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# SSLL11 - Lattice of pin jointed struts under concentrated loading

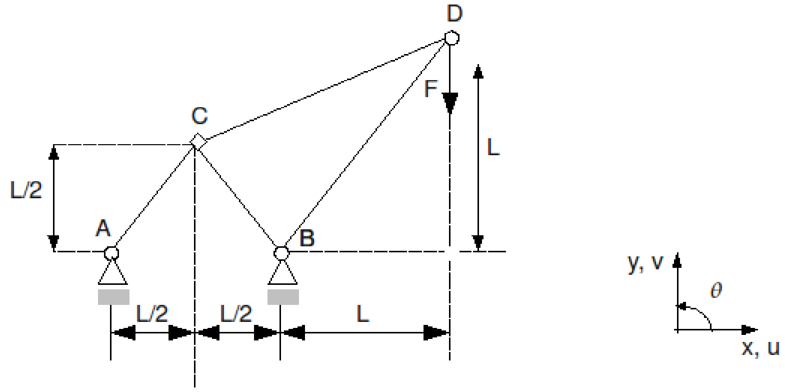
**Summary:**
This test makes it possible to check the elements of bar and beam for the structural analysis out of lattice. The lattice considered is plan. Calculation is static, elastic, linear. The reference solution is analytical.

Three modelings make it possible to test the elements POU_D_T with and without rotulées connections, as well as the elements BAR.

Three modelings make it possible to test the elements POU_D_TG, POU_D_EM and POU_D_TGM with and without rotulées connections.

# 1 Problem of reference

## 1.1 Geometry




Length $L=1m$

elements $AC$ and $BC$ of circular section $A=2.10^{-4}m^2$

elements $CD$ and $BD$ of circular section $A=1.10^{-4}m^2$

**Coordinates of the points (in $m$ ):**

| | $A$ | $B$ | $C$ | $D$ |
|---|---|---|---|---|
| $x$ | 0. | 1. | 0.5 | 2. |
| $y$ | 0. | 0. | 0.5 | 1. |
| $z$ | 0. | 0. | 0. | 0. |

## 1.2 Material properties

Young modulus: $E=1.962\,10^{11}Pa$

## 1.3 Boundary conditions and loadings

Nodes $A$ and $B$ are articulated: $u=v=0$

Vertical specific force in $D$ : $F=-9.81\,10^3N$

# 2 Reference solution

## 2.1 Method of calculating used for the reference solution

The reference solution is that given in card SSLL11/89 of guide VPCS.
It is obtained by the method of displacements in [bib1].

## 2.2 Results of reference

Displacements of the points $C$ and $D$.

## 2.3 Uncertainty on the solution

Analytical solution.

## 2.4 Bibliographical references

[1] RAO (J.S.): The finite element method in engineering , problem 5.1, p. 275.

# 3 Modeling A

## 3.1 Characteristics of modeling

Taking into account the twinges, the taking into account of the articulations modifies the results little. For this modeling, articulations in $A$ , $B$ , $C$ and $D$ are rigidified (continuity of the 3 components of generalized efforts).

4 beams of full circular section: 4 meshs SEG2

| | | |
|---|---|---|
| elements $AC$ and $BC$ | ray $R=7.978845\,10^{-3}\,m$ | (surface $A=2.10^{-4}\,m^2$ ) |
| elements $CD$ and $BD$ | ray $R=5.641895\,10^{-3}\,m$ | (surface $A=1.10^{-4}\,m^2$ ) |
| Poisson's ratio: | $\nu=0.3$ | |

**Limiting conditions:**

in all them nodes :

```
DDL_IMPO= (
    _F (TOUT=' OUI', DZ= 0. , DRX= 0. , DRY= 0. ),
    _F (NOEUD= (WITH, B), DX= 0. , DY= 0.)
)
```

Name of nodes : Not $A$ = $A$ Not $C$ = $C$
Not $B$ = $B$ Not $D$ = $D$

## 3.2 Characteristics of the grid

Number of nodes : 4
Many meshs and types: 4 SEG2

## 3.3 Sizes tested and results

| Identification | Type of reference | Value | Tolerance |
|---|---|---|---|
| DX at the point $C$ | 'ANALYTICAL' | 2.65E-04 | 3.0E-04 |
| DY at the point $C$ | 'ANALYTICAL' | 0.8839E-04 | 3.0E-04 |
| DX at the point $D$ | 'ANALYTICAL' | 3.47902E-03 | 3.0E-04 |
| DY at the point $D$ | 'ANALYTICAL' | - 5.60084E-03 | 3.0E-04 |

# 4 Modeling B

## 4.1 Characteristics of modeling

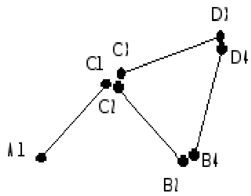
4 elements `POU_D_T` of full circular section: 4 meshs `SEG2`

| | | |
|---|---|---|
| elements $AC$ and $BC$ | ray $R=7.978845\,10^{-3}\,m$ | (surface $A=2.\,10^{-4}\,m^2$ ) |
| elements $CD$ and $BD$ | ray $R=5.641895\,10^{-3}\,m$ | (surface $A=1.\,10^{-4}\,m^2$ ) |
| Poisson's ratio: | $\nu=0.3$ | |

**Limiting conditions:**

```
DDL_IMPO=_F (Tout=' OUI', DZ= 0. , DRX= 0. , DRY= 0. )
```

To treat the rotary joints, one creates as many nodes as of ends of bar.




- with the nodes $A1$ , $B2$ and $D4$ : `DDL_IMPO=_F (Tout=' OUI', DZ= 0. , DRX= 0. , DRY= 0. )`
- with the nodes $C1$ , $C2$ , $C3$ and $D3$ , $D4$ continuity of the translations, by `LIAISON_DDL` `DX` and `DY`.
- no rotation is imposed.

## 4.2 Characteristics of the grid

Many nodes: 4
Many meshs and types: 4 `SEG2`

## 4.3 Sizes tested and results

| Not | Displacement (m) | Type of Reference | *Reference* | *Tolerance* |
|---|---|---|---|---|
| $C$ | $u_c$ | ANALYTICAL | 2.6517E-04 | 3.0E-04 |
| | $v_c$ | ANALYTICAL | 0.8839E-04 | 3.0E-04 |
| $D$ | $u_D$ | ANALYTICAL | 3.47902E-03 | 3.0E-04 |
| | $v_D$ | ANALYTICAL | – 5.60084E-03 | 3.0E-04 |

# 5 Modeling C

## 5.1 Characteristics of modeling

4 elements `BAR` of full circular section: 4 meshs `SEG2`

| | | |
|---|---|---|
| elements $AC$ and $BC$ | ray $R=7.978845\,10^{-3}\,m$ | (surface $A=2.10^{-4}\,m^2$ ) |
| elements $CD$ and $BD$ | ray $R=5.641895\,10^{-3}\,m$ | (surface $A=1.10^{-4}\,m^2$ ) |
| Poisson's ratio: | $\nu=0.3$ | |

**Limiting conditions:**

```
DDL_IMPO= (
    _F (TOUT=' OUI', DZ= 0. )
    _F (NOEUD= (WITH, B), DX= 0. , DY= 0.)
)
```

## 5.2 Characteristics of the grid

Many nodes: 4
Many meshs and types: 4 `SEG2`

## 5.3 Sizes tested and results

**Static calculation:**

| Not | Displacement (m) | Type of Reference | Reference | Tolerance |
|---|---|---|---|---|
| $C$ | $u_c$ | ANALYTICAL | 2.6517E -04 | 1.0E-04 |
| | $v_c$ | ANALYTICAL | 8.84E-05 | 1.0E-04 |
| $D$ | $u_D$ | ANALYTICAL | 3.47902E-03 | 1.0E-04 |
| | $v_D$ | ANALYTICAL | – 5.60084E-03 | 1.0E-04 |

**Harmonic calculation:**

| Not | Field | Freq. | Comp | Type of Reference | Reference | Tolerance |
|---|---|---|---|---|---|---|
| $C$ | DEPL | 100 | DX | NOT REGRESSION | 4.01805E-08 - 4.21987E-06j | 1.0E-03 |
| $C$ | DEPL | 100 | DY | NOT REGRESSION | 1.66019E-08-1.406541E-06j | 1.0E-03 |
| $D$ | DEPL | 100 | DX | NOT REGRESSION | 5.81263E-07-5.53643E-05j | 1.0E-03 |
| $D$ | DEPL | 100 | DY | NOT REGRESSION | -9.72590E-7+8.91215E-5j | 1.0E-03 |
| $D$ | QUICKLY | 100 | DX | NOT REGRESSION | 0.03478 + 3.652186E-04j | 1.0E-03 |
| $D$ | QUICKLY | 100 | DY | NOT REGRESSION | -0.05599 - 6.11096E-04j | 1.0E-03 |
| $D$ | ACCE | 100 | DX | NOT REGRESSION | -0.22947 + 21.85696j | 1.0E-03 |
| $D$ | ACCE | 100 | DY | NOT REGRESSION | 0.383963 - 35.1837j | 1.0E-03 |
| $B$ | EFGE_ELNO | 100 | NR | NOT REGRESSION | -3.83891 + 331.15804j | 1.0E-03 |
| $D$ | EFGE_ELNO | 100 | NR | NOT REGRESSION | -3.83891 + 331.15804j | 1.0E-03 |

# 6 Modeling D

## 6.1 Characteristics of modeling

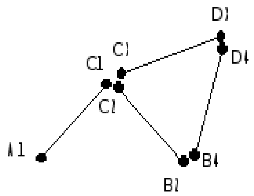
4 elements POU_D_TG of hollow circular section: 4 meshs SEG2

| | | |
|---|---|---|
| elements $AC$ and $BC$ | ray: $R=8.305164\,10^{-3}\,m$<br>Thickness: $e=0.006\,m$ | surface $A=2.10^{-4}\,m^2$ |
| elements $CD$ and $BD$ | ray: $R=5.683099\,10^{-3}\,m$<br>Thickness: $e=0.005\,m$ | surface $A=1.10^{-4}\,m^2$ |
| Poisson's ratio: | $\nu=0.3$ | |

**Limiting conditions:**

```
DDL_IMPO= (Tout=' OUI', DZ=0. , DRX=0. , DRY=0. )
```

To treat the rotary joints, one creates as many nodes as of ends of bar.




- with the nodes $A1$ , $B2$ and $D4$ : DDL_IMPO=_F (Tout=' OUI', DX= 0. , D4= 0. ,)
- with the nodes $C1$ , $C2$ , $C3$ and $D3$ , $D4$ continuity of the translations, by LIAISON_DDL DX and DY.
- no rotation is imposed.

## 6.2 Characteristics of the grid

Many nodes: 8
Many meshs and types: 4 SEG2

## 6.3 Remarks

In this modeling one calculates the dynamic response complexes system subjected to a complex harmonic excitation ( $F=-9810.+0.j$ ) in the presence of a viscous damping proportional to rigidity and the mass. (AMOR_ALPHA=AMOR_BETA=0.1). The results are compared with the results got with modeling POU_D_T.

## 6.4 Sizes tested and results

The results (Displacement, Speed and Acceleration) were got at a frequency of $100\,Hz$

| Not | Displacement ( $m$ ) | Type of Reference | Reference | Tolerance |
|---|---|---|---|---|
| $D$ | $DX$ | NOT REGRESSION | -1.65073E-05-9.22424E-06j | 1,00E-003 |
| | $DY$ | NOT REGRESSION | 2.52829E-05+1.80184E-05j | 1,00E-003 |

| Not | Speed ( $m/s$ ) | Type of Reference | Reference | Tolerance |
|---|---|---|---|---|
| $D$ | $DX$ | NOT REGRESSION | 5.79576E-03-1.03719E-02j | 1,00E-003 |
| | $DY$ | NOT REGRESSION | -1.13213E-02+1.58857E-02j | 1,00E-003 |

| Not | Acceleration ( $m/s^2$ ) | Type of Reference | Reference | Tolerance |
|---|---|---|---|---|
| $D$ | $DX$ | NOT REGRESSION | 6.51684+3.64158j | 1,00E-003 |
| | $DY$ | NOT REGRESSION | -9.98130-7.11336j | 1,00E-003 |

# 7 Modeling E

## 7.1 Characteristics of modeling

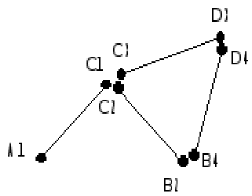
4 elements POU_D_EM of hollow circular section: 4 meshs SEG2

| | | |
|---|---|---|
| elements $AC$ and $BC$ | ray: $R=8.305164\,10^{-3}\,m$ Thickness: $e=0.006\,m$ | surface $A=2.10^{-4}\,m^2$ |
| elements $CD$ and $BD$ | ray: $R=5.683099\,10^{-3}\,m$ Thickness: $e=0.005\,m$ | surface $A=1.10^{-4}\,m^2$ |
| Poisson's ratio: | $\nu=0.3$ | |

**Limiting conditions:**

```
DDL_IMPO= (Tout=' OUI', DZ= 0. , DRX= 0. , DRY= 0. )
```

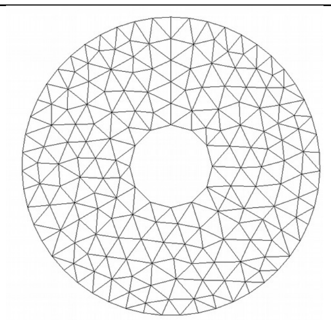
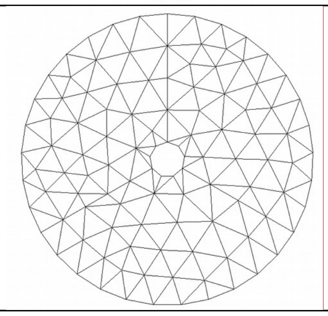
To treat the rotary joints, one creates as many nodes as of ends of bar.



- with the nodes $A1$ , $B2$ and $D4$ : DDL_IMPO=_F (Tout=' OUI', DX= 0. , D4= 0. ,)
- with the nodes $C1$ , $C2$ , $C3$ and $D3$ , $D4$ continuity of the translations, by LIAISON_DDL DX and DY.
- no rotation is imposed.

## 7.2 Characteristics of the grid

Many nodes: 8
Many meshs and types: 4 SEG2

| Grid of the two hollow sections | | |
|---|---|---|
| Elements | Grid | Characteristics |
| $AC$ and $BC$ |  | 240 nodes<br>79 SEG2<br>415 TRIA3 |
| $CD$ and $BD$ |  | 127 nodes<br>56 SEG2<br>210 TRIA3 |

## 7.3 Remarks

In this modeling one calculates the dynamic response complexes system subjected to a complex harmonic excitation ( $F=-9810.+0.j$ ) in the presence of a viscous damping proportional to rigidity and the mass. (AMOR_ALPHA=AMOR_BETA=0.1). The results are compared with the results got with modeling POU_D_T.

## 7.4 Sizes tested and results

The results (Displacement, Speed and Acceleration) were got at a frequency of $100\,Hz$

| Not | Displacement ( $m$ ) | Type of Reference | Reference | Tolerance |
|---|---|---|---|---|
| $D$ | $DX$ | AUTRE_ASTER | -1.65073E-05-9.22424E-06j | 3.50% |
| | $DY$ | AUTRE_ASTER | 2.52829E-05+1.80184E-05j | 3.00% |

| Not | Speed ( $m/s$ ) | Type of Reference | Reference | Tolerance |
|---|---|---|---|---|
| $D$ | $DX$ | AUTRE_ASTER | 5.79576E-03-1.03719E-02j | 3.50% |
| | $DY$ | AUTRE_ASTER | -1.13213E-02+1.58857E-02j | 3.00% |

| Not | Acceleration ( $m/s^2$ ) | Type of Reference | Reference | Tolerance |
|---|---|---|---|---|
| $D$ | $DX$ | AUTRE_ASTER | 6.51684+3.64158j | 3.50% |
| | $DY$ | AUTRE_ASTER | -9.98130-7.11336j | 3.00% |

# 8 Modeling F

## 8.1 Characteristics of modeling

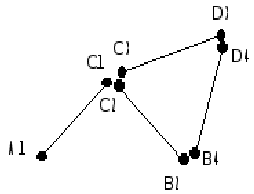
4 elements POU_D_TGM of hollow circular section: 4 meshs SEG2

| | | |
|---|---|---|
| elements $AC$ and $BC$ | ray: $R=8.305164\,10^{-3}\,m$<br>Thickness: $e=0.006\,m$ | surface $A=2.10^{-4}\,m^2$ |
| elements $CD$ and $BD$ | ray: $R=5.683099\,10^{-3}\,m$<br>Thickness: $e=0.005\,m$ | surface $A=1.10^{-4}\,m^2$ |
| Poisson's ratio: | $\nu=0.3$ | |

**Limiting conditions:**

```
DDL_IMPO= (Tout=' OUI', DZ= 0. , DRX= 0. , DRY= 0. )
```

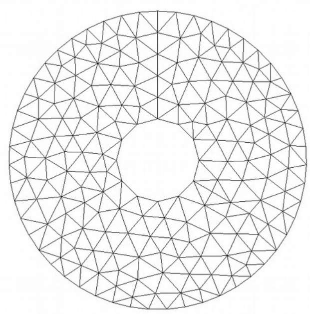
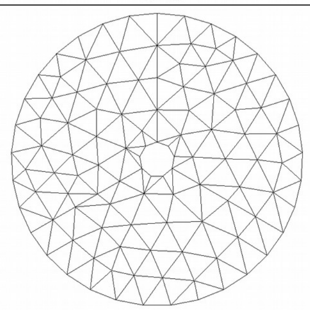
To treat the rotary joints, one creates as many nodes as of ends of bar.



- with the nodes $A$, $B$ and $D4$ : DDL_IMPO=_F (Tout=' OUI', DX= 0. , D4= 0. ,)
- with the nodes $C1$, $C2$, $C3$ and $D3$, $D4$ continuity of the translations, by LIAISON_DDL DX and DY.
- no rotation is imposed.

## 8.2 Characteristics of the grid

Many nodes: 8
Many meshs and types: 4 SEG2

| Grid of the two hollow sections | | |
|---|---|---|
| Elements | Grid | Characteristics |
| $AC$ and $BC$ |  | 240 nodes<br>79 SEG2<br>415 TRIA3 |
| $CD$ and $BD$ |  | 127 nodes<br>56 SEG2<br>210 TRIA3 |

## 8.3 Remarks

In this modeling one calculates the dynamic response complexes system subjected to a complex harmonic excitation ( $F=-9810.+0.\mathrm{j}$ ) in the presence of a viscous damping proportional to rigidity and the mass. (AMOR_ALPHA=AMOR_BETA=0.1). The results are compared with the results got with modeling POU_D_T by taking of account characteristics $A$, $IY$ and $IZ$ equal to those calculated by integrations on fibres.

## 8.4 Sizes tested and results

| Not | Displacement ( $m$ ) | Type of Reference | Reference | % tolerance |
|---|---|---|---|---|
| $C3$ | $DX$ | 'ANALYTICAL' | 2.6517E-4 | 0.50 |
| $C3$ | $DY$ | 'ANALYTICAL' | 0.8839E-4 | 0.50 |
| $D3$ | $DX$ | 'ANALYTICAL' | 3.47902E-3 | 0.50 |
| $D3$ | $DY$ | 'ANALYTICAL' | -5.60084E-3 | 0.50 |

| Identification | Component | Type of Reference | Reference | % tolerance |
|---|---|---|---|---|
| Mesh $AC$ - Node $A1$ - Not $1$ - SIEQ_ELNO | $TRIAX$ | 'AUTRE_ASTER' | 4.082482905E-01 | 0.10 |

The results (Displacement, Speed and Acceleration) were got at a frequency of $100\mathrm{hz}$

| Not | Displacement ( $m$ ) | Type of Reference | Reference | % tolerance |
|---|---|---|---|---|
| $D$ | $DX$ | AUTRE_ASTER | -1.64397E-05-9.09482E-06j | 0.10 |
| | $DY$ | AUTRE_ASTER | 2.51858E-05+1.78386E-05j | 0.10 |

| Not | Speed ( $m/s$ ) | Type of Reference | Reference | % tolerance |
|---|---|---|---|---|
| $D$ | $DX$ | AUTRE_ASTER | 5.71444E-03-0.0103293j | 0.10 |
| | $DY$ | AUTRE_ASTER | -0.011208+0.0158247j | 0.10 |

| Not | Acceleration ( $m/s^2$ ) | Type of Reference | Reference | % tolerance |
|---|---|---|---|---|
| $D$ | $DX$ | AUTRE_ASTER | 6.490118+3.590490j | 0.10 |
| | $DY$ | AUTRE_ASTER | -9.942974-7.0424160j | 0.10 |

# 9 Modeling G

## 9.1 Characteristics of modeling

4 elements POU_D_TG of circular section: 4 meshs SEG2

| | | |
|---|---|---|
| elements $AC$ and $BC$ | ray: $R=7.97884\,10^{-3}\,m$ | Surface $A=2.10^{-4}\,m^2$ |
| elements $CD$ and $BD$ | ray: $R=5.683099\,10^{-3}\,m$<br>Thickness: $e=0.005\,m$ | surface $A=1.10^{-4}\,m^2$ |

**Limiting conditions:**

- DDL_IMPO= (TOUT=' OUI'     DZ= 0. , DRX= 0. , DRY= 0. )
- with the nodes $A$ , $B$ : DDL_IMPO=_F (DX= 0. , DY= 0. ,)

## 9.2 Characteristics of the grid

Many nodes: 8
Many meshs and types: 4 SEG2

## 9.3 Sizes tested and results

Displacements:

| Component | Node | Reference | Value |
|---|---|---|---|
| $DX$ | $C$ | ANALYTICAL | $2.65170E-04$ |
| $DY$ | $C$ | ANALYTICAL | $8.83900E-05$ |
| $DX$ | $D$ | ANALYTICAL | $3.47902E-03$ |
| $DY$ | $D$ | ANALYTICAL | $-5.60084E-03$ |

Constraints of type beam:

| Size | Component | Node | Reference | Value |
|---|---|---|---|---|
| SIPO_ELNO | SN | $A$ | ANALYTICAL | $6.93641E+07$ |
| SIPO_ELNO | SN | $B$ | ANALYTICAL | $-3.46815E+07$ |
| SIPO_ELNO | SN | $C$ | ANALYTICAL | $1.55074E+08$ |
| SIPO_ELNO | SN | $D$ | ANALYTICAL | $-2.08067E+08$ |
| SIPM_ELNO | SIXXMAX | $A$ | ANALYTICAL | $6.93641E+07$ |
| SIPM_ELNO | SIXXMIN | $B$ | ANALYTICAL | $-3.80667E+07$ |

# 10 Summary of the results

The results are in conformity with the reference solution for three modelings:

- model of beams,
- model of beams and linear relations,
- model of bars.

Elements POU_D_TG, POU_D_EM and POU_D_TGM allow to get results very close to those obtained with the elements POU_D_T.