SSNP136 – Test of foundation filanteavec the Summarized Camwood-Clay model

One carries out a test of foundation slipping by using the Camwood-Clay model. The calculated solutions are compared with results resulting from the code finite elements SPLASH.

1 Problem of reference

1.1 Description of the model

The model of slipping by foundation consists of a rigid foundation of width B equal to $2\,m$ posed on a half-plane representing a soil poro-élasto-plastic. The foundation is regarded as being infinitely long, so that the problem can be brought back on a vertical plan ($2\mathrm{D}$) containing a section of the foundation (Figure 1). A vertical displacement directed to the bottom is imposed on the foundation, and one observes the evolution of the behavior of the soil located under this one. The problem also having a symmetry compared to the vertical plan dividing the foundation over its length in two equal parts, one represents only one half of the problem. One thus represents the soil by a square of $10\,m$ with dimensions, the sufficiently large one not to disturb the evolution of the behavior of the soil around the foundation (assumption of the infinite half-plane for the soil).

The behavior of the soil is modelled by the Camwood-Clay model. One also supposes the presence of a fluid (water) *in saturated condition* (coupling hydo-mechanics).

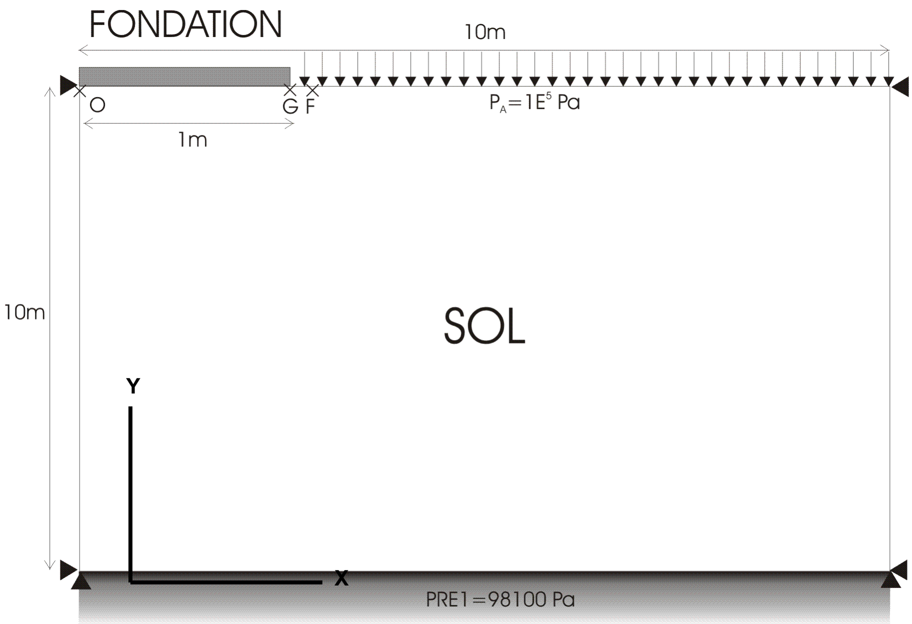

Figure 1 : model slipping by foundation.

1.2 Boundary conditions and initial conditions

the mechanical boundary conditions are:

- $Ux=0$ on side edges (horizontal symmetry);
- $Uy=0$ on lower edge (vertical symmetry sufficiently far from the foundation);
- a pressure imposed $P_A=1.\mathrm{E}^{+5}\,Pa$ (atmospheric pressure) on edge higher, supposed than open air;

The hydraulic conditions are:

- Pore water pressure $PRE1=98100\,Pa$ on lower edge (drainage downwards).

It is pointed out that the absence of explicit boundary conditions amounts for the hydraulics imposing a null flux on the edges (condition of NON-drainage).
The initial conditions in the soil are:

- <u>in the case without water</u>

$$\sigma_y=\rho_S\,.\,g\,.(h-y)+P_A\,.$$
$$\sigma_x=K_0.(\sigma_y-P_A)+P_A$$

* in the case with water

$$\sigma_y=\rho_h.g.(h-y)+P_A$$
$$\sigma_x=K_0.(\sigma_y-P_A)+P_A$$
$$PRE1=\rho_e.g.(h-y)$$

ρ_S, ρ_e and $\rho_h=\rho_S+n.\rho_e$ the densities of soil, fluid represent and homogenized, respectively;
n represent the porosity of the soil;
h represent the thickness of the soil (or free surface dimensions it), with $h=10m$;
P_A represent the fixed part of the initial stress in the soil, equal to the atmospheric pressure $1.E^{+5} Pa$;
K_0 represent the coefficient of thorough grounds, here equalizes to 1.

1.3 Material properties

the unelastic parameters of the Camwood-Clay model are:

* porosity: $n=0.5$ (corresponds to an initial index of the vacuums $e_0=\frac{n}{1-n}=1$);
* the elastic coefficient of compressibility: $\kappa=0.05$ (elastic slope in the plane [E, ln (P)]);
* the plastic coefficient of compressibility: $\lambda=0.2$ (plastic slope in the plane [E, ln (P)]);
* the slope of the right of critical condition: M = 1.02 (corresponds to a friction angle of 25.85°);
* critical pressure: $P_{CR}=P_{CO}/2=trace(\sigma)/6=\sigma_x/3+\sigma_y/6$;

The elastic parameters of the soil are:

* density of the grains: $\rho_S=1900\,kg/m^3$;
* the Poisson's ratio: $\nu=0.3$;
* the modulus of Young1On[1] : $E=10\,Mpa$;
* parameters allowing to control the tension: $K^{cam}=Ptrac=0$.

Lastly, the hydraulic parameters are:

* density of water: $\rho_e=1000\,kg/m^3$;
* viscosity: $\nu=0.001$;
* the hydraulic permeability[2] : $K^{\text{int}}=1.E^{-12}\,m^3/kg/s$;
* the coefficient of compressibility of water: $K_e=1.E^{+10}$;

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1 must choose a data file (E,ν) satisfying the relation: $E<\frac{3(1+\nu)P_0(1+e_0)}{\kappa}$ *at the initial state*. In our case, with $E=10\text{MPa}$ and $\nu=0.3$, one a:
$E<\frac{3(1+\nu)P_0(1+e_0)}{\kappa}=156.\text{P}_{co}$, where P_{co} the pressure of initial consolidation of the soil represents. However $P_{co}=trace(\sigma_0)/3$ is strictly increasing according to the depth. The minimal value of P_{co} is thus reached at free surface, and is worth $P_{co,min}=P_A=10^{+5}\,Pa$. Thus $E=10\text{MPa}<15\,MPa$.

2 intrinsèque2La conductivity is written: $\lambda=\frac{\rho_e g K^{\text{int}}}{\nu}\approx 1.E^{-5}\,m/s$.

1.4 Loadings

the loadings are the following:

- gravity $g=9.81\,m/s^2$, directed downwards;
- a vertical displacement going down imposed on the foundation, varying linearly 0 with $D_Y=-0.05\,m$ enters $t_0=0\,s$ and $t_1=1.\mathrm{E}^{+7}\,s$.

If one considers one time step understood enters $1.\mathrm{E}^{+5}s$ and $1.\mathrm{E}^{+6}s$, one obtains a distance characteristic of diffusion of the fluid between each time step understood enters $1\,m$ and $10\,m$. Compared with the size characteristic of the foundation ($2\,m$), one can consider that *the permanent mode is reached between each time step*.

1.5 Results

the solutions post-are treated with the points O , G and F directly located under the foundation, in terms of trajectories of loading in the plane $(P\text{'},Q)$. One is also interested in the evolution of the resultant of the vertical force over the width B of the foundation, according to his depression. One compares the solutions obtained by Code_Aster with those calculated by SPLASH.

2 Modelization A

2.1 Characteristic of the modelization

The modelization A is *two-dimensional* and *static nonlinear*. The computation is realized in *pure mechanics*, without hydro-mechanical coupling (equivalent of a perfectly drained soil).

One can check the coherence of the initial state initially (in particular of the boundary conditions with the state of pre-consolidation of the soil): the mechanical equilibrium must be established when only gravity acts, therefore the state of the system should not evolve.

Vertical displacement is imposed on `GROUP_MA = "APPUI"` representing the interface between the foundation and the soil, and varies between $0.$ and $-0.05\,m$ in 20 time step enters $t=0.\,s$ and $t=1.\mathrm{E}^{+7}\,s$.

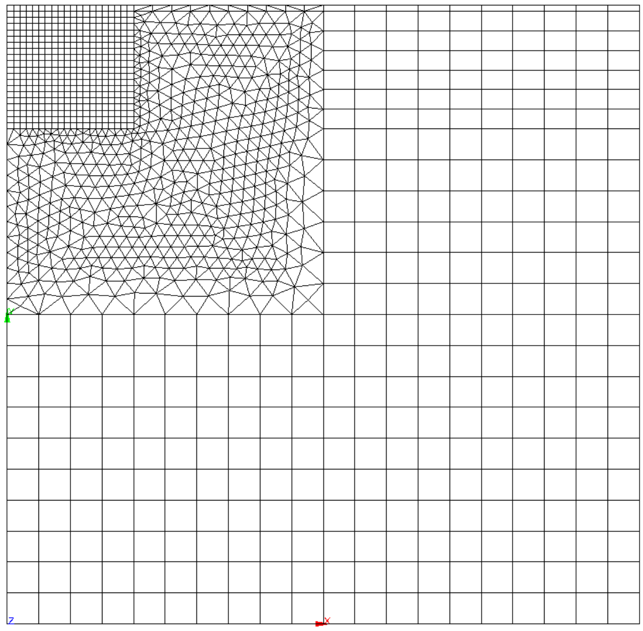

Figure 2 : mesh of the foundation slipping by for modelization A.

2.2 Grandeurs tested and results

the solutions are calculated at the points O and F are compared with references SPLASH. They are initially given in terms of equivalent stress Q according to the pressure of consolidation effective P', and recapitulated in the following tables:

$P'=\frac{1}{3}.trace(\sigma')$; $Q=\sqrt{\frac{3}{2}s:s}$ (where $s=\sigma'-P'.1$)

With point: O

P' [Pa]	Code_Aster [Pa]	SPLASH [Pa]	error relative
102000	434.450		-0.035%
110000	19662	20000	-1.689%
120000	25837	26060	-0.855%
130000	29290	29490	-0.679%
146000	34006	34040	-0.100%

To point: F

P' [Pa]	Code_Aster [Pa]	SPLASH [Pa]	relative error
101900	227	76	+199%
100000	4945	4950	-0.110%
98000	9941	10420	-4.593%
96000	15283	16830	-9.190%
94000	20036	21870	-8.385%

One calculates then the resultant of the forces exerted on the foundation according to its depression. This one is also compared with the solution given by SPLASH:

UY [m]	Code_Aster [N/m]	SPLASH [N/m]	relative error
-0.005	-110105	-108500	+1.479%
-0.02	-129224	-125800	+2.722%
-0.04	-149470	-144600	+3.368%
-0.06	-167066	-160900	+3.832%
-0.0875	-188825	-181100	+4.266%

2.3 Comments

the comparison of the solutions given by the two codes in the preceding tables shows a relatively satisfactory convergence. Only the variation at the point F for $P'=101900\ Pa$ appears high into relative ($+199\%$), but is actually of an order of magnitude in acceptable absolute compared to the other points.

For better determining the comparison between the various solutions obtained by Code_Aster and SPLASH, one presents on Figure **3** the comparison of the ways of loadings to the points O , G and F in the plane (P',Q) , and on Figure **4** the comparison of the resultants of the forces on the foundation.

In term of way of loading in plane (P',Q) (FIG.3), if the solutions coincide rather well at the point O , they present variations relating to the point F , but more significant at the point G . These variations can be explained by the conjunction of two factors:

- on the one hand, the two codes post-do not treat the solutions in the same way: Code_Aster with the nodes and SPLASH at the points of Gauss3On[3] ;
- in addition, the points G and F are located around the end of the foundation, which is a rather critical place since it is the border between the compression zones (under the foundation) and thermal expansion of the soil (outside the foundation). The gradients of stress are high there from one Gauss point to another, and one can thus understand that an extrapolation with the nodes from Gauss points closest is only imperfectly representative of the actual values in these Gauss points.

In terms of resultant of the forces (figure **4**), the solutions given by Code_Aster and SPLASH coincide relatively well, but tend to deviate as the depression of the foundation increases.

3 could also recover the solutions of Code_Aster to Gauss points, but it is difficult to automate the intercomparison of the solutions obtained by the two codes in this case (`TEST_RESU` does not allow it).

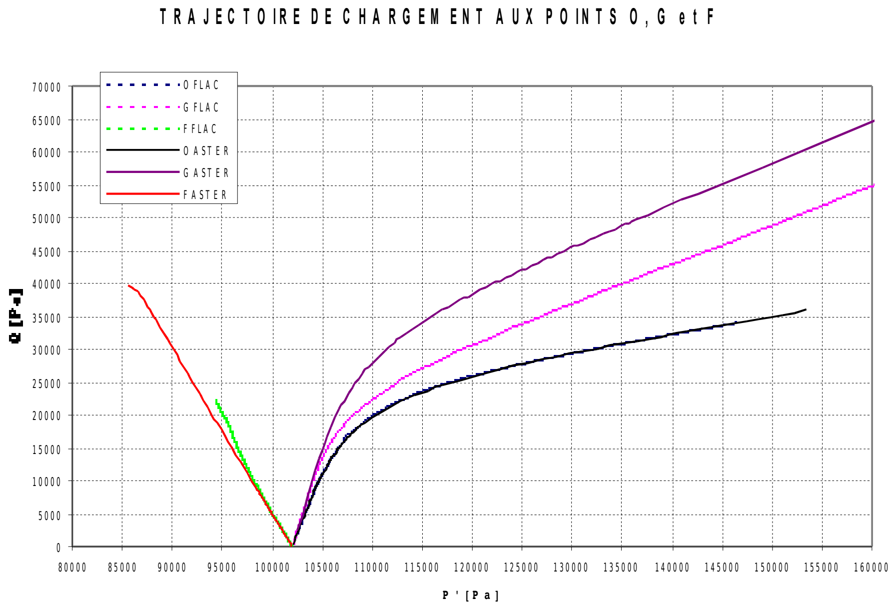

Figure 3 : comparison of the ways of loading in the plane (P', Q) at the points O, G and F given by Code_Aster and SPLASH for modelization A.

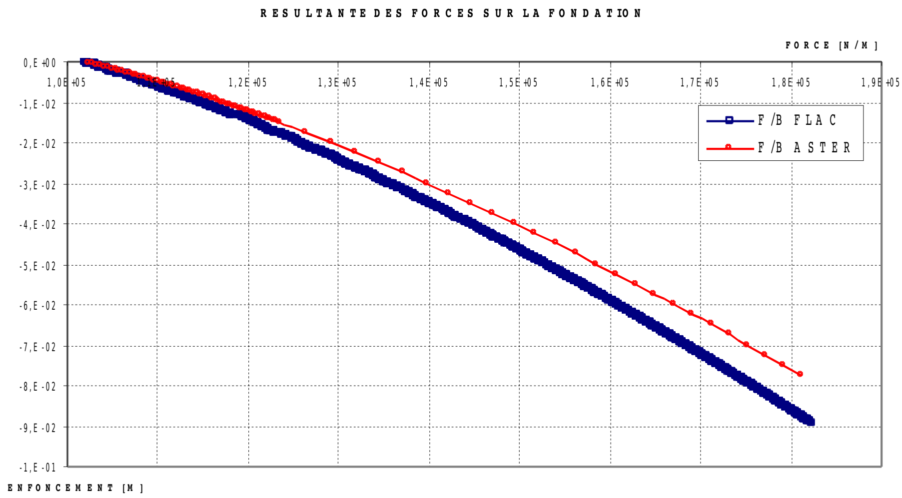

Figure 4 : comparison of the resultants of the forces exerted on fondationdonnées by Code_Aster and FLAC for the modelization A.