SURFACE WAVES

In this validation document surface waves on an elastic half space are studied, generated by a harmonic prescribed displacement. A comparison is made between PLAXIS results and the results obtained by Chouw, Le & Schmid (1991) using boundary elements.

Used version:

- PLAXIS 2D - Version 2018.0
- PLAXIS 3D - Version 2018.0

Geometry: In PLAXIS 2D, due to symmetry, only the right half of the model is considered, as presented in Figure 1. The model is 200 m wide and 30 m deep. In PLAXIS 2D the plane strain mesh is composed of 15-noded elements. A harmonic vertical displacement with amplitude of 0.48 m and frequency of 5 Hz is used to generated surface waves. Its length in x-direction equals 1.5 m starting from the plane of symmetry (left model boundary).

In PLAXIS 3D the model is extended by 1 m in the y-direction and 10-noded mesh elements are used. In both PLAXIS 2D and PLAXIS 3D, the bottom and right dynamic model boundaries are set to be *Viscous*, while every other dynamic boundary is set to *None*.

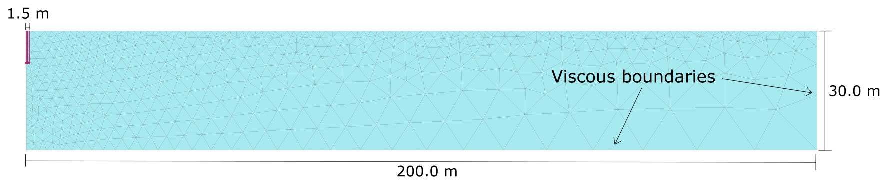

Figure 1 Model geometry and generated mesh (PLAXIS 2D)

Ten mesh points (nodes) are selected to evaluate the results. Table 1 gives their coordinates in PLAXIS 2D and PLAXIS 3D.

Table 1 Selected mesh points in PLAXIS 2D and PLAXIS 3D

Point	Coordinates in PLAXIS 2D (x, y)	Coordinates in PLAXIS 3D (x, y, z)
A	(0, 30)	(0, 0.5, 30)
B	(10, 30)	(10, 0.5, 30)
C	(20, 30)	(20, 0.5, 30)
D	(40, 30)	(40, 0.5, 30)
E	(60, 30)	(60, 0.5, 30)
F	(80, 30)	(80, 0.5, 30)
G	(100, 30)	(100, 0.5, 30)
H	(120, 30)	(120, 0.5, 30)
I	(150, 30)	(150, 0.5, 30)
J	(200, 30)	(200, 0.5, 30)

Materials: The soil is assumed to be *Linear elastic* with the following properties:

Soil: Linear elastic γ=17.64 kN/m^3 G=53280 kN/m^2 ν'=0.33

Meshing: In both PLAXIS 2D and PLAXIS 3D, the *Coarse* option is used for the

Element distribution. The left and top model boundaries are refined with a *Coarseness factor* equal to 0.1.

Calculations: In the Initial phase, initial stresses are generated by using the *K0 procedure*. A dynamic analysis is performed in Phase 1, in which the dynamic component of the prescribed displacement is activated. The *Time interval* is set equal to 2.5 s. The *Mass matrix* value is selected equal to 1, considering a consistent mass matrix. The *Newmark alpha* and *Newmark beta* coefficients for the numerical time integration are defined as 0.25 and 0.5 respectively (average acceleration method). The *Time step determination* is set to *Manual*, the *Maximum steps* of the analysis are selected to be 250 and the *Number of sub steps* is set to 10.

Output: Figure 2 illustrates the amplitude of the surface waves versus horizontal distance from the source. PLAXIS 2D and PLAXIS 3D results are in perfect agreement. The results obtained by Chouw, Le & Schmid (1991) using boundary elements are plotted in the same graph.

Figure 3 depicts the vertical displacement calculated at points *A* and *H* (refer to Table 1) versus time (arbitrary points). PLAXIS 2D and PLAXIS 3D results are in perfect agreement.

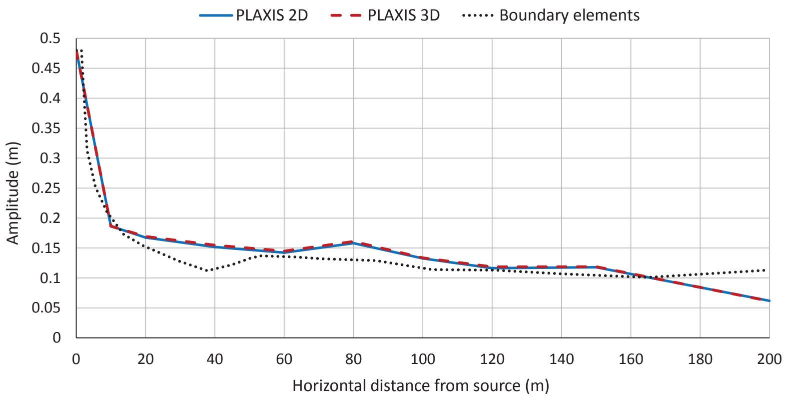

Figure 2 Amplitude versus horizontal distance from the source

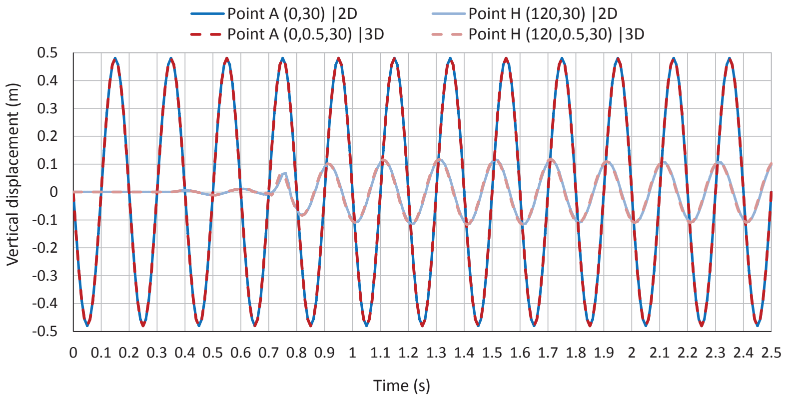

Figure 3 Vertical displacement of points *A* and *H* versus time

Verification: Based on Figure 2 it is concluded that PLAXIS results are in good agreement with the boundary elements solution.

As observed in Figure 3, point *A*, which is located at the plane of symmetry, starts oscillating at t = 0 s. The wave period equals 1/5 s (T = 1/f), thus for t = 2.5 s, 12.5 cycles are completed. The amplitude at point *A* is constant, equal to 0.48 m.

Point *H* is located 120 m away from the plane of symmetry. Based on the selected material properties, the pressure wave velocity V_p equals 341.7 m/s. Thus, the time needed for the pressure wave to reach point *H* is approximately 0.35 s. As observed in Figure 3, point *H* starts oscillating at t $\approx$ 0.35 s, fact that verifies the arrival of the pressure wave. The shear wave velocity V_s equals 172.1 m/s. The shear wave needs approximately 0.70 s to reach point *H*. As illustrated in Figure 3, the vertical displacement amplitude at point *H* increases at t $\approx$ 0.70 s, indicating the arrival of the shear wave.

It is concluded that surface waves generated by prescribed displacement are correctly simulated using PLAXIS.

REFERENCES

[1] Chouw, N., Le, R., Schmid, G. (1991). Impediment of surface waves in soil. In Mathematical and Numerical aspects of wave propagation phenomena.