Niobium Nb

HIGH STRENGTH STEEL - A SOLUTION FOR LEAN DESIGN IN INDUSTRIAL BUILDINGS

CBMM DESULPHURIZATION PLANT II CASE STUDY

Niobium microalloyed high strength steels are widely used in various structural applications. They improve strength and toughness simultaneously, as well as the elongation and weldability of the frame set. The Desulphurization Plant II, an industrial building located at CBMM's Plant in Araxá, Brazil, is one example of how the use of ASTM A572 Gr. 50, equivalent to Q355 of the Chinese standard GB / T 1591-2018, took advantage of these properties. This resulted with a 22% reduction in raw material consumption, when compared to using ASTM A36, equivalent to Q235 of the Chinese standard GB / T 700-2006.

This leaflet aims to show the benefits of using ASTM A572 Gr. 50 instead of ASTM A36 and consequently Q355 instead of Q235. It shows the main calculations for a single beam, under bending and a single column, under compression, which have been considered as examples of the application and use of the high strength steel concept. The selected beam is located on one of the various operational floors of the building. The selected column is in between floors, in order to simplify the calculations, considering it is pinned by both ends, without any lateral load. The beam and the column considered within this leaflet are submitted to the same projected loads intended for the building.

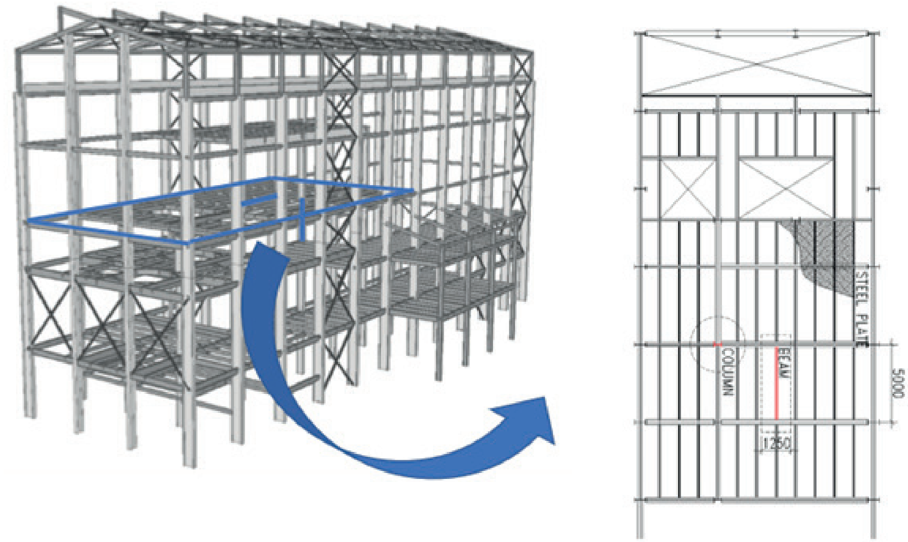


Figure 1: Desulphurization Plant II of CBMM's plant in Araxá. Indication of the beam and the column that have been considered for structural weight calculations according with respective mechanical strength.

LOAD CONDITIONS AND COMBINATIONS

Table 1: Loads applied to the building components of Desulphurization Plant II.
All calculations consider EN1993-1-1 and correlated standards.

DEAD LOADS (PERMANENT)	
Self-Weight-Beam	0.20 kN/m
Self-Weight-Column	0.86 kN/m
Floor Steel Plate	0.82 kN/m
LIVE LOAD (VARIABLE)	
Minimum Design Live Load	12.5 kN/m^2
COMBINATION OF ACTIONS	
ϒG Partial Factor for Permanent Loads	1.35
ϒQ Partial Factor for Variable Loads	1.50
DESIGN LOADS: Beam	
Distribution Loads	0.28 + 0.82 x 1.25 = 1.38 kN/m
Live Load	12.5 x 1.25 = 15.6 kN/m
Combined Loads	1.35 x 1.31 + 1.50 x 15.6 = 25.2 kN/m
DESIGN LOADS: Column	
Permanent Load	0.86 x 5.3 + 0.82 x (6.5 x 7.5) = 44.5 kN
Live Load	12.5 x (6.5 x 7.5) = 609.4 kN
Combined Loads	1.35 x 44.5 + 1.50 x 609.4 = 976 kN

REDUCTION OF WEIGHT AND COSTS OF BEAM BY USING ASTM A572 GR. 50 INSTEAD OF ASTM A36 STEEL

REQUIRED BENDING MOMENT AND SHEAR

Beams are usually the main structural element for floor systems in industrial buildings. According to the size, these beams can be hot rolled and, for the larger dimensions, fabricated sections are used. The Desulphurization Plant II has several platform levels in order to support personnel, operational processes and equipment for the important operation of reducing sulphur content of the niobium ferroalloy. The steel ASTM A36 (fy = 250 MPa) equivalent to the Chinese Q235, was used for angles in the bracing system and ASTM A572 Gr. 50 (fy = 345 MPa) equivalent to the Chinese Q355 for all other elements, including steel beams in floor systems and columns. The beams have full lateral restraint due to the floor system so lateral torsional instability will not occur.

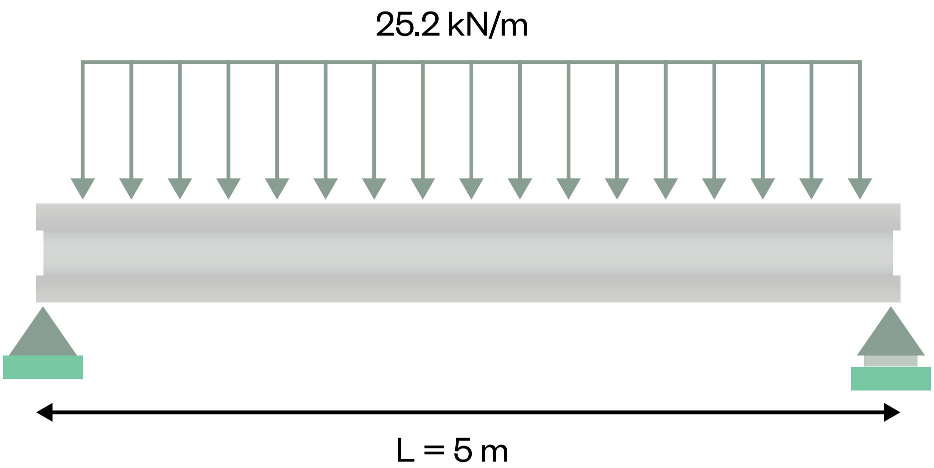
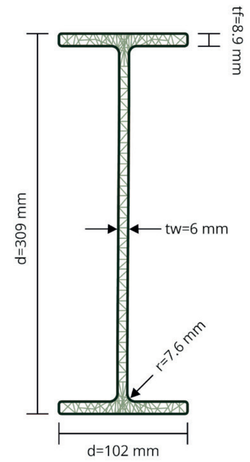


Figure 2: Distributed design load applied to the considered beam of the Desulphurization Plant II.

The geometric characteristics and design verification of the highlighted beam, located in the floor system of the building are based on EN 1993-1-1 (Eurocode 3). It was considered best to use two different steel grades, calculating the resulting beam dimensions and weight necessary to support the loads. The final weight savings and design parameters are demonstrated in Table 2.

When using the high strength steel, there was 26% weight reduction, corresponding to 7.3 kg/m less for this component.

Table 2: Comparison of the deflection and linear weight of a beam submitted to the same load but designed using different steel grades: ASTM A36 and ASTM A572 Gr. 50.

<table>
<tr><th>ATSM 36 (W310x28.3)</th><th>ATSM A572 Gr. 50 (W310x21)</th></tr>
<tr><td>Linear Weight
28.3 kg/m</td><td>Linear Weight
21.0 kg/m</td></tr>
<tr><td colspan="2">26% weight reduction when using ASTM A572 Gr. 50</td></tr>
<tr><td>


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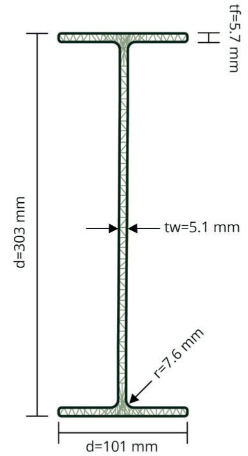


</td></tr>
<tr><td>I_y = 5,500 cm^4; $W_{pl,y}$ = 399.6 cm^3; A = 36.5 cm^2</td><td>I_y = 3,376 cm^4; $W_{pl,y}$ = 279.6 cm^3; A = 27.2 cm^2</td></tr>
</table>

Section classification $\varepsilon = \sqrt{235/250} = 0.97$ • For flange $c_f/t_f = 4.1$ $9\ \varepsilon = 8.7 > 4.1$ ∴ Class 1 (plastic) •For web $c_w/t_w = 61.6$ $72\ \varepsilon = 69.8 > 61.6$ ∴ Class 1 (plastic)	Section classification $\varepsilon = \sqrt{235/345} = 0.83$ • For flange $c_f/t_f = 6.3$ $9\ \varepsilon = 7.5 > 6.3$ ∴ Class 1 (plastic) •For web $c_w/t_w = 52.4$ $72\ \varepsilon = 59.8 > 52.4$ ∴ Class 1 (plastic)
Bending resistance $M_{pl,y,Rd} = \frac{W_{pl,y} x f_y}{Y_{MO}} = \frac{399627x250}{1.0} = 99.9\ kNm$	Bending resistance $M_{pl,y,Rd} = \frac{W_{pl,y} x f_y}{Y_{MO}} = \frac{279570x345}{1.0} = 96.5\ kNm$
Shear resistance • Shear area $A_v = A - 2bt_f + (t_w + 2r)\ t_f$ $= 3650 - 2x102x8.9 + (6.0 + 2.12)8.9$ $= 2{,}101.4\ mm^2 \cong 21.0\ cm^2$ • Shear strength $V_{pl,Rd} = \frac{A_v x (f_y / \sqrt{3})}{Y_{MO}} \cong \frac{2{,}100x\left(\frac{250}{\sqrt{3}}\right)}{1.0}$ $\cong 303.1\ kN$	Shear resistance • Shear area $A_v = A - 2bt_f + (t_w + 2r)\ t_f$ $= 2720 - 2x101x5.7 + (5.1 + 2x12)5.7$ $= 1{,}734.5\ mm^2 \cong 17.3\ cm^2$ • Shear strength $V_{pl,Rd} = \frac{A_v x (f_y / \sqrt{3})}{Y_{MO}} \cong \frac{1{,}735x\left(\frac{345}{\sqrt{3}}\right)}{1.0}$ $\cong 345.6\ kN$
Deflection verification $\delta_{max,midspan} = \frac{5}{384} x \frac{F_{Ed} x L^4}{EI_y}$ $= \frac{5}{384} x \frac{12.5x5000^4}{210000x5500.10^4}$ $\delta_{max,midspan} = 8.8\ mm < 13.9\ mm$ $= span/360$	Deflection verification $\delta_{max,midspan} = \frac{5}{384} x \frac{F_{Ed} x L^4}{EI_y}$ $= \frac{5}{384} x \frac{12.5x5000^4}{210000x3776.10^4}$ $\delta_{max,midspan} = 12.8\ mm < 13.9\ mm$ $= span/360$

REDUCTION OF WEIGHT AND COSTS OF THE COLUMN USING ASTM A572 GR. 50 INSTEAD OF ASTM A36 STEEL

The column is pinned without any lateral movement.

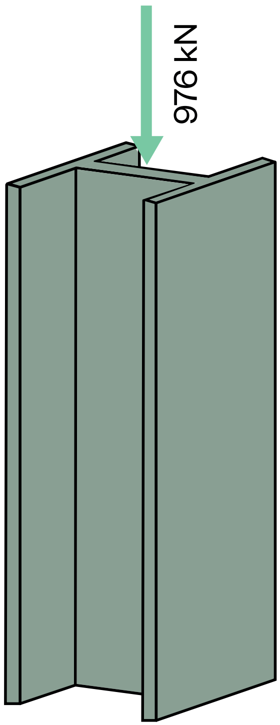
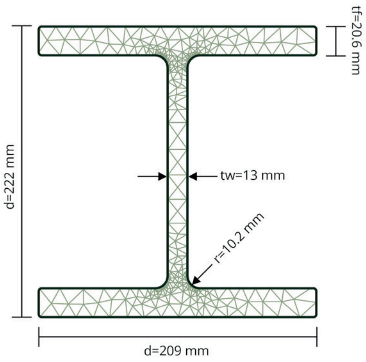
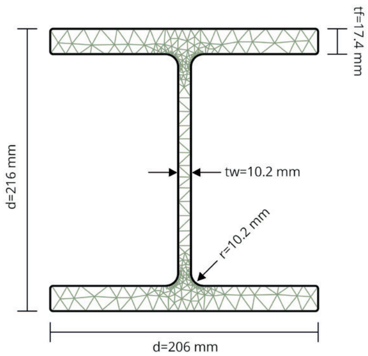


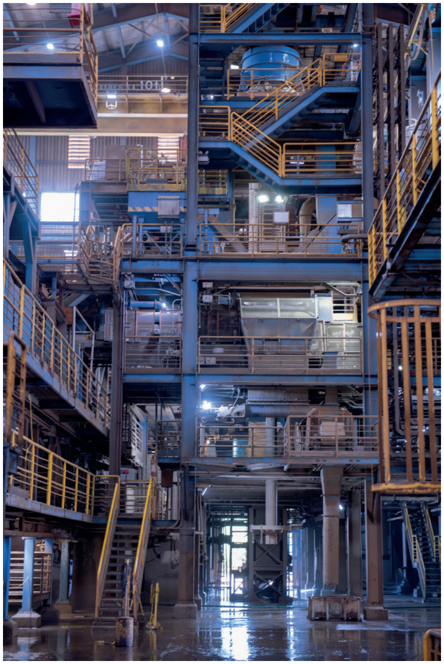
Figure 3: Concentrated design load applied to the corresponding column of the Desulphurization Plant II.

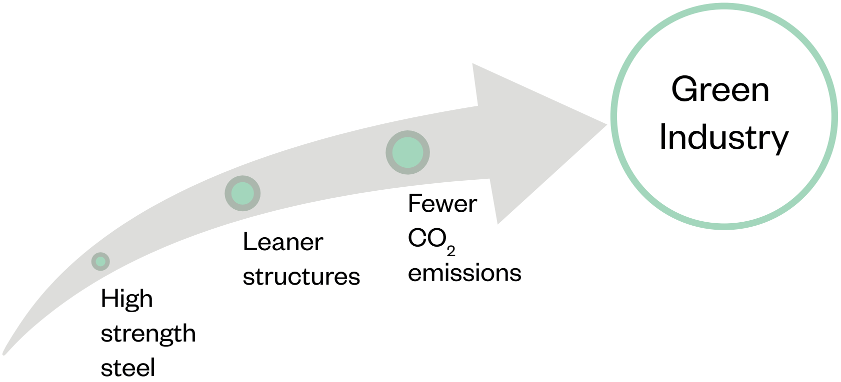
For the column, when using the high strength steel, there was 17% weight reduction, corresponding to 15 kg/m less for this component.

Table 3: Comparison of the buckling and linear weight of a column submitted to the same load but designed using different steel grades: ASTM A36 and ASTM Gr. 50

ASTM A36 (W200 x 86 H)	ASTM A572 Gr. 50 (W200 x 71 H)
Linear Weight 86 kg/m	Linear Weight 71 kg/m
17% weight reduction when using ASTM A572 Gr. 50	
	
A = 110.9 cm² $I_z = 3139\ cm^4$; $i_z = 5.32$ cm Second moment of inertia; radius of gyration	A = 91.0 cm² $I_z = 2537\ cm^4$; $i_z = 5.28$ cm Second moment of inertia; radius of gyration
Resistance of cross section (compression) $N_{c,Rd} = \frac{A.f_y}{Y_{M0}} = \frac{11090x250}{1.0} \cong 2{,}772.5$ kN	Resistance of cross section (compression) $N_{c,Rd} = \frac{A.f_y}{Y_{M0}} = \frac{9100x345}{1.0} \cong 3{,}139.5$ kN
Flexural buckling resistance $N_{b,z,Rd} = X_z \frac{A.f_y}{Y_{M0}} = 0.80 \frac{11090x250}{1.0} \cong 2{,}772.5$ kN	Flexural buckling resistance $N_{b,z,Rd} = X_z \frac{A.f_y}{Y_{M0}} = 0.87 \frac{9100x345}{1.0} \cong 2{,}731$kN

REDUCTION OF STRUCTURE'S COSTS BY USING HIGH STRENGTH STEEL





Considering the entire structure of the CBMM Desulphurization Plant II, it represented around 362,000 kg when designed with ASTM A36, but there was a total weight reduction of 22% when using ASTM A572 Gr. 50 instead. The price of these materials fluctuate according to market conditions, but currently, due to the presence of numerous, good quality suppliers, the price can be considered almost the same, being just a little higher for ASTM A572 Gr. 50. In this example, the use of the high strength steel resulted in costs savings directly proportional to the structure weight reduction, that represented 17% less in the building structure costs. In addition, this weight reduction also contributes to reductions in the foundations, welding consumables and transportation. Due to using less steel, there was a reduction around 140 t of CO_2 emissions, representing 22% of total emissions for the steel structure. This reduction of CO_2 emissions is totally in line with dematerialization, a very important concept used in construction in order to reach carbon neutrality targets.

EFFECT OF LOAD ON BUCKLING LENGTH OF COLUMNS

Another advantage of using high strength steels is the opportunity to adopt more functional project designs. When long span ranges and high building heights are necessary for the installation and proper operation of industrial equipment, high strength steels can be a solution, as exemplified in Figure 4. Once the height between each floor of this building was higher than 5 m, there was a clear benefit for the critical buckling load when using ASTM A572 Gr. 50 when compared to ASTM A36.

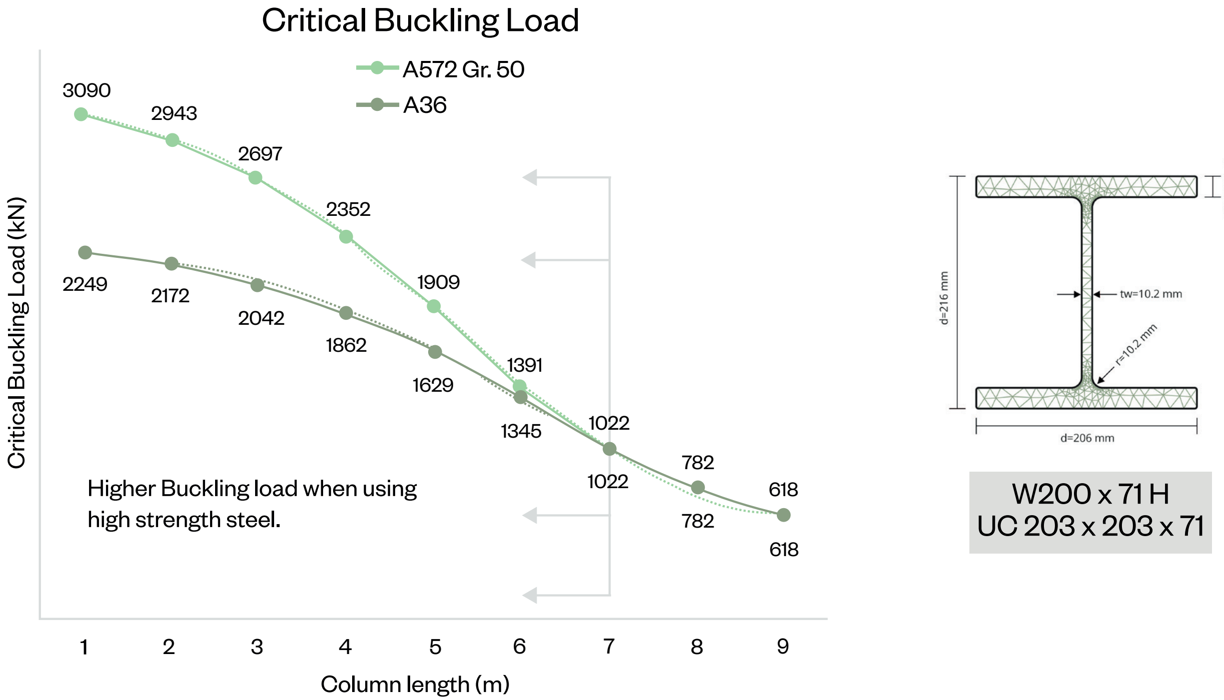


Figure 4: Ultimate load for columns made with ASTM A36 and ASTM A572 Gr. 50

For more information contact CBMM technical experts who are available to advise on how the use of high strength steel beams and columns can help you reduce overall construction costs and reduce the environmental footprint of your projects as well. Using high strength steel allows you to adopt projects with much leaner and safer structures.

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World leader in the production and commercialization of Niobium products, CBMM has customers in over 40 countries. With headquarters in Brazil and offices and subsidiaries in China, Netherlands, Singapore, Switzerland and the United States, the company supplies products and cutting-edge technology to the infrastructure, mobility, aerospace and energy sectors. CBMM was founded in 1955 in Araxá, Minas Gerais, and relies on a strong technology program to increase Niobium applications, growing and diversifying this market.

Further information can be obtained at **www.niobium.tech**