THE EFFECT OF GEOMETRICAL PARAMETERS OF CONNECTION ON CONNECTION BEHAVIOR AND STRESS DISTRIBUTION

Dr. Abbass Z. Salman Dr.Saad T. Hamidi
University of Technology

Abstract

In this paper the effect of connection geometric parameters on moment and stress distribution is reported. A comprehensive parametric analysis of steel beam-to-column connection using T-Stiffener is conducted to determine the connection behavior and stress distributions. A general-purpose finite element software, ANSYS is used to model the connection plate components with shell elements type 43. Whereas welds are modeled with linkage elements to reflect weld stiffness. The finite element mesh configurations are selected on the basis of h-refinement procedure. Geometric and material nonlinearities are incorporated in the analysis by adopting the modified Newton-Raphson technique and nonlinear stress-strain curve respectively. It is found that parameters describing the thickness of T-Stiffener web and flange plates and the ratio of beam flange width to T-Stiffener flange width have a significant effect on the connection behavior and stress distribution. Unlike conventional design assumptions, the applied moment is found to be almost equally distributed among the T-stiffener web and flange plates. Stress analysis shows that the moment capacity of a connection designed by the conventional method is limited to 43% of the beam allowable moment.

KEYWORDS: T-stiffener non-linear analysis, steel connection, semi-rigid, beam-to-column connection, finite element analysis.

الخلاصة:

يتناول البحث دراسة تأثير الابعاد الهندسية واللحام على توزيع الاجهادات والعزوم على وصلة العتبة والعامود الفولاذي بأستخدام دعامة على شكل حرف (T)ً. وتم تمثيل الوصلة بطريقة العناصر المحددة بأستخدام برنامج التحليل الانشائي (ANSYS) حيث تم تمثيل الالواح المعدنية المكونة للوصلة باستخدام عناصر قشرية نوع 43 بينما تم تمثيل اللحام باستخدام عناصر خطية تتناسب جسائتها مع جساءة اللحام ، وتم ادخال التأثير اللاخطي للمادة والابعاد الهندسية في الحل وتبين ان سمك شفة وساق الدعامة وعرضها الى عرض شفة العتبة هي اكثر المتغيرات تأثيراً في توزيع الاجهادات بالوصلة، كما تبين ان العزوم المعرضة على الوصلة تتوزع بالتساوي على شفة وساق الدعامة على خلاف الفرض المستخدم في الطريقة التقليدية لتصميم الوصلة وظهر ان الوصلة المصممة بالطريقة التقليدية لا تتحمل اكثر من 43% من العزوم المسموح بها على العتبة.

1. INTRODUCTION

Beam-to-column connection with T-Stiffener is often used to provide framing action of beams connected to column web in high rise buildings. The connection consists of a structural T-section or an equivalent built-up section welded to the column as shown in Fig. 1- The web of the T-stiffener is welded to column web by fillet weld whereas the T-section flanges are welded to column flanges via fillet or groove weld. The beam is welded to T-stiffener flange by groove or fillet weld. This connection configuration is classified as semi-rigid connection that provides partial restraint against angle change between connected components [1,2,3&4]. Salmon et al [1] and Machaly [2] outlined a simple design procedure, designated herein as the conventional design method, for this type of connections based on previous research work. The applied moment M. is replaced by a couple, F, computed as follows:

$$F = \frac{M}{d_b} \tag{1}$$

The T-stiffener flange is treated as a continuous beam supported along T-stiffener flange welds and T-stiffener web weld. It is assumed that the T-stiffener web weld supports 3/4 of F whereas the flange welds support 1/3 of F. Such an assumption did not only result in a conservative web design but was also limited to equal beam and T-stiffener flange widths. It is uncomfortable, however, that equilibrium of forces is not maintained since sum of force assumed to be transmitted to the T-stiffener web weld and T-stiffener flange weld exceeds the applied force F.

Tension and compression forces in beam flanges are assumed to spread through T-stiffener web over a length equals to (t_b+5k_{st}) as illustrated in Figure 2. This means that the slope of stress distribution through T-stiffener web, η, is assumed 2.5, although it should be varied with connection geometric configuration. Since the force F in the beam flanges is proportional to beam Range area, $b_b t_b$, the thicknesses of plates comprising the T-stiffener arc computed as follows [1, 2]:

$$t_f \geq 0.4\sqrt{(0.75\, b_b . t_b)} = 0.35\sqrt{(b_b . t_b)} \tag{2}$$

$$t_w \geq \frac{0.7\, b_b . t_b}{(t_f + 5k_{st})} \tag{3}$$

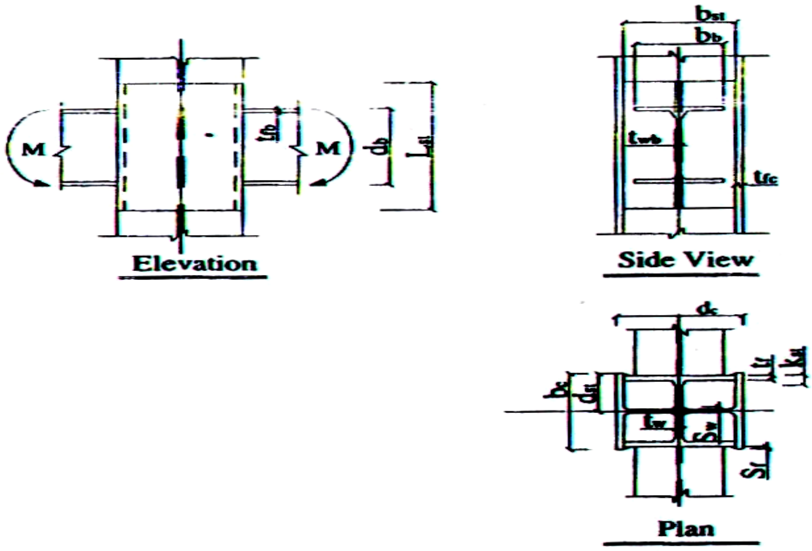

Fig. 1. Geometric Configuration of Beam-to-Column Connection with T-Stiffener ref.[1]

The normal, F_w, induced in T-stiffener Range and web welds; respectively were computed from the relations [1,2]:

$$q_w = \frac{F}{(6S_f\,(t_b + 5t_f))} \tag{4}$$

$$F_w = \frac{0.75\,F}{(2S_w\,(t_b + 5k_{st}))} \tag{5}$$

Equations 2 to 5 are limited for equal beam and T-stiffener flange widths- For beam flanges narrower than T-stiffener flange the applied beam flange force, F, is assumed to be entirely supported by the T-stiffener web and thus Equations. 2 to 5 are replaced by the following equations [1,2]:

$$t_f \geq 0.4\sqrt{(b_b \cdot t_b)} \tag{6}$$

$$t_w \geq \frac{b_b \cdot t_b}{(t_f + 5k_{st})} \tag{7}$$

$$q_w = \frac{F}{(2S_w(t_b + 5k_{st}))} \tag{8}$$

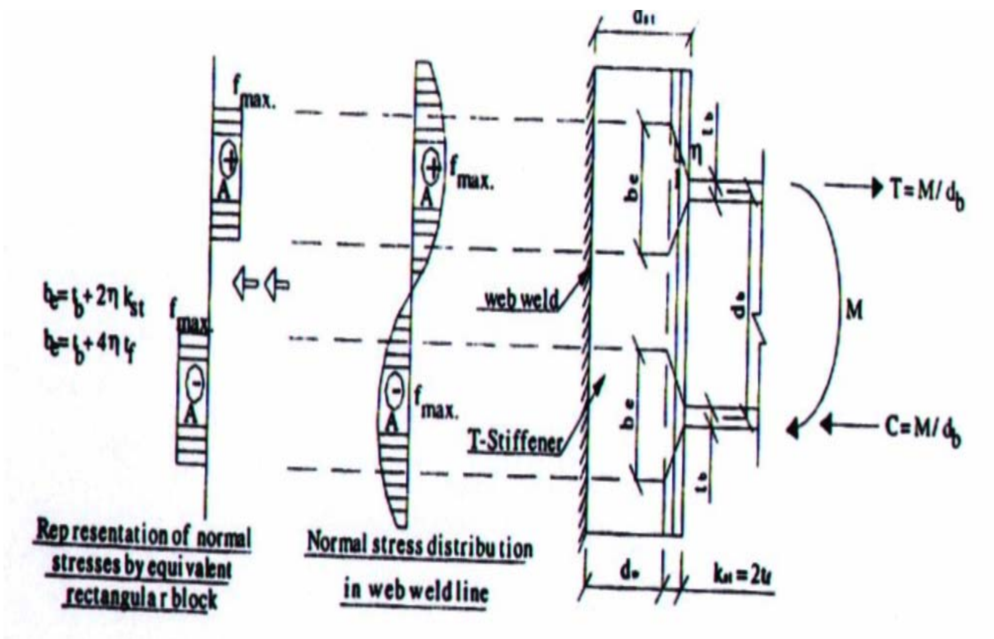

Fig. 2 Distribution of Beam Flange Forces in T-stiffener [1]

In this work, a finite element model for the connection is established using the general purpose finite element software element ANSYS [5]. Effect of material and geometric nonlinearities is studied and incorporated in a comprehensive parametric analysis to evaluate the effect of the connection geometric variables on the distribution of the stress and moment in the elements or the connection. The structural assessment of the connection designed by the conventional method is also presented.

2. Finite Element Modeling

2.1 Plate Elements

All plate elements in the connection are modeled with thin shell elements [6,7]. The four-noded isoparametric flat shell element designated as "Shell 63" in ANSYS [5] is utilized to model all plate elements in the connection. This element was only utilized to conduct mesh sensitivity study since it is only applicable for small deflection applications.

In order to account for material and geometric nonlinearities, 'Shell 63 is replaced by "Shell 43" element available in ANSYS which is a four nodded-isoperimetric warped shell element with quadratic shape function. It has stress stiffening, plasticity, and large deformation capabilities. It is used in the parametric analysis to account for all sources of nonlinearities.

2.2 Welds

Although modeling of welds is rather complex, it would be appropriate to represent weld lines by linkage elements with elastic properties for the purpose of studying the global behavior of the connection, and distribution of stresses in steel plates.

2.3 Non-Linear Material Model

A non-linear stress-strain relation is adopted in the parametric study to include the effect of "lock-in" or residual stresses. The stress – strain relation is derived [8] from the column research council (CRC), Column strength curve. Residual stresses are conservatively assumed to be 0.50 of the yields stress, σ_y, compared to the experimentally determined value of 0.30 σ_y [8].

2.4 Boundary Conditions

It was assumed that the column is connected from both sides to an identical beam (Fig, 1). Therefore, only one quarter of the connection is modeled. Symmetry boundary conditions are applied on nodes lying in planes of symmetry. Column base is restrained against vertical translation to maintain the model stability.

2.5 Mesh Sensitivity Study

A mesh sensitivity study is conducted using h-refinement method [6, 7]. Four mesh configurations designated as Mesh (A) to Mesh (D) are generated in which element dimensions are successively reduced front Mesh (A) to Mesh (D) (see Fig, 3) The continuity assumption used in displacement-based finite element formulations results in continuous displacement field but a discontinuous stress field- Therefore, the percentage error in energy norm obtained by normalizing the model strain energy against the strain energy using average stresses is used herein as an error measure to select the suitable mesh configuration [5].

The four meshes are compared with respect to percentage error in energy , normal stresses in T-Stiffener web and flange and weld stresses. Results indicated that solution accuracy measured by percentage of error in energy norm is successively improved by 20% when elements size is reduced from Mesh (A) to Mesh(C). However, a minor improvement of 7% is noticed in percentage of error in energy norm from Mesh (C) to Mesh (D). Table I indicates that there is a significant change in stresses when element size is reduced from Mesh (A) to Mesh (C). However, stresses and moment distributions computed by Mesh (C) and (D) are converged. Therefore, the finite element analysis conducted in the parametric study will be Conducted using Mesh (C) configurations.

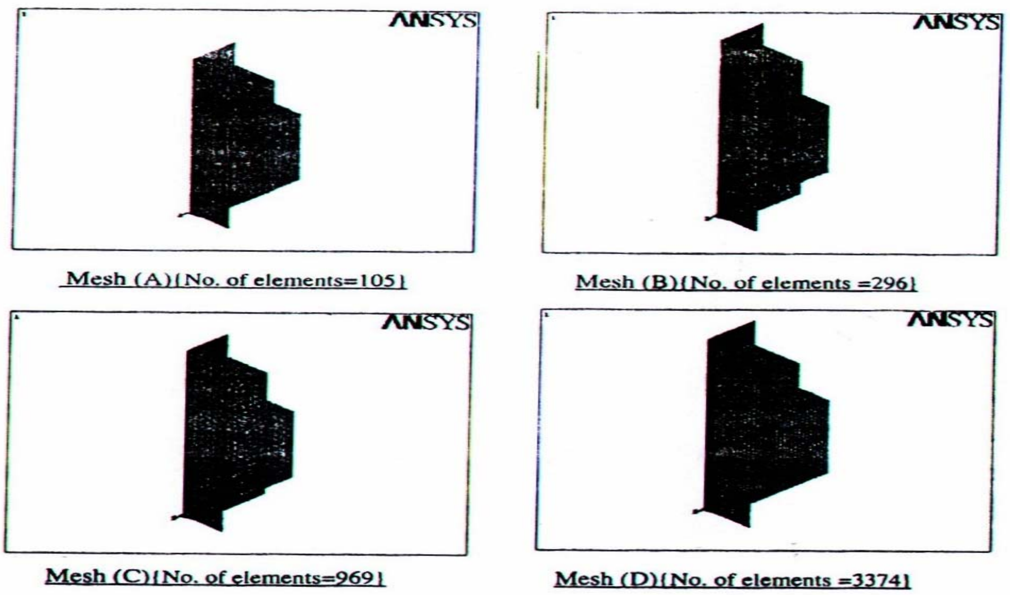

Fig.3. mesh Configurations in Mesh Sensitivity Study.

3. ANALYSIS PROCEDURE

The analysis conducted herein is static analysis at which the resulting stress pattern in connection components and moment distribution among weld lines are computed due to an applied beam moment, M.

The effect of a shearing force transmitted from the beam to the column is neglected. The T-stiffener web is assumed compact and thus buckling failure of T-stiffener web is discarded. Since column dimensions are relatively large compared to T-stiffener stresses in column web and flanges are not concerned whereas stresses in T-stiffener and welds are thoroughly investigated.

Table 1. Comparison of mesh results [6,7]

Item	Mesh (A)	Mesh (B)	Mesh (C)	Mesh (D)
% Error in energy norm	69.98	49.26	29.57	22.57
Max. stress in T-stiffener web, t/cm^2	1.042	1.369	1.860	1.924
Max. stress in T-stiffener flange, t/cm^2	0.069	0.081	0.124	0.128
% Moment transmitted to flange weld	60	55	52	51.5
% Moment transmitted to web weld	40	45	48	48.5
Max. shear stress in flange weld (t/cm^2)	0.631	0.649	0.667	0.667
Max. normal stress in web weld (t/cm^2)	1.175	1.480	1.320	1.336

Geometric nonlinearity is included in the analysis by adopting the modified Newton-Raphson technique [5.6]. Results indicate that the inclusion of geometric nonlinearities my cause significant increase in T-stiffener flange bending stresses by 15% [7].

4. ASSESSMENT OF THE CONVENTIONAL DESIGN METHOD

The finite element analysis of a connection designed by the conventional method is conducted to evaluate the applied stresses in plates and welds and to check the conventional method moment distribution assumption. The beam and column cross sections; are assumed to be HEB (340) and HEA (320) hot-rolled sections; respectively. Considering the moment strength of fillet welds connecting the beam to T-stiffener flange, the applied moment is conservatively assumed to be 0.85 of the beam allowable moment capacity [2].

Results indicate that bending stresses in T-stiffener flange are peaked at beam flanges and sharply reduced to minimum at the beam center as illustrated in Fig. 4. Maximum normal stresses in T-stiffener web located at beam flanges are gradually spread through T-stiffener web as shown in Fig. 5. Flange weld stress distribution showed that shear stresses in flange welds are peaked at beam flanges with sharp stress gradient (Fig. 6).

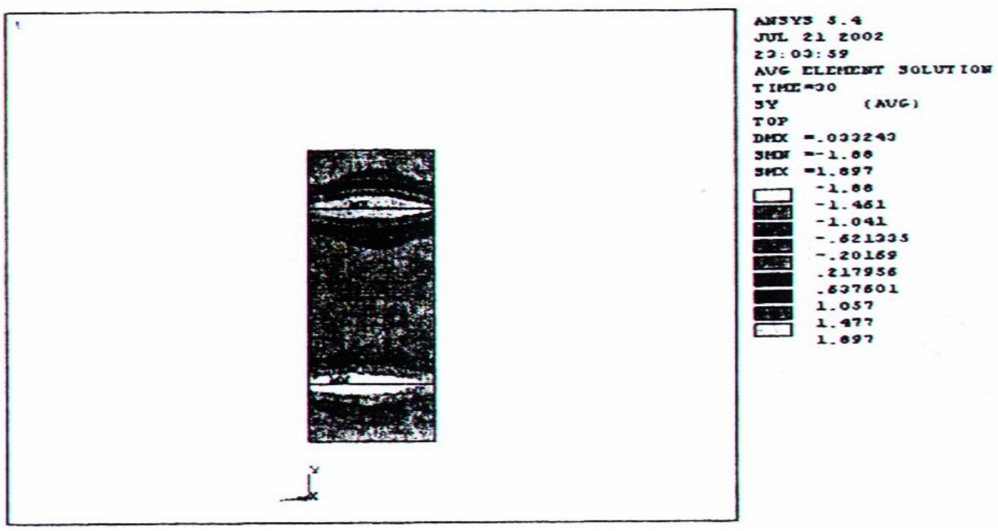

Fig. 4. Bending stresses in T-stiffener flange designed by conventional method [1,2]

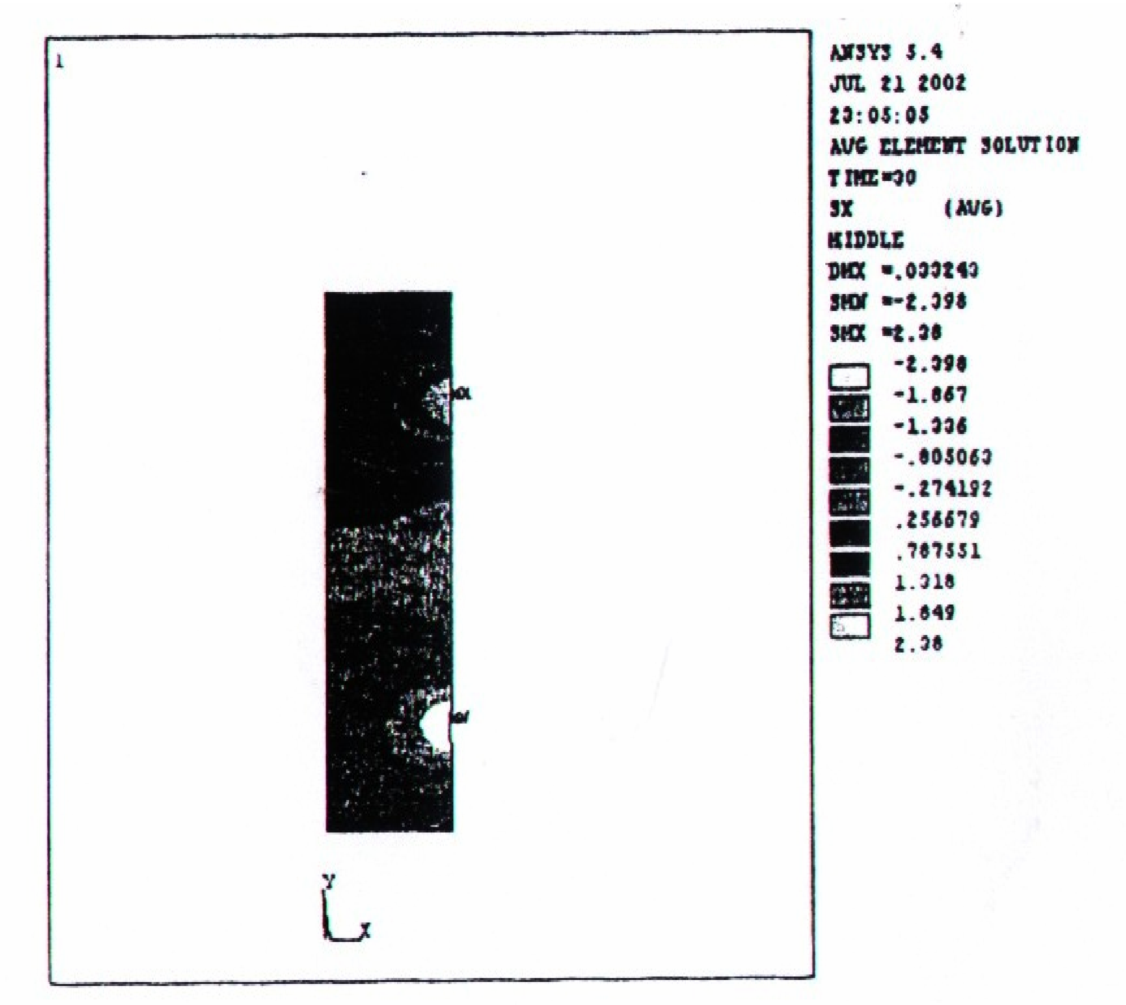

Fig. 5. Bending stresses in T-stiffener web designed by conventional method [1,2]

On the other hand, normal stress gradient in web welds is significantly reduced compared to flange weld stresses to obtain an almost linear distribution (Fig. 7) due to the large web bending stiffness. It is noticed that a shear force: reversal (Fig.6) took place in flange welds near the beam tension flange analogous to prying action in endplate moment connections [1,2,&9]. Such reversed shear force will be designated herein as prying force [8].

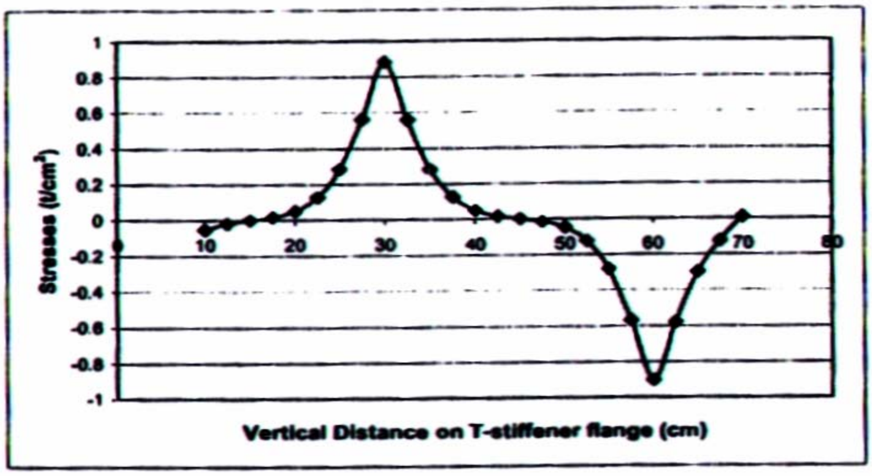

Fig.6. Shear stresses on T-stiffener flange welds designed by conventional method.

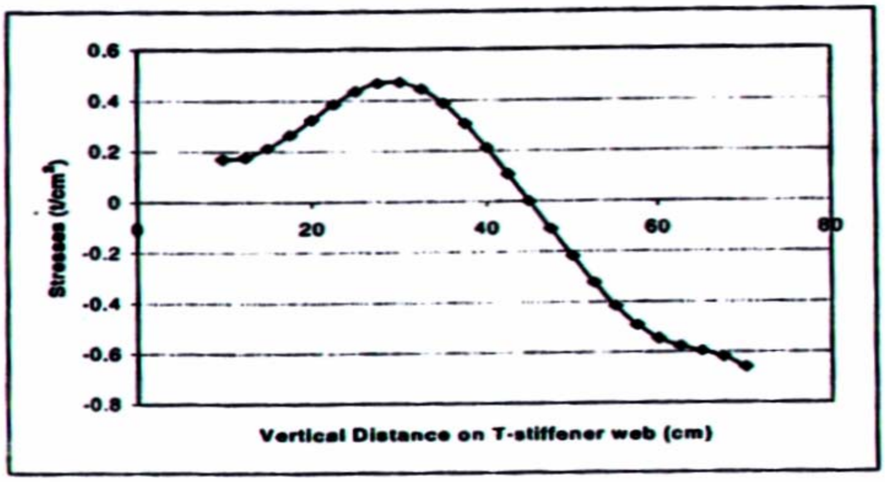

Fig.7. Normal stresses on T-stiffener web welds designed by conventional method.

Maximum bending and normal in T-stiffener flange and web plates and welds are listed in Table 2 together with percentage of moment transmitted to web and flanges.

Finite element results indicate that the allowable stresses in T-stiffener plates and welds are exceeded. Therefore, the conventional connection design would satisfy allowable stress requirements if the applied moment is reduced to 43% of the bow allowable moment or if the thickness of T-stiffener flop and web is increased by 23% and 56% respectively.

Table 2, Assessment of conventional method design [1]

Items	Finite Element	Conventional method(1) [1,2]	Allowable stresses(2) [14]
Max. stress in T-Stiffener flange	1.897	1.482	1.536
Max. stress in T-Stiffener web	2.398	1.77	1.536
Max. shear stresses flange welds	0.90	0.70	0.72
Max. normal stresses in web welds	0.66	0.60	0.72
% Moment transmitted to flange	52	33	NA
%Moment transmitted to web welds	48	75	NA

(1) Computed using Equations (4) & (5) and assumptions stated in Sec. 1.

(2) Allowable stresses are $0.64\sigma_y$ for compact plates and $0.3\ \sigma_y$ for welds.

5. PARAMETRIC ANALYSIS

The parameters describing the connection (Fig.1) are written in a non-dimensional form analogous to the conventions method design equations (2,3,6&7). The T-Stiffener flange and web thickness t_f and t_w are described in terms of beam flange area A_f, since it reflects the value of the applied moment M as follows:

$$t_f = \propto \sqrt{A_f} \tag{11}$$

$$t_w = \beta\sqrt{A_f} \tag{12}$$

Where

$$\beta = \frac{C_i}{(\alpha(1+4\eta))} \tag{13}$$

α: is the ratio of the T-stiffener flange thickness to the square root of the beam flange area C_l: constant depending on the ratio of beam flange width to T-stiffener flange width [8], and η: slope of normal stress distribution in T-Stiffener web (see Fig. 2). The beam flange width, b_b, is described in a non-dimensional form as a ratio of T-Stiffener flange width, b_{st} in the form of the parameter, b_r, computed as follows:

$$b_r = \frac{b_b}{b_{st}} \tag{14}$$

The slope of normal stress distribution in web η is based on approximating normal stresses in web welds by an equivalent rectangular block [8] as shown in Fig. 2. The value of the equivalent stress block is equal to the peak stress computed. The area of the equivalent stress block reflecting the transmitted compressive or tensile force is equal to the area under the computed stress distribution. Since the value of η is computed from web weld stresses, it is regarded as a dependent parameter and designated as η_{compo}. However the width of the equivalent rectangular block b_e can be written in terms of beam flange thickness t_b and T-Stiffener flange thickness t_f based on an initially assumed value of η designated as η_{assum}, when stresses are projected on the toe of flange fillet (Fig. 2) as follows:

$$b_e = t_b + 2\,\eta_{assum}\ ,\ k_{st} = t_b + 4\,\eta_{assum}\,t_f \qquad (15)$$

The assumed slope η_{assum} is considered among the connection independent parameters. The value of η_{assum} is used to compute the T-stiffener web thickness parameter β (Eq.13). The length of T-Stiffener, L_{st}, is considered among the independent parameters describing the connection configuration and is written in terms of beam depth and k_{st} considering a non-dimensional parameter C as follows:

$$L_{st} = d_b + C\,k_{st} \qquad (16)$$

On the other hand, weld size and type, beam depth, d_{st}, were also considered among the independent parameters describing the connection configuration. The effect of each parameter on stress patterns and moment distribution is investigated by changing its value while all other parameters were kept constant.

5.1 Effect of C_1

When the parameter C_1 (Eq. 13) is varied from 0.75 to 1.5, stress distribution in T-stiffener plates and welds took a similar pattern to that plotted in Figs 4 to 7, however peak values are altered as listed in Table 3. Note that C, range selected herein covers the assumed range by the conventional method that starts from 0.75 at equal beam and T-stiffener flange widths to unity when the beam flange width is less than the T-stiffener width.

When C_1 increased the moment transmitted to web is gradually increased to reach a maximum ratio of 51.6% of M. Shear stresses and prying force in flange welds are reduced whereas normal stresses in web weld are increased. The slope of stress distribution, η_{comp}, in flange welds is not affected and took an average value of 1.57. The value of η_{comp} computed for web welds increases from 2.25 to 2.35 with the increase of C_1.

Table 3. Effect of C_1 on results

Item	Dependent parameters	C_1			
		0.75	1	1.2	1.5
welds	%Moment transmitted to flange	52	50.4	49.5	48.4
	%Moment transmitted to web	48	49.6	50.5	51.6
	Max.flange weld stresses	0.90	0.88	0.86	0.84
	Max.web weld stresses (t/cm^2)	0.66	0.68	0.69	0.70
	Prying force (ton)	0.24	0.21	0.2	0.19
	Concentration factor (k_w)	1.64	1.64	1.54	1.64
	ζ_{comp} (flange)	1.60	1.54	1.58	1.57
	ζ_{comp} (web)	2.25	2.27	2.30	2.35
T-stiffener plates	Max.stress in the flange.t/cm^2	1.90	1.81	1.77	1.72
	Max.stress in the web .t/cm^2	2.40	2.07	1.84	1.55
	Max. flange stress/ f_{all}	1.24	1.18	1.15	1.12
	Max. web stress/f_{all}	1.56	1.35	1.19	1.01

The degree of flange weld stresses concentration is measured by the ratio of maximum stresses computed by ANSYS to those computed using η_{assum} and is designated as K_w [8]. It is shown that K_w is almost not affected by C_1 and took an average value of 1.62. Bending stresses in T-stiffener flange are reduced by 10% whereas normal stresses in web arc significantly reduced from yield tol.55 t/cm^2. Therefore, it was recommended to keep C_1 less than 1.5 to meet allowable stress requirements [9] in the web.

5.2 Effect of α

When the parameter c4 reflecting the T-Stiffener flange thickness, is varied in the practical range from 0.35 to 0.5 the moment transmitted to flange is increased by 9.5% due to the pronounced T-stiffener flange bending stiffness (see Table 4). Bending stresses in T-stiffener flange plate is reduced by 22.6% whereas the bending stress pattern is kept almost constant as shown in Fig. 4. Normal stresses in web are slightly reduced. Stress distribution in flange and web welds is not affected. However, maximum stresses in flange and web welds are reduced by 16.6% and 9.5% respectively when α increased.

Table 4. Effect of α on results

Item	Dependent parameters	α			
		o.35	0.4	0.45	0.5
welds	%Moment transmitted to flange	48.4	50	52	53
	%Moment transmitted to web	51.6	50	48	47
	Max.flange weld stresses	0.841	0.79	0.74	0.70
	Max.web weld stresses (t/cm^2)	0.703	0.68	0.65	0.64
	Prying force (ton)	0.19	0.24	0.3	0.34
	Concentration factor (k_w)	1.64	1.68	1.69	1.73
	ζ_{comp} (flange)	1.57	1.55	1.53	1.51
	ζ_{comp} (web)	2.34	2.04	1.82	1.64
T-stiffener plates	Max.stress in the flange.t/cm^2	1.72	1.57	1.44	1.33
	Max.stress in the web .t/cm^2	1.55	1.58	1.57	1.55
	Max. flange stress/ f_{all}	1.12	1.02	0.94	0.87
	Max. web stress/f_{all}	1.01	1.03	1.02	1.01

The factor, k_w, in flange welds is increased, consequently, the slope of sum distribution, η_{assum}, in the flange is gradually reduced and took an average value of 1.54. On the other hand, η_{assum} in the web is significantly reduced from 2.34 to 1.64. Prying forces computed in flange welds we increased, however, it is kept less than 1% of F. Therefore, it is recommended to keep the value of a more than 0.45 to limit the bending stresses in the flange below $0.64\sigma_y$, [9].

5.3 Effect of η_{assum}.

The parameter η_{assum} is varied from 1.80 to 2.50 while all other parameters are kept constant. This range covers the values of η_{assum} starting from the assumed conventional value of 2.5 to the lowest computed value of 1.80. Since, η_{assum} had a minor effect on changing web plate thickness as stipulated from Eqs. 12 & 13, it is noticed that it had a minor effect on the connection behavior as listed in Table 5. The moment transmitted to web is reduced by 2% when η_{assum} is increased due to reduced web bending stiffness.

Table 5. Effect of η_{assum} on results.

Item	Dependent parameters	η_{assum}			
		1.8	2	2.2	2.5
welds	%Moment transmitted to flange	47.4	48	48.2	48.4
	%Moment transmitted to web	52.6	52	51.8	51.6
	Max.flange weld stresses	0.82	0.83	0.83	0.84
	Max.web weld stresses (t/cm^2)	0.73	0.72	0.71	0.70
	Prying force (ton)	0.172	0.18	0.18	0.19
	Concentration factor (k_w)	1.23	1.29	1.47	1.64
	ζ_{comp} (flange)	1.55	1.56	1.56	1.57
	ζ_{comp} (web)	2.40	2.38	2.36	2.34
T-stiffener plates	Max.stress in the flange.t/cm^2	1.68	1.69	1.70	1.72
	Max.stress in the web .t/cm^2	1.23	1.33	1.42	1.55
	Max. flange stress/ f_{all}	1.09	1.10	1.11	1.12
	Max. web stress/f_{all}	0.80	0.86	0.92	1.01

Stress pattern in web and flange plates are not varied by increasing η_{assum} however peak bending stress in flange increased by 2.9% and normal stresses in web increased by 26%.

Similarly, stress distribution in flange and web welds is not affected by increasing η_{assum}. However, peak values of flange welds are increased by 2.6% and peak values of web welds are reduced by the same ratio when η_{assum} increased from 1.80 to 2.50. The factor, k_w, increased with η_{assum} whereas the computed slope, η_{comp}, of stress distribution in web and flange are slightly affected and took an average value of 2.37 and 1.56; respectively.

5.4 Effect of b_r

The parameter b_f, describing the beam flange width (Eq. 14) is varied in the practical range from 1.0 to 2/3 by decreasing the beam flange width using a virtual built up beam identical to (HEA 320) except for flange width. The section modulus and the allowable beam moment are computed based on the new flange width while all other connection parameters are kept unchanged. A summary of the results of the connection analysis is listed in Table 6. When b, is reduced, the percentage of moment transmitted to web is increased due to concentration of flange forces; near the web plate. Normal stresses in the web are increased by 25.5% with an identical stress pattern as that depicted in Fig. 5. Bending stresses pattern in the flange had almost the same shape as that shown in Fig. 4, however, peak values are slightly increased by 9%. Flange weld stresses are significantly affected, a reduction of 78% in flange weld stresses was recorded when b_r was reduced from 1.0 to 2/3. Consequently, stress concentration factor k_w is significantly reduced by 47.25%. The distribution of the normal stresses in the web welds is not affected and peak values are slightly increased by 10%. Slope of stress distribution computed for welds. η_{comp} is increased by 18.75%, Prying forces computed for all values of b, are less than 1.2% of die applied moment force, F.

Table 6. Effect of b_r on results.

Item	Dependent parameters	b_r		
		1	5/6	2/3
welds	%Moment transmitted to flange	48.4	35	23
	%Moment transmitted to web	51.6	65	77
	Max.flange weld stresses	0.84	0.37	0.19
	Max.web weld stresses (t/cm^2)	0.70	0.72	0.68
	Prying force (ton)	0.19	0.15	0.11
	Concentration factor (k_w)	1.64	1.11	0.87
	ζ_{comp} (flange)	1.57	2.43	3.12
	ζ_{comp} (web)	2.34	2.54	2.78
T-stiffener plates	Max.stress in the flange.t/cm^2	1.72	1.87	1.88
	Max.stress in the web .t/cm^2	1.55	1.79	1.95
	Max. flange stress/ f_{all}	1.12	1.21	1.22
	Max. web stress/f_{all}	1.01	1.16	1.27

5.5 Effect of L_{st}

The length of the T-stiffener, L_{st}, had a minor effect on the connection behavior [8]. The moment transmitted to the web is only increased by 4.9% when L. increased from 50 to 60 cm. Sum pattern in web and flange plates are not varied by increasing L_{st}, and peak bending and normal sum in flange and web, respectively are almost kept constant. Similarly, sum distribution in flange and web welds is not affected. Peak values of the flange weld stresses are almost unchanged whereas maximum web weld stresses were reduced by 22A%. The factor, k_w is almost constant with L_{st} as well as η_{comp} in web and flange welds and took an average value of 195 and 1.56; respectively. Prying force is increased significantly, however, it is always below 1.5% or the applied force F calculated from Eq.1.

5.6 Effect of d_b

The parameter db is varied from 20 to 35cm to resemble the case of a virtual built up beam similar to (HEA 320) except for beam depth. The beam section modulus and allowable moment are calculated based on the new depth, while all other connection parameters are kept unchanged. Results that d_b a minor effect on connection behavior. The moment transmitted to web is reduced by 4.75% by increasing db. Stress pattern in the web and the flange plates are not varied, however, peak bending stress in flange reduced by 4.0% and normal stresses in web are unchanged. The shape of stress distribution in the flange and the web welds is not affected by changing dband has identical peak values. The factor, k_w was reduced with d_b, whereas the computed slope of stress distribution in web and flange, η_{comp}, are slightly affected and took an average value of 2.34 and 1.54 respectively.

5.7 Effect of d_{st}

Results indicated that d_{st} had a minor effect on the connection behavior [8]. The moment transmitted to web is reduced by 2.1% by increasing d_{st} in the practical range from 10 to 17.5 cm. Sum pattern in web and flange plates are not varied by changing d. however peak bending stress in flange and normal stresses in web is almost identical while increasing 4. Stress distribution in flange and web welds is not affected when 4 is increased since peak stresses am only vaired by 3% [8]. The factor, k. is almost constant when d. increased, whereas the computed slope of stress distribution in web and flange are slightly affected. Prying action in flange welds is reduced by 31.6% when it increased.

5.8 Effect of Weld Type and Size

The effect of flange weld type o the connection behavior is investigated, Flange weld can be either fillet or butt weld [1,2]. Results indicated that type of flange weld had a minor effect on connection behavior. Due to pronounced shear stuffiness of the weld, shear stresses in flange, welds, stress concentration factor and prying action are increased in the flange welds when butt weld is used since stiffer structurally elements capture larger forces and stresses compared to flexible structural elements. Similarly, varying the size of the flange weld, S_f only affected the flange weld stresses whereas the other connection parameters ac almost unchanged [8]. The size of the web weld, S_w, has a limited effect on the stresses of the web weld and has no effect on the behavior of all other parameters.

6. CONCLUSIONS

In this work, a nonlinear static analysis of welded beam-to-column connection with T-stiffener is conducted using the finite element method. Analysis of a connection designed by the conventional method showed that it can only support 43% of the beam allowable moment it is recommended, however, to use a T-stiffener web thickness twice that adopted by the conventional method to achieve an allowable moment capacity of 85% of the beam allowable moment. Unlike conventional method assumption, the analysis shows that the applied moment is almost equally distributed among T-stiffener flange and web welds.

A comprehensive parametric study is performed. Results show that the T-stiffener flange and web thicknesses and beam flange width have a major effect on stress and moment distribution. The remaining parameters such as weld size and type, length of T-stiffener, beam depth, and depth of T-stiffener web have an insignificant effect. The results of the parametric analysis presented herein can be used to establish design formulas and simple mathematical expressions describing stress and moment distribution of the connection.

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THE LIST SYMBOL:

d_b The distance between the centers of the beam
t_b The beam flange thickness
k_{ST} The distance to root of T- section fillet
ζ Slope of stress distribution through T- stiffener web
t_F Thickness of stiffener flange
b_b Width of beam flange
t_w Thickness of stiffener
q_w Shear force
F Applied force
F_W Normal force
s_W Size of T-stiffener web weld
s_F Size of T-stiffener web flange
$\propto$ The ratio of the T-stiffener flange thickness to the square root of the beam flang area
C_1 constant
A_f flange area
β T-stiffener web thickness parameter
L_{st} The length of T-stiffener
d_{st} Beam depth
k_w Concentration factor
h_{st} T- stiffener flange width
b_e The width of the equivalent rectangular block