Example 2.1 Analysis of a square raft on irregular subsoil

1 Description of the problem

This example is carried out to show the influence of irregular subsoil on the values of settlements, contact pressures and moments.

The analysis of the square raft is carried out by the two familiar types of soil models: *Winkler*'s and Continuum models for elastic foundations, besides the analysis of rigid raft on Continuum model, using the following three calculation methods:

Method 3 Variable modulus of subgrade reaction method
Method 7 Modulus of compressibility method
Method 8 Rigid raft on compressible subsoil

A square raft of 10 [m] side is subdivided into 144 square elements as shown in Figure 2.7. The raft thickness is d = 0.4 [m].

2 Soil properties

3 boring logs characterize the subsoil under the raft. Each boring has a soil layer of thickness 10 [m], resting on a rigid base as shown in Figure 2.7. The modulus of compressibility E_s represents the irregularity of the soil material in x- and y-directions, which in this example is chosen to be variable. The moduli of compressibility of the three borings are:

E_{s1} = 6666.67 [kN/m^2]
E_{s2} = $1.5 \times E_{s1}$ [kN/m^2]
E_{s3} = $2.0 \times E_{s1}$ [kN/m^2]
with average value of E_s = 10000 [kN/m^2]

The moduli of compressibility lead to the following mean moduli of subgrade reactions for the three borings:

k_{sm1} = 1448 [kN/m^3]
k_{sm2} = $1.5 \times k_{sm1}$ [kN/m^3]
k_{sm3} = $2.0 \times k_{sm1}$ [kN/m^3]
with average value of k_{sm} = 1563 [kN/m^3]

Possion's ratio is ν_s = 0.3 for the soil material of the borings.

3 Loads

The external loads are chosen to be symmetrical about the raft center. The loads are four symmetrically loads, each of P = 500 [kN] as shown in Figure 2.7. The self weight of the raft is ignored.

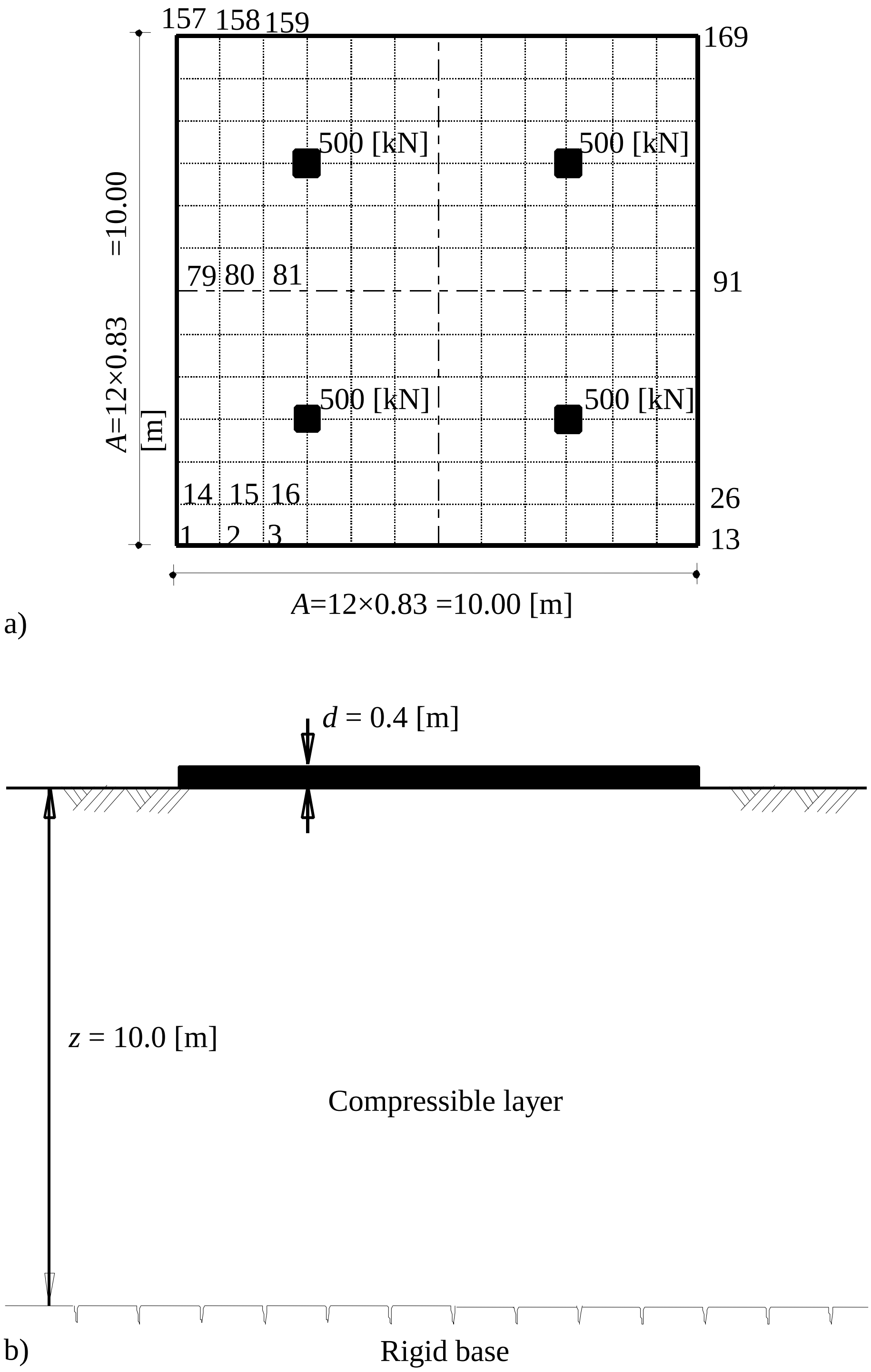

Figure 2.7 a) Raft numbering, loading and dimensions
b) Soil cross-section

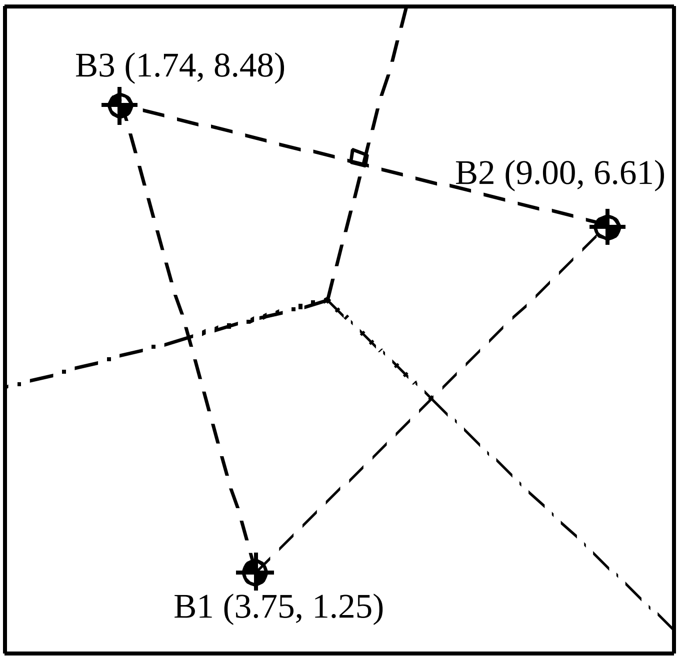

Figure 2.8 Boring locations and subareas (Subareas method)

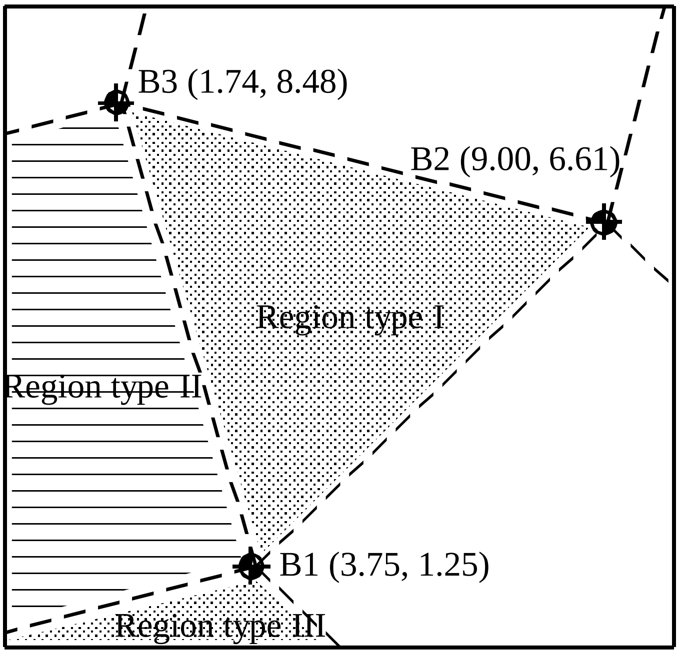

Figure 2.9 Boring locations and region types (Interpolation method)

4 Raft material

The raft material is supposed to have the following parameters:

Young's modulus	E_b	= 2 × 107	[kN/m^2]
Poisson's ratio	ν_b	= 0.25	[-]
Unit weight of raft material	γ_b	= 0.0	[kN/m^3]

Unit weight of raft material is chosen γ_b = 0.0 to neglect the own weight of the raft.

5 Analysis of the raft

For comparison, the flexibility coefficient and the modulus of subgrade reaction are determined by the following two methods:

- Subareas method, Figure 2.8
- Interpolation method, Figure 2.9

6 Results and evaluation

Figures 2.10 and 2.11 show the contour lines of settlements for each of the two types of soil models (*Winkler*'s model 3 and Continuum model 7), while Figure 2.12 shows contour lines of settlements for the rigid raft on the Continuum model 8. The flexibility coefficients for the three calculation methods are obtained using the interpolation method. As expected, the settlement form is unsymmetric about the raft center when the irregularity of the subsoil is considered, although the raft is symmetric in shape and carries symmetrical loads. The Figures 2.10 to 2.12 show that the boring which has minimum value of E_s (boring B1) leads to higher settlements at nodes close to that boring.

Figure 2.13 shows the contour lines of settlements when the soil is a regular layer having a constant value of E_s = 10000 [kN/m^2]. A comparison between Figure 2.12 and Figure 2.13 shows a great variation of settlement shape when using variable E_s values. This means that the detailed variation of soil properties with vertical and horizontal directions must be taken into account.

Figures 2.14 to 2.17 present a comparison between the results computed by the interpolation method and that of the subareas method. Figures 2.14 and 2.15 show the contact pressures at the edge of the raft (node 157 to 169) for the two types of soil models (*Winkler*'s model 3 and Continuum model 7), while Figure 2.16 shows the contact pressures at the edge of the raft for the rigid raft on Continuum model 8. Figure 2.17 shows the bending moments at the middle of the raft, section I-I, for Continuum model 7. From the above comparison, it can be concluded that the continuity requirement of the soil material between the adjacent borings is not met when using the subareas method. Therefore, it is expected that the results of the subareas method will not be as accurate as those of the interpolation method, especially if the borings have great differences in the soil material. This is explained in Figures 2.14 to 2.17 where the subareas method leads to a sudden change in the contact pressures and moments between two adjacent subareas.

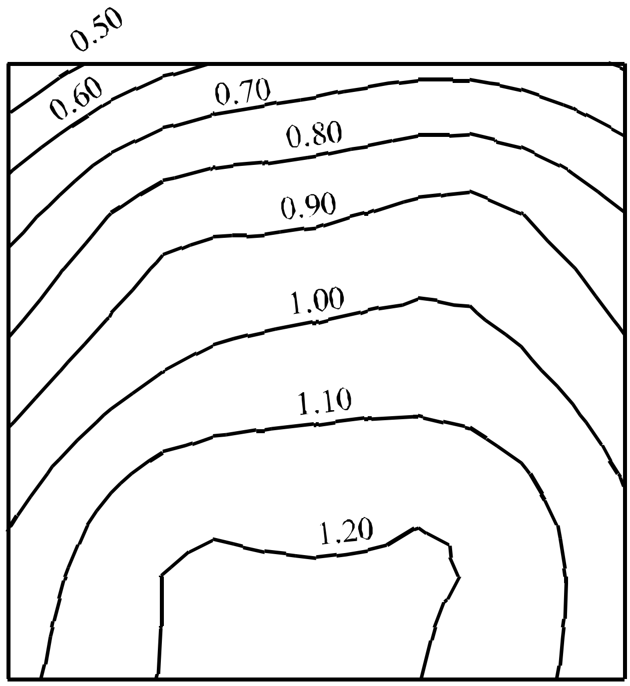

Figure 2.10 Contour lines of settlements [cm] for *Winkler*'s model 3

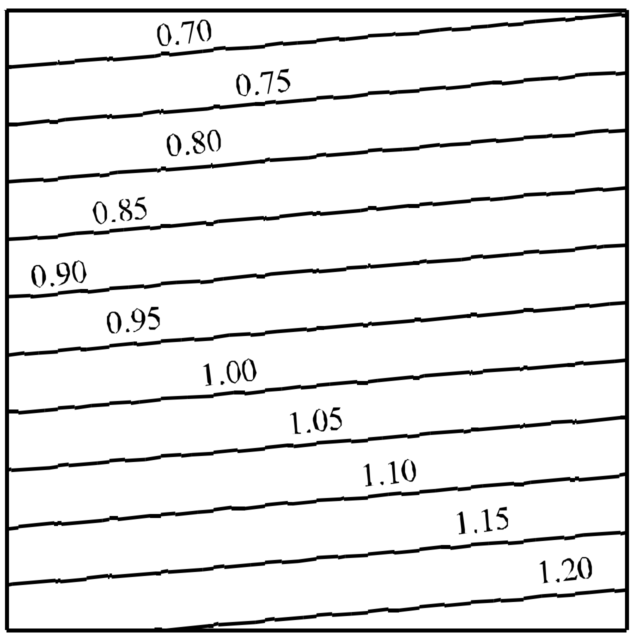

Figure 2.11 Contour lines of settlements [cm] for rigid raft on Continuum model 8

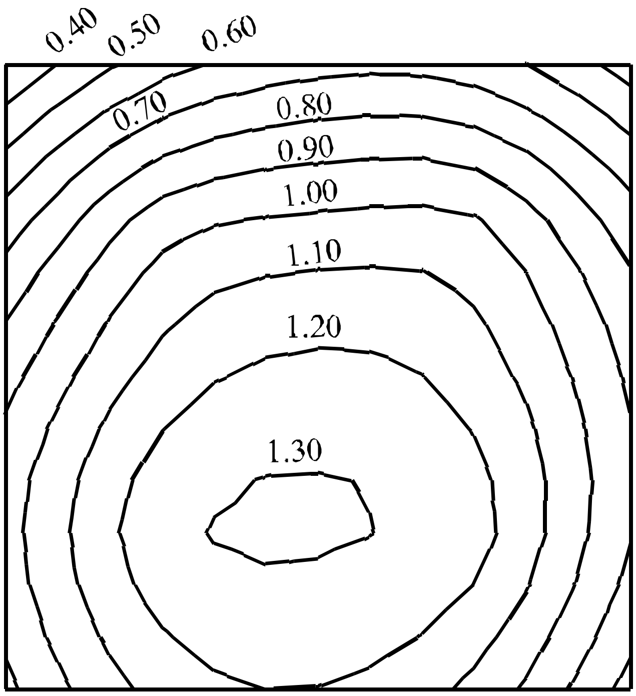

Figure 2.12 Contour lines of settlements [cm] for Continuum model 7

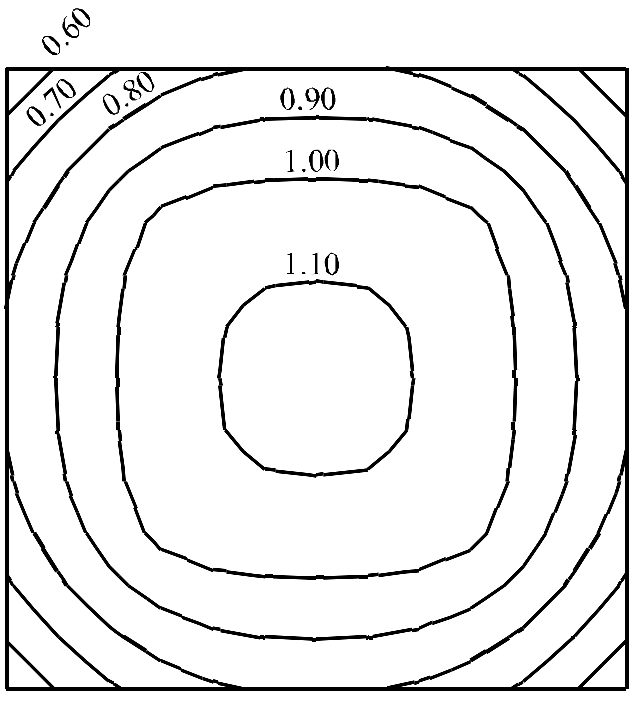

Figure 2.13 Contour lines of settlements [cm] for Continuum model 7, constant E_s

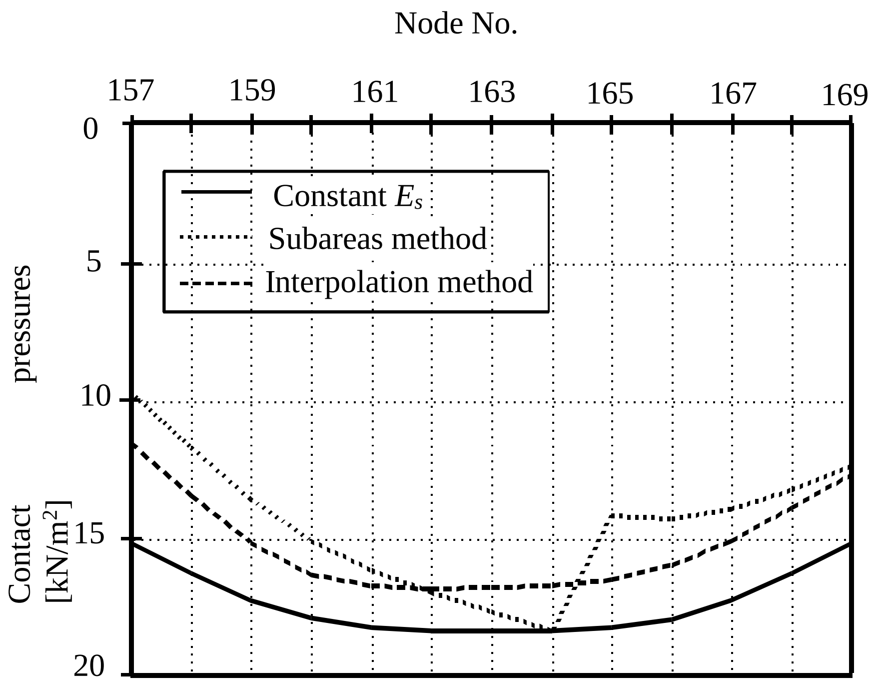

Figure 2.14 Contact pressures at the raft edge for *Winkler*'s model 3

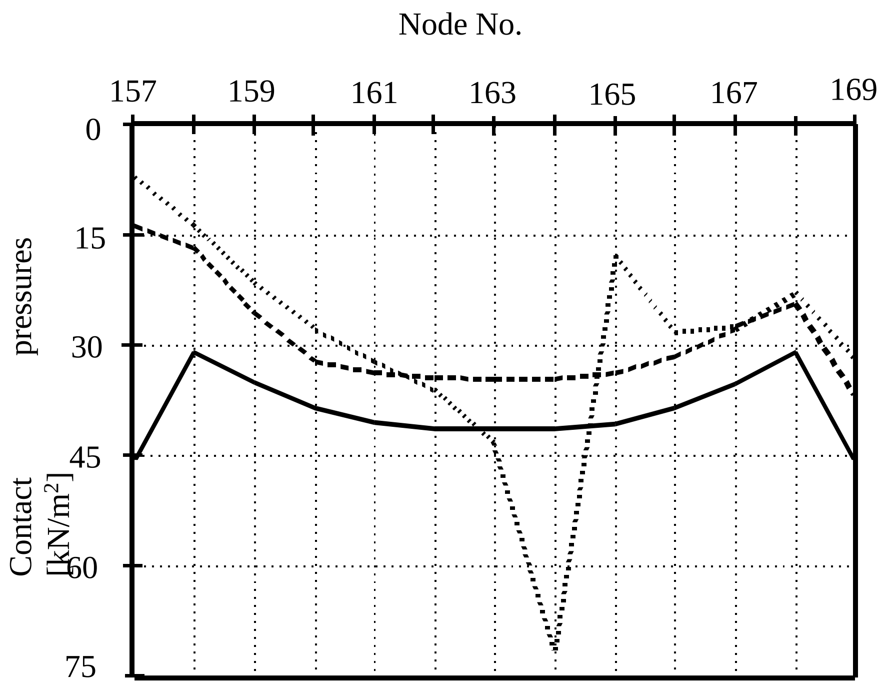

Figure 2.15 Contact pressures at the raft edge for Continuum model 7

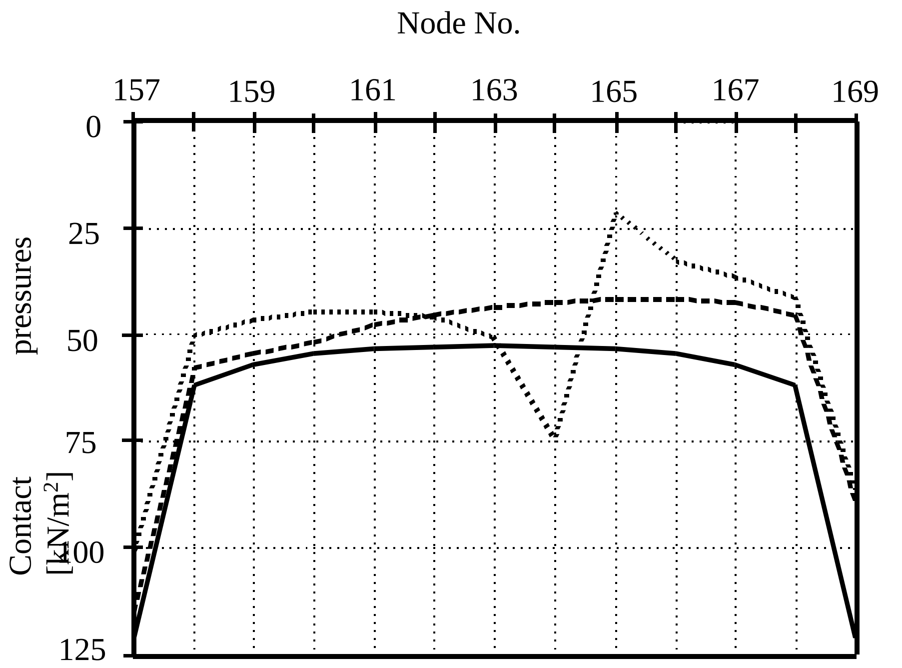

Figure 2.16 Contact pressures at the raft edge for rigid raft on Continuum model 8

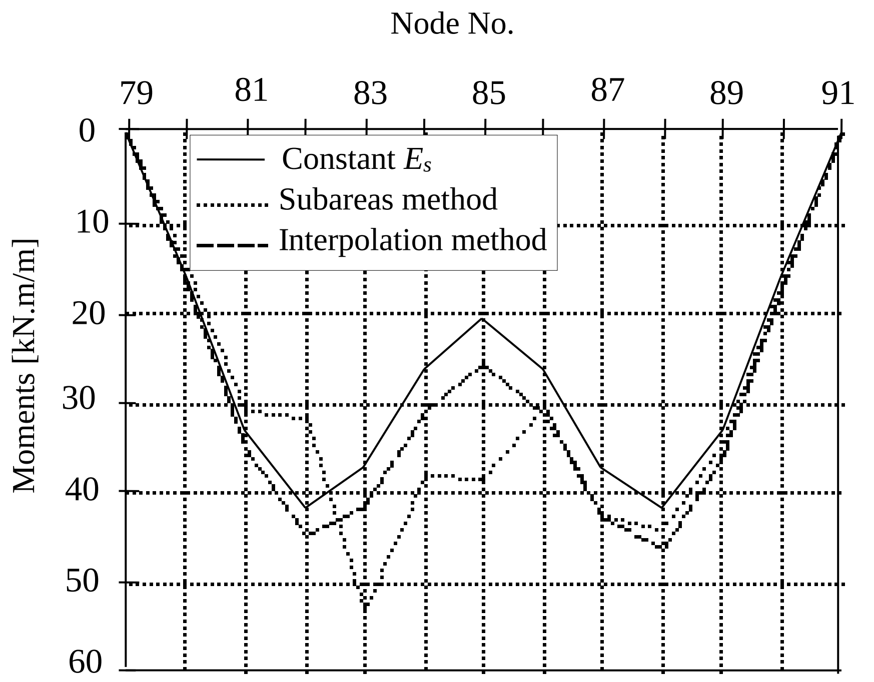

Figure 2.17 Moments at the raft middle for Continuum model 7