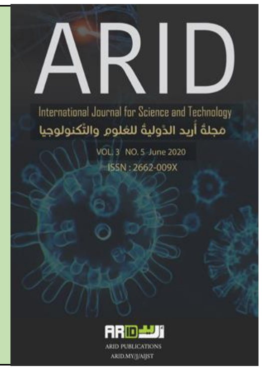
ARID Journals

ARID International Journal for Science and Technology (AIJST)
ISSN: 2662-009X

Journal home page: http://arid.my/j/aijst



مَجلةُ أُريد الدَّوليةُ للعُلومِ والتِّكنولوجيا

العدد 5 ، المجلد 3 ، حزيران 2020 م

The Effect of Weld Length on the Tension Capacity of Hollow Structural Section (HSS)

Nooruldeen D. Salman [2] , Fatih ALEMDAR[1]

[1]Department of Civil Engineering, Faculty of Engineering, Yildiz Technical University, Istanbul, Turkey
[2]Department of Civil Engineering, Faculty of Engineering ,Mansour University College, Baghdad, Iraq

تأثير طول اللحام على مقاومة الشّد للمقاطع الإنشائية المجوّفة

نورالدين داود سلمان (2)، فاتح علم دار (1)

(1) قسم الهندسة المدنية – كلية الهندسة – جامعة يلدز التقنية - إسطنبول – تركيا

(2) قسم الهندسة المدنية – كلية الهندسة – كلية المنصور الجامعة – بغداد - العراق

Nooraldeen.dawood93@gmail.com

arid.my/0004-0119

https://doi.org/10.36772/arid.aijst.2020.354

ARTICLE INFO

Article history:
Received 03/4/2019
Received in revised form 20/02/2020
Accepted 25/03/2020
Available online 15/06/2020

Abstract

The non-uniform stress distribution occurs in a tension member adjacent to a connection, in which all elements of the cross-section are not directly connected.

This effect reduces the member’s design strength because the entire cross-section is not fully effective in the critical section’s location. That's why an experimental study has been done to investigate the effect of the weld length on the tension capacity, two specimens (hollow structural sections) have been tested by using Instron 8800 machine with two weld lengths, 46 mm and 56 mm. The 46 mm size is the minimum requirement of the sufficient size of the tension connection depending on United States Steel Standard. The Result proved that there has been too much effect on the connection carrying tension capacity. The result of the 46 mm weld length is about 155 KN and about 180 KN for the 56 mm weld length. While the ABAQUS simulation results were about 168 KN for the 46 mm weld length and about 172 KN for the 56 mm weld length.

.

Keywords: tension member, tensile test, welding size effect, hollow structural section.

الملخص

توزيع الإجهاد يكون غير منتظم في مقطع التوتر (الشّد) خاصة في مناطق اللحام حيث تكون جميع عناصر المقطع غير متصلة بشكل مباشر.

يقلل هذا التأثير من القوة التصميمية للمقطع، بسبب أن المقطع العرضي بأكمله غير فعّال بشكل كامل في موقع الجزء الحرج، لهذا السبب تم إجراء دراسة تجريبية لعينتين من أقسام هيكلية مجوفة (hollow structural sections) باستخدام آلة INSTRON باستخدام طولين مختلفين للحام لدراسة تأثير طول اللحام على القوة التصميمة باستخدام طول لحام 46 ملم و 56 ملم، وأثبتت النتيجة ذلك التأثير الكبير لطول اللحام على قدرة الشّد التصميمية، حيث بلغت سعة الشد حوالي 155 كيلو نيوتن لنموذج ذو طول 46 ملم، في حين بلغت سعة الشد حوالي 180 كيلو نيوتن للنموذج الثاني ذو طول لحام 56 ملم. في حين وصلت قيمة سعة الشد في عملية المحاكاة في برنامج الـ ABAQUS إلى 168 كيلو نيوتن لنموذج ذو طول 46 ملم وحوالي 172 كيلو نيوتن للنموذج الثاني ذو طول لحام 56 ملم.

الكلمات المفتاحية : القوة التصميمة ، برنامج اباكوس ، هيكلة مجوفة

1. Introduction

Shear lag might be defined as one of the phenomena which creates losses in the resistance regarding tension member that is connected via just part related to its cross-section. It is considered as a complicated issue that was studied for a lot of years (examples are provided by Easterling and Giroux in 1993[1], Tremblay 2001[2], Bauer and Benaddi 2002[3,4] Benaddi and Bauer 2002[5], 2003[6]). There are many parameters that are impacting the shear lag phenomenon, also they are complex to evaluate: the size and the type are related to the cross-section, joint eccentricities, length of welds, type of connection, length of the member, and so on. The approach utilized for analyzing tension as well as the welds of the shear fillet require principal stress in the weld being evaluated from knowledge which is related to stress, act as 3 mutually perpendicular planes. The main stresses are specified with the use of standard theory which is related to the stress analysis that was defined thoroughly via a lot of studies. (Mendelson 1968[7], Southwell 1941[8]) The theory has been studied briefly prior to analyzing the welds and has been defined for the purpose of understating the applied approach.

The authors have recently proposed an analytical approach to calculate the reduction in strength because of the effect of the shear lag on the tension member welded connections (“Abi-Saad and Bauer 2004” [9]). Distribution of the stress was considered at both the elastic and the ultimate load levels. The predicted strength of welded connections for flat bars, angles, channels and rectangular hollow sections was found to coincide with results from several test series (Bauer and Abi-Saad 2005[10]).

In order to further validate the analytical method, stress distributions in welded connections were obtained at various load levels using non-linear finite element analyses. The case of a flat bar welded to a gusset plate was considered for simplicity in an attempt to uncover the basic mechanisms of the shear lag effect. The main parameter governing shear lag is the fact that the weld length ratio to bar width varied.

The strength of the connections predicted by the experimental work with using the Instron machine and the analytical method will be compared herein to the strength that has been obtained from the finite element analyses using the Abaqus program.

The rules for designing these joints have been initially introduced by (Freeman1931[11]) and after that by (Vreedenburgh 1954[12]). The two sets of suggestions were based on the results of the experiments. The proposals of freeman have been extremely uncomplicated, yet the proposals of Vreedenburgh have been more complicated.

For the common use, rules have been basic and provided in Codes of Practice, a lot of them have been summarized in (Clark’s 1971[13]). Usually, the approach applied via Codes of Practice is finding the force that acts on and perpendicular to the plane which is related to the weld’s throat and for calculating stresses acting on the area of the throat considering them as uniform along weld’s length.

Such stresses have been combined in a certain way and made for satisfying certain design standards. With regard to (British Standard for buildings,1969[14]), normal and shear stress on weld’s throat that is deposited on the Grade43 parent metal are fixed on 115N/mm^2 and corresponding stress, estimated with the use of the formula of Von Mises Stresses, has been fixed on 230N/mm^2. High stress is permitted in the welds which are deposited on the Grade50 and Grade55 parent metal that proper electrodes have been applied. Comparable requirements are defined for the welds in (steel girder bridges 1972[15]), yet acceptable stresses are considered to be lower in comparison to those applied in buildings. Frequently, the actual process of design has become more uncomplicated through considering that the weld transmits applied forces just through the action of shearing on the area of the throat, and shear stress, estimated as applied force divided by the area of the throat, is fixed on 115N/mm^2.

Even though the stresses' treatment on the throat area is defined thoroughly, British Standards did not indicate an external force system that is applied to calculate such stresses.

As can be seen through (Clark 1971[13]), the design approaches which are used in the USA and in Europe are considered to be comparable to those utilized in Britain even though the approach in which stresses on the throat are combined vary to some extent. Permissible stresses depend on yield stress related to parent metal in all cases.

2.Finite Element Model Simulation

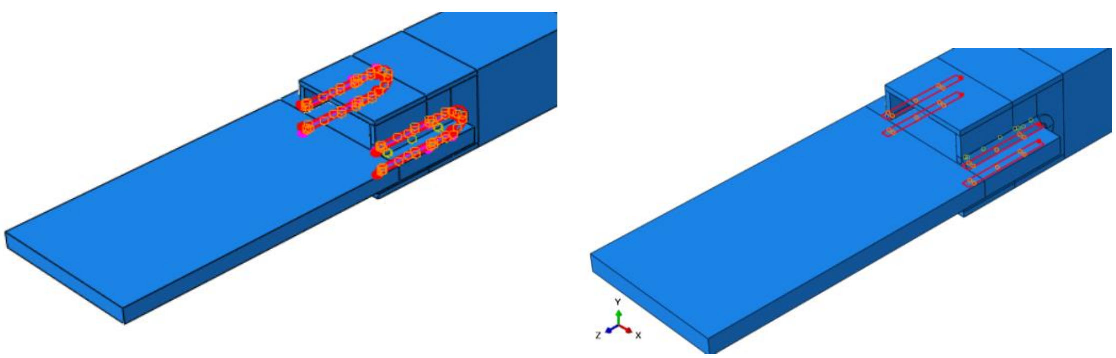
model is established by creating different parts that are (FE)The Finite Element assembled together to form the ribbed model. All parts are connected with the assumption that they are perfectly fixed to each other. All parts are assigned with isotropic material properties, for the detailed solid model, specifications as shown in Table 1.

Table (1): Specifications of the specimen.

Parts	Length mm	Width/throat mm	Thickness mm	Mass Density	Young's Modulus	Poisson's Ratio
Hollow structural section (hss)	500 Length	50*50 width	2.8	0.0078	200000	0.3
Plate	200 Length	80 width	10	0.0078	200000	0.3
Weld *	Variable (46,56)	Variable (3,3.5,4) throat	-	0.0078	200000	0.3

*the weld length and thickness were variable in order to study the effect of weld size on the fatigue load, the length was 46,56 mm while the throat of the weld was 3,3.5 and 4 mm.

In the constraints module, the weld part was assigned as a tie surface with the HSS profile as shown in figure 1.



B. First type of constraint between the HSS and the weld part

A. Second type of constraint between the plate and the weld part

Figure (1): Constraints1 between HSS and weld part.

Creating boundary conditions is an important part of FE-modelling where mistakes are sometimes made. The model is a fixed supported member from one side.

Boundaries are placed at one side of the member in order to lock the movement from one, in line with the real state of the model in the laboratory.

The boundary condition which has been used is that the surface is not allowed to move vertically so that local unrealistic deflection of elements is avoided.

The boundary conditions from the type symmetry/ Antisymmetric/ Encaster, while the (U1=U2=U3=UR1=UR2=UR3=0).

In the load case, A displacement/Rotation type load has been performed with a displacement in z-direction equal to 1 mm in order to represent the pulling load for the tension member. This results in uniform pressure which is used in the finite element model. There is only one load case considered.

To verify that the density of the mesh is adequate a convergence study is performed by changing the mesh size and examining how this affects the result of the analysis. Before meshing the model, the location of the crack initiation must be known since this is the area that is to be meshed with higher density.

It is important that the mesh size is chosen approximately equal for the whole model by a global size of 2 mm, different mesh is taken in the weld region affected by the applied load more than other parts as a global size of 1 mm, which will be more affected by the applied load compared to the other parts of the member.

Real results from the specimen are obtained depending on the mesh size in the weld zone.

3. Description of Experimental Specimens:

Through our experiment we have discussed the effect of weld length on the tension capacity, it was decided to work with HSS section (50*50) with 2.8 mm thickness and the gusset plate was with 10mm thickness as shown in (figure 2).

The hand calculation was to calculate the weld length:

Ag = 541 mm

An = 541-(2*(10*4)) = 541-80 = 461 mm

tensile strength for steel S235 (fu) = 360 MPa

yield strength for steel S235 (fy) = 235 MPa

for yielding on the gross area

p = 0.9*235*541 = 114,421.5 N

for rupture on the net effective region

P = 0.75 * 360 *461 = 124,470 N

114,421.5= 0.75 * 360 *(4*3*length of weld)

length of weld = 35.31 mm < 40 mm

But according to the American national standard (AISC360-16) the minimum weld length is 40 mm.

By considering for starting and end of weld = 40 + 6 = 46 and for the purpose of observing the effect of the weld length on the tension capacity on of the specimen was with 46 mm weld length and the other was with 56 mm and the weld throat thickness was 3 mm for both samples.

Figure (2): The two specimens before making the test

4. Weld Properties:

In our case, the weld was fillet weld joint and the type of weld which has been used was the gas metal arc welding (GMAW), as shown in figure 3.

The gas metal arc welding (GMAW) process uses an electric arc to generate heat to melt the parent material in the joint. A separate filler material supplied as a consumable electrode also melts and combines with the parent material to form a molten weld pool.

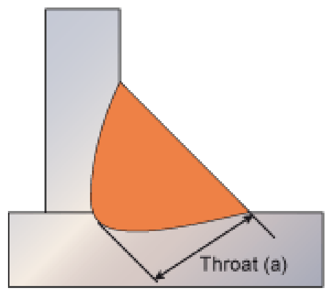


Figure (3): Fillet weld

The throat of the laboratory specimens was about 3.5 mm and for that we made the tensile test simulation in ABAQUS program for three different throats in order to discuss the throat size on the tension capacity, the throat size was 3 mm, 3.5 mm and 4 mm.

5. Results and Discussions:

A comparison for all the obtained results from the tension which have been made by Instron Machine as shown in figure 4 will be made, in order to explain the behavior of the two specimens, comparing the values of stress and strain and their variations according to the change in the length.

Figure (4): INSTRON testing system

The results are shown in Table 2 below:

Table (2): The results of the tensile test

		46 mm weld length	56 mm weld length
1	Tension capacity	156,069 N	182,254 N
2	Tensile stress(maximum)	280.36 MPa	332.51 MPa
3	Tensile extension (maximum)	10.28 mm	24.41 mm
4	Time at Break	237.83500"s	242.77540" s
5	tensile stress at Break	121 MPa	152 MPa
6	Young's modulus	198923 MPa	199796 MPa
7	Extension at Break	9.95232 mm	24.38597 mm
8	tensile strain (extension) gauge length	490 mm	478 mm
9	tensile strain (extension) at Break	0.02031 mm/mm	0.05102 mm/mm
10	Extensometer at Break	0.00339 mm/mm	0.10705 mm/mm
11	Extensometer gauge	25 mm	25

The behavior of the two specimens after carrying out the tensile test is shown in figure (5) while figure (6) shows a comparison between the two specimens with the tension capacity and the extension.

Also, the value of the tension capacity which has been obtained from the laboratory test has been compared with the ABAQUS simulation as shown in figure (7) and figure (8).

While the tensile test simulation results were listed in Table 3

Table (3): The results of the tensile test simulation of ABAQUS program

Specimen	Tension capacity of 3 mm throat size	Tension capacity of 3.5 mm throat size	Tension capacity of 4 mm throat size
46 mm weld length	167(KN)	167.9(KN)	168.5(KN)
56 mm weld length	172.7 (KN)	173.4(KN)	172(KN)

Specimen with 46 mm weld length Specimen with 56 mm weld length

Figure (5): The deformation of the specimens after doing the tensile test

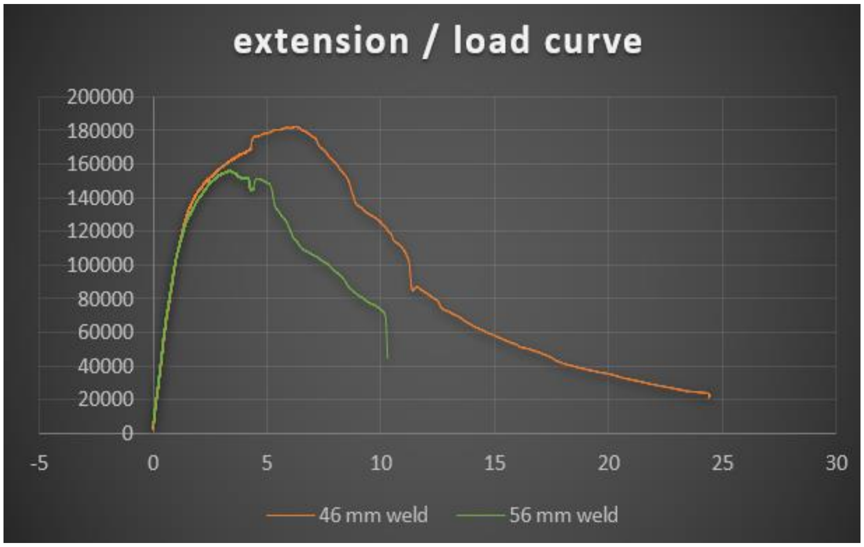


Figure (6): The tension capacity of specimen one and two

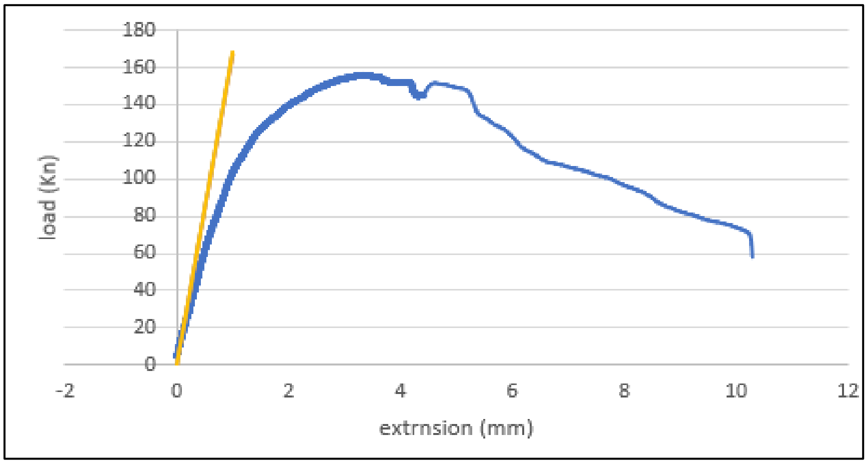


Figure (7): Comparison between experiment result and ABAQUS simulation result for 46 mm weld length specimen

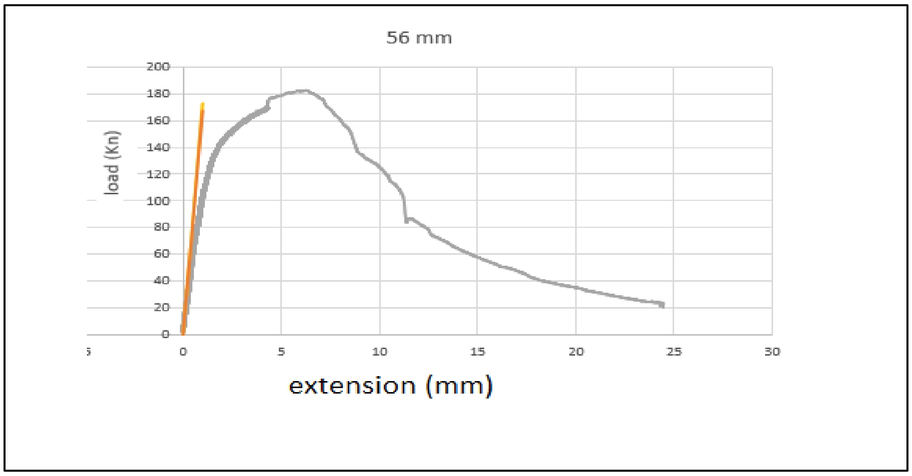


Figure (8): Comparison between experiment result and ABAQUS simulation result for 56 mm weld length specimen

6. Conclusions:

The purpose of this investigation was to review the tension capacity provisions for welded tension members. Two tension members were considered with two different lengths of weld for the purpose of investigating the effect of the weld length on the tension capacity. Experimental strains were determined directly from tensile tests an example demonstrated that the predictions which are related to the suggested approach are in practical agreement with the results of tests.

With regard to the flexible structural steel connections which are not showing peak load or pronounced yield in load vs. the response of the deformation, it has been indicated that the scholars have faced certain difficulties in specifying connection capacity, with all the suggested approaches appearing somewhat arbitrary. Yet, the analytical expressions regularly depend on the yield line theory suggested by researchers for different flexible connections, there is a difficulty in assessing the precision of the models of capacity and their variants (that might involve yield fans, and so on.).

Based on the experimental investigations reported herein, it was concluded that:

1. The tension capacity for the 46 mm weld length was equal to 156 KN while for 56 mm weld length was about 182 KN, and that shows the effect of weld length on the tension capacity.
2. Also, the tensile extension was about 10 mm for the 46 mm weld length and about 24 mm for the 56 mm weld length.
3. The Young's modulus was 198923 MPa for the 46 mm while it was 199796 MPa for the 56 mm which is almost the same because the length of weld has no considerable impact.
4. It is indicated that strength related to the tension fillet welds where longitudinal residual stress exists, is greater in comparison to that of the stress-relieved welds, assuming the fact that the stress system is still 2-D. Strength related to shear fillet welds does not depend on the existence of longitudinal residual stresses.
5. Shear lag effects at the connection will not control the capacity of welded channels under tension. All the channel sections, except for the one that failed in the welds, also failed at the gross section fracture away from the welds.
6. For HSS tension members, before more test results become available, the weld length should be at least equal to the width between two longitudinal welds. It is also recommended that a transverse weld be used across the thickness of the gusset plate at the location where the slot contacts the gusset plate.
7. Shear lag effects at the connection have a limited effect on the capacity of HSS tension members due to tension stiffening provided by the gusset plate. Most of the HSS specimens failed at the gross section fracture away from the connections.
8. After doing the ABAQUS simulation the tension capacity for the 46 m weld length was about 168 KN and 172 KN for the 56 mm weld length specimen.

List of Abbreviations and Symbols

AISC	American Institute of Steel Association
FE	Finite Element
GMAW	Gas Metal Arc Welding
HSS	Hollow Structural Sections
UTS	Ultimate Tensile Strength
σ	Stress
ε	Strain
E	Modulus of Elasticity

References:

[1] S. Easterling, , and L. G. Giroux , ” Shear Lag Effects in Steel Tension Members”. ENGINEERING JOURNAL,3 22 (2016) 77-89.

[2] R. Tremblay. ”Effets du décalage en cisaillement sur la résistance en traction des membrures d’âme de poutrelles à treillis en acier”. Rapport d’essais. École polytechnique, Montréal, Que. Project No. (2001) CDT-ST01-03.

[3] D. Bauer, and A. Benaddi . ”Shear lag in double angle truss connection”s. Elsevier, December (2002)1, 181-188.

[4] D. Bauer, and A. Benaddi. ”DÉCALAGE EN CISAILLEMENT DANS LES CORNIÈRES JUMELÉES”. 4th Structural Specialty Conference. Montreal,Canada. June (2002).

[5] D. Bauer, and A. Benaddi,” Essais en laboratoire de modèles simples d’assemblages de poutres à treillis avec cornières doubles”. Rapport de laboratoire Département de génie de la construction, École de technologie supérieure, Montréal, Canada. (2002).

[6] D. Bauer, and A. Benaddi,” Shear lag in double angle truss connections”. In Proceedings of the 3rd International Conference on Advances in Steel Structures, Hong Kong, (2003). P181-188.

[7] Alexander MENDELSON. ”Plasticity: Theory and application”. New York: Macmillan Co. (1968).

[8] Richard Vynne SOUTHWELL. ”An introduction to the theory of elasticity for engineers and physicists”,2nd eddition. Oxford University Press.London (1941).

[9] G. Abi-Saad, and D. Bauer , ” Rational approach for shear lag in tension members”. Structural Specialty Conference of the Canadian Society for Civil Engineering.June (2004). ST166, pp. 1-12.

[10] G. Abi-Saad, A. Benaddi and D. Bauer , ” Shear lag in tension member welded connections”. Annual General Conference of the Canadian Society for Civil Engineering. June (2005). GC246, pp. 1-10.

[11] F R FREEMAN, SIR C HINDLEY, E G COKER. ” The strength of arc-welded jouints”. Minutes of the Proceedings of the Institution of Civil Engineers, (1931). 231(1753-7843), 305-343.

[12] C. G. Vreedenburgh. ” New principles for the calculation of welded joints”. International Shipbuilding Progress,Welding Journal,NewYork, (1954).743-51.

[13] P. J. CLARK, ” Basis of design forfillet welded joints under static loading”. Improving Welding Product Design.Conference,A bington, The welding institute (1971).

[14] Specification for the use of structural steel in building. INSTITUTION BRITISH STANDARDS. (1969).

[15] Specification for steel girder bridges. BRITISH INSTITUTION STANDARDS. (1972).