BENDING OF PLATES

This document describes an example that has been used to verify the behaviour of plates in PLAXIS. The problem involves a concentrated load and a uniformly distributed load acting on a plate.

Used version:

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

Geometry: In PLAXIS the structures cannot be used individually. A soil cluster is used to create the geometry. Note that the properties of the material assigned to the soil do not affect the results as the clusters will be deactivated in the calculation phase. The assignment of a soil material to the clusters is required before generating the mesh.

In PLAXIS 2D two plates of unit length (1 m) are modelled. A vertically downward point load equal to 100 kN/m is assigned to the one plate, while a vertically downward line load equal to 200 kN/m/m is assigned to the other plate. Point displacements are used to model the fixities at the edges. In both cases, plates are simply-supported. The model geometry in PLAXIS 2D is presented in Figure 1.

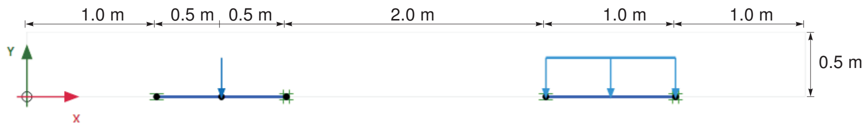

Figure 1 Model geometry in PLAXIS 2D

In PLAXIS 3D two plates of unit dimensions are modelled (1 x 1 m^2). A vertically downward line load equal to 100 kN/m is assigned to the one plate, while a vertically downward surface load equal to 200 kN/m^2 is assigned to the other plate. Line displacements are used to model the fixities at the edges. In both cases, plates are simply-supported in one direction. The model geometry in PLAXIS 3D is presented in Figure 2.

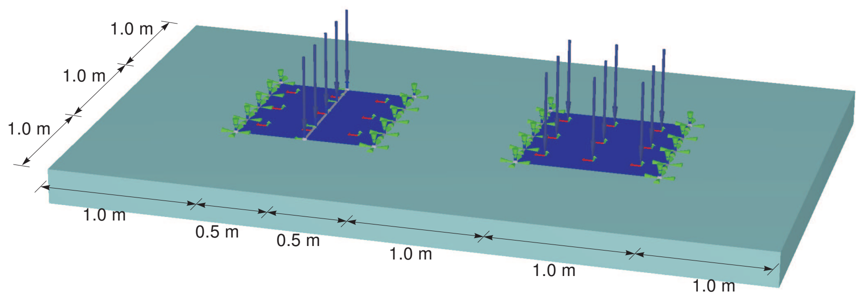

Figure 2 Model geometry in PLAXIS 3D

Materials: The material properties of the plate are:

Linear elastic & isotropic	E = 10^6 kN/m^2	d = 0.10 m	ν = 0.0
	EA = 10^5 kN/m	EI = 83.33 kN m^2/m	

Meshing: The *Very coarse* option is selected for the *Element distribution* of the *Global coarseness* in PLAXIS 2D. The geometry lines representing the plates are refined with a *Coarseness factor* of 0.25. In PLAXIS 3D, the *Coarse* option is selected for the *Element distribution* and the plates are refined with a *Coarseness factor* of 0.075.

Calculations: In the Initial phase zero initial stresses are generated by using the K0 procedure (γ = 0). A new calculation phase is introduced (Phase 1) and the *Calculation type* is set to *Plastic analysis*. The *Reset displacements to zero* option is selected and the *Tolerated error* for *Iterative procedure* is set to 0.001. In this phase the soil clusters and the default fixities are deactivated, while the plates, the prescribed displacements (fixities) and the loads are activated.

Output: The results of the calculations in PLAXIS 2D are plotted in Figures 3 to 5.

Point load:	M_{max} = 25.00 kNm/m	Q_{max} = 50.61kN/m	u_{max} = 25.60 mm
Distributed load:	M_{max} = 25.00 kNm/m	Q_{max} = 101.3kN/m	u_{max} = 31.85 mm

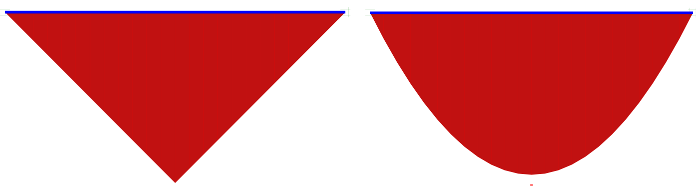

Figure 3 Computed distribution of bending moments (PLAXIS 2D, scaled up 0.02 times)

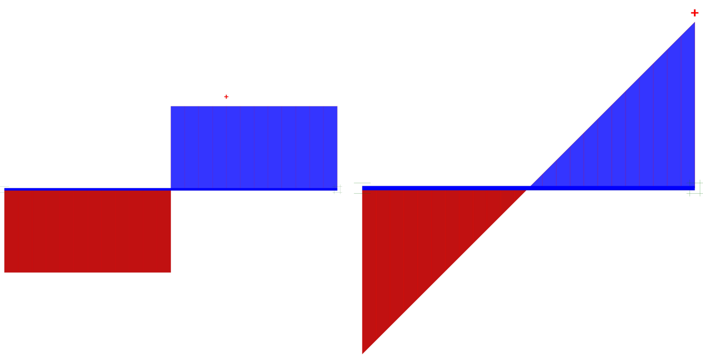

Figure 4 Computed shear forces (PLAXIS 2D, scaled up 0.005 times)

The results of the calculations in PLAXIS 3D are plotted in Figures 6 to 8.

Line load:	M_{max} = 25.00 kNm/m	Q_{max} = 50.61 kN/m	u_{max} = 25.60 mm
Distributed load:	M_{max} = 25.03 kNm/m	Q_{max} = 101.3 kN/m	u_{max} = 31.85 mm

Verification: As a first verification, it is observed that PLAXIS yields the correct

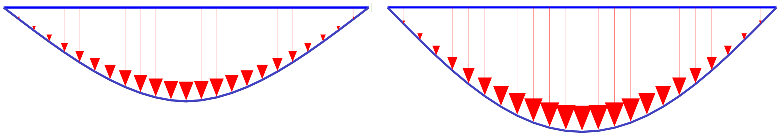

Figure 5 Computed displacements (PLAXIS 2D, scaled up 10 times)

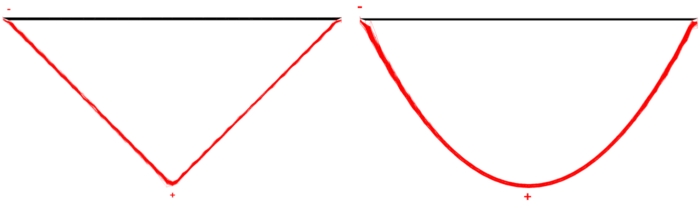

Figure 6 Computed distribution of bending moments (PLAXIS 3D, scaled up 0.02 times)

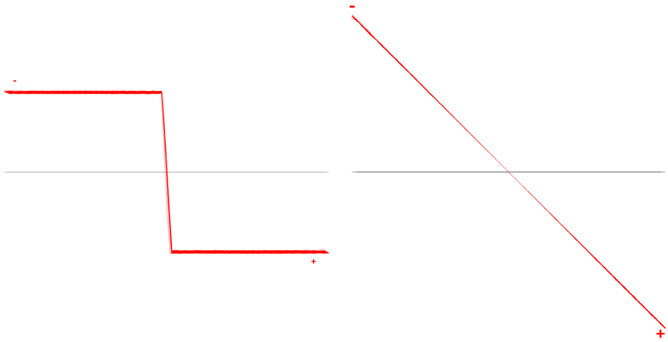

Figure 7 Computed shear forces (PLAXIS 3D, scaled up 0.005 times)

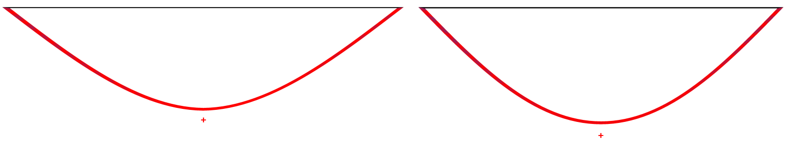

Figure 8 Computed displacements (PLAXIS 3D, scaled up 10 times)

distribution of moments, shear forces and displacements. For further verification we consider the formulae listed below.

Point load: $M_{max} = \frac{1}{4} Fl = 25 \text{ kNm}$ $\qquad Q_{max} = \frac{F}{2} = 50 \text{ kN}$

$$u_{max} = \frac{1}{48} \frac{Fl^3}{EI} = 25.00 \text{ mm}$$

Distributed load: $M_{max} = \frac{1}{8} ql^2 = 25 \text{ kNm}$ $\qquad Q_{max} = \frac{ql}{2} = 100 \text{ kN}$

$$u_{max} = \frac{5}{384} \frac{ql^4}{EI} = 31.25 \text{ mm}$$

The analytical formulae consider only vertical displacement due to bending, whereas the 'Mindlin' element in PLAXIS 2D and PLAXIS 3D counts for shear deformation as well, leading to larger vertical displacements. The formulae presented below are used to calculate the additional vertical displacements due to shear deformation. By taking into account the obtained results, PLAXIS results are nearly exact to the overall analytical solution.

Point load: $u_{shear} = \frac{6}{20}\frac{Fl}{GA} = 0.6$ mm

Distributed load: $u_{shear} = \frac{6}{40}\frac{ql^2}{GA} = 0.6$ mm