SSNA112 – Axisymmetric test of wrenching for the study of the steel-concrete connection: law JOINT_BA

Summary:

In this case test of mechanics one modelled the test of wrenching carried out by Borderie & Pijaudier- Pooch [bib1] of which the goal was to study the influence of the state of stress in the matrix on the mechanical properties of the interface. The geometrical data and the characteristic materials result from their report, and the digital results will be compared with the experimental results.

For axisymmetric modeling, one uses elements QUAD4 for the concrete and steel, in combination with elements joint for the interface (see Doc. [R3.06.09]). The concrete and steel are considered elastic in order to test only to it not linearity of the law of behavior of the steel-concrete connection, JOINT_BA (see document [R7.01.21]). One carries out a monotonous calculation with the displacements imposed at the end of the steel bar.

1 Problem of reference

1.1 Geometry and boundary conditions

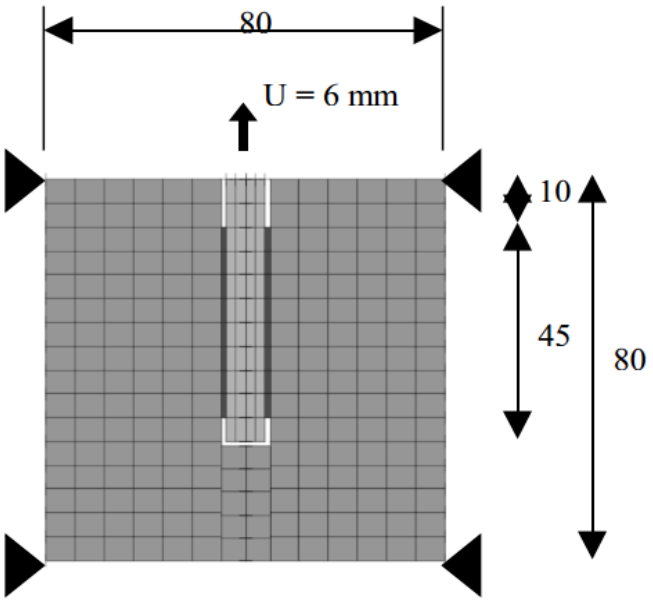


Figure 1.1-a: Geometry and boundary conditions

1.2 Properties of material

Steel : rubber band

$$E = 2.1 \times 10^5 \, MPa$$
$$\nu = 0.3$$

Concrete : rubber band

$$E = 1.55 \times 10^4 \, MPa$$
$$\nu = 0.17$$

Element of joint :

- law of behavior ELAS with the following parameters:

$$E = 1.55 \times 10^4 \, MPa$$
$$\nu = 0.17$$

- law of behavior JOINT_BA with the following parameters:

- Initial parameters:

coefficient of penetration: $Hpen = 0.64 \, mm$ (keyword: HPEN)

module of rigidity: $G_{lia}=6.65\text{x}10^{3}\,MPa$ (keyword: GTT)

- Parameters of tangential damage:

threshold of elastic strain:	$\varepsilon_\gamma^0 = 5 \times 10^{-4}$	(keyword: GAMD0)
coefficient of damage area 1:	$Ad_1 = 1.0$	(keyword: AD1)
coefficient of damage area 1:	$Bd_1 = 0.5$	(keyword: BD1)
threshold of the great slips:	$\varepsilon_\gamma^2 = 9.6 \times 10^{-1}$	(keyword: GAMD2)
coefficient of damage area 2:	$Ad_2 = 4 \times 10^{-5}\ MPa^{-1}$	(keyword: AD2)
coefficient of damage area 2:	$Bd_2 = 1.0$	(keyword: BD2)

- Parameters for the friction of the cracks and containment:

coefficient material by friction:	$\gamma = 10.0\ MPa$	(keyword: VIFROT)
coefficient by kinematic work hardening:	$\alpha = 4 \times 10^{-1}\ MPa^{-1}$	(keyword: F)
coefficient of containment:	$c = 1.0$	(keyword: FC)

- Parameters of normal damage:

normal deformation criticizes (opening):	$\varepsilon_N^0 = 9 \times 10^{-1}$	(keyword: EPSTR0)
coefficient of normal damage:	$Ad_N = 1 \times 10^{-9}\ MPa^{-1}$	(keyword: DNA)
coefficient of normal damage:	$Bd_N = 1.5$	(keyword: BDN)

1.3 Boundary conditions and loadings

Worthless displacements imposed (embedding) on the side face of the elements of the concrete.
The axis of rotation is fixed in the middle of the steel bar.
The mechanical loading into monotonous is applied in the form of displacements imposed to the end of the steel bar in two stages:

- 20 increments of $0.005\,mm$, for $U = \{0 \text{ à } 0.1\,mm\}$
- 118 increments of $0.05\,mm$, for $U = \{0.1 \text{ à } 6\,mm\}$

2 Reference solution

It is about a digital comparison - experimental. The work of Borderie & Pijaudier-Pooch [bib1] consisted in a trial run of wrenchings carried out on fibres and reinforcements for reinforced concrete. The object of these tests was to study the influence of the state of stress in the matrix on the mechanical properties of the interface.

Each specimen was a cube of $80\times 80\times 80\,mm$ whose concrete paste was $Grade\,C30/37$ (gravel of $16\,mm$) with a resistance at the time of the test (three days after the casting and with 4 hours a heat treatment) of $14.5\,MPa$, a Young modulus of $15500\,MPa$ and a Poisson's ratio of $0,17$. For the reinforcements, they used deformed bars of $8\,mm$ of diameter, with a length of steel-concrete contact of $45\,mm$, more $10\,mm$ free at the edge of the concrete, which made it possible to eliminate the singularities in the field from the concrete stresses in the embedded surface of the cube. The test was carried out with controlled displacements ($\dot{u}=8.3\times 10\text{E-}3\,mm/s$) and four levels of containment: $0,5$, 10 and $15\,MPa$, constant during each experiment.

2.1 Bibliographical references

- BORDERIE C. & PIJAUDIER-CABOT G. - experimental Study of the behavior of reinforced materials: Experimental determination of the laws of behavior of the interface matrix fibre. Laboratory of Mechanics and Technology (LMT); ENS Cachan/CNRS/Université Paris 6 ; Contract I 70/1F 3146 with Électricité de France, 1994

3 Modeling A

3.1 Characteristics of modeling

It is about a modeling 2D axisymmetric, where one can identify 2 groups of elements:

Axisymmetric modeling (keyword AXIS) for the elements of the concrete and steel.
Modeling fissures axisymmetric (keyword AXIS_JOINT) for the element of joint.

The concrete and steel are modelled with elements QUAD4.
The interface is modelled with elements QUAD4 degenerated (confused nodes).

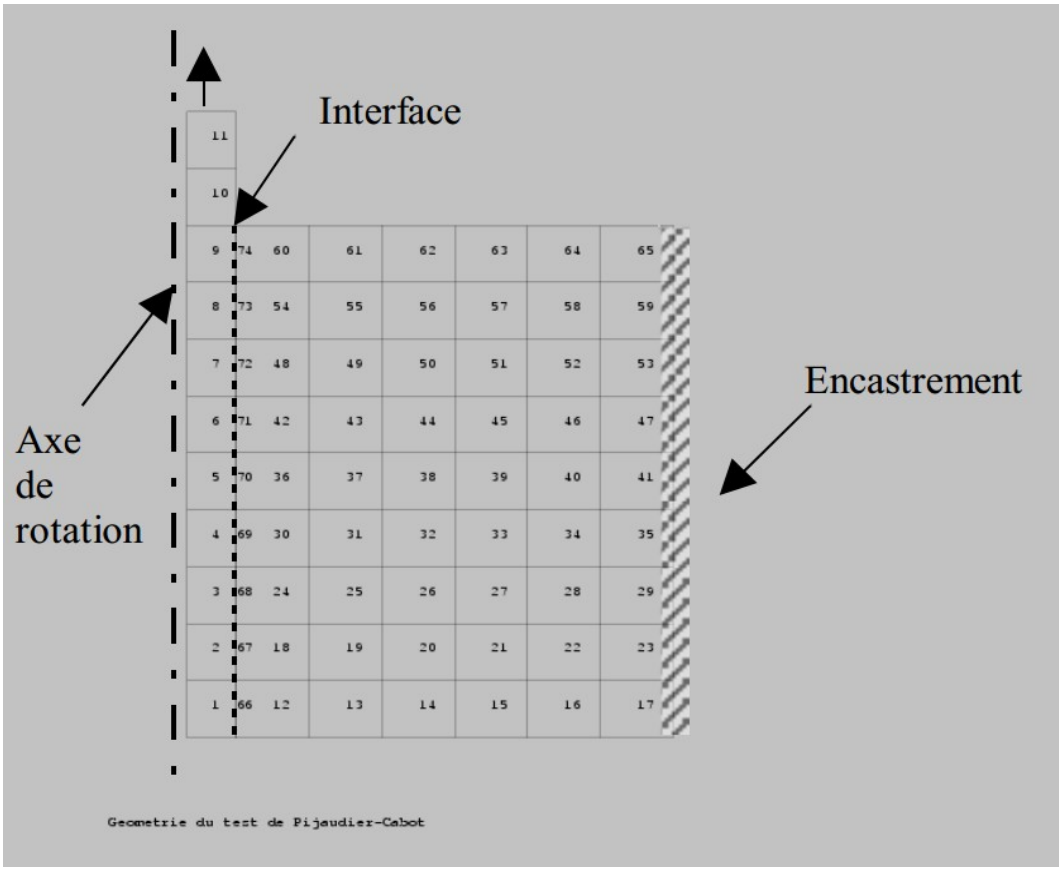


Figure 4.1-a: Modeling of the test into axisymmetric

3.2 Characteristics of the grid

Many nodes: 94 (with 20 confused nodes)
Number of meshs and type: 11 QUAD4 for steel
+ 9 QUAD4 for the interface
+ 54 QUAD4 for the concrete.

3.3 Sizes tested and results

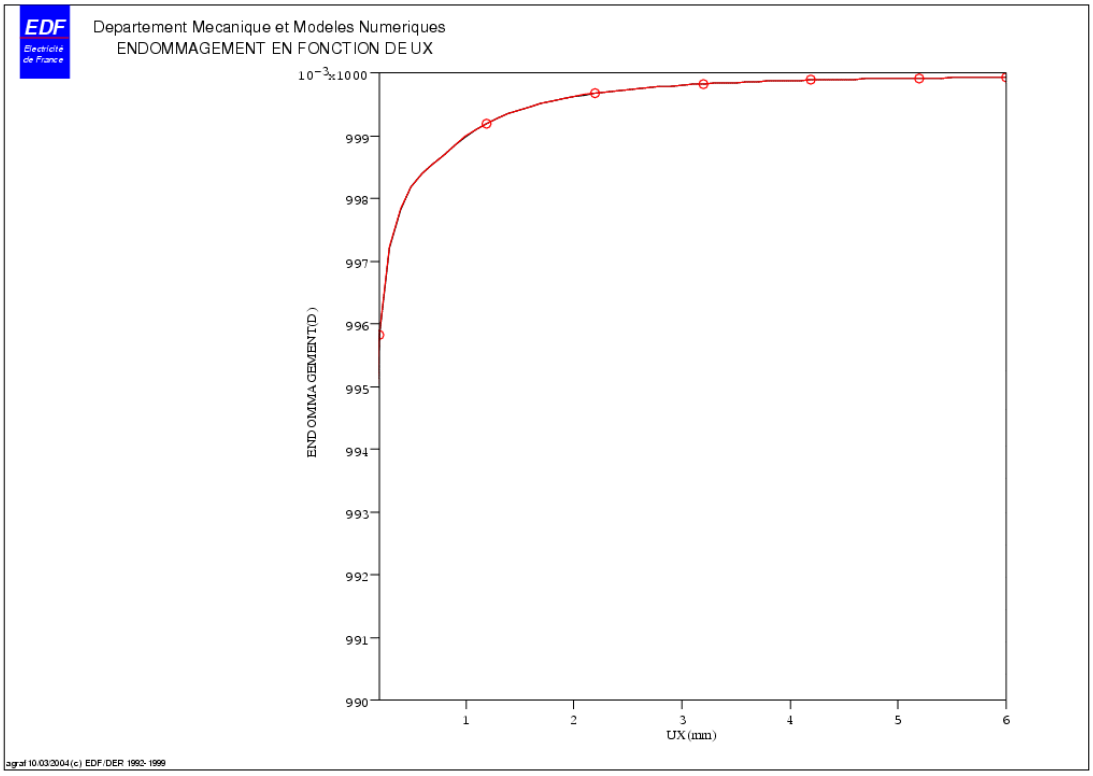
The components are tested xy element which corresponds to the tangential components of the local law of behavior in the interface, starting from the stress field SIEF_ELGA. The values are tested at the point of Gauss 2 of the element joint, with 4 pas de different times: at the beginning of the loading, during the phase of growth of the damage, in the peak of maximum resistance and after the peak of the resistance of the connection.

Field SIEF_ELGA component SITX

Identification	Reference	% tolerance
For an imposed displacement $U_{TT}=0.2\,mm$	-7.20 E+00	5
For an imposed displacement $U_{TT}=0.8\,mm$	-1.14 E+01	5
For an imposed displacement $U_{TT}=1.0\,mm$	-1.26 E+01	5
For an imposed displacement $U_{TT}=1.6\,mm$	-1.22 E+01	5

3.4 Evolution of the damage

To observe the coherence of the evolution of the damage in the various connection elements, one builds the graphics of the variable of damage compared to imposed displacement.



4 Summary of the results

With lower deviations than $5.0\ \%$ compared to the experimental results got by Borderie & Pijaudier-Pooch [bib1], one considers that the axisymmetric simulation of the test of wrenching is satisfactory. However, in order to test the stability of the law of behavior in combination with other laws (the law MAZARS for the concrete, for example), it will be necessary to decrease the size of the steps of time by considering that the other laws are made normally for formulations in small deformations.