LABORATORY VALIDATION OF IDEA STATICA STEEL CONNECTIONS AND DETAILS

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1. Introduction

In past years, there has been done a huge amount of testing in the CTU in Prague laboratories. Team of university assistants and Phd. students under the lead of prof. František Wald spend few years of thorough comparison of steel joints live tests and calculations carried on in the IDEA StatiCa software. Thanks to this complex observation of real behavior of various steel connections and details, IDEA StatiCa got even more improved to the nowadays shape.

This collage of pictures and drawings is showing the highlights of the laboratory works performed at the Department of Steel and Timber Structures at the Faculty of Civil Engineering.

2. Haunch tests

The experiment of haunches covered six specimens with different types of edge reinforcement. Three specimens called A to C are without flanges, three specimens called D to F have flanges with different stiffness. Tensile tests of the used steel plates were part of the experimental program. The main goal was to evaluate the influence of the flange stiffness in connections with haunches. The test set-up is shown in Fig. 1. A hydraulic press is presented to apply vertical load at the top of the specimen. Lateral torsional buckling is prevented by lateral supports. Hinges are used at the bottom. Loading is carried out in predetermined steps until the collapse of the specimen.

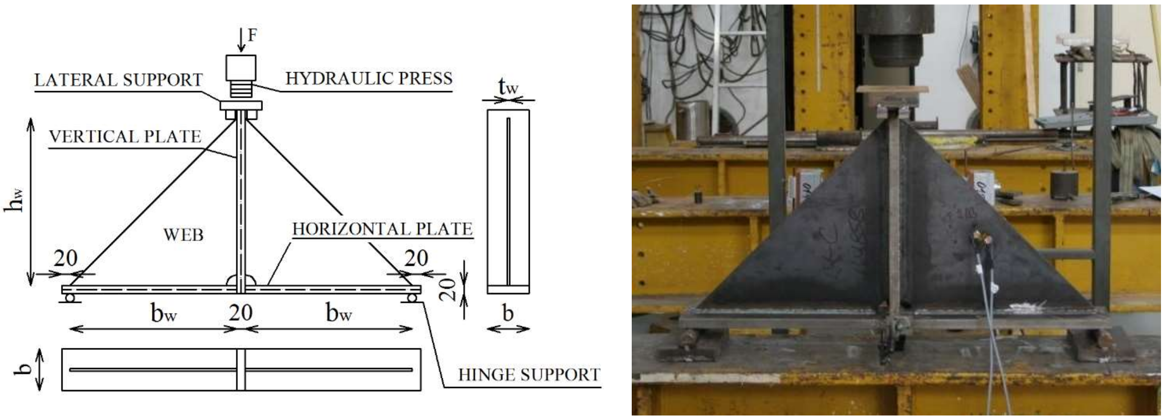

Fig. 1: Test set-up

In the tests of haunches without a flange, the collapse occurs by buckling of the triangular web. Large deformations are enabled by the effect of membrane stresses and the post-buckling reserve is significant. Specimens stiffened with a flange exhibit collapse by local buckling of webs and flanges. The results show that adding a flange with very small stiffness has a large influence on the resistance. The specimens after testing are shown in Fig. 2 – Fig. 7.

Fig. 2: Sample A after the test

Fig. 3: Sample B after the test

Fig. 4: Sample C after the test

Fig. 5: Sample D after the test

Fig. 6: Sample E after the test

Fig. 7: Sample F after the test

3. Validation of research FE model of haunches

For further investigations, a research FE model is developed and numerical studies are carried out. The numerical analyses are completed by the RFEM 5.0 (Dlubal RFEM) finite element program system. The purpose of validation is to verify the behavior of the haunch with and without a flange. The materials are endowed with nonlinear properties. In the numerical model, 4-node quadrilateral shell elements with nodes at its corners are applied with a maximum side length of 10 mm. Equivalent geometric imperfections are derived from the first buckling mode and the amplitude is set according to Annex C EN 1993-1-5. The comparisons of the final deformation states of all connections between numerical simulations and experimental results are performed at the end of the tests. The comparison of the deformation of specimen A, B, D and E after failure with the numerical model are presented in Fig. 8 – Fig. 11. The developed model well reflects the actual behavior of the haunches, so it is applicable in further studies.

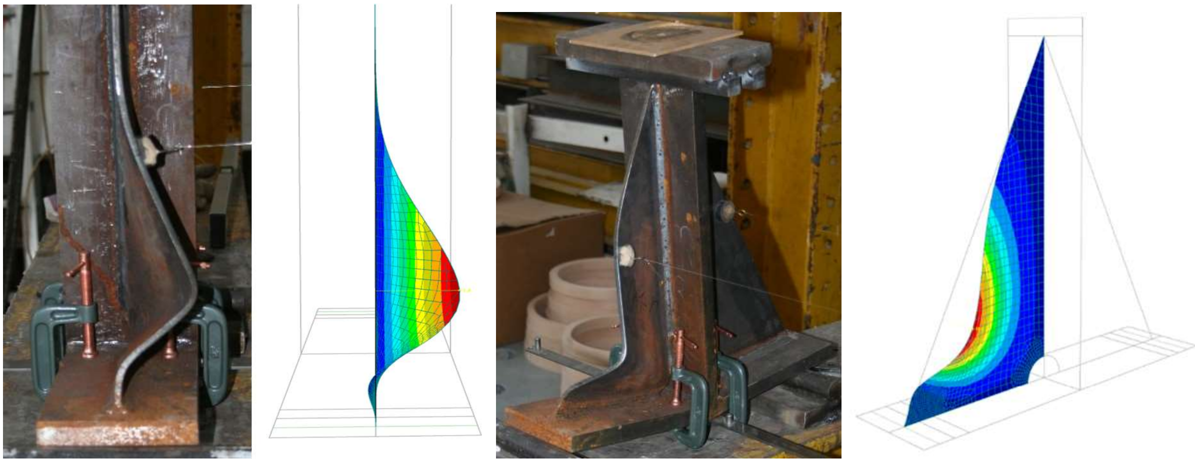

Fig. 8: Sample A - comparison of the deformed shape and numerical model

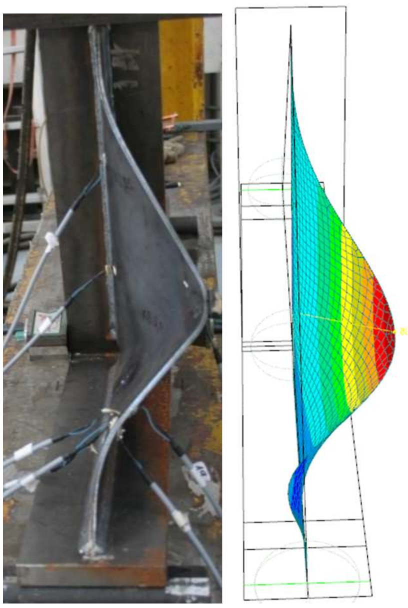

Fig. 9: Sample B - comparison of the deformed shape and numerical model

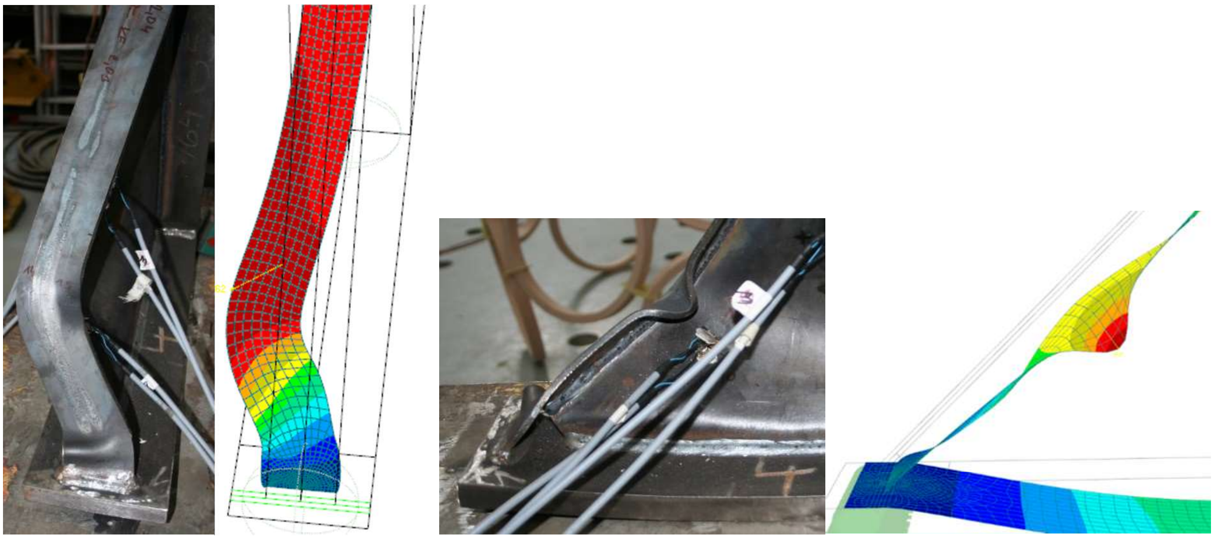

Fig. 10: Sample D - comparison of the deformed shape and numerical model

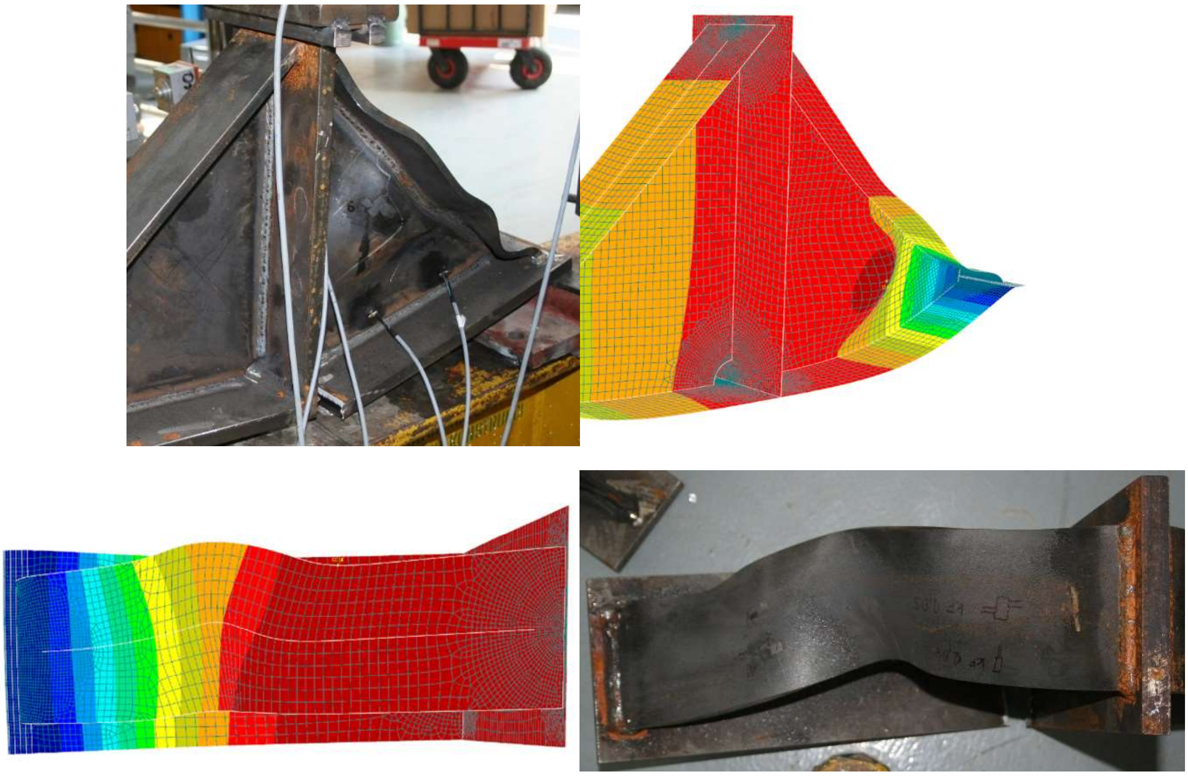

Fig. 11: Sample E - comparison of the deformed shape and numerical model

4. Bolts in tension

Bolts in tension were experimentally tested to obtain the force-deformation behavior. Initial stiffness, tensile resistance, and maximum elongation are main characteristics of interest. Bolts were fixed to the testing machine by tools with bearing caps to ensure hinges on its ends. The test set-up is shown in Fig. 12.

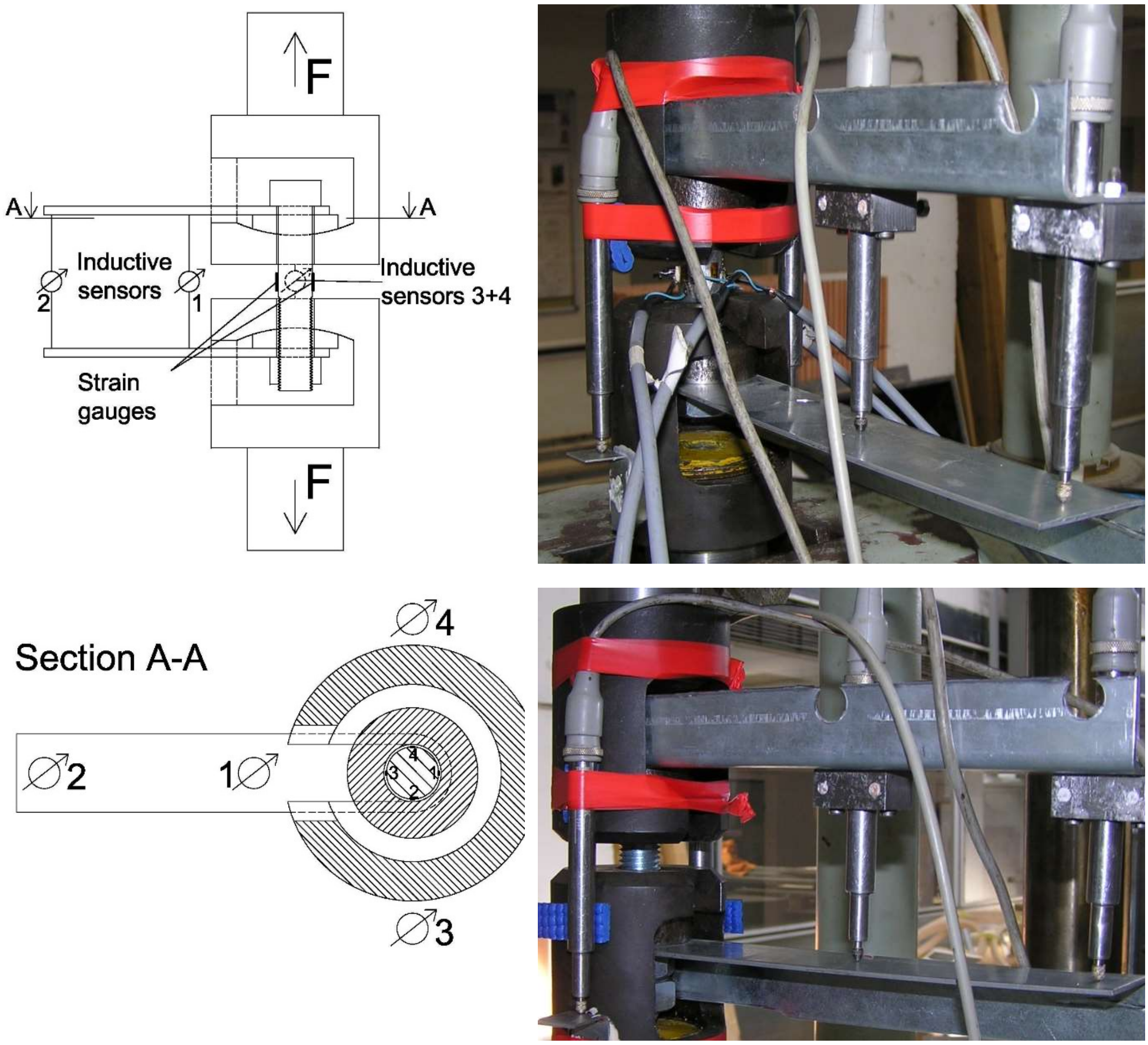

Fig. 12: Scheme of the measuring instruments

Four failure patterns were observed, namely stripping of bolt threads, stripping of the nut threads, a rupture of a bolt close to the nut and a rupture of a bolt close to the head, see Fig. 13.

Sample 1: Stripping of the nut threads

Sample 2: Rupture of the bolt close to the nut

Sample 4: Stripping of the bolt threads

Sample 11: Rupture of the bolt close to the head

Fig. 13: Failure patterns of the bolts

5. T-stub in tension

Two T-stubs were tested within the experimental program. The first sample was prepared from cross sections HEB300 and the second from HEB400, see Fig. 15 and 16. Two bolts M24 8.8 were used in both samples, see Fig. 14. Measured values were used for a validation of numerical models.

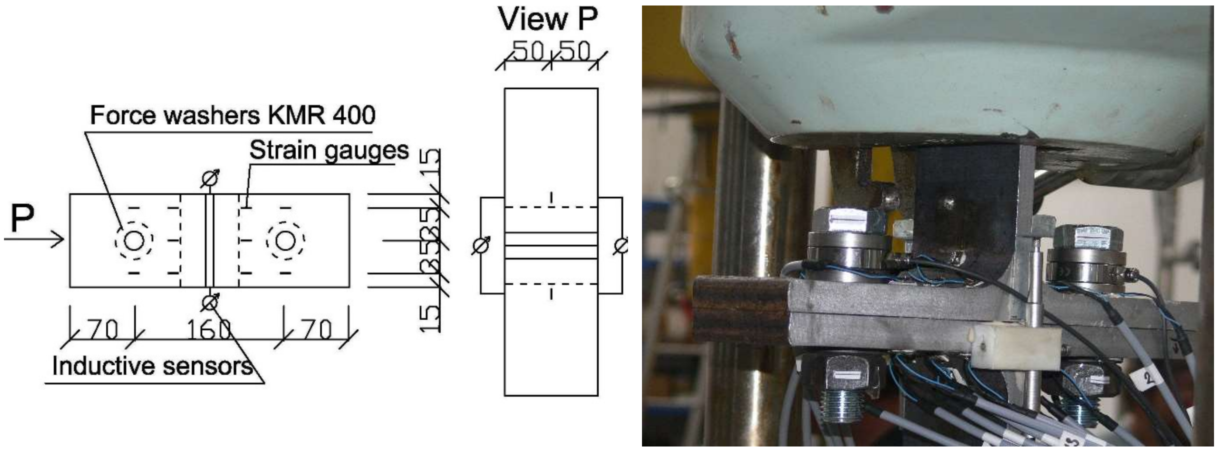

Fig. 14: Scheme of the T-stub experiment.

Fig. 15: HEB 300

Fig. 16: HEB400

6. Validation of research FE model of T-stub

Research FEM model (RM) was prepared using solid elements. The model was validated on experiments and allows to verify the CBFEM model. The RM was created in Midas FEA software using 6-nodes and 8-nodes solid elements, see Fig. 17. One-quarter of the sample was modeled to use the symmetry. Contact elements activated in pressure are placed between flanges of the T-stubs.

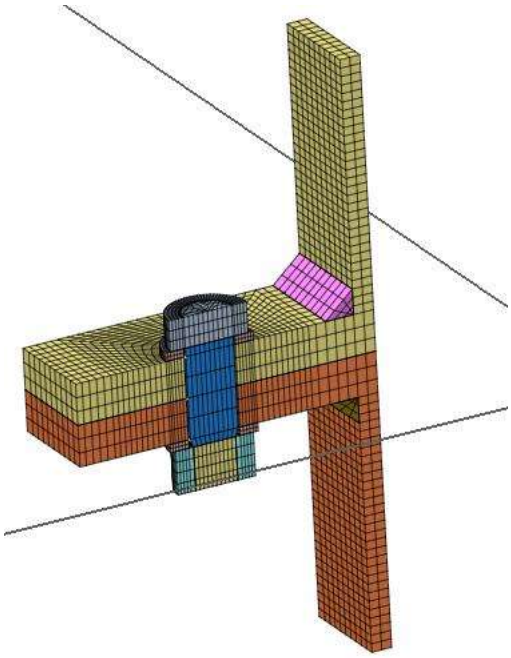

Fig. 17: Research FEM models

7. Generally loaded end plate

The experimental investigation of three samples of end plate joints was performed. The end plates were welded on two RHS 250x150x16 beams of different lengths 2000 mm and 1000 mm. The configuration creates shear forces and bending moments in the connection. The results of the contact imprints on paper placed between the end plates are included. The inclination of the specimens varied from 0°; 30° till 45°. The test set-up with a 0° inclination is documented in Fig. 18, a 30° inclination in Fig. 19 and a 45° inclination in Fig. 20. A design resistance calculated by CBFEM was compared with the results of CM and experimental results. CM with a linear interaction gives conservative values of the resistance. CM with a quadratic interaction gives the highest resistances, which are still rather conservative compared to the experimental results. CBFEM gives similar results as CM with the quadratic interaction.

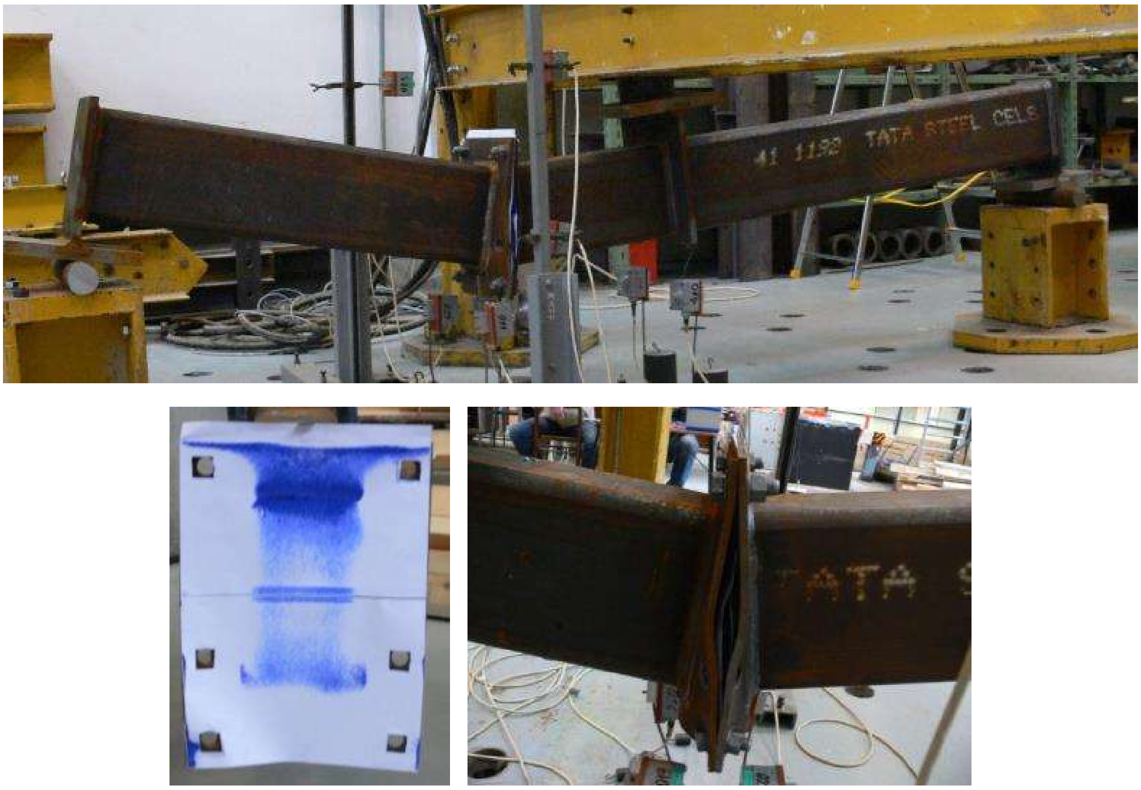

Fig. 18: Test set up 0°

Fig. 19: Test set up 30°

Fig. 20: Test set up 45°