GEOMOD

TECHNICAL NEWS

2007

Editorial

In 2007 GeoMod has benefited from current favorable economic circumstances and worked on about thirty projects. Beside "classic" projects, three of which are described in this booklet (seismic verification of a dam, piles foundation, braced excavation), the company has also carried out more original projects, such as:

- implementation of a user-defined constitutive law for shales in Z-Soil
- fatigue verification of a pipe
- hydrogeological modelling of a pumping well's influence on groundwater with the software FEFlow

As our team has grown and our activities have diversified, in 2008 we will be able to offer you an even larger range of services.

Seismic verification of a weight-arch dam (Vieux-Emosson dam)

Contractor : CFF Infrastructures-Energie SA, Zollikofen

The verified dam (45 metres of height ; 13 mio m3 of water - Figure 1) is founded on good quality rock (Gneiss).

According to SFOE (Swiss Federal Office of Energy) guidelines, for Class I concrete dams, it is necessary to carry out a complete dynamic analysis.

Figure 1. View of the dam

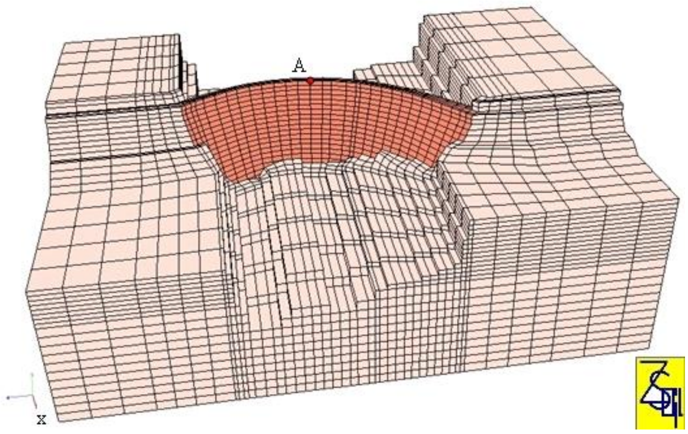

Figure 2. 3D mesh

The used mesh is depicted in Figure 2.

The numerical model is first calibrated on a static loading case (dead weight, hydrostatic pressure and temperature). In this way, displacements' time history at point A (situated on the dam's crown), for the years 2004-2007, was reproduced by a thermo-mechanical computation and then compared with the existing measures (Figure 3).

There is a good correspondence between the measures observed during the summers 2004-2007 and the displacements computed by the numerical model; the model is therefore validated.

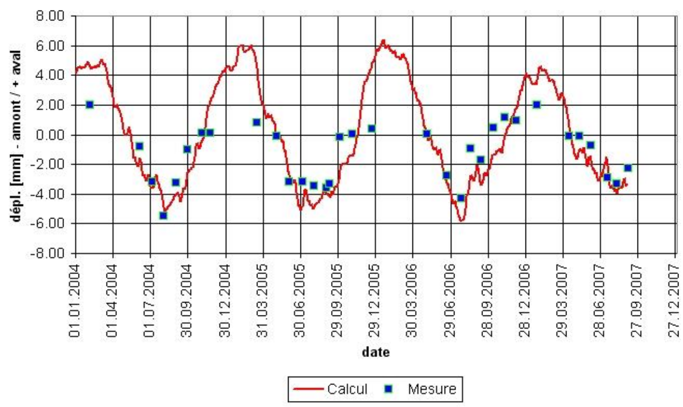

Figure 3. Model calibration on a static loading case

To check the actual seismic safety of the dam, 3 sets of accelerograms have been applied to the domain (one in each spatial direction), according to the swiss seismic map, the dam's class and the foundation soil. They each last 20 seconds and the horizontal peak acceleration corresponds to approximately 30% of Earth's gravity (Figures 4 and 5).

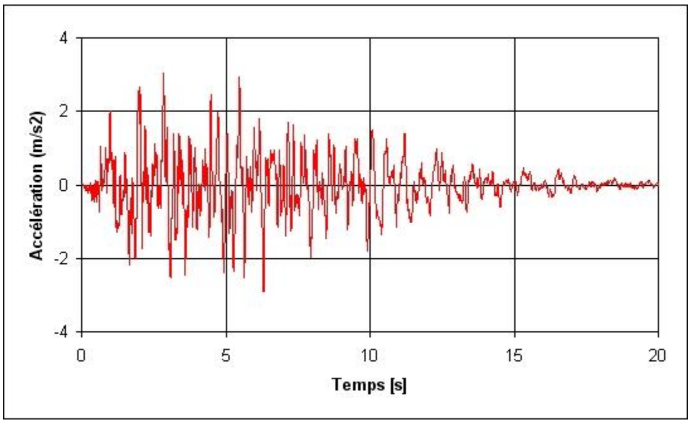

Figure 4. Time history of 1 of the 9 accelerograms

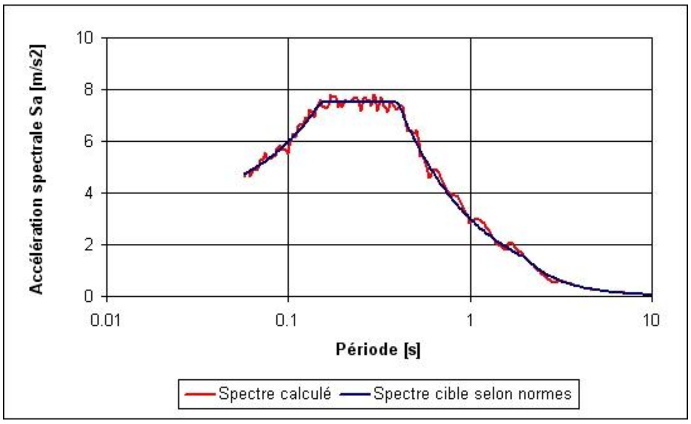

Figure 5. Response spectrum of 1 of the 9 accelerograms

Water is assumed incompressible. Its influence is introduced into the model through oscillating masses on the upstream face of the dam (Figure 6).

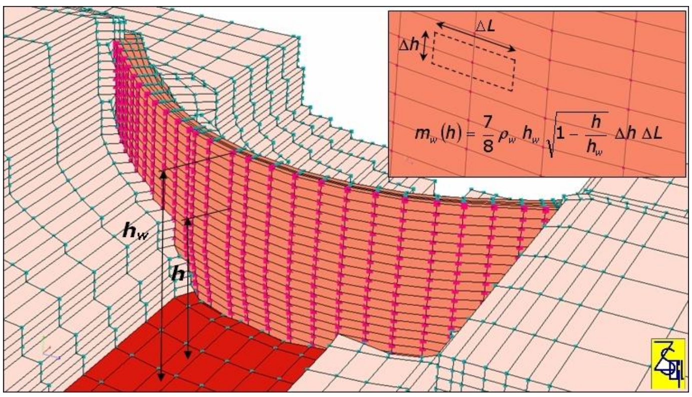

Figure 6. Modelling of the oscillating mass

The behaviour of the materials used for concrete and rock (foundation) is considered to be linear elastic. The dynamic elastic moduli are determined from static elastic moduli and damping is introduced into the model according to SFOE guidelines.

Moreover, we use a massless foundation approach. This hypothesis allows to simplify the resolution of the dynamic soil – structure interaction problem and to avoid a reflection of the waves on the models' boundaries, which would lead to an overestimation of seismic activity.

The seismic input is added to the dam's usual loads (dead weight, hydrostatic pressure, temperature variation). The model's response to the input is evaluated and it is checked, on the one hand, that the evolution of concrete stresses do not exceed the material's limit values, determined by laboratory testing and fixed by guidelines (risk of cracks) and, on the other hand, that the dam will not slide on its toe or rock (general stability).

As an example, the absolute displacement of point A is shown in Figure 7. The initial displacement of 1.2 cm corresponds to the displacement caused by the seasonal temperature variation (if it is admitted that the dam's construction was finished in spring and that the earthquake occurs in winter).

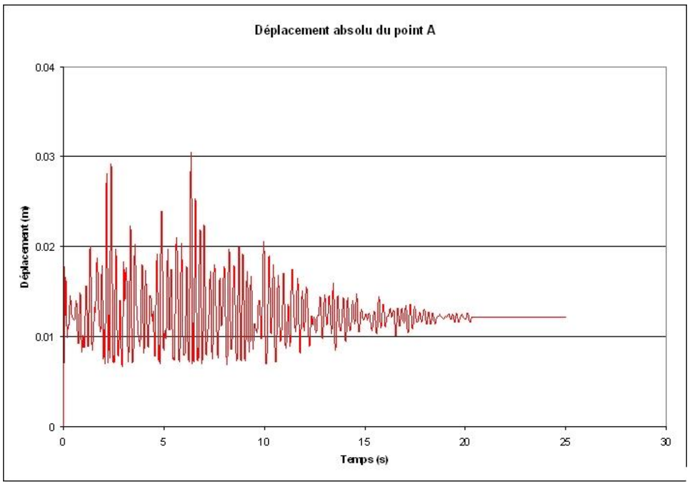

Figure 7. Evolution of the absolute displacement of point A

Figure 8 illustrates the distribution of the principal stresses σ_{11} at the moment when it is the less favourable to the dam. The examination of the tensile zones enables to determine the risk of cracks of the dam, when subjected to a given seismic input.

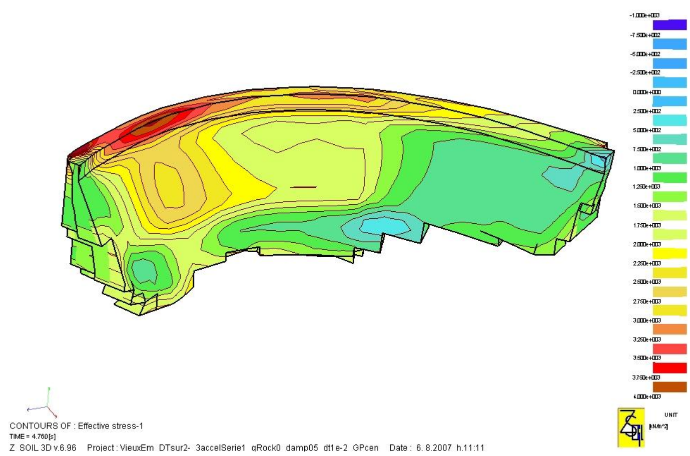

Figure 8. Principal stresses σ_{11}

Modelling of piles foundations of an industrial production unit

Civil engineer : Perret-Gentil Rey et Associés SA, Lausanne
Geotechnician : De Cérenville Géotechnique SA, Ecublens

In order to choose a foundation system for a manufacture whose structure has important loads with extremely severe deformation criteria (1/1000), several numerical simulations were carried out. The influence of the presence, the diameter, the type, the spacing and the length of piles under different parts of the manufacture has been estimated, as well as the influence of the preloading on the absolute and differential settlements under service loads.

The validity of the hypotheses concerning the soil's parameters has been verified by comparing the load-settlement curve measured during a static test and the one given by the model after calibration (Figure 10).

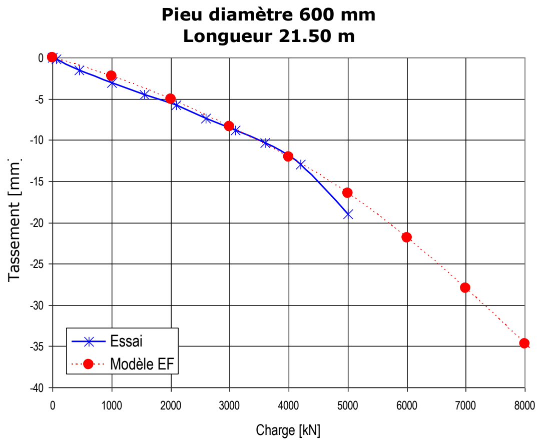

Figure 10. Load-settlement curve

The mesh of a representative strip covering three distinct zones of the manufacture is shown in Figure 11. Structures are modelled either with the help of continuum elements (piles), or with thin shells (mat foundations.) The presence of water in the sands is also taken into account.

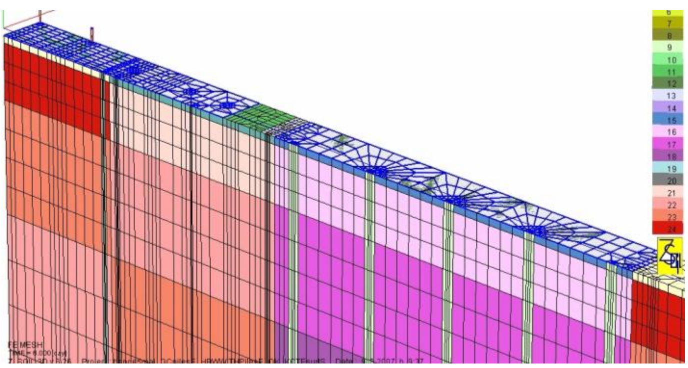

Figure 11. 3D mesh of a representative strip

As an example, Figures 12 and 13 show the vertical displacements predicted in one of the manufacture's stocking zones, for a given loading case, in service state. The influence of the piles' presence is noticeable and piles could be proved necessary to limit the differential settlements.

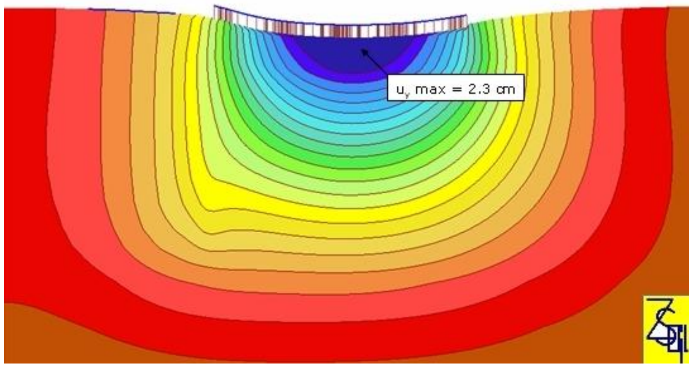

Figure 12. Vertical displacements without piles

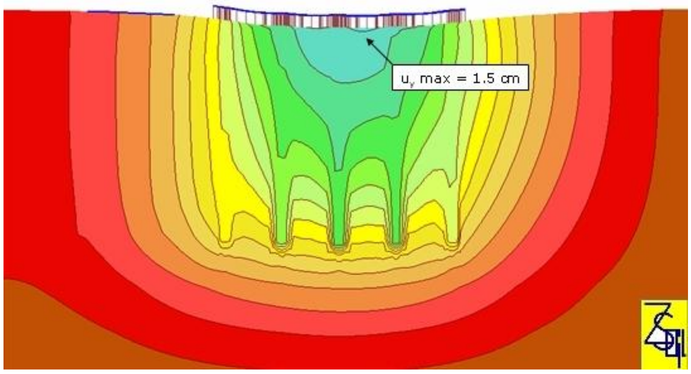

Figure 13. Vertical displacements with piles

Modelling of the behaviour of «Plan-Léman» excavation in Renens

Construction company (earthworks) : Marti AG, Bern
Civil engineer (earthworks) : De Cérenville Géotechnique SA, Ecublens

Within the framework of a real-estate project in urban environment, the excavation's behaviour (Figure 14) was predicted with the help of a hydromechanically coupled 3D simulation.

The project included the realization of a retaining slurry wall braced on one level.

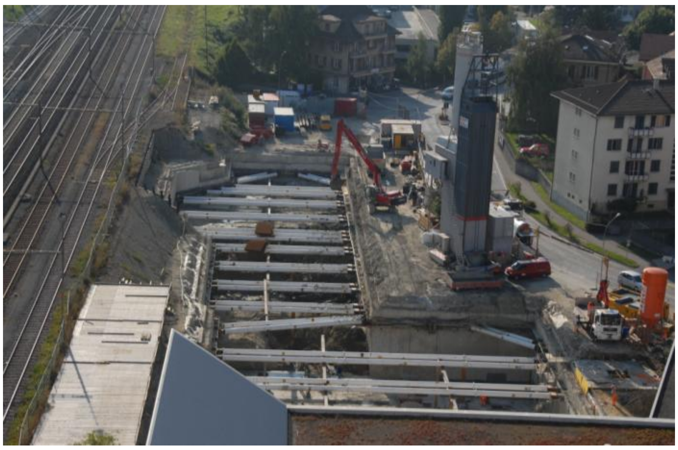

Figure 14. Excavation view (picture MP ingénieurs conseils SA)

The aim of the modelling was to :

- predict the service behaviour, and particularly the risks of settlements near a railway line located behind the excavation.
- evaluate the internal forces in the slurry wall
- check the slurry wall's depth
- clarify the excavation's hydro-gelogical behaviour with the help of auxiliary models.

The 3D modelling allows to take into account the complex excavation stages, and particularly the step-by-step realization of a blocking foundation mat, which is a significant advantage comparing to more "classic" approaches (such as reaction moduli). As an example, the earthworks map of the large excavation is depicted in Figure 15, and its corresponding simulation in Figure 16.

Figure 15. Excavation map extract: construction stages of the foundation mat (DCG SA)

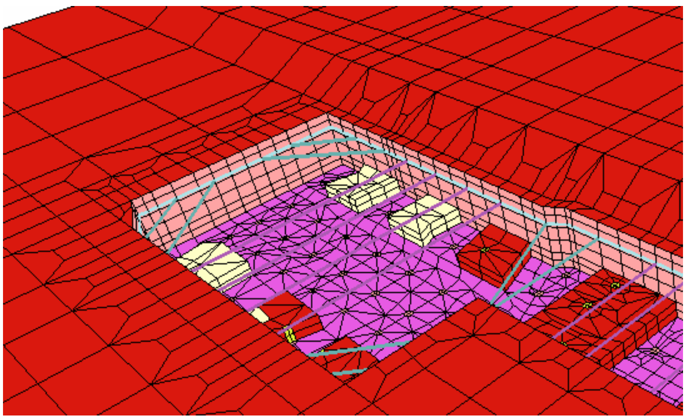

Figure 16. Illustration of a construction stage of the foundation mat (3D model)

Bending moments in the slurry wall and horizontal displacements predicted once the bottom of the excavation has been reached are shown in Figures 17 and 18. A complete monitoring system has been set up for this excavation and has allowed the validation of the model's hypotheses. Figure 19 compares the predictions with the inclinometric results on both sides of the large excavation (Figure 18 shows the location of the inclinometers I1 and I7).

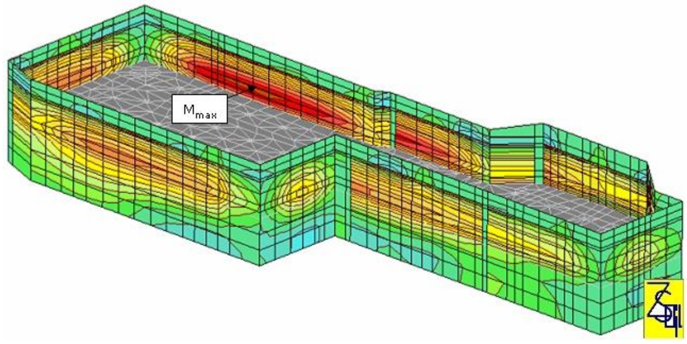

Figure 17. Bending moments in the slurry wall

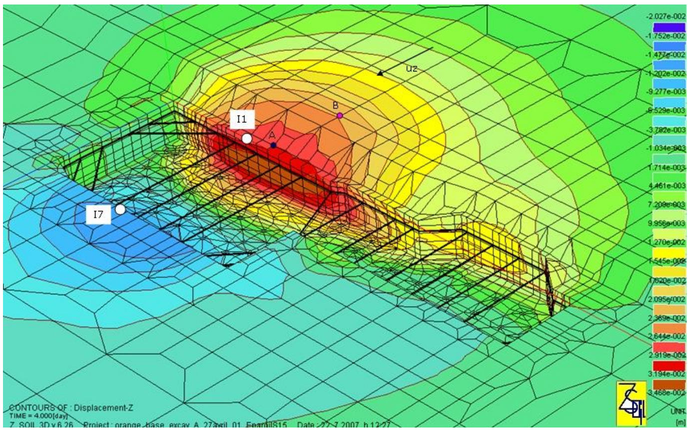

Figure 18. Predicted horizontal displacements along z axis

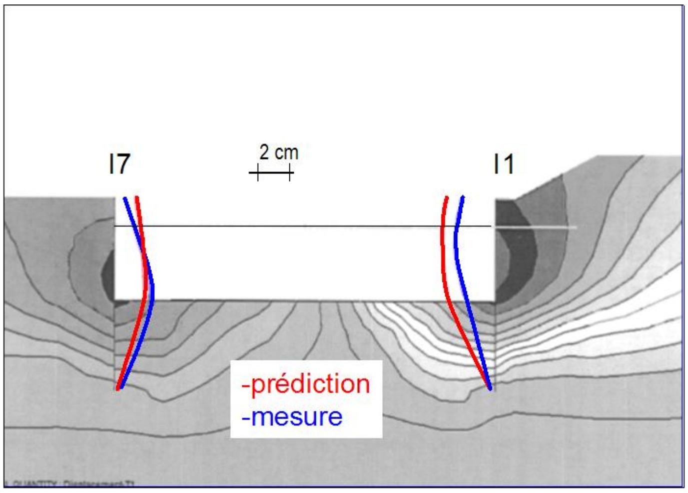

Figure 19. Predicted horizontal displacements along z axis

In conclusion, the complete 3D simulation allows to satisfactorily predict the displacements in and around the excavation and to optimize reinforcement steel in the slurry wall.

GEOMOD

GeoMod ingénieurs conseils SA
Av. des Jordils 5
CH-1006 Lausanne
T : +41 21 311 34 30
F : +41 21 311 34 29
www.geomod.ch
info@geomod.ch