1.Theoretical basis.

1.1 Design of draining soil filters.

1.1.1 Terzaghi

The Terzaghi's design method is based on the following relations:

$$4 < \frac{d_{15f}}{d_{15t}} < 20\,; \frac{d_{15f}}{d_{85t}} < 5\,; \frac{d_{50f}}{d_{50t}} < 25$$

where:
d_{15} = pass-through diameter 15%;
d_{50} = pass-through diameter 50%;
d_{85} = pass-through diameter 85%.

The indexes *t* and *f* are referred, respectively, to the natural soil (*t*) and to the soil filter (*f*).

1.1.2 USBR

The USB's design method is is based on the following relations:

- filter with sharp-cornered grains:

$$6 < \frac{d_{15f}}{d_{15t}} < 18\,; 9 < \frac{d_{50f}}{d_{50t}} < 30\,;$$

- filter with rounded grains:

$$12 < \frac{d_{15f}}{d_{15t}} < 40\,; 12 < \frac{d_{50f}}{d_{50t}} < 58\,;$$

where:
d_{15} = pass-through diameter 15%;

d_{50} = pass-through diameter 50%;

The indexes *t* and *f* are referred, respectively, to the natural soil (*t*) and to the soil filter (*f*).

1.2 Vertical drains applied to soil consolidation problems.

Vertical drains are cylinders of coarse-grained soil, gravel and sand, which can be used to accelerate the dissipation of the interstitial pressure in fine-grained soils. Designing is usually performed using the Barron's formula, modified by Hansbo:

$$t(s)=(D^2/8c_h)(F_n+F_s+F_r)\ln(1/(1-U_h))$$

where:

t = time required to achieve U_h;

U_h = average degree of consolidation due to the horizontal drainage;

D (m) = diameter of the cylinder of influence of the drain;

c_h (mq/s) = horizontal coefficient of consolidation;

F_n = drain-spacing factor, given by:

$$F_n=\ln(D/d_w)-3/4$$

d_w (m) = equivalent diameter of the drain, equal to the diameter in case of circular cross-section, and equal to (a+b)/2 in case of band-shaped drain;

F_s = factor for soil disturbance, given by:

$$[(k_h/k_s)-1]\ln(d_s/d_w)$$

k_h (m/s) = horizontal coefficient of permeability of the undisturbed soil;

k_s (m/s) = horizontal coefficient of permeability of the disturbed soil;

d_s (m)= diameter of the cylinder of the disturbed soil;

F_r = factor for drain resistance, given by:

$$\pi z(L-z)(k_h/q_w)$$

z (m) = distance below the ground surface of the middle point of the compressible soil layer;

L (m) = effective drain length, equal to the total length of the drain when the drainage occurs at one end only, equal to the half total length when it occurs at both ends;

q_w (mc/s) = discharge capacity of the drain at gradient = 1.0.

Practically the time t is imposed by designing and the unknown variable is D.

1.3 Vertical drains applied to the drawdown of the water table.

Vertical drains can be used to the drawdown of the water table too. In this case drains are wells of small diameter which extract water through a pumping system. To estimate the drawdown of the water table in a specific point inside the drained area, the following formula can be used:

where:

$$H^2 - h^2 = \sum_{i=1}^{N} \frac{Q_i}{\pi K} \ln\left(\frac{r_{e,i}}{r_i}\right)$$

H (m) = depth of the undisturbed water table;
h (m) = depth of the disturbed water table;
K (m/s) = horizontal coefficient of permeability of the aquifer;
Q*i* (mc/s) = discharge capacity of the drain *i*;
$r_{e,i}$ (m) = radius of influence of the drain *i*;
r_i (m) = distance between the drain *i* and the point of calculation of the drawdown.

1.4 Horizontal drains applied to the drawdown of the water table.

To estimate the drawdown of the water table due to a set of horizontal drains, the Hooghoudt's formula can be used. The drain spacing is given by:

$$L = 2\sqrt{\frac{2Khd}{q} + \frac{Kh^2}{q}}$$

where:
L (m) = drain spacing;
K (m/s)= horizontal coefficient of permeability of the aquifer;
q (mc/s) = discharge capacity of the drain;
h (m) = design drawdown of the water table;
d (m) = equivalent thickness, given by:

$$d = \frac{D}{\frac{8D}{\pi L}\ln\frac{D}{u} + 1} \qquad \text{if } D<0.5L$$

$$d = \frac{\pi L}{8\ln\frac{L}{u}} \qquad \text{if } D>0.5L$$

D (m) = distance between the drain and the impervious boundary;
u (m) ≈ 5.6368 x d/2.

The Hooghoudt's formula has to be resolved through a iterative procedure.

1.5 Draining trenches applied to the drawdown of the water table.

In case of phreatic aquifer the drawdown due to the drainage by a trench is estimable through the following formula:

$$H^2 - h^2 = 2qL/K$$

where:
L (m) = trench spacing;

H (m) = depth of the undisturbed water table;
h (m) = hydrometric level inside the trench, measured from the ground surface;
q (mc/s) = discharge capacity of the trench;
K (m/s) = horizontal coefficient of permeability of the aquifer.

To take in account the effect due to the vertical filtration close to the trench, a corrective factor is added to the parameter h:

$$h' \approx h + 0.74(q/K)(1-cr);$$

where:
$cr = (h-H)/(h_i-H)$;
h_i (m)= depth of the impervious boundary.
Thus the previous formula becomes:

$$H^2-h_i^2=2qL/K$$