Example 19: Evaluation of iteration methods

1 Description of the problem

One of the difficulties to apply the Continuum model to practical problems is the long computation time. Therefore, a comparison for time and accuracy required for analysis of the raft by the Continuum model is carried out by the following calculation methods shown in Table 27.

Table 27 Calculation methods

Method No.	Method
4	Modification of modulus of subgrade reaction by iteration after *Ahrens/ Winselmann* (1984) (*Winkler's* model/ Continuum model)
6	Modulus of compressibility method for elastic raft on layered soil medium after *El Gendy* (1998) (Solving system of linear equations by iteration) (Layered soil medium - Continuum model)
7	Modulus of compressibility method for elastic raft on layered soil medium (Solving system of linear equations by elimination) (Layered soil medium - Continuum model)

To evaluate the iterative procedures used in *ELPLA*, consider the raft shown in Figure 31. The raft has a dimension of 10 [m] × 20 [m] and 0.6 [m] thickness.

2 Soil properties

The raft rests on two different soil layers of thickness 5 [m] and 10 [m], respectively. The modulus of compressibility of the first soil layer is E_{s1} = 20 000 [kN/ m^2], while for the second layer is E_{s2} = 100 000 [kN/ m^2]. *Poisson's* ratio for the soil is ν_s = 0.0 [-].

3 Raft material

The raft material was supposed to have the following parameters:

Young's modulus	E_b	= 2.6 × 10^7	[kN/m^2]
Poisson's ratio	ν_b	= 0.15	[-]
Unit weight	γ_b	= 0.0	[kN/m^3]

Unit weight of concrete is chosen γ_b = 0.0 to neglect the self weight of the raft.

4 Loads

The raft carries 15 column loads as shown in Figure 31. Each of the three inner columns carries a load of P_3 = 1850 [kN], each of the edge columns carries a load of P_2 = 1200 [kN] and each of the corners columns a load of P_1 = 750 [kN].

5 Analysis of the raft

The raft is divided into 1056 elements yielding to 1125 nodal points for the raft and the soil as shown in Figure 31. Because of the symmetry in shape and load geometry about *x*- and *y*-axes, only one quarter of the raft is considered. Taking advantage of the symmetry in shape, soil and load geometry about both *x*- and *y*-axes, the analysis is carried out by considering only a quarter of the raft. The quarter of the raft has 299 nodes, each node has three unknowns (w, θ_x, θ_y). This gives 897 equations by applying the method 7.

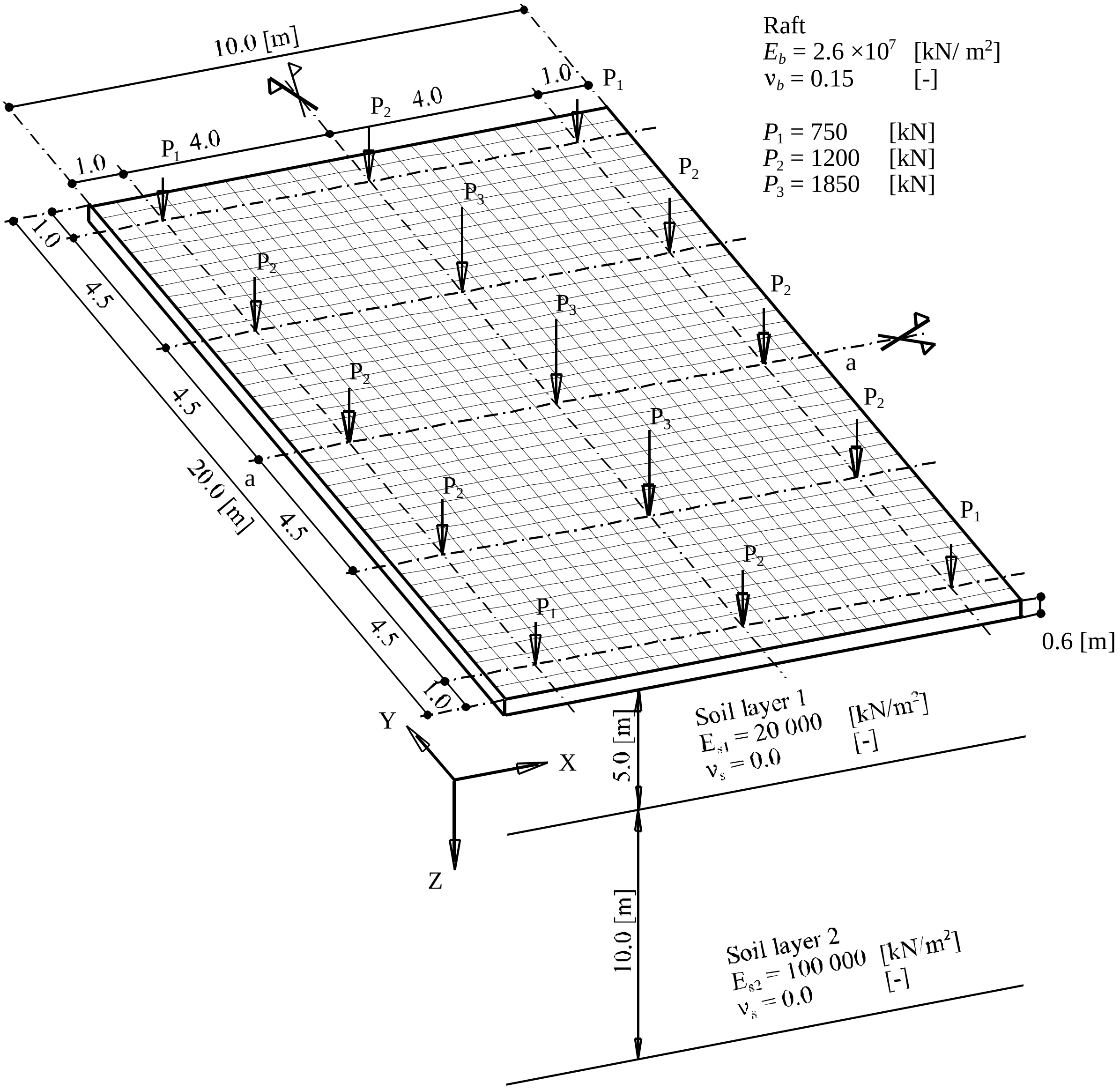

Figure 31 Raft dimensions, loads, FE-Net and subsoil

6 Evaluation of the iteration method 6

To judge the iteration method 6, the settlements *s*, contact pressures *q* and moments m_x at the middle section a-a of the raft against iterative cycles are plotted in Figure 32 to Figure 34. It can be concluded that the results of the computation can be obtained after only two iterative cycles. It can be shown also the first iterative cycle gives good results with maximum settlement error of 2.9 [%].

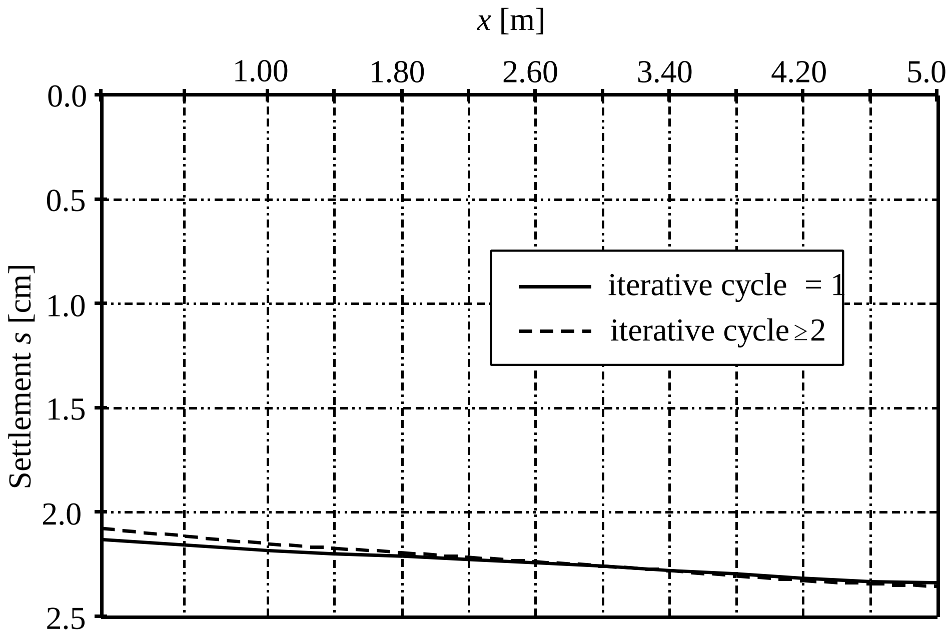

Figure 32 Settlements *s* [cm] at the middle section a-a for many iterative cycles

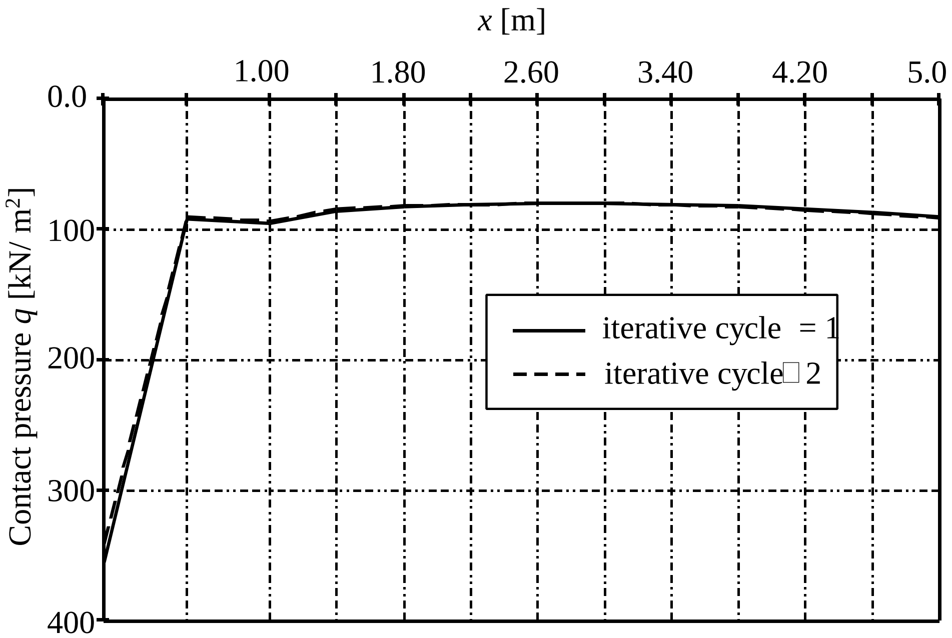

Figure 33 Contact pressures *q* [kN/m^2] at the middle section a-a for many iterative cycles

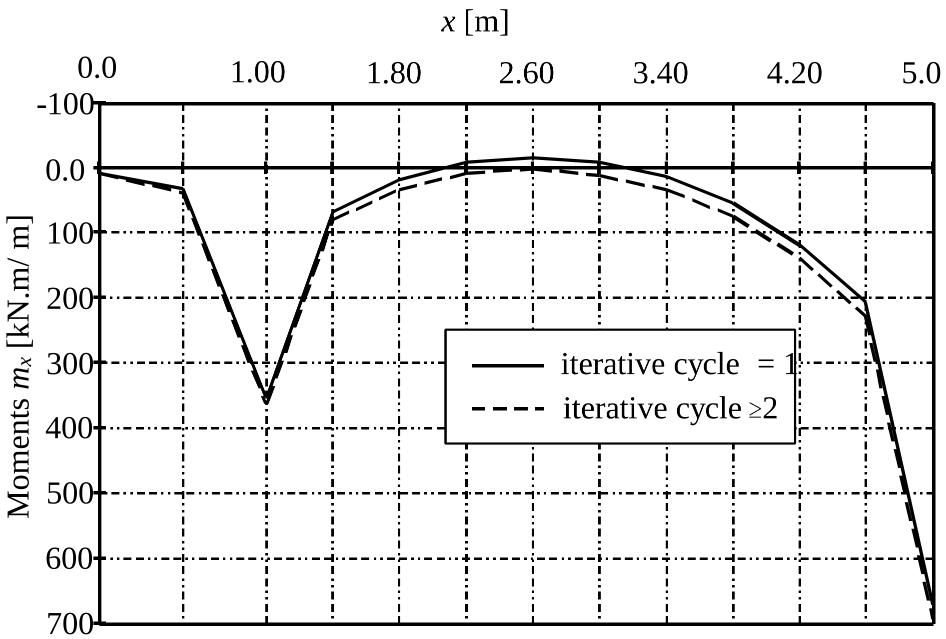

Figure 34 Moments m_x [kN.m/m] at the middle section a-a for many iterative cycles

7 Comparison between iteration method 4 and 6

To show the speed of convergence of the iteration method 4 with that of iteration method 6, a comparison between the two methods has been carried out. The maximum difference between the settlement calculated from iterative cycle *i* and that of the previous cycle *i*-1 is considered as an accuracy number for both methods 4 and 6. The accuracy of computation was plotted against the iterative cycle number in Figure 35 for the two iteration methods. This figure shows that the iteration method 6 converges more rapidly than method 4, which takes four iteration cycles while the iteration method 4 required 65 cycles to reach the same accuracy number.

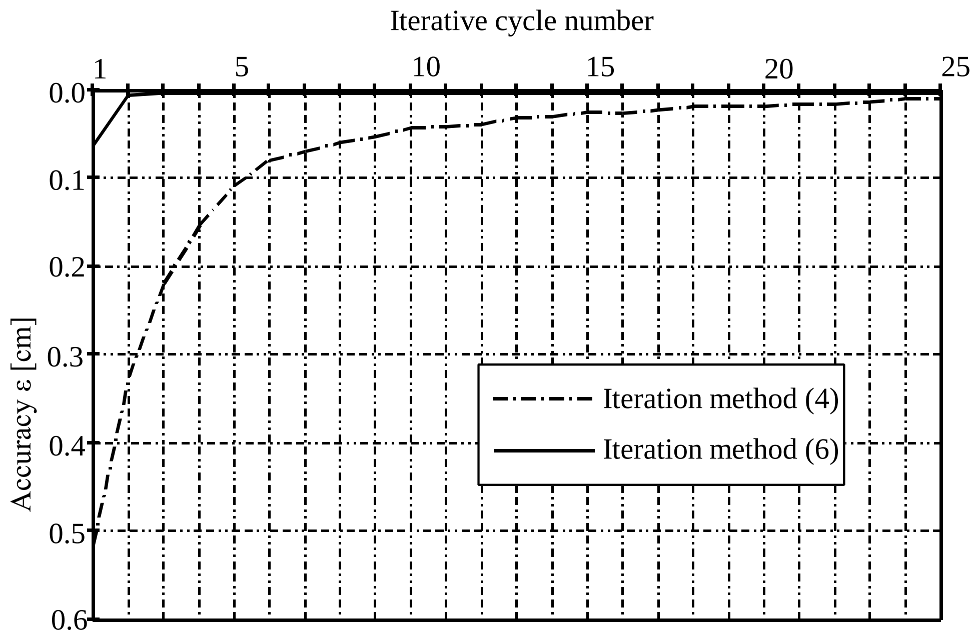

Figure 35 Accuracy against the iterative cycle number for the two iteration methods 4 and 6

8 Computation time required for solution of system equations

Table 28 compares the computation time required for the iteration processing by applying methods 4 and 6. In addition the computation time required for elimination processing by applying method 7. The analysis was carried out for the quarter raft (897 equations) using Pentium 100 computer. The accuracy was ε = 0.0016 [cm] for both two iteration methods.

Table 28 Computation time required for analysis of the raft (Computer Pentium 100)

Calculation method		Method 4	Method 6	Method 7
Number of iteration cycles		65	4	-
Center settlement [cm]		2.31	2.31	2.31
CPU Time [Min] required for	Assembling of soil stiffness matrix	-	1.05	1.05
	Assembling of plate stiffness matrix	-	-	0.04
	Iteration process	6.90	0.99	-
	Equation solving	-	-	11.30
	Total time	6.90	2.04	12.39

It can be seen from Table 28 that the iteration methods 4 and 6 give rapid results after a few steps of iteration process, especially by the method 6.

The settlement value, which is obtained at the center of the raft by iteration methods 4 and 6, coincides with that of the method 7, where the systems of equations are solved by elimination process.

The computation times used in Pentium 100 computer for the cases involving quarter of the raft are 6.9, 2.04 and 12.39 [Min.] for the three calculation methods 4, 6 and 7, respectively. Therefore, it can be concluded that for a symmetrically loaded raft, taking advantage of symmetry is always desirable and consider only a part of the raft rather than the entire raft to reduce the computation time.