Example 2.3 Analysis of system of footings on irregular subsoil

1 Description of the problem

The influence of irregularity of the subsoil material on the behavior of foundations is illustrated through the study of the differential settlements for a system of 9 footings. Consider the group of footings shown in Figure 2.29 and Table 2.3. Thickness of footings is d = 0.5 [m]. Unit weight of the footing is γ_f =25 [kN/m^3]. Arrangement of footings and footing loads are shown in Figure 2.29a.

2 Soil properties

The group of footings is resting on a three-dimensional subsoil model. Four boring logs characterize the subsoil under the footings. Each boring has three layers as shown in Figure 2.29 and Table 2.4. *Poisson*'s ratio is ν_s = 0.3 [-] for all soil layers. The level of ground water is GW = 1.3 [m], while the level of foundation for all footings is t_f = 2.2 [m] under the ground surface. The effects of reloading and water ground are taken into account. Boring locations and section through B1-B2 are shown in Figure 2.29.

Table 2.3 Loads, dimensions and origin coordinates of the footings

Footing No.	Load P [kN]	Dimensions		Origin coordinates		
		Length [m]	Width [m]	x [m]	y [m]	β [°]
1	2500	2.0	2.0	1.00	1.00	0
2	900	1.5	1.5	6.25	1.25	0
3	800	1.5	1.5	11.25	1.25	0
4	2500	2.0	2.0	1.50	6.00	0
5	5400	3.0	3.0	5.00	6.00	0
6	950	1.5	1.5	11.25	6.25	0
7	5400	4.5	2.0	2.12	8.7	45
8	3000	2.5	2.0	5.75	11.00	0
9	2000	2.0	1.5	10.00	10.25	0

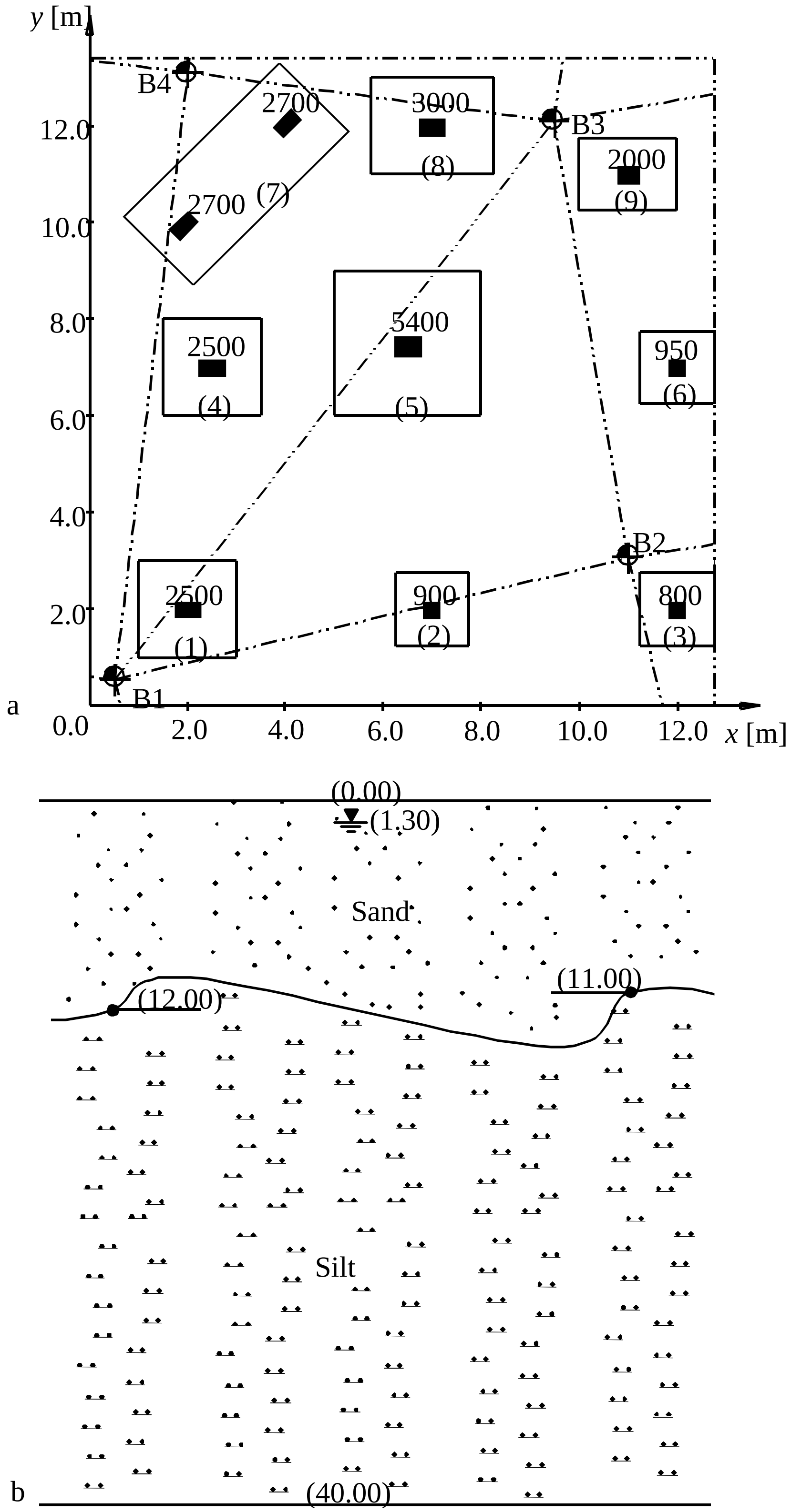


Figure 2.29 a) Arrangement of footings, footing loads [kN] and boring locations
b) Section through B1-B2

Table 2.4 Soil material and layer levels for the four borings

Layer No.	Type of soil	Layer level under the ground surface z [m]	Modulus of elasticity for		Unit weight of the soil
			loading E_s [kN/m^2]	reloading W_s [kN/m^2]	γ_s [kN/m^3]
1	Sand	1.3	98 000	135 000	19
2	Sand	12/11/14/10	98 000	135 000	11.2
3	Silt	40	9 500	12 000	12

3 Analysis and results

Because the footing dimensions are relatively small, the footings may be treated as rigid footings resting on compressible subsoil. In this case, it is enough to determine the soil settlement at the footing centers. For a good judgment on the proposed analysis, the group of footings has been treated four times according to the following cases:

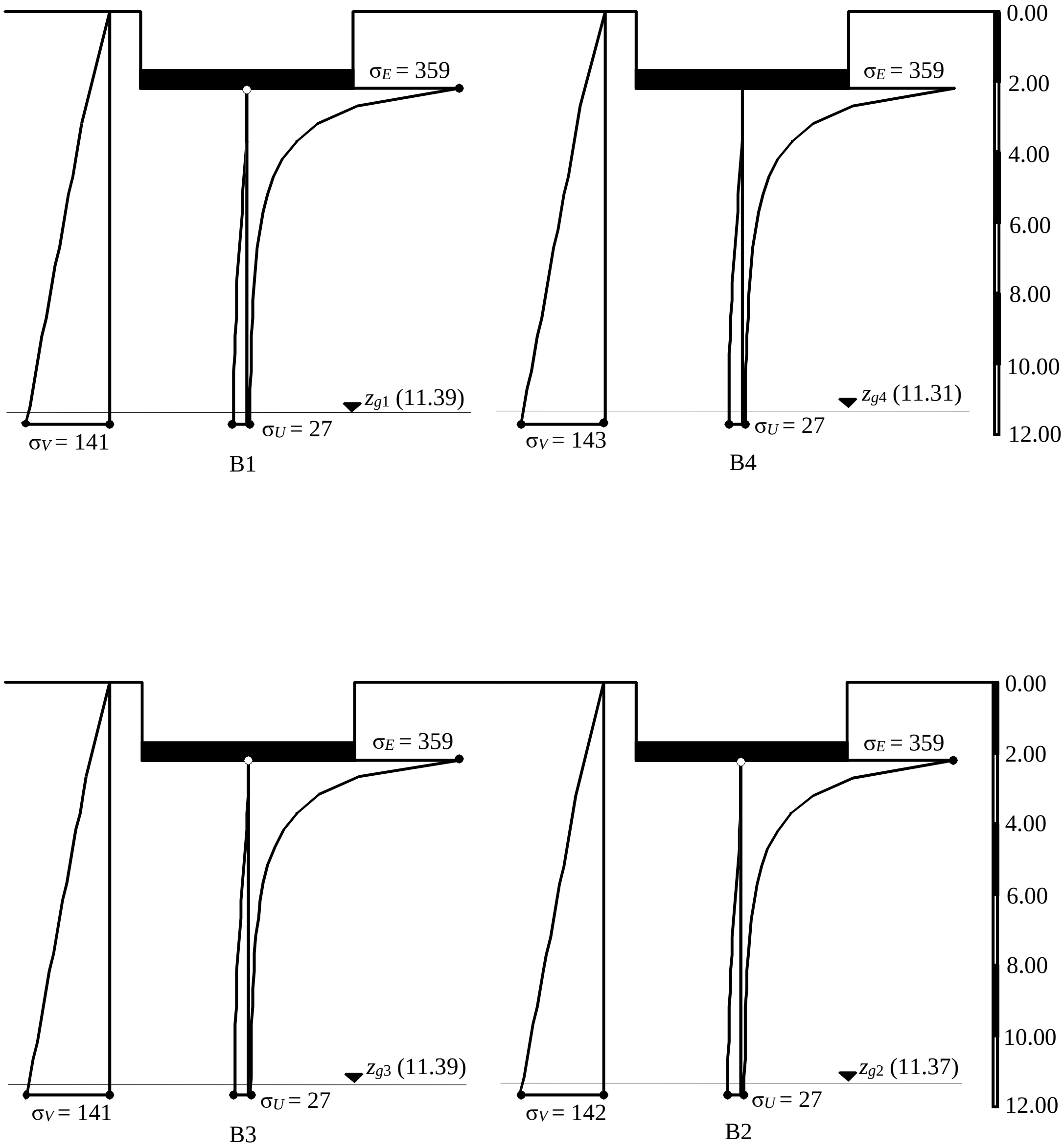
i) The limit depths for all boring logs are obtained due to the maximum loaded footing (footing 5)

ii) The limit depths for all boring logs are obtained due to the minimum loaded footing (footing 3)

iii) Without limit depths: the last layer for each boring extends to a depth of 40 [m] below the ground surface

iv) The limit depth is obtained through interpolation

The limit depths are determined at the level of which the stress σ_U due to footings reaches the ratio $\zeta = 0.2$ of the initial vertical stress σ_V. The limit depths of boring B1 to B4 due to footing 3 are shown in Figure 2.30 while those due to footing 5 are shown in Figure 2.31. The limit depths for the maximum loaded footing (footing 5) are ranged from 16.90 [m] to 17.00 [m] while those for the minimum loaded footing (footing 3) are ranged from 11.31 [m] to 11.39 [m]. Table 2.5 shows the central settlements of the footings for the four cases. As expected, the numerical results show that the limit depths have a significant influence on the settlement of the footings. It can be seen from Table 2.5 that there is a great difference in the settlement values by applying the four cases. Case i) gives high values of settlement where that of case ii) is small and that of case iii) is very high. This proves that the interpolation analysis is a suitable procedure to study the interaction of a group of footings. Table 2.5 shows also that cases i) and ii) give only the accurate settlements under footings 5 and 3, respectively. Where the settlement under footing 5 is s_5 = 3.70 [cm] while that under footing 3 is s_3 = 0.48 [cm].



<u>Figure 2.30</u> Limit depths of boring logs B1 to B4 due to footing 3

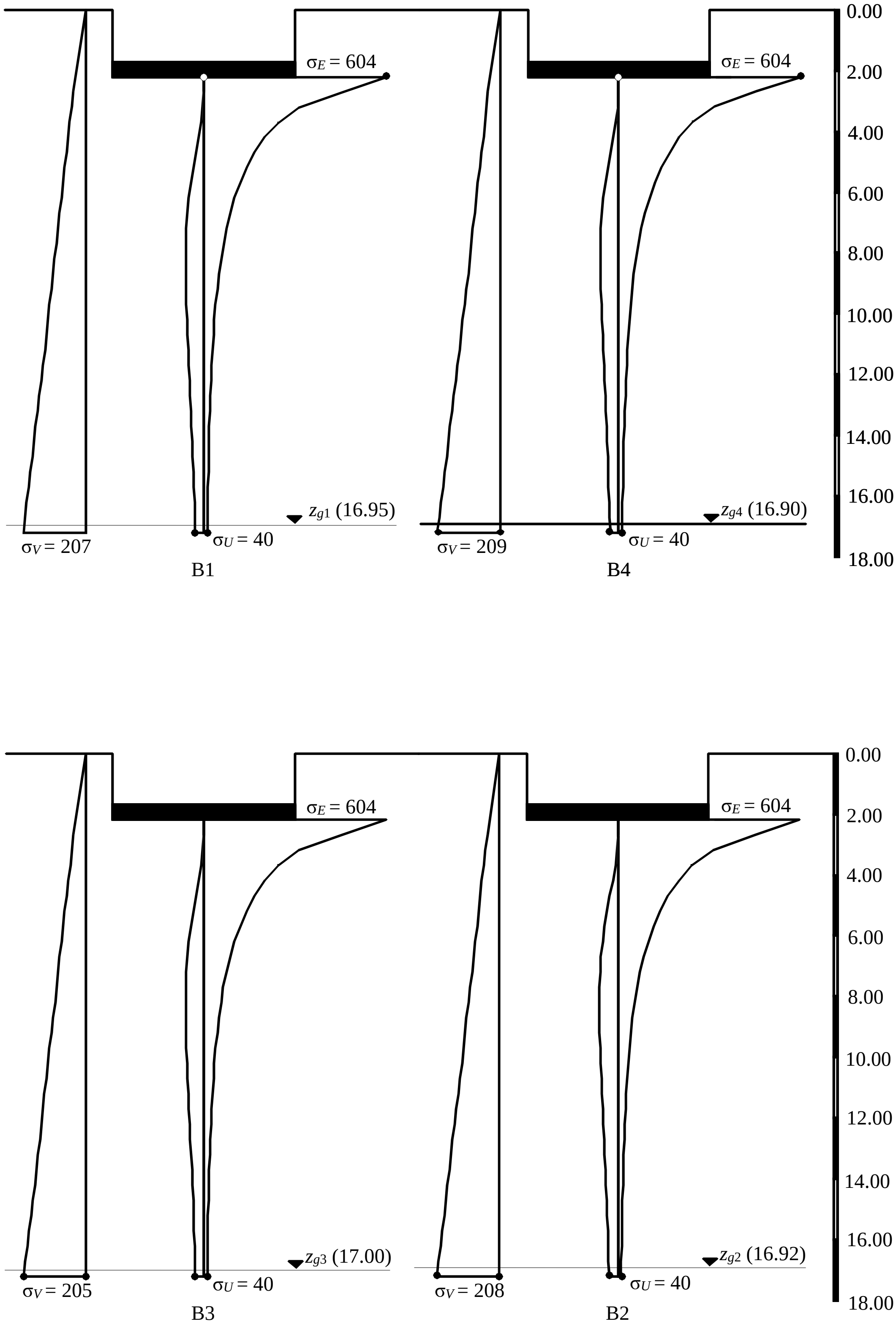


Figure 2.31 Limit depths of boring logs B1 to B4 due to footing 5

Table 2.5 Central settlements of the footings

Footing No.	Calculation of central settlement [cm] based on			
	Limit depths related to footing 5	Limit depths related to footing 3	Without limit depths z = 40 [m]	Limit depths related to its corresponding footing
1	2.58	0.91	6.07	1.74
2	2.55	0.63	6.19	1.80
3	1.81	0.48	4.86	0.48
4	4.15	1.55	8.35	3.99
5	3.70	1.45	8.05	3.70
6	2.30	0.66	5.91	1.55
7	4.56	1.94	8.67	4.34
8	3.48	1.50	7.59	3.26
9	2.33	0.96	6.05	1.72