Summary:

This three-dimensional problem first of all consists in carrying out a modal analysis and then to study the harmonic answer of a mechanical structure of a netting plan of beams. This test of Mechanics of the Structures corresponds to a dynamic analysis of a linear model having a linear behavior. It understands only one modelling.

This problem thus makes it possible to test the element of beam of Euler Bernouilli in transverse inflection, the calculation of the frequencies and the modes of vibration by the method of Lanczos and the use of linear relations between displacements of two points in modal analysis and harmonic answer.

The results are in agreement with the analytical results of guide VPCS.
1 Problem of reference

1.1 Geometry

Length: \( L1 = L2 = 5 \text{ m} \)

Cross-section (section in \( I \) ): \( IPE 200 \)

- surface \( A = 2.872 \times 10^{-3} \text{ m}^2 \)
- moment of inertia \( I_z = 1.943 \times 10^{-5} \text{ m}^4 \)

Coordinates of the points (in meters):

<table>
<thead>
<tr>
<th></th>
<th>( A )</th>
<th>( B = H )</th>
<th>( C )</th>
<th>( D )</th>
<th>( E = I )</th>
<th>( F )</th>
<th>( G )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( x )</td>
<td>-2.5</td>
<td>-2.5</td>
<td>-2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>0</td>
</tr>
<tr>
<td>( y )</td>
<td>-2.5</td>
<td>0</td>
<td>2.5</td>
<td>-2.5</td>
<td>0</td>
<td>2.5</td>
<td>0</td>
</tr>
<tr>
<td>( z )</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

1.2 Material properties

\( E = 2.10^{11} \text{ Pa} \)
\( \rho = 7800. \text{ kg/m}^3 \)

1.3 Boundary conditions and loadings

Points \( A, C, D, F \) : (\( u = v = w = 0 \) )
Points \( B, E \) : rotulée connection (continuity of \( u, v, w \) )

Force sinusoïdale au point G

\[ F_G(t) = F_0 \sin \Omega t \]
\[ F_0 = 1 \cdot 10^5 \text{ N} \]
\[ \Omega = 80 \text{ rad/s} \]

1.4 Initial conditions

With \( t = 0 \) , structure at rest.

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2 Reference solution

2.1 Method of calculating used for the reference solution

The reference solution is that given in card SDLL08/89 of the guide VPCS which presents the method of calculating in the following way:

A method of Rayleigh-Ritz makes it possible to calculate with two degrees of freedom starting from the assumptions of following symmetrical deformations:

- for the point of X-coordinate $y$ members $AC$ and $DF$ of length $L_1$

\[ W_{AB} = W_B \sin \frac{\pi y}{L_1} + \frac{L_1}{2} \]

- for the point of X-coordinate $x$ cross-piece $BE$ of length $L_2$

\[ W_{BE} = W_B + W_G \sin \frac{\pi x}{L_2} + \frac{L_2}{2} \]

2.2 Results of reference

The first two Eigen frequencies and clean modes symmetrical (the other Eigen frequencies of this system are not studied). For the clean modes, one has the following value: $W_B / W_G$

In harmonic answer one a:

- $W_B \max$ et $W_G \max$
- $W_B + W_G \max$ at the point $G$.

2.3 Uncertainty on the solution

Analytical solution.

2.4 Bibliographical references

3 Modeling A

3.1 Characteristics of modeling

One uses the element of beam of Euler Bernoulli $POU_D_E$.

3 beams: $ABC$, $DEF$, $HGI$ cut out each one in 10 meshes $SEG2$.

Nodes $(B, H)$ and $(E, I)$ the same coordinates have.

Limiting conditions:

- beams $ABC$ and $DEF$:
  - $DDL_IMPO$: (GROUP_NO: (PABC, PDEF) DX: 0., DY: 0., DRY MARTINI: 0.)
  - $HGI$ beam:
    - $DDL_IMPO$: (GROUP_NO: (PHGI) DX: 0., DY: 0., DRX: 0.)
    - (GROUP_NO: (NACDF) DZ: 0.)

- Liaison ddl$: $DZ_B-DZ_H=0.$ and $DZ_E-DZ_I=0.$
- Force nodale: $DZ = -1.E5$

Names of the nodes:

$A = N1$  $B = N6$  $C = N11$
$D = N21$  $E = N26$  $F = N31$
$H = N41$  $G = N46$  $I = N51$

3.2 Characteristics of the grid

- Many nodes: 33
- Many meshes and types: $3*10 = 30$ $SEG2$

3.3 Remarks

The blocking of the degrees of freedom $DX$ and $DY$ in all the nodes allows to select only the modes of transverse inflection (in the "vertical" plane).
3.4 Sizes tested and results

Frequency (Hz)

<table>
<thead>
<tr>
<th>Order of the clean mode</th>
<th>Reference</th>
<th>Aster</th>
<th>% difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16,456</td>
<td>16.4190</td>
<td>- 0.22</td>
</tr>
<tr>
<td>2</td>
<td>38,165</td>
<td>38.0468</td>
<td>- 0.31</td>
</tr>
</tbody>
</table>

Clean mode: value of $\frac{W_B}{W_G}$

<table>
<thead>
<tr>
<th>Order of the symmetrical clean mode</th>
<th>Reference</th>
<th>Aster*</th>
<th>% difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.213</td>
<td>1.213</td>
<td>0.</td>
</tr>
<tr>
<td>2</td>
<td>- 0.412</td>
<td>- 0.412</td>
<td>0.</td>
</tr>
</tbody>
</table>

* $W_B = DZ$ in $B$ (N6) $W_G + W_B = DZ$ in $G$ (N46)

mode 1: $W_B = 0.5480$ $W_G + W_B = 1.$

mode 2: $W_B = - 0.6698$ $W_G + W_B = 0.9559$

Harmonic answer:

<table>
<thead>
<tr>
<th>Not</th>
<th>Type of value</th>
<th>Reference</th>
<th>Aster</th>
<th>% difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B,E, G$</td>
<td>$W_B^{\text{max}}$</td>
<td>- 0.098</td>
<td>- 0.1003</td>
<td>2.45</td>
</tr>
<tr>
<td>$G$</td>
<td>$W_G^{\text{max}}$</td>
<td>- 0.125</td>
<td>- 0.1271</td>
<td>1.60</td>
</tr>
<tr>
<td>$G$</td>
<td>$W_B + W_G^{\text{max}}$</td>
<td>- 0.227</td>
<td>- 0.2274</td>
<td>0.18</td>
</tr>
</tbody>
</table>

3.5 Remarks

Calculations carried out by:

```
CALC_MODES
OPTION = 'PLUS_PETITE'
CALC_FREQ=_F (NMAX_FREQ = 3)
SOLVEUR_MODAL=_F (METHOD = 'TRI_DIAG')
```

One obtains an antisymmetric mode for a frequency $f = 22.5676$ Hz. This Eigen frequency depends on the constant of provided torsion; this one is not defined in the bench-mark data.

Values $\frac{W_B}{W_G}$ are not checked in the test but are obtained manually from $W_B$ and $W_G + W_B$. The value $(W_G)^{\text{max}}$ is not checked in the test. One has only access to $W_B^{\text{max}}$ and $(W_B + W_G)^{\text{max}}$. $W_G^{\text{max}}$ is obtained manually by difference.

Contents of the file results:

the first 3 Eigen frequencies, displacement of the nodes $B,E,G$ in harmonic answer.
4 Summary of the results

The values of the Eigen frequencies and the clean vectors are obtained with a precision $< 0.3\%$.

The variation of $2.5\%$ on the maximum arrows at the points $B$ and $E$ would deserve to check the reference solution, to supplement the validation of the harmonic answer.