Examples to verify and illustrate *ELPLA*

Determining
contact pressures, settlements, moments
and shear forces of slab foundations by the
method of finite elements

Version 2010

Program authors:

M. El Gendy
A. El Gendy

GEOTEC: GEOTEC Software Inc.
PO Box 14001 Richmond Road PO
Calgary AB, Canada T3E 7Y7

http://www.elpla.com
geotec@elpla.com

Contents

Introduction
Purpose of the examples

This book presents analysis of many foundation examples. These examples are presented in order to

- verify the mathematical models used in the program *ELPLA* by comparing *ELPLA* results with closed form or another published results

- illustrate how to use *ELPLA* for analyzing foundation by different subsoil models

The examples discussed in this chapter cover many practical problems. For each example discussed in this book, data files and some computed files are included in *ELPLA* software package. The file names, contents and short description of examples are listed below. Besides, a key figure of each problem that contains the main data concerning the foundation shape, loads and subsoil is also shown.

Examples can be run again by *ELPLA* to examine the details of the analysis or to see how the problem was defined or computed and to display, print or plot the results.

When ordering package *ELPLA*, a CD is delivered. It contains the programs and 29 project data files for test purposes, which are described in this book. Data are stored in 67 files. These data introduce some possibilities to analyze slab foundations by *ELPLA*.

Firstly, the numerical examples were carried out completely to show the influence of different subsoil models on the results. Furthermore, different calculation methods for the same subsoil model are applied to judge the computation basis and the accuracy of results. In some cases the influences of geological reloading, soil layers and also the structure rigidity are considered in the analysis. In addition, for applying *ELPLA* in the practice, typical problems are analyzed as follows:

- Stress in soil or plane stress
- Immediate settlement
- Final consolidation
- Ultimate bearing capacity of the soil
- Modulus of subgrade reaction
- Analysis of beams, grids or frames by FE method
- Floor slabs
- Soil settlement due to surcharge fills
- Flexible, elastic and rigid rafts

For this purpose, the following numerical examples introduce some possibilities to analyze foundations. Many different foundations are chosen, which are considered as some practical cases may be happened in practice. All analyses of foundations were carried out by *ELPLA*, which was developed by *M. El Gendy* / *A. El Gendy*.

Description of the calculation methods

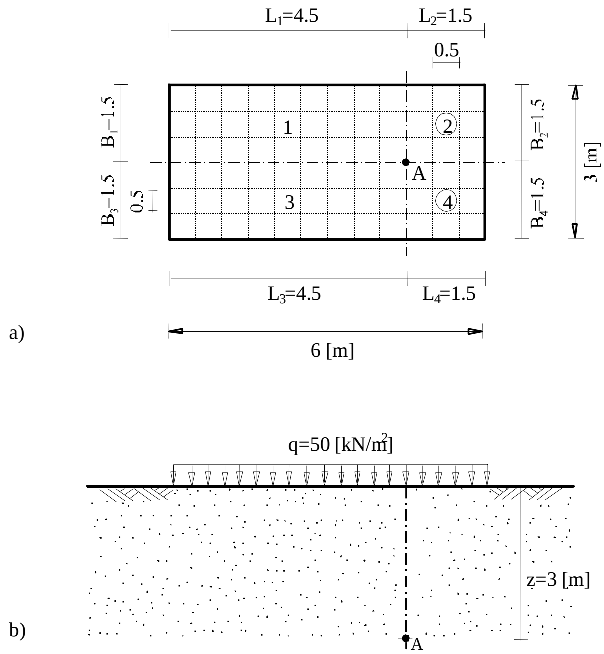
A general computerized mathematical solution based upon the finite elements-method was developed to represent an analysis for foundations on the real subsoil model, and it is capable of analyzing foundations of arbitrarily shape considering holes within the slabs and the interaction of external foundations. The developed computer program is also capable of analyzing different types of subsoil models, especially a three dimensional continuum model that considers any number of irregular layers. Additionally, the program can be used to represent the effect of structural rigidity on the soil foundation system and the influence of temperature change on the slab. In *ELPLA*, there are 9 different numerical methods considered for the analysis of slab foundations as follows:

1. Linear contact pressure
2. Constant modulus of subgrade reaction
3. Variable modulus of subgrade reaction
4. Modification of modulus of subgrade reaction by iteration
5. Modulus of compressibility method for elastic raft on half-space soil medium
6. Modulus of compressibility method for elastic raft (Iteration)
7. Modulus of compressibility method for elastic raft (Elimination)
8. Modulus of compressibility method for rigid raft
9. Modulus of compressibility method for flexible foundation

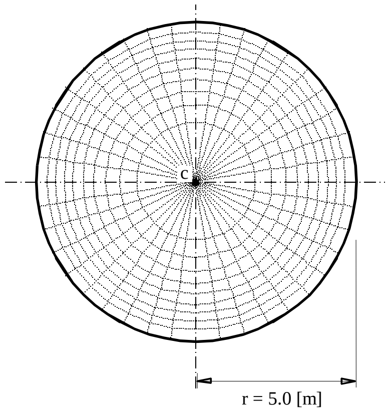
Besides the above 9 main methods, *ELPLA* can also be used to analyze

- System of flexible, elastic or rigid foundations
- Floor slabs, beams, grids, plane trusses, plane frames and plane stress

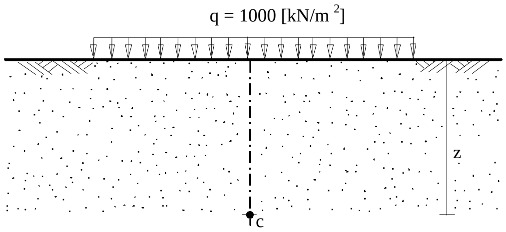
File names, contents and short description of examples

File	Content	Foundation shape, loads, subsoil, ... etc.
str	Stress on soil	
Example 1:	Verifying stress on soil under a rectangular loaded area	

File	Content	Foundation shape, loads, subsoil, ... etc.
cir	Stress on soil	



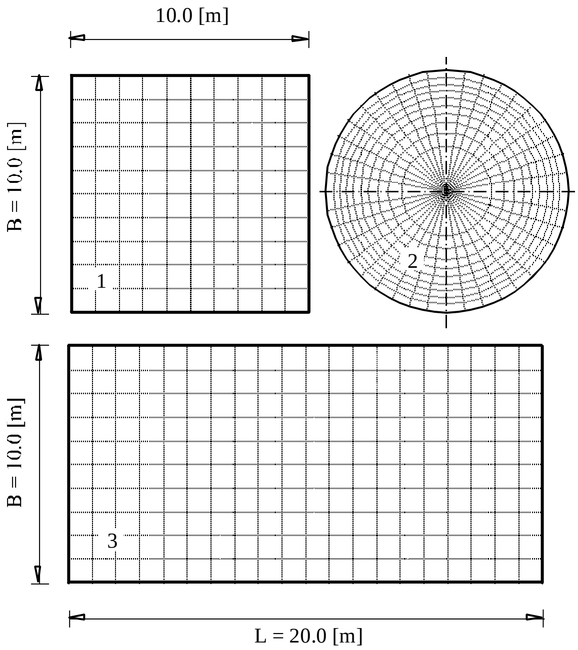
a)



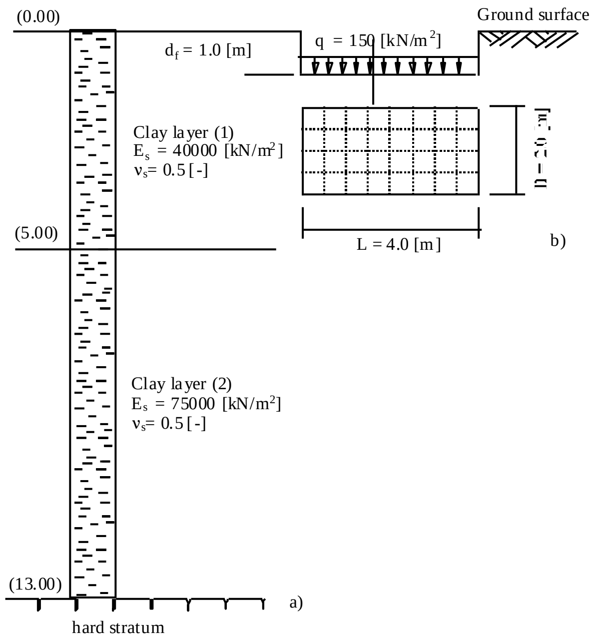
b)

Example 2: Verifying stress on soil under a circular loaded area

File	Content	Foundation shape, loads, subsoil, ... etc.
circ	Circular area	
rec	Rectangular area	
squ	Square area	

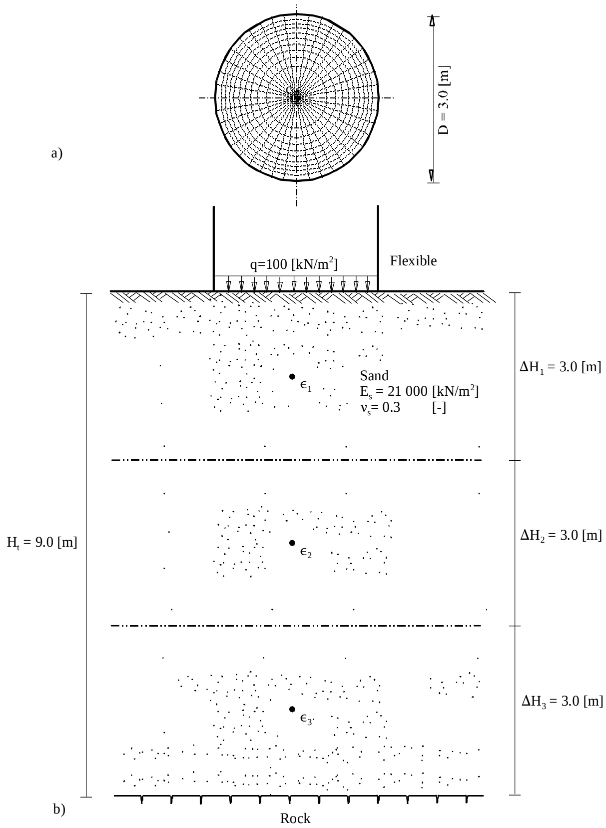


Example 3: Verifying immediate settlement under a loaded area on Isotropic elastic half-space medium

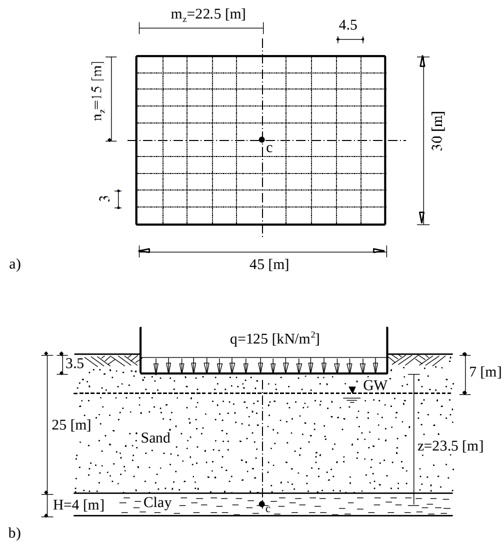
File	Content	Foundation shape, loads, subsoil, … etc.
rec	Immediate settlement	

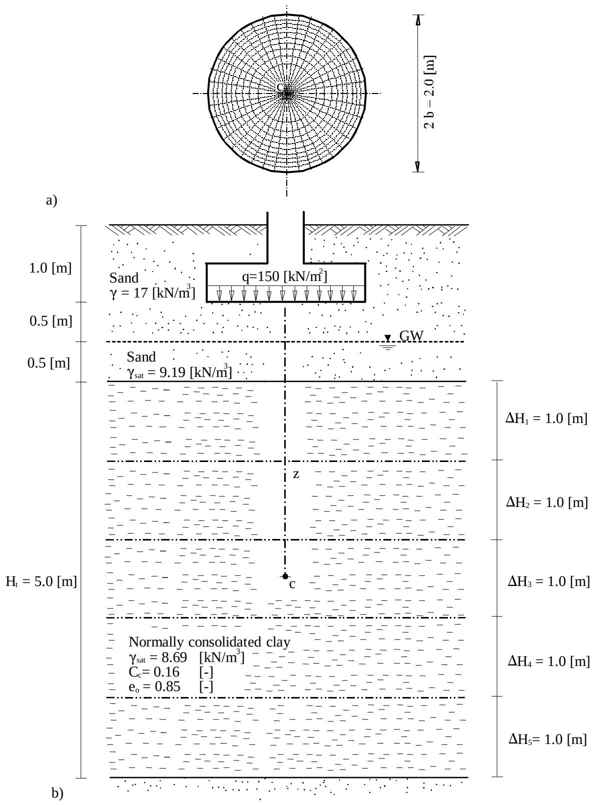
Example 4: Verifying immediate settlement under a rectangular loaded area on layered subsoil

File	Content	Foundation shape, loads, subsoil, ... etc.
tan1	One layer	
tan2	Three layers	

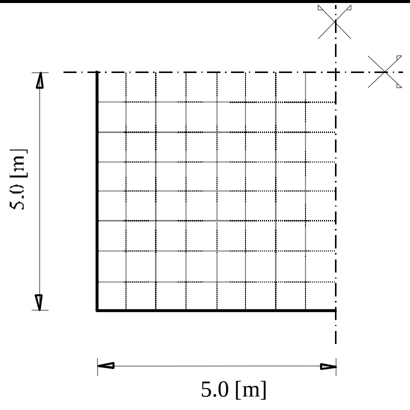
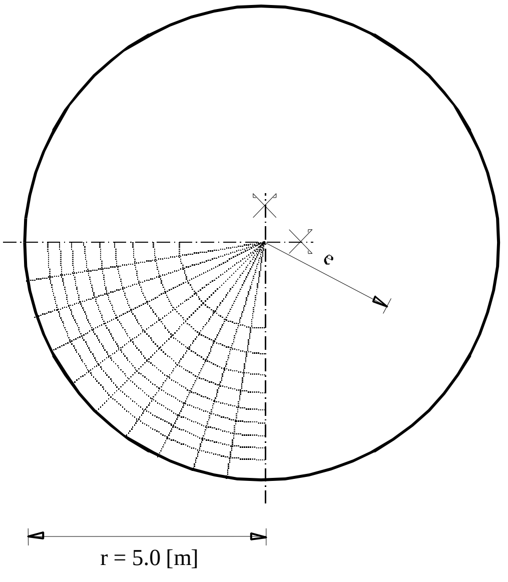


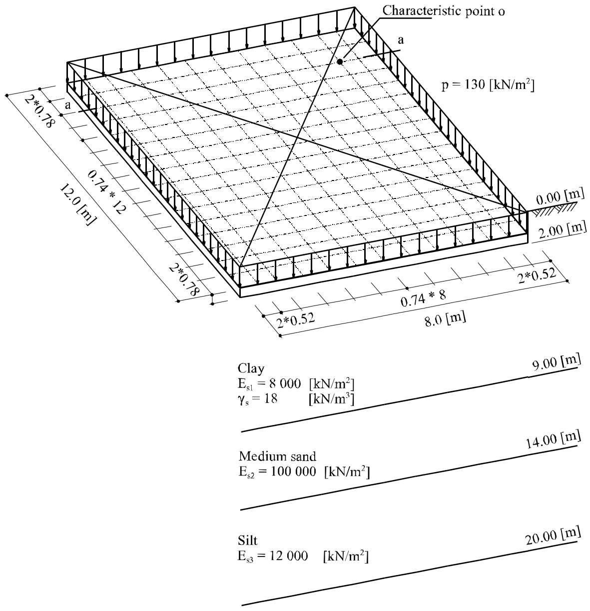
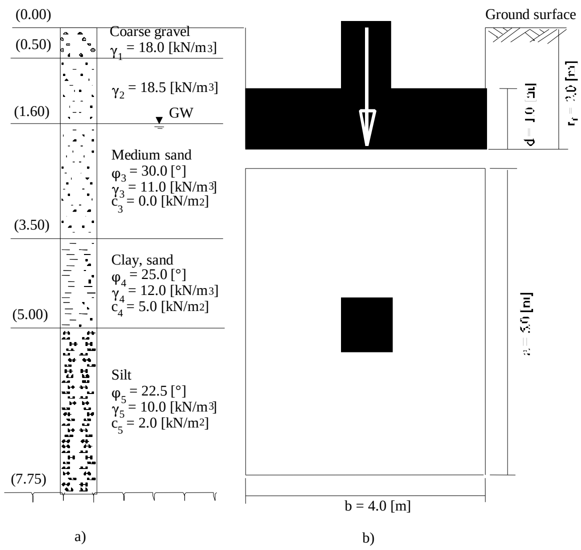
Example 5: Verifying immediate settlement under a circular tank on layered subsoil

File	Content	Foundation shape, loads, subsoil, ... etc.
Cons	Consolidation settlement	
Example 6:	Verifying consolidation settlement under a rectangular raft	

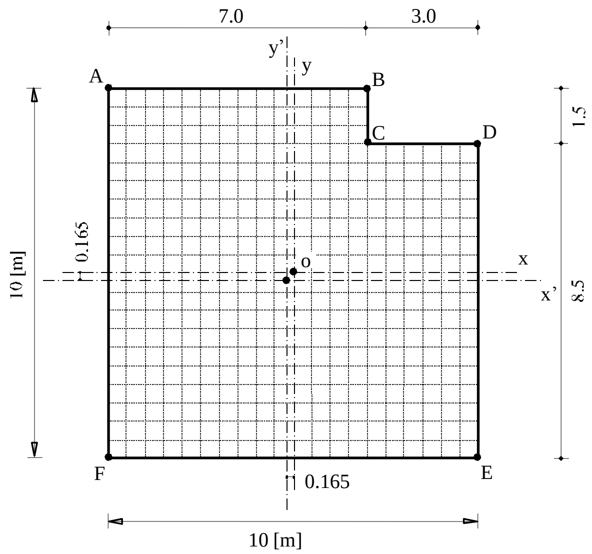
File	Content	Foundation shape, loads, subsoil, ... etc.
scc	Consolidation settlement	

Example 7: Verifying consolidation settlement under a circular footing

File	Content	Foundation shape, loads, subsoil, ... etc.
		
rf2	Raft with 2 * 2 net	
rf4	Raft with 4 * 4 net	
rf6	Raft with 6 * 6 net	
rf8	Raft with 8 * 8 net	
rf12	Raft with 12 * 12 net	
rf16	Raft with 16 * 16 net	
rf20	Raft with 20 * 20 net	
rf24	Raft with 24 * 24 net	
rf32	Raft with 32 * 32 net	
rf48	Raft with 48 * 48 net	
Example 8:	Verifying rigid square raft on Isotropic elastic half-space medium	
rig	Rigid raft	
Example 9:	Verifying rigid circular raft on Isotropic elastic half-space medium	

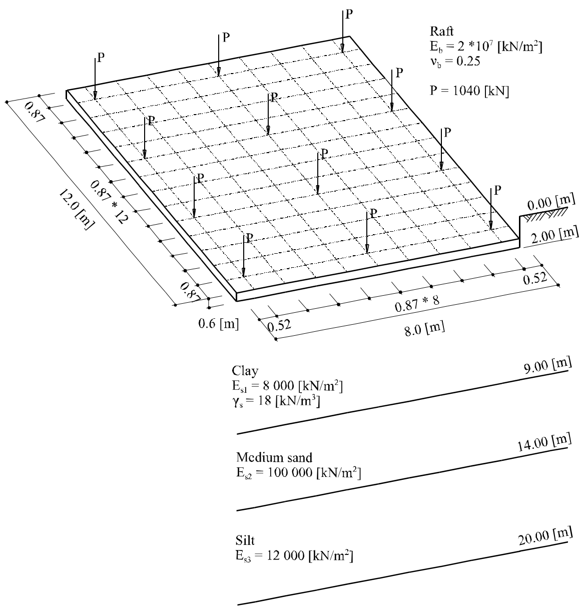
File	Content	Foundation shape, loads, subsoil, ... etc.
fle rig	Flexible raft Rigid raft	
Example 10: Verifying flexible foundation and rigid raft on layered subsoil		
bea	Ultimate bearing capacity	
Example 11: Verifying ultimate bearing capacity for a footing on layered subsoil		

File	Content	Foundation shape, loads, subsoil, ... etc.
lin	Simple assumption model	

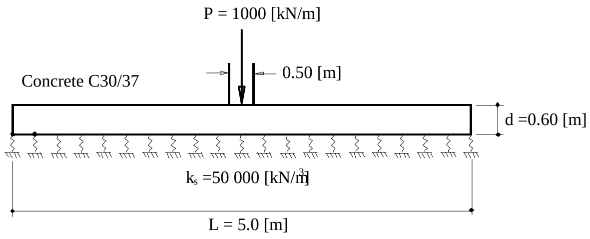
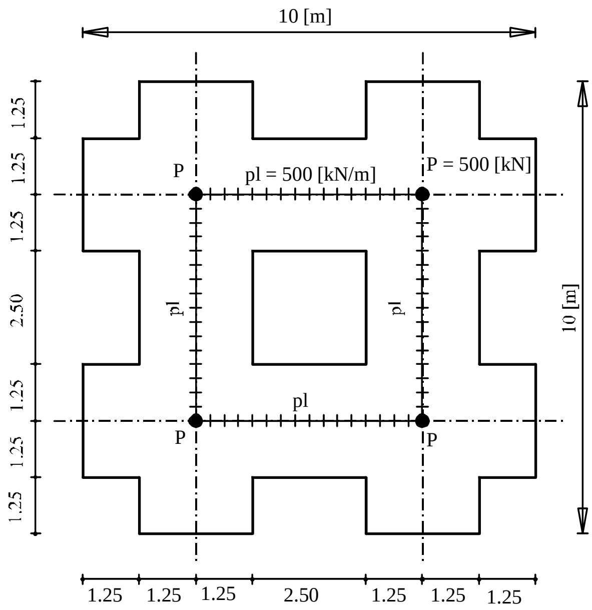


Example 12: Verifying simple assumption model for irregular raft

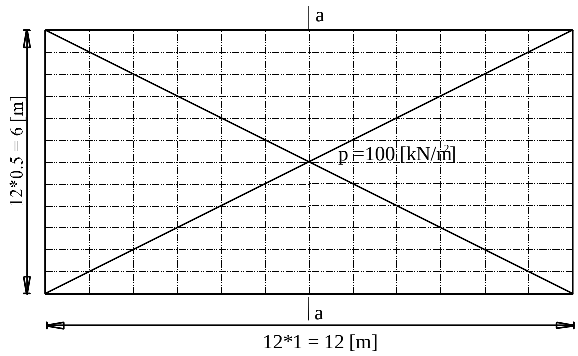
File	Content	
be1	Modulus of subgrade reaction	



Example 13: Verifying main modulus of subgrade reaction k_{sm}

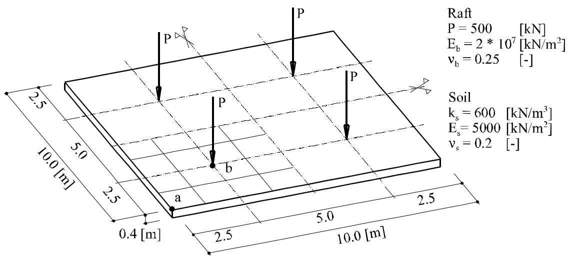
File	Content	Foundation shape, loads, subsoil, ... etc.
bea	Beam foundation	
Example 14:	Verifying beam foundation on elastic springs	
gri	grid foundation	
Example 15:	Verifying grid foundation on elastic springs	

File	Content	Foundation shape, loads, subsoil, ... etc.
ma1	$k_B = \pi/30$, d = 18.5 [cm]	
ma2	$k_B = \pi/10$, d = 26.7 [cm]	
ma3	$k_B = \pi/3$, d = 40 [cm]	



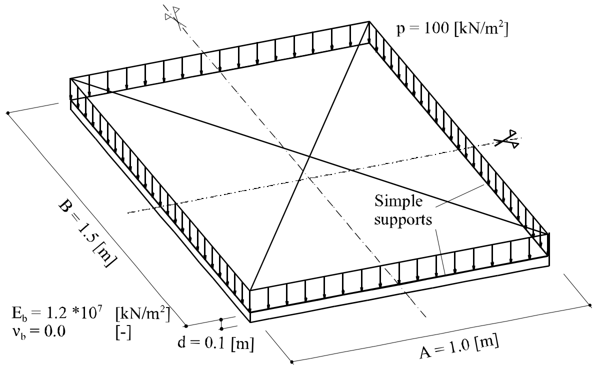
Example 16: Verifying elastic raft on Isotropic elastic half-space soil medium

File	Content	
win	*Winkler's* model	
iso	Half-space soil medium	



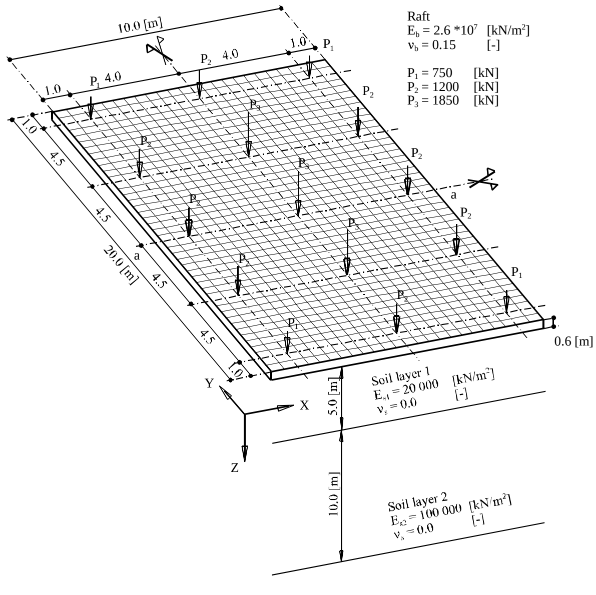
Example 17: Verifying *Winkler's* model and Isotropic elastic half-space soil medium

File	Content	Foundation shape, loads, subsoil, ... etc.
ne1	Slab with 1 element	
ne4	Slab with 4 elements	
ne9	Slab with 9 elements	
ne16	Slab with 16 elements	



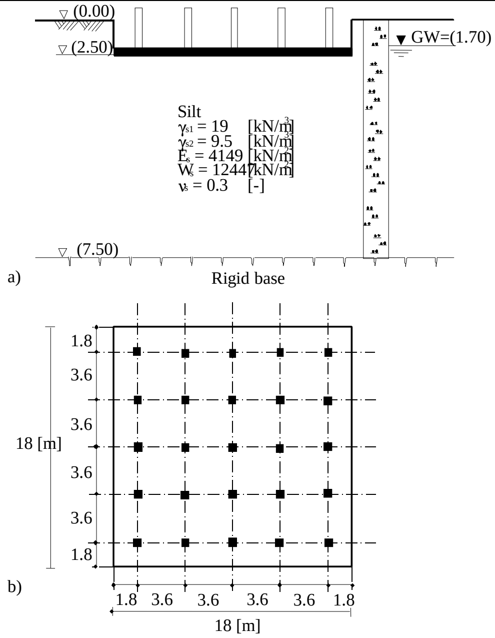
Example 18: Verifying simply supported slab

File	Content	
au1	Method 4	
au2	Method 6	
au3	Method 7	



Example 19: Evaluation of iteration methods

File	Content	Foundation shape, loads, subsoil, ... etc.
vo1	$W_s = E_s$	
vo2	W_s = 900 000 000 [kN/m^2]	
vo3	$W_s = 3 * E_s$	



Example 20: Examination of influence of overburden pressure

Load geometry a

qa1 Linear contact pressure method
qa2 Modulus of subgrade reaction method
qa3 Isotropic elastic half-space
qa4 Modulus of compressibility method
qa5 Rigid slab

Load geometry b

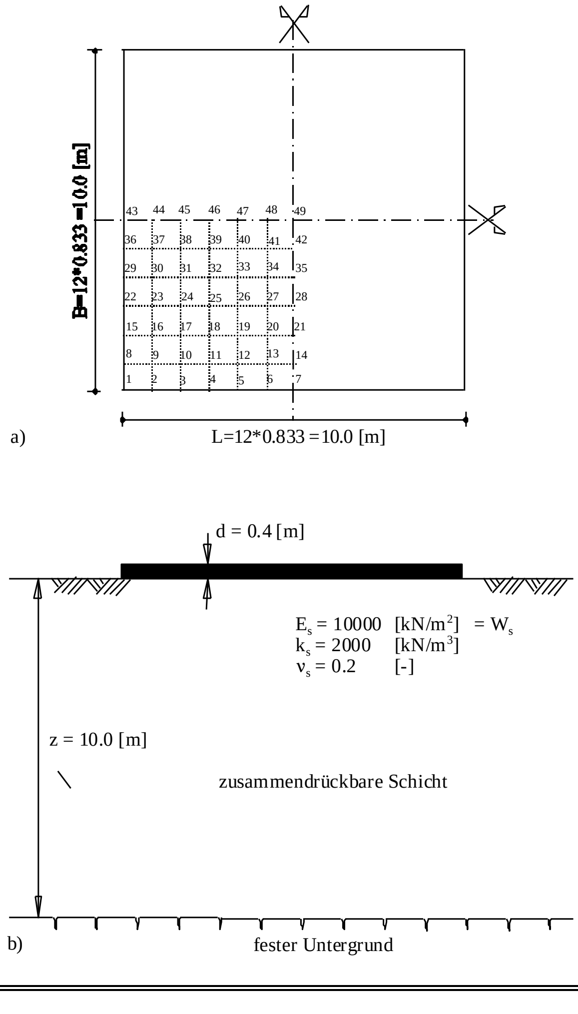
qb1 Linear contact pressure method
qb2 Modulus of subgrade reaction method
qb3 Isotropic elastic half-space
qb4 Modulus of compressibility method
qb5 Rigid slab

Load geometry c

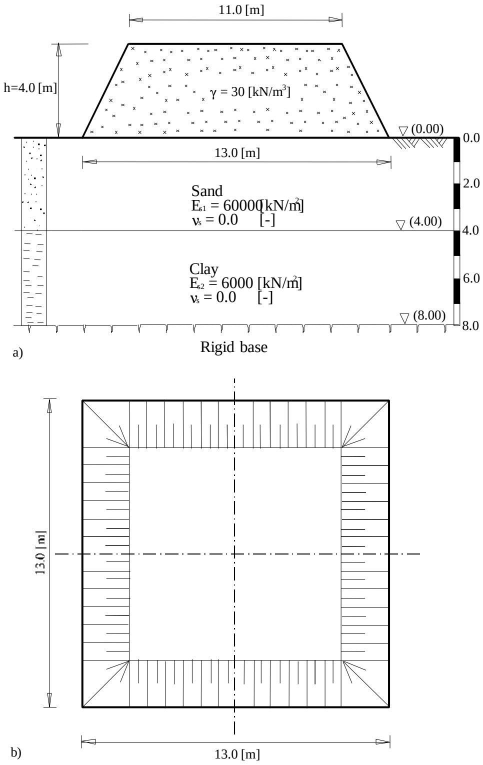
qc1 Linear contact pressure method
qc2 Modulus of subgrade reaction method
qc3 Isotropic elastic half-space
qc4 Modulus of compressibility method
qc5 Rigid slab

Load geometry d

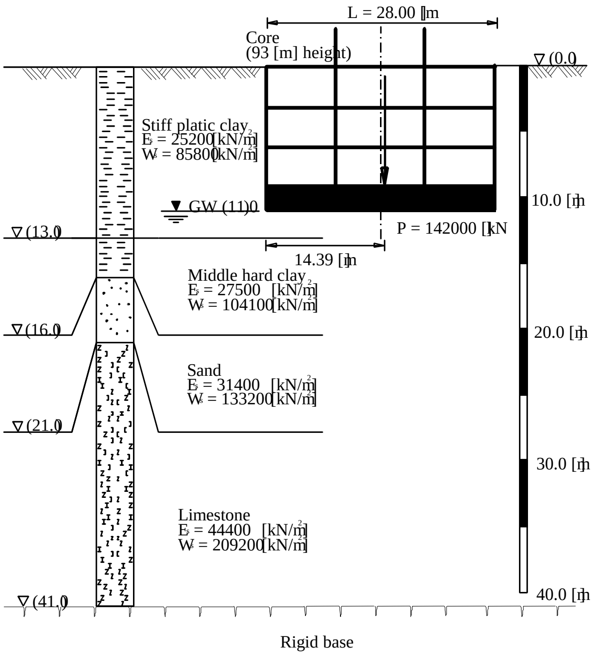
qd1 Linear contact pressure method
qd2 Modulus of subgrade reaction method
qd3 Isotropic elastic half-space
qd4 Modulus of compressibility method
qd5 Rigid slab



Example 21: Examination of influence of load geometry

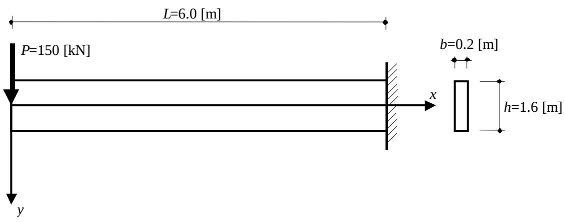
File	Content	Foundation shape, loads, subsoil, ... etc.
flex	Settlement calculation	

Example 22: Settlement calculation under flexible foundation of an ore heap

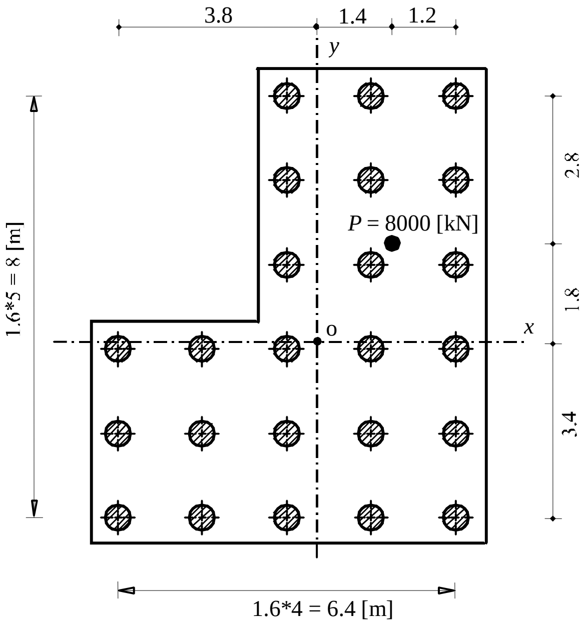
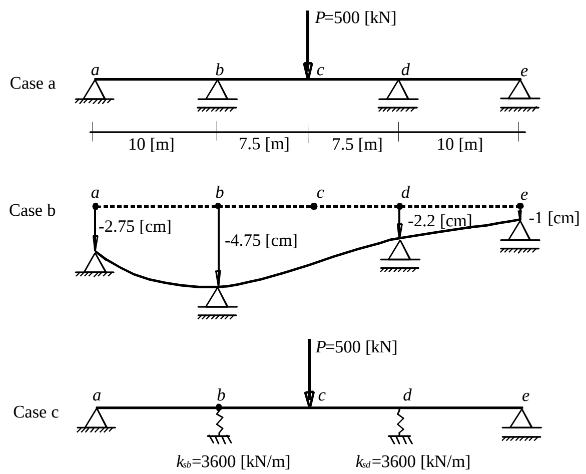
File	Content	Foundation shape, loads, subsoil, ... etc.
sta	Rigid raft	

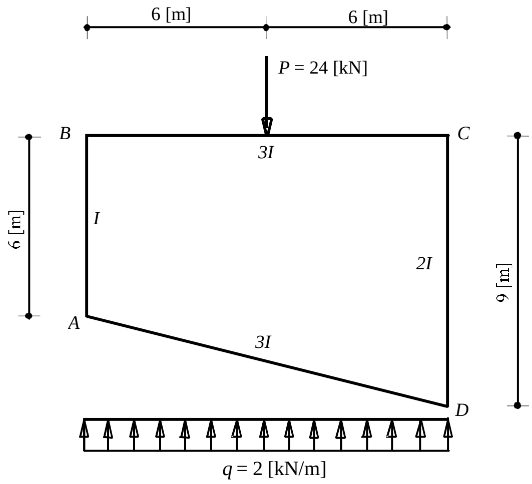
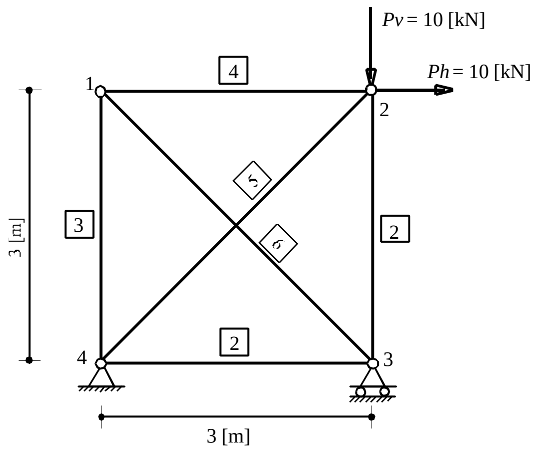
Example 23: Settlement calculation for a rigid raft subjected to an eccentric load

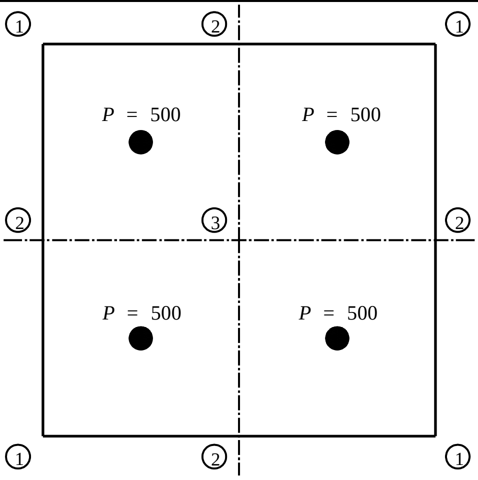
Plane Stress 10 10 Mesh size 10 * 10 [cm^2]
Plane Stress 15 15 Mesh size 15 * 15 [cm^2]
Plane Stress 20 20 Mesh size 20 * 20 [cm^2]
Plane Stress 30 30 Mesh size 30 * 30 [cm^2]



Example 24: Verifying deflection of a thin cantilever beam

File	Content	Foundation shape, loads, subsoil, ... etc.
Forces in piles	Pile group	
Example 25:	Verifying forces in piles of a pile group	
Case a Case b Case c	Case a Case b Case c	
Example 26:	Verifying continuous beam	

File	Content	Foundation shape, loads, subsoil, ... etc.
Frame	Closed frame	
Example 27:	Verifying moments in an unsymmetrical closed frame	
Plane Truss	Plane Truss	
Example 28:	Verifying plane truss	

File	Content	Foundation shape, loads, subsoil, ... etc.
poi	Settlement calculation	

Example 29: Influence of *Poisson's* ratio