Impact of falling cables on bulkhead beams

Impacto da queda de cabos nas vigas das anteparas

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ABSTRACT
In this work, 585.95 meters long falling cable will be considered to compute its impact on a steel beam. The beam is lifted by two cranes and used as a shield to protect structures under the cables, during its installation. Using energy conservation concepts, it is possible to find the impact force on the beam, and, with that, to design the ideal steel cross section to support such impact. A model was also developed using the STRAP software, via Finite Element Method, to perform a more refined analysis and check the design of the metal beam.

Keywords: Impact, Design, Steel beam.

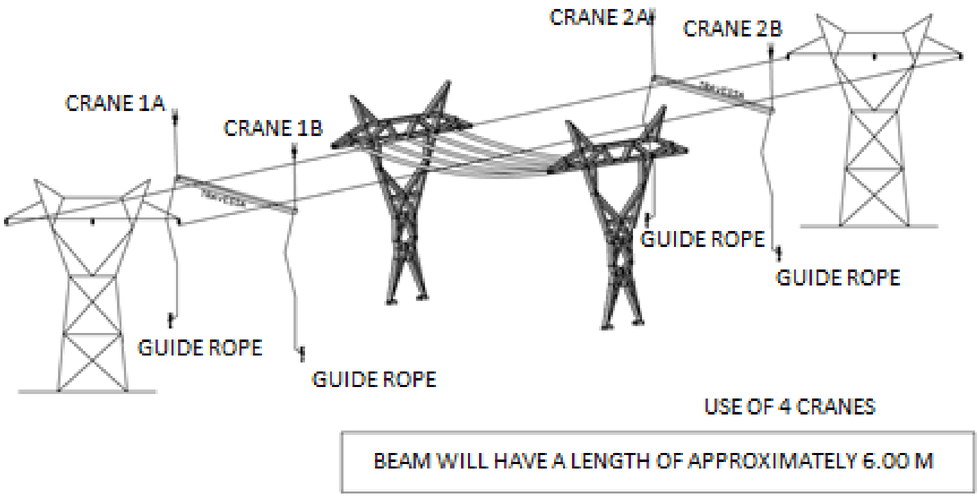
RESUMO
Neste trabalho, 585,95 metros de cabo em queda serão considerados para calcular o seu impacto sobre uma viga de aço. A viga é levantada por duas gruas e utilizada como escudo para proteger estruturas sob os cabos, durante a sua instalação. Utilizando conceitos de conservação de energia, é possível encontrar a força de impacto sobre a viga, e, com isso, conceber a secção transversal ideal de aço para suportar tal impacto. Foi também desenvolvido um modelo utilizando o software STRAP, através do Método dos Elementos Finitos, para realizar uma análise mais refinada e verificar o desenho da viga metálica.

Palavras-chave: Impacto, Desenho, Viga de aço.

1 INTRODUCTION

The impact between two structures can be classified into two types, an elastic collision, when kinetic energy is conserved, and an inelastic collision, when kinetic energy is partially dispersed (Souza, 2015). The impact of a cable on a structure that serves as a protective shield can be considered as an inelastic collision as the cable will remain stationary on the structure. Thus, using energy conservation, the gravitational potential energy of the cable before the fall is equal to the beam deformation energy after the impact. The deformation energy of the beam can be replaced by the deformation energy of a spring. With such deformation, it is possible to calculate the force produced by the spring (Brasil and Silva, 2015). This paper is on rigging and transportation. Stefano et. Al (2020) accomplished a complete analysis of the research in engineering of transport in the past fifty years.

Figure 1. Cable crossing scheme.

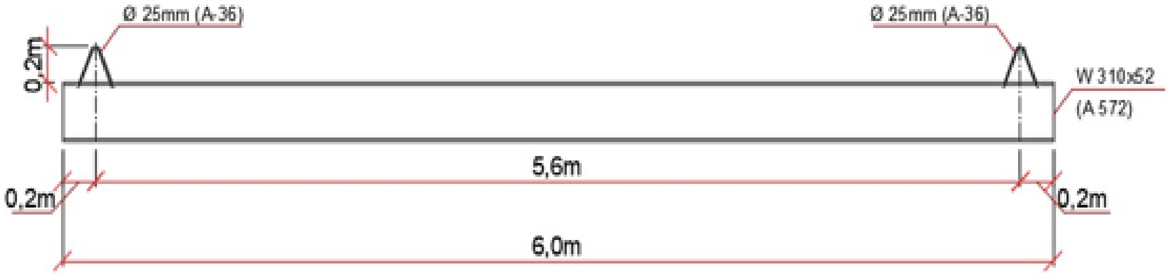


Source: Authors

2 GEOMETRY AND STRUCTURE PROPERTY

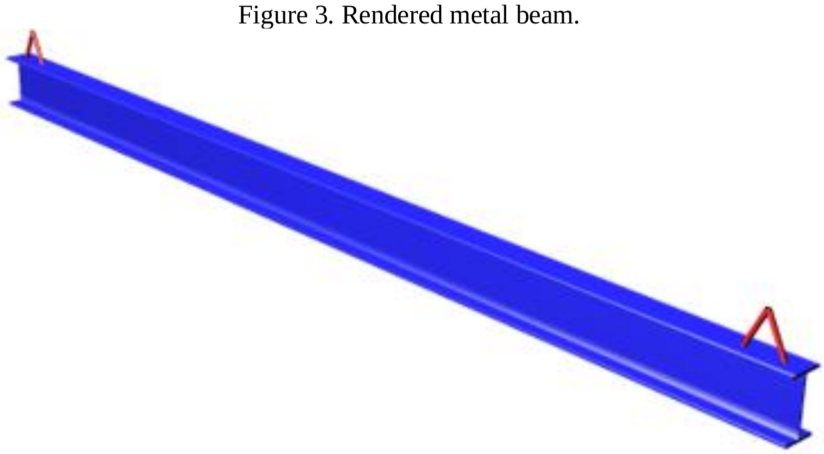
According to figure 1, the metal beam will be approximately 6 meters long. The section used for the metal beam is W 310 x 52.0 A572, with bars with diameters 25 mm (A-36) as handles for lifting. Figures 2 and 3 show the drawings of the metal beam and the rendered drawing elaborated in the finite element program STRAP model, used in the structural calculation.

Figure 2. Front view of metal beam.



Source: Authors

Figure 3. Rendered metal beam.



Source: Authors

The crane considered for lifting is the QY50K with a boom height of 40 m from the ground and an angle of 77.3 degrees.

3 CALCULATIONS OF LOADING

Modeling the cranes that will support the metal beam in the STRAP software, figure 4, it is possible to apply a unit load in the middle of the beam and, with the displacement found, determine the equivalent spring stiffness.

Figure 4. Crane Modeling.

Source: Authors

To calculate the impact force of the cable, we have that the gravitational potential energy is equal to the beam deformation energy (Brasil and Silva, 2015), thus:

$$mgh = \frac{1}{2}ku^2 \quad (1)$$

where m is the mass of the cables, g is the acceleration of gravity, h is the height of the cable in relation to the beam, k is the stiffness of the beam and u is the deformation of the beam.

As the impact force of the cable is given by:

$$F_{imp} = ku \quad (2)$$

We have that the impact force can be written as:

$$F_{imp} = \sqrt{2kmgh} \quad (3)$$

This type of impact analysis between bodies can be found in (Clough and Penxien, 1993).

As a result, 4 cables were considered with the largest unit mass being 1.402 kg/m and the largest span of 585.95 m. Assuming a maximum cable fall height of 50 cm, the impact force of the cables can be estimated at 9.26 tf, as shown in table 1.

Table 1. Calculation of impact force.

CRANE

Name	**QY50K**		
Total L=	**41.0**	m	Total length of the jib
q =	**77.3**	degrees	Jib inclination

Section	Li (m)	bi (mm)	hi (mm)	ti (mm)	xi (m)	yi (m)
0	**8.20**	**665**	**665**	**10**	1.80	8.00
1	**8.20**	**639**	**639**	**10**	3.60	16.00
2	**8.20**	**600**	**600**	**10**	5.40	24.00
3	**8.20**	**575**	**575**	**10**	7.20	32.00
4	**8.20**	**524**	**524**	**10**	9.00	40.00

Li **-** Length of the jib section
bi **-** Jib cross section width
hi **-** Jib cross section height
ti **-** Jib cross section thickness
xi **-** Abscissa of the upper position of the section
yi **-** Ordinate from the top position of the section

Lc =	**1.50**	m	Length of the wood footing
Kv =	**2000**	tf/m3	Soil bearing support coefficient
kcv =	**4500**	tf/m	Vertical soil stiffness
kch =	**1350**	tf/m	Horizontal soil stiffness

DETERMINATION OF THE BEAM ELASTIC CONSTANT

Funit =	**1.0**	tf	Applied load
u =	**1.88**	cm	Displacement
k =	**53.2**	tf/m	Elastic constant (= Funit/u)

TRANSFORMATION OF GRAVITATIONAL POTENTIAL ENERGY INTO DEFORMATION ENERGY

Fimp =	**$(2kmgh)^{1/2}$**		Impact load
g =	**9.81**	m/s^2	Gravity acceleration
L =	**585.95**	m	Spam of the transmission line
pcabo =	**1.402**	kgf/m	Cable unit weight
ncabo =	**4**		Number of cables
Ptot =	**3286**	kgf	Total cable weight
napo =	**2**		Number of supports
Papo =	**1643**	kgf	Reaction load per support
m =	**1643**	kg	Impact mass
h =	**0.5**	m	Cable drop height
Fimp =	**9.26**	**tf**	**Impact load on beam (system)**

Source: Authors

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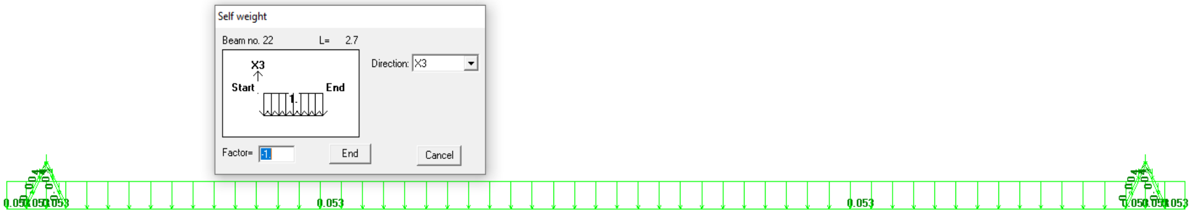
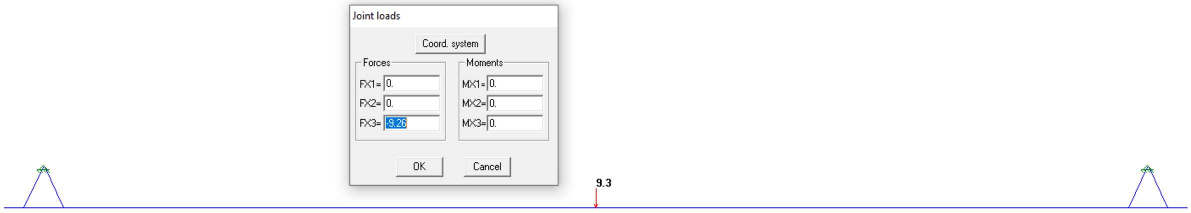
Figures 5 and 6 show the loads applied to the structure.

Figure 5: Loading due to own weight.



Source: Authors

Figure 6: Load due to cable impact.



Source: Authors

Table 2: Loading combination.

Combination	Impact Load	Self Weight
Design	1.50	1.25

Source: Authors

4 RESULTS

The structure for the shipments described in Section 4 was analyzed. The results obtained are shown in what follows. The maximum value of the stresses must be less than 100% of the allowable stress for the structure to comply with the adopted Standards. The force increase coefficients were adopted as prescribed in NBR-8800, 2008.

Figure 7. Percentage of tension in the structure.

Source: Authors

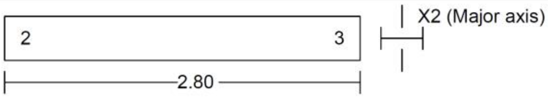
The most stressed W 310 x 52.0 section check follows.

Figure 8. Metal beam check - Strap

Detailed Results Table

*Moments: ton*meter , Forces: ton , Stresses: mPa , Section prop.: cm.*

Beam:
2, 22



Ignore: deflections

CONSTRAINTS
- Sections : Check
- Steel Grade: AR345

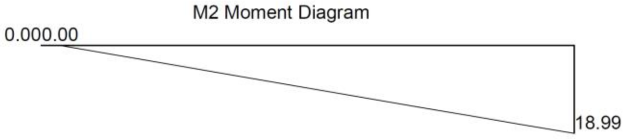
DESIGN DATA
- Kx = 1.00 - Ky = 1.00
- Allow. Slend. : 200 (compr.) 240 (tens.)
- Allowable Deflection : 1/360
- Tension Area Reduction Factor : 1.00
- Building type : Unbraced

Section: W 310x52.0

Ix = 11909.0 Iy = 1026.00cm4 Wplx = 842.5 Wply = 188.8cm3 Area = 67.00
hw = 317.00 bf = 167.00mm tw = 7.60 tf = 13.20mm
J = 31.81 Cw = 0.24dm6

DESIGN COMBINATION = 1

M2 Moment Diagram



Max. AXIAL Force = 3.57 (tens.) Max. SHEAR Force = 7.12

SECTION CLASSIFICATION: *** COMPACT ***

Limiting Ratios:		Compact	Non-Compact	Slender -axial	
h/t= 35.66	<	90.5	137.2	35.9	(fy= 345.0 R = -0.015)
b/t= 6.33	<	9.1	24.1	13.5	

DESIGN	EQUATION	FACTORS	VALUES	RESULT
V3 Shear 5.4.3.1.1a	Vsd/Vrk < 1 Vrd=0.6*fy*Aw/1.1	Aw = 24.09	Vsd = 7.12 Vrd = 45.34	0.16
M2 Moment (G.2.1a) without LTB	Msd / Mrd < 1.00	Z = 842.50	Msd = 18.99 Mrd = 26.42	0.72
Axial Force 5.2.2a	Nsd / Agfy/1.1 < 1.00	(kL/r)x =21 (kL/r)y =72	Nsd = 3.57 Ag = 67.00 fy = 345.00	0.02
Lateral Torsional Buckling G.2.1b	Msd / Mrd < 1.00	Lb = 2.80 Lp = 1.66 Lr = 5.11 Cb = 1.70	Msd = 18.99 Mrd = 26.42 Mr = 18.15 Mp = 29.07	0.72
	Critical Segment from 0.00 to 2.80 on +z flange Segment End Moments: 0.00 and 18.99			

Detailed Results Table

*Moments: ton*meter , Forces: ton , Stresses: mPa , Section prop.: cm.*

DESIGN	EQUATION	FACTORS	VALUES	RESULT
Combined Forces (tension) 5.5.1.2b	Nsd/2Nrd + Msdx/Mrdx + Muy/Mrdy < 1.00		Msdx = 18.99 Msdy = 0.00	0.73

Source: Authors

Checks the most stressed 25 mm bar used as a handle.

Figure9. Strap bar check - Strap

Detailed Results Table

*Moments: ton*meter , Forces: ton , Stresses: mPa , Section prop.: cm.*

Beam: 27 | 17 — 21 | X3 (Major axis) | 0.22

Ignore: deflections

CONSTRAINTS
- Sections : Check
- Steel Grade: MR250

DESIGN DATA
- Kx = 1.00 - Ky = 1.00
- Allow. Slend. : 200 (compr.) 240 (tens.)
- Allowable Deflection : 1/360
- Tension Area Reduction Factor : 1.00
- Building type : Unbraced

Section: Property no. 2

Ix = 2.04 Iy = 2.04cm4 Wplx = 2.73 Wply = 2.73cm3 Area = 5.07
D = 25.40 t = 12.50mm
J = 4.09 Cw = 3.22dm6

DESIGN COMBINATION = 1

Max. AXIAL Force = 7.99 (tens.) Max. SHEAR Force = 0.00

SECTION CLASSIFICATION: *** COMPACT ***

Limiting Ratios:		Compact	Non-Compact	Slender -axial	
h/t= 2.03	<	56.0	248.0	88.0	(fy= 250.0 R = -0.631)

DESIGN	EQUATION	FACTORS	VALUES	RESULT
Axial Force 5.2.2a	Nsd / (Agfy/1.1) < 1.00	(kL/r)x =35 (kL/r)y =35	Nsd = 7.99 Ag = 5.07 fy = 250.00	0.69

Source: Authors

5 CONCLUSIONS

Based on the exposed in the present text, it is concluded that the proposed solutions, using a steel beam of section W310 x 52.0, supports the impact of the cable.

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AUTHORSHIP STATEMENT

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