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

Summary:

The goal of this CAS-test 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 behavior material in the elbows.

For that, one realizes hasnalyse transitory direct nonlinear on the structure, in particular using modeling `TUYAU_3M`. One tests then displacements, the nodal reactions and the plastic deformation cumulated in certain points of the 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

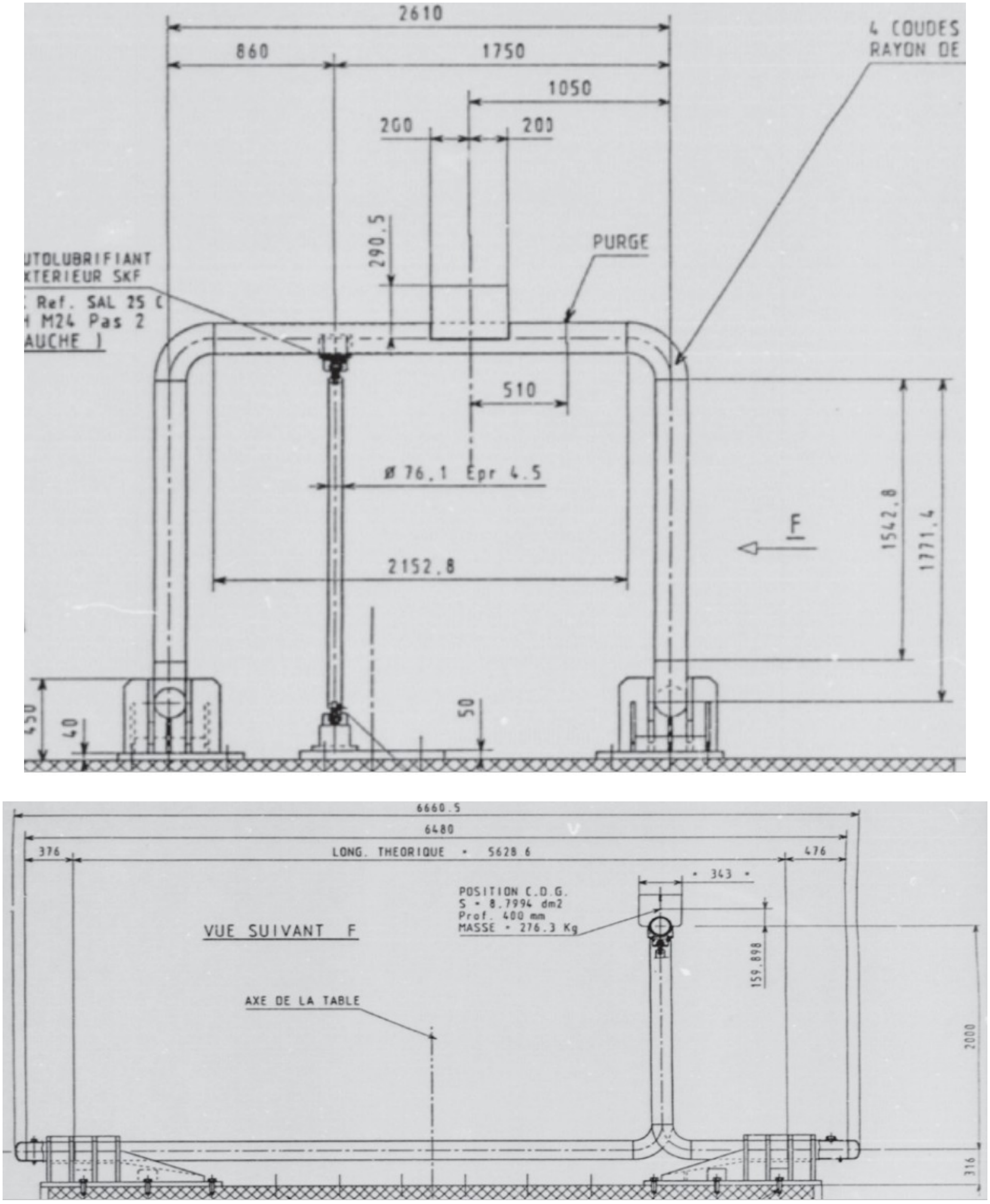

Figure 1.1-a: Geometry (tests ELSA realized by the CEA/EMSI).

Group of meshs:

$POUTRES$: together right pipes

$COUDES$: together bent pipes

$PATVAN$, $VANNE$, $ENCBIS1$, $ENC1$, $ENC2$

$ENCBIS2$, $PATBIELA$, $PATBIELB$

$PATBIELC$, $BIELA$, $BIELB$, $BIELC$, $CDGVAN$

Group of nodes:

$A, \ldots, L$

Geometry of the pipes:

$SECTION\ A$

- Groups of meshs: $POUTRES$ $COUDES$ $PATVAN$
  - $R = 8.485 \times 10^{-2} m$ External ray
  - $EP = 7.345 \times 10^{-3} m$ Thickness
- Groups of meshs: $BIELA$, $BIELB$, $BIELC$
  - $R = 38.05 \times 10^{-3} m$ External ray
  - $EP = 4.5 \times 10^{-3} m$ Thickness

$SECTION\ B$

- Groups of meshs: $PATBIELC$
  - $R = 4.55 \times 10^{-2}$ Ray
- Groups of meshs: $PATBIELA$
  - $R1 = 8.6 \times 10^{-2} m$ Ray at end 1
  - $R2 = 4.55 \times 10^{-2} m$ Ray at end 2

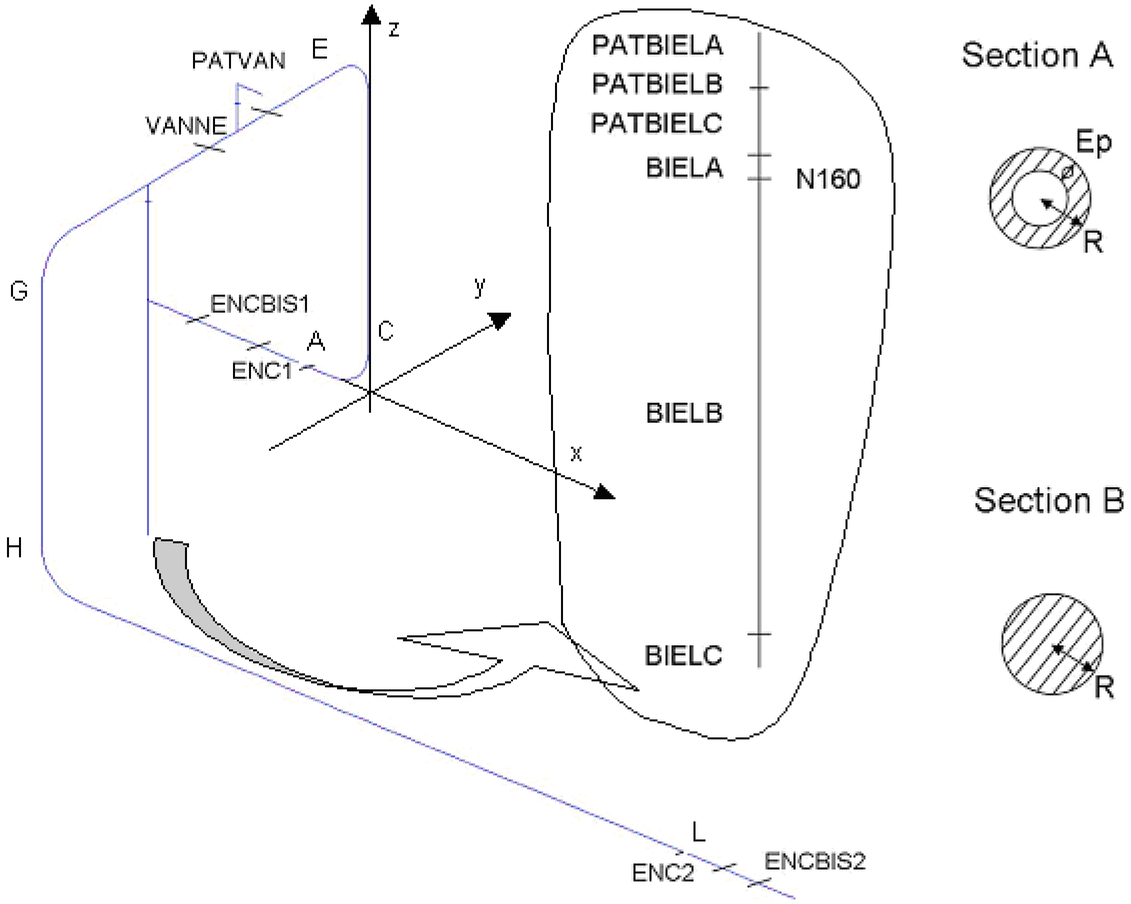

Figure 1.1-b: Modeling of the geometry.

1.2 Elastic properties of materials

- *POUTRES* :
  - Young 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 modulus: $E=1.9\times10^{11} Pa$
  - Poisson's ratio: $\nu=0.3$
  - Density: $\rho=1.47373\times10^{4} kg\, m^{-3}$
  - Slope of the traction diagram: $D\_SIGM\_EPSI=7.67\times10^{9} N\, m^{-2}$
  - 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 modulus: $E=1.9\times10^{11} Pa$
  - Poisson's ratio: $\nu=0.3$
  - Density: $\rho=0.0 kg\, m^{-3}$
- *PATBIELA* :
  - Young modulus: $E=1.8\times10^{11} Pa$
  - Poisson's ratio: $\nu=0.3$
  - Density: $\rho=4.43\times10^{3} kg\, m^{-3}$
- *PATBIELC* :
  - Young 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 modulus: $E=1.8\times10^{11} Pa$
  - Poisson's ratio: $\nu=0.3$
  - Density: $\rho=6.86\times10^{3} kg\, m^{-3}$
- *POUTRES* :
  - Young modulus: $E=1.9\times10^{11} Pa$
  - Poisson's ratio: $\nu=0.3$
  - Density: $\rho=1.47373\times10^{4} kg\, m^{-3}$

- $PATBIELB$ added mass:

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

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

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

- $m=275\,kg$ 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 mass tensor of inertia

- $e_x=e_y=e_z=0.$ component of the vector of offsetting of the mass

Non-linearity is due to the behavior material in the elbows.
The law of behavior employed is: under `COMORTEMENT: RELATION=' VMIS_ECMI_LINE'`, which corresponds to elastoplasticity with isotropic and kinematic work 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 direction X. the imposed accélérogramme is characterized by one total duration of $40{,}95\,s$ and one pas de time of $0{,}01\,s$.

1.4 Initial conditions and list of moments of calculation

The system is initially at rest.

To limit time CPU, one will carry out the digital simulation only up to one final moment being worth $0{,}17\,s$. At this moment, the level of loading reached is such as plasticity was already declared.

One builds a list of moments of calculation optimized: the step of busy time of $0{,}01\,s$ to 0.001 S in order to go quickly into linear and to reduce the step of time right before plasticization.

2 Reference solution

2.1 Calculation of reference

This calculation is a test of nonregression. It thus does not have results of reference.

Course of calculation:

- Calculation of the matrices of rigidity and mass (operator ASSEMBLY),
- Calculation of the seismic loading,
- Nonlinear direct transitory analysis in relative reference mark, mono-support.

2.2 Sizes references

DX : represent, according to the field of size:

- DEPL : the component of relative displacement following the axis x
- REAC_NODA : the component of the nodal reaction along the axis x

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

2.3 Results of reference

Localization	Moment (s)	Field	Component
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
Under-point 25 of the node $N10$ mesh $M10$	0.17	VARI_ELNO	$V1$

3 Modeling A

3.1 Characteristics of modeling

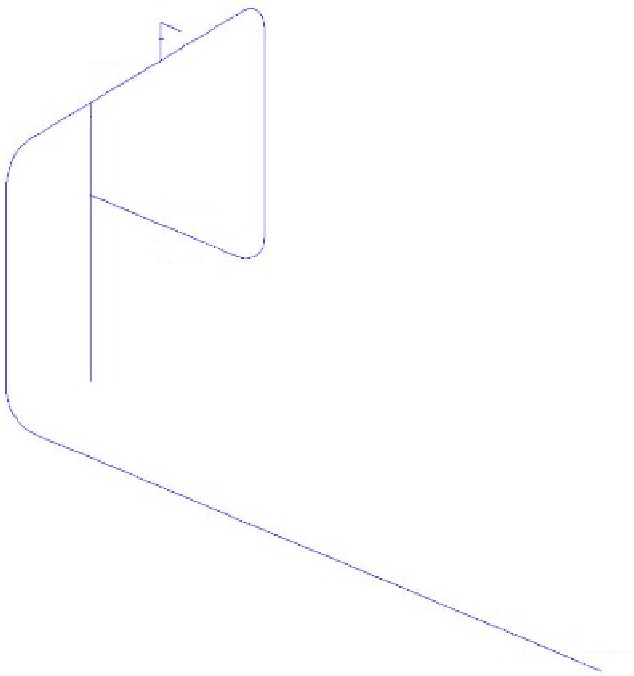

Figure 3.1-a: Grid.

Modeling POU_D_T :
Group of meshs: *PATBIELA , PATBIELC , PATVAN , BIELA , BIELB , BIELC*

Modeling TUYAU_3M :
Group of meshs: *POUTRES , COUDES*

Modeling DIS_TR :
Group of meshs: *CDGVAN*

Modeling DIS_T :
Group of mesh: *PARBIELB*

Many nodes:	161			
Many meshs:	86	That is to say:		
			POI1	2
			SEG2	9
			SEG3	75

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

4 Summary of the results

The got results are satisfactory.