Technical Note

Not peer-reviewed version

# Class 4 Sections Computing Section Properties and Stresses Due to the Bimoment

Antonio Aguero *, Ivan Baláž, Yvona kolekova

Posted Date: 13 February 2025

doi: 10.20944/preprints202502.0989.v1

Keywords: warping torsion; bimoment; Class 4 section; effective width doi:10.20944/preprints202502.0989.v1



*Technical Note*

# Class 4 Sections Computing Section Properties and Stresses Due to the Bimoment

**Antonio Agüero [1,*], Ivan Baláž [2] and Yvona Koleková [3]**

[1] Department of Continuous Medium Mechanics and Theory of Structures, Universitat Politècnica de València, c/Camino de Vera s/n, 46022 Valencia, Spain
[2] Department of Metal and Timber Structures, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, 810 05 Bratislava, Slovakia
[3] Department of Structural Mechanics, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, 810 05 Bratislava, Slovakia
* Correspondence: author: anagra@mes.upv.es

**Abstract:** The present paper deals with warping torsion, bending and axial forces. Presenting a method to compute the shear center of the effective section, the warping constant and warping coordinates needed to compute the stresses due to the bimoment. The stresses are compared between stresses in the gross and effective section when a Bimoment only is applied for the sake of simplicity but any combination with axial and biaxial bending moment is allowed. This paper fills the gap of the current codes to deal with bimoment in Class 4 sections.

**Keywords:** warping torsion; bimoment; Class 4 section; effective width

---

## 1. Introduction

*Elastic Theory*

The classical approach to determining section properties is presented including sectorial coordinates using centroidal coordinates $y_c$ and $z_c$ see Figure 1 (a) and (b).

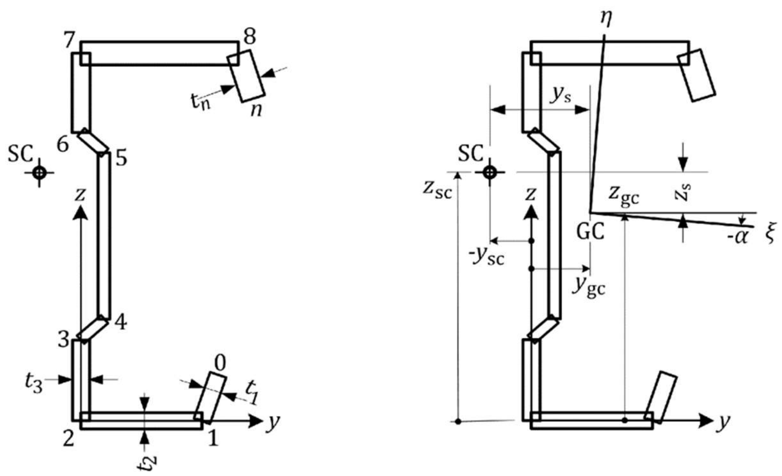


**Figure 1.** General thin walled section.

$$I_y = \int z_c^2 dA = \tfrac{1}{3}\sum\left(z_{c,i}^2 + z_{c,i}z_{c,i-1} + z_{c,i-1}^2\right)A_i \quad (1)$$
$$I_z = \int y_c^2 dA = \tfrac{1}{3}\sum\left(z_{ci}^2 + z_{c,i}z_{c,i-1} + z_{c,i-1}^2\right)A_i \quad (2)$$
$$I_{yz} = \int y_c z_c dA = \tfrac{1}{6}\sum\left(2y_{c,i-1}z_{c,i-1} + y_{c,i-1}z_{c,i} + y_{c,i}z_{c,i-1} + 2y_{c,i}z_{c,i}\right)A_i \quad (3)$$
$$I_{y\omega} = \int y_c\omega_c dA = \tfrac{1}{6}\sum\left(2y_{c,i-1}\omega_{c,i-1} + y_{c,i-1}\omega_{c,i} + y_{c,i}\omega_{c,i-1} + 2y_{c,i}\omega_{c,i}\right)A_i \quad (4)$$
$$I_{z\omega} = \int z_c\omega_c dA = \tfrac{1}{6}\sum\left(2z_{c,i-1}\omega_{c,i-1} + z_{c,i-1}\omega_{c,i} + z_{c,i}\omega_{c,i-1} + 2z_{ci}\omega_{c,i}\right)A_i \quad (5)$$

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 13 February 2025 doi:10.20944/preprints202502.0989.v1



$$\omega_{c,i} = \omega_{c,i-1} + y_{c,i-1}(z_{c,i} - z_{c,i-1}) - z_{c,i-1}(y_{c,i} - y_{c,i-1}) \quad (6)$$

$$= \omega_{c,i-1} + y_{c,i-1}z_{c,i} - y_{c,i}z_{c,i-1} \text{ where } \omega_{c,0} = 0 \quad (7)$$

($\omega_{c,0}$ can be chosen arbitrarily, typically taken as 0)

$$y_{sc} = \frac{I_z I_{z\omega} - I_{yz} I_{y\omega}}{I_y I_z - I_{yz}^2} \quad (8)$$

$$z_{sc} = \frac{I_y I_{y\omega} - I_{yz} I_{z\omega}}{I_y I_z - I_{yz}^2} \quad (9)$$

$$\omega_{s,i} = \omega_{s,i-1} + (y_{c,i-1} - y_{sc})(z_{c,i} - z_{c,i-1}) - (z_{c,i-1} - z_{sc})(y_{c,i} - y_{c,i-1}) \text{ where } \omega_{s,0} = 0 \quad (10)$$

($\omega_{s,0}$ can be chosen arbitrarily, typically taken as 0)

$$\omega_{n,i} = \omega_{s,i} - \omega_{s,mean} \quad (11)$$

$$\omega_{s,mean} = \frac{1}{A}\int \omega_s dA = \frac{1}{A}\sum \frac{\omega_{s,i-1} + \omega_{s,i}}{2} A_i \quad (12)$$

$$I_w = \int \omega_n^2 dA = \frac{1}{3}\sum(\omega_{n,i}^2 + \omega_{n,i}\omega_{n,i-1} + \omega_{n,i-1}^2)A_i \quad (13)$$

$$B = \int \sigma \omega_n dA \quad (14)$$

$$\sigma_w = B\, \omega_n / I_w \quad (15)$$

$$B_{el} = f_y\, I_w / \omega_{n,max} \quad (16)$$

It is convenient computationally to use any arbitrary starting coordinate system (y, z, ω) and the parallel axis theorem to obtain the centroidal properties. For sectorial coordinates with respect to any pole,

$$\omega_i = \omega_{i-1} + y_{i-1}(z_i - z_{i-1}) - z_{i-1}(y_i - y_{i-1})$$

$$= \omega_{i-1} + y_{i-1}z_i - y_i z_{i-1} \text{ where } \omega_0 = 0 \quad (17)$$

The normalized sectorial coordinates about the shear center can then be determined using

$$\omega_{n,i} = \omega_i - \omega_{mean} + z_{sc}y_{c,i} - y_{sc}z_{c,i} \quad (18)$$

$$\omega_{mean} = \frac{1}{A}\int \omega dA = \frac{1}{A}\sum \frac{\omega_{i-1} + \omega_i}{2} A_i \quad (19)$$

$$\sigma = \left[\frac{N}{A} + \frac{(M_y I_z + M_z I_{yz})}{(I_y I_z - Iyz^2)} z - \frac{(M_z I_y + M_y I_{yz})}{(I_y I_z - Iyz^2)} y + \frac{B}{I_w} w\right] \quad (20)$$

Once the stresses are computed the effective width of each is plate is computed, the effective width depend on the Axial force N, bending moments My, Mz and Bimoment B combination according to EN 1993-1-1:2022 [1] and EN 1993-1-5:2006 [2] Lee [3].

2 methods can be used to compute the stresses:

Method 1: Consider each internal force independently and compute its stresses with the effective section.

Method 2: Consider all the internal forces simultaneously and compute the stress distribution to altogether and the effective width related to those stresses.

Now taking into account the effective width the effective section properties are computed starting with:

- Centroid, second moment of area about the y and z axes and product of inertia ($I_{yeff}$, $I_{zeff}$, $I_{yzeff}$))
- Shear center, warping coordinates and warping constant ($I_{weff}$).

The warping with respect to any pole can be obtained as usual, the mean value $w_{mean,eff}$ takes into account that only the effective areas are considered, as well to compute the shear center position of the effective section $I_{yw,eff}$ and $I_{zw,eff}$ have to be computed for the effective section, finally the warping constant $I_{w,eff}$ of the effective section is computed.

- Due to possible shift of the centroid there will be a change in the bending moments ($M_{yeff}$,$M_{zeff}$).

Following the stresses in the effective section are computed:

$$\sigma = \left[\frac{N}{A_{eff}} + \frac{(M_{yeff} I_{zeff} + M_{zeff} I_{yzeff})}{(I_{yeff} I_{zeff} - I_{yzeff}{}^2)} z_{eff} - \frac{(M_{zeff} I_{yeff} + M_{yeff} I_{yzeff})}{(I_{yeff} I_{zeff} - I_{yzeff}{}^2)} y_{eff} + \frac{B}{I_{weff}} w_{eff}\right] \quad (21)$$

The coordinates $y_{eff}$ and $z_{eff}$ are referred to the effective centroid, while the warping $w_{eff}$ is referred to the new shear center.

## 2. Numerical Examples

The following software is used by Agüero [4] :
https://labmatlab-was.upv.es/webapps/home/thinwallsectionmaterials_class4.html

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 13 February 2025 doi:10.20944/preprints202502.0989.v1



In this software 10 fibers are used per element, more accurate in case the number of fibers is increased.

Following examples to compute section properties in class 4 sections comparing the results for the gross and effective section when a Bimoment is applied. The material used is steel S355

*2.1. I Shape Section 2 Axes of Symmetry*

Section dimensions b=30cm h=30cm t=0.4cm

Section properties and stresses Figure 2 and 3:

Gross section:

Iw=405000cm$^6$

Centroid and shear center in the intersection 2 axes of symmetry

Effective section:

Iweff=169282cm$^6$

Centroid and shear center (the effective section is point symmetric)

To obtain the effective width [2] is used:

$k_\sigma$=0.57 therefore λp=2.1496 , ρ=0.424 and the effective width of the compression is flange=0.424*15=6.36cm

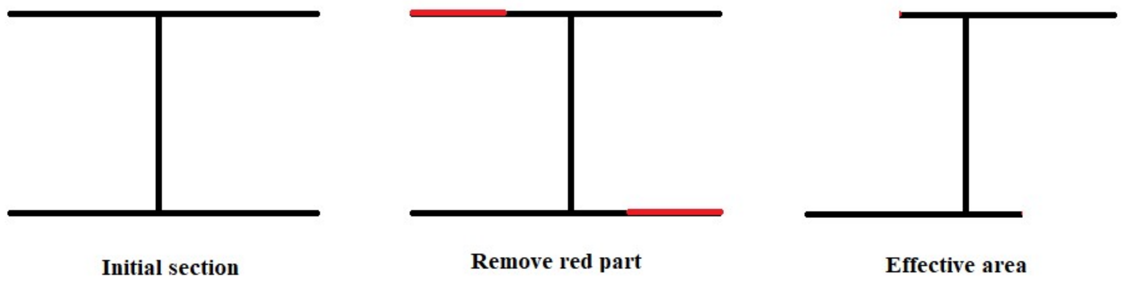


**Figure 2.** Gross intital section and effective section in case bimoment on Class 4 section I shape.

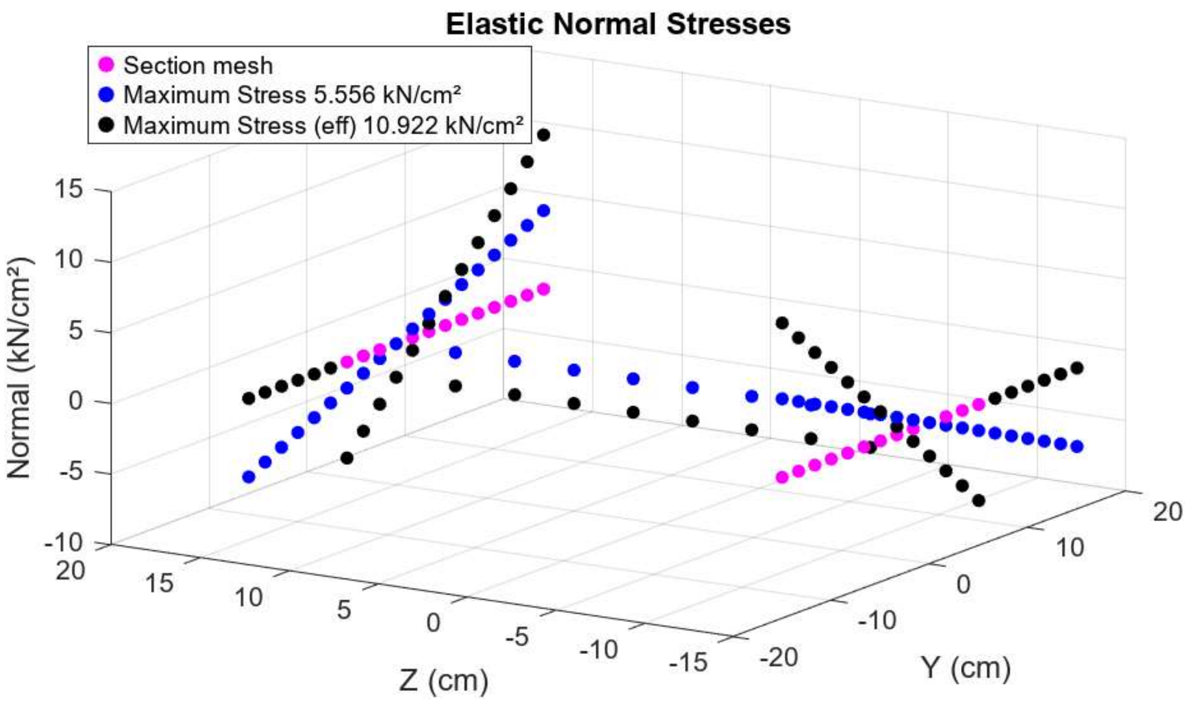


**Figure 3.** stresses in the gross (Blue) and effective (Black) section due to a bimoment B=10000kNcm$^2$.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 13 February 2025 doi:10.20944/preprints202502.0989.v1



*2.2. Monosymmetric Section*

Channel section stresses Figure 4:
Section dimensions b=15cm h=30cm t=0.4cm
Section properties:
Gross section:
Iw=88593cm$^6$
The origin of the reference system is at the intersection bottom flange and web.
Centroid position in the axis of symmetry: Zg=15 Yg=3.75
and shear center in the axis of symmetry: Zsc=15 Ysc=-5.625
Effective section:

To compute the effective part of the bottom flange. Taking into account that $\psi$=-0.6 , $k_\sigma$=0.72, $\lambda$p=1.91 , $\rho$=0.47 , the part of that flange under tension is 5.624cm and the effective part under compression is $\rho$*bc=4.4cm, the remaining part of the flange is 15-4.4-5.624=4.96cm length that has to be removed.

Iweff=53730cm$^6$
Centroid position: Ygeff=3.06 Zgeff=16.12
and shear center: Zsceff=9.63 Ysceff=-7

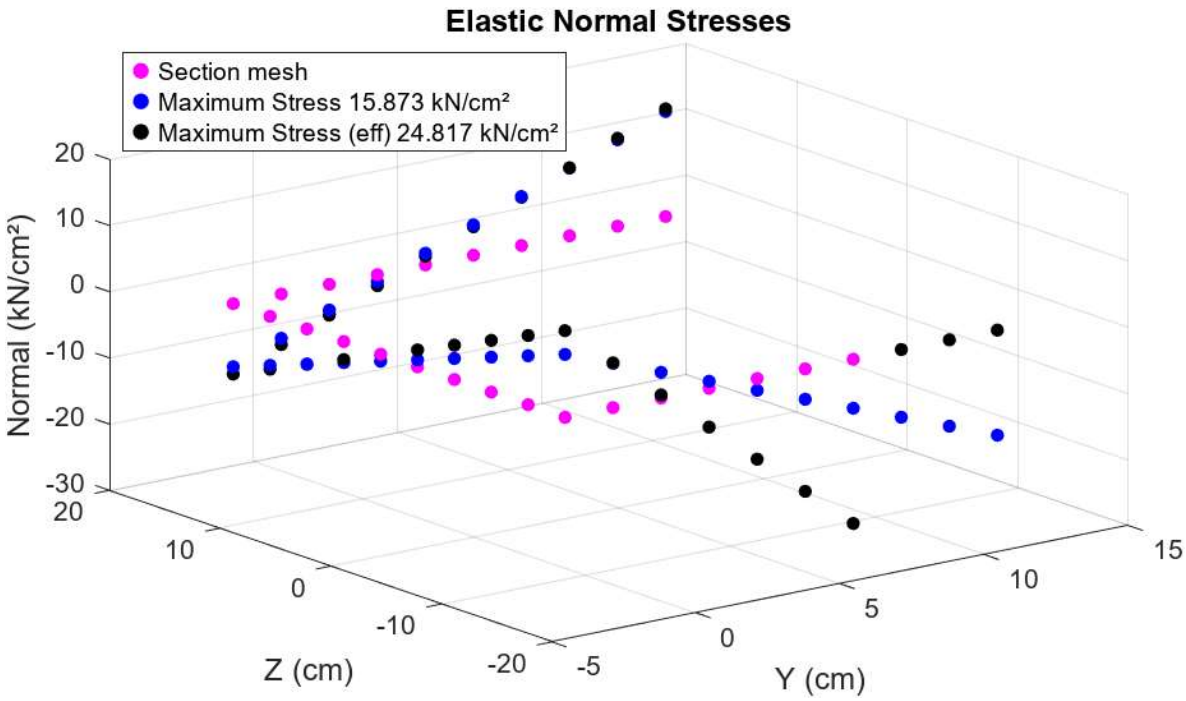


**Figure 4.** stresses in the gross (Blue) and effective (Black) section due to a bimoment B=10000kNcm$^2$.

*2.3. Non Symmetric Section*

Channel non symmetric section:

Section dimensions top flange width bu=15cm, bottom flange width bl=30cm tf=0.4cn h=30cm tw=0.2cm

Section properties and stresses Figure 5:
Gross section:
Iw=135000cm$^6$
The origin of the reference system is at the intersection bottom flange and web.

Centroid position in the axis of symmetry: Zg=11.25 Yg=9.375 and shear center in the axis of symmetry: Zsc=5 Ysc=-7.5

Effective section:
Iweff=88379cm$^6$
Centroid position: Zgeff=13.27 Ygeff=6.44 and shear center: Zsceff=-0.637 Ysceff=-7.83

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 13 February 2025 doi:10.20944/preprints202502.0989.v1



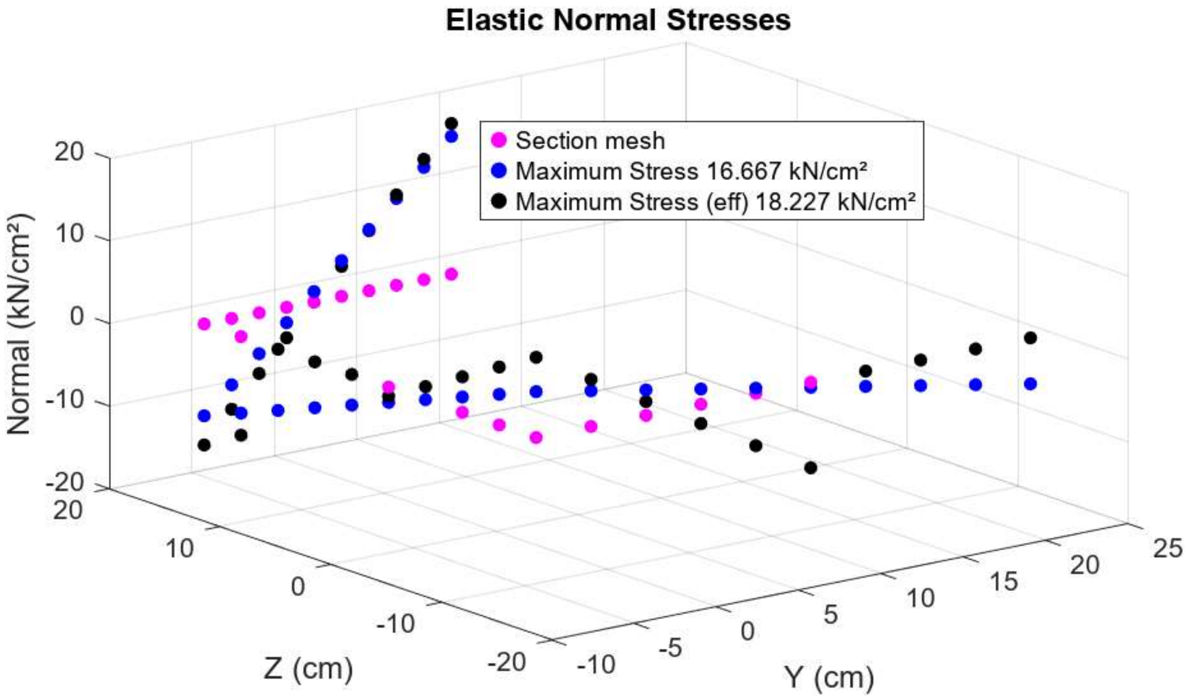


**Figure 5.** stresses in the gross (Blue) and effective (Black) section due to a bimoment B=10000kNcm².

## 3. Conclusions

The present paper deals with warping torsion, bending and axial forces. Presenting a method to compute the shear center of the effective section, the warping constant and warping coordinates needed to compute the stresses due to the bimoment. The stresses are compared when a Bimoment only is applied for the sake of simplicity but any combination with axial and biaxial bending moment is allowed. This paper fills the gap of the current codes to deal with bimoment in Class 4 sections.

**Funding:** This research project is supported by the Slovak Grant Agency VEGA no. 1/0155/23.

## Nomenclature

according to the Eurocode3

## References


1. EN 1993-1-1:2022; Eurocode 3: Design of Steel Structures. Part 1-1: General Rules and Rules for Buildings. CEN: Brussels, Belgium, 2022.
2. EN 1993-1-5:2006; Eurocode 3: Design of steel structures - Part 1-5: General rules - Plated structural Elements.
3. Lee C.K., Chiew S.P., A review of class 4 slender section properties calculation for thin-walled steel sections according to EC3. Advanced Steel Construction Vol. 15, No. 3, pp. 259-266 (2019)
4. Agüero A. , "Thin wall section Class 1,2,3 & 4" Software, Online available from https://labmatlab-was.upv.es/webapps/home/thinwallsectionmaterials_class4.html , 2024.