# Comparison of the use of NBR 8800 and NBR 14762 for the flexural design of steel profiles

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**ABSTRACT**

This article presents the results of the flexural strength of rolled steel profiles with U shape and cold-formed sections of UDCS section (single plate bent U), using the procedures of the Brazilian Standards ABNT NBR 8800:2008, which deals with the design of steel structures and composite steel and concrete structures for buildings, and ABNT NBR 14762:2010, which addresses the design of steel structures consisting of cold-formed profiles. For the analysis, routines were developed in the Microsoft Excel software, which made it possible to make comparisons regarding the feasibility of using the two types of profiles. The comparisons included groups of profiles of the two types, selected based on similar cross-sectional areas and close moments of inertia, in order to establish more precise parameters for the analysis. The results indicated that, although both profiles meet specific resistance requirements, the normative procedures of the two ABNT standards applied are not directly comparable to each other, which implies the need for different considerations for each type of profile when evaluating its structural feasibility. This difference highlights the importance of a careful analysis in the choice of profiles to be used in structural projects, considering the specificities and limitations of each standard.

**Keywords:** Resistant bending moment, Comparison, ABNT standards.

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## INTRODUCTION

Civil Construction needs technical and material knowledge that makes it more efficient, with higher quality and better performance. Metal structures have gained great prominence in recent decades because they are produced with prefabricated elements, ensuring speed and precision in the execution of the works.

Cold-formed steel profiles (PFF), also known as bent sheet profiles, are manufactured using machines, at room temperature, from flat steel sheets that are deformed into sections that are conveniently shaped and specific to the project needs.

These profiles are widely used in civil construction due to their cost-effectiveness, lightness, ease of handling and transport, especially in works that have small spans and loads. Examples of the use of these profiles are: purlins, scaffolding, ceiling frames, stringers, among others (RODRIGUES, 2000).

However, as a consequence of the large width-thickness ratio of the plane elements that compose their cross-section, these profiles are more susceptible to local buckling, which does not mean, in general, exhaustion of the resistant capacity of the profile, according to Javaroni and Gonçalves (2002). The theory of plate instability allows the prediction of critical loads, as well as the analysis of post-critical behavior, which can be done through the concept of effective width.

In particular in the case of UDCS (single sheet metal bent U) profiles, the protagonist of this article, the ABNT technical standard that governs their design and verification is NBR 14762:2010.

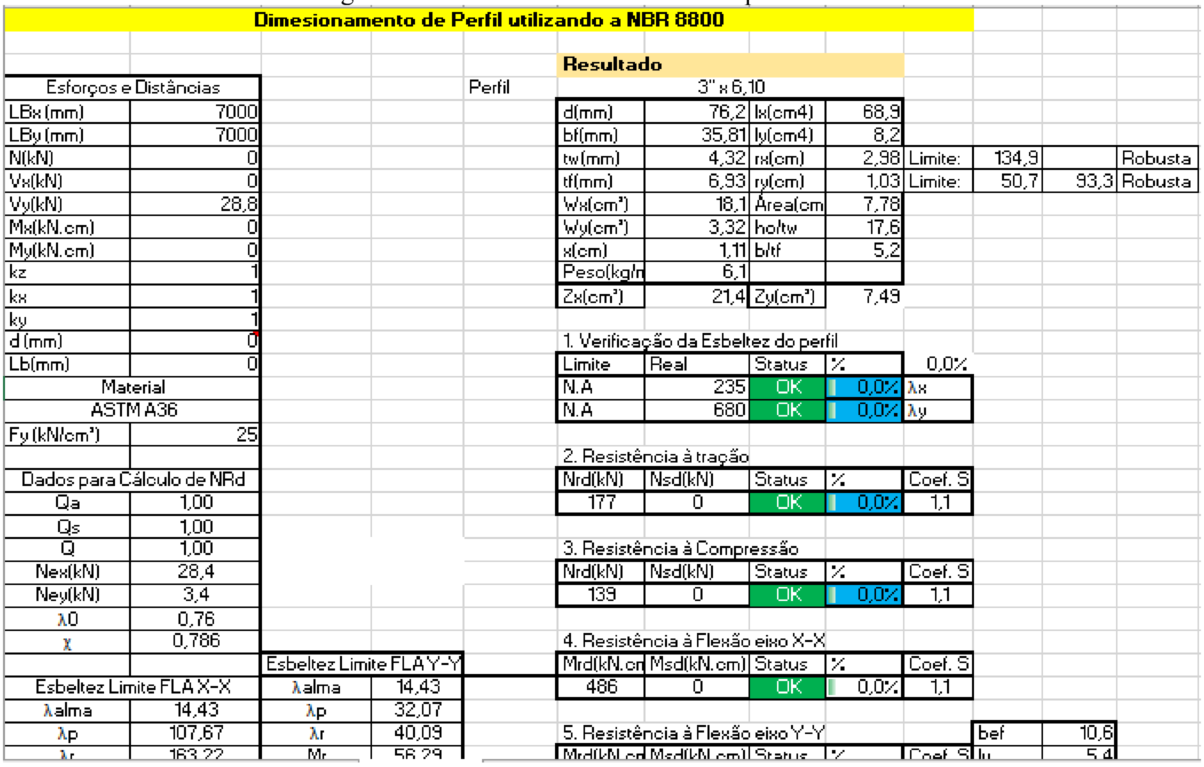
Rolled profiles are produced by rolling steel blocks, in a continuous rolling system. These profiles are parts that have great structural efficiency, mainly due to the manufacturing method and the fact that they are single pieces, without welds, with a slight inclination in the constitution of the AL elements (tables and flaps), and can be found under different geometries: H, I, U, etc. It is ideal for applications that require greater strength and robustness, being used mainly as beams, columns and bracing elements.

For this article, the profile used was the American standard, type U, whose design and verification will be governed by the ABNT NBR 8800:2008 standard.

## METHODOLOGY

A routine was developed in the Excel software, with all the necessary calculation procedure to calculate the flexural strength, using the NBR 8800:2008 standard for the rolled profiles as sources. On the side of the UDCS profiles, manual calculations were performed based on NBR 14762:2010, checked with the help of the DimPerfil4.0 software. In figure 1, you can see the spreadsheet for rolled profiles.

Figure 1: Interface of the routine developed in Excel.



**Dimesionamento de Perfil utilizando a NBR 8800**

| Esforços e Distâncias | |
|---|---|
| LBx (mm) | 7000 |
| LBy (mm) | 7000 |
| N(kN) | 0 |
| Vx(kN) | 0 |
| Vy(kN) | 28,8 |
| Mx(kN.cm) | 0 |
| My(kN.cm) | 0 |
| kz | 1 |
| kx | 1 |
| ky | 1 |
| d (mm) | 0 |
| Lb(mm) | 0 |
| Material | |
| ASTM A36 | |
| Fy (kN/cm²) | 25 |

| Dados para Cálculo de NRd | |
|---|---|
| Qa | 1,00 |
| Qs | 1,00 |
| Q | 1,00 |
| Nex(kN) | 28,4 |
| Ney(kN) | 3,4 |
| λ0 | 0,76 |
| χ | 0,786 |

| Esbeltez Limite FLA X-X | |
|---|---|
| λalma | 14,43 |
| λp | 107,67 |
| λr | 163,22 |

| Esbeltez Limite FLA Y-Y | |
|---|---|
| λalma | 14,43 |
| λp | 32,07 |
| λr | 40,09 |
| Mr | 56,29 |

**Resultado**

Perfil 3" x 6,10

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| d(mm) | 76,2 | Ix(cm4) | 68,9 | | | | |
| bf(mm) | 35,81 | Iy(cm4) | 8,2 | | | | |
| tw(mm) | 4,32 | rx(cm) | 2,98 | Limite: | 134,9 | | Robusta |
| tf(mm) | 6,93 | ry(cm) | 1,03 | Limite: | 50,7 | 93,3 | Robusta |
| Wx(cm³) | 18,1 | Área(cm | 7,78 | | | | |
| Wy(cm³) | 3,32 | ho/tw | 17,6 | | | | |
| x(cm) | 1,11 | b/tf | 5,2 | | | | |
| Peso(kg/m | 6,1 | | | | | | |
| Zx(cm³) | 21,4 | Zy(cm³) | 7,49 | | | | |

1. Verificação da Esbeltez do perfil

| Limite | Real | Status | % | 0,0% |
|---|---|---|---|---|
| N.A | 235 | OK | 0,0% | λx |
| N.A | 680 | OK | 0,0% | λy |

2. Resistência à tração

| Nrd(kN) | Nsd(kN) | Status | % | Coef. S |
|---|---|---|---|---|
| 177 | 0 | OK | 0,0% | 1,1 |

3. Resistência à Compressão

| Nrd(kN) | Nsd(kN) | Status | % | Coef. S |
|---|---|---|---|---|
| 139 | 0 | OK | 0,0% | 1,1 |

4. Resistência à Flexão eixo X-X

| Mrd(kN.cm) | Msd(kN.cm) | Status | % | Coef. S |
|---|---|---|---|---|
| 486 | 0 | OK | 0,0% | 1,1 |

5. Resistência à Flexão eixo Y-Y

| Mrd(kN.cm) | Msd(kN.cm) | Status | % | Coef. S | bef | 10,6 |
|---|---|---|---|---|---|---|
| | | | | | lu | 5,4 |

Research source: The author.

# THEORETICAL FOUNDATION

## APPLICATION OF ABNT NBR 8800:2008[3] TO FLEXED PROFILES

To verify the resistant capacity of the U-laminated metal profiles to the stresses requesting bending, the following limit states were evaluated: Local Web Buckling (FLA), Local Table Buckling (FLM) and Lateral Torsional Buckling (FLT).

## LOCAL BUCKLING WITH TORSION (FLT)

In this verification, the U profiles were considered to have no lateral containment. Soon we have $L_b \neq 0$, and $L_b$ the length is unlocked.

Determination of the slenderness coefficient of the torsional profile ( $\lambda$ ): $\lambda = \dfrac{L_b}{r_y}$.

This value must be compared with the slenderness value $\lambda_p = 1,76\sqrt{\dfrac{E}{f_y}}$ or

$\lambda_r = 1,38\dfrac{\sqrt{I_y J}}{r_y J \beta_1}\sqrt{1+\sqrt{1+\dfrac{27C_w\beta_1^2}{I_y}}}$, respectively, the slenderness at plasticizing and at the beginning of flow.

[3] The items and annexes described below refer to this standard.

Once these slenderness parameters were defined and item G.2.1 was available, it was possible to find the resistant bending moment of calculation by checking three cases:

Case 1, compact profile ($\lambda \leq \lambda_p$): $M_{Rd} = \dfrac{M_{pl}}{\gamma_{a1}}$, where $M_{pl} = Z.f_y$ and $Z = \int |y| \, dA$.

Case 2, semi-compact profile ($\lambda_p \leq \lambda \leq \lambda_r$): $M_{Rd} = \dfrac{C_b}{\gamma_{a1}}\left[ M_{pl} - \left( M_{pl} - M_r \right) \dfrac{\lambda - \lambda_p}{\lambda_r - \lambda_p} \right]$, with $M_r = \left( f_y - \sigma_r \right) \cdot W$.

Case 3, slender profile ($\lambda > \lambda_r$): $M_{Rd} = \dfrac{M_{cr}}{\gamma_{a1}}$, where $M_{cr} = \dfrac{C_b \pi^2 E I_y}{L_b^2} \sqrt{\dfrac{C_w}{I_y}\left( 1 + 0{,}039 \dfrac{J L_b^2}{C_w} \right)}$,

$$\beta_1 = \frac{\left( f_y - \sigma_r \right) \cdot W}{EJ} \text{ and } C_w = \frac{t_f \left( b_f - 0{,}5 t_w \right)^3 \left( d - t_f \right)^2}{12} \left[ \frac{3\left( b_f - 0{,}5 t_w \right) t_f + 2\left( d - t_f \right) t_w}{6\left( b_f - 0{,}5 t_w \right) t_f + \left( d - t_f \right) t_w} \right]$$

## LOCAL BUCKLING OF THE SOUL (FLA)

Using table G.1, it is initially verified whether the profiles have a non-slender web, i.e., whether the local slenderness parameter $\lambda$ is less than or equal to the $\lambda_r$ (slenderness at the beginning of the flow), for the limit state of FLA. Otherwise, the profile would be slender and the verification would be conducted by the expressions in Annex H.

From table G.1, notes 1 and 6, and from annex H of the standard, it was possible to obtain the expressions presented below.

Determination of the coefficient of slenderness of the soul ($\lambda$): $\lambda = \dfrac{h}{t_w}$.

This value must be compared with the slenderness values at the plasticization and at the beginning of the flow, that is, respectively: $\lambda_p = 3{,}76 \sqrt{\dfrac{E}{f_y}}$ or $\lambda_r = 5{,}70 \sqrt{\dfrac{E}{f_y}}$.

Once these slenderness parameters were defined and item G.2.2 was available, it was possible to find the resistant bending moment of calculation by checking two cases[4]:

Case 1, compact profile ($\lambda \leq \lambda_p$): $M_{Rd} = \dfrac{M_{pl}}{\gamma_{a1}}$, where $M_{pl} = Z.f_y$ and $Z = \int |y| \, dA$ (LANDESMANN, 1999).

Case 2, semi-compact profile ($\lambda_p \leq \lambda \leq \lambda_r$): $M_{Rd} = \dfrac{1}{\gamma_{a1}}\left[ M_{pl} - \left( M_{pl} - M_r \right) \dfrac{\lambda - \lambda_p}{\lambda_r - \lambda_p} \right]$,

[4] For FLA, the case for slender web profiles does not apply to U-shaped sections. Item G.2.2

where $M_r = f_y \cdot W$.

## LOCAL TABLE BUCKLING (FLM)

Determination of the slenderness coefficient of the table ( $\lambda$ ): $\lambda = \frac{b}{t}$.

This value shall be compared with the appropriate slenderness values at the plasticization and at the beginning of the flow, i.e., respectively: $\lambda_p = 0,38\sqrt{\frac{E}{f_y}}$ or $\lambda_r = 0,83\sqrt{\frac{E}{\left(f_y - \sigma_r\right)}}$.

Once these slenderness parameters are defined for the table, the resistant bending moments of calculation are obtained with the same expressions of item G.2.2, presented above, plus the third case[5]:

Case 3, Slender profile ( $\lambda > \lambda_r$ ): $M_{Rd} = \frac{M_{cr}}{\gamma_{a1}}$, where $M_{cr} = \frac{0,69E}{\lambda^2} W_c$

All the expressions mentioned above refer to the axis of greatest inertia, since this is the preponderant axis for the results.

To ensure the validity of the elastic analysis, the resisting bending moment of calculation $M_{Rd} \leq 1,5 \cdot \frac{W.f_y}{\gamma_{a1}}$, where $W$ is the modulus of elastic resistance, given by $W = \frac{I}{y}$, where $y$ *is* the greatest distance from the GC of the section to the most compressed or most tensile fiber.

After calculating the resistant moments by the three limit states, the smallest of them is then adopted.

## APPLICATION OF ABNT NBR 14762:2010[6] TO FLEXED PROFILES

To verify the resistant capacity of the UDCS metal profiles to the stresses requesting bending, the calculations were based on two methods: the Effective Width Method (MLE), in items 9.2.2 and 9.2.3, and the Effective Section Method (MSE), in items 9.7.2.b, 9.8.2.1.b and 9.8.2.2.b. According to Silva (2008), the recommended method is that of effective widths, as it is a classic procedure used for the design of cold-formed profiles, in which each constituent element of the profile (core and tables) is analyzed separately based on the concept of effective widths.

The calculation resistant bending moment ( $M_{Rd}$ ) shall be adopted as the lowest value calculated in accordance with paragraphs 9.8.2.1, 9.8.2.2 and 9.8.2.3, as presented below.

[5] For FLM, the case for slender web profiles does not apply to U-shaped sections. Item G.2.2

[6] The items and annexes described below refer to this standard.

## START OF RUNOFF OF THE EFFECTIVE SECTION

$M_{Rd} = \frac{W_{ef} \cdot f_y}{\gamma}$, where $W_{ef}$ it is calculated in the effective width method (MLE), according to 7.1.1, considering the stress σ calculated for the ultimate limit state of the start of flow of the effective section.

To calculate the $\lambda_p = \left(\frac{W \cdot f_y}{M_l}\right)^{0,5}$, it is necessary to determine the bending moment of elastic local buckling $M_l$, given by the following expression: $M_l = k_l \frac{\pi^2 E}{12\left(1-v^2\right)\left(\frac{b_w}{t}\right)^2} W_c$, where

$k_l = \left(\frac{b_f}{b_w}\right)^{1,843}$.

## LATERAL BUCKLING WITH TORSION

For the resistant bending moment of calculation referring to lateral buckling with torsion, a section between laterally contained sections is taken, and is given by the expression:

$$M_{Rd} = \frac{\chi_{FLT} \cdot W_{c,ef} \cdot f_y}{\gamma}.$$

The stress σ calculated for the ultimate limit state of lateral buckling by torsion, in the MLE, according to 5.1.1, adopts: $\sigma = \chi_{FLT} f_y$. To calculate the $\lambda_p = \left(\frac{\chi_{FLT} \cdot W \cdot f_y}{M_l}\right)^{0,5}$, it is necessary to calculate the $M_l$ one presented above.

Since $\lambda_o = \left(\frac{W_c \cdot f_y}{M_e}\right)^{0,5}$ the slenderness index of the profile is reduced and $M_e$ the bending moment of lateral buckling with torsion for bending around the axis of symmetry (x is the axis of symmetry), $M_e = C_b \cdot r_0 \left(N_{ey} \cdot N_{ez}\right)^{0,5}$ with $C_b$ =1.0, when there is no guarantee of impediment to warping; the radius of rotation given by $r_o = \left[r_x^2 + r_y^2 + x_0^2 + y_0^2\right]^{0,5}$. The axial force of global flexural elastic buckling and the axial force of global torsional elastic buckling, according to item 9.7.2.1, are obtained respectively by: $N_{ey} = \frac{\pi^2 EI_y}{\left(K_y L_y\right)^2}$ and $N_{ez} = \frac{1}{r_0^2}\left[\frac{\pi^2 EC_w}{\left(K_y L_y\right)^2} + GJ\right]$.

The transverse modulus of elasticity, *G*, was adopted as 77GPa according to the recommendations of the standard.

## DISTORTIONARY MOMENT

According to NBR 14762:2010, in item 9.3 it is stated that the distortional moment for UDCS profiles does not present criticality, so this verification can be waived.

## PROFILE SELECTION

The geometric properties of the cross-sections for the various rolled and cold-formed profiles used for this proposal are presented in tables 1 and 2, respectively. These properties are referred to the nominal cross-sectional dimensions of commercially available profiles.

For the calculation of some of the geometric properties of the sections, ShapeBuilder 11.0 software was used.  The software easily allows the creation and customization of cross-sections, providing advanced geometric properties that are difficult to obtain manually.

The colors indicated in Tables 1 and 2 relate the groups of profiles that were compared, taking into account the similarity by area and by moment of inertia.

For example, the blue color relates the 3" x 6.10 laminated profile to 5 UDCS profiles: 100 x 40 x 2.65, 100 x 40 x 4.75, 100 x 50 x 2.25, 100 x 50 x 4.25 and 100 x 75 x 3.35.

Table 1:P Geometric properties of the laminated profiles.

| Laminated Profile | A ($cm^2$) | $I_x$ ($cm^4$) | Iy ($cm^4$) | It ($cm^4$) | xg (cm) | $R_o$(cm) | Cw ($cm^6$) |
|---|---|---|---|---|---|---|---|
| **3''x6,10** | 7,78 | 68,90 | 8,20 | 0,96 | 1,11 | 14,0 | 65,4 |
| **4''x8,04** | 10,10 | 159,50 | 13,10 | 1,43 | 1,16 | 4,1 | 193,0 |
| **6''x12,20** | 15,50 | 546,00 | 28,80 | 2,74 | 1,30 | 19,0 | 1040,0 |

Research source: The author.

Table 2:P Geometric properties of UDC profiles.

| UDCS Profile | A ($cm^2$) | $I_x$ ($cm^4$) | Iy ($cm^4$) | It ($cm^4$) | xg (cm) | $R_o$(cm) | Cw ($cm^6$) |
|---|---|---|---|---|---|---|---|
| **U 100x40x2,65** | 3,88 | 57,7 | 5,84 | 0,06 | -0,99 | 4,6 | 94,90 |
| **U 100x40x4,75** | 7,81 | 109,4 | 11,11 | 0,58 | -1,1 | 4,5 | 158,80 |
| **U 100x40x6,30** | 10,03 | 133,3 | 13,80 | 1,32 | -1,17 | 4,4 | 178,08 |
| **U 100x50x2,25** | 4,33 | 68,5 | 10,85 | 0,07 | -1,35 | 5,3 | 175,69 |
| **U 100x50x4,25** | 7,91 | 118,9 | 19,09 | 0,47 | -1,45 | 5,2 | 283,21 |
| **U 100x50x6,30** | 11,29 | 161,0 | 26,28 | 1,49 | -1,55 | 5,1 | 348,67 |
| **U 100x75x3,35** | 8,01 | 136,5 | 47,5 | 0,30 | -2,42 | 7,2 | 749,36 |
| **U 100x75x4,25** | 10,03 | 167,6 | 58,82 | 0,60 | -2,46 | 7,1 | 897,07 |
| **U 100x75x6,30** | 14,44 | 230,3 | 82,41 | 1,90 | -2,57 | 7,0 | 1153,50 |
| **U 125x50x3,35** | 7,17 | 164,6 | 16,68 | 0,27 | -1,26 | 5,8 | 415,60 |
| **U 125x50x4,75** | 9,94 | 221,6 | 22,57 | 0,74 | -1,32 | 5,7 | 532,16 |
| **U 125x75x6,30** | 16,02 | 388,1 | 89,70 | 2,11 | -2,35 | 7,4 | 2025,90 |
| **U 150X50X8,00** | 17,89 | 518,5 | 36,23 | 3,80 | -1,35 | 6,1 | 1108,60 |
| **U 150X75X6,30** | 17,59 | 595,9 | 95,69 | 2,32 | -2,17 | 7,8 | 3201,50 |
| **U 200x75x4,75** | 15,88 | 924,0 | 81,85 | 1,19 | -4,14 | 9,0 | 5304,40 |

Research source: The author.

## RESULTS AND DISCUSSIONS

With the routine developed in the Excel software, the flexural strengths in the x and y axes were calculated for the chosen rolled profiles, these results are shown in Table 3.

Table 3A: Cold rolled profiles resistant moments.

| Profile | MRx(kN.cm) | MRy(kN.cm) |
|---|---|---|
| **3''x6,10** | 324,92 | 113,18 |
| **4''x8,04** | 526,39 | 157,16 |
| **6''x12,20** | 1913,64 | 278,18 |

Research source: The author.

To design the flexural strength of the bent sheet metal profiles, the calculations were made following the calculation procedures of the respective standard. These results are shown in Table 4.

Table 4A: Resistant moments of UDC profiles.

| Profile | MRx (kN.cm) | MRy (kN.cm) |
|---|---|---|
| U 100x40x2,65 | 113,65 | 45,51 |
| U 100x40x4,75 | 304,23 | 83,65 |
| U 100x40x6,30 | 442,57 | 106,59 |
| U 100x50x2,25 | 131,77 | 42,49 |
| U 100x50x4,25 | 359,94 | 116,1 |
| U 100x50x6,30 | 580,22 | 166 |
| U 100x75x3,35 | 404,76 | 136,48 |
| U 100x75x4,25 | 580,22 | 229,85 |
| U 100x75x6,30 | 920,89 | 361,79 |
| U 125x50x3,35 | 299,78 | 92,32 |
| U 125x50x4,75 | 511,4 | 133,99 |
| U 125x75x6,30 | 1195,13 | 380,02 |
| U 150X50X8,00 | 1508,31 | 216,92 |
| U 150X75X6,30 | 1733,63 | 391,56 |
| U 200x75x4,75 | 1950,48 | 312,16 |

Research source: The author.

Two parameters were taken into consideration: area and moment of inertia (in relation to the axis of symmetry). Thus, for a laminated profile, three UDCS profiles were determined to have areas close to each other and two to have moments of inertia close to the respective reference laminated profile.

For the 3" x 6.10 U laminated profile, some analyses were performed. As for the area**,** Table 5 shows the preponderant results of cold-formed profiles with areas close to the laminated profile.

Table 5: Resistant moments, area and moment of inertia.

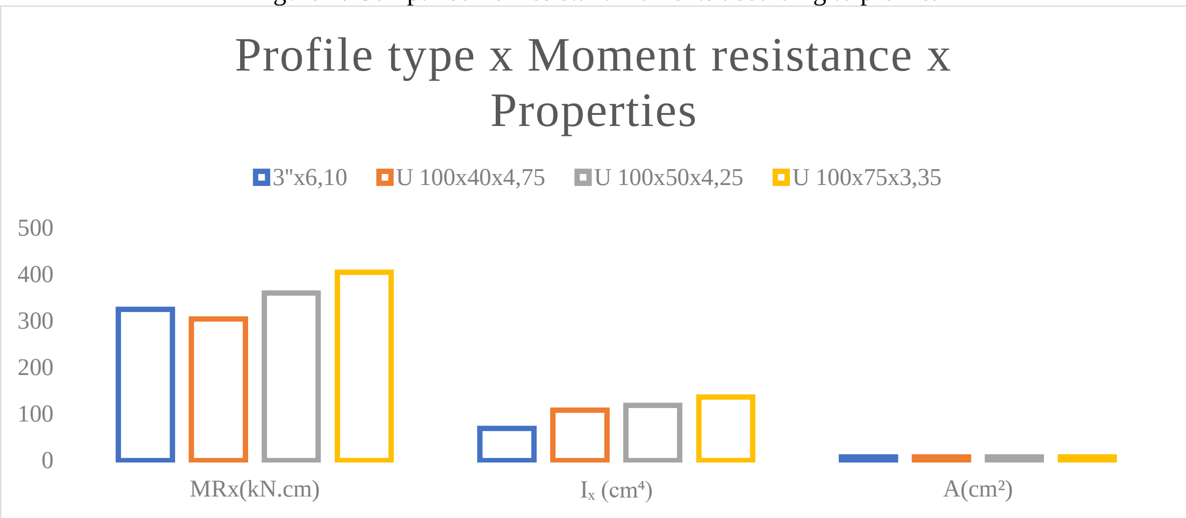
| Profile Type | Profile | MRx(kN.cm) | $I_x$ ($cm^4$) | A($cm^2$) |
|---|---|---|---|---|
| **Laminate** | 3"x6,10 | 324,92 | 68,90 | 7,78 |
| **Simple UDC** | U 100x40x4,75 | 304,23 | 108,44 | 7,80 |
| | U 100x50x4,25 | 359,94 | 118,86 | 7,90 |
| | U 100x75x3,35 | 404,76 | 136,48 | 8,00 |

Research source: The author.

Analyzing the data presented in Table 5, it is noted that when with approximately equal areas, the preponderant factor for determining resistance is the moment of inertia. Thus, when the moment of inertia of this bent sheet profile is up to 40% greater than a rolled one, the rolled profile has a higher flexural strength, for all the other profiles tested values above 40% of the moment of inertia of the rolled stock, they have lower resistance of the rolled in relation to those of bent sheet.

Analyzing Figure 2, it is observed that, for nearby areas and distinct moments of inertia, there is little variation in resistance. Which leads us to question the advantage of using the laminated profile.

Figure 2: Comparison of resistant moments according to profile.




Research source: The author.

Table 6 shows that the folded sheet metal profiles have a lower cost/kg ratio when compared to the rolled sheet for very similar strength values.

Table 6: Resistant moments and cost/kg.

| Guy | Profile | R$/kg | MRx(kN.cm) |
|---|---|---|---|
| **Laminate** | 3"x6,10 | 5,16 | 324,92 |
| **Simple UDC** | U 100x40x4,75 | 4,27 | 304,23 |
| | U 100x50x4,25 | 4,27 | 359,94 |
| | U 100x75x3,35 | 4,48 | 404,76 |

Research source: The author.

For the same laminated profile above, some UDCS profiles were also analyzed regarding the moment of inertia.  In table 7, the results are when the moment of inertia of the rolled profile is considered to be close to the moment of the folded sheet profiles.

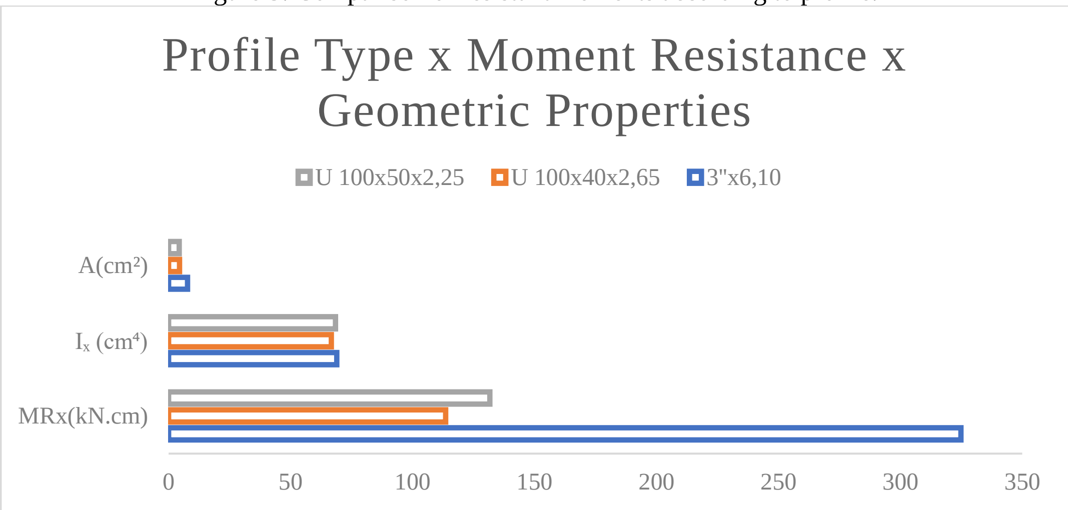
Table 7:Resistant moments, area and moment of inertia.

| Profile Type | Profile | MRx(kN.cm) | $I_x$ (cm$^4$) | A(cm$^2$) |
|---|---|---|---|---|
| **Laminate** | 3"x6,10 | 324,92 | 68,90 | 7,78 |
| **Simple UDC** | U 100x40x2,65 | 113,65 | 66,75 | 4,54 |
| | U 100x50x2,25 | 131,77 | 68,47 | 4,33 |

Research source: The author.

Table 7 shows that, for profiles with close moments of inertia, the geometric properties have a significant influence, because when the cross-sectional area of the rolled profile is approximately 40% smaller, the resistance becomes about 60% smaller.

Figure 3: Comparison of resistant moments according to profile.




Research source: The author.

When evaluating nearby moments of inertia and nearby areas, the moment does not vary significantly, as shown in Figure 3. However, when the area is significantly smaller, the resistance decreases considerably, so the desired resistance is not met.

Table 8: Resistant moments and cost/kg.

| Guy | Profile | R$/kg | MRx(kN.cm) |
|---|---|---|---|
| **Laminate** | 3"x6,10 | 5,16 | 324,92 |
| **Simple UDC** | U 100x40x2,65 | 4,60 | 113,65 |
| | U 100x50x2,25 | 4,47 | 131,77 |

Research source: The author.

Analyzing Table 8, it can be seen that the cost and weight of bent sheet profiles are much lower than the rolled one, but as it has a much lower resistance, it could not replace a rolled profile.

For the laminated profile U 4" x 8.04, some analyses were made. As for the area, Table 9 shows the preponderant results of the cold-formed profiles with areas close to the 4" x 8.04 U laminated profile.

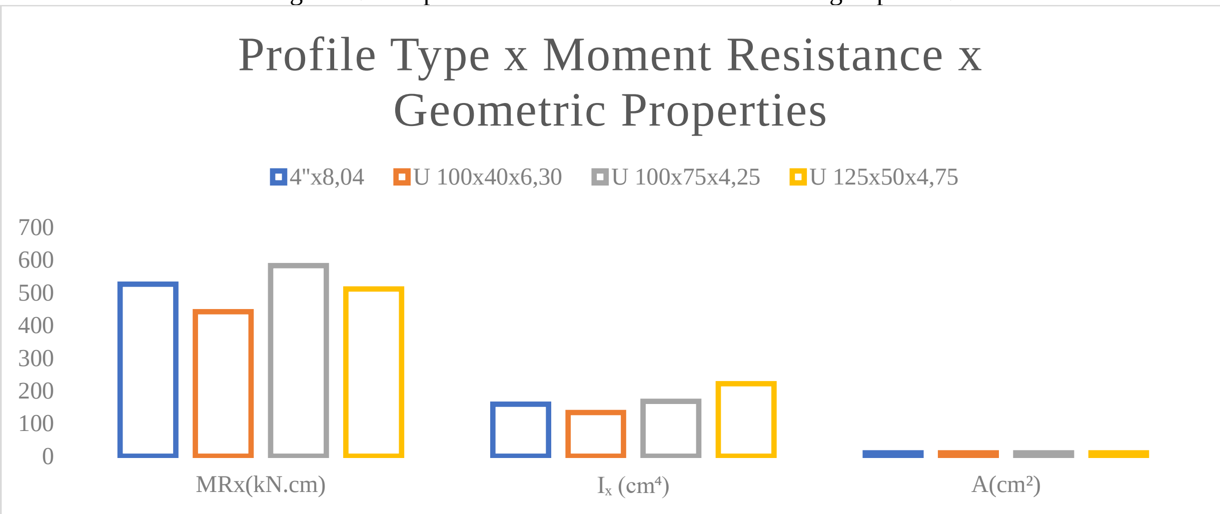
Table 9: Resistant moments, area and moment of inertia.

| Profile Type | Profile | MRx(kN.cm) | $I_x$ (cm⁴) | A(cm²) |
|---|---|---|---|---|
| Laminate | 4"x8,04 | 526,39 | 159,50 | 10,10 |
| Simple UDC | U 100x40x6,30 | 442,57 | 133,31 | 10,03 |
| | U 100x75x4,25 | 582,75 | 167,60 | 10,03 |
| | U 125x50x4,75 | 511,4 | 221,56 | 9,94 |

Research source: The author.

Analyzing profiles with a similar area, shown in Table 9, it is found that folded sheet metal profiles that have a lower moment of inertia have lower resistance. Thus, when the moment of inertia of this bent sheet metal profile is about 5 % higher than a rolled one, the bent sheet metal profile has a higher flexural strength. It is also noted that when there is a variation in the dimensions of the web height and the width of the table, there is a variation in the flexural strength, but this variation was not evaluated in this study.

Figure 4: Comparison of resistant moments according to profile.




Research source: The author.

Analyzing Figure 4 above, it is observed that, for nearby areas and different moments, there is little variation in resistance.

Table 10: Resistant moments and cost/kg.

| Guy | Profile | R$/kg | MRx(kN.cm) |
|---|---|---|---|
| **Laminate** | 4"x8,04 | 4,81 | 526,39 |
| **Simple UDC** | U 100x40x6,30 | 4,18 | 442,57 |
| | U 100x75x4,25 | 4,78 | 582,75 |
| | U 125x50x4,75 | 5,06 | 511,4 |

Research source: The author.

Table 10 shows that only one UDCS profile can overcome the laminate strength and present a very close price/kg ratio.

Comparisons were also made with the 4"x8.04 laminated profile and some UDCS profiles, comparing them as to the moment of inertia.

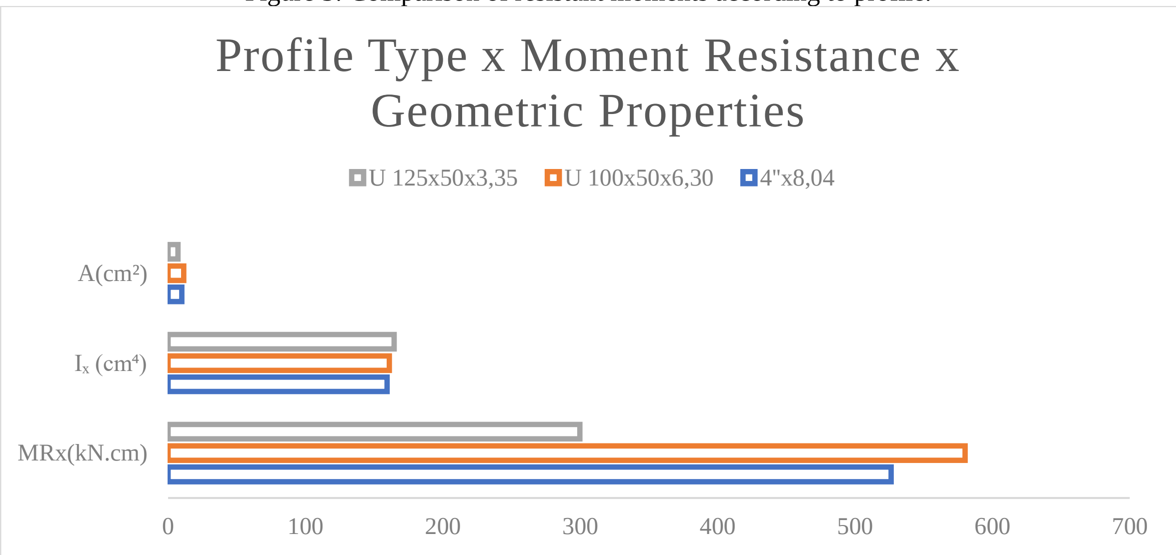
Table 11: Resistant moments, area and moment of inertia.

| Profile Type | Profile | MRx(kN.cm) | $I_x$ (cm⁴) | A(cm²) |
|---|---|---|---|---|
| **Laminate** | 4"x8,04 | 526,39 | 159,50 | 10,10 |
| **Simple UDC** | U 100x50x6,30 | 580,22 | 161,01 | 11,29 |
| | U 125x50x3,35 | 299,78 | 164,58 | 7,20 |

Research source: The author.

With regard to close moments of inertia, it is noted that if the area of the UDC is smaller than that of the laminated profile, there is a lower resistance. If the area is larger, the resistance is also larger, according to Table 11.

Figure 5: Comparison of resistant moments according to profile.




Research source: The author.

In Figure 5, it can be seen that when moments of inertia close and areas are evaluated, the moment does not vary significantly, but when the area is significantly smaller, the resistance decreases considerably.

Table 12A: Resistant moments and cost/kg.

| Guy | Profile | R$/kg | MRx(kN.cm) |
|---|---|---|---|
| **Laminate** | 4"x8,04 | 4,81 | 526,39 |
| **Simple UDC** | U 100x50x6,30 | 4,52 | 580,22 |
| | U 125x50x3,35 | 4,46 | 299,78 |

Research source: The author.

According to Table 12, the UDCS 100 x 50 x 6.30 profile presents a better cost-benefit ratio, since it is lighter, less expensive and still has a higher resistance when compared to the laminate.

For the 6" x 12.20 U laminated profile, some analyses were made. As for the area, the data are shown in Table 13.

Table 13: Resistant moments, area and moment of inertia.

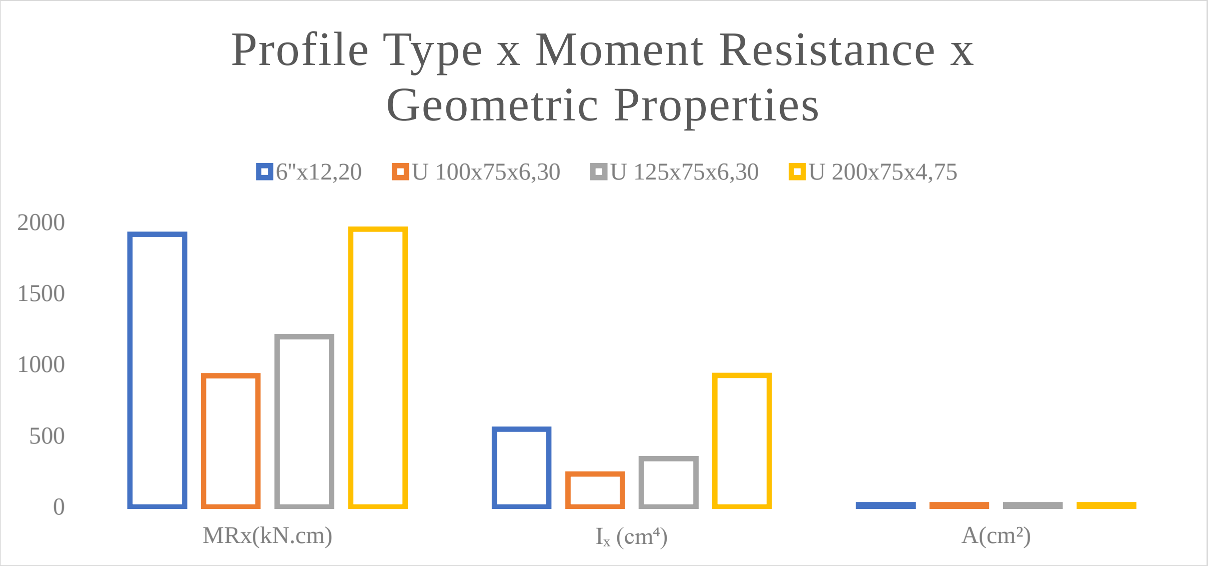
| Profile Type | **Profile** | **MRx(kN.cm)** | **$I_x$ (cm⁴)** | **A(cm²)** |
|---|---|---|---|---|
| Laminate | 6"x12,20 | 1913,64 | 546,00 | 15,50 |
| Simple UDC | U 100x75x6,30 | 920,89 | 230,25 | 14,44 |
| | U 125x75x6,30 | 1195,13 | 338,06 | 16,02 |
| | U 200x75x4,75 | 1950,48 | 923,97 | 15,88 |

Research source: The author.

Analyzing Table 13, it can be seen that, for areas close to the rolled profile in relation to the folded sheet profile, when the moment of inertia is lower, the resistance is also lower. The UDCS profile only overcomes the laminate strength if the moment of inertia is about 70% greater.

Observing Table 13 and Figure 6, it can be seen that the area of the profiles presents a small variation, so the U profile 200 x 75 x 4.75, which has the closest area, presents a very coherent resistance, showing that, for nearby areas and different moments, there is little variation in resistance.

Figure 6: Comparison of resistant moments according to profile.




Research source: The author.

Table 14 shows that all folded sheet metal profiles have a lower cost/kg than the rolled one, but only one reaches a similar strength.

Table 14A: Resistant moments and cost/kg.

| Guy | Profile | R$/kg | MRx(kN.cm) |
|---|---|---|---|
| **Laminate** | 6"x12,20 | 4,81 | 1913,64 |
| **Simple UDC** | U 100x75x6,30 | 4,32 | 920,89 |
| | U 125x75x6,30 | 4,42 | 1195,13 |
| | U 200x75x4,75 | 4,28 | 1950,48 |

Research source: The author.

For the same laminated profile above, some UDCS profiles were also analyzed for the moment of inertia.

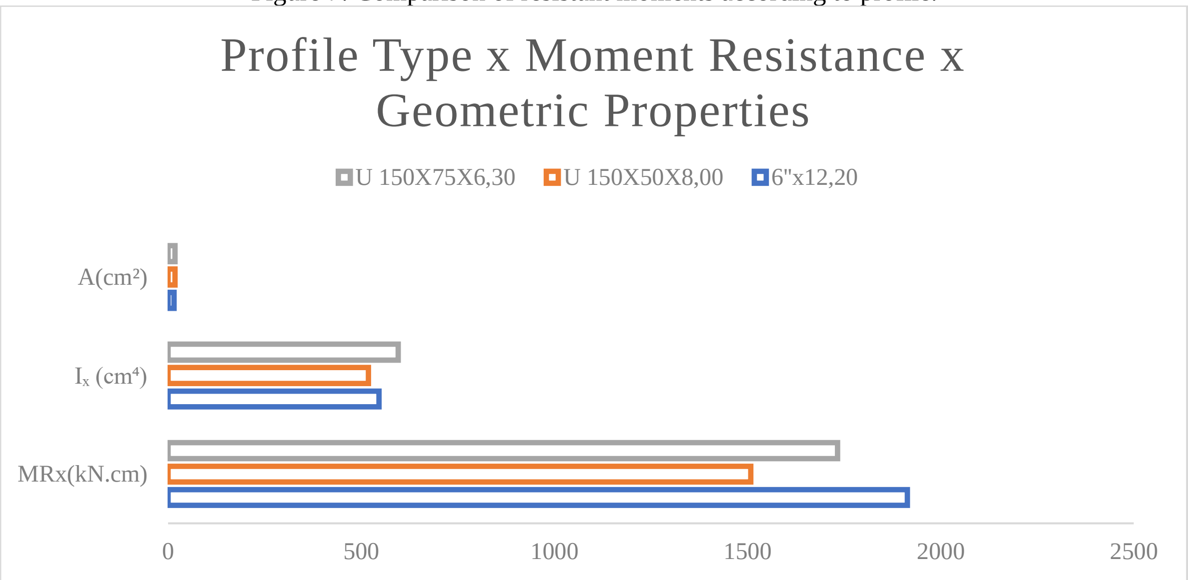
Table 15: Resistant moments, area and moment of inertia.

| Profile Type | Profile | MRx(kN.cm) | $I_x(cm^4)$ | $A(cm^2)$ |
|---|---|---|---|---|
| **Laminate** | 6"x12,20 | 1913,64 | 546,00 | 15,50 |
| **Simple UDC** | U 150X50X8,00 | 1508,31 | 518,48 | 17,89 |
| | U 150X75X6,30 | 1733,63 | 595,93 | 17,59 |

Research source: The author.

The compared areas present a reasonable proximity, as shown in table 15, indicating that when the analyzed areas are close and the moments of inertia are also close, the resistance is lower in the UDCS. However, when the moment of inertia is 8% greater, it does not have a significant influence on resistance.

Figure 7: Comparison of resistant moments according to profile.




Research source: The author.

When evaluating nearby moments of inertia and nearby areas, the moment does not vary significantly. This behavior is observed in Figure 7.

Table 16A: Resistant moments and cost/kg.

| Kind | Profile | R$/kg | MRx(kN.cm) |
|---|---|---|---|
| **Laminate** | 6" x 12,20 | 4,81 | 1913,64 |
| **Simple UDC** | U 150 x 50 x 8.00 | 4,07 | 1508,31 |
| | U 150 x 75 x 6.30 | 3,62 | 1733,63 |

Research source: The author.

Table 16 shows that the folded sheet profiles studied do not reach the strength of the rolled profile, but as the strengths are close depending on the use, it is possible to analyze the feasibility of its use.

Therefore, for bent sheet metal profiles with areas very close to the rolled sections, the moment of inertia is the preponderant factor, since, if the moment of inertia of the folded sheet profile is greater than that of the rolled sheet, it presents variations in the resistances that are not very discrepancies, and is therefore not so different in relation to the resistance of the laminate.

When the moment of inertia is lower, there are variations in resistance as well, but they are also not considerable.

In the case of close moments of inertia, the influencing factor is the area, and this is relevant, because the smaller the area of the folded sheet profile in relation to the laminate, the resistance of the folded sheet profile drastically reduces, a reduction in resistance that can be up to 60% lower in the folded sheet profile when the area of this is about 40% smaller in relation to the laminate.

In these cases, we can notice that the simple modifications of the geometric properties of the analyzed sections promoted a considerable increase in the final strength of the sets when submitted to simple bending.

## CONCLUSION

When we analyze profiles that have close areas and moments of inertia greater than the rolled ones, the resistances are equivalent and the feasibility of using the folded sheet profile is greater, since it is lighter and has a lower cost.

It is evident that bent sheet metal profiles that have a moment of inertia equivalent to that of the rolled profile, but a much smaller area, do not reach the desired strength. Although the cost is considerably lower, it is not possible to replace it. However, it was not possible to establish a pattern of the Area x Moment of Inertia x Resistant Moment relationship.

Due to most of the folded sheet profiles studied above, they have a lower cost when compared to the laminate, in addition to the lower weight, facilitating transport and assembly *on site*, these would have made their use feasible when compared to a laminated profile that has a close resistance.

For reasonable requesting moments (about 500kN.cm), most folded sheet metal profiles have a better cost-benefit ratio to be used instead of laminate, but when analyzed at higher moments (about

1900kN.cm) the Simple UDC profiles cannot overcome the resistance of the rolled profiles, despite having a close resistance. Thus, bent sheet profiles have an excellent cost-benefit ratio in relation to the rolled profile depending on the request, making it necessary to analyze for each project whether replacement is feasible.

It is known that, according to the literature, the greater the moment of inertia, the greater the resistant moment of the profile, but in this work this finding was not made, for all the profiles studied using both 8800:2008 and 14762:2010 the profiles that presented close moments of inertia were the ones that presented the most discrepancy in the resistances. Thus, it is suggested that some more studies be carried out in order to verify if this discrepancy occurs in other cases, and if so, to suggest a change in order to make the two standards compatible.

It is thus concluded that it is inconclusive to state that one norm can be compared to another.

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