Behaviour of Welded Connections in Square and Circular Hollow Sections

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ABSTRACT

Hollow Structural Section (HSS) members are known to possess many advantages over equivalent open sections, including better resistance to torsion as well as tension and compression loading, aesthetic appearance and economy in terms of material cost. Connections between HSS members could be made simple by cutting the ends and welding together. However, depending on joint configuration and number of members connected, this may result in complex and expensive connections. This paper presents the results of an analytical investigation done in ANSYS Software. Special attention was paid to T-joints that consist of the chord member of a single square section and brace members of different kinds of cross sections as Square and Circular Hollow sections. A finite element model was developed for 6 specimens to investigate the influence of some variables such as geometry and β-parameter (ranging from β= 0.60 to 1.00) on the joint's response. The brace load (compressional load) was incremented up to joint failure, while the chord was kept unloaded. The Stress-Strain curves were plotted. The force-displacement curves corresponding to the different geometries are analysed and compared, focusing on the failure loads and elastic stiffness. With respect to the geometry, the test results revealed that the use of square hollow section lead to increased joint capacity. With respect to the type of section, it can be concluded that the resistance of a joint with β= 0.75 is greatly influenced by the type of brace member.

Key Words: Fillet Weld, Finite Element Model, Geometry and type of section, Hollow Structural Section, Joint Capacity

1. INTRODUCTION

Steel is crucial to the development of any modern economy and is considered to be the backbone of human civilization. All major industrial economies are characterized by the existence of a strong steel industry and the growth of many of these economies has been largely shaped by the strength of their steel industries in their initial stages of development. India is currently the world's fourth largest producer of crude steel. While steel continues to have a stronghold in traditional sectors such as construction, housing and ground transportation, special steels are increasingly being used in engineering industries such as power generation, petrochemicals and fertilizers, automobile, pipes and tubes etc. The Indian steel industry is largely iron-based through the blast furnace or the direct reduced iron route. India occupies a central position on the global steel map, with the establishment of new state-of-the-art steel mills, acquisition of global scale capacities by players, continuous modernization and up gradation of older plants, improving energy efficiency and backward integration into global raw material sources.

2. STRUCTURAL STEEL

Structural steel is a category of steel used as a construction material for making structural steel shapes. A structural steel shape is a profile, formed with a specific cross section and following certain standards for chemical composition and mechanical properties. Structural steel shapes, sizes, composition, strengths, storage practices, etc., are regulated by standards in most industrialized countries.

2.1. Common Structural Shapes

The shapes available are described in many published standards worldwide, and a number of specialist and proprietary cross sections are also available.

- I-beam
- Z-Shape (half a flange in opposite directions)
- HSS-Shape (Hollow structural section) also known as SHS (structural hollow section) and including square, rectangular, circular (pipe) and elliptical cross sections)
- Angle (L-shaped cross-section)
- Structural channel (or) C cross-section
- Tee (T-shaped cross-section)
- Rail profile (asymmetrical I-beam)
- Bar, a piece of metal, rectangular cross sectioned (flat) and long, but not so wide so as to be called a sheet.
- Rod, a round or square and long piece of metal, see also rebar and dowel.
- Plate, metal sheets thicker than 6 mm or 1⁄4 in.
- Open web steel joist

3. HOLLOW STRUCTURAL SECTION

A hollow structural section (HSS) is a type of metal profile with a hollow tubular cross section. HSS members can be circular, square, or rectangular sections, although other shapes are available, such as elliptical. HSS is only composed of structural steel per code. HSS is sometimes mistakenly referenced as hollow structural steel. Rectangular and square HSS are also commonly called tube steel or structural tubing. Circular HSS are sometimes mistakenly called steel pipe though true steel pipe is actually dimensioned and classed differently from HSS. The corners of HSS are heavily rounded, having a radius which is approximately twice the wall thickness. The wall thickness is uniform around the section. Rather, the three basic shapes are circular, square, and rectangular hollow sections.

3.1. Designation

The preferred designations for structural applications are:

- Structural Hollow sections (SHS)
- Circular Hollow Sections (CHS)
- Rectangular Hollow Sections (RHS)

3.2. Advantages of HSS over Open Sections

The radius of gyration, especially about the minor axis, of a structural hollow section is significantly higher than that of an open section of a similar size and area. This results in a much lower slenderness ratio for the same effective length and hence a higher compression capacity.

Any residual stresses that may be in the section due to the method of manufacture are generally also distributed in a much more favourable way than those in open sections because of the different shape characteristics and this can also result in an increase in the compression capacity.

Structural hollow sections are generally available in lengths up to 12 or 15 m (40 or 50 ft.), but in some circumstances longer lengths, up to 20 m, maybe available. This means that for buildings of up to about 4 storeys only one length per column is required.

Structural hollow sections are unique among structural steel profiles in that they can be protected from fire damage by using either internal or external methods of protection.

The closed shape without sharp corners reduces the area to be protected and extends the corrosion protection life.

3.3. Applications of HSS

The applications of structural hollow sections nearly cover all fields. Sometimes hollow sections are used because of the beauty of their shape, to express lightness or in other cases their geometrical properties determine their use.

- Buildings and halls
- Bridges
- Barriers
- Offshore Structures
- Towers and Masts

4. CONNECTIONS OF HSS

Connecting technology plays an important role in the performance of hollow section structures. A distinction has to be made between CHS and RHS connected members, because the behaviour of joints, e.g. local behaviour of members is different. There are two main methods of making site connections:

- Bolting and
- Welding

5. WELDED CONNECTIONS

A weld joint is a permanent joint which is obtained by the fusion of the edges of the two or more parts to be joined together, with or without the application of pressure and filler material. It is unavoidable factor in the welded joints, while evaluating the performance of welded joint it is important to consider the influence of residual stress.

Three basic types of welds account for practically all structural weld joints, including those between HSS are

- Complete - Joint - Penetration (CJP) groove welds,
- Partial - Joint - Penetration (PJP) groove welds and
- Fillet welds.

5.1. Advantages of Welded Connections

- The most common type of joint in hollow sections is the fully welded joint, because it is quite simple and aesthetically appealing.
- One of the reasons for the popularity of this solution is the cumbersome access to the inside of the column, making bolted solutions more complex and costly.

6. MATERIAL SELECTION AND MODELLING

6.1. HSS- Product Specifications

A lot of factors that influence the stiffness of the joint need to be taken into account in the design. These include its geometry, the material used, stress application, welding etc. As regards the geometry of the joint, two different types of joint are to be compared. In the first type of joint, both the chord and brace members are composed of square hollow sections. In the second type of joint, the chord member is composed of a square hollow section as in the first case; however, the brace member is made of a circular hollow section. To this, the following specimens are to be used.

Table 6.1. Specimens Considered

Specimens	Chord Member	Brace Member
Specimen 1	SHS 80 X 80 X 3.2	SHS 80 X 80 X 3.2
Specimen 2		SHS 60 X 60 X 3.2
Specimen 3		SHS 49.5 X 49.5 X 3.6
Specimen 4	SHS 80 X 80 X 3.2	CHS 76.1 X 3.2
Specimen 5		CHS 60.3 X 3.6
Specimen 6		CHS 48.3 X 3.2
All dimensions are in mm		

6.2. Joints

The welding of Hollow Structural Sections (HSS) does have some unique features. Unlike open sections, where welding is typically possible from both sides of an element, welding of HSS is only possible from one side, thus requiring larger weld sizes.The weld size adopted is 5 mm.

6.3. JointParameters

The geometry of a particular joint is generally defined by the dimensions and by the joint parameters α, β, γ, τ and g'.

The variable that can characterize the joint is a β-parameter. It is the ratio of the mean diameter or width of the brace members to that of the chord. Our aim was to cover as wide a range of β-parameters as possible. This can be given as

$$\beta = \frac{\text{mean dia or width of the brace members}}{\text{mean dia or width of the chord members}}$$

The β-parameter for all types of sections ranges from 0.6 to 1.00. The above parameter makes it possible to create a total of six experimental types of joint (three joints consisting of square sections and three joints consisting of circular sections).

6.4. Geometric Models

The following Fig. 1 shows the geometry adopted in this study, known as "T- Joint", where the horizontal element is the chord, to which the vertical element, the brace, is fully welded. In this paper, the brace is submitted to axial tension loading, incremented up to joint failure.

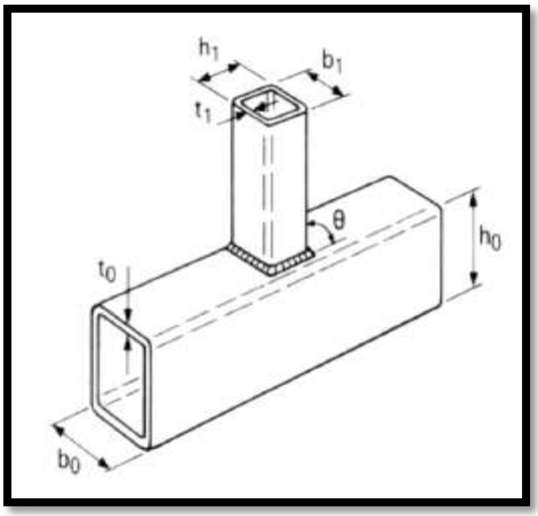

Fig. 6.4.1 Welded T-Joint

Having in mind that the parameters governing the behaviour of the joint are related to the dimensions of the loaded area (the brace section dimensions) and to the dimensions of the loaded chord face, a representative range of geometries is established.

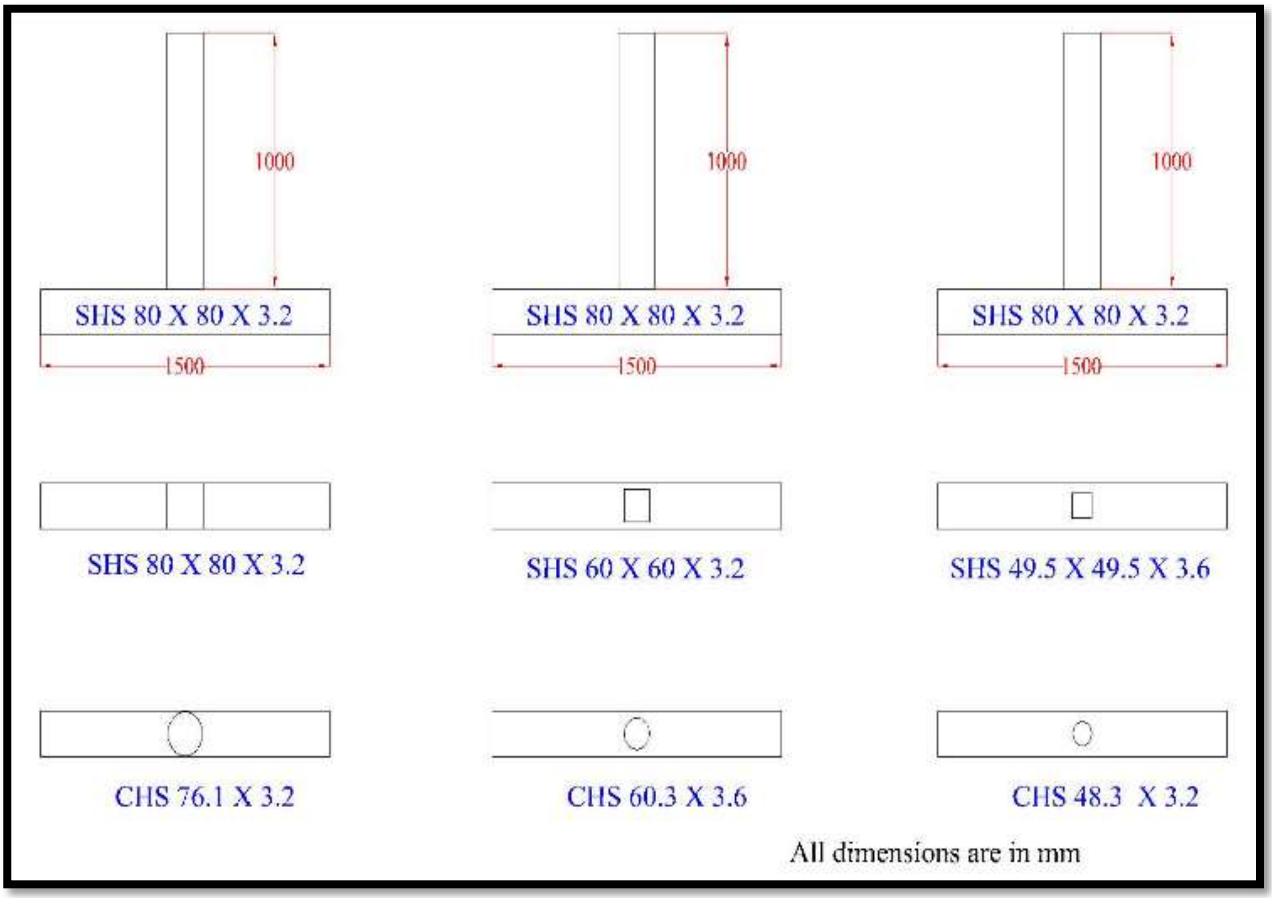

Fig. 6.4.2. Geometry Modelling

6.5. Boundary and Loading Conditions

In this study, the boundary conditions applied to the chord member of the T-joints are approximated to chord end fixity for all degrees of freedom. The chord is held as fixed –fixed from both ends.

To simulate the real behaviour of the joint in a lattice structure, the chord member was assumed to act in horizontal compression, while the brace members were compressed in a vertical direction. Vertical load imposed on the specimens was gradually increased until the total failure of the specimen. The loads are applied for all the types to the free end of the brace in different directions, depending on the load type. Detailed weld fillets are not modelled.

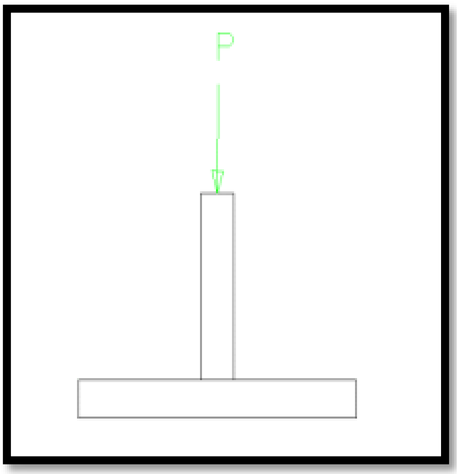

Fig 6.4.3 Loading Conditions

7. ANALYSIS BY ANSYS

7.1. Finite Element Model

Modelling by finite elements techniques require the development of a model that is at the sametime accurate and simple enough not to consume to much computational resources in the context of parametrical studies. In this study a numerical model accounting for material and geometrical nonlinearities using the ANSYS software is to be developed.

8. RESULTS AND DISCUSSION

The types of joints selected were observed for both stress and deformation of the joints. The following sections provide an exact view of the real behaviour of the individual types of joint. The figures presented compare deformations of the joints.

8.1. Comparison of Deformations in the joints consisting of the identical type of the Brace Member

The joints with the identical type of the brace member are compared (Fig. 8.1.1.and Fig. 8.1.2.).

First, when there is a linear deformation, the joint is in the elastic range. Later, as the load is increased, the joint deviate from this linear proportionality and the deformation goes through the elasto-plastic and eventually into its plastic range of action. Of all the types of brace members, the **most resistant** certainly seem to be those with the values of **β = 0.75**.

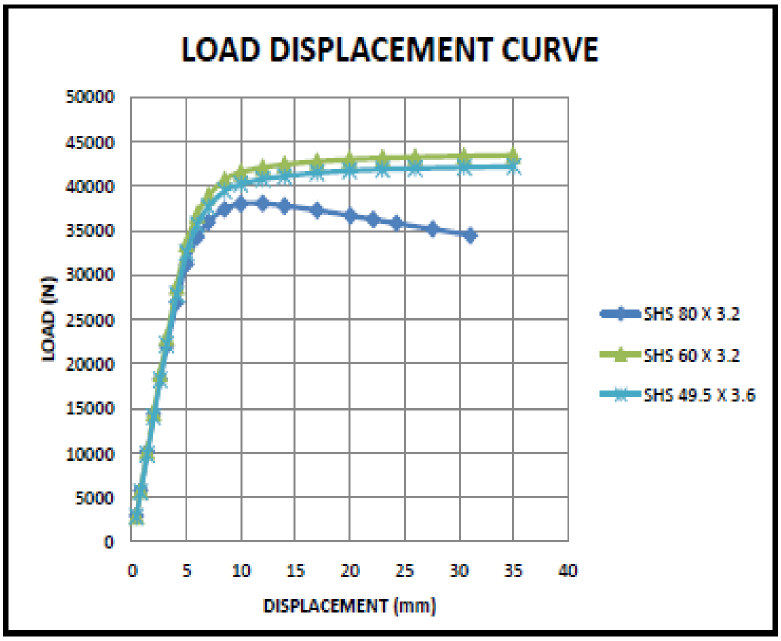

Fig. 8.1.1. Comparison of Deformations in the joints composed of the Brace Members with Square Hollow Sections

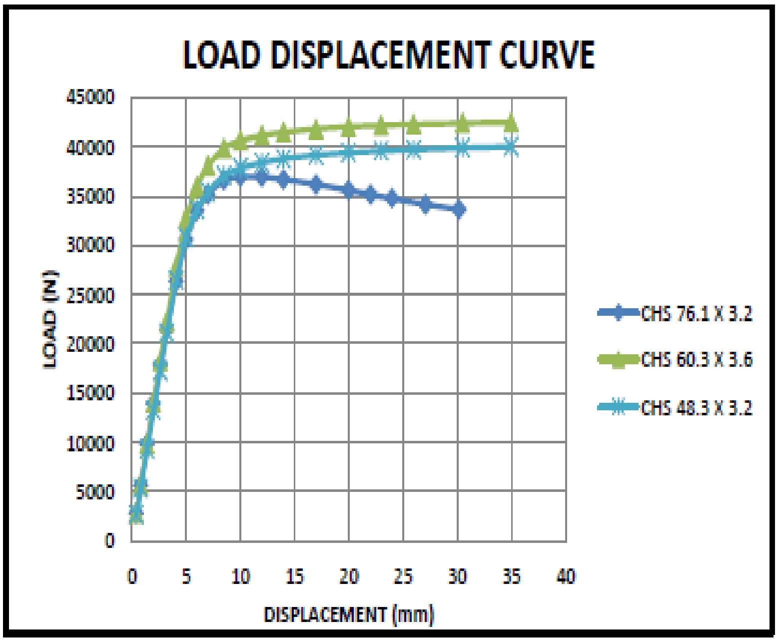

Fig. 8.1.2. Comparison of Deformations in the joints composed of the Brace Members with Circular Hollow Sections

8.2. Comparison of Deformations in the Joints with the Same Widths of Chord and Brace Members

The stiffness of the joint does not depend only on its dimensions but also on the type of the brace member used. The comparisons are presented in the form of the following (Fig. 8.2.1., Fig. 8.2.2. and Fig. 8.2.3.).

In the first type of joint (**β=1**), the stability of the chord web (wall) was crucial for the overall resistance of the joint. The Fig.8.2.1. presents the distribution of values deformation in the chord member. When the resistance of square and circular sections was compared, **the square sections proved to be the stiffest**.

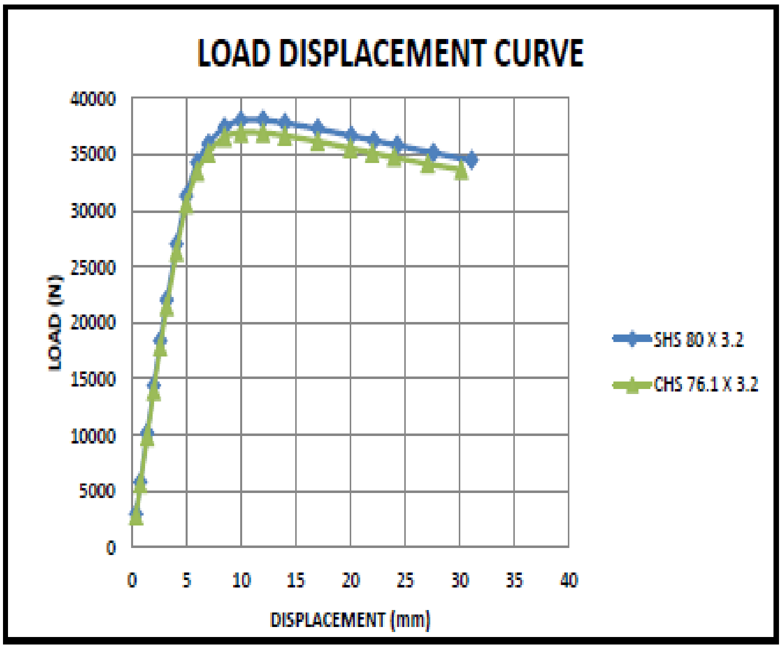

Fig. 8.2.1. Deformation of the T-Joint With β =1.00 depending on the Type of Brace Member used

As can be seen from the Fig. 8.2.2. the buckling effect of the chord web (wall) on the overall resistance of the joint can be also observed in the joints with **β=0.75**. When comparing the types of brace member used, the **square section** appeared to be the **most resistant** of all.

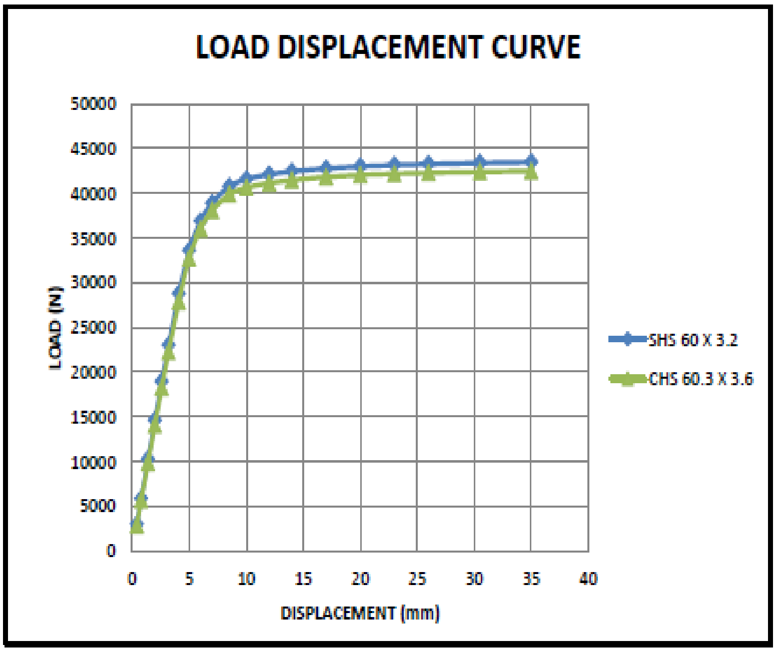

Fig. 8.2.2. Deformation of the T-Joint With β=0.75 depending on the Type of Brace Member used

In the third type of joint (Fig. 8.2.3.), for **β= 0.60**, the overall resistance of the joint was influenced by the loss of stability of the vertical web (wall). When comparing the types of brace member used, the **square section** appeared to be the **most resistant** of all.

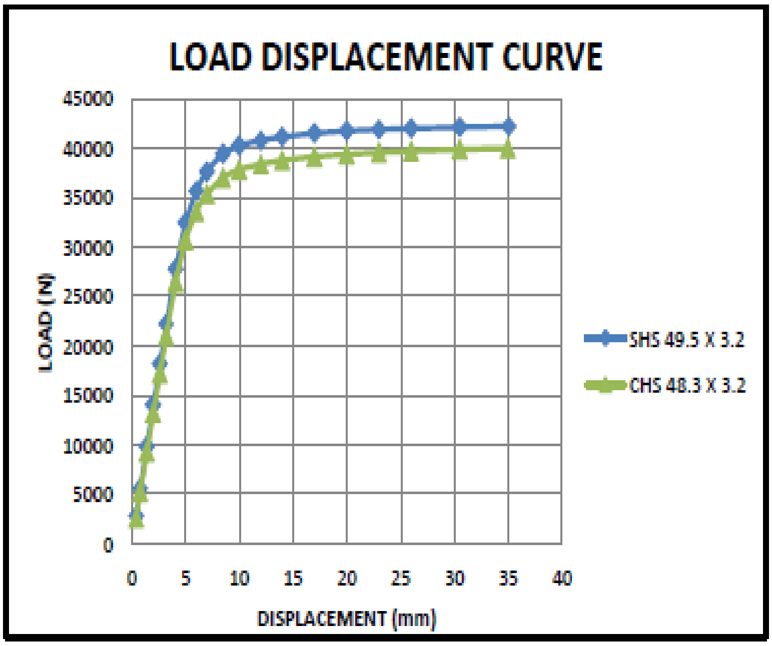

Fig. 8.2.3. Deformation of the T-Joint with β=0.60 depending on the Type of Brace Member used

9. CONCLUSION

- The results and evaluations presented characterize the correlations regarding the global resistance of joints in lattice structures in the light of the latest scientific knowledge that should be responsibly taken into consideration in their reliable and cost-effective design.
- From the results obtained some patterns of behaviour of T-joints may be identified.
- With respect to the geometry, it can be concluded that the **square section proved to be the stiffest.**
- With respect to the geometry and type of section, it can be concluded that the resistance of a joint with **β = 0.75** is greatly influenced by the type of brace member. This influence sharply diminishes with the decreasing value of a β-parameter. With very low β-parameters, the influence of the type of brace member becomes virtually negligible and unimportant.

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REFERENCES

[1] Fidelis Rutendo Mashiri, Xiao-Ling Zhao, Manfred A. Hirt and Alain Nussbaumer, "Size Effect of Welded Thin-Walled Tubular Joints",Manuscript for IJSSD.

[2] Jaap Wardenier and Yoo Sang Choo (2006), "Recent Developments in Welded Hollow Section Joint Recommendations", Advanced Steel Construction 2 (2006) 109-127.

[3] Jeffrey A. Packer and Matthew R. McFadden (2012), "Welding of Hollow Structural Sections", Technical Paper, Steel Tube Institute, Glenview, IL.

[4] K. Satyanarayana, R.T.Naik, L.V.V.Gopala Rao and R.T.Babu Naik (2011), "Static Strength Analysis of Tubular T-Joints Using Ansys", Journal of Basic and Applied Scientific Research, J. Basic. Appl. Sci. Res., 1(9)989-997, 2011 © 2011, TextRoad Publication.

[5] L. W. Tong, H. Z. Zheng, F. R. Mashiri, M.ASCE and X. L. Zhao, F.ASCE (2013), "Stress-Concentration Factors in Circular Hollow Section and Square Hollow Section T-Connections: Experiments, Finite-Element Analysis, and Formulas", Journal of Structural Engineering © ASCE / NOVEMBER 2013, J. Struct. Eng., 2013, 139(11): 1866-1881

[6] Lip H Teh and Kim JR Rasmussen (2002), "Strength of Butt Welded Connections between Equal-width Rectangular Hollow Sections", Research Report No R817, The University of Sydney, Department of Civil Engineering Centre for Advanced Structural Engineering, http://www.civil.usyd.edu.au

[7] Mahesh Dhone and Dr. R.D. Palhade (2016), "Finite Element Simulation of Fillet Welded Cruciform Joint for Evaluation of Fatigue Behavior", International Journal of Scientific Engineering and Research (IJSER), Volume 4 Issue 4, April 2016, Paper ID: IJSER15766, ISSN (Online): 2347-3878, Impact Factor (2015): 3.791.

[8] R.M.M.P. de Matos, L.F. Costa-Neves, L.R.O. de Lima P.C.G.S. Vellasco and J.G.S. da Silva (2015), "Resistance and elastic stiffness of RHS "T" joints: part I - axial brace loading", Latin American Journal of Solids and Structures,www.lajss.org, http://dx.doi.org/10.1590/1679-78251790

[9] V.Kvočáka, P. Bekea and R. Vargováa (2012), "Joint composed of various section", Steel Structures and Bridges 2012, © 2012 Published by Elsevier Ltd. Selection and review under responsibility of University of Žilina, FCE, Slovakia.

[10] Vaibhav B. Chavan, Vikas N. Nimbalkar and Abhishek P. Jaiswal (2014), "Economic Evaluation of Open and Hollow Structural Sections in Industrial Trusses", International Journal of Innovative Research in Science, Engineering and Technology, Vol. 3, Issue 2, February 2014, ISSN: 2319-8753.