Example 7.1 Verification of nonlinear analysis for *Winkler*'s model

1   Description of the problem

To verify the nonlinear analysis of the program *ELPLA* for *Winkler*'s soil model, the results of a square footing resting on elastic springs obtained through nonlinear analysis by *Hasnien* (1993) are compared with those obtained by the program *ELPLA*.

A flexible square footing of 0.12 [m] thickness with dimensions of 2 [m] × 2 [m] is considered as shown in Figure 7.4.
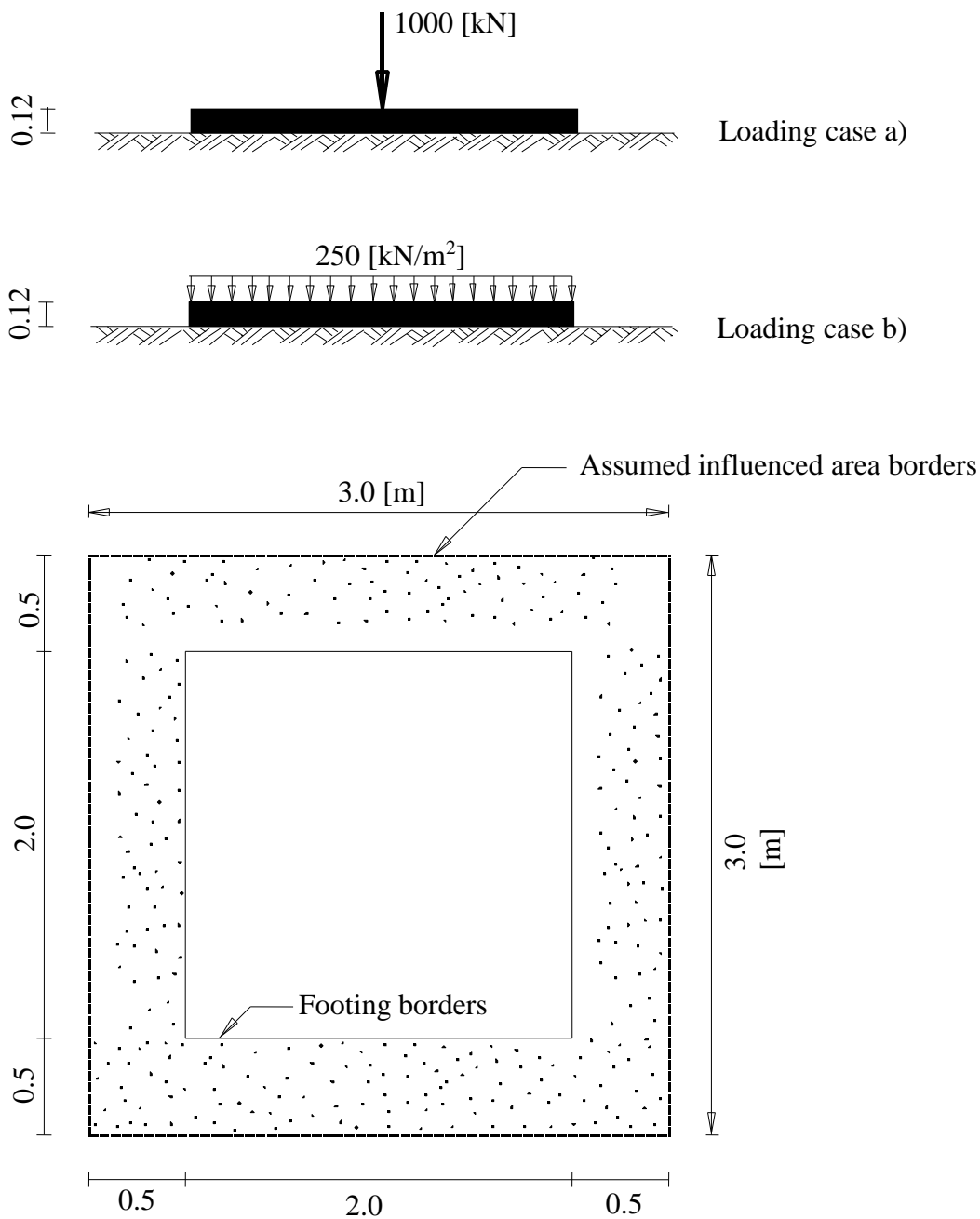

Figure 7.4   Footing geometry and loading

2 Soil properties

The soil under the footing has modulus of subgrade reaction $k_{st} = 30000$ [kN/m^3] and ultimate bearing capacity $q_{ult} = 600$ [kN/m^2].

3 Footing material

The footing material has the following parameters:

Young's modulus $E_b = 1.4 \times 10^7$ [kN/m^2]
Poisson's ratio $\nu_b = 0.15$ [-]
Unit weight $\gamma_b = 25$ [kN/m^3]

4 Analysis

Two cases of loading are studied:

a) The footing carries a concentrated load of 1000 [kN]
b) The footing carries a uniform load of 250 [kN/m^2]

To study the soil settlements outside the footing borders due to nonlinear analysis, imaginary surrounding elements of thickness 0.001 [m] are assumed to be around the footing. The footing and surrounding elements are subdivided into 144 square elements and each element has dimensions of 0.25 [m] $\times$ 0.25 [m].

5   Comparison

Tables 7.1 and 7.2 compare the results of settlements s, contact pressures q and moments m_x at the center of the footing obtained by *Hasnien* (1993) with those obtained by *ELPLA*. From these tables it can be seen that the results of both analyses are in good agreement.

Table 7.1   Comparison of the results at the center of the footing obtained by *Hasnien* (1993) and *ELPLA* (The footing carries a concentrated load of 1000 [kN])

Item	Type of analysis	*Hasnien* (1993)	*ELPLA*
Settlement s [cm]	Linear analysis	1.78	1.85
	Nonlinear analysis	2.55	2.58
Contact pressure q [kN/m^2]	Linear analysis	535	556
	Nonlinear analysis	337	338
Moment m_x [kN.m/m]	Linear analysis	213	272
	Nonlinear analysis	229	293

Table 7.2   Comparison of the results at the center of the footing obtained by *Hasnien* (1993) and *ELPLA* (The footing carries a uniform load of 250 [kN/m^2])

Item	Type of analysis	*Hasnien* (1993)	*ELPLA*
Settlement s [cm]	Linear analysis	0.78	0.81
	Nonlinear analysis	1.18	1.18
Contact pressure q [kN/m^2]	Linear analysis	232	242
	Nonlinear analysis	222	223
Moment m_x [kN.m/m]	Linear analysis	12	9
	Nonlinear analysis	13	12