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INFLUENCE OF CHORD AXIAL LOAD ON THE STIFFNESS AND RESISTANCE OF WELDED "T" JOINTS OF SHS MEMBERS

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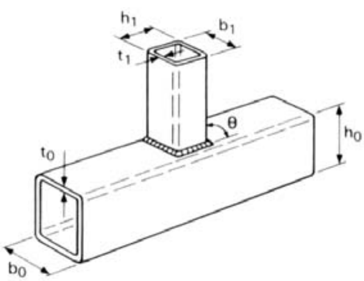
Abstract. *The use of structural hollow sections is currently growing very fast, being of major importance an accuracy assessment of the analytical approaches available to these elements, namely their connections. These elements are mainly used in truss structures where the connected members are submitted to important axial forces.*
In this paper some results concerning Square Hollow Section (SHS) welded "T" joints will be presented. An emphasis is given to the effect of the chord axial loading on the connection resistance, to the ratio between membrane stiffness and initial stiffness, and also to the comparison between numerical and Eurocode 3 resistances.

1 INTRODUCTION

The use of structural hollow sections presents a constant growing in their use, namely in truss structures where members are loaded mainly in tension or in compression. The connections of these elements are a singularity with major importance, so its behavior should be carefully investigated.

This study is concerned to the so-called welded "T" joints of SHS members. The geometry and the main parameters of this particular typology of connections are presented in Figure 1. The main member of this connection is called chord (horizontal in the example) and the secondary is called brace (vertical in the example).



$$\beta = \frac{b_1}{b_0} \quad (1)$$

$$\mu_1 = \frac{b_1}{t_1} \quad (2)$$

$$\mu_0 = \frac{b_0}{t_0} \quad (3)$$

$$\gamma = \frac{b_0}{2t_0} \quad (4)$$

Figure 1: Welded "T" joint connection and geometrical parameters

In this study different values of axial force will be applied in the chord, and four different geometries of connections (2 values of β and 2 values of γ) will be considered as well.

The numerical results obtained will be compared to the values provided by the EC3 approach to assess the accuracy of the analytical expressions that are the obvious tool to be used in current design.

These types of connections show the typical behavior represented in Figure 2: the force-displacement curve has an initial stiffness $S_{j,ini}$ and a post elastic membrane stiffness $S_{j,m}$. These connections do not present a clear yielding force level, and therefore some approaches were proposed in the past to estimate the yielding force based on displacement limits.

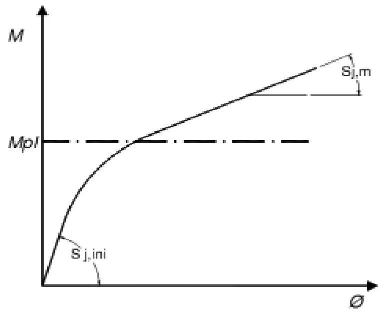


Figure 2: Typical behavior of the connection

2 EUROCODE 3 APPROACH

The part of Eurocode 3 dealing with connection design is the part 1.8. This document is based on the so-called component method, where the connections are modeled by some springs (components) placed in parallel and/or in series. For each component a resistance and a stiffness are obtained and are then used to derive the connection characteristics.

For this specific geometry of connection, the EC3-1-8 assumes a different approach that is based on the assumption that it is pinned and therefore the connection resistance is given by the resistance of the members individually.

The effect of the axial load in the chord is dealt with in EC3 in the expressions concerning the chord face failure for β≤0,85. These expressions are:

$$N_{i,Rd} = \frac{k_n f_{y0} t_0^2}{(1-\beta)\sin\theta_i}\left(\frac{2\eta}{\sin\theta_i} + 4\sqrt{1-\beta}\right) \Bigg/ \gamma_{M5} \tag{5}$$

$$k_n = 1{,}3 - \frac{0{,}4n}{\beta} \text{ but } k_n \leq 1 \text{ (compression) ; } k_n = 1 \text{ (tension)} \tag{6}$$

3 NUMERICAL SIMULATION

This paper presents a parametric numerical study composed by 32 simulations. In this chapter the model and all the simulations performed will be described.

3.1 Numerical Model

The model was generated using shell elements (Shell181) of Ansys® [3] database. Also, account for the weld as well as the root radius of the chord was taken. Figure 3 shows this model.

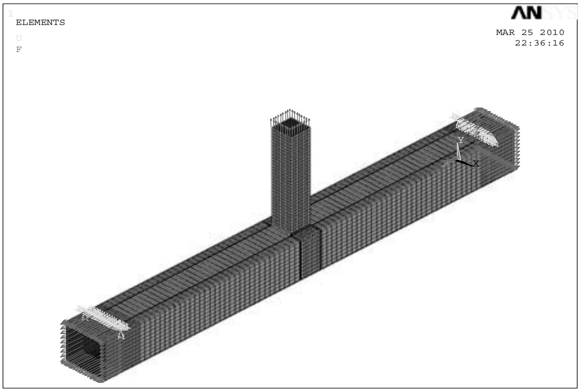


Figure 3: Numerical Model

As it can be depicted from Figure 3, the mesh is more refined near the supports and near the connection, where the high stress concentration is more likely to occur. The mesh is formed with regular elements and with low form factors to avoid numerical problems.

The material used for the members was S355 steel with an elastic modulus of 210 GPa and with an yielding stress of 355 MPa without strain hardening.

The chord load was applied in one load step and was kept constant, while the brace load was applied in some increasing sub steps up to the connection failure.

3.2 Model Validation

The numerical model was validated with the results obtained by Lie et al. [4]. The model was simulated with the same test layout used by the authors and adopting the same mechanical characteristics.

The test layout used by Lie et al. [4] is presented in Figure 4.

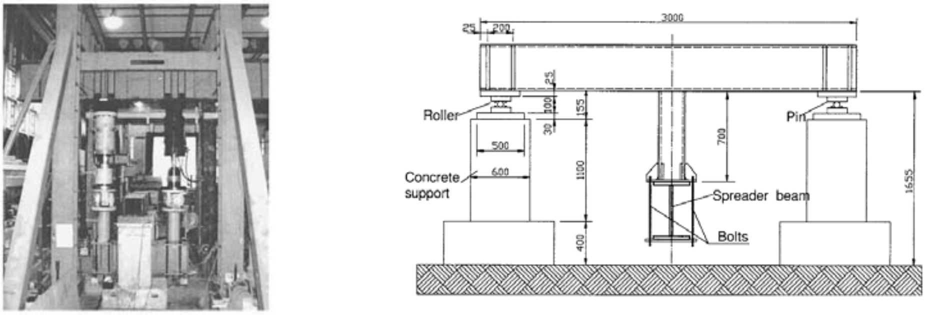


Figure 4: Test Layout [4]

In Figure 5 the comparison between the numerical and the experimental results expressed in terms of a force-displacement curve is presented. The numerical and the experimental results present a quite good agreement that shows that the numerical model is giving acceptable results.

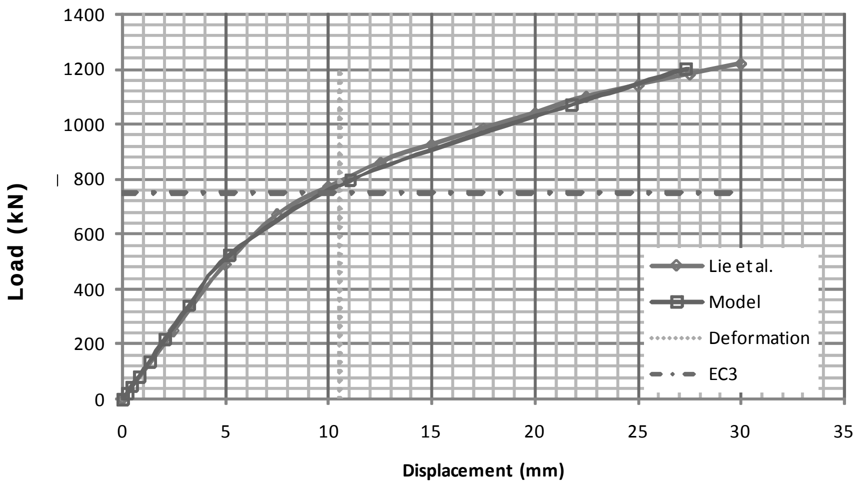


Figure 5: Numerical model validation

3.3 Numerical Model Tests

Table 1 shows the 32 numerical simulations performed. It is worth to stress that two chord geometries were used, by changing the thickness of this member, while two brace geometries were used (100 and 150 mm wide, to vary the parameter β). The tension load applied in the brace was increased up to failure, and eight different load levels in the chord were applied and kept constant during all the loading process. Null, tension and compression forces were used for a better assessment of the effect of this loading.

Table 1: Numerical simulations

Chord (mm)	**Brace (mm)**	**Brace Force**	**Chord Force (N/N_{pl})**
SHS 300x300xE E=8, 12	SHS 100x100x12 SHS 150x150x12	Tension	0 0,25 (Tension) 0,25 (Compression) 0,5 (Tension) 0,5 (Compression) 0,8 (Tension) 0,8 (Compression) 0,95 (Tension)

To compute the actual value of β for the connections, the brace width of the corresponding SHS plus 2x0,8xt_w (with t_w representing the weld width) was considered. In Table 2 the geometrical parameters of the connections studied are presented.

Table 2: Geometrical parameters

	E8 (γ =18,75)		E12 (γ =12,5)	
	t_w	β	t_w	β
M100	12	0,40	12	0,40
M150	12	0,56	12	0,56

4 RESULTS

The numerical simulations performed in this study were used to derive the force-displacement curves corresponding to the described connections with varying chord axial load.

As referred, to obtain the connection yielding point some approximation method is needed, and in this case the method proposed by the International Institute of Welding (IIW) stating that the connection resistance is the force corresponding to a displacement of 3% b_0 (with b_0 presented in Figure 1) for ultimate limit state was used. As this study is performed with a chord of 300mm wide, the corresponding limit displacement is 9mm.

4.1 Force-displacement curves

Figure 6 shows the force-displacement curves obtained for the connection with a chord of 300x300x8 [mm] and a brace of 100x100x12 [mm].

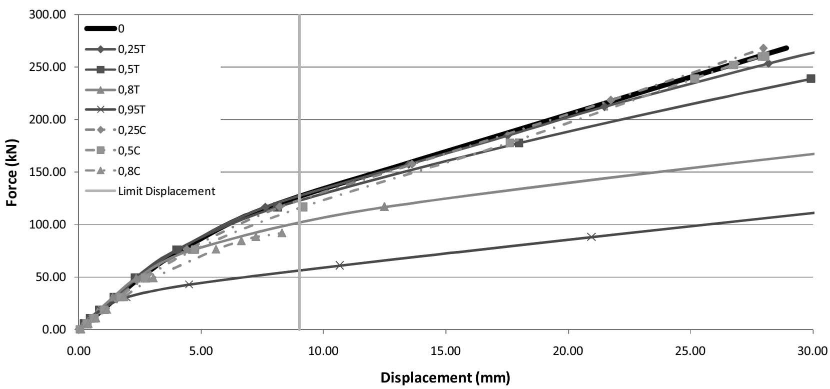


Figure 6: Force-displacement curve

In Figure 6 “T” corresponds to tension forces and “C” to compression forces in the chord, and the number corresponds to the value of the ratio N/N_{pl} in the chord.

It may be observed that these curves present the characteristic shape referred in Figure 2.

4.2 Eurocode 3 approach performance

A comparison of the ratio F/F_{pl} (where F is the numerical resistance and F_{pl} the corresponding value obtained with the EC3 approach) for two values of β is presented in Figure 7.

As it can be seen, the EC3 approach seems to be unsafe for high values of compression in the chord, while for tension this approach tends to be too conservative with the increase of the chord axial load.

4.3 Influence of chord axial load

Figure 8 plots the ratio F/F_{N0} (where F is the numerical resistance and F_{N0} is the numerical resistance of a connection without chord axial load) for two values β. It may be concluded that an increase of the chord axial load leads to a drop of the resistance of the connection both in tension and in compression. The resistance decrease in the tension range is slightly higher than the resistance decrease in the compression range.

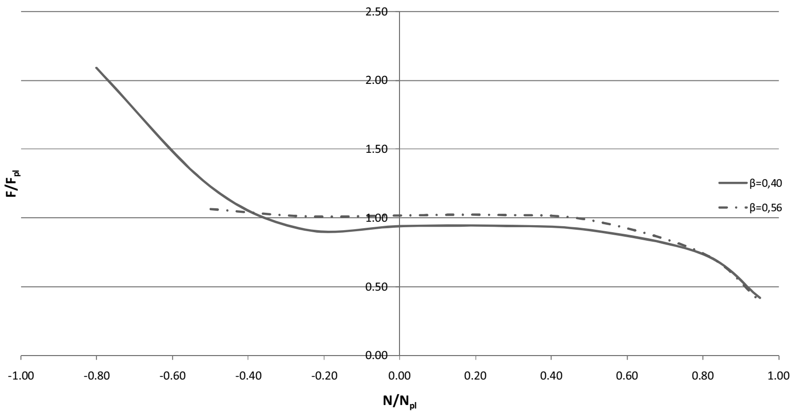


Figure 7: EC3 approach performance

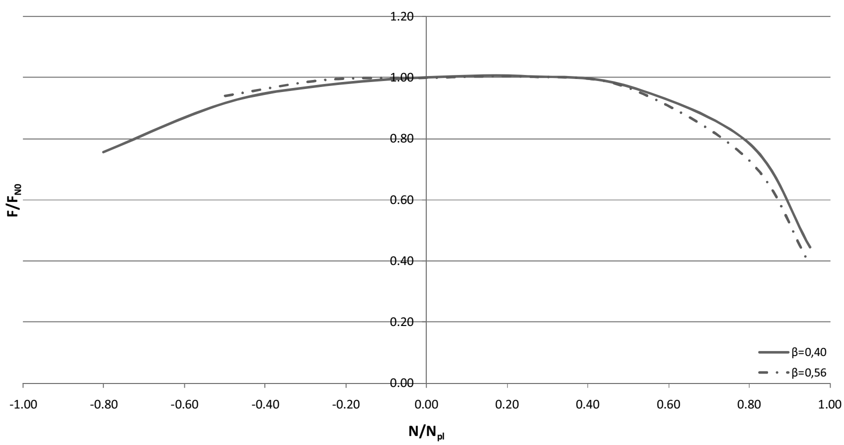


Figure 8: Influence of chord axial load

4.4 Relative importance of initial ($S_{j,ini}$) and membrane ($S_{j,m}$) stiffness

As described in Figure 2, this type of connection presents a behavior with a stiffness reserve after connection yielding called membrane stiffness - $S_{j,m}$. This section presents the variation of the ratio $S_{j,m}/S_{j,ini}$ for different values of the chord axial load. These results are plotted in Figure 9.

In Figure 9 E8M100 concerns a connection between a chord of 300x300x8 mm and a brace of 100x100x12 mm, while E12M100 represents a connection with a chord of 300x300x12 mm and a brace of 100x100x12 mm.

As it can be seen both curves present a similar same shape, but the connection with an higher value of γ (E8M100) presents higher values for this ratio when compared to the connection with a lower value of this parameter γ.

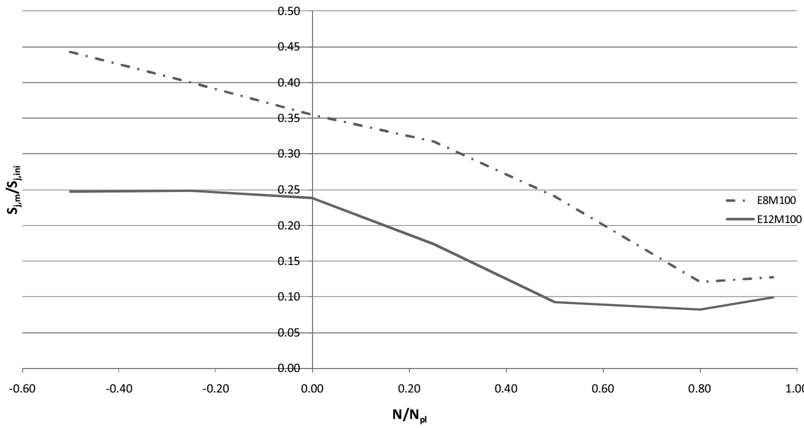


Figure 9: Ratio between membrane and initial stiffness for different levels of chord axial load

5 CONCLUSIONS

This study shows an evaluation of the Eurocode 3 approach performance for the prediction of the failure load in axially loaded braces in "T" connections, with an axially loaded chord. Also, the influence of the chord axial load level on the connection resistance and on the ratio between $S_{j,m}/S_{j,ini}$ were highlighted.

Concerning the EC3 approach performance it may be concluded, from Figure 7, that for higher compression values in the chord this approach seems to be too unsafe, while for higher values of chord tension forces the approach gives very conservative results.

This approach tends to reduce the connection resistance when chord compression forces are present, but this study suggests that this reduction should be even greater for larger values of the ratio N/N_{pl} in compression.

Both tension and compression forces applied in the chord reduces the connection resistance when compared with the case without chord axial load (Figure 8). The curves for both geometries presented a very similar shape and almost symmetrical in relation to the case without chord axial load.

Regarding the stiffness (initial and membrane), it can be concluded (Figure 9) that the curve relating the ratio between these stiffnesses with the variation of the chord axial load presents a similar shape for different values of γ, but this ratio increases with the increase of γ.

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