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RamSeries - Validation Case 2

Cable loaded with punctual load

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15.1.0

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1 Validation Case 2 - Cable loaded with punctual load

Model Description

This test case deals with the simulation of a cable of length L_o. subjected to the action of a punctual load W applied to its center and directed upwards along the vertical direction.

According to the formulation used in RamSeries (Green strain, see Annex: Strain formulations -pag. 5-) for cable elements, the relation between the applied load (W) and the deflection (u), is given by:

$W_G = 8 \cdot E \cdot A \cdot u^3 / L_o^3$ (Eq. 1)

In equilibrium, the cable will suffer an elongation so that its total length will be given by the following expression:

$L = \sqrt{(L_o^2+(2u)^2)}$ (Eq. 2)

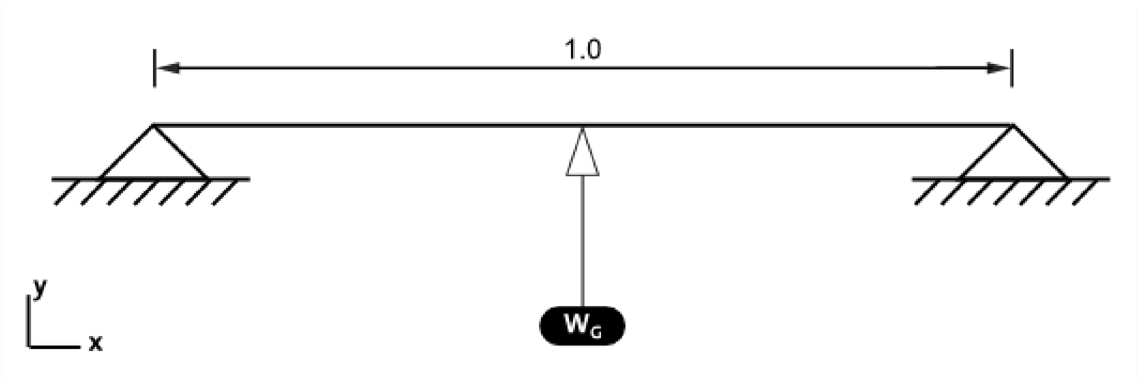
where u is the maximum vertical displacement taking place at the center of the cable.

Following the example showed in Ref. [2], the data used for this test is:

$A=0.001\ m^2$ (Area of the cable element section).

$E=5.0E6\ N/m^2$ (Young modulus of the material).

$L_o=1.0$ m (Initial length of the cable).



Geometric description of the test. Units [m]

Various simulations were run applying different loads (W_G), in order to verify that the obtained deflection in RamSeries ($u_{RamSeries}$) coincides with the corresponding deflection (u) in Eq. 1.

Results

For the sake of validation, various simulation were run as described in the previous chapter. Therefore different loads, W_G, were applied.

The mesh used has 2 linear elements and 3 nodes.

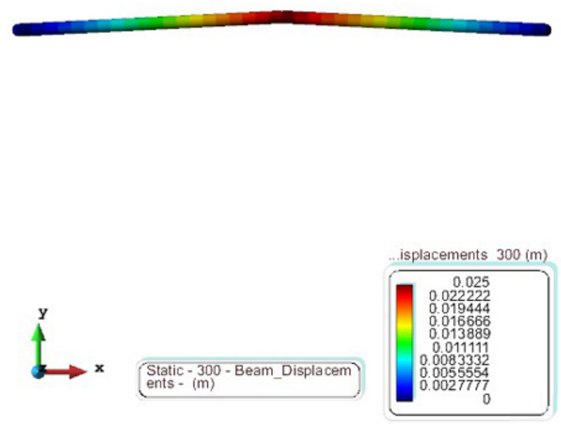
The following table show the RamSeries deflection results (third column: u_RamSeries) for a given applied load (second column: W_G). This load corresponds to a certain deflection (first column: u) via the formulation previously mentioned (Eq. 1)

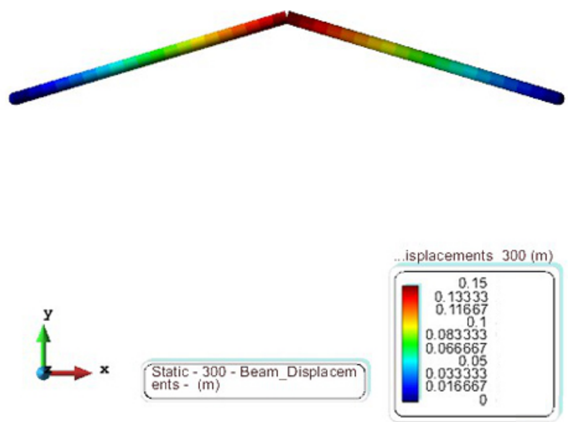
u [m]	W_G [N]	u_RamSeries [m]
0.025	0.625	0.025
0.050	5.000	0.050
0.100	40.000	0.100
0.150	135.000	0.150
0.200	320.000	0.200
0.250	625.000	0.250
0.300	1080.000	0.300
0.350	1715.000	0.350
0.500	5000.000	0.500
0.750	16875.000	0.750
1.000	40000.000	1.000

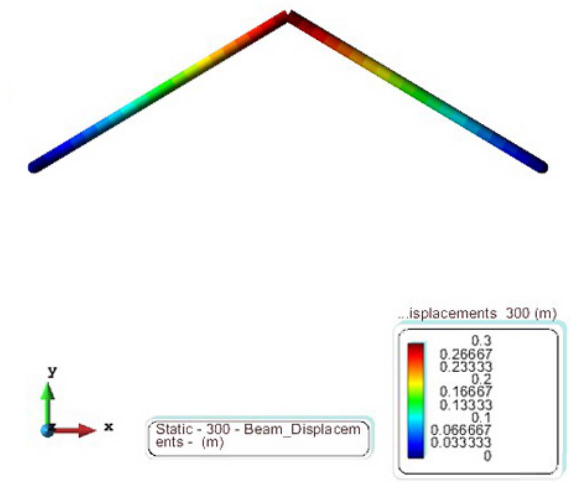
The maximum vertical displacement obtained in RamSeries, (u_RamSeries), coincides exactly with the analytical reference values.

Next, some result images corresponding to different loads (W_G) are shown. From left to right, and downwards, the images correspond to loads:

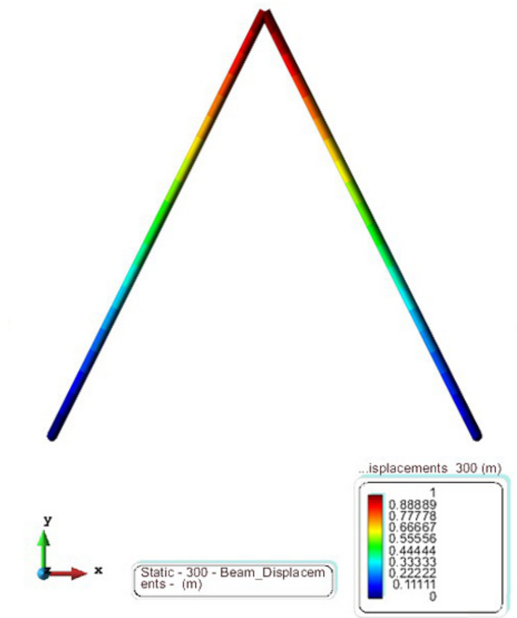
- W_G_1 = 0.625 N (u = 0.025 m)
- W_G_4 = 135 N (u = 0.15 m)
- W_G_8 = 1080 N (u = 0.3 m)
- W_G_{12} = 40.0e3 N (u = 1.0 m)


...isplacements 300 (m)
0.025
0.022222
0.019444
0.016666
0.013889
0.011111
0.0083332
0.0055554
0.0027777
0
y
x
Static - 300 - Beam_Displacements - (m)


...isplacements 300 (m)
0.15
0.13333
0.11667
0.1
0.083333
0.066667
0.05
0.033333
0.016667
0
y
x
Static - 300 - Beam_Displacements - (m)



...isplacements 300 (m)
0.3
0.26667
0.23333
0.2
0.16667
0.13333
0.1
0.066667
0.033333
0
y
x
Static - 300 - Beam_Displacem ents - (m)



...isplacements 300 (m)
1
0.88889
0.77778
0.66667
0.55556
0.44444
0.33333
0.22222
0.11111
0
y
x
Static - 300 - Beam_Displacem ents - (m)

Annex: Strain formulations

Different strain formulations

Following Reference [1], different strain measures may be considered. In the following lines, two of the most commonly used formulations are shown, particularized for this test.

*Note: There are more formulations (Ref. [1]), like "rotated log-strain" or "rotated log-strain formulation allowing for volume change".

- Rotated engineering strain:
  This formulation is used in the example showed in Ref. [2], regarding cable elements. This is valid only for small displacements.

  $\varepsilon_E = (L - L_o)/L_o$

  The relation between the load (W) and the deflection (u), is given by:

  $W_E = 2 \cdot E \cdot A \cdot (2 \cdot u) \cdot (L - L_o)/(L \cdot L_o) = 4 \cdot E \cdot A \cdot u \cdot \varepsilon_E / L$

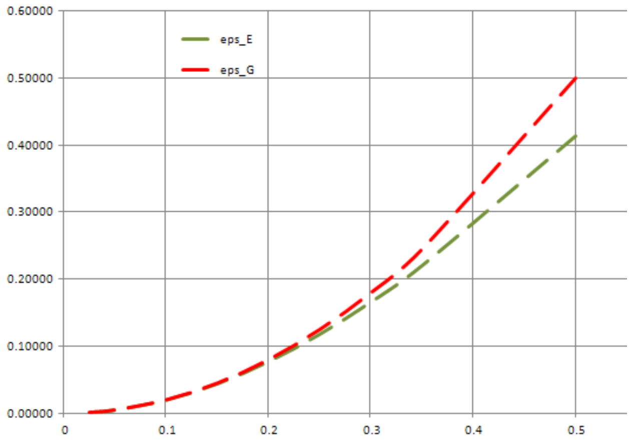
- Green strain:
  This formulation is the one used for RamSeries cable elements, and suits better for large displacements.

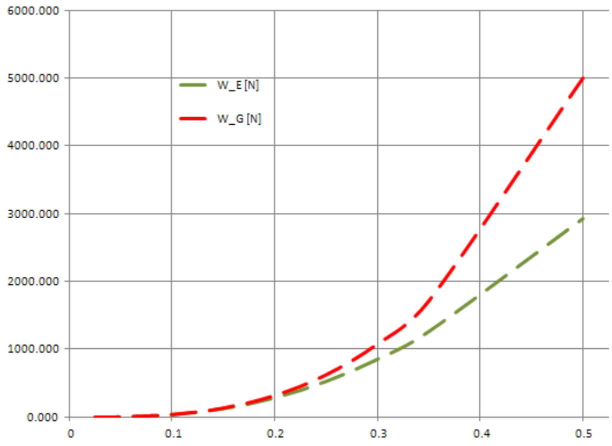
  $\varepsilon_G = (L^2 - L_o^2)/(2 \cdot L_o^2)$

  In this case, the relation between the load (W) and the deflection (u), is given by:

  $W_G = 2 \cdot E \cdot A \cdot (2 \cdot u) \cdot (2 \cdot u)^2/(2 \cdot L_o^3) = 8 \cdot E \cdot A \cdot u^3/L_o^3$

When the strains are small ($L \approx L_o$), the two strains measures coincide. Hence, for small strains, the two load/deflection relationships, also coincide. To the contrary, as strains grow larger, a significant difference in the strain measures is observed. The next graphs show the differences between both formulations, for the strain measures (left), and for the load/deflection relationship (right):


eps_E
eps_G
0.60000
0.50000
0.40000
0.30000
0.20000
0.10000
0.00000
0
0.1
0.2
0.3
0.4
0.5


W_E [N]
W_G [N]
6000.000
5000.000
4000.000
3000.000
2000.000
1000.000
0.000
0
0.1
0.2
0.3
0.4
0.5

References

[1] M. A. Crisfield. Non-linear Finite Element Analysis of Solids and Structures. VOLUME 1: ESSENTIALS. . John Wiley & Sons (1991).

[2] I.Ortigosa. Development of a decision support system for the design and adjustment of sailboat rigging. PhD. Thesis 2011.

Validation Summary

CompassFEM version	15.1.0
Tdyn solver version	15.1.0
RamSeries solver version	15.1.0
Benchmark status	Successfull
Last validation date	27/11/2018