High Performance Computing in Geosciences
Safety of constructions with respect to
rock deformations and movements
HIPERGEOS

Benchmark problems

BENCHMARK 1 [Square footing problem (STRIP)] A soil mechanic problem, illustrated in Figure 1. The domain is $100 \times 100 \times 40$ m. A square domain of size 10×10 m on the top side is loaded uniformly ($V = 2.4$ MPa). The material is homogeneous and isotropic ($E = 14, \nu = 0.3, \gamma = 2.5$). The grid is rectangular and is refined under the footing. The problem is solved for two discretizations: $40 \times 40 \times 40$ and a $80 \times 80 \times 80$ mesh. The total number of degrees of freedom is 192000 and 1536000, respectively.

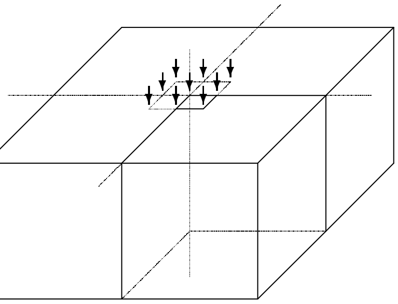

Figure 1: The STRIP problem

BENCHMARK 2 [STOPE] A mining problem. $\Omega = 300 \times 150 \times 150$ m, situated in the depth of 500 m under the surface (see Figure 2). (Only half of the domain is considered.) The materials are three in this case:

material	$E(MPa)$	ν	$\gamma(kN/m^3)$
rocks	8000	0.2	2.5
coal	800	0.3	1.29
goaf	200	0.4	2.2

The problem is solved for two discretizations: $40 \times 40 \times 40$ and a $80 \times 80 \times 80$ mesh. The total number of degrees of freedom is 192000 and 1536000, respectively.

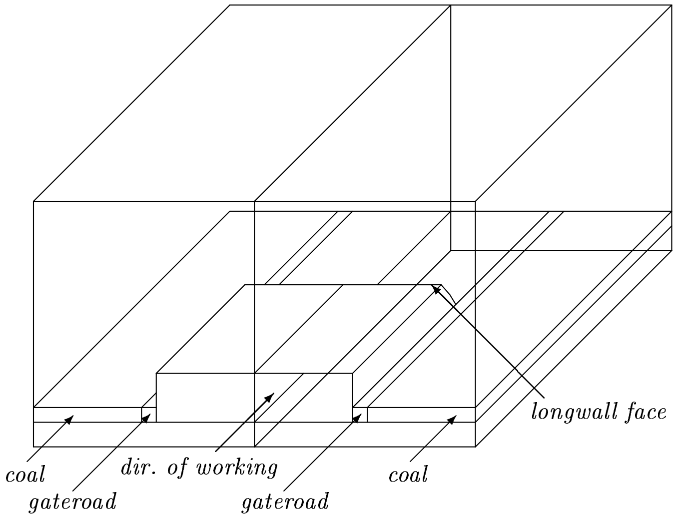

Figure 2: The STOPE problem

BENCHMARK 3 [HEADGATE] A mining problem. $\Omega = 1800 \times 237 \times 86\ m$, see Figure 3.

The problem concerns the stability of coal pillars which are periodically distributed in a corridor passing throw a coal seam. Beside the corridor, the problem includes a mined out area excavated by the longwall mining technology. We shall consider three variants of the described problem:
A – the whole situation,
B – restricted problem situated in 2/3 of the whole computational domain,
C – restricted problem situated in 1/3 of the whole computational domain.

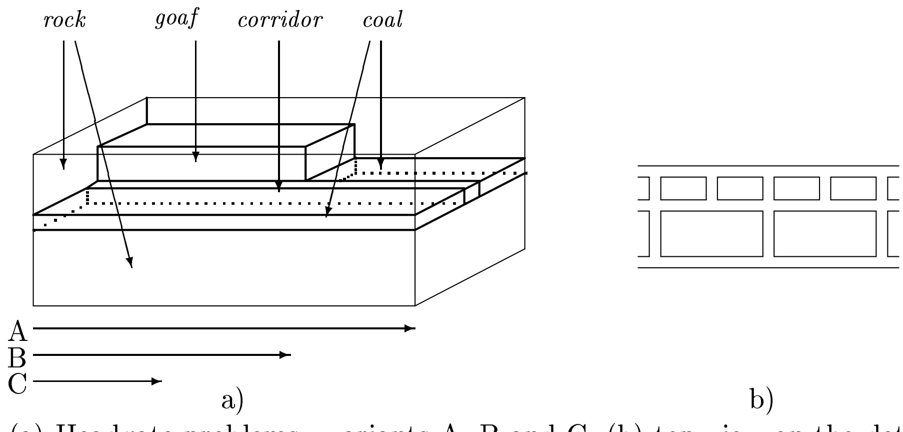

Figure 3: (a) Headgate problems - variants A, B and C, (b) top view on the detail of distribution of the coal pillars in the corridor.

The materials are the same as for the STOPE benchmark. The top side is loaded by the pressure 12.5 MPa. Zero normal displacements and zero tangential stresses are assumed on the other sides. The problem is solved for three discretizations with $302 \times 26 \times 33$, $202 \times 26 \times 33$

and $102 \times 26 \times 33$ node meshes. These discretizations use rectangular grids and correspond to the variants A, B and C, respectively. The grids are refined in the vicinity of the corridor. The total number of degrees of freedom is 777348, 519948 and 262548, respectively.

Benchmark 4 [Rožınka] A mining problem. $\Omega = 1430 \times 550 \times 600\ m$, see Figure 4 and Figure 5.

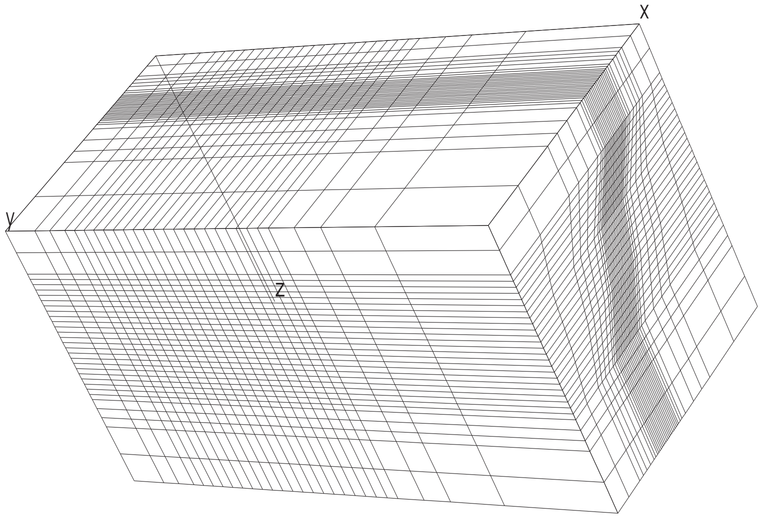

Figure 4: The target domain for Rožna mine

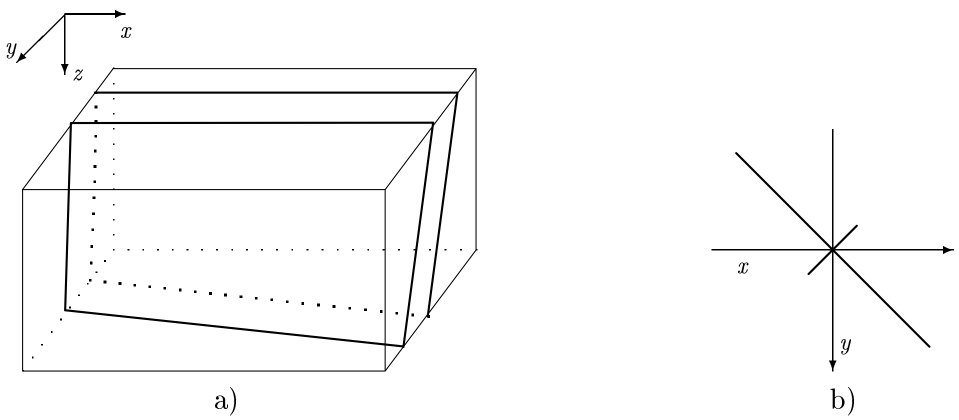

Figure 5: (a) Computational domain with screwed zone containing three ore veins (b) principal stresses in the horizontal plane with the size $2\,s_{zz}$ and $0.5\,s_{zz}$ where s_{zz} is the vertical stress given by the weight of rocks.

The problem concerns the assessment of stability of mine openings at the uranium ore deposit Rožná. The benchmark represent the first excavation stage of the modelling. We consider two variants of the problem. The variant "S" uses pressures given by the pre-mining stress field on the whole boundary of Ω. The second variant "R" uses prescribed

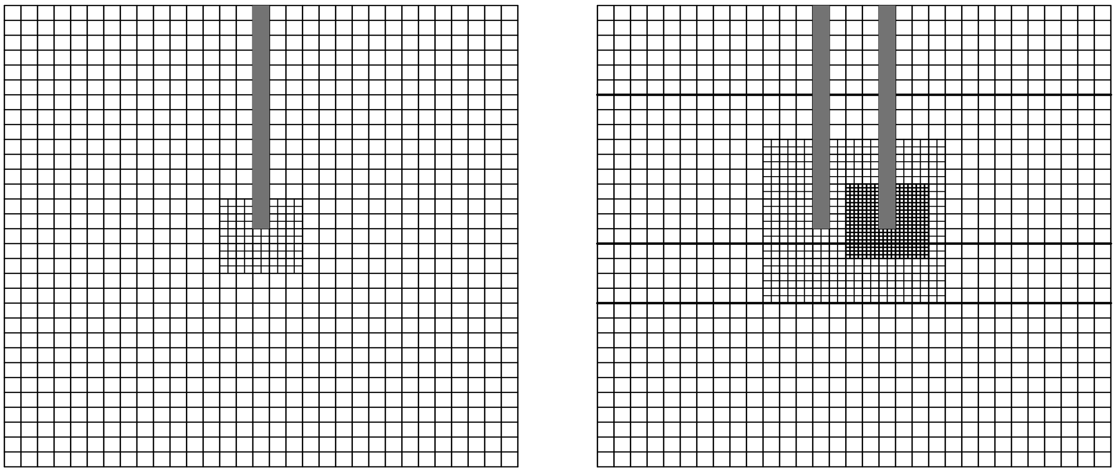

Figure 6: 3-D simulation of pile systems with patched local refinement

displacements, taken from the variant "S", on the whole boundary of Ω. The materials are according to the following table:

material	$E(MPa)$	ν	$\gamma(kN/m^3)$
rocks	20000	0.25	2.7
uranium ore	20000	0.25	2.7
goaf	2500	0.4	2.0

The problem is solved for a discretization with $124 \times 137 \times 76$ node nonorthogonal mesh. The total number of degrees of freedom is 3 873 264.

BENCHMARK 5 [MOST-1] Single pile in a homogeneous sandy clay soil layer is considered. It is assumed that the construction technology guarantees an ideal contact between the piles and the surrounding soil layers. The computational domain is the parallelogram $\Omega = (0, x_1^{max}) \times (0, x_2^{max}) \times (0, x_3^{max})$. The boundary conditions are as follows: homogeneous Dirichlet conditions on the bottom side $x_3 = 0$ (the displacements are equal to zero); homogeneous Neumann conditions on the vertical sides of Ω (the stresses are equal to zero); nonhomogeneous Neumann boundary conditions on the top side $x_3 = x_3^{max}$, where the load (V, H) coming from the upper construction is applied.

The computational domain is determined by $x_1^{max} = x_2^{max} = 37.2\ m$; $x_3^{max} = 31.0\ m$. The vertical cross section $x_2 = 18.6$(the same as with $x_1 = 18.6$) of Ω is presented in the left part of Figure 6.

The cross section size of the pile is $D = 1.2\ m$. The length of the pile is $L_P = 15\ m$. The mechanical characteristics of the soil layer and the pile are as follows: $E_{soil} = 10\ MPa$, $\nu_{soil} = 0.3$;$E_P = 31500\ MPa$, $\nu_P = 0.2$. The external loading includes a vertical force $V = 3000\ kN$ and a horizontal force $H = 250\ kN$ oriented along the x_1 direction. It is assumed that the loads are uniformly distributed on the cross section of the pile. The size of the discrete problem corresponding to the basic mesh is $N = 98304$.

Benchmark 6 [MOST-2] Double pile system in a multi-layer soil media is considered. The computational domain as well as the sizes and the mechanical characteristics of the piles are the same as in the previous benchmark (see the right figure below). The distance between the piles is $a = 2.4\ m$. The scheme of the loading of the piles is given by $V_1 = 2000\ kN$, $V_2 = 4000\ kN$ and $H_1 = H_2 = 150\ kN$. The indexes of the forces correspond to the number of the pile where the left one is the first. The soil media is considered as nonlinear, and consists of four horizontal layers. The stress-strain diagrams $\sigma = \varphi(\epsilon)$ and the other needed characteristics of the different soil layers are given in table form. The basic scheme of discretization is the same as in Benchmark 5. A composite grid for three-level local mesh refinement is shown in Figure 6.

Benchmark 7 [MOST-1A] The setting is as in Benchmark 5 but is discretized using an irregular tetrahedra mesh, which is locally refined around and below the pile. Figure 7 shows horizontal cross-sections of three consecutive refinement levels of the domain.

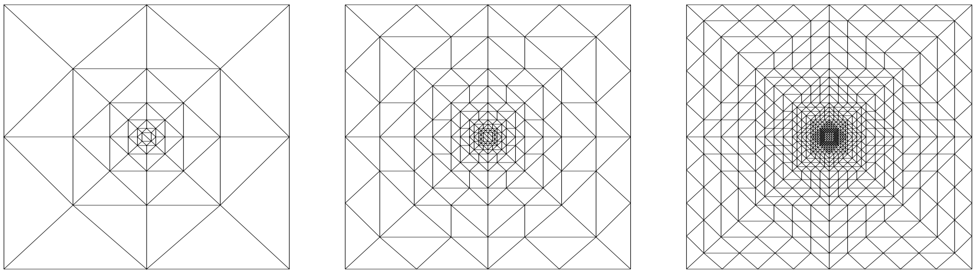

Figure 7: A xy-cross section of the 3D domain with three discretizations, locally refined around a single pile.