

## OPTIMIZATION SOLUTIONS FOR TRUSS BEAMS ELEMENTS WELDED JOINTS

Dorin Radu<sup>1</sup>

Florin-Teofil Galatanu<sup>2</sup>

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*Summary:* The structural advantages of tubular steel elements have become increasingly obvious in recent decades because of research and experience in construction. Worldwide, these elements are frequently used especially at large span structures. In the past, the cheap permitted the manufacturing of the truss beams made of angle type elements joint in nodes with gussets. With 21<sup>st</sup> century in our country appeared new structural solutions for lattice subassemblies, one of the solutions being the use of RHS (Rectangular Hollow Section) elements joined with welding directly onto the chords.

The present paper propose the applying of the component method [1] to a common joint (truss beam), calibrating a finite element model and determine the improvements possibilities.

**Keywords:** welded joints, truss beams, steel structures

### 1. INTRODUCTION

An important aspect in the development of these types of structural elements was the configuration of new design procedure based on component method which is presented in Eurocode provisions - EN1993-1-8 [1]. In terms of designing and execution of steel structures, the implementation of European normative in our country led to a design adapted to the new standards complex calculation options (considering multiple failure modes) and to better execution control. Node type plays an important role both in manufacturing cost as well as the resistance values obtained. Also joining technology greatly influences the performance of hollow section structures.

In terms of the welding connection type, node elements can be connected directly through welded gussets or with welding of the processed elements at the ends. The most economical way to combine common and rectangular hollow section is by direct welding without gusset or other steel plates. This solution also provides the most effective way of corrosion protection and time maintenance. Rectangular hollow section joints can be easily achieved because the cutting only be provided with straight end cuts. Thus can be achieved nodes in T, K, V, X with space between elements or with overlapping (total or partial).

<sup>1</sup> Faculty of Civil Engineering, *Transilvania* University of Braşov, dorin.radu@unitbv.ro

<sup>2</sup> Faculty of Civil Engineering, *Transilvania* University of Braşov, teofil.galatanu@yahoo.com

## 2. EN1993-1-8 DESIGN PROCEDURE

In order to determine the parameters which are having an influence on tubular cross section elements behavior, are used analytical, numerical or experimental models. The Eurocode adopted model is an analytic type based on component method. Thus a joint is made of a number of components depending on joint different area load type. In case of truss rectangular or circular hollow cross section elements joints, may be considered following failure modes: chord face failure (plastic failure of the chord face) or chord plastification (plastic failure of the chord cross-section), chord side wall failure (or chord web failure) by yielding, crushing or instability (cripling or buckling of the chord side wall or chord web) under compression brace member, chord shear failure, punching shear failure of a hollow section chord wall (crack initiation leading to rupture of the brace members from the chord member), brace failure with reduced effective width (cracking in the welds or in the brace members), local buckling failure of a brace member or of a hollow section chord member at the joint location [2].

Based on experimental tests combined with numerical models analysis results, Wardenier et al. [3], in 2008 proposed a new design formulation of the RHS/CHS elements welded joints design. Thus resulted the designing guide – CIDECT [2].

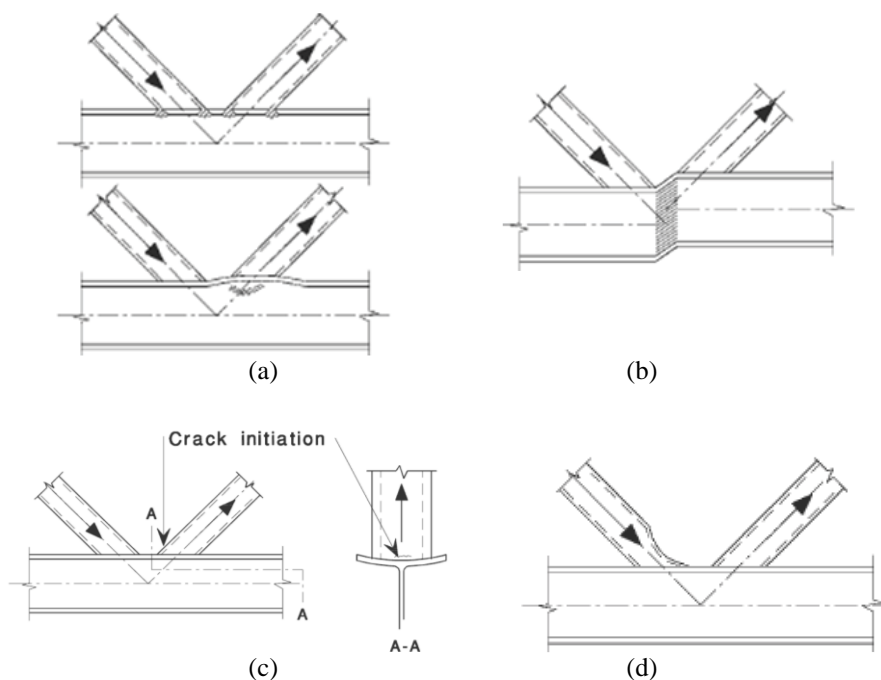


Figure 1. Failure modes of the joints for truss beams with RHS/CHS diagonals and I or H chord profile type.

The EN normative [1] is presenting also the design procedures for the RHS truss to IPE/HEA chords welded joints, taken into account several failure modes: failure of the chords web through yielding under the truss compression - Figure 1 (a), share failure of

the chords flange - Figure 1 (b), failure of the truss on an reduced effective width (cracks in the welding or in truss element) - Figure 1 (c), and local buckling of the truss (truss wall) - Figure 1 (d).

Although the resistance of a joint with properly formed welds is generally higher under tension than under compression, the design resistance of the joint is generally based on the resistance of the brace in compression to avoid the possible excessive local deformation or reduced rotation capacity or deformation capacity which might otherwise occur.

The welds connecting the brace members to the chords should be designed to have sufficient resistance to allow for non-uniform stress-distributions and sufficient deformation capacity to allow for redistribution of bending moments [1].

Giving the geometry presented in the figure 2, for the K and/or N gap type joints, the norm [1] requires a chord web yielding checking with the relation

$$N_i \cdot \sin \theta_i = f_{y0} \cdot t_w \cdot b_w / \gamma_{M5} \quad (1)$$

where  $b_w = \frac{h_i}{\sin \theta_i} + 5 \cdot (t_0 + r)$

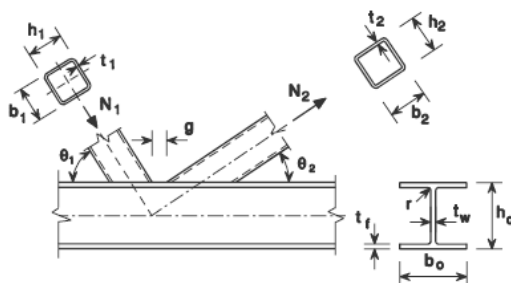


Figure 2. K/N gap type joints geometry

The brace failure need to be taken into account also:

$$N_{iRd} = 2f_{yi} \cdot t_i \cdot p_{eff} / \gamma_{M5} \quad (2)$$

where  $p_{eff} = t_w + 2r + 7t_f \cdot f_{y0} / f_{yi}$

The chord shear failure is considered checked by the relation (3).

$$N_{i,Rd} = \frac{f_{y0} \cdot A_v}{\sqrt{3} \cdot \sin \theta_i} / \gamma_{M5} \quad (3)$$

The failure of the weld is checked by the proper designing of the welded joint ([1] and [2]).

The local yielding of the truss element through buckling is considered as form the beam to column joint design

$$N_i = 2 \cdot f_{yi} \cdot t_i \cdot b_{eff} / \gamma_{M5} \quad (4)$$

where in case of  $b_{eff} > b_i$ , conservatively is taken also the perimeter of the joint.

### 3. CASE STUDY – 24 METER SPAN TRUSS BEAM JOINT

The present paper propose the applying of the component method [1] to a common joints (truss beam), calibrating a finite element model and determine the improvements possibilities.

The designed joints are a 24m span beam truss welded joint with RHS 120x6,3 compressed truss, RHS 90x6,3 tensioned truss, a HEB140 chord for the lower chord joint and RHS 120x6,3 , RHS 90x6,3 and HEA200 chord for the upper chord joint. The trusses are made of S235JR steel and the chords are made of S355 steel grade.

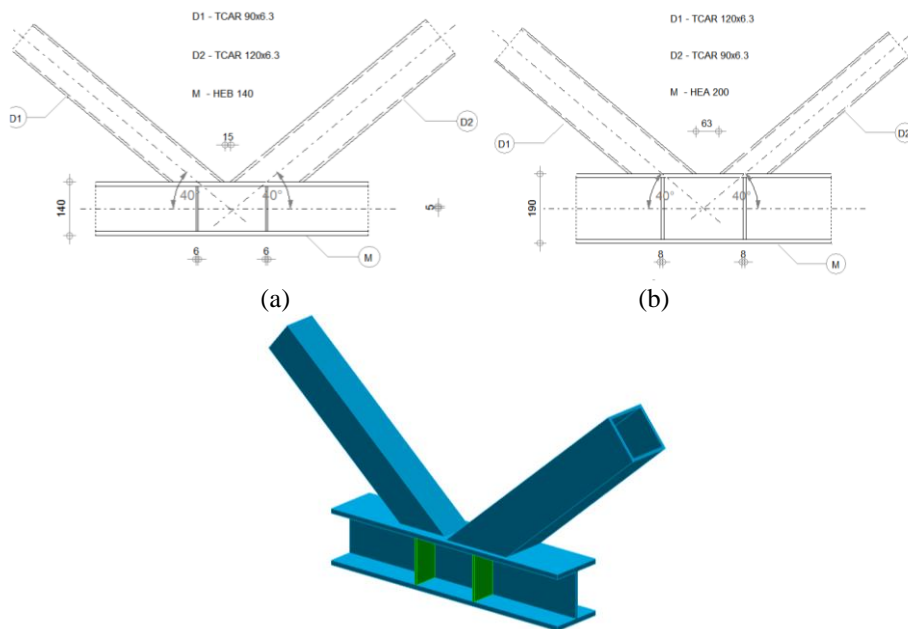


Figure 3. (a) Lower chord joint (b) Upper chord joint

Additional chord web stiffeners are needed due to the shear force in the area of the web. Following the component method design, for the lower chord, the highest stress ratio is reached in tensioned RHS90x6,3 diagonal is 0.68, corresponding to a stress of 244,78 MPa. The upper chord is having almost the same behaviour, the values of the stresses being comparable to the lower chord. The value of the stress dimensioned stress is 251,20 MPa.

In order to decrease the stress value, it is proposed an additional stiffener in the area of the centre of the joints and a redistribution of the other two stiffeners, with the aim to diminish the influence of the tension diagonal effort/stress.

Considering that according with Eurocode [1], the design implication of the additional element cannot be assessed, it was done a FEM analysis for the in case joints.

The general purpose finite element software Ansys was used for the numerical investigation. The modelling was done using solid finite elements with 15 and 20 nodes. Meshing was made automatically by the software, resulting HEX20 (quadratic hexahedral- 20 nodes hexahedron is very robust, but very memory intensive) and WED

15 (15 nodes linear wedge-prism).

In the contact between elements in the joint, was required thickening of the mesh for accuracy results.

After analysing truss beams-diagonal to lower chord joint it was obtained the stress distribution. It should be noted that the stress by web of chord was significant increased (Figure 4).

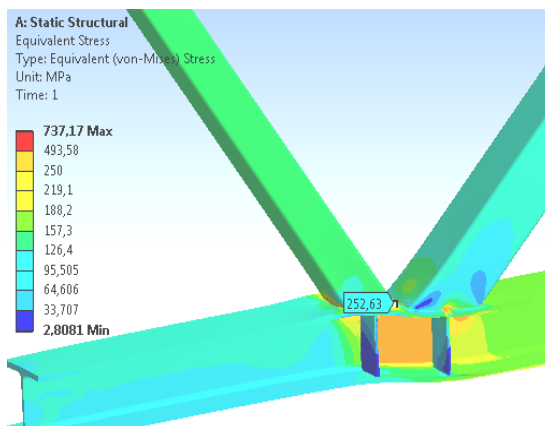


Figure 4. Equivalent stress in the lower chord joint

The value of maximum equivalent (von-Mises) stress it is  $253\text{N/mm}^2$  for the lower chord joint and  $262\text{N/mm}^2$  for the upper chord joint (Figure 4 and 5).

Considering the comparable values of the stresses – FEM analysis vs. component method [1], the model was considered calibrated.

The next step was to redesign the geometry of the joint model – applying an additional stiffener in the centre of the joint with a reconsidered position of the other stiffeners – position correlated with the walls of the truss diagonals.

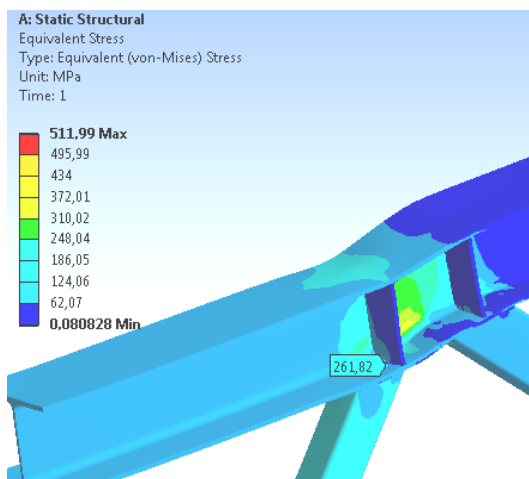


Figure 5. Equivalent stress in the upper chord joint

By rearrangement of the stiffeners and by adding the new stiffener, it was obtained an improvement of stress distribution in the joint (figure 6 and figure 7). Thus a reduction of almost 35% of the stress was achieved.

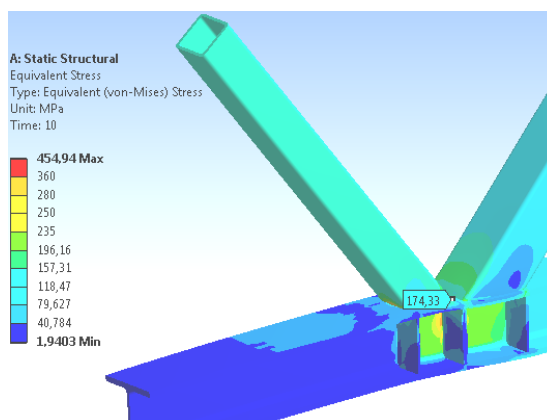


Figure 6. Equivalent stress in the lower chord joint proposal

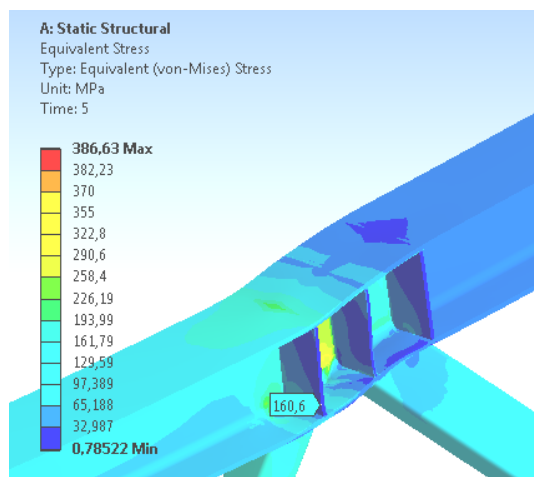


Figure 7. Equivalent stress in the upper chord joint proposal

#### 4. CONCLUSIONS

The Eurocode [1] is presenting a detailed design procedure for the truss beams welded joints – the component method. The present article is underlining that can be achieved better joint behaviour by adding additional elements with geometries that cannot be taken into account by means of present normative. The position and the number of the stiffeners is important, taken into account the differences found out through our study. Decreasing the joint stress value can lead to better joint behaviour and optimized design.

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