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Experimental tests of a new class of steel joints

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Abstract

This paperwork presents the tests carried out in the Structural Testing Laboratory of the Faculty of Civil Engineering of Iaşi on several assemblages of steel joints. The main goal was to find out the proper disposal of the node elements in order to optimize the joint behavior. This class of joints is designed for the thin-walled steel profiles. The joint boxes were used for the KONTI steel members.

The tests carried out on the joints connected with HSFG bolts demonstrated a decrease of the bearing capacity as a consequence of the painting layer used for the protection of the gussets. Under these circumstances it was advocated a new type of joint connected with normal bolts, based on the bolt strength when working in shear and compression on the hole.

The proposed box joint is capable to carry on the efforts from the node area without being necessary the HSFG bolts. A better behavior of the rotation of the KB profile in the box might be obtained in case of a better manufacturing process.

The experimental results obtained in the case of the 5mm thick profiles should be extended to other thicknesses (such as 3.0, 3.5 and 4 mm) used in several types of structures.

The actually accumulated experience during the tests allowed us to consider that the hardening of the KB profiles into the joint box might be better exploited, with significant economies in metal consumptions for joints.

KEYWORDS: Thin-walled steel profiles, Steel Joint Design, Quasi-static testing

1. INTRODUCTION

This paperwork presents the results of the study concerning the optimization of the KONTI type element joints. The justification of the present study is due to the existence of several lacks noticed at the joints connecting the KB elements used for beams and columns is structures with several destinations. These joints are made by the means of gussets assembled of welded steel plates. The effective connection

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of the KB profiles to the joints is currently performed by the means of the high strength pre-stressed (HSFG) bolts (see Fig. No.1).

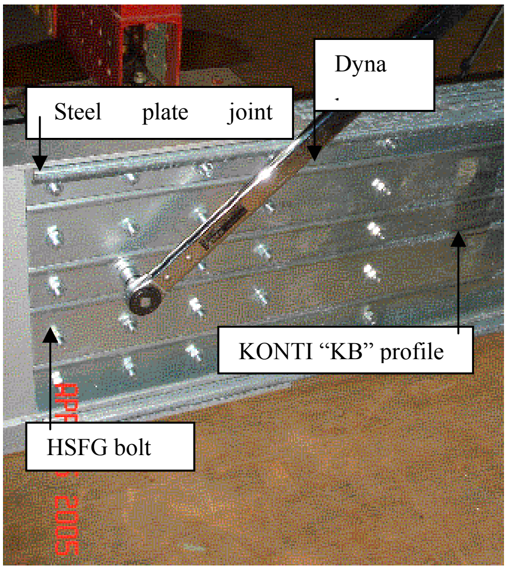

Fig.1 Classic joint connected with HSFG bolts

The tests carried out on the joints connected with HSFG bolts demonstrated a decrease of the bearing capacity as a consequence of the painting layer used for the protection of the gussets.

Under these circumstances it was advocated a new type of joint connected with normal bolts, based on the bolt strength when working in shear and compression on the hole.

The carbon steel strip of the profiles is protected by immersion into a zinc bath and is made of FeE 320 G as stated in the EN 10147 Product Norm (Euro Norm).

The mechanical properties of material (base - steel) are:

- The yielding strength of the basic material $f_{yb} = f_y = 320$ N/mm^2,
- The ultimate strength of the basic material $f_u = 390$ N/mm^2.

Ratio $f_u / f_y = 390/320 = 1,22 > 1,2$.

2. THE JOINT ASSEMBLY

The design of such a joint is performed in order to undertake the maximum stresses that occur when subjected to load combinations, (N – axial force; Q – shear; M – bending moment).

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The HSFG bolts of a usual assemblage (Fig. No.1) are designed to carry on simultaneously all these efforts (N, Q, M).

By analyzing the different kinds of elements that are connected and the loads acting on them it was thought a system that carries on the three efforts separately, each at the level of a separate element of the new joint, not only the bolts, which in turn are acting like usual bolts. Thus it is advocated the construction of the joint as a box, Figure No.2 where the axial efforts, which are usually of compression, are supported by a steel plate placed at lower part (inside) of the box, Figure No. 3.

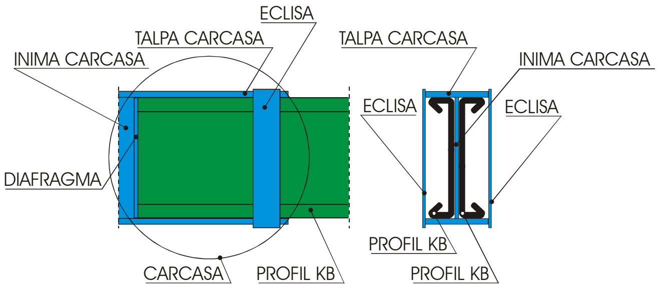

Fig. 2 Box-type joint

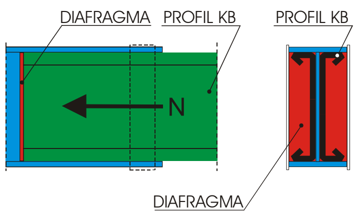

Fig. 3 Steel plate that undertakes the axial force

The shear is carried on by the box using some plates to connect the bottom parts (flanges), Figure No. 4. The bending moment is undertaken both by the bolts placed on the contour of the KB flanges and a pair of bolt rows fixed on the web. Moreover, the KB profiles are mounted into the box, thus one may consider that the bending is carried on by the entire box, the bolts now having mainly a fixing purpose.

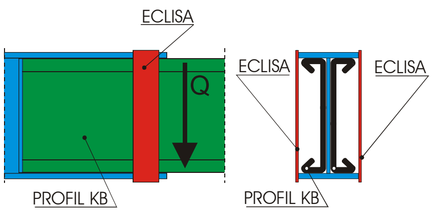

Fig. 4 Steel plate to undertake the shear

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To check on the behavior of the new joint, in the first stage it was proposed the testing of a specimen consisting of 600mm height and 5mm thick KB thin-walled steel profiles (the commonly used elements in KONTIROM structures).

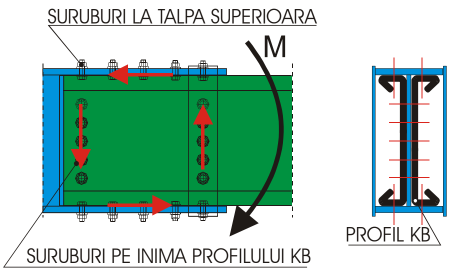

Fig. 5 The positions of the bolts that carry on the bending moment

The simply supported beam with a central joint was selected for the experimental model. In order to compare the jointing systems, two specimens were constructed, the (G0) with HSFG bolts fixed as in the classical way and (GN) with the new joint system (see Fig. No. 6).

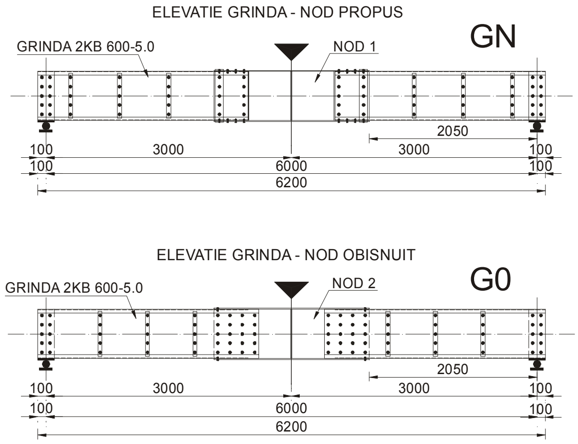

Fig. 6 The dimensions of the proposed specimens

3. THE TESTING ENVIRONMENT

A 300.000daN hydraulic press was used for testing. In the Figure No. 7 it is presented how the transducers are mounted on the specimens and the complementary elements used in the experiments. The beams were identically equipped (G0 – Fig. No. 7 and GN – Fig. No. 8).

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Fig. 7 The G0 Beam

Fig. 8 The GN Beam

The tests were carried out in several loading – unloading steps up to 100 KN, 200 KN and 350 KN, the last value corresponding to the value of 2900 daN/cm^2 for the KB stress, i.e. the design strength.

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Fig. 9 The driving elements mounted to prevent the lateral buckling

The specimens were instrumented with:

- 2 displacement transducers mounted on the central joint from the midspan (D0, D1);
- 2 displacement transducers mounted at the joint edge (D2, D4 – D3, D5);
- 2 displacement transducers mounted on the KB profile at the joint vicinity(D6, D8 – D7, D9);
- One force transducer to accomplish the automatic load recording.

In order to avoid the lateral buckling of the beams a driving system was thought and mounted at each specimen edge, as depicted in Fig. No. 9.

3.1 Test Results for the G0 Beam (joint with HSFG bolts)

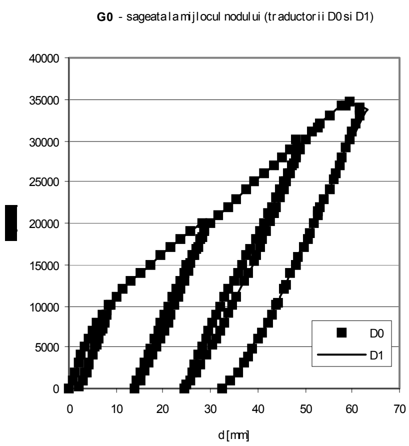

Fig. 10

In the figure No. 10 there is presented the force-displacement relationship for the G0 beam, corresponding to the transducers mounted on the both sides.
The experiment shows the occurrence of some important permanent deflections for each loading-unloading cycle. These permanent deflections are caused by the KB element rotations in the central node as a consequence of the lack of adherence between the contact sides and fixed with HSFG bolts.
During this test one may notice a shift between the KB profile and the central node, thus confirming the rotation of the KB element.

After the analysis of the results one may notice that the permanent deflections are decreasing as the load increases, thus means the KB profile is hardening inside the node, as an effect of the rotation.

3.2 Test results for the GN Beam (the new proposed joint)

In the figure No. 11 there is presented the force-displacement relationship for the GN beam recorded by the transducers mounted on both sides. For this beam type the tests were performed using the same loading steps.

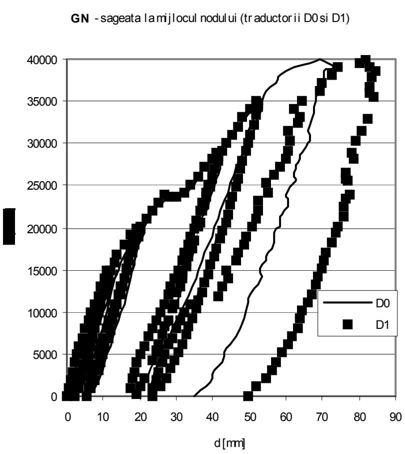

Fig. 11

After the test end the bolts from the flanges were eliminated and a second test was carried out with the profiles mounted inside the box and fixed with the bolts only in the web (a test denominated as GN-0). For this experiment a new loading cycle up to 400 KN was introduced, corresponding to the coverage of the yielding strength, see Figure No. 11.

It is important to underline that in all the cases the local buckling of flanges did not occur, even when the yielding strength was bypassed.

Even though the GN beam was loaded to a level greater than that corresponding to the yielding stress, when reloading was performed for the GN-0 test a well behavior was observed, the maximum deflections were smaller than in previous tests. This was due to the rotation of the KB profile in the central node and the hardening.

A series of deficiencies in the GN behavior were caused by the manufacturing of the central node. The sinuous shape of the recorded deflections is caused by the rotations and re-positioning of the elements.

4 CONCLUSIONS

After the tests several conclusions were stated. The assemblage of the G0 beam with the HSFG bolts do not provide the expected stiffness, the painting layer do not allow the correct behavior – finally one must consider the hardening of the profile

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into the joint, thus the loads are carried on by the means of bolt shear and pressure on the hole.

The joint of the GN beam had some manufacturing imperfections that leaded to the rotation of the KB profile in the box during the tests and the breaking in tension of some bolts from the flanges.

The GN-0 beam showed the best behavior because it was produced the hardening in the box after loading over the yielding limit; the permanent deflections were insignificant in comparison to the other 2 cases. In the Figure No. 12 there are presented the load-displacement curves for the 3 beams at several loading steps/cycles.

Comparing the maximum displacements for the two types of beams (G0 and GN) it results an increase of 12% for the maximum displacement corresponding to the design strength (2900 daN/cm2) in the case of the beam fixed with HSFG bolts (G0) as the beam with normal bolts(GN), Figure No.12.

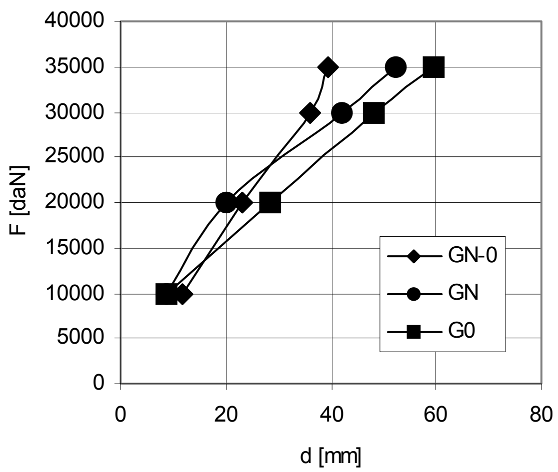

Fig. 12 The maximum displacements for the 3 tested beams

The proposed box joint is capable to carry on the efforts from the node area without being necessary the HSFG bolts. A better behavior of the rotation of the KB profile in the box might be obtained in case of a better manufacturing process.

The experimental results obtained in the case of the 5mm thick profiles should be extended to other thicknesses (such as 3.0, 3.5 and 4 mm) used in several types of structures.

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