RESEARCH ARTICLE   **OPEN ACCESS**

Bending Stresses Calculation in Welded Joint

Abdullah Hussain Nouri Ateyah
Industrial Institute - Shuwaikh
The Public Authority for Applied Education & Training

ABSTRACT
This particular paper would be dealing with the analysis of the cantilever beam box that would be focusing on fluctuating torsional or statics moment loading. Those types of beams might be having many locations that could be critical from the view's strong point; among the interesting information is that, the cross-section where loading would be imposed. Although such information could be designed typically so that they could be possessing smooth shapes, and it would result in concentrations that could be moderating stress, that would be meaning that the fatigue failures could be avoided. Although, the cross section's distortional deformation and it would be inducing transverse bending stress, which might be detrimental, mainly in welded beam box. Moreover, the fixed location where the beam would be typically welded in the endplate might have become an essential point. This particular paper would be presenting an approach that would be analytical for the calculation of longitudinal stresses because of the cross-section's warping with the longitudinal stresses and distortion-induced transverse in the sections of the rectangular hollow. FEAs would be carried out so that an analytical approach could be verified and shedding light on vital points in the details of the plates with weld penetration's different levels. By the use of ENS the idea and suggesting design proposals for the structural detail that could be efficient of plates diaphragm in decreasing the behavior of warping.

RHS (Rectangular hollow sections) frequently offer better, the structural performance that would be focusing on some loads like, shears and axial forces and the torsional and bending moments (Tuomas Skriko, 2020). The cross-section in warping of the beam would be remaining in its actual shape, while in distortion, it would be taking the parallelogram shape. Those deformations would be causing membrane stresses or axial displacement of the beam. However, the distortion would be caused by crosswise bending stresses of the cross section's wall. Those phenomena would be an independent level of freedom in the beam. Mainly from the viewer's point of fatigue design, the bi-moment that would be causing the distortional loads and cross section's warping to the RHS beams would be interesting, although it would be having load conditions that would be lesser.

There was a research that took place which stated on the corner radius effect on RHS' primary warping. It was also showing how it was causing primary warping on the sections of SHSs. Besides, earlier researches were tending to be focusing on the distortion's theoretical background and cross-section's warping. Small attention would be paid to the designing proposals and the practical analysis in preventing the fatigue failure because of distortion
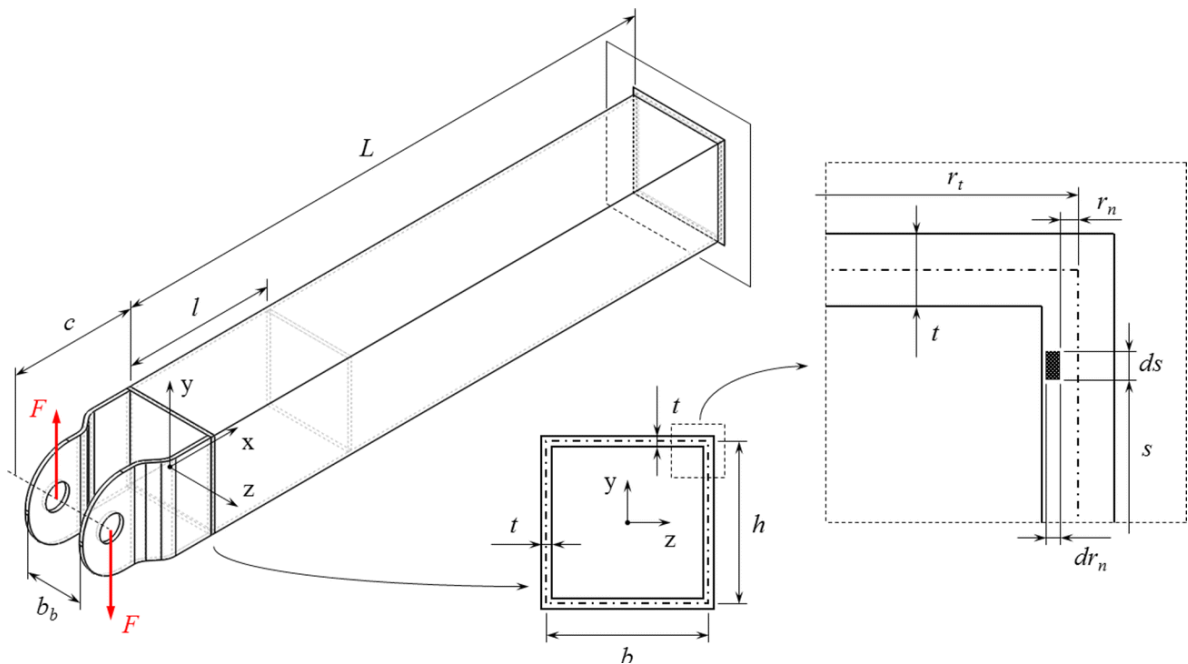
and warping. In the weight-critical beams, using the ultra-high-strength steels with a yield strength of around 1100 MPa would be becoming reasonable (Tuomas Skriko, 2020). With the UHSS grades, hot-or-cold-formed outlines would not be available typically, and the box beams would be made from the metals of welded sheets would be used. Those types of structures, the details of fatigue-critical would be the longitudinal welds, brackets, and the transverse welds that would be jointing the beam into the endplate.

The paper would be introducing the analytical approach of calculating the stresses that would be used in the cantilever beam's fatigue analysis. First, the warping stress and bi-moment distributions towards the length of the beam and above the cross-section would be obtained subsequently. Distortion behavior would be establishing a base towards the BEF. FEAs by the use of the 2D element of mid-element models would be conducted so that it would be obtaining numerical outcomes for the comparison. Moreover, many secondary warping's detailed analysis for the SHS (square hollow section) and the round corner would be conducted by the use of the element model 3D solid (Wu & Kim, 2020). The fatigue analysis would be conducted on the cantilever beam's

endplate with the assistance of ENS as well a considering weld root and weld toe fatigue failures. Nevertheless, with the modeling of FE, the transverse diaphragm's effect and the location along the cross-section's distortion would be investigated; that would be followed through several design recommendations.
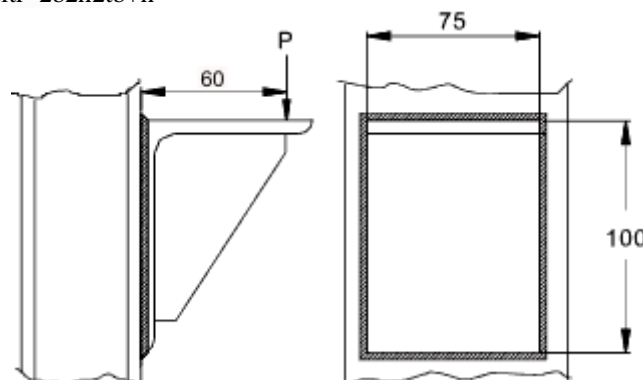
The boundary conditions, geometry, and load of the cantilever beam towards this research state that the couple loading force F would be imposed on the brackets' pair at the cantilever beam's free end as it would be illustrated below. On the beam's other end, it would be fixed, it would be fixed to the end that would be stiff, hence it would be representing a boundary that would be completely rigid. The beam's loaded end would be provided with the diaphragm plate; thus, it would be avoiding the cross-section's distortion within the section that the brackets would be fixed towards the beam. Although, since the plate, most of the time would be very thin, it would not be preventing the beam's free warping in that section.

The structure of the box beam

By using the symbols of the cross-section that has been denoted above, for the section of the thin-walled by the constant plate thickness of t, the inertia Its torsional moment would be

$$I_t = \frac{4A_0^2}{\oint \frac{ds}{t}} = \frac{4b^2h^2}{\sum_i \frac{s_i}{t_i}} = \frac{2b^2h^2t}{b+h}$$

D= 100mm
B= 75mm
P= 3000 newtons
Y= 50mm

Abdullah Hussain Nouri Ateyah. International Journal of Engineering Research and Applications
www.ijera.com
ISSN: 2248-9622, Vol. 12, Issue 1, (Series-I) January 2022, pp. 01-06

Design Stress p_w = 220 N/mm^2 (Electrode E35 steel S275)   Design Strength
Moment = M = 30000*60=18.10^5 Nmm

Simple Method as BS 5950 clause 6.8.7.2

Unit Weld Area = A_u = 2(d+b) =2(100+75) =350mm^2
Unit Moment of Inertia = I_u
= d^2(3b+d) / 6 = 100^2 (3.75 +100) / 6 =5,42.10^5 mm^4

τ_r = Sqrt($\tau_s^2 + \tau_b^2$)
τ_s = P / A_u = 30000/350 = 85,71 N/mm^2
τ_b = M.y / I_u = 18.10^5 . 50 / 5,42.10^5 = 166,05 N/mm^2
τ_r = Sqrt(85,71^2 + 166.05^2) =186,86 N/mm^2
τ_r / p_w = 186,86 / 220 = 0,85 = Throat Tshickness.....
Leg Length = Throat thickness *1,414 = 1,2mm use 3mm weld thickness</subr<>

The internal forces' schematic distribution over warping stresses and beam length in the cross-section area would be illustrated in the figure below. In SHS, the bi-moment would be occurring only during the fixed and loaded off the beam's end.

a Bi-moment, **b** distributions torsional moment in the length of the beam, **c** secondary and primary warping stresses of the RHS cross-section's corner, and **d** warping and Bredt's shear stress within the RHS's cross-section.
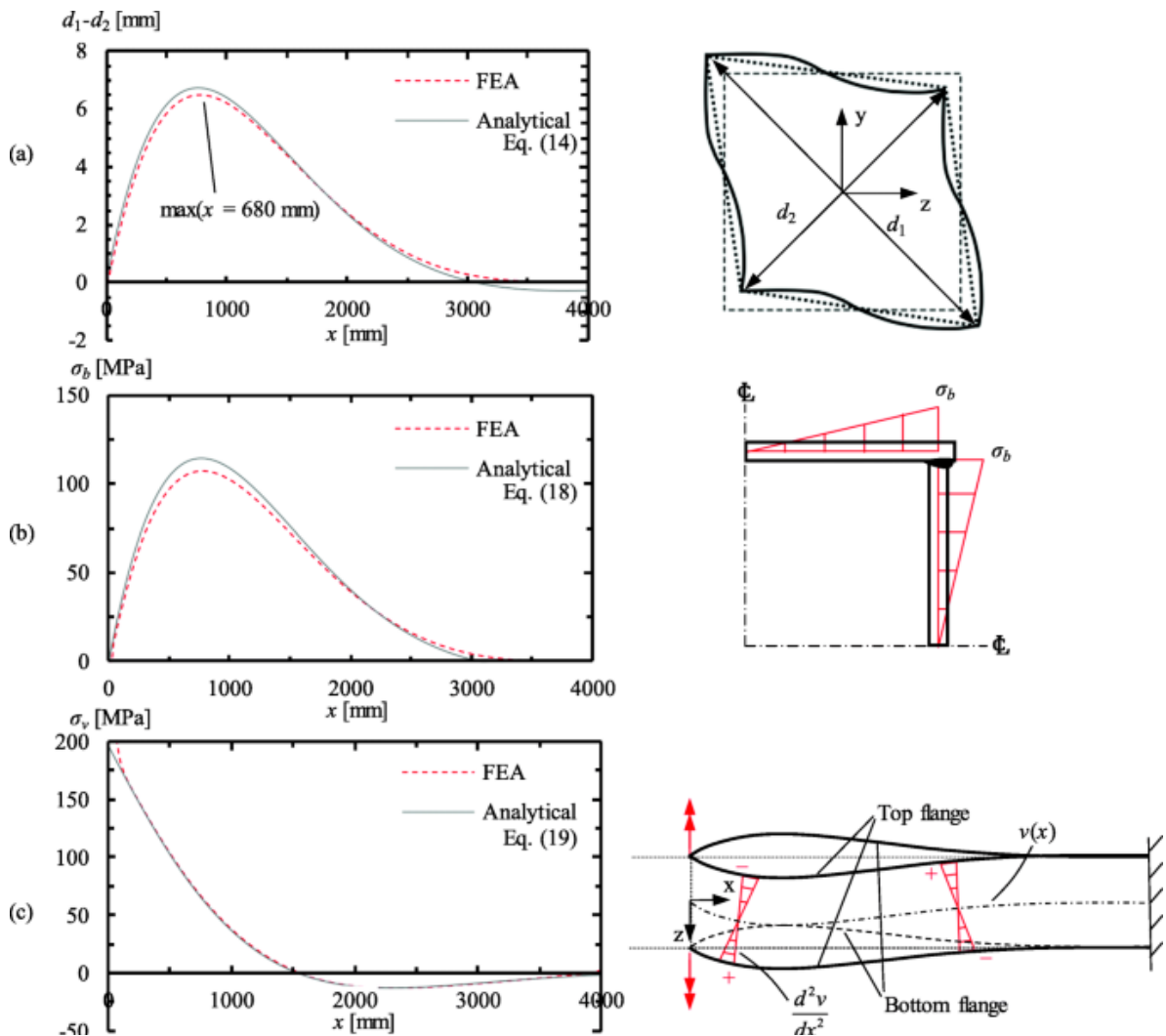
Secondary warping would be occurring very locally mostly on the box section's corners; however, it could be inducing detrimental stresses when the freedom's local degree, would be involved in secondary warping and prevented. That would occur if the cross-section's wall would be locally prevented from rotating. For instance, because beam had joined the welding making it become a hard-transverse plate. That would be advisable to be noted, however, the stresses of the primary warping would be depending on the conditions in the global boundary in the beam. While the stresses of the secondary would be depending on the conditions of the local boundary of the cross-section's wall. Consequently, secondary and primary warping could be occurring towards each other independently. The cross-section's primary warping that would be having corners, was investigated analytically with Rubin.

In the beam's distortion, torsional load and the warping, that would be causing local bi-moment in the beam's load end, would be also be establishing the distortional loading. Different from warping, the distortion and the cross-section would

not be remaining in their actual form however, it would be deforming to the parallelogram shape. Since the box section's corners are usually rigid, the distortion would be causing the stresses of transverse bending. And the distributions on profile perimeter would be affine and disassociated towards the beam's longitudinal directional. According to

BEF's theory, the figure below would be showing the transverse and longitudinal distribution of the distortion. In some cases, they would be differentiated in numerical analyses. The deformation of distortion is known as the distinction amongst the cross-section's diagonal dimension as it was defined by deformed geometry.
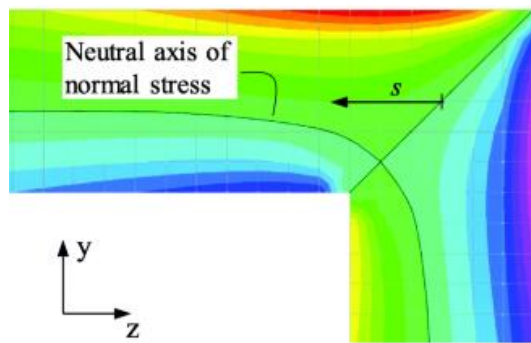

When the distortion would be occurring because of the fluctuating torsion, that could a detrimental phenomenon and causing the longitudinal welds' fatigue whenever they would be located within the box beam's corners. Longitudinal welds are usually prepared by the use of single-sided welding; hence, the fatigue weld root capacity might be becoming a serious design criterion. That phenomenon could be destroyed by using the diaphragm plates; however, that effect would only be occurring locally. Normally, the diaphragm plate would be located towards the fixed point within the brackets, on the beam's loaded end. Although the plate would be used for preventing the cross-

section's distortion at that position only. The distortion would be increasing, thus enabling it to reach the maximum distance, and fading gradually and subsequently. An easy concept of engineering design would be able to illustrate the placement of the 2nd diaphragm, precisely at the maximum distortion's place.
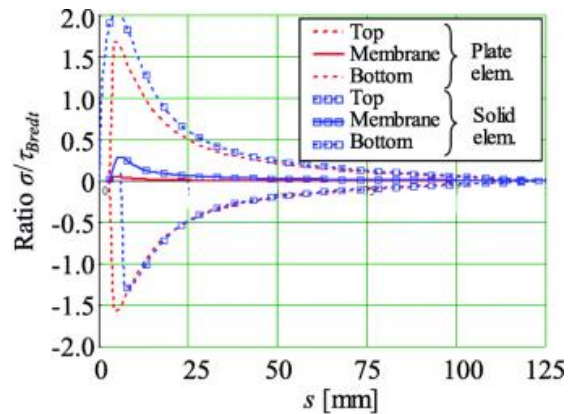
Theoretically, the optimal location of the additional diaphragm would be determined by the use of the theory that was shown by Hetenyi. However, that would be requiring a highly complex analytical formulation since it would be ignored there. Although, the next diaphragm plate's optimal location would be investigated numerically through

FEAs. In the cross-section's warping, the SHS that would be having corners, the stresses, and deformations because of the primary warping would be zero. Although, the secondary warping would be occurring at the beam's fixed end (Hemer et al., 2020). The general analysis of the usual distribution of stress in the same stress and the fixed corner distribution at the middle, outer, and inner profile face's surfaces would be derived by the use of the solid element and plate in the figure below. The normal adjacent components of stress in the vertical and horizontal plates would be opposite and, hence inducing shear stresses that would be high local in the acting parallel at the corner to the beam's longitudinal axis. The shear and normal stresses would be occurring locally only and would not affect the capacity like the beam structure. However, they should be measured in the fatigue analysis since they could be having a remarkable unpleasant role in the durability and structural performance.
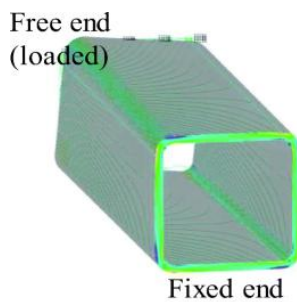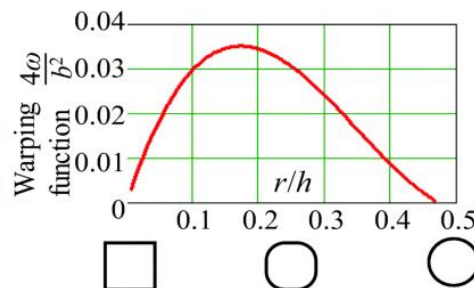

(a)

(b)

In case that box section would be having round corners, there would be the existence of secondary or stresses, membrane or primary stresses because of the SHS's warping. The figure below would be depicting the SHS profile's characteristic stress distribution and the corner radius's effect on the ratio of beam height on the primary warping's degree at the corner section. When the profile's corner radius towards the height ratio would be approaching zero, the membrane warping would vanish. Moreover, when the ratio would be approaching 0.5, the rest of the warping would vanish too.

(a)

(b)

In the distribution of axial stress at the fixed point and **b** the corner radius's effect to the ratio of height on the warping's degree of SHS.

To notice the SHS's fatigue that would be having a certain round corner, the concept of ENS, there was the application to the 3D geometry. It was having radius reference and modeled welds on the weld root and toe, into the joint that there was the occurrence of axial stress that was the highest. The thickness of the weld throat was equal to all the FE models. However, the penetration's degree was varied since the models were supposed to represent the joints with half and fully penetrated and welds that would be pure fillet. Generally, the weld toe

would be considered to be the most important part of the joint compared to the root side. Therefore, the distributions of stress over the thickness of the plate would be presented only on the weld toe.

Discussion

The shear and normal stresses because of distortion and warping could not be ignored in the structures that would be subjected to the torsional loading. There should be the consideration of distortion in the study of fatigue, ultimate, and the joints' fatigue capacity having hollow sections. The presented paper above has shown the warping and distortion behavior of RHS and SHS members that were subjected to the torsional moment. They were analytically investigated on the theoretical model's basic for the analysis of stress and conducting FEAs numerically. The beam structure's length had would be playing an important duty in the distortion and warping distributions at the length of the beam. In the beams of RHS, membrane warping would be seen to be small and the values of the local peak would be occurring only in the fixing and loading beam points. The distortion was having its maximum distance since it was fading very smoothly. Even the beam that would be 4000 mm long, having the dimensions of the cross-section being $240 \times 240 \times 4$ mm, would not last long enough for it to destroy the stresses and distortional deformations. That would be causing a comparison between the FEA and theoretical model. However generally, the treaty between FEA and analytical calculation was good.

Conclusions

According to the numerical and theoretical analyses as well as the experimental researches from literature, some conclusions were made; primary warping that would be causing either deformations and axial membrane stresses would be occurring also in the SHSs having round corners. Secondary and primary warping is supposed to be considered on the SHSs' fatigue analysis that would be subjected to the loading of fluctuating torsional, mainly at the rigid fixing's end. Distortion could have impacted the stability, flexibility, and the joints' ultimate capacity and in the loading of static. Transverse bending was stressing because the distortion could be having some negative impacts on the beams' fatigue performance having hollow cross-sections. Particularly when those fixing welds were placed in the cross-section's corners.

REFERENCES

[1]. Hemer, A. M., Milović, L., Kljajin, M., & Lozanović Šajić, J. (2020). Analytical vs Numerical Calculation of Fatigue Life for Different Welded Joint Regions. *Tehnički vjesnik*, *27*(6), 1931-1937.

[2]. Tuomas Skriko. (2020, May 9). *On the distortion and warping of cantilever beams with hollow section*. Welding in the World. https://link.springer.com/article/10.1007/s40194-020-00911-5

[3]. Wu, C., & Kim, J. W. (2020). Numerical prediction of deformation in thin-plate welded joints using equivalent thermal strain method. *Thin-Walled Structures*, *157*, 107033.