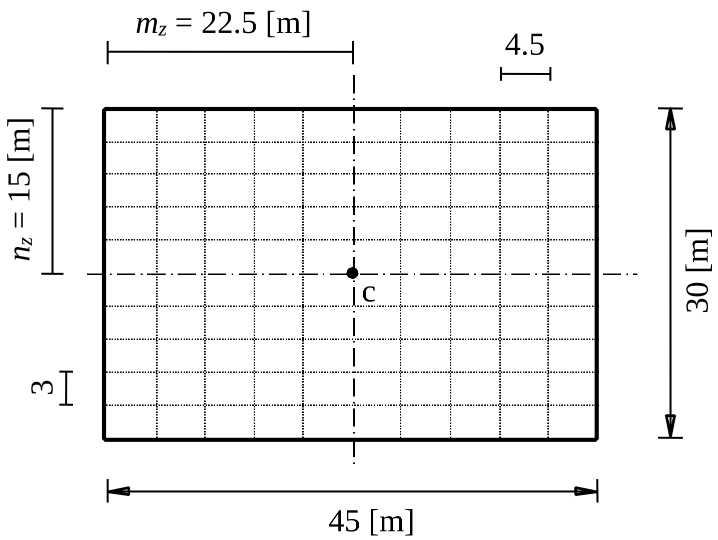
Example 6: Consolidation settlement under a rectangular raft

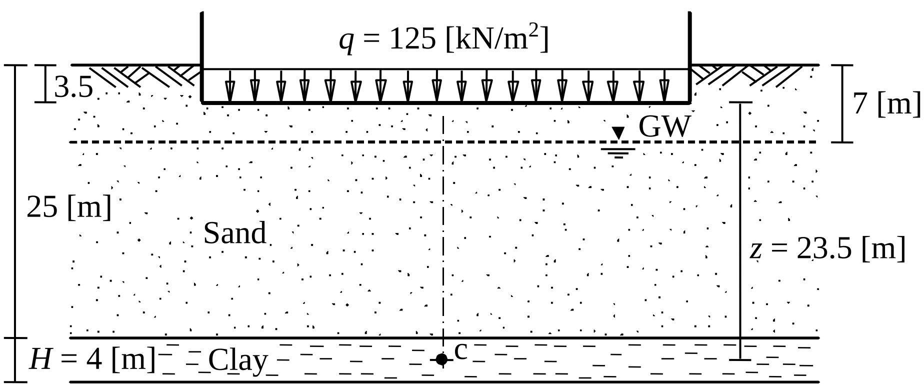
1 Description of the problem

To verify the consolidation settlement calculated by *ELPLA*, the final consolidation settlement of a clay layer under a rectangular raft calculated by *Graig* (1978), Example 7.2, page 186, is compared with that obtained by *ELPLA*.

A building supported on a raft 45 [m] × 30 [m] is considered. The contact pressure is assumed to be uniformly distributed and equal to q = 125 [kN/m^2]. The soil profile is as shown in Figure 6. The coefficient of volume change for the clay is m_v = 0.35 [m^2/MN]. It is required to determine the final settlement under the center of the raft due to consolidation of the clay.



a)



b)

Figure 6 a) Plan of the raft with dimensions and FE-Net

b) Cross section through the soil under the raft

2 Hand calculation of consolidation

According to *Graig* (1978), the consolidation of the clay layer can be obtained by hand calculation as follows:

The clay layer is thin relative to the dimensions of the raft. Therefore, it can be assumed that the consolidation is approximately one-dimensional. In this case, it will be sufficiently accurate to consider the clay layer as a whole. The consolidation settlement is to be calculated in terms of m_v. Therefore, only the effective stress increment at mid-depth of the layer is required. The increment is assumed constant over the depth of the layer. Also, $\Delta\sigma' = \Delta\sigma$ for one-dimensional consolidation and can be evaluated from *Fadum's* charts (1948), Figure 7.

The effective stress increment $\Delta\sigma'$ at mid-depth z = 23.5 [m] of the layer below the center of the raft is obtained as follows

$$\mathbf{m} = \frac{\mathbf{m_z}}{\mathbf{z}} = \frac{22.5}{23.5} = 0.96 \text{ [-]}$$

$$\mathbf{n} = \frac{\mathbf{n_z}}{\mathbf{z}} = \frac{15}{23.5} = 0.64 \text{ [-]}$$

From *Fadum's* charts (1948)

$$I_r = 0.14 \text{ [-]}$$

The effective stress $\Delta\sigma'$ is given by

$$\Delta\sigma' = 4\, I_r\, q = 4\times0.14\times125 = 70 \text{ [kN/m}^2\text{]}$$

The final consolidation settlement s_c is given by

$$s_c = \Delta\sigma'\, m_v\, H = 0.35\times70\times4 = 98 \text{ [mm]} = 9.8 \text{ [cm]}$$

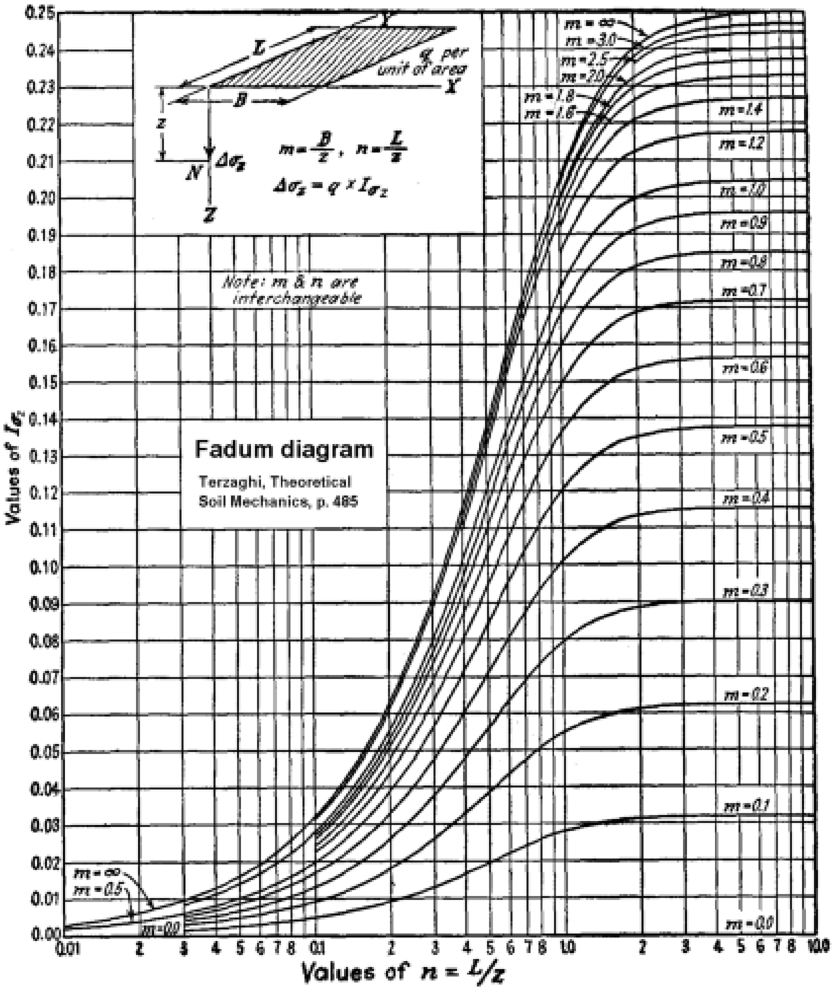
3 Consolidation by *ELPLA*

The raft rests on two different soil layers. The first layer is sand of 21.5 [m] thickness, while the second layer is clay 4.0 [m] thick as shown in Figure 6. As it is required to determine the settlement due to the consolidation of the clay only, the settlement due to the sand can be eliminated by assuming very great value for modulus of compressibility of the sand E_{s1}. Consequently, the settlement due to the sand tends to zero. The settlement due to the sand becomes nearly equal to zero when for example $E_{s1} = 1 \times 10^{20}$ [kN/m^2]. The modulus of compressibility of the clay E_{s2} is obtained from the modulus of volume change m_v as

$$\mathbf{E_{s2}} = \frac{\mathbf{1}}{\mathbf{m_v}} = \frac{1}{0.35} = 2.857 \text{ [MN/m}^2\text{]} = 2857 \text{ [kN/m}^2\text{]}$$

Because the settlement is considered in the vertical direction only, *Poisson's* ratio for the clay is assumed to be zero, $\nu_s = 0.0$ [-].

The contact pressure of the raft in this example is known. Also, the raft rigidity is not required. Therefore, the available method "Flexible foundation 9" in *ELPLA* may be used here to determine the consolidation of the clay. A coarse FE-Net may be chosen, where more details about the results are not required, only the settlement under the center of the raft due to consolidation of the clay. A net of equal elements is chosen. Each element has dimensions of 3 [m] × 4.5 [m] as shown in Figure 6a. The final consolidation settlement of the clay under the center of the raft obtained by the program *ELPLA* is s_c = 9.8 [cm] and quite equal to that obtained by hand calculation.



Graph for determining influence value for vertical normal stress $\Delta\sigma_z$ at point *N* located beneath one corner of a uniformly loaded rectangular area.

Figure 7 *Fadum* diagram after *Terzaghi* (1970)