CILAMCE 2017
Florianópolis - Santa Catarina - Brazil

SOFTWARE FOR DESIGN OF BOLTED CONNECTIONS ACCORDING TO NBR 8800:2008 AND ANSI/AISC 360-16 STANDARDS

Tárique Samir Bezerra Sena

tarique.samir@hotmail.com

Pedro Henrique Gama Neiva

bending.ufpa@gmail.com

Gabriella Darold Vieira

gabriella_darold@hotmail.com

Plínio Glauber Carvalho dos Prazeres

plinio@ufpa.br

Federal University of Para, Civil Engineering Department

01 Augusto Correa St, 66075-110, Belem, Para, Brazil

Caio Rodrigues Laranjeira Vilar

caiorlvilar@gmail.com

Federal University of Parana, Civil Engineering Studies Center

w/ n Cel Francisco H dos Santos Ave, 81530-900, Curitiba, Parana, Brazil

Abstract. *Connections on steel buildings contribute significantly to the structural system response and, depending on geometry of these connections, they can be considered critical components in structural members which have the primary function of resisting bending moments. Among many kinds of connections, bolted ones are very often chosen for steel buildings due to its reliability, economy, ease of execution and inspection. In Brazil, the standard responsible for addressing steel members design uses mathematical models and members dimensions presented in American standards, such as strength checks of members and geometry of connectors. This paper aims to introduce a software developed in Matlab for bolted connections design based on Brazilian and American standard recommendations, represented by NBR 8800:2008 and ANSI/AISC 360-16, respectively. At the end of this work, results are compared with data found in literature.*

Keywords: *ANSI/AISC 360-16, bolt, connection, design, Matlab, NBR 8800, shear, steel.*

1 INTRODUCTION

In steel structures, moment connections are often critical components in beams, at the same time shear connections – or flexible connections – are the most common type of beam-to-column joint due to its reliability, economy, ease of execution and inspection. An example of connection usually treated as flexible is the double angle connection (Silva et al., 2016). Fig. 1 shows the beta software interface described in this paper and the connection representation described by Silva (2016).

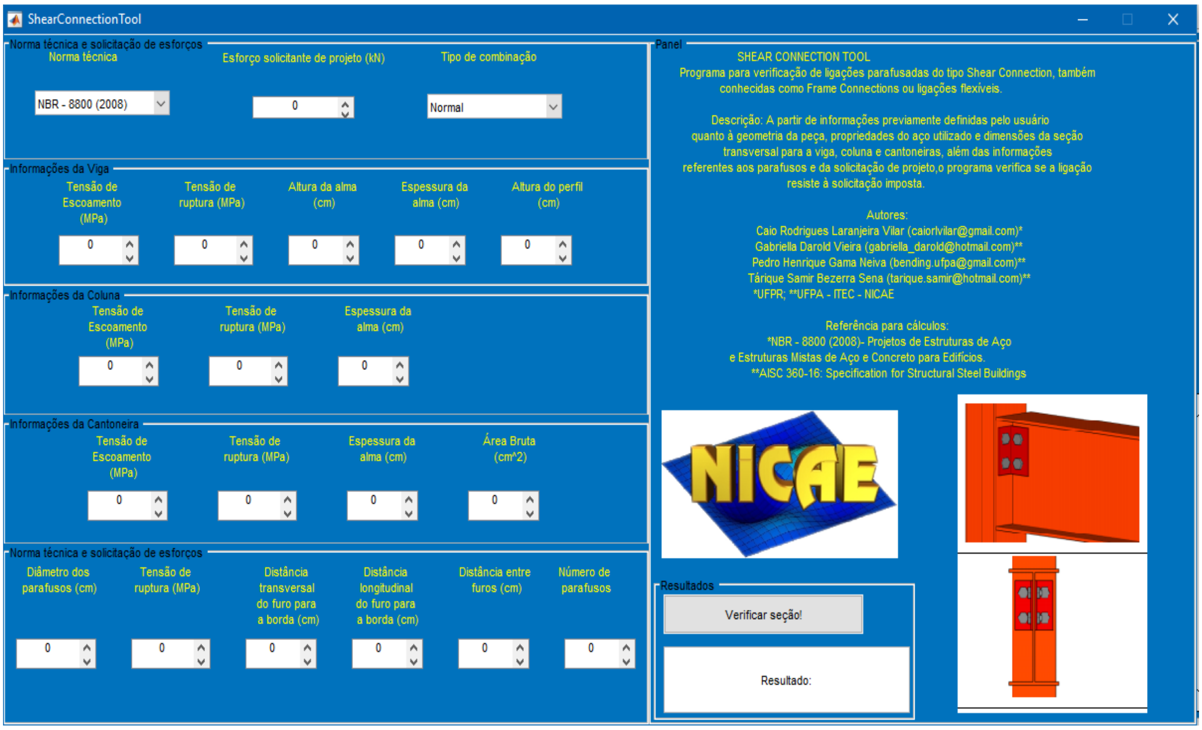

Figure 1: Preliminary software interface

Although it is considered that only shear is transferred in double angle connections, Astaneh (1989) proposed that bending moments are also present in these joints and this could affect significantly the structural system response. Given the importance of structural steel connections, this paper has the objective of present a software developed in Matlab platform that perform strength design of double angle connections subjected to shear load according to NBR 8800 – the 2008 Brazilian standard for structural steel – and ANSI/AISC 360-16 – the 2016 American standard for steel buildings.

2 METODOLOGY

Calculation procedures of Brazilian and American standards were reviewed to select relevant recommendations for our problem and develop the software. Further, we adopted Matlab functions to perform verifications suggested by the standards. Finally, the software was defined by the compilation of all these functions.

2.1 Calculation Procedures for Shear Connections According to NBR 8800:2008 and ANSI/AISC 360-16

Checking the safety of connection requires verifications on connecting elements (angles), bolts, and structural members that are jointed, in this case beam and column. On the other hand, almost all verifications are repeated for two or more elements, such as bearing strength. All verifications performed for design are summarized on Table 1.

NBR 8800:2008 recommend calculating the width-thickness ratio of steel shape to initiate design. Then, this value is compared with two limits presented in Eq. (1) and (2), as follows:

$$\lambda_p = 1.1 \times \sqrt{\frac{k_v \times E}{f_y}} \tag{1}$$

$$\lambda_r = 1.37 \times \sqrt{\frac{k_v \times E}{f_y}} \tag{2}$$

In Eq. (1) and (2) k_v is a coefficient associated with transverse stiffeners. In this case it was considered that the beam does not have these elements, so the value of k_v is 5. Whether the width-thickness ratio is less than or equal to λp, then tensile strength of beam for shear design is given by Eq. (3); if the value is greater than λp and smaller than λr, the tensile stress will be given by Eq. (4); if the value is greater than λr, the tensile stress will be given by Eq. (5).

$$V_{Rd} = \frac{0.6 \times d \times t_w \times f_y}{\gamma_{a1}} \geq V_{Sd} \tag{3}$$

$$V_{Rd} = \frac{0.6 \times d \times t_w \times f_y \times \lambda_p}{\lambda \times \gamma_{a1}} \geq V_{Sd} \tag{4}$$

$$V_{Rd} = \frac{0.6 \times d \times t_w \times f_y \times {\lambda_p}^2}{\lambda^2 \times \gamma_{a1}} \geq V_{Sd} \tag{5}$$

To check contact pressure, it is necessary to calculate two values of strength, and choose the smallest one. When the deformation at the bolt hole is a design consideration, the Eq. (6) and (7) can be applied. Otherwise, the same equations are valid, however the factors 1.2 and 2.4 are replaced by 1.5 and 3.0, respectively.

$$F_{c,Rd} = \frac{1.2 \times l_c \times t \times f_u}{\gamma_{a2}} \tag{6}$$

$$F_{c,Rd} = \frac{2.4 \times d_b \times t \times f_u}{\gamma_{a2}} \tag{7}$$

To verify shear strength of angles, we calculate the resistance for both tensile strength and yield stress failure, as shown in Eq. (8) and (9), where A_{gv} e A_{nv} are the gross and the net area for shear forces, respectively.

$$F_{Rd} = \frac{0.6 \times f_y \times A_g}{\gamma_{a1}} \tag{8}$$

$$F_{Rd} = \frac{0.6 \times f_u \times A_{nv}}{\gamma_{a2}} \tag{9}$$

To verify block shear rupture, we adopt the smallest of values calculated by Eq. (10) and (11), where A_{nt} is the net area for tension and C_{ts} is a factor related to the uniformity of the tension stress (C_{ts} = 1.0, since we considered that tension stress is uniform).

$$F_{r,Rd} = \frac{1}{\gamma_{a2}} \times (0.6 \times f_u \times A_{nv} + C_{ts} \times f_u \times A_{nt}) \tag{10}$$

$$F_{r,Rd} = \frac{1}{\gamma_{a2}} \times (0.6 \times f_y \times A_{gv} + C_{ts} \times f_u \times A_{nt}) \tag{11}$$

Finally, we can verify the shear strength of bolts through Eq. (12), where n is the number of bolts, d_b is the bolt diameter, and f_{ub} is the specified minimum tensile strength for the bolt.

$$F_{v\,,Rd} = \frac{n}{\gamma_{a2}} \times (0.1 \times \pi \times d_b^2 \times f_{ub}) \geq V_{sd} \tag{12}$$

The procedures for calculation presented in this paper for American and Brazilian standards are similar. Then only shear bolt strength calculation is shown further which is the most different method from Brazilian Standard. Other differences between those standards are minimum but can be viewed at ANSI/AISC 360-16 document. The shear strength of bolts was calculated by Eq. (13), according to limit state of shear rupture as follow:

$$\phi R_n = \phi \times F_n \times A_b \tag{13}$$

3 RESULTS

To validate our software, we used the exercise 9.10.2 from 8th edition of Steel Structures – Practical Design book through some adaptations. The data used was: f =150 kN, A325 16 mm bolts, 76 x 9.1 kg/m clip angles in A36 steel. Welds were not considered here. Additional information is provided on Fig. 2.

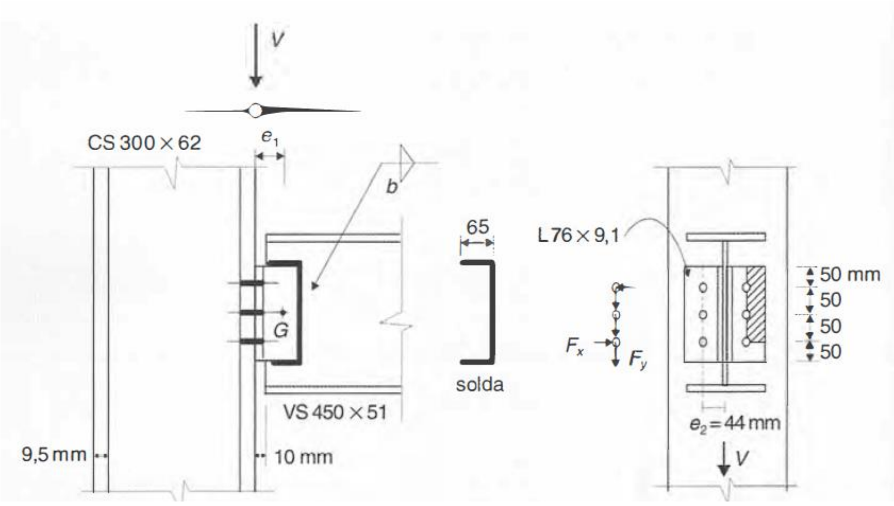

Figure 2. Connection example

The results presented by our software after processing input data are related in Table 1.

Table 1. Verifications for double angle bolted connections

Verifications		NBR (kN)	AISC (kN)
Beam	Shear strength	386	380
	Bearing at bolt holes	210	215
Bolts in beam	Shear strength	404	418
Clip angle, section at beam	Bearing at bolt holes	263	271
	Shear yielding, gross area	215	235
	Shear rupture, net area	229	203
	Block shear rupture	187	164
Clip angle, section at column	Bearing at bolt holes	263	271
	Shear yielding, gross area	215	235
	Shear rupture, net area	229	203
	Block shear rupture	187	164
Bolts in column	Shear strength	404	418
Column	Bearing at bolt holes	316	326

4 CONCLUSION

Both standard procedures provided similar results for design. Then since NBR 8800 is based on previous editions of ANSI/AISC 360-16, we can consider that results are reasonable and that the software development was satisfactory. Nevertheless, we are still working on new modules for our software to include additional systems of steel connections and design.

REFERENCES

American Institute of Steel Construction, 2016. ANSI/AISC 360-16, Specification for Structural Steel Buildings.

Astaneh, A., Nader, M. N., Malik, L., (1989). Cyclic Behavior of Double Angle Connections. *Journal of Structural Engineering*, n. 115, p. 1101-1118.

Brazilian Association for Technical Standards, 2008. NBR 8800, Design of steel structures and mixed steel and concrete structures of buildings.

Pfeil, W., 2009. Steel Structures: Practical Design According to NBR 8800:2008. 8.ed. *Rio de Janeiro: LTC*.

Silva, F. L., Goedel, F., Pravia, Z. M. C., 2016. Evaluation of Rotational Stiffness of Beam-Column Bolted Connection with Double Angles in Web. *XXXVII South American Conference on Structural Engineering*.

Valenciani, V. C., 1997. *Connections in Steel Structures*. Master dissertation, Sao Carlos Engineering School, Sao Paulo University.