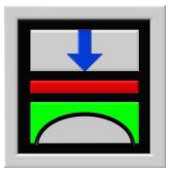
Part A

Short description of the program package ELPLA



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

Version 9.2

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1 Introduction

ELPLA (ELASTIC PLATE) is a program for analyzing raft foundations of arbitrary shape with the real subsoil model. The mathematical solution of the raft is based on the FE-Method. The program can analyze different types of subsoil models, especially the three-dimensional Continuum model that considers any number of irregular layers. A good advantage of this program is the capability to handle the three analyses of flexible, elastic and rigid foundations. In addition, the mesh of the rigid and flexible foundations can be constructed to be analogous to the finite elements mesh of the elastic foundation. Therefore the three analyses can be compared easily and correctly. ELPLA can also be used to represent the effect of external loads, neighboring foundations, tunneling and the influence of the temperature difference on the raft.

ELPLA is a 32-bit, graphical software product that operates under Microsoft Windows 9x/ NT/ ME/ XP. The common "what you see is what you get" of Windows applications makes it easy to learn how to use ELPLA, especially if you are already familiar with the Windows environment.

The program package ELPLA consists of 7 separate programs. These can run independently. The names and short descriptions of the separate programs are shown in Table A-1.

Table A-1 Names and descriptions of ELPLA programs

Program name	Description of the program
ELPLA-Data	Editing project data
ELPLA-Solver	Analyzing the project problem
ELPLA-Graphic	Displaying data and results graphically
ELPLA-List	Listing project data and calculated results
ELPLA-Section	Displaying results graphically at specified sections
ELPLA-Boring	Editing and displaying boring logs graphically
GEOTEC-Editor	Simple word processing program

2 Calculation methods

In ELPLA 9 different numerical methods with 3 soil models are considered for analyzing raft foundations as follows:

1) Linear contact pressure
(Simple assumption model)

2) Constant modulus of subgrade reaction
(*Winkler*'s model)

3) Variable modulus of subgrade reaction
(*Winkler*'s model)

4) Modification of modulus of subgrade reaction by iteration
(*Winkler*'s model/ Continuum model)

5) Modulus of compressibility method for elastic raft on half-space soil medium
(Solving system of linear equations by elimination)
(Isotropic elastic half-space soil medium - Continuum model)

6) Modulus of compressibility method for elastic raft
(Solving system of linear equations by iteration)
(Isotropic elastic half-space soil medium and 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)

8) Modulus of compressibility method for rigid raft
(Isotropic elastic half-space soil medium and layered soil medium - Continuum model)

9) Modulus of compressibility method for flexible raft
(Isotropic elastic half-space soil medium and layered soil medium- Continuum model)

Beside the above 9 main methods ELPLA can also be used to analyze system of flexible, elastic or rigid foundations. Furthermore ELPLA can be used to analyze many other structural problems such as slab floors, grids, plane frame and plane stress.

3 Geometry and loads

It is possible to consider raft with any arbitrary shape including holes, Figure A-1. It is also possible to consider raft with variable thickness, Figure A-2. Loads on the raft can be applied independently on the mesh at any position. Loads may be defined in different types such as point loads, line loads and polygon uniform loads, Figure A-3.

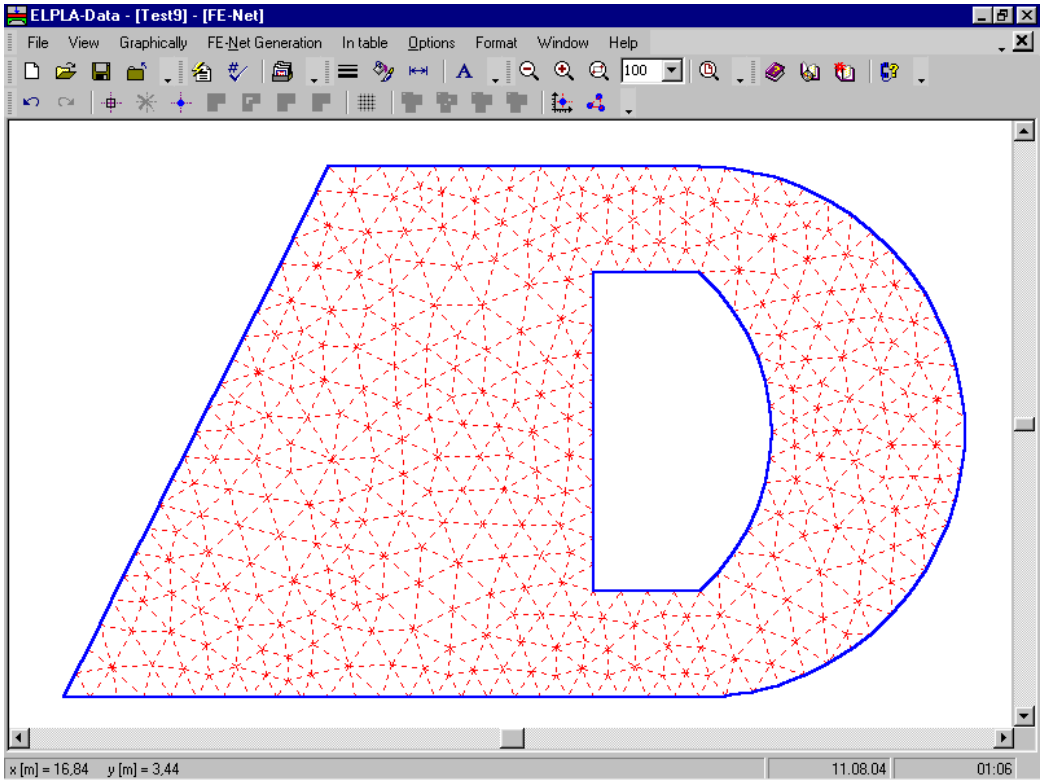


Figure A-1 Arbitrary shape of raft with hole

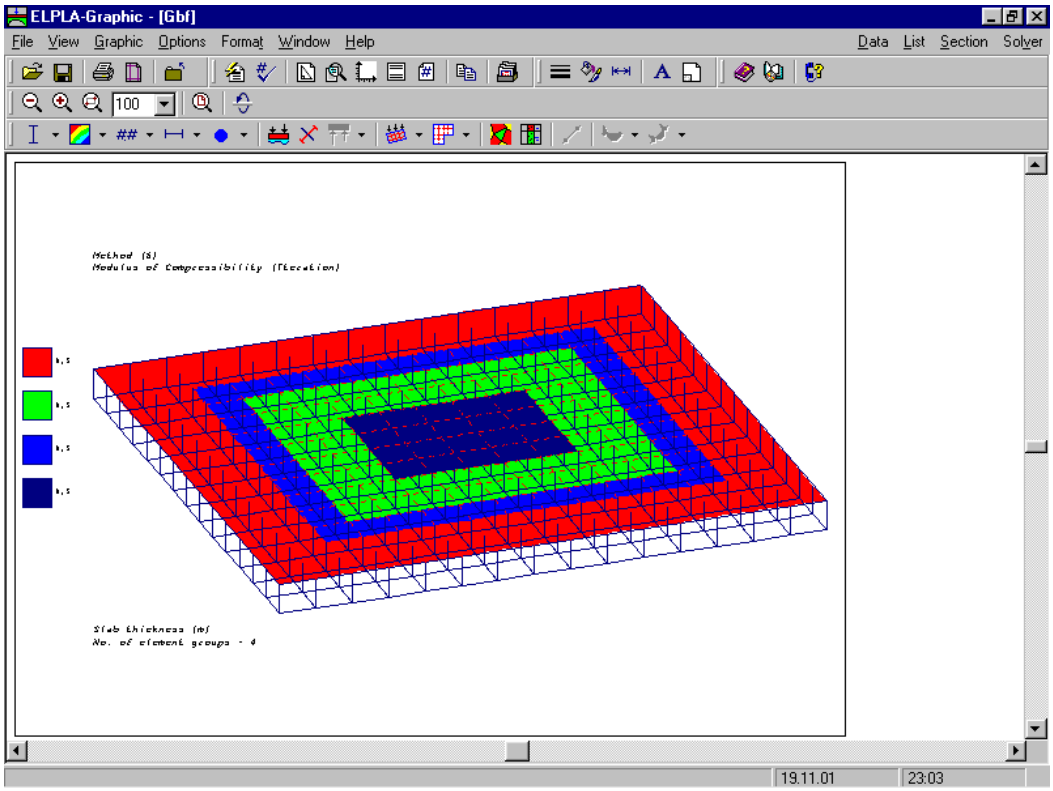


Figure A-2 Variable slab thickness

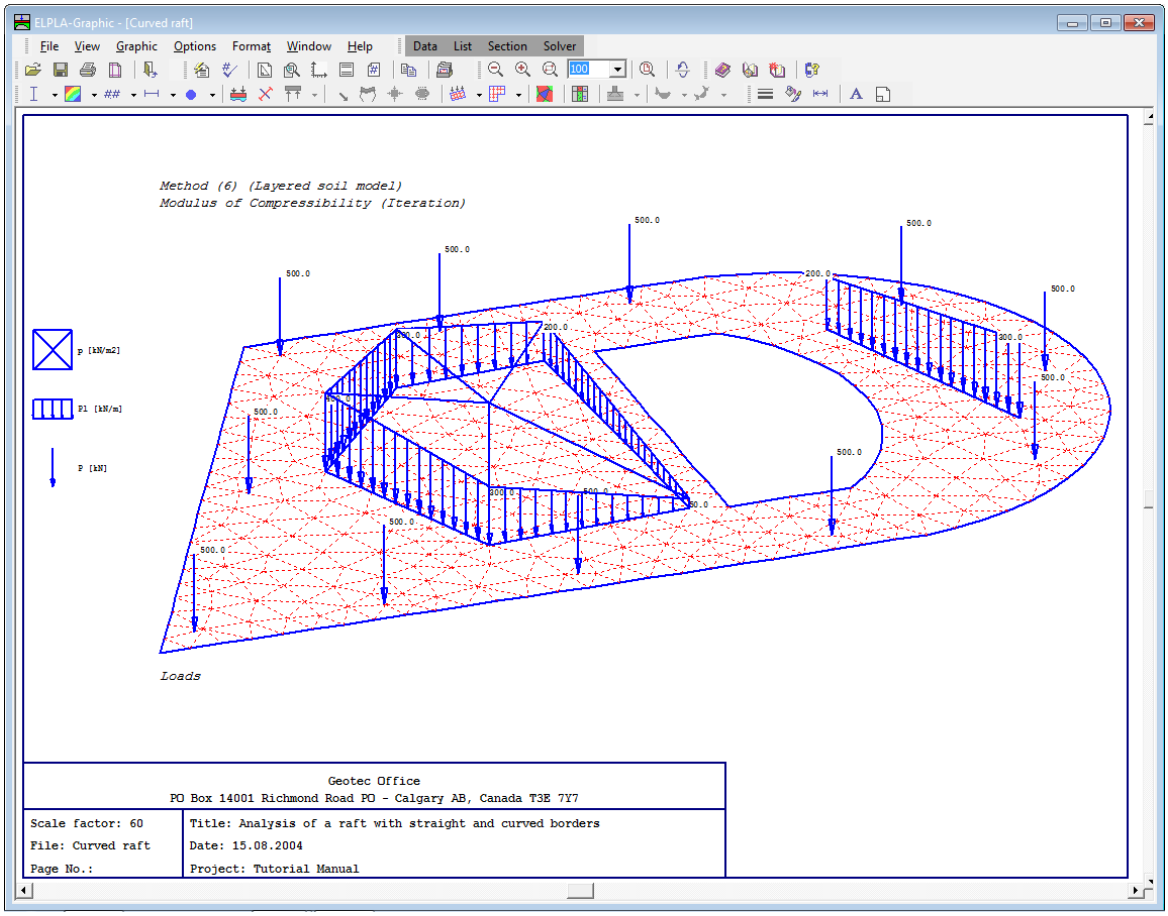


Figure A-3 Arbitrary type of loads

4 Boundary conditions

It is possible to define elastic or fixed rotations and displacements on the raft, Figure A-4. Also translational or rotational springs may be defined.

5 Soil

The soil is defined by a number of borings; each boring has multi-layers with different soil materials, Figure A-5. Variable thickness and discontinuous soil strata can be considered, Figure A-6. Loading and reloading of the soil modulus can be taken into account by the analysis, Figure A-7. Three different methods are used to determine the flexibility coefficients or the modulus of subgrade reaction:

1 Hand-Division of boring logs to nodes
2 Subareas method
3 Interpolation method (Figure A-5)

It is possible to draw soil layers by different symbols according to the German Standard DIN 4023 for easy identification. Also the limit depth of soil layers can be determined. Variable foundation levels can be considered in the analysis (Figure A-6).

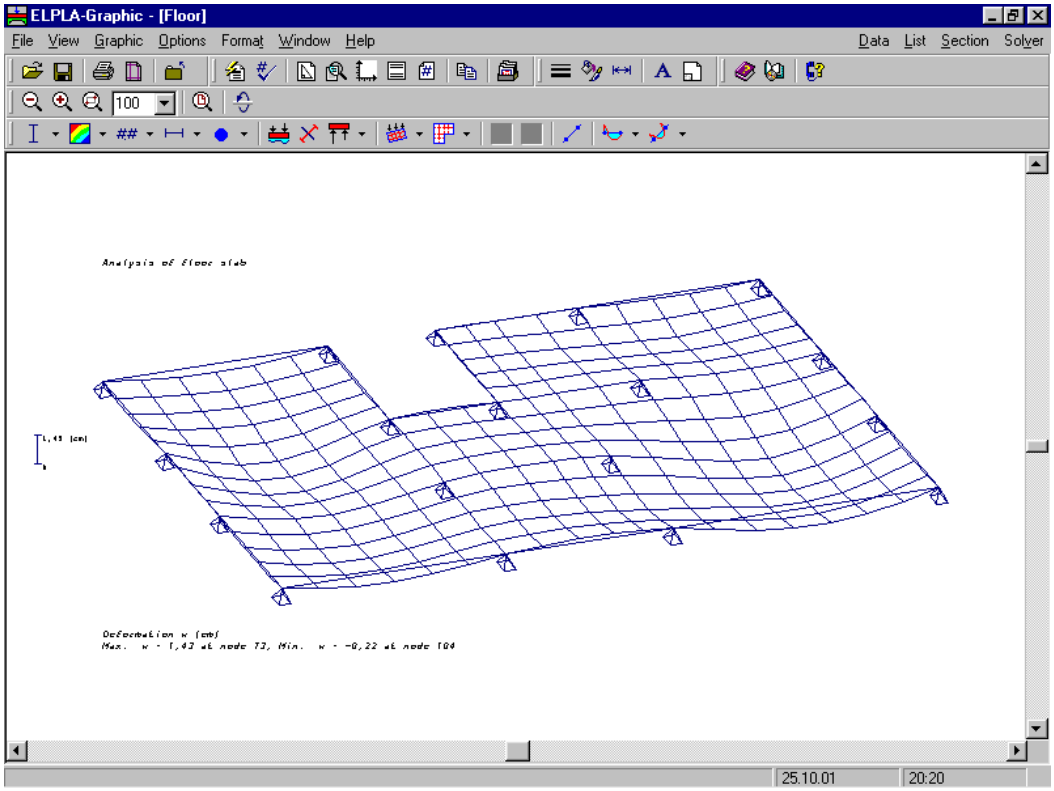


Figure A-4 Fixed displacements

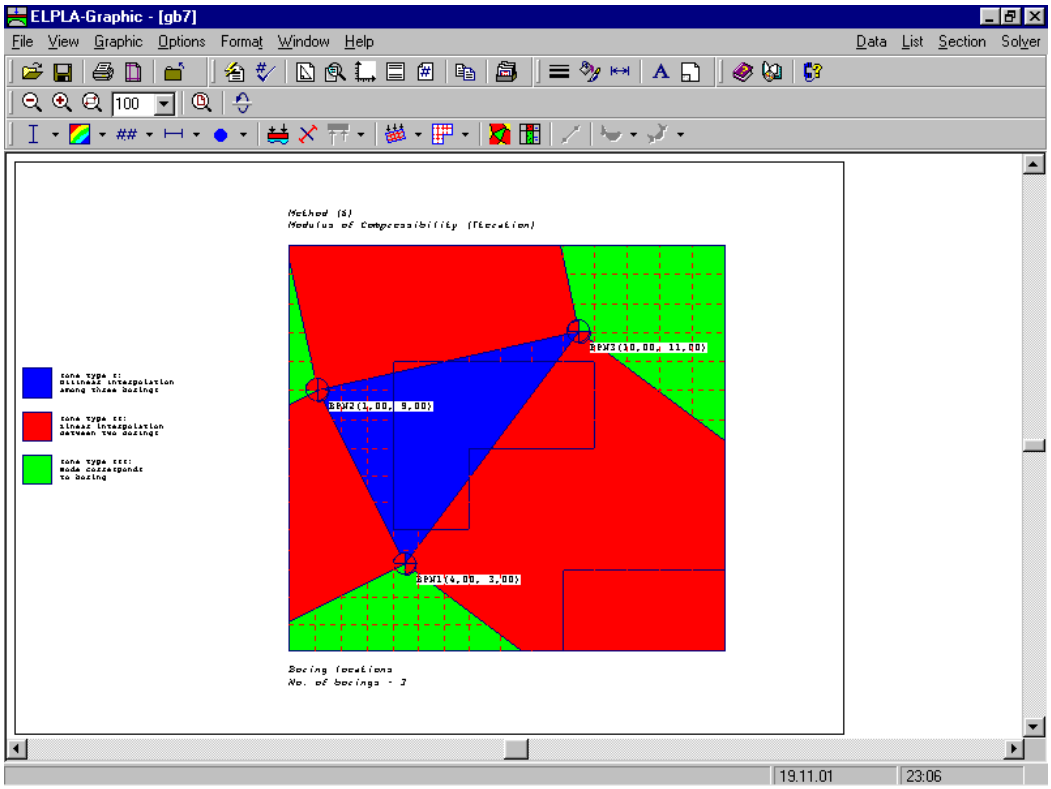


Figure A-5 The soil is defined by a number of borings

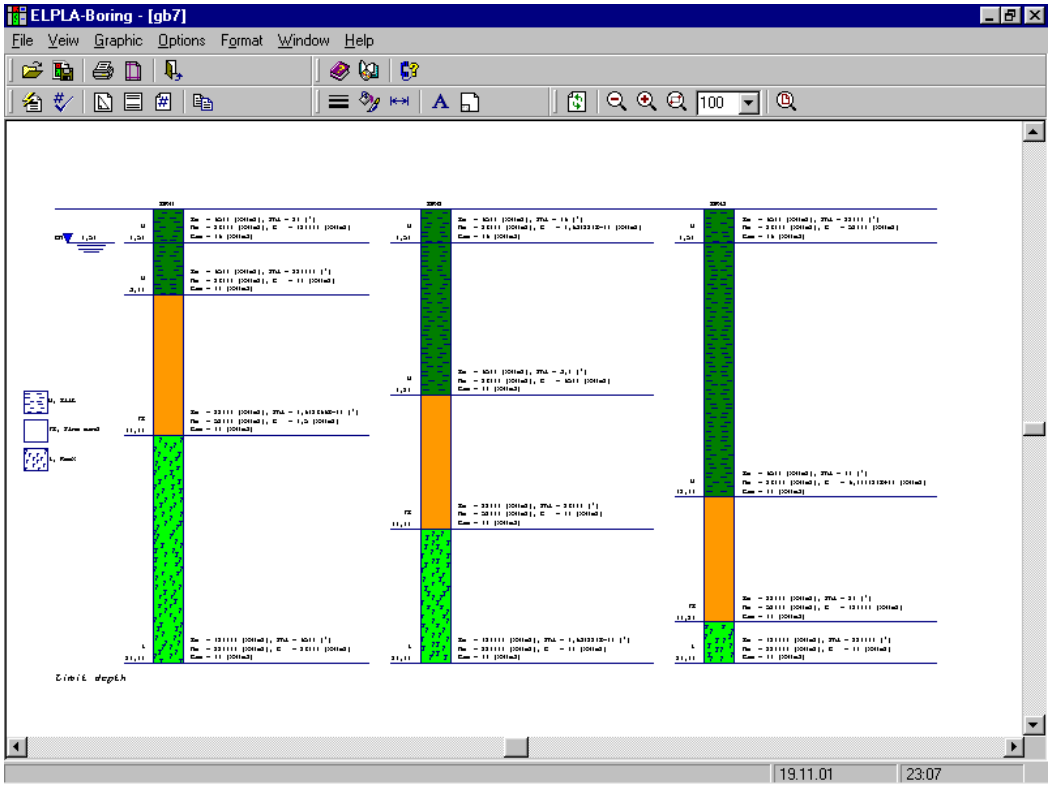
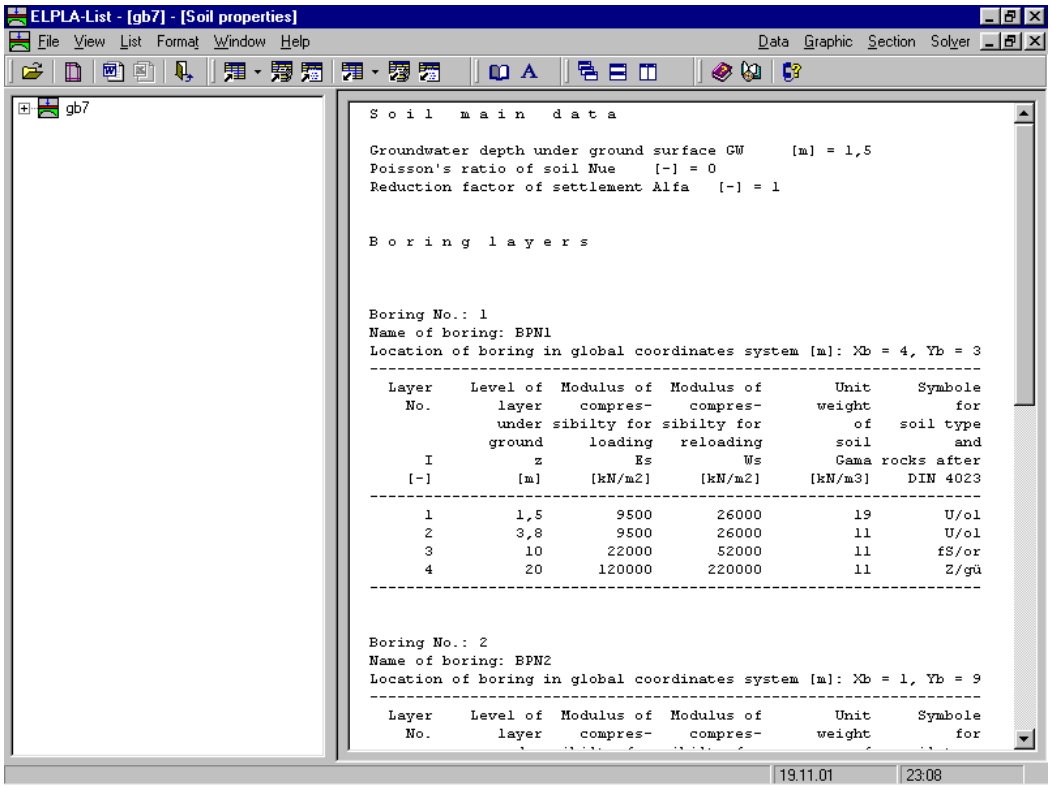


Figure A-6 Variable thickness soil strata




```
S o i l   m a i n   d a t a

Groundwater depth under ground surface GW      [m] = 1,5
Poisson's ratio of soil Nue     [-] = 0
Reduction factor of settlement Alfa    [-] = 1


B o r i n g   l a y e r s



Boring No.: 1
Name of boring: BPN1
Location of boring in global coordinates system [m]: Xb = 4, Yb = 3
-------------------------------------------------------------------
  Layer    Level of  Modulus of  Modulus of        Unit      Symbole
   No.       layer    compres-    compres-      weight          for
             under sibilty for sibilty for          of   soil type
            ground     loading   reloading        soil          and
     I          z          Es          Ws       Gama rocks after
   [-]        [m]     [kN/m2]     [kN/m2]    [kN/m3]    DIN 4023
-------------------------------------------------------------------
     1        1,5        9500       26000         19        U/ol
     2        3,8        9500       26000         11        U/ol
     3         10       22000       52000         11        fS/or
     4         20      120000      220000         11        Z/gü
-------------------------------------------------------------------


Boring No.: 2
Name of boring: BPN2
Location of boring in global coordinates system [m]: Xb = 1, Yb = 9
-------------------------------------------------------------------
  Layer    Level of  Modulus of  Modulus of        Unit      Symbole
   No.       layer    compres-    compres-      weight          for
```

Figure A-7 Loading and reloading soil modulus are considered

6 Design of the slab

The design of the slab for determining reinforcement and punching stress can be carried out according to the following design codes:

- EC 2 — European Committee for Standardization, Design of Concrete Structures Eurocode 2
- DIN 1045 — German Institute for Standardization, Design and Construction of Reinforced Concrete
- ACI — American Concrete Institute Building Code Requirements for Structural Concrete
- ECP — Egyptian Code of Practice for Design and Construction of Reinforced Concrete Structures

7 Graphical drawing of data and results

You can display, plot and print data and results graphically using the sub program ELPLA-Graphic. It is possible to draw raft geometry, boring locations, soil profiles, loading, boundary conditions, settlement, deformation, contact pressure, moment, shear, modulus of subgrade reaction and reinforcement (Figure A-8 to Figure A-14).

The results and data can be presented graphically as follows:

- Data in the plan
- Data in isometric view
- Boring locations
- Boring logs
- Limit depth
- Arrangement of rafts including neighbor foundations
- Result values in the plan
- Distribution of results in the plan
- Results as contour lines
- Results in isometric view
- Results as circular diagrams
- Principal moments as streaks
- Support reactions as arrows
- Deformation
- Girders

The graphical drawing, if desired, can be saved as WMF-File, in which it can be exported into other Windows applications to prepare reports, slide presentations or add further information to the drawing.

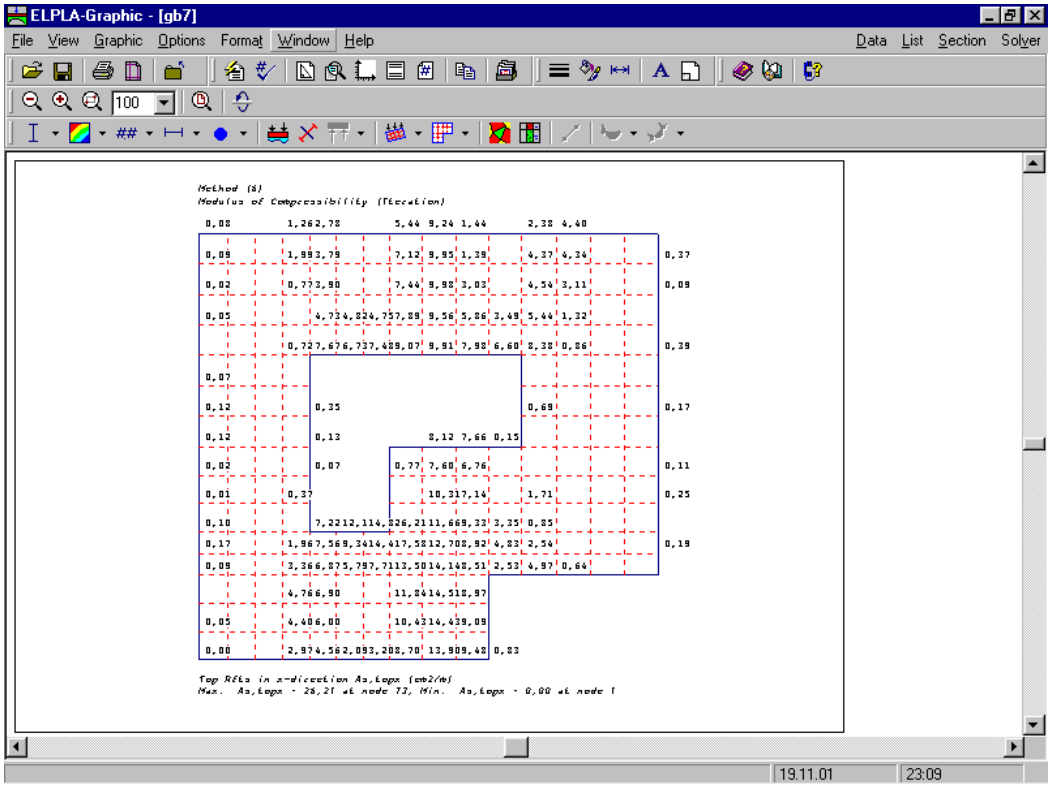


Figure A-8 Results can be tabulated on the mesh

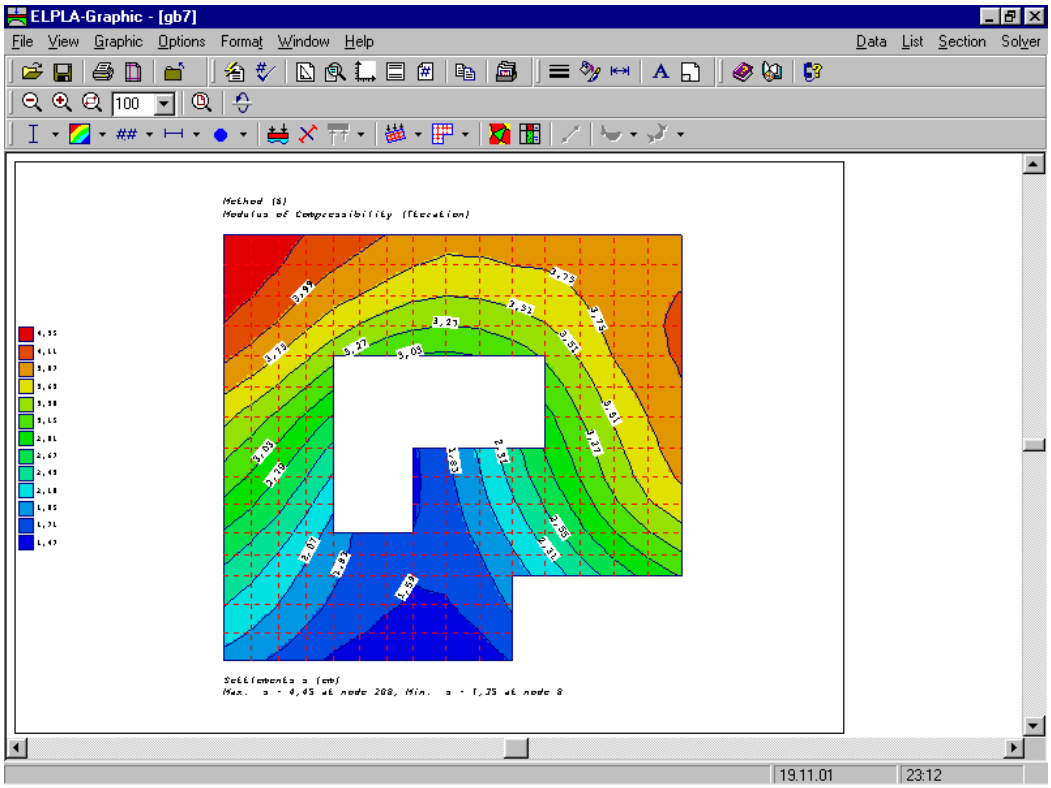


Figure A-9 Results can be contoured

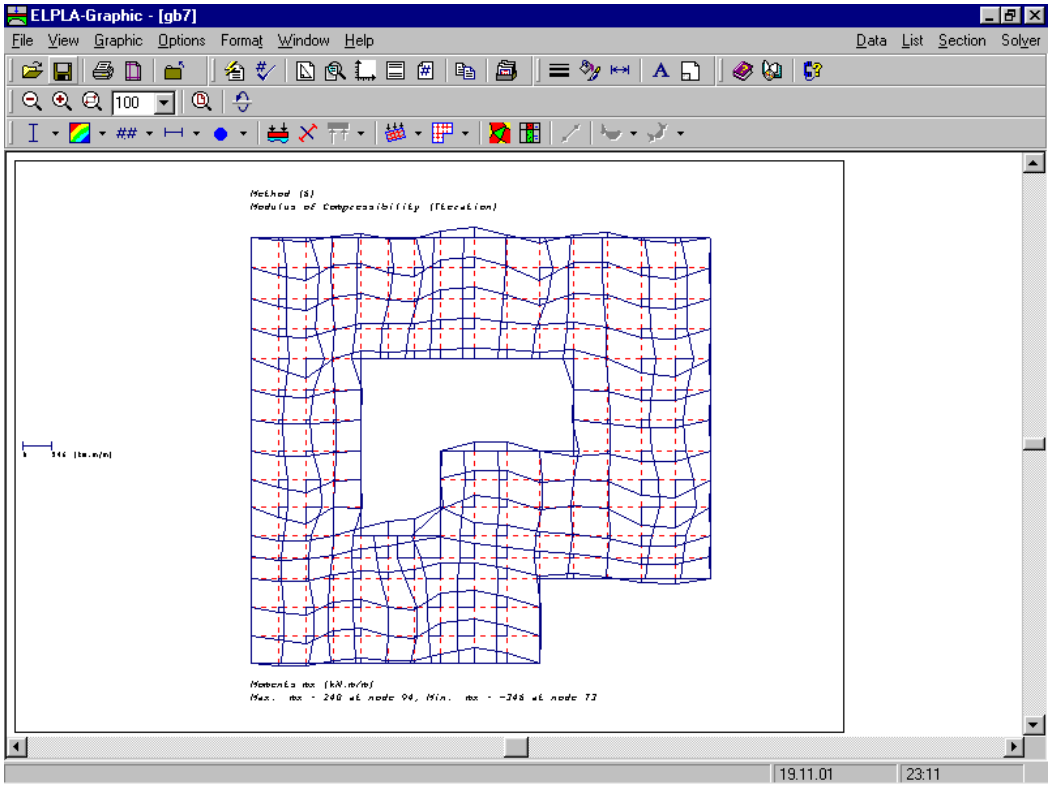


Figure A-10 Moment distribution on the raft can be plotted

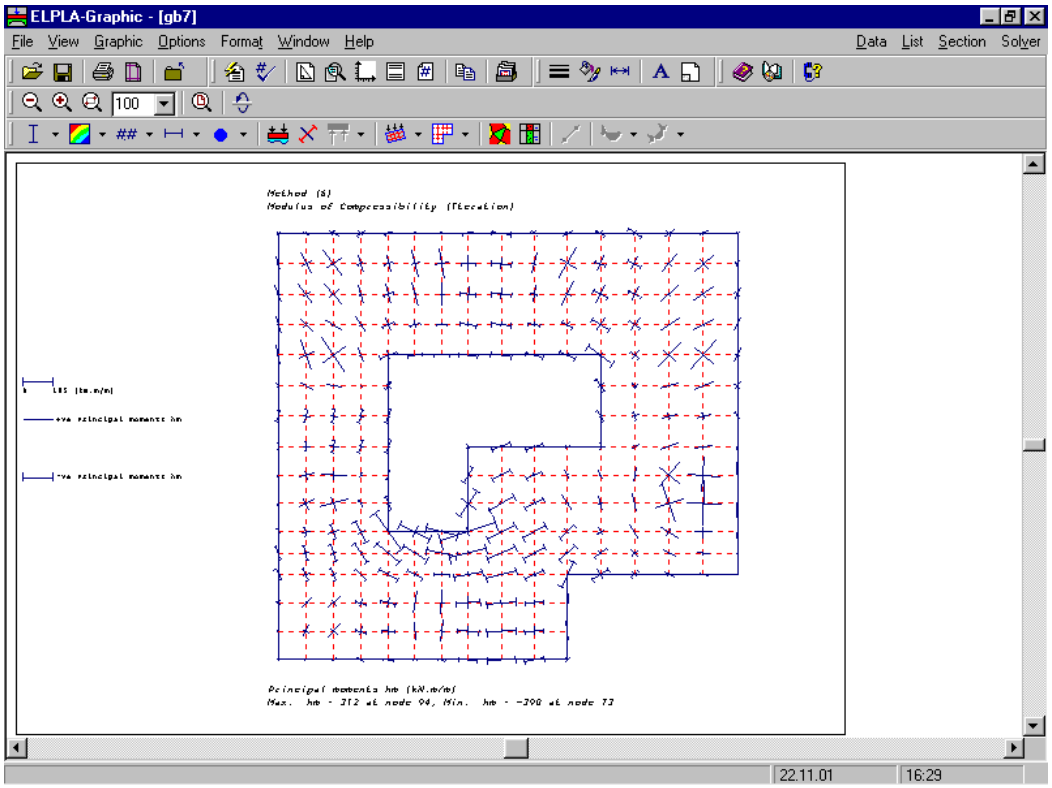


Figure A-11 Principal moments as streaks

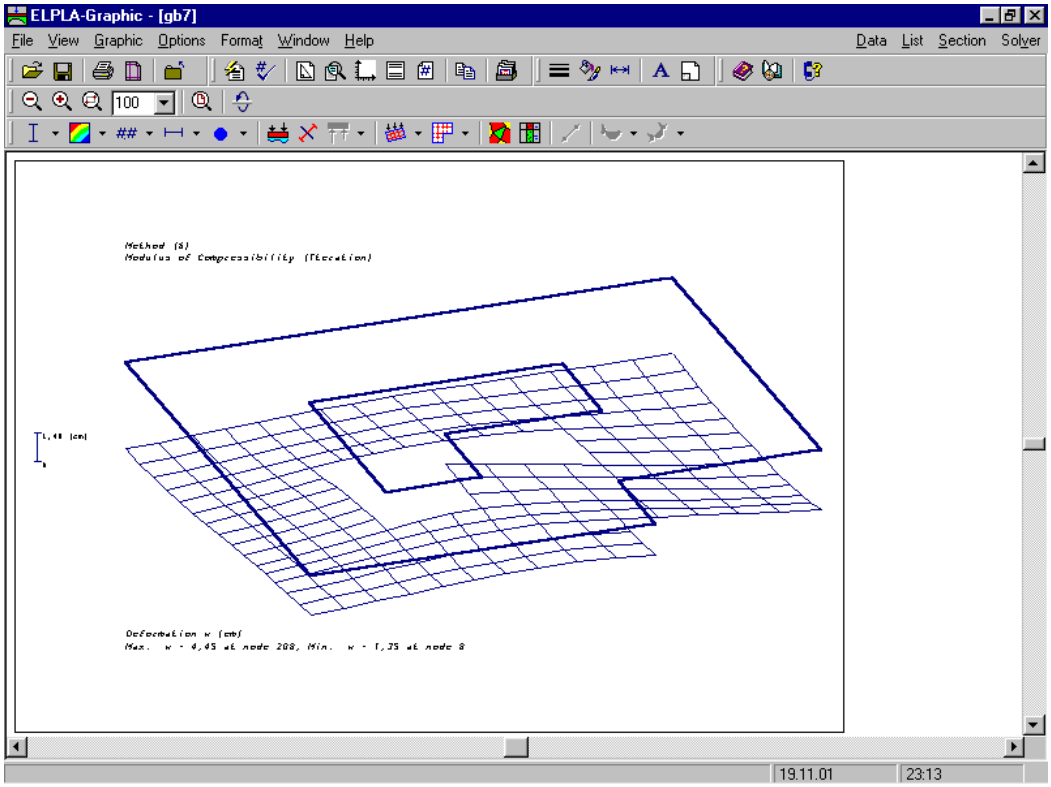


Figure A-12 Raft deformation can be plotted as a deformed mesh

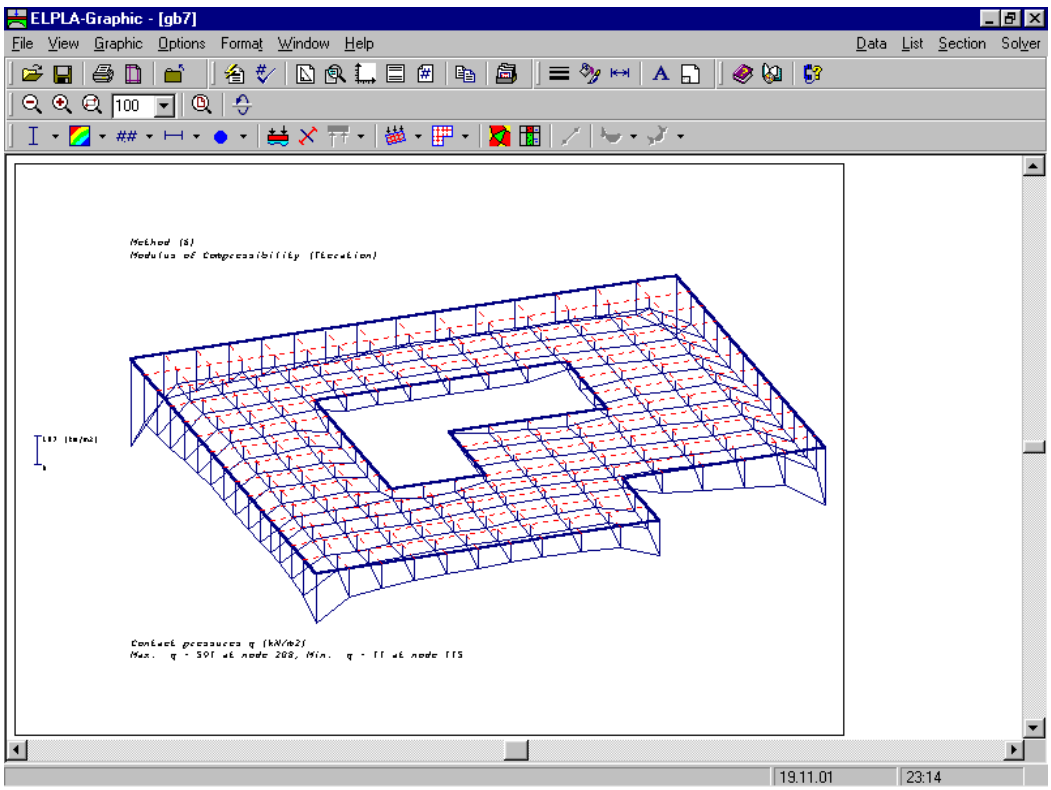


Figure A-13 Results can be plotted in isometric shape

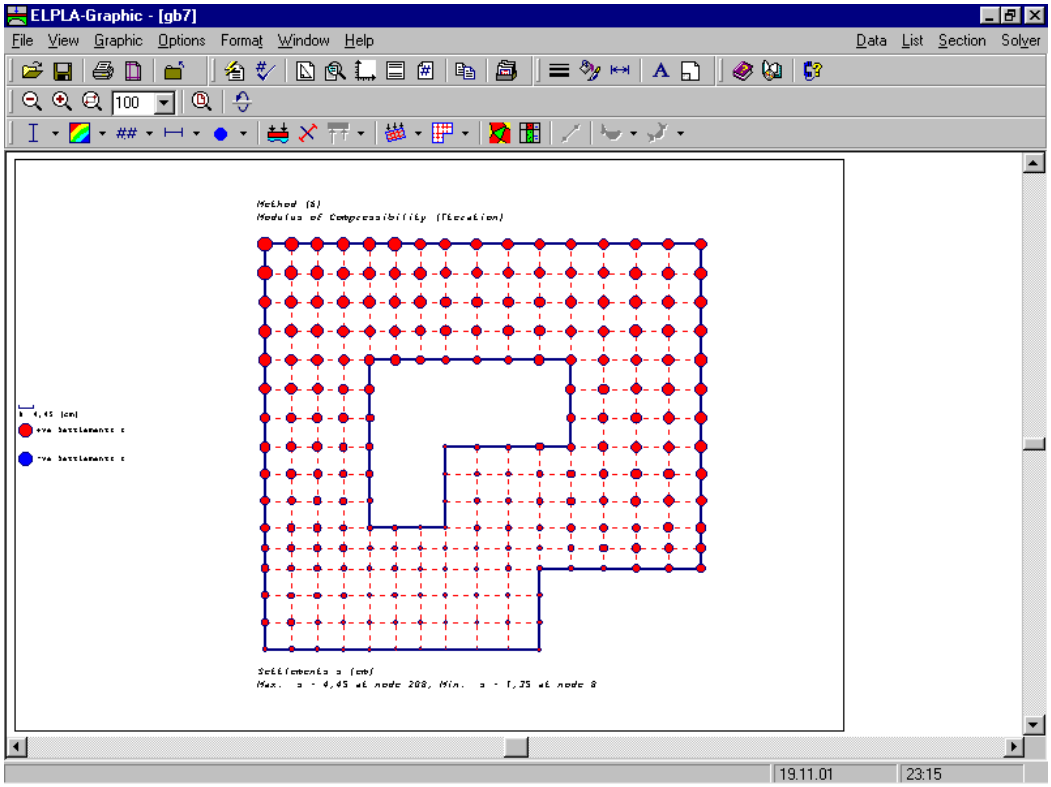


Figure A-14 Results can be plotted as circular diagram

8 Drawing sections

Further more you can display, plot and print results at specified sections graphically using the sub program ELPLA-Section. It is possible to draw settlements, contact pressures, deformation, internal forces, modulus of subgrade reaction and reinforcement (Figure A-15 to Figure A-17). It is also possible to determine extreme values of the results from many load cases. The results can be presented graphically as follows:

- Section in x-direction
- Max./ Min. values in x-direction
- Overlapping in x-direction
- Section in y-direction
- Max./ Min. values in y-direction
- Overlapping in y-direction
- Arbitrary section

Also drawing sections, if desired, can be saved as WMF-Format files, in which they can be exported to other Windows applications to prepare reports, slide presentations or add further information.

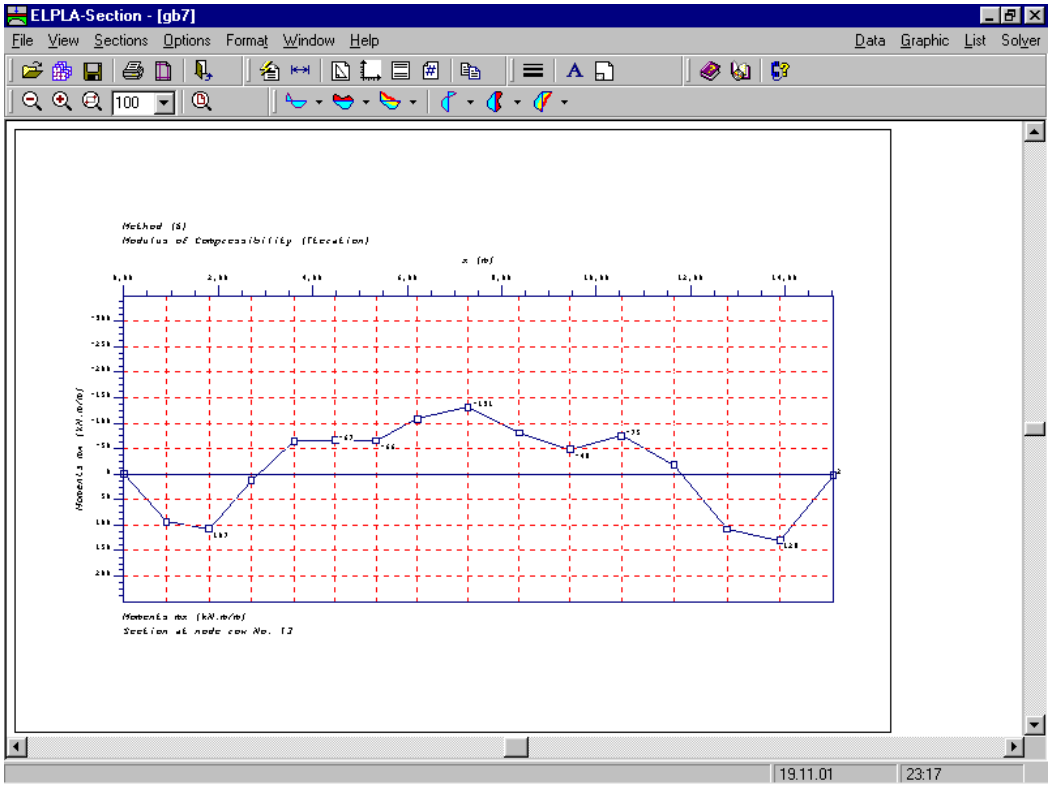


Figure A-15 Results can be plotted at specified section

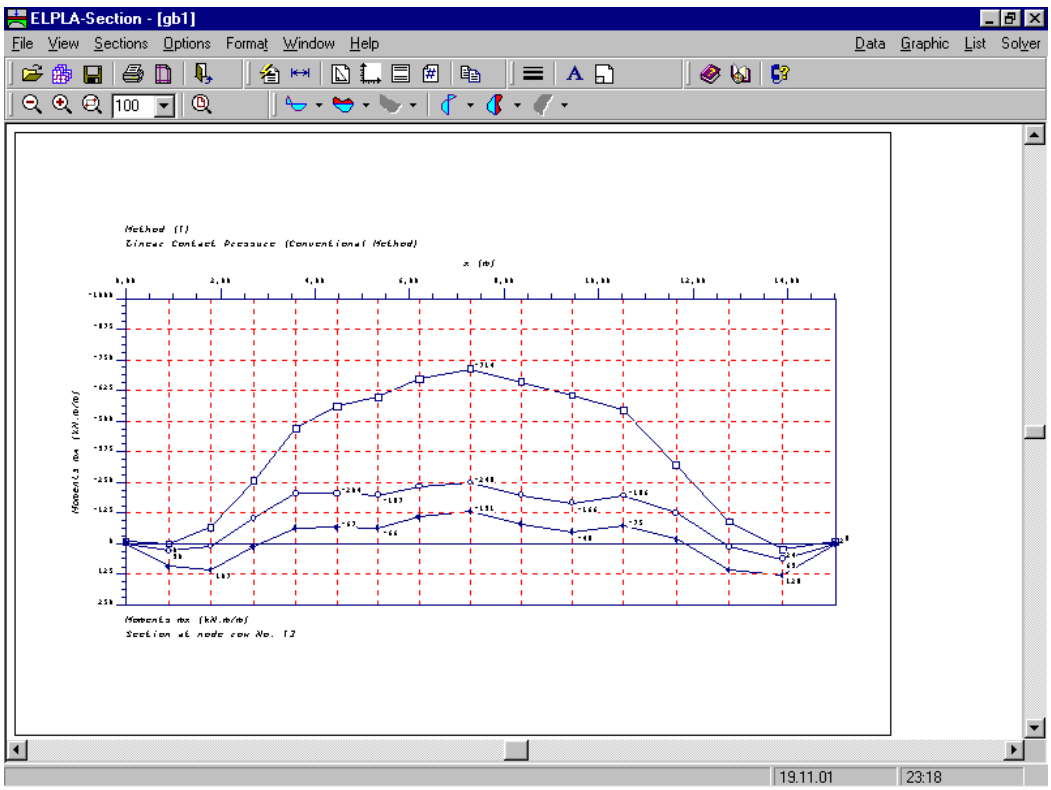


Figure A-16 Results from many projects can be plotted together

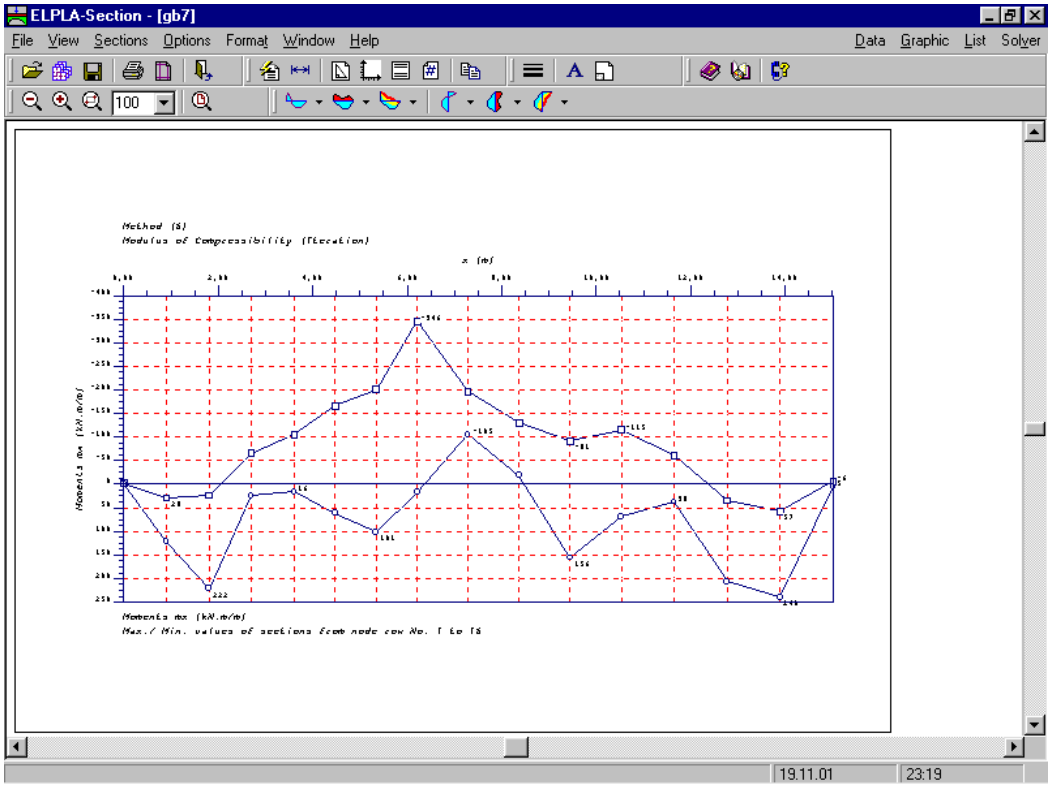


Figure A-17 Max. and Min. values can be calculated and plotted together

9 Tabulation of data and results

You can list data and results using the sub program ELPLA-List. Listing the data and results can be displayed first on the screen and then can be sent to the printer (Figure A-18 to Figure A-20). The results and data can be listed as follows:

- Display tables of data
- Print tables of data
- List tables of data through Text-Editor
- Display tables of results
- Print tables of results
- List tables of results through Text-Editor

The listed results and data, if desired, can be saved as ASCII-format Files, in which they can be exported to other Windows applications to prepare reports or add further information.

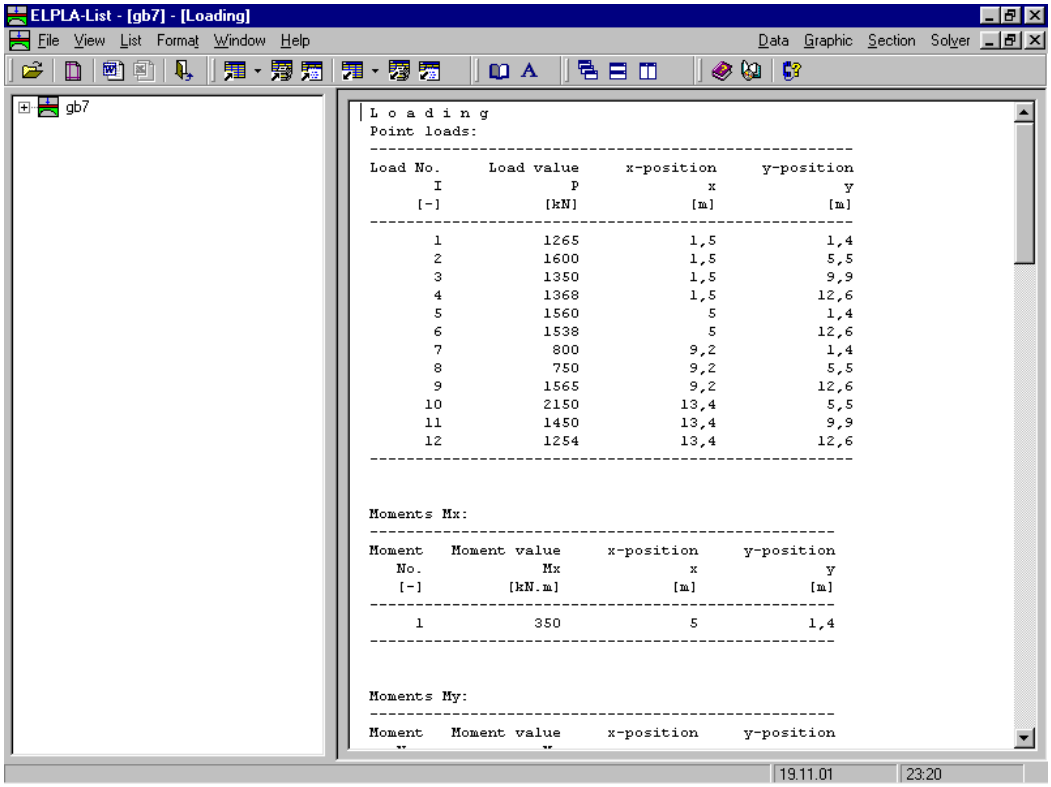


Figure A-18 Data can be tabulated

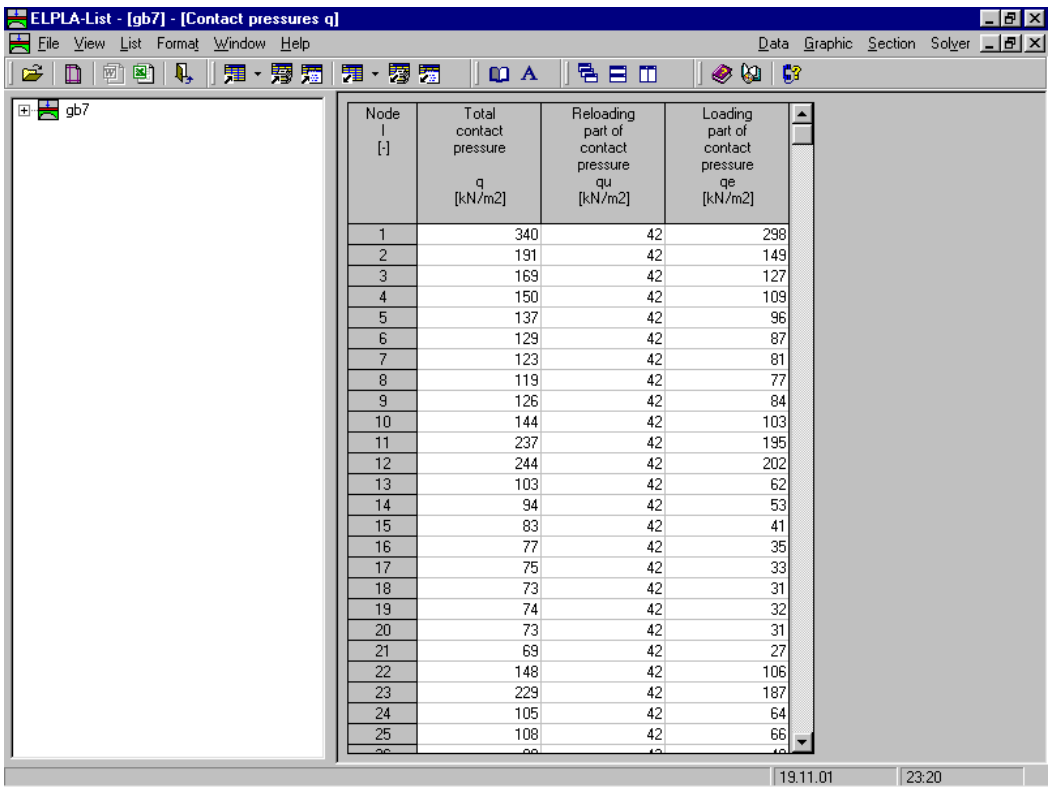


Figure A-19 Results can be tabulated

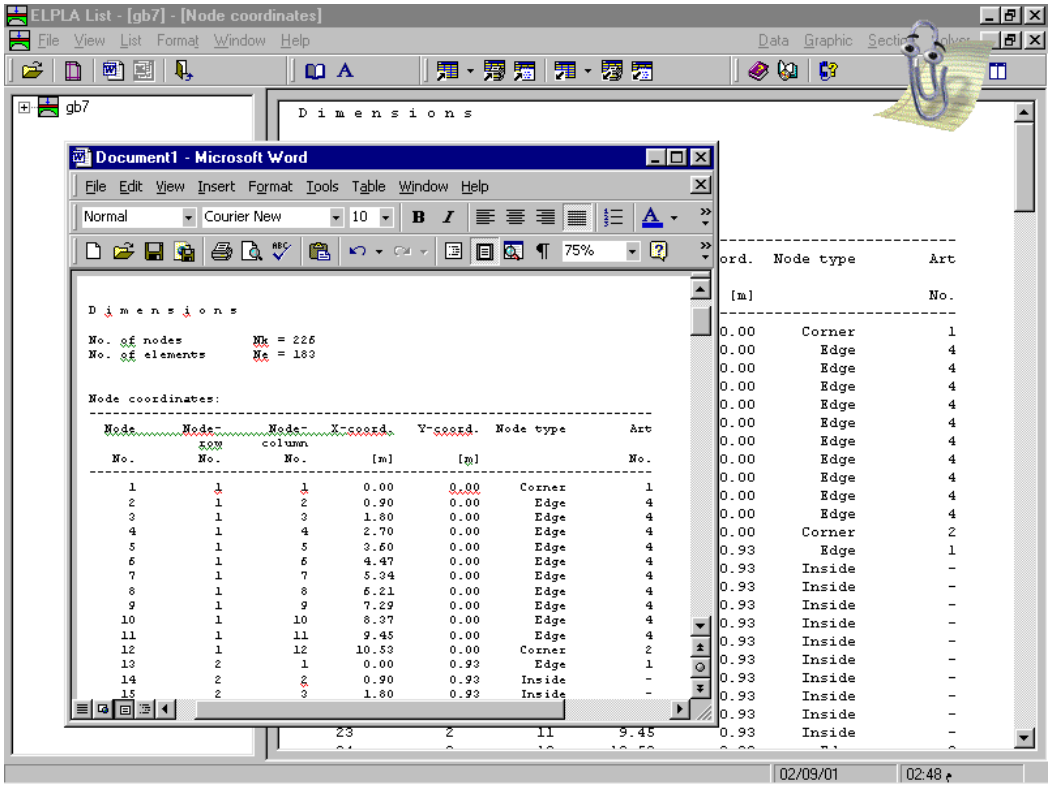


Figure A-20 Data can be imported to other text editor applications

10 Typical applications of ELPLA

* Soil-structure interaction problems
* Analysis and design of rafts
* Analysis of rigid rafts
* Analysis of flexible foundations
* Analysis and design of slab floors
* Determining the consolidation settlements
* Analysis and design of pile caps
* Determining forces on piles due to structure loads
* Settlement calculation of surface foundations
* Determining the settlement due to surcharge fills or surcharge concentrated loads
* Determining the surface settlement around rafts
* Determining the constant or variable modulus of subgrade reaction
* Effect of external loads or neighboring foundations
* Effect of temperature difference
* Effect of tunneling
* Analysis of system of flexible, elastic or rigid foundations
* Analysis of beams or grids by FE-Method
* Simulation of excavations and construction of embankments
* Determining the ultimate bearing capacity of the soil
* Determining the limit depth
* Eliminating negative contact pressure
* Design of slabs according to codes ACI, EC 2, DIN 1045 and ECP
* Determining the stress in soil

11 References

The program is a result of many extensive research works after many authors. Some of these references are:

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