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Impact of falling cables on bulkhead beams

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Abstract. In this work, 585.95 meters long falling cable will be analyze 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, dimension which is the ideal metallic profile to support such impact. A model was also developed using the STRAP software, via Finite Element Method, to perform a more refined analyze and check the design of the metal beam.

Keywords: Impact, Design, Steel beam.

1 Introduction

The impact between two structures can be classified into two types, an elastic collision, where kinetic energy is conserved, and an inelastic collision, where kinetic energy is dispersed [1]. 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 where, with such deformation, it is possible to calculate the force produced by the spring [2].

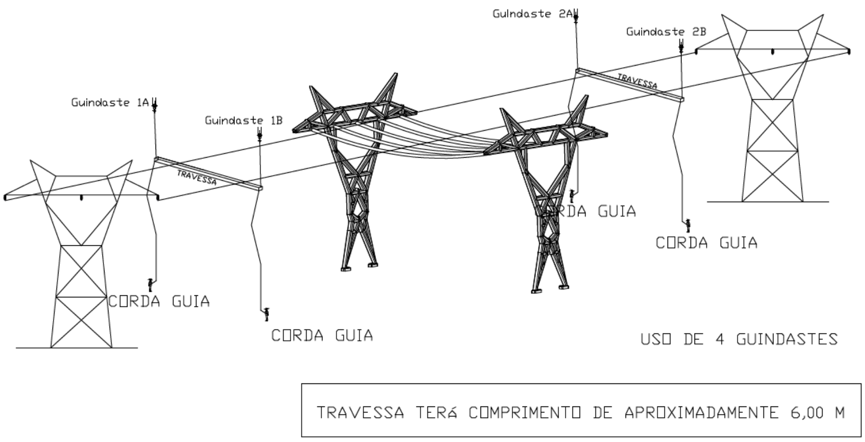


Figure 1. Cable crossing scheme.

2 Geometry and structure property.

According to figure 1, the metal beam will be approximately 6 meters long. The profile 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, used in the structural calculation.

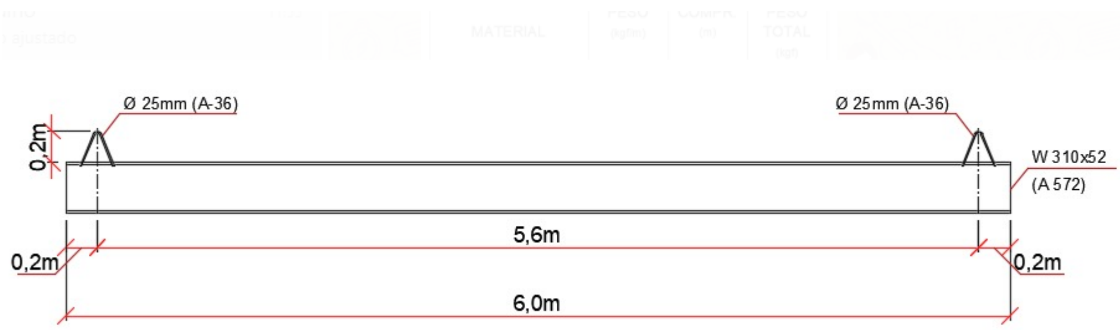


Figure 2. Front view of metal beam.

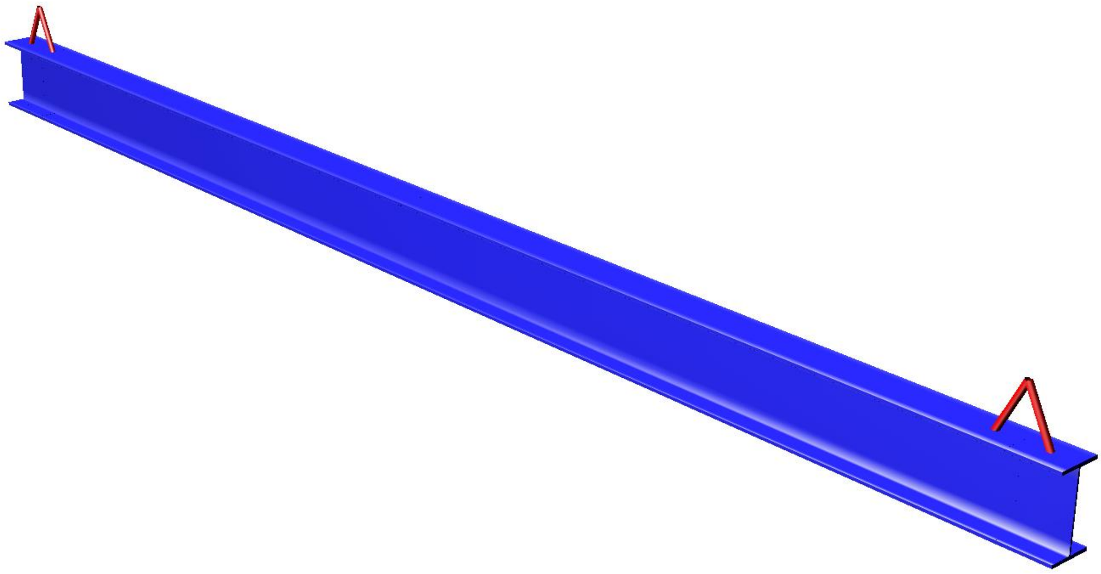


Figure 3. Rendered metal beam.

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 Calculation 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 spring stiffness equal to the system and the impact elasticity.

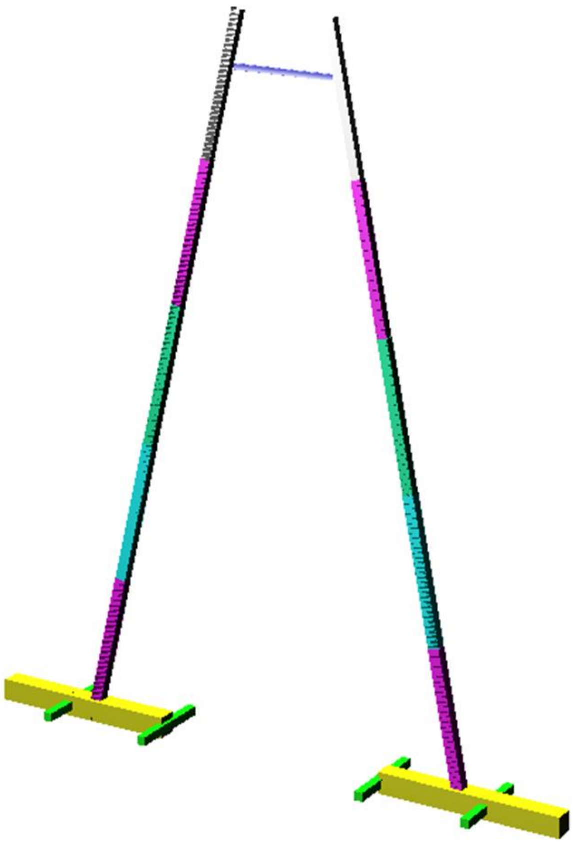


Figure 4. Crane Modeling.

To calculate the impact force of the cable, we have that the gravitational potential energy is equal to the beam deformation energy [2], thus:

$$mgh = \frac{1}{2}ku^2 \tag{1}$$

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:

$$F_{imp} = ku \tag{2}$$

We have that the impact force can be written as:

$$F_{imp} = \sqrt{2kmgh} \tag{3}$$

This type of impact analysis between bodies can be found in [3].
As a result, it was considered 4 cables with the largest unit mass being 1.402 kgf /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.

GUINDASTE								
Nome:	**QY50K**							
L Total =	**41,0**	m	comprimento total da lança					
q =	**77,3**	graus	inclinação da lança					
Trecho	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 - comprimento do trecho de lança								
bi - largura da seção transversal da lança								
hi - altura da seção transversal da lança								
ti - espessura da seção transversal da lança								
xi - abscissa da posição superior do trecho								
yi - ordenada da posição superior do trecho								
Lc =	**1,50**	m	largura da cama de dormente para patola					
Kv =	**2000**	tf/m3	coeficiente de reação vertical do solo					
kcv =	**4500**	tf/m	mola de apoio do guindaste - vertical					
kch =	**1350**	tf/m	mola de apoio do guindaste - horizontal					
DETERMINAÇÃO DA CONSTANTE ELÁSTICA DO BALANCIM								
Funit =	**1,0**	tf	força aplicada					
u =	**1,88**	cm	deslocamento calculado					
k =	**53,2**	tf/m	constante elástica do balancim (= Funit/u)					
TRANSFORMAÇÃO DE ENERGIA POTENCIAL GRAVITACIONIAL EM ENERGIA DE DEFORMAÇÃO								
Fimp =	**$(2kmgh)^{1/2}$**		força de impacto no balancim					
g =	**9,81**	m/s^2	vão da travessia					
L =	**585,95**	m	vão da travessia					
pcabo =	**1,402**	kgf/m	peso unitário do cabo					
ncabo =	**4**		número de cabos					
Ptot =	**3286**	kgf	peso total do cabo no vão					
napo =	**2**		número de apoios no meio do vão					
Papo =	**1643**	kgf	peso por apoio					
m =	**1643**	kg	massa de impacto no apoio					
h =	**0,5**	m	altura de queda do cabo					
Fimp =	**9,26**	**tf**	**força de impacto no balancim**					

The figures below show the loads applied to the structure.

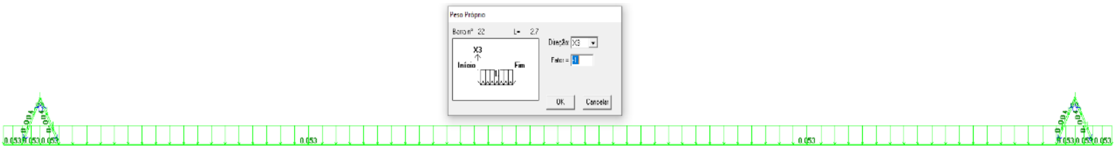


Figure 5: Loading due to own weight.

Figure 6: Load due to cable impact.

Table 2: Loading combination.

Combinação	Força de Impacto	Peso Próprio
Normal	1,50	1,25

4 Results

The structure for the shipments described in Section 4 was analyzed. The results obtained are shown below. The maximum value of the voltages must be less than 100% of the allowable voltage for the structure to comply with the adopted Standards. The force increase coefficients were adopted as prescribed in NBR-8800 [4].

Figure 7. Percentage of tension in the structure.

The most requested W 310 x 52.0 profile check follows.

R e s u l t a d o s   D e t a l h a d o s

*Momentos:tf*metro , Forças:tf , Tensões:MPa , Propriedades:cm*

Barra:
2, 22

2 — 3   X2 (Eixo maior)

2.80

Ignorar: deformações

RESTRIÇÕES

- Seções : Verificar
- Aço Tipo: AR345

DADOS de CALCULO

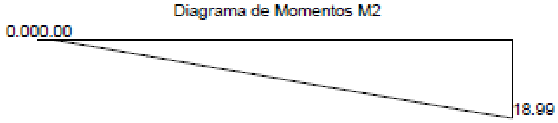
- Kx = 1.00 - Ky = 1.00
- Esbeltez adm. : 200 (compr.) 240 (trac.)
- Flecha admissível : 1/360
- Fator Redutor de Área Tracionada :1.00
- Sistema : Deslocável

Seção: W 310x52.0

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

COMBINAÇAO de CALCULO= 1

Diagrama de Momentos M2



Máx. Força AXIAL = 3.57 (trac.) Máx. Força CORTANTE= 7.12

CLASSIFICAÇAO DA SEÇAO: *** COMPACTA ***

Relação Limite:		Comp.	Não-Compacta	Esbelto -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	

CALCULO	EQUAÇAO	FATORES	VALORES	RESULT
Cortante V3 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
Momento M2 (G.2.1a) sem FLT	Msd / Mrd < 1.00	Z = 842.50	Msd = 18.99 Mrd = 26.42	0.72
Forca Axial 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
Flambagem Lateral com Torcao 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
	Segmento critico de 0.00 a 2.80 na mesa +z Momentos na extr. do segmento: 0.00 e 18.99			

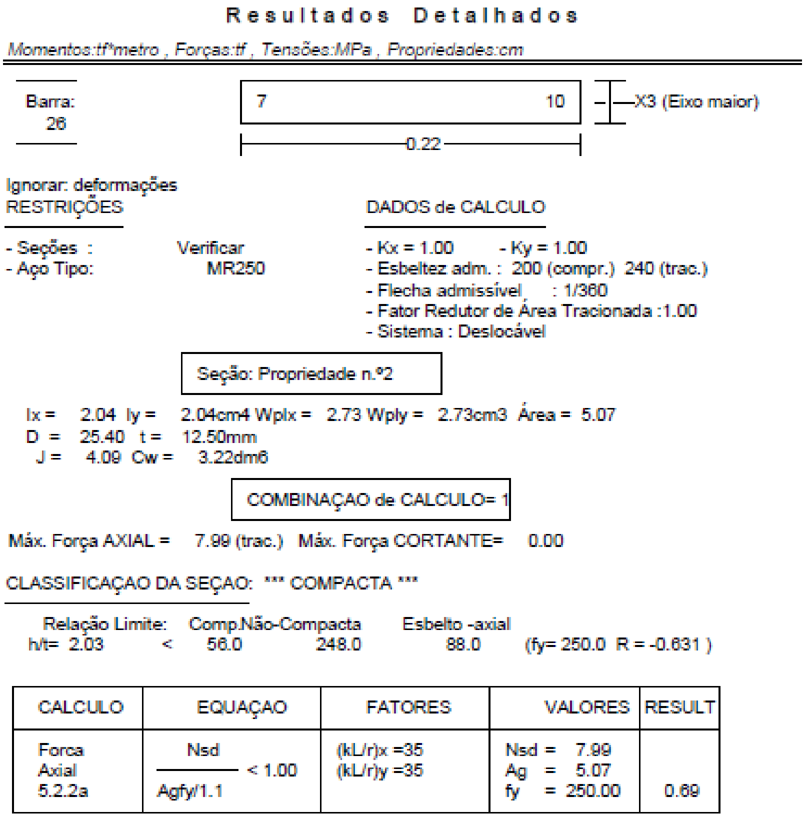
R e s u l t a d o s   D e t a l h a d o s

*Momentos:tf*metro , Forças:tf , Tensões:MPa , Propriedades:cm*

CALCULO	EQUAÇAO	FATORES	VALORES	RESULT
Forcas Combinadas (tracao) 5.5.1.2b	Nsd/2Nrd + Msdx/Mrdx + Muy/Mrdy < 1.00		Msdx = 18.99 Msdy = 0.00	0.73

Figure 8. Metal beam check - Strap

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



CALCULO	EQUAÇAO	FATORES	VALORES	RESULT
Forca Axial 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

Figure9. Strap bar check - Strap

5 Conclusions

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

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