Example 4.3 Interaction of two rafts considering two additional footings

1 Description of the problem

Besides, the possibility of analysis of large foundation system with many elements by the procedure of *Kany*/ *El Gendy* (1997), the mesh of the rigid foundation can be generated in analog mode to the finite element mesh of the elastic foundation in one program. Comparing results from analysis of system of rigid rafts with those of elastic or flexible rafts with the same input data is possible. Subsequently the results of the three analyses are compared in an example.

In this example, the settlements of structures due to interactive analysis of system of rigid, elastic and flexible rafts are studied. This example is chosen from *Graßhoff*/ *Kany* (1997). Two large rafts and additional two external footings are constructed near each other. The dimensions are shown in Figures 4.10 to 1.12 and Table 4.3.

2 Soil properties

The soil has two layers with different materials as shown in Figure 4.10 and Table 4.2. *Poisson*'s ratio is constant for both of the two soil layers and is taken ν_s = 0. The foundation level for the system of rafts is 1.3 [m].

Table 4.2 Soil properties

Layer No.	Type of soil	Depth of layer underground surface z [m]	Modulus of elasticity of the soil for Loading E_s [kN/m^2]	Modulus of elasticity of the soil for Reloading W_s [kN/m^2]	Unit weight of the soil under *GW* γ_s [kN/m^3]
1	Silt	4.7	9000	27000	20
2	Sand	15	100000	300000	-

3 Raft material and thickness

Raft material (concrete) and thickness were supposed to have the following properties:

Young's modulus	E_b	= 2 × 10^7	[kN/m^2]
Poisson's ratio	ν_b	= 0.25	[-]
Raft thickness	d	= 0.5	[m]
Unit weight	γ_b	= 0.0	[kN/m^3]

Young's modulus E_b, *Poisson*'s ratio ν_b and thickness d of rafts don't play any role for the analysis of system of rigid rafts. The self weight of the raft is ignored. Therefore, unit weight of raft material is chosen γ_b = 0.0 to neglect the own weight of the raft.

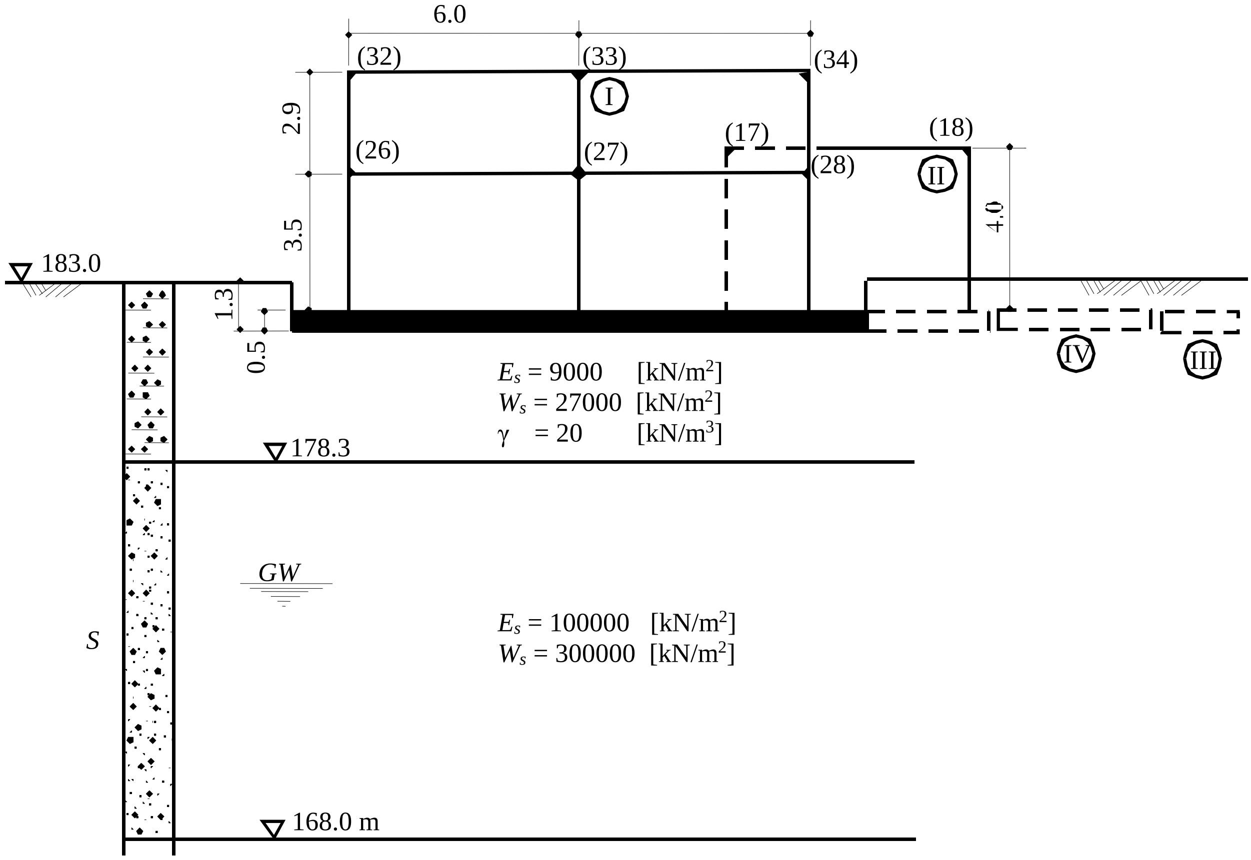

Figure 4.10 Section 1-5 with layer profile, soil properties and node numbers of superstructure *Graßhoff/ Kany* (1997)

Table 4.3 Dimensions of rafts I and II and footings III and IV

Foundation	Length A [m]	width B [m]	Origin coordinates	
			x [m]	y [m]
Raft I	15	8	-1.5	-0.5
Raft II	8	12	9.0	7.6
Footing III	2	2	21.0	11.0
Footing IV	4	3	17.0	1.5

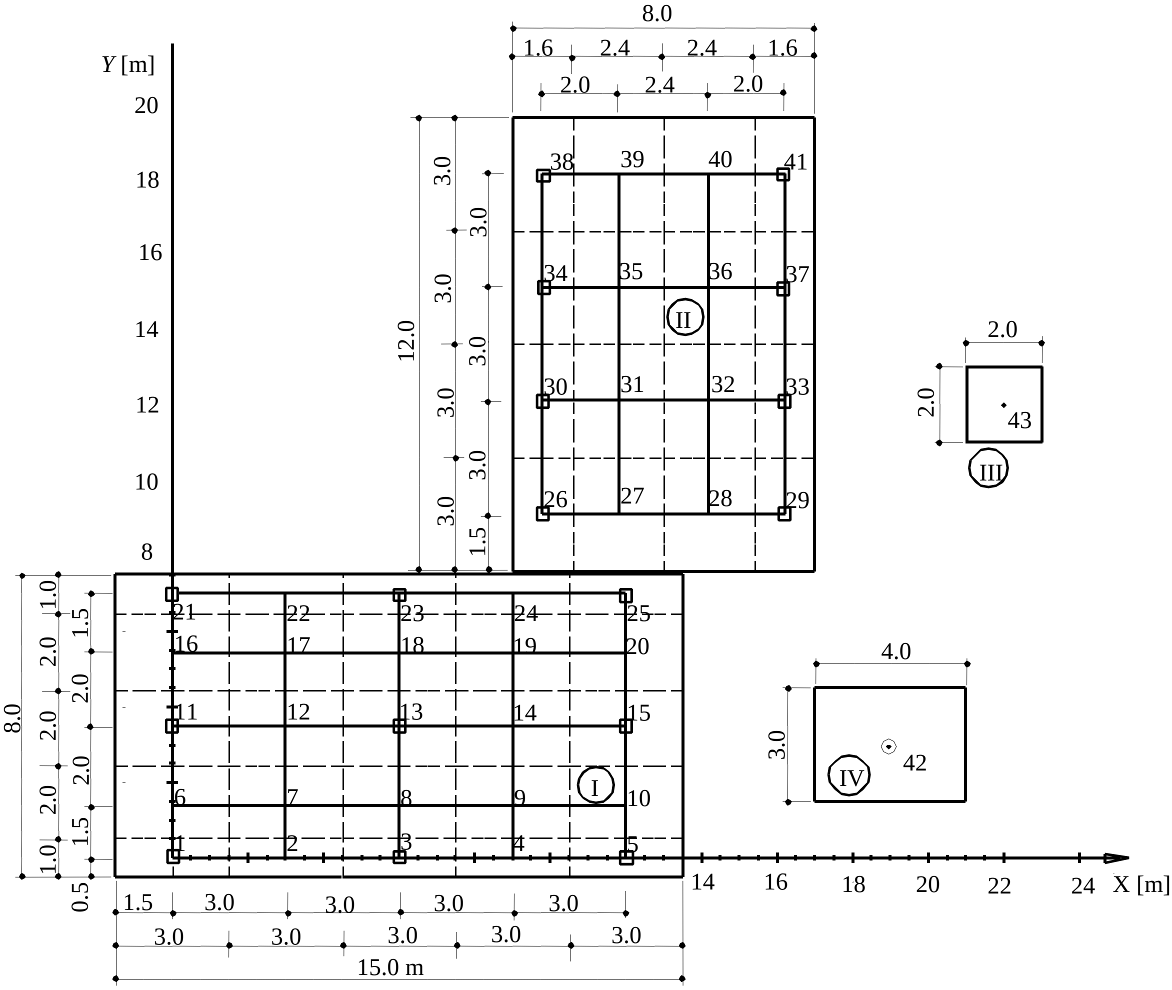

Figure 4.11 Plan view for system of rafts I and II as well as the footings III and IV
Subdivision of the rafts: 43 fields (*Graßhoff*/ *Kany* (1997))

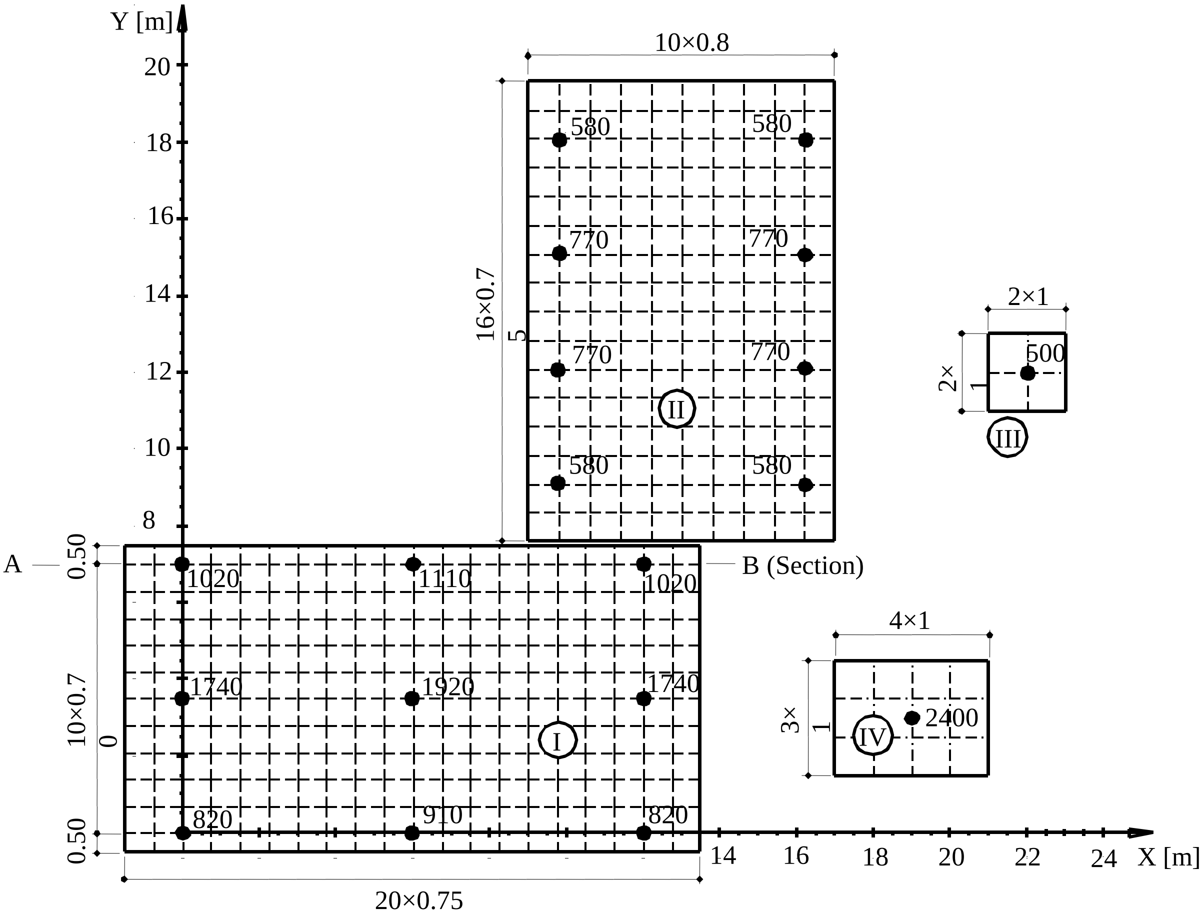

Figure 4.12 Plan view for loads [kN] on the rafts I and II as well as the footings III and IV
Subdivision of the rafts: 489 nodes (Calculation by *ELPLA*)

4 Analysis

For the space structure system shown in Figure 4.11, the settlements at all nodes on the rafts are determined. The analysis of the two rafts I and II with external footings III and IV was carried out at three different rigidities:

1. System of flexible rafts
2. System of elastic rafts
3. System of rigid rafts

With the same input data, the three analyses are carried out to allow a comparison. To represent the flexible foundations, the raft thickness is chosen d = 20 cm, while for elastic foundations the raft thickness is 50 [cm]. For rigid foundations, defining the raft properties is not necessary because the analysis treats the rafts as rigid bodies.

5 Results and evaluation

Figures 4.13 to 4.15 show the settlements for the system of flexible, elastic and rigid rafts, while Figure 4.16 shows in one diagram, to good comparison, the settlements of the three analyses at section A-B. Through the comparison between the results of the analysis obtained by the program *ELPLA* and those obtained by *Graßhoff*/ *Kany* (1997), it can be recognized that the deformation and contact pressure considering superstructure rigidity are nearly similar to those obtained by the analysis of rigid rafts.

From Tables 4.4 and 4.5 it can be seen that the superstructure rigidity has great influence on the rafts.

The analysis of the system of rafts without interaction of foundations gives symmetrical deformation for all rafts at three different rigidities, because the loads are applied symmetrical on each raft.

It can be recognized from the results that the settlements at the edge of structure I close to the neighboring structure II increase strongly. Therefore, the settlement of field 25 increases from 3.25 [cm] to 3.39 [cm] in case 1 (flexible raft), from 2.59 [cm] to 2.77 [cm] in case 2 (elastic raft) and from 2.46 [cm] to 2.65 [cm] in case 3 (rigid raft). This means that design of the rafts must consider the effect of neighboring foundations.

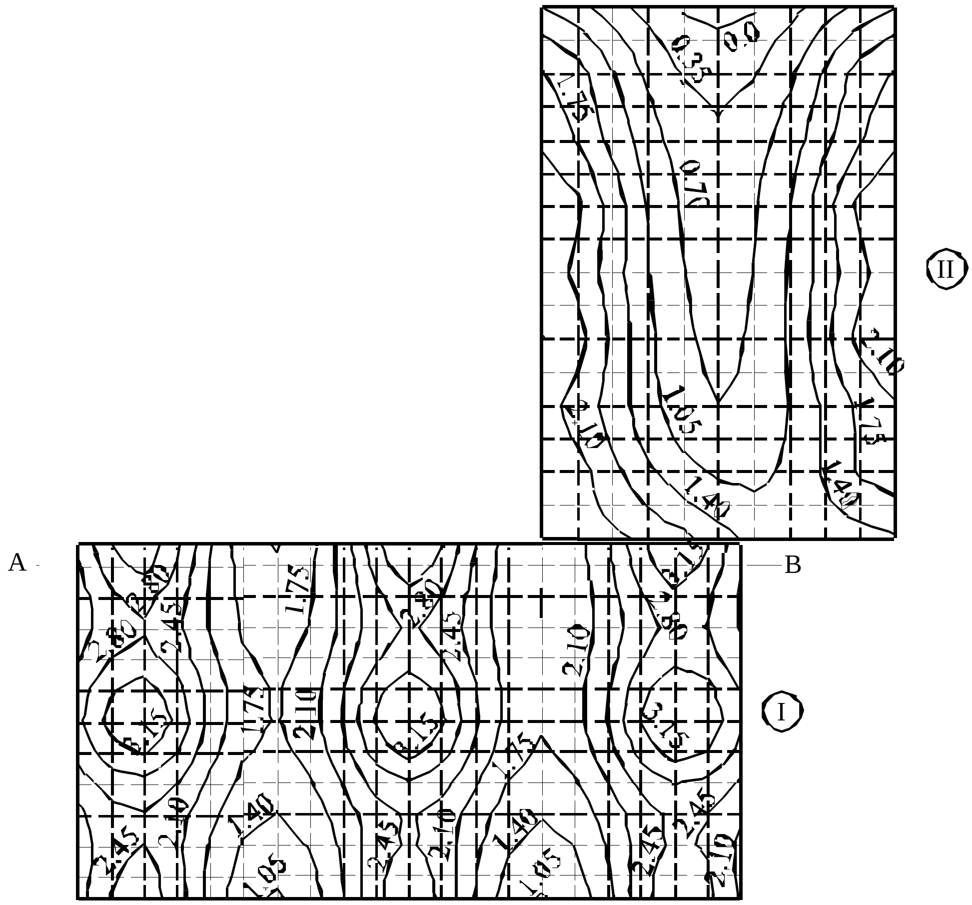

Figure 4.13 Contour lines of settlements *s* [cm] by analyzing as system of flexible rafts

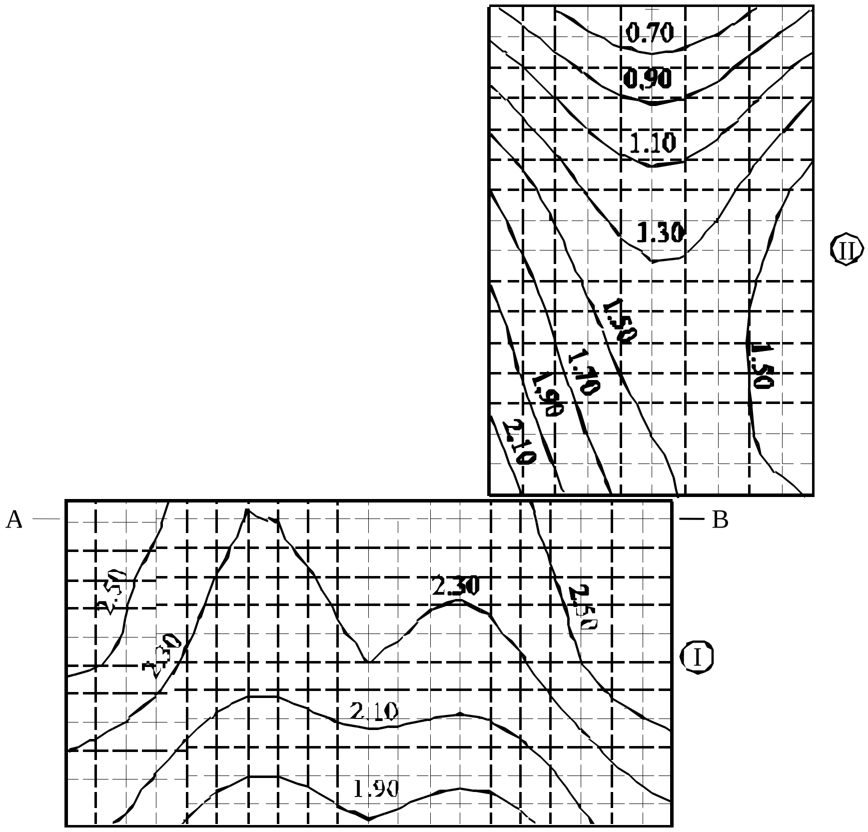

Figure 4.14 Contour lines of settlements *s* [cm] by analyzing as system of elastic rafts

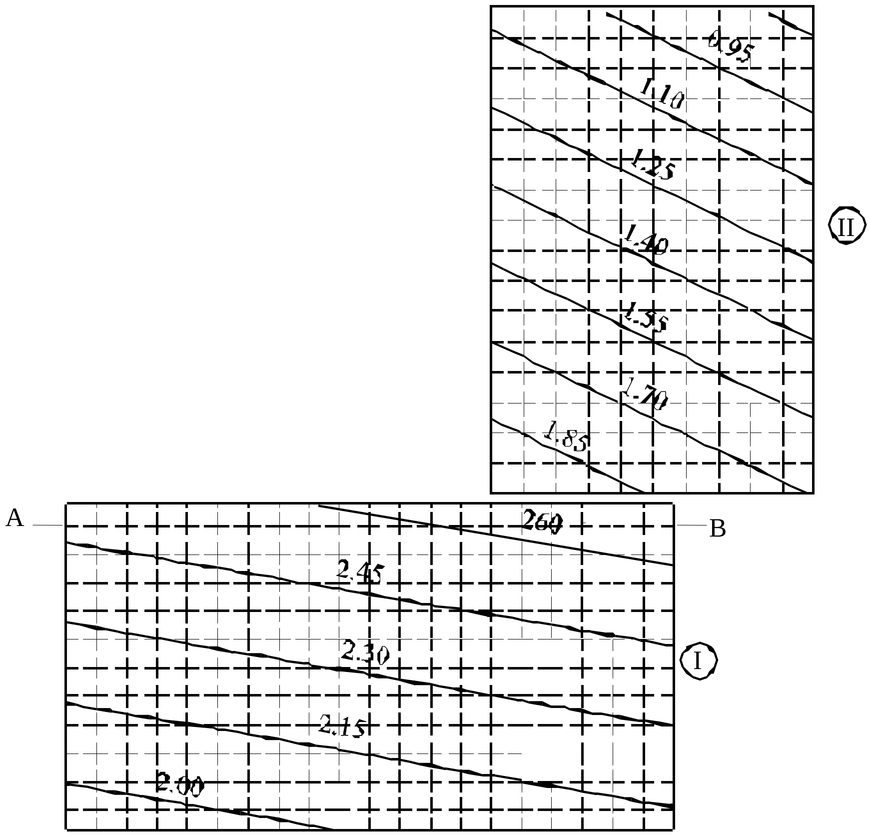

Figure 4.15 Contour lines of settlements *s* [cm] by analyzing as system of rigid rafts

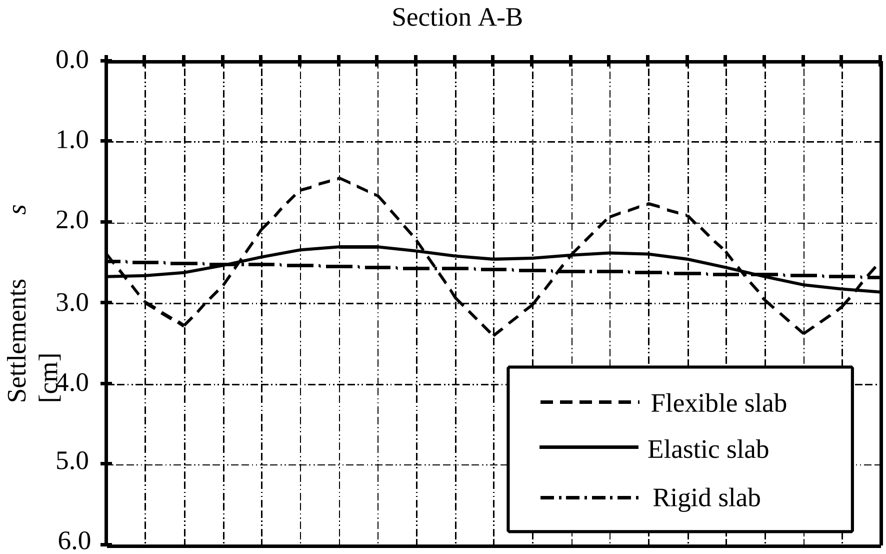

Figure 4.16 Settlements *s* [cm] at section A-B under raft I
(with neighboring influence of building II and the two footings III and IV)

Table 4.4 Comparison between the analysis by *Graßhoff/ Kany* (1997) and *ELPLA* for settlements *s* [cm] under raft I (without neighboring influence)

Type of analysis	*Graßhoff/ Kany* (1997)		New analysis	
	Point 21	Point 25	Point 21	Point 25
System of flexible rafts	3.65	3.65	3.25	3.25
System of elastic rafts	3.04	3.04	2.59	2.59
System of rigid rafts	2.78*	2.78*	2.46	2.46

* Calculated as elastic raft with the superstructure

Table 4.5 Comparison between the analysis by *Graßhoff/ Kany* (1997) and *ELPLA* for settlements *s* [cm] under raft I
(with neighboring influence of building II and the two footings III and IV)

Type of analysis	*Graßhoff/ Kany* (1997)		New analysis	
	Point 21	Point 25	Point 21	Point 25
System of flexible rafts	3.66	4.00	3.27	3.39
system of elastic rafts	3.03	3.51	2.62	2.77
System of rigid rafts	2.79*	3.16*	2.50	2.65

* Calculated as elastic raft with the superstructure

Figure 4.13 shows that the analysis of flexible rafts leads to concentration of settlements on the nodes close to the applied loads. In the other extreme analysis case of rigid rafts, Figure 4.15 shows a linear shape of contour lines for settlements due to the neighboring influence.

The neighboring influence for the analysis of elastic rafts is also obvious in Figure 4.14. It can be concluded also from Figures 4.13 to 4.15 that although all rafts are supposed to symmetrical loading, the settlements are unsymmetrical. Unsymmetrical results are expected also for contact pressures and internal forces due to the neighboring influence.