SDNL113 - Pipework in the shape of quadrant (tests ELSA) under seismic loading

Abstract:

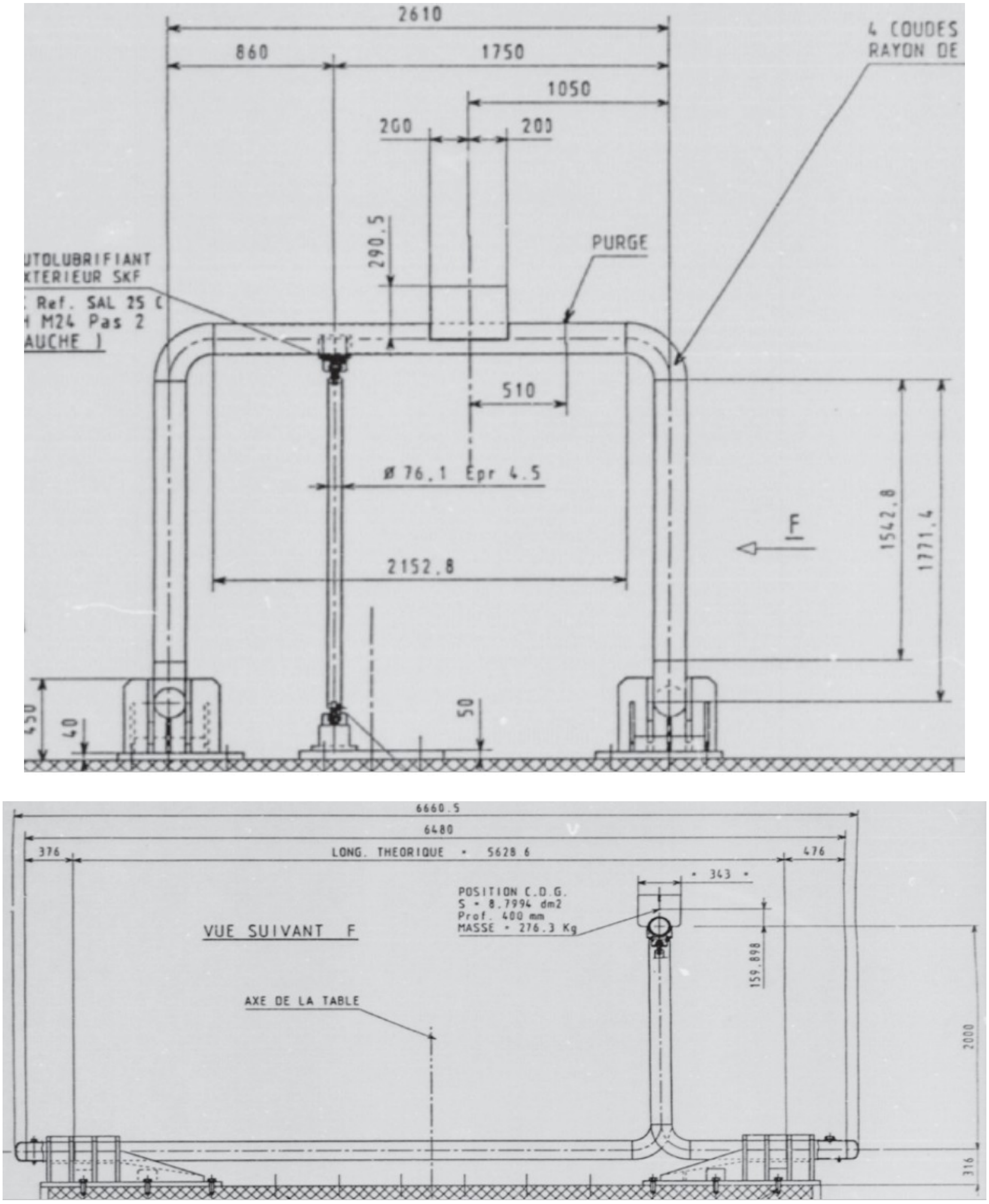
The goal of this benchmark is to test the results of a structure, made up of pipes (right or bent), rods and valves, subjected to a seismic loading and whose non-linearity comes from the material behavior in the elbows.

For that, one carries out a nonlinear direct transient analysis on the structure, in particular using modelization `TUYAU_3M`. One tests then displacements, the nodal reactions and the plastic strain cumulated in certain points of structure.

In order to limit the computing time, very into having plasticity rather early during the transient, one divides by two the values of the yield stress.

1 Problem of reference

1.1 Geometry



Appears 1.1-a: Geometry (tests ELSA realized by the CEA/EMSI).

Mesh group:
POUTRES : together right pipes
COUDES : together pipe elbows
PATVAN , VANNE , ENCBIS1 , ENC1 , ENC2
ENCBIS2 , PATBIELA , PATBIELB
PATBIELC , BIELA , BIELB , BIELC , CDGVAN

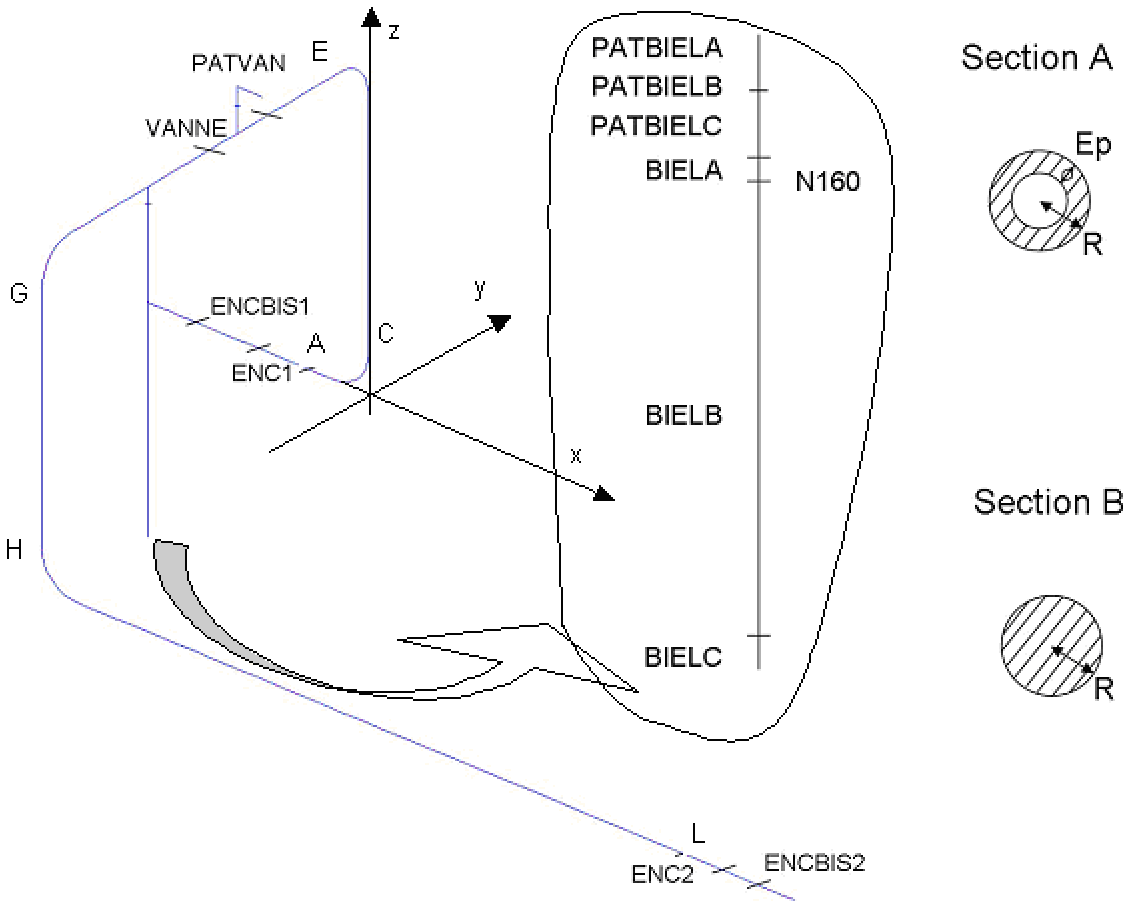
Nodes group:
A , ... , L

Geometry of the pipes:
SECTION A

- Mesh groups : *POUTRES COUDES PATVAN*
  - $R=8.485\times10^{-2}m$ External radius
  - $EP=7.345\times10^{-3}m$ Thickness
- Mesh groups: *BIELA BIELB , BIELC*
  - $R=38.05\times10^{-3}m$ external Radius
  - $EP=4.5\times10^{-3}m$ Thickness

SECTION B

- Mesh groups: *PATBIELC*
  - $R=4.55\times10^{-2}$ Radius
- Mesh groups: *PATBIELA*
  - $R1=8.6\times10^{-2}m$ Radius at end 1
  - $R2=4.55\times10^{-2}m$ Radius at end 2



Appears 1.1-b: Modelization of the geometry.

1.2 Elastic properties of the materials

- $POUTRES$:
  - Young's modulus: $E=1.9\times10^{11}\,Pa$
  - Poisson's ratio: $\nu=0.3$
  - Density: $\rho=1.30273\times10^{4}\,kg\,m^{-3}$
- $COUDE1, COUDE2, COUDE3, COUDE4$:
  - Young's modulus: $E=1.9\times10^{11}\,Pa$
  - Poisson's ratio: $\nu=0.3$
  - Density: $\rho=1.47373\times10^{4}\,kg\,m^{-3}$
  - Slope of curve of tension: $D\_SIGM\_EPSI=7.67\times10^{9}\,N\,m^{-2}$
  - Elastic limit: $SY=121.2\times10^{6}\,N\,m^{-2}$
  - Constant of $PRAGER$: $C=5.328434\times10^{9}$

The elastic limit was reduced in order to plasticize earlier.

- $PATVAN$:
  - Young's modulus: $E=1.9\times10^{11}\,Pa$
  - Poisson's ratio: $\nu=0.3$
  - Density: $\rho=0.0\,kg\,m^{-3}$
- $PATBIELA$:
  - Young's modulus: $E=1.8\times10^{11}\,Pa$
  - Poisson's ratio: $\nu=0.3$
  - Density: $\rho=4.43\times10^{3}\,kg\,m^{-3}$
- $PATBIELC$:
  - Young's modulus: $E=1.8\times10^{11}\,Pa$
  - Poisson's ratio: $\nu=0.3$
  - Density: $\rho=6.92\times10^{3}\,Kg/m^{3}$
- $BIELA, BIELB, BIELC$:
  - Young's modulus: $E=1.8\times10^{11}\,Pa$
  - Poisson's ratio: $\nu=0.3$
  - Density: $\rho=6.86\times10^{3}\,kg\,m^{-3}$
- $POUTRES$:
  - Young's modulus: $E=1.9\times10^{11}\,Pa$
  - Poisson's ratio: $\nu=0.3$

- Density: $\rho = 1.47373 \times 10^4 \, kg \, m^{-3}$

- $PATBIELB$ added mass:

$$[M] = \begin{bmatrix} m & 0. & 0. \\ 0. & m & 0. \\ 0. & 0. & m \end{bmatrix} \text{ with } m = 2.46 \, kg$$

- $CDGVAN$ (center of gravity of the valve) added mass:

$$[M] = \begin{bmatrix} m & 0. & 0. & 0. & -m.e_z & -m.e_y \\ 0. & m & 0. & m.e_z & 0. & -m.e_x \\ 0. & 0. & m & -m.e_y & m.e_x & 0. \\ 0. & 0. & 0. & V_{xx} & V_{xy} & V_{xz} \\ 0. & 0. & 0. & 0. & V_{yy} & V_{yz} \\ 0. & 0. & 0. & 0. & 0. & V_{zz} \end{bmatrix} \text{ with } \begin{array}{c} V_{xx} = I_{xx} + m(e_y^2 + e_z^2) \\ V_{yy} = I_{yy} + m(e_x^2 + e_z^2) \\ V_{zz} = I_{zz} + m(e_x^2 + e_y^2) \\ V_{xy} = I_{xy} - m.e_x e_y \\ V_{yz} = I_{yz} - m.e_y e_z \\ V_{xz} = I_{xz} - m.e_x e_z \end{array}$$

- $m = 275 \, kg$ mass

- $\begin{bmatrix} I_{xx} = 2.696123 \\ I_{yy} = 3.81480 \\ I_{zz} = 0.9166667 \\ I_{xy} = I_{xy} = I_{yz} = 0. \end{bmatrix}$ values of the tensor of component mass

- $e_x = e_y = e_z = 0.$ inertia of the vector of eccentring of the mass

non-linearity is due to the material behavior in the elbows.
The constitutive law employed is: under `COMP_INCR: RELATION=' VMIS_ECMI_LINE'`, which corresponds to elastoplasticity with isotropic and kinematical hardening mixed linear.

1.3 Boundary conditions and loadings

imposed Displacements:

- $ENC1, ENCBIS1$:
  $DX=DY=DZ=DRX=DRY=DRZ=0$
- $ENC2, ENCBIS2$:
  $DX=DY=DZ=DRX=DRY=DRZ=0$
- $PATBIEL4$:
  $DX=DY=DZ=DRZ=0$
- $PATBIEL3$:
  $DRZ=0$

Imposed connections:

- $PATVAN, VANNE$: `LIAISON_SOLIDE`
- $PATBIEL3, PATBIEL2$: `LIAISON_UNIF (DX, DY, DZ)`

imposed Pressure:

- $COUDES, POUTRES$:
  $PRES=120.5\,Pa$

Seismic loading:

- The structure is subjected to a seismic loading according to the direction X. the imposed accelerogram is characterized by a total period of $40{,}95\,s$ and time step of $0{,}01\,s$.

1.4 Initial conditions and list of computation moments

the system is initially at rest.

To limit the TEMPS CPU, one final moment will carry out computational simulation only until one being worth $0{,}17\,s$. A this time, the level of loading reaches plasticity is such that was already declared.

One builds one list of computation moments optimized: time step the passer by of $0{,}01\,s$ to 0,001 S in order to going quickly into linear and reducing the time step right one before plasticization.

2 Reference solution

2.1 Computation of reference

This computation is a test of non regression. It thus does not present of results a reference.

Course of computation:
- Computation of the stiffness matrixes and mass (operator ASSEMBLY),
- Computation of the seismic loading,
- nonlinear Direct transient analysis in relative reference, mono-bearing.

2.2 Quantities references

DX : represent, according to the field of variables:
- DEPL : the component of relative displacement following axis x
- REAC_NODA : the component of the nodal reaction along the axis x

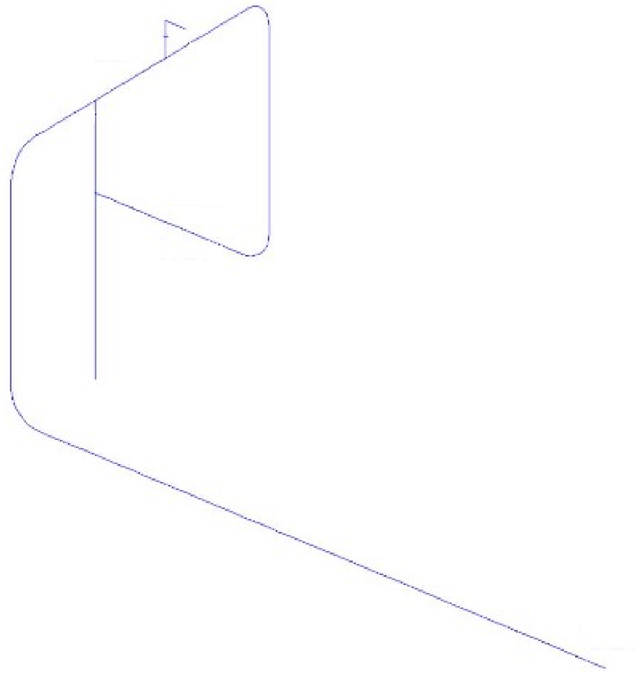
$V1$: component of field VARI_ELNO giving the cumulated plastic strain.

2.3 Results of reference

Component	Localization (s)	Time	Field
Node $N160$	0.01	DEPL	DX
Node L	0.01	REAC_NODA	DX
Node A	0.01	REAC_NODA	DX
Node L	0.17	REAC_NODA	DX
Subpoint 25 of node $N10$ of the mesh $M10$	0.17	VARI_ELNO	$V1$

3 Modelization A

3.1 Characteristic of the modelization



Appears 3.1-a: Mesh.

Modelization POU_D_T :
Mesh group: *PATBIELA , PATBIELC , PATVAN , BIELA , BIELB , BIELC*

Modelization TUYAU_3M :
Mesh group: *POUTRES , COUDES*

Modelization DIS_TR :
Mesh group: *CDGVAN*

Modelization DIS_T :
Group of mesh: *PARBIELB*

Many nodes:	161			
Number of meshes:	86	That is to say:		
			POI1	2
			SEG2	9
			SEG3	75

the diagram of integration in time is: NEWMARK, in formulation DEPLACEMENT. The only parts treated in nonlinear (RELATION=' VMIS_ECMI_LINE') are the elbows.

4 Summary of the results

the got results are satisfactory.