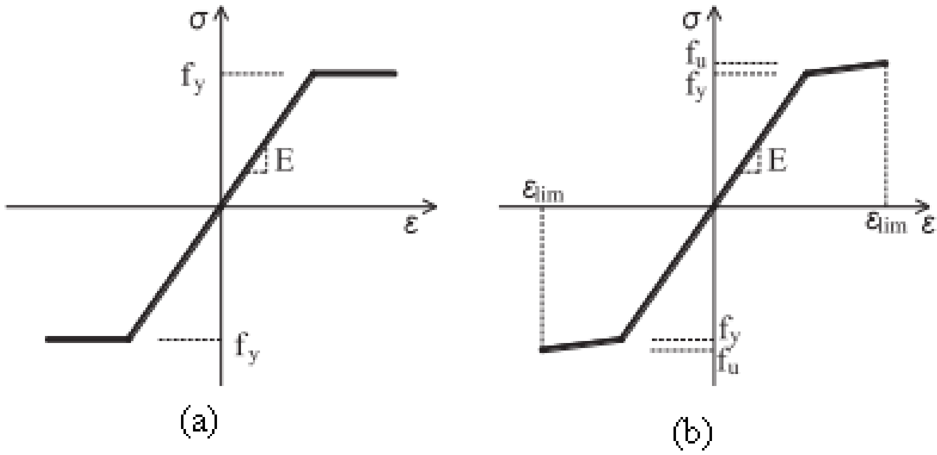


Figure 3. *Stress-strain for: (a) steel of stud and beam; (b) reinforcement*

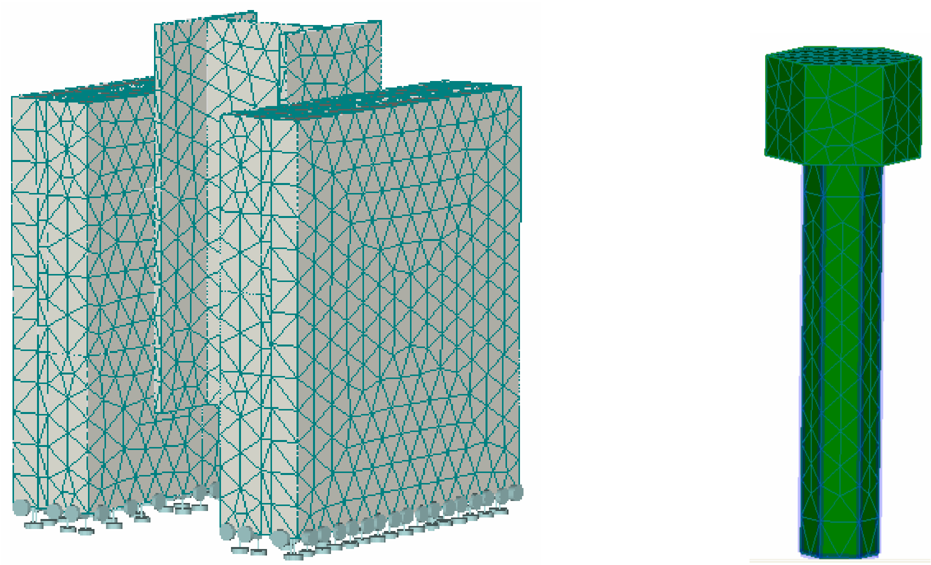
3.3. Interaction modeling and boundary conditions

The interaction behavior of steel-concrete is simulated by using "interface element".

For the application of the support conditions, all the nodes of the concrete slab in the opposite direction of loading are restricted from moving in the X, Y, Z.

IV. VALIDATIONS OF NUMERICAL ANALYSIS

In order to validate the capability of the numerical modeling, the push-out test [3] is investigated for verification. The FE mesh used in this simulation is represented in figure 4.

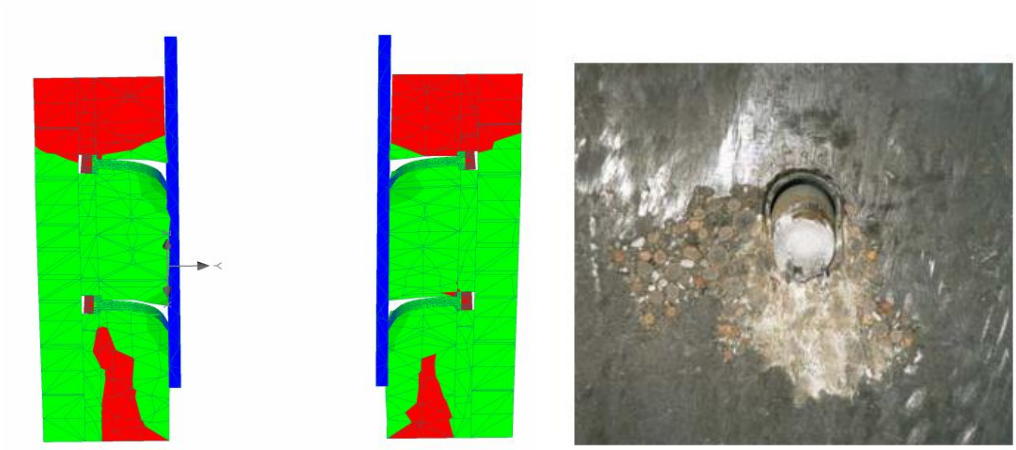


(a) (b)

Figure 4. *Finite element mesh: a) slab concrete and steel beam ; b) stud*

Figure 5a shows the deformed shapes of studs obtained from numerical analysis. This is in accordance with the behaviour observed in the experiment (figure 5b).

The load–slip behaviour is shown in figure 6. As can be seen, no significant shift exists between the simulation and experimental curves.



a) Simulation *b) Experiment*

Figure 5. *Deformed shapes of studs*

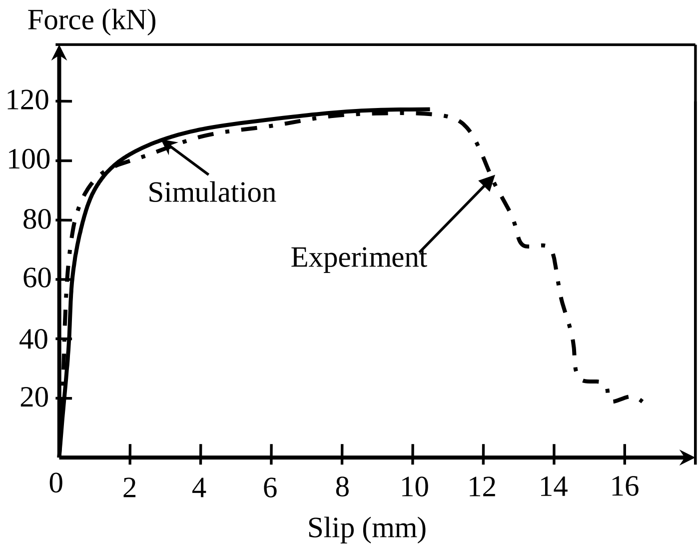


Figure 6. *Comparison between the experiment and the simulation*

V. CONCLUSIONS

A FE model has been developed to simulate the load-slip characteristic of headed shear stud in a solid reinforced concrete slab. The numerical study takes into account the linear and nonlinear material properties of the concrete and shear stud. The simulation results were compared with the results obtained from the experiments. As can be seen, the load–slip behaviour and failure mode of the headed stud were predicted from the finite element analysis and compared well with the experimental results from other researches. In the future the extensive parametrical studies and experimental investigation are envisaged.

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