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FINIT ELEMENT MODELING OF THE BACK-TO-BACK CONECTED COLD FORMED STEEL PROFILES BOLTED JOINTS

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Abstract: The most favourable method of determining the behaviour of the structural elements, before being used at a large scale, is numerical simulation. This paper presents finite element modelling of some types of the compound sections of back-to-back cold-formed steel profiles with bolted joints. There are presented numerical models of the joints between these steel members with the aid of welded gusset elements, which are used in making of light steel portal frames. The purpose is to identify the areas of local buckling in order to ensure their safety by adding stiffening elements to increase the bearing capacity of the structure. The results are based on the experimental studies and numerical modelling.

Key words: Thin-Walled Steel Profiles, Finite Elements, Steel Bolted Joint Design, Strengthening.

1. THE DESCRIPTION OF THE JOINT PROTOTYPE AND OF THE MEANS OF MODELING

The thin-walled cold-formed steel profiles used for the joint assemblage are produced by the Kontirom manufacturer and are so-called KB profiles; they have a cassette shape and are used as linear elements of the structural resistant frames [1]. A frame element is typically made of two KB profiles positioned back-to-back and fixed together with a thick steel connector, as in the Fig. 1.

The mechanical characteristics of the material are:

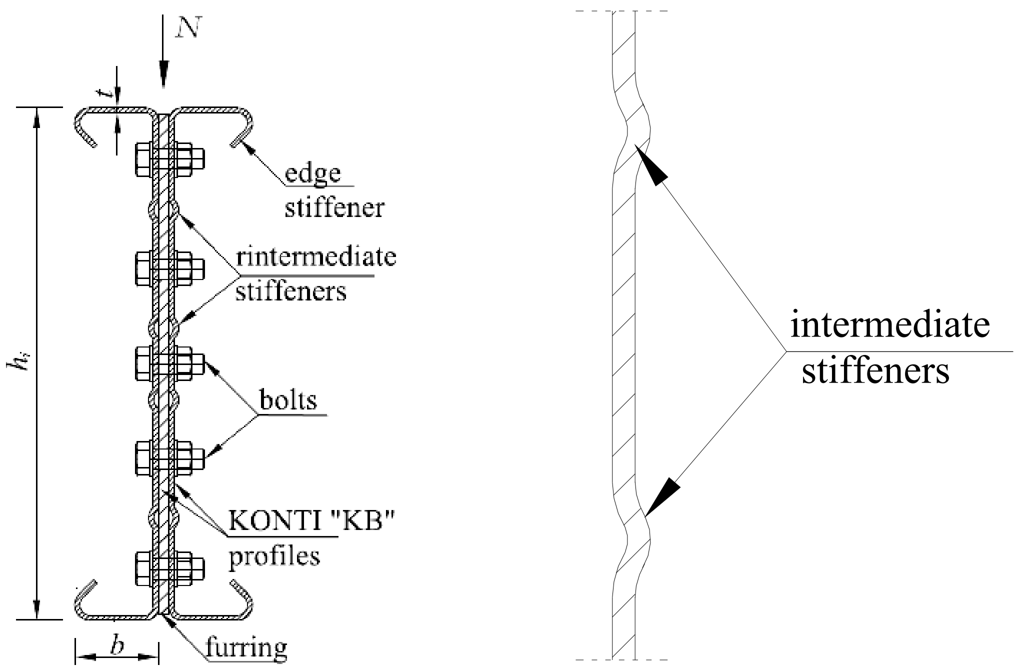
- the yield strength of the basic material $f_{yb}=f_y=320N/mm^2$
- the ultimate strength of the basic material, $f_u=390\ N/mm^2$
- the ratio $f_u/\ f_y=390/320=1,22>1,2$.

The thin-walled profiles are manufactured with the thickness from 1,5mm to 5,0mm and the depth of the cross section from 250mm to 600mm [3].

Their design and engineering is carried out according to Eurocode 3 provision, Appendix 1.3, and for the joints where the thickness sheet profile exceeds 4,0 mm the recommended standard is

Eurocode 3, Appendix 1.8. Usually the joints are made by means of gussets assembled of welded steel plates [3].

The profiles types “KB” are the ratio between the height web and depth flange relatively large. The flange is finished by stiffeners and to the web some intermediate stiffeners are introduced [3], [6].



a) Cross section of cold-formed steel portal frame taken at the joints

b) Intermediate stiffeners form of grooves

Fig.1 The thin-walled cold formed steel profiles „KB”

The reason of the present study is induced by existence of several lacks noticed at the joints connecting the KB elements used for beams and columns of the structures with several destinations.

2. THE DESCRIPTION OF THE JOINT PROTOTYPE AND OF THE MEANS OF MODELING

There are many ways of modeling, but the time and the necessary resources are function of the size of the model to be analyzed. It was proposed to model a girder with a central joint with the static scheme a simply supported beam, and for the numerical analysis, instead of the whole model, there was considered only half of the assembly loaded with the computed value of the reaction. The simply supported beam of length l was replaced with a beam of length l/2 that is simply supported at one end, and at the other (meaning the middle of the real beam) a rotation fixed translation free joint. The force applied to the model is half of the force considered for the whole model (it is equal to the support reaction).

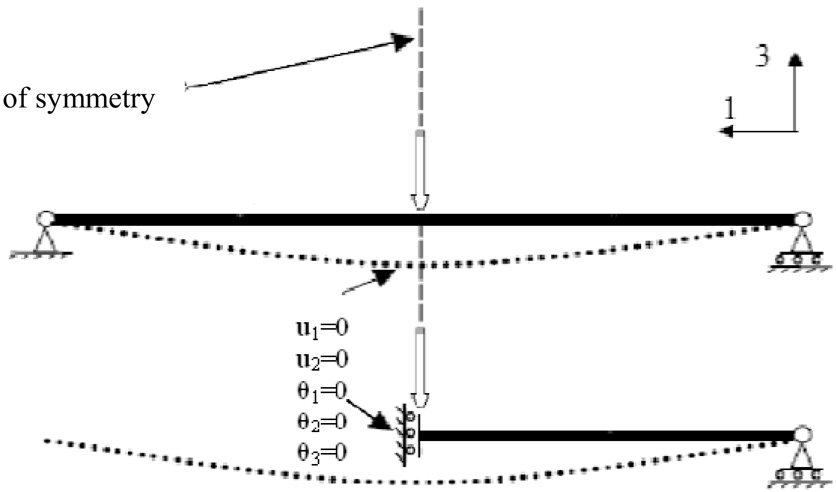
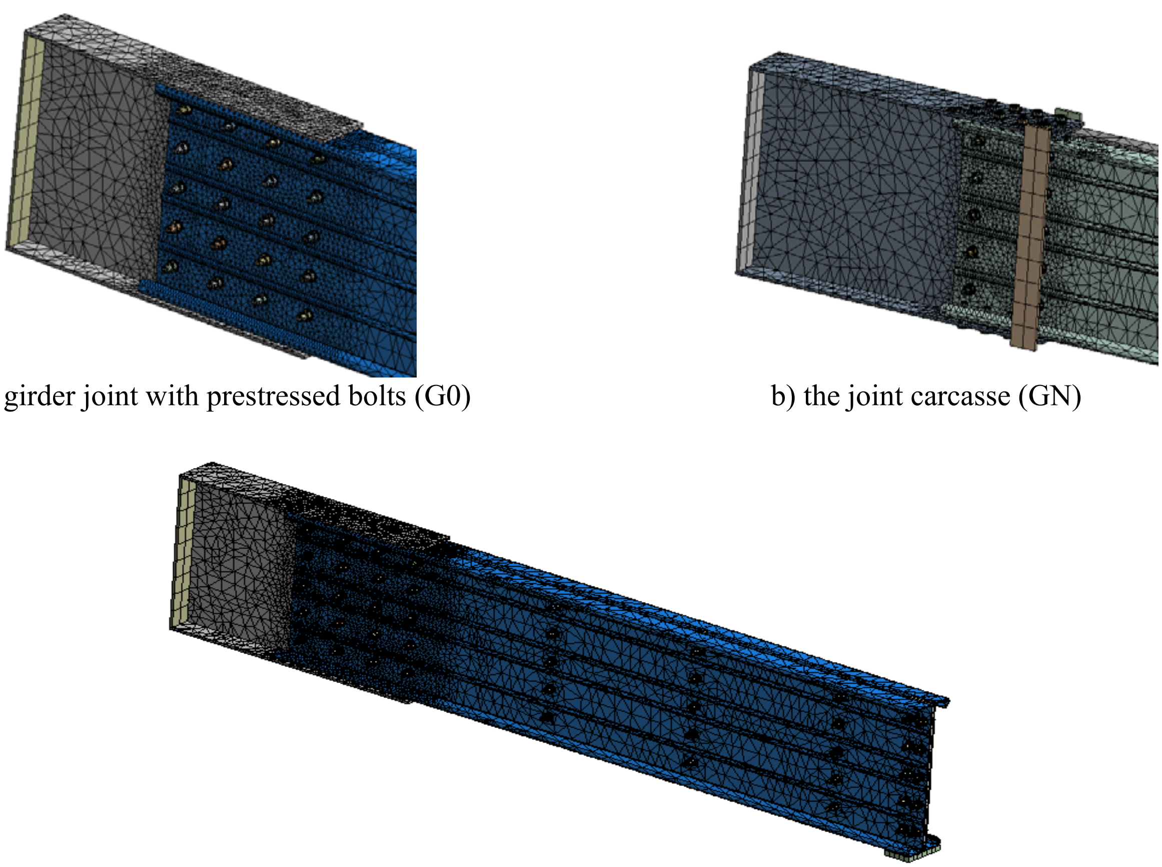


Fig.2 Static scheme of the models

The modeling was done using solid finite elements interconnected considering „contact surfaces-surfaces with friction” [4]. In such case, meshing is one of the most important steps, because the accuracy of the results depends on it. The joint is made of distinctive parts: profile, steel plate joint, splice plates between the profiles, bolts, nuts and washers [5].



a) girder joint with prestressed bolts (G0)

b) the joint carcasse (GN)

c) KB450-3,5 assembly

Fig. 3 Meshing of the beams and joints

A finer modeling of the areas where there is friction contact is imperative for the results to converge, while a too fine meshing leads to significant resources consumption and even to the impossibility to solve the system [4].

Another aspect that was taken into account was the modeling of the contact between the joint surfaces considreing the mounting tolerances.

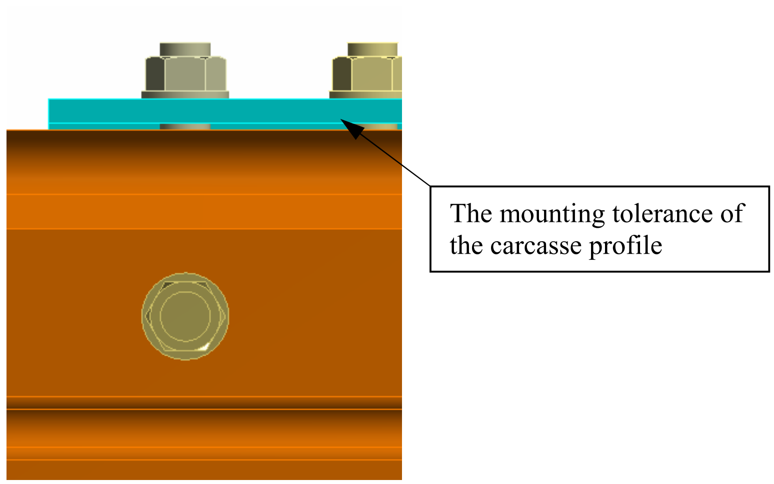


Fig. 4. Modeling of the contact with tolerances between surfaces

3. FINIT ELEMENT MODELLING AND RESULTS INTERPRETATION

In the first stage there was modeled the joint with presterssed bolts and then, the joint where the profile was inserted in the welded connecting gusset elements (S355 - fy=355N/mm2), counting on the bearing capacity obtained by turning the profile in the joint.

If we refer to the typical model with presterssed bolts, the minimum principal tension σ_{min} occurs because of the diameter pressure of the bolts that are furthest from the gyration center of the joint. This happens after the friction force is exceeded and the displacement between the surface of the profile and that of the joint has been initiated. The minimum value of the resulting tension on the contour of the holes is close to the yielding strength of the material of the profiles (f_y=390 N/mm^2).

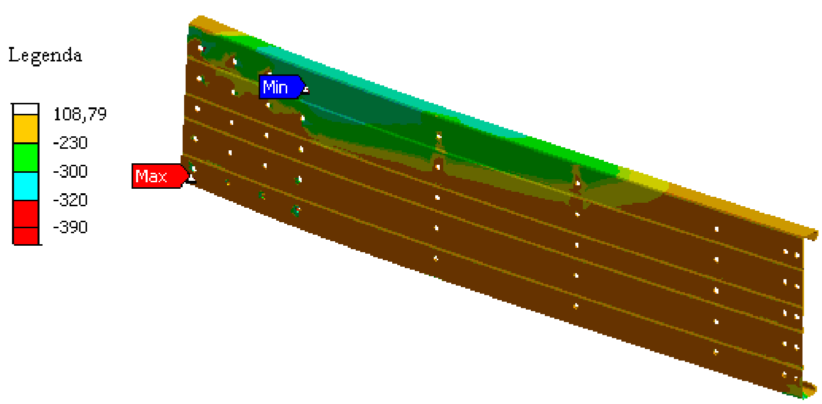


Fig. 5 Tensiuni minime principale σ_{min} [N/mm^2]

A close look of the displacements shows that the 2KB600-5 beam has a normal behavior with an increase of rigidity in the the area of the joint welded connecting gusset elements. The maximum displacement of the joint is approximately 60 mm. But we must take notice that the flanges of the profile tend to curve towards the inside because of the lack of bolts at their level.

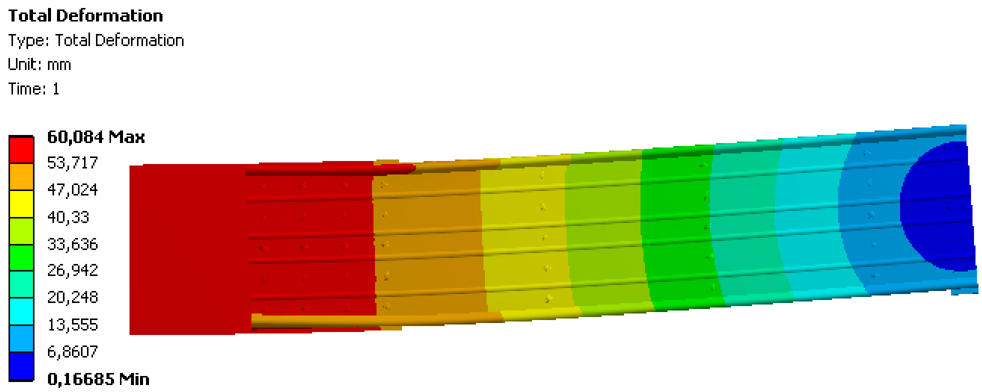


Fig. 6 Deformed shape of the beam with prestressed bolts on the web [mm]

Then we passed on to modeling the carcasse joints without prestressed bolts, where the profiles are inserted in the welded connecting gusset elements.

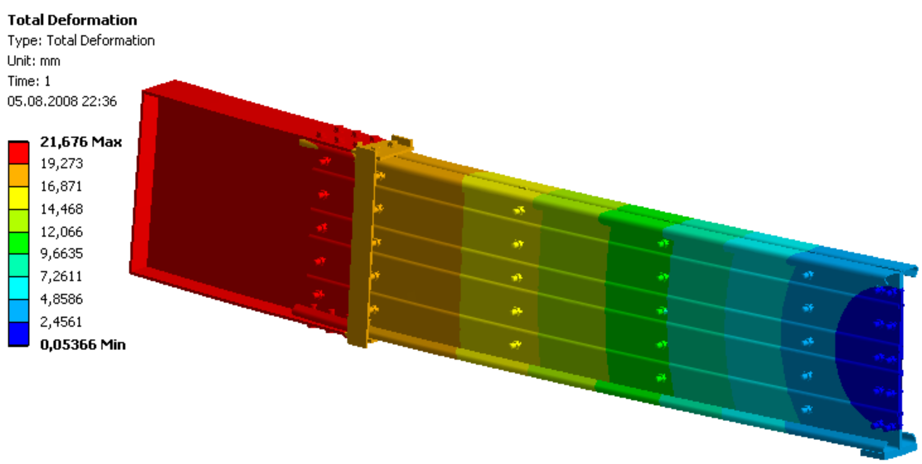


Fig. 7 Maximum displacement of he beam with carcasse joint [mm]

The difference of displacements of almost 30% from the beam with prestressed bolts [Fig. 7] and the beam with carcasse joint is due, on one hand, to the wedging of the profile in the carcasse for the beam that is inserted in the carcasse and on the other hand, to the inability to reach a great enough fiction coefficient between the contact surfaces for the presteressed bolted joint.

The lateral buckling due to the bending-twisting for such a beam that is slender and tall is prevented by points of lateral support. But, as it can be seen in figure 8, buckling waves appear locally near the entering of the profile in the joint, which is difficult to avoid.

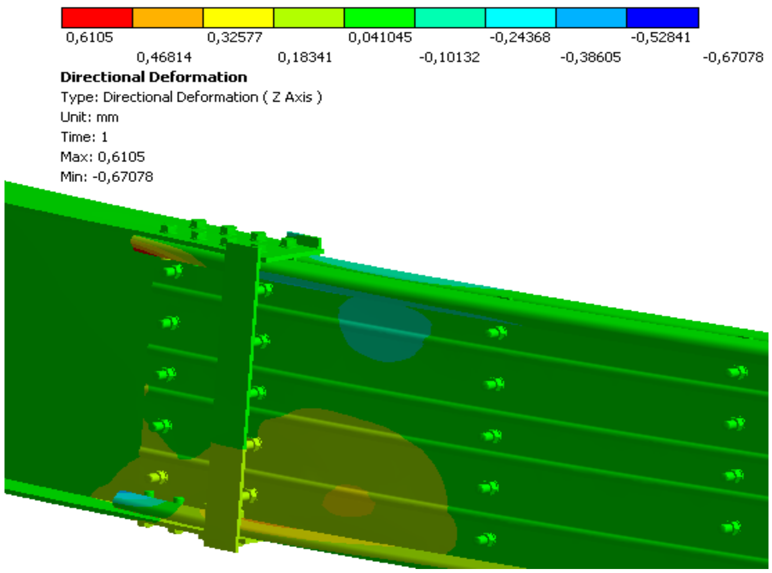


Fig. 8 Lateral displacement of the profile in the carcasse [mm]

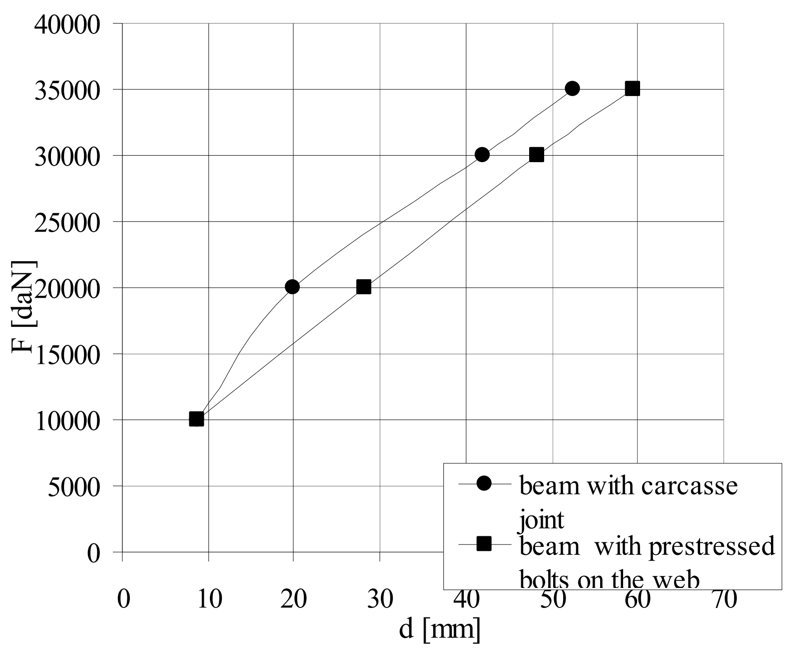


Fig. 9 The force-deflection relationship for beams

The joint tensions are uniformly distributed, without exaggerated values in specific areas, except for the tensions due to the pressure on the hole of the bolt.

4. INCREASING THE BEARING CAPACITY OF THE JOINTS

Experimental tests showed that adding steel stiffening elements S355 (OL52) on the KB flange profiles has obtained an increasing of the bearing capacity. In this way in the future we propose that the modeling of the joints between KB profiles to be made by adding stiffening elements/consolidation elements in the area of maximum tensions [2].

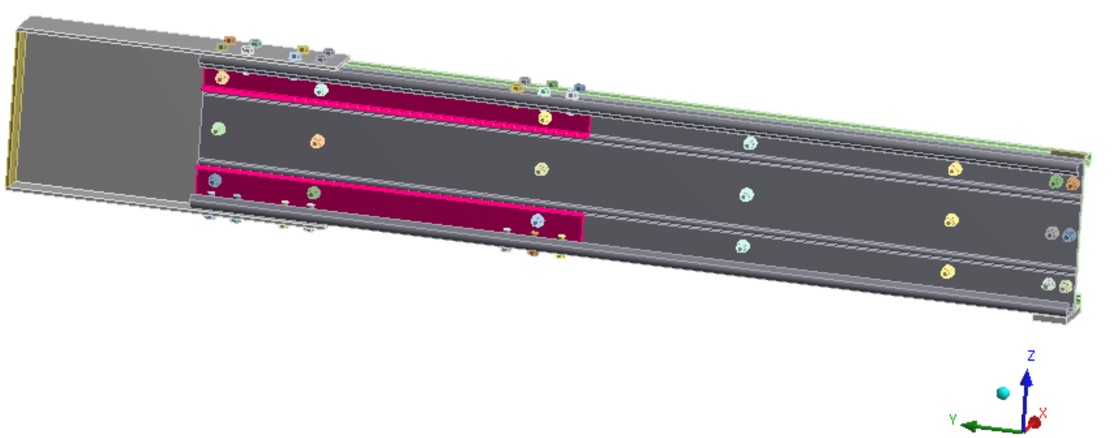


Fig. 10. The positions of the stiffening elements

In the area where it was developed the local buckling, there were added steel elements, 1500 mm long, and having the shape that permits them to be assembled on the KB flange profiles. Adding them represents an insignificant increase of material and a plus of resistance and rigidity.

The frame like joint between KB450-3,5 profiles without stiffening elements /consolidation elements had at a force of 170.000 N a maximum displace of 30 mm. Following how the beam with consolidation elements behaves could be observed a decrease of maximum displacement with approximate 30%.

5. CONCLUSION

The joints between profiles with thin KB type walls were modeled, fulfilling the real condition by: modeling the contact between the surfaces, keeping the tolerance of assembling between the KB profile and welded connecting gusset elements (S355 - f_y=355N/mm2), modeling the prestressed bolts etc. A proper meshing of the beams could be obtained by half reducing the beam of the testing stall. In detail, we could observe the buckling of the web profiles in the end area of the welded steel plate, thing that could not be observed at the load of the beam on the stall. We determined the place of the area with maximum tensions from the node and their way of distribution. The increasing of bearing capacity has been obtained by adding supplementary elements at the end of the node which made possible a significant decreasing of the tensions from that area.

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