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FINITE ELEMENT ANALYSIS ON TRUSS TYPE SHEAR CONNECTORS

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ABSTRACT

Shear connectors are important in composite steel beams. This paper presents a connector named truss-type shear connector. A nonlinear finite element analysis of the push-out test has been carried out to investigate the capacity of truss-type shear connectors embedded in the solid slab. The material nonlinearities of concrete, truss-type shear connector, steel beam and rebar were included in the finite element model. The connector's geometry was conceived aiming at low cost, easy execution, high resistance, efficiency concerning slipping and uplift. The specimen was constructed for push-out test. The behaviour of the specimen was investigated for slipping. The results obtained from the finite element analysis were verified against experimental results of other research. The finite element simulation shows good agreement and providing a global view of the shear connector behaviour.

Keywords- Finite element modeling, Truss type shear connector, Push out test, Composite beam.

I. INTRODUCTION

The economic, technical and scientific developments in the construction industry have brought about a great number of structural systems. Among them, steel-concrete composite structures have proved to be efficient from the structural and constructive points of view. As for the structural aspect one cam emphasize the better usage of materials resistance properties effectively exploring in a better way the potentials of concrete and steel [1]. The resulting combination of steel and concrete in composite beams provides lighter but more resistant structures. The use of composite structures with all its structural efficiency advantages [2] should be encouraged for bridge construction and even made more popular for medium and small construction too.

Such composite beams are formed by a steel beam, concrete slab and mechanical shear connectors that are responsible for horizontal shear force transfer at the steel-concrete interface [3]. Effective links between concrete slab and steel profile are required because those two materials have to act as a unique structure. Steel connectors are used as a shear connectors and generally they are welded to the steel flange and merged into the concrete slab even through other options are available today [4].

One important characteristic for a shear connector in composite beams is ductility. Shear connector may be classified in two categories depending on its ductility rigid or flexible. For the classification of shear connectors as rigid or ductility, a criterion commonly accepted today is defined by the European Standard EN 1994-1-1:2004 [5] for composite structures. The criterion is based on the characteristic slipping that each connector type may present and this characteristic slipping can be measured in standard push-out tests.

There are many recent researches on new types of shear connectors that could substitute the traditional stud bolt [6]. This research shows a type of shear connector, the Truss-Type (TT) shear connectors made of plain rod. The geometry of the alternative TT connector was conceived targeting: (a) no need for special equipment for the installation of the connector, (b) low cost of production, (c) easy installation and execution, (d) high resistant value, (e) efficiency concerning relative slip and uplift resistances between steel section profile and concrete slab. The main objective of this paper is to develop an accurate three dimensional finite element model to investigate the behavior of shear connectors. The finite element program ABAQUS [7] used in the analysis. The result obtained from the finite element analysis is verified against the test result carried out by other research.

II. CONCEPTION OF THE TRUSS TYPE CONNECTOR

The shear connectors designed for this research was built using steel rebar type f_y 450 for reinforced concrete structures and bent in triangular shape. In this connector, for bending downwards, the concrete slab and the steel I-beam flange act, respectively, as the top and bottom chords of a truss, and the legs of the TT connector are like truss diagonal elements. These observations are important to explain the name given to this connector: Truss-Type (TT) shear connector. The goal in developing TT shear connector is also to get an alternative connector that could be used in situations where the use of stud bolts is not possible [1].

The TT connector of 12.5mm diameter is modeled in the finite element with 130mm height. For the TT connector, a piece of 40mm in length was welded to the each angle of each connector to resist the uplift.

1.1 FINITE ELEMENT MODEL

It is noted that experimental methods are often unable to give the complete state of displacement, stress and strain through the use of single experimental techniques like push-out tests. In contrast, the modern finite element, among other analytical methods can yield a much more precise picture of the complete state of visualization in a body under load. Therefore, as a complement to the experimental push-out tests and for a better under understanding of the behaviour of the TT connector, the analytical modeling of the push-out test using FE analysis in ABAQUS[7] software was developed in this research.

The three- dimensional geometry of the push-out test specimen, the non-linearity of steel and concrete were considered in the analytical model. In order to obtain accurate results from the FE analysis, all components in touch with the shear connection are properly modeled which means that in the specimen, the main components affecting the behaviour of shear connection are considered: concrete slab, reinforced bars inside the concrete slab, truss-type shear connectors, steel I-beam and contact interaction.

1.1.1 MODELING OF STEEL

Based on different researches on modeling of concrete-steel composite structures, ABAQUS uses the classic rule of associated plastic flow and the isotropic yielding **[7]** to represent the behaviour of steel material in the three-dimensional (3D) space of stresses. The steel properties of the TT-12.5 connectors, reinforcing bars inside the concrete slab and the I-section beam are included in the finite element model. The density of all steel components was assumed to be 7800 kg/m^3.

1.1.2 MODELING OF CONCRETE

In this work, concrete material was modeled considering the Concrete Damaged Plasticity (CDP) model available in ABAQUS based on the researched by Lubliner et al., and Lee and Fenves [8]. The CDP model is acknowledged to provide a general ability to model efficiently the behavior of concrete and other quasi-brittle materials. The above mentioned model for concrete [8] has been previously used exhibiting very good results [9, 10, 11]. The CDP model follows non-associated plasticity flow rule, whereby the plastic potential function and the yield surface do not coincide with each other. For the flow potential ABAQUS [7] uses the Drucker-Prager hyperbolic function. For calibration, different parameters must be defined in CDP model. The concrete properties for the CDP model are (a) initial modulus of elasticity, $E_\circ$ =26 GPa, (b) Poisson's ratio v = 0.2, (c) concrete weight density Υc = 2500 kg/m^3, and (d) an angle of dilation of 13°. $E_\circ$ and Υ_C were taken based on average values from experiments in the Civil Engineering Laboratory at University of Brasilia, and v = 0.2 was assumed. The value for the angle of dilation was taken from journal. For the other plasticity parameters, the default value suggested by ABAQUS has been assumed [7]. With such data, ABAQUS is able to represent concrete damage according to CDP model for more details see reference [12].

The analysis is carried out using ABAQUS/Static Riks analysis program, the top of the steel beam in the push-out test arrangement was very slowly loaded by applying a constant velocity of 0.25mm/s.

1.1.3 FINITE ELEMENT TYPE AND MESH

The specimens of the push out test arrangement with truss-type shear connectors were modeled in ABAQUS. The push out test specimen is composed of concrete slab, steel beam, TT-connectors, reinforcement bars. The each part of the profile is modeled as presented in Fig 1.

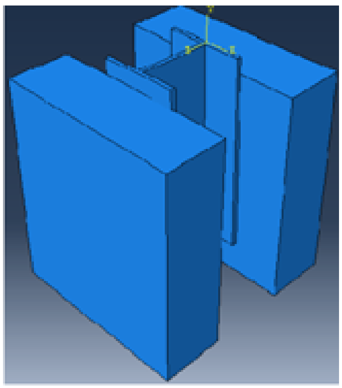

Fig. 1 Design of push out test specimen

The concrete slab part was meshed with C3D8R solid element which is available in ABAQUS library. The steel beam and headed studs are also meshed with C3D8R solid element and it is modeled in the same part. The reinforcement is modeled by the T3D2 truss element. The overall mesh size used was 25mm. It is shown in Fig 2.

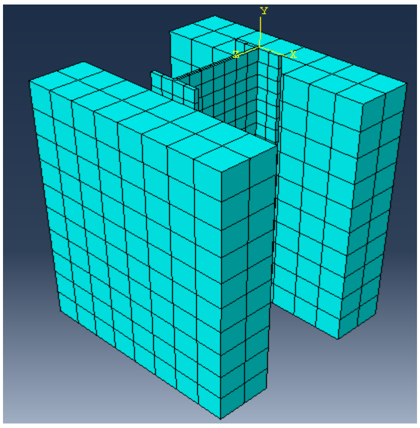

Fig.2 Finite element type and Mesh

2.1.4 INTERACTION PROPERTIES

Surface to surface interactions were considered for the contact surfaces between concrete and the shear connectors, between the concrete and the steel beam. To stimulate the weld between the TT-shear connector and the steel beam, the "Tie" constraint option was made to connect the stiffeners to the steel beam between the connecting nodes of the two components. It is shown in Fig.3. All reinforcement bars were embedded in the concrete of the composite slab. In a tangential direction, a friction coefficient (μ) 0.25 between the contact surfaces need to be defined which was taken from the Ellobody,et al., [13]

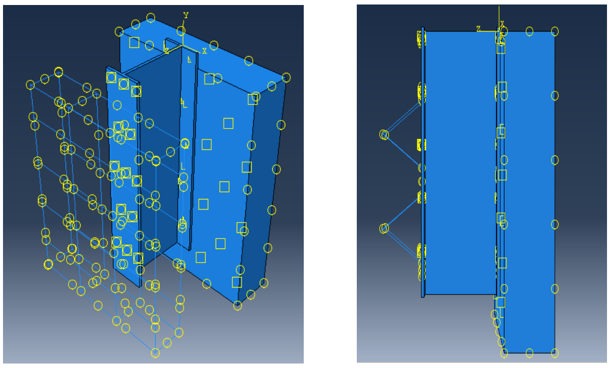

Fig.3 Interaction surfaces

2.1.5 LOADING AND BOUNDARY CONDITION

Because of the symmetry of the push out test arrangement, the symmetric boundary condition (BC) was applied to the bottom surfaces as shown in Fig 4 for which the translational U_1, U_2, U_3 and rotational displacements R_1, R_2, R_3 were restrained. The contact between the concrete slab and the steel I-beam surfaces was defined as frictionless based on researches [9, 10, 11]. The loading was applied to the top surface of the steel beam as downward enforced displacement. The load was applied incrementally using the Riks method. It is down in the Fig.4.

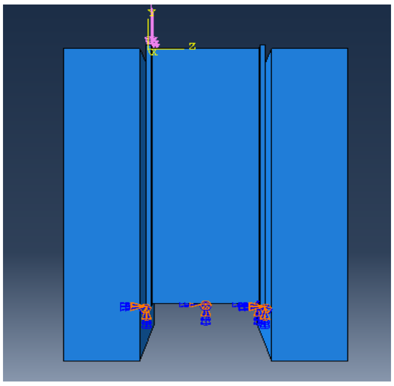

Fig.4 Loading surfaces and boundary condition

2.1.6 ANALYSIS METHOD

The RIKS method was often used to investigate the behavior of shear connection in push out test. It is generally used to predict the unstable and nonlinear collapse of structure. It is an implicit load control method. In this method the load is applied proportionally in several load steps. In each load step the equilibrium interaction is performed and the equilibrium path is tracked in the load–displacement space. This method is often used in static analysis and shows to be a strong method for non linear analysis.

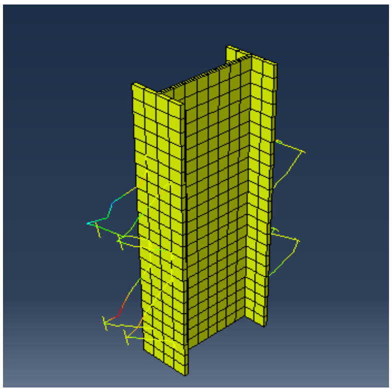

Fig.5 Deformed shape of a model

III. RESULT AND DISCUSSIONS

The current Finite element result is compared against experimental result proposed by Luciano M. Bezerra et al**.,** [14] shows the comparison of experimental and analytical results. Thus it is shown that the present finite element analysis is in good agreement with the experimental results of the TT shear connector.

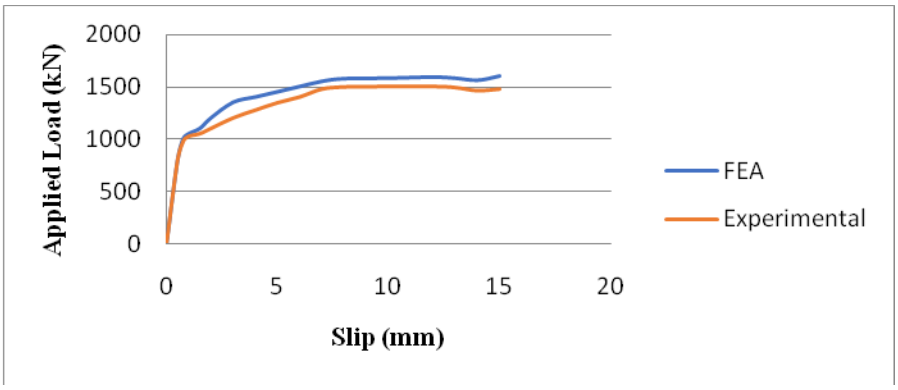

Fig.6 Comparison of experimental and analytical analysis

IV. CONCLUSIONS

The accurate finite element models of push out specimen have been developed to investigate the capacity of truss type shear connectors embedded in a solid slab. The material properties of the concrete, steel beam, reinforcement bars and truss type shear connectors. The material damage and failure mode were also included for the headed stud shear connectors to accurately obtain ultimate strength of the studs. The load slip behaviour of the truss type shear connector were predicted from the finite element analysis and compared well with the experimental results.

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