

THE IMPORTANCE OF MESH MODULE IN FEM ANALYSIS OF PUSH-OUT TESTS

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Abstract. Standard push-out tests are nowadays often performed by many researchers around the world in order to determine the elastic shear resistance of the selected shear element. Later, these experiments are modelled in several softwares based on finite element method (FEM). The main topic of this article is the importance of choosing the right mesh settings for such analysis – shape, curvature control and specifically size. Their effect is closely described below.

Keywords

Continuous shear connector FEM, Mesh, push-out tests, steel-concrete.

1. Introduction

FEM analysis of the continuous shear connectors is important for better understanding of the stresses inside the connectors as well as inside the concrete and for easier future change in the geometry – more options for future investors, examined by a parametric study in the chosen FEM software as a prove of reliability.

Several authors published FEM analysis of push-out tests in past. Oguejiofor and Hosain [1] did the analysis using ANSYS software, whilst Bezzerá et al. [2] as well as Nguyen and Kim [3] performed the analysis in ABAQUS software.

2. Push-out Tests

Push-out tests were performed on four different types of shear connectors; marked PT1, PT2, PT4 and PT5 (see Fig. 4). These experiments serve for determining the shear resistance of each shear connector. This is achieved by placing the steel strips perpendicularly (in vertical direction) on polystyrene of 10 mm thickness. The layout of the experiments is visible in Fig. 1.

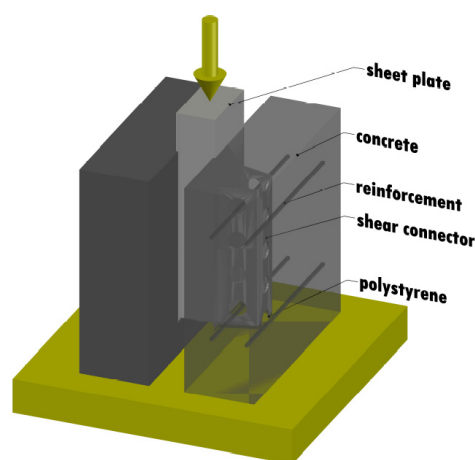


Fig. 1: Push-out test.

Of each type of the strip, three valid experiments were completed, twelve in total. Then, average graph of each type was created, see Fig. 2.

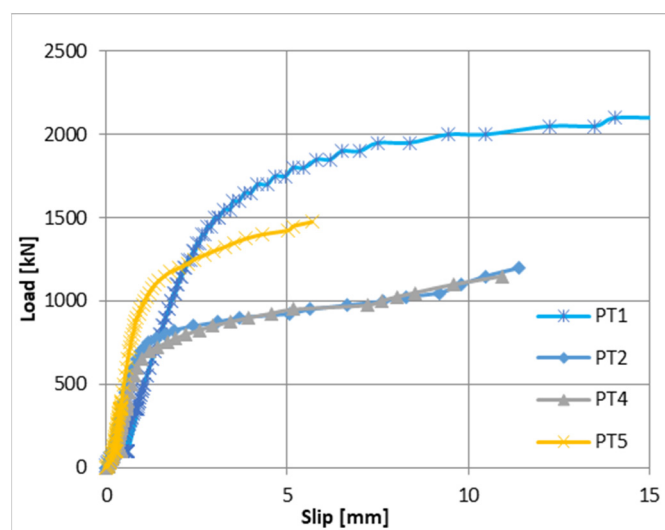


Fig. 2: Average results of the experimental analysis of four different types of shear connectors.

For these graphs, the load and the slip were taken into

account. The load was measured in loading cycles by the hydraulic press, which was compressing the specimens. The slip was measured by inductive displacement sensors, which were put in the middle between the two concrete blocks from both sides of the connecting steel part.

The loading, as well as the each experiment, was done in accordance with the STN EN 1994-1-1 Appendix B [4], which specifies twenty-five loading cycles between the 40% and 5% of expected shear resistance.

3. Mesh Module

Due to a way that finite element method works, every single FEM analysed element needs to be divided into a number of smaller elements, connected in nodes. Stress is then counted in each node and therefore the size and shape of the smaller elements can determine the preciseness of the results.

These elements are almost always of linear shape. Because of this, the round parts of the examined element are not exact. Their accuracy depends not only on the size of the elements, but on the curvature control as well. Curvature control allows the elements to be smaller than the general elements around the rounded parts (see Fig. 3 b). To put some limits into curvature control, deviation factor and minimum size control have to be specified. The first mentioned expresses the ratio h/L (see Fig. 3 a), while the second one is the scale of the global size. [5]

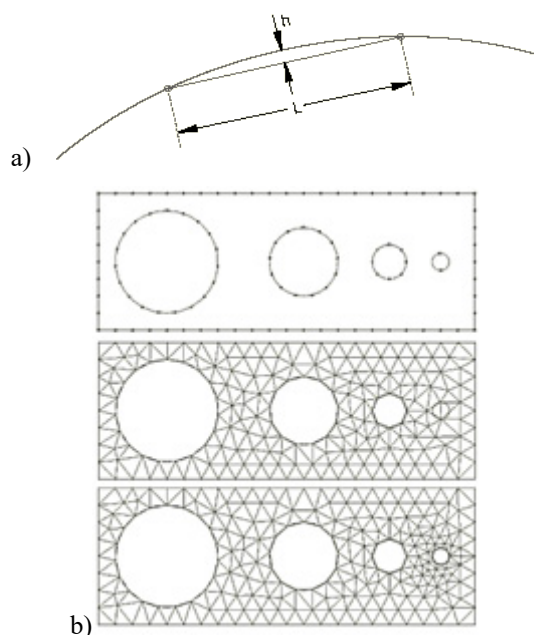


Fig. 3: Curvature control in FEM software – a) the deviation factor, b) a display of a mesh with (bottom) and without (middle) curvature control.

By trial and error method, these factors were determined. As visible in the Tab. 1, they were set the same for all four types of steel stripes. [5]

Element shapes were chosen differently for different materials – as they represented different parts of the specimens. For steel and concrete, because they shared the complex edges of the specimens, the C3D4 element – tetrahedron with four nodes, was chosen. For reinforcement, because it does not play as big of a role in push-out tests, the C3D8R element was chosen to ease the analysis (hexahedron with eight nodes). [5]

Tab.1: Curvature control and element shape settings of mesh in FEM software of push-out tests analysis.

		Concrete	Steel	Reinforcement
Global Seeds	Maximum deviation factor	0.12	0.09	0.1
	Minimum size control	0.12	0.09	0.1
Mesh controls	Element Shape	Tet	Tet	Hex
	Technique	Free	Free	Sweep

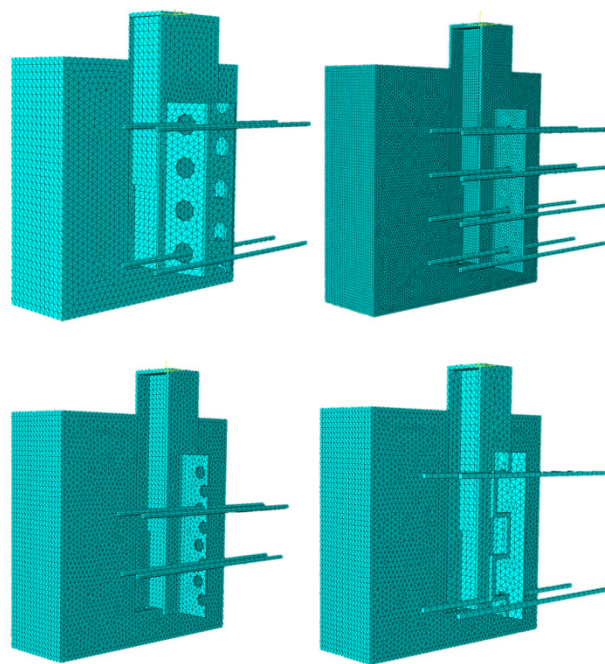


Fig. 4: Meshing of four types of shear connectors (PT1, PT2, PT4 and PT5, respectively) for push-out tests.

The compared global size of each part of each of the represented specimens is specified in Tab. 2.

Tab.2: Bigger/lower global size of parts of four different push-out tests specimens.

	PT1	PT2	PT4	PT5
Steel	40/17	13/7	40/12	40/12
Concrete	40/17	13/7	40/12	40/17
Reinforcement	40/20	40/20	40/20	40/20

4. Results

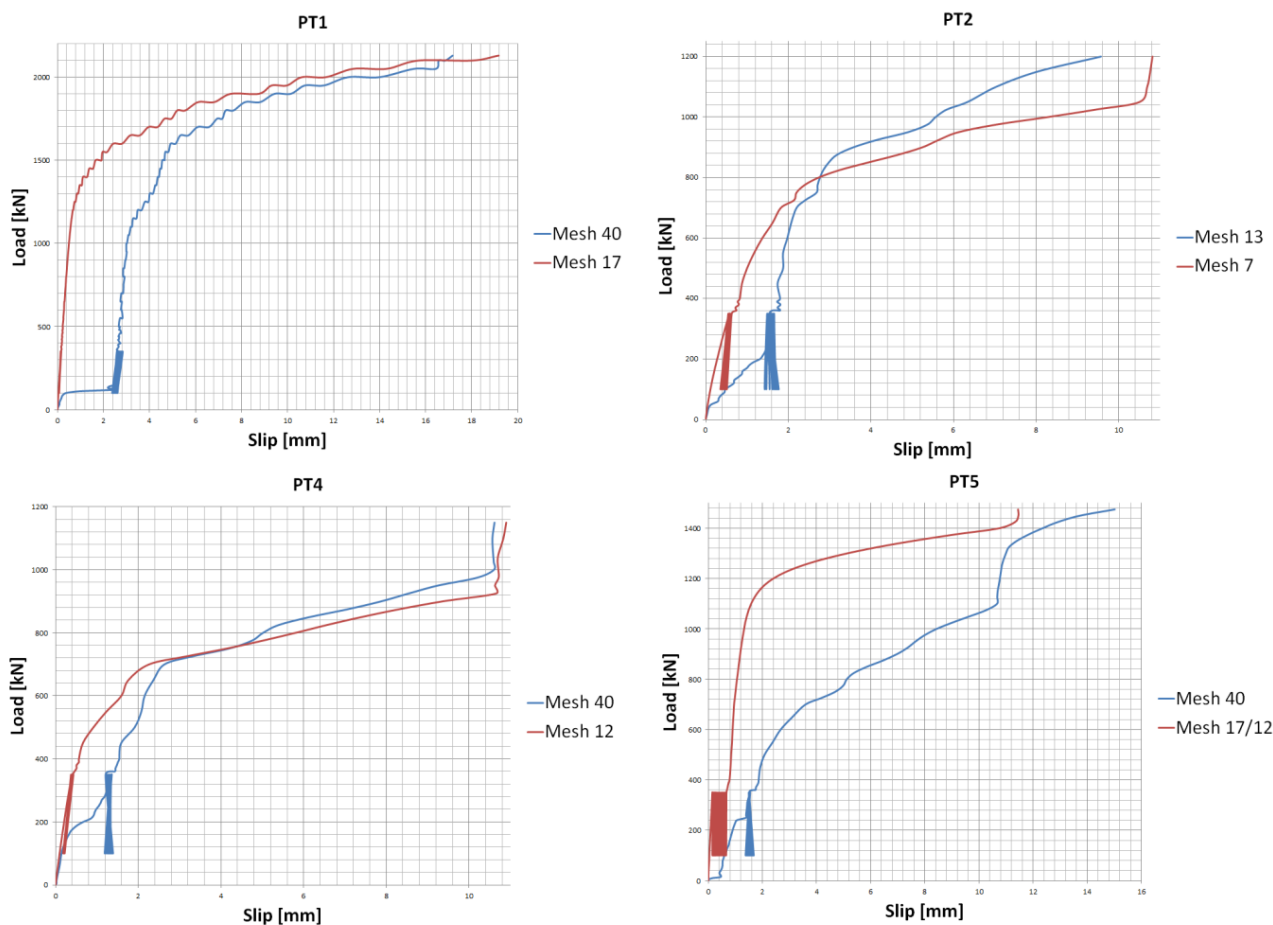


Fig. 5: Comparison of results between bigger and lower global size of each push-out test analysis.

The different results of different global sizes described in Tab. 2 are depicted in Fig. 5.

Tab.3: Summarization of warnings during the FEM analysis.

		PT1	PT2	PT4	PT5
concrete	number of elements	750792	1639959	995013	223685
	number of analysis warnings	2	16	134	0
	percentage of analysis warnings	0.00026	0.00097	0.01346	0
steel	number of elements	28467	49299	15237	18645
	number of analysis warnings	112	2	7	13
	percentage of analysis warnings	0.39343	0.00405	0.045941	0.069724
reinforcement	number of elements	864	1728	864	160
	number of analysis warnings	0	0	0	0
	percentage of analysis warnings	0	0	0	0
SUM of analysis warnings		114	18	141	13

Based on the global size of the parts, each part

contained of certain number of elements, of which several were always ineffective (see Tab. 3) – due to the disortage of the elements or their wrong fit to the general geometry. The ideal percentage of the analysis warnings would be zero (such as for reinforcing bars – see Tab. 3), however the acceptable number would be lower than 0.2% - as it was for all the final numerical analysis with lower sized elements.

5. Conclusion

From the Fig. 5 it is visible how big effect the size of the elements has onto the analysis results. This is also specific to the push-out tests due to the small distance – 10 mm – of the measured slip. In all the compared analysis the difference in results occurred before the cycle between 40 and 5% of the expected resistance, with deviation lower than 1mm. In the last type of the strip, PT5, the mesh size of concrete and steel had to be divided into different numbers, probably due to the small, 20mm in diameter, holes in its walls.

Based on the trial and error method it was found that the maximum deviation control as well as minimum size control performed well when the ratio was around 0.1 for

all parts and that the global size of the parts of push-out tests was acceptable when lower or equal to 20, with reinforcement at its higher limit and steel parts with lower numbers.

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