1.5 Permeability Tests

1.5.1 General

- To determine the coefficient of permeability(or coefficient of hydraulic conductivity) k
- General method for determining k directly.

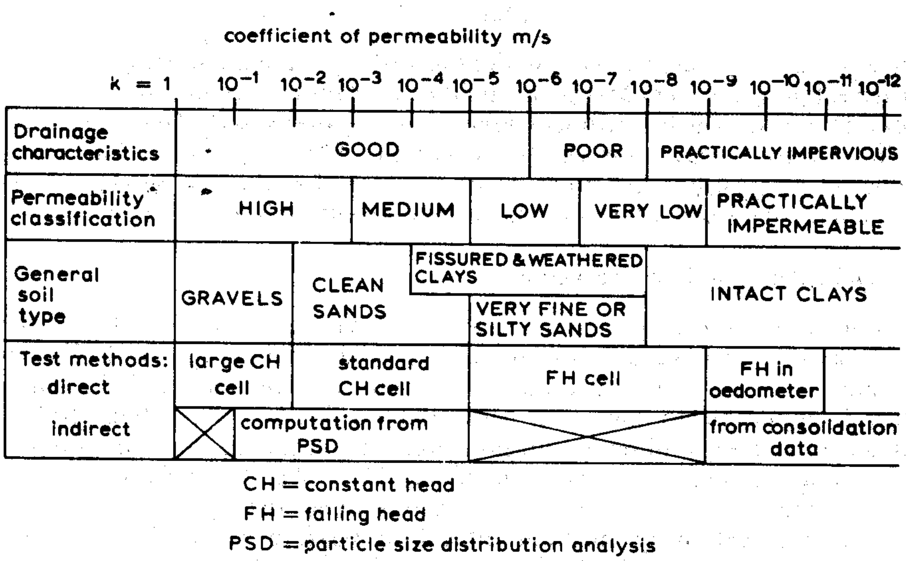

Fig. 10.14 Permeability and drainage characteristics of main soil types

- Darcy' law

$$v = ki$$

$$or \qquad q = kiA$$

where q = flow quantity in a unit time.
v = flow velocity
i = hydraulic gradient = h/L
h = total head difference
L = flow path
A = cross-sectional area of soil mass

- It is difficult to get a reliable value of *k* with conventional laboratory testing methods. (Its variation can be one order of magnitude.)

- The major reasons for the variation of the measured *k* (The reason for the difference between in-situ *k* values and *k* values obtained from lab test) :
  1) Cannot duplicate the same state of soil as in the field (density, <u>structure and orientation of the in situ stratum</u>, degree of saturation…)
  2) Conditions at the boundary. (The smooth wall of permeability mold in the laboratory makes for better flow path than if they were rough.)
  3) The effect of the applied hydraulic gradient *i* (*i* in the lab is usually 5 – 10 times larger than in the field.)
  4) Darcy's law can be nonlinear (at least at large values of *i*).
  5) Size effect of sample (Usually *k* in the field is much larger (more than 10 times) than *k* obtained with small specimens in the lab.)

- Influence factors on the coefficient of permeability of a soil.

1) The viscosity of the pore fluid $\Rightarrow$ depending on the type of pore fluid and temperature.

   As the temperature increases, viscosity decreases, and *k* increases.
   (4^{o}C change in temperature of the pore water results in about 10% increase of *k*).
   Practically, the temperature correction is not necessary but is required in most “standard” test procedure.

2) The void ratio of the soil

$$k = f(e)$$

$$k \propto e^3/(1+e)$$

$$\log k \propto e$$

3) The size and shape of the soil particles

   k in angular and platy particles is larger than *k* in rounded and spherical particles.
   k increases with increase of particle size.

   Hazen’s formula (for clean sands and gravels)

$$k = 100D_{10}^2\ cm/s$$

(in the range of particle size , $0.01\text{cm} < D_{10} < 0.3\text{cm}$)

4) The degree of saturation S.

   As the degree of saturation increases, the apparent coefficient of permeability also increases. (due to reducing the breakage effort of surface tension)

1.5.2 <u>The Constant Head Permeability Test</u>

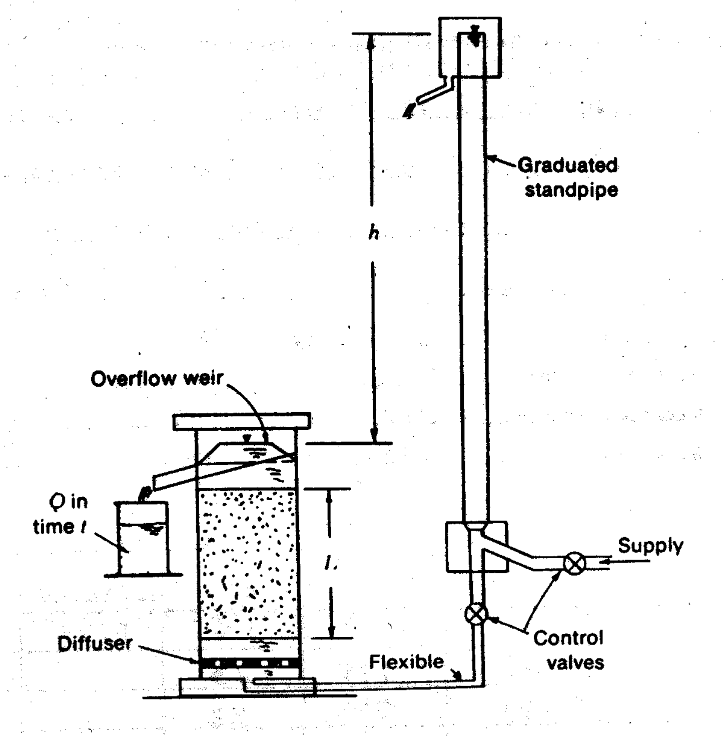

Figure 11-2

- Use the constant head ⇒ Employ the overflow weir in both inlet (at the bottom) and outlet of flows (on the top).
⇒ A large amount of water is wasted unless the test is of short duration ⇒ Apply cohesionless soils only.

- The standard compaction mold is widely used. (The base with porous stone and the cap with valve.) as shown in Fig 11-2.
  1) Advantages: Easy to control and to make a sample.
  2) Disadvantages: No potential of observation and possible head loss across the porous stone.

- Modified device by Bowles
  Employ the transparent cylinder for permeameter and #200 sieve screen instead of porous stone.

1.5.3 Falling Head Permeability Test

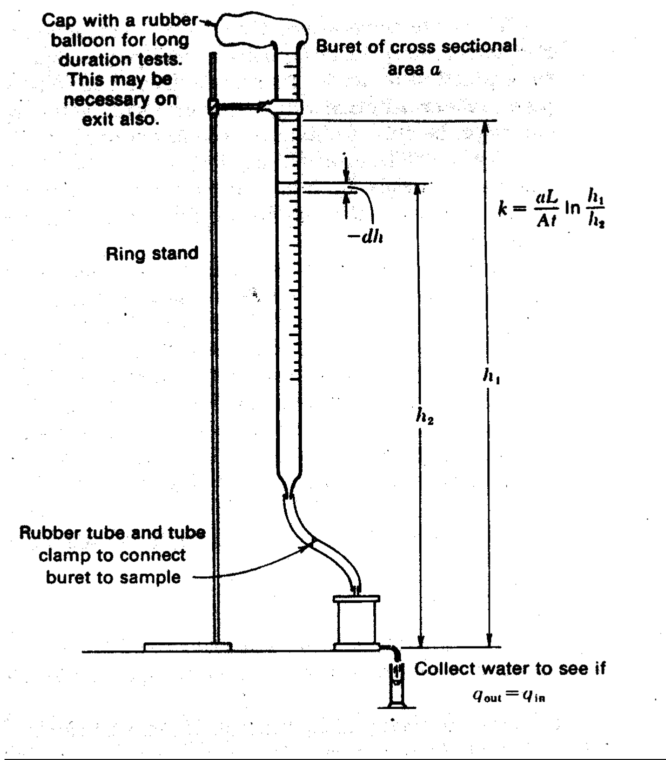

Figure 12-2

- For cohesive soils with low permeability, flow quantity is very small.

  Permeability of soils, $k = 1\times10^{-6}$cm/min

  $\Rightarrow$ Flow quantity = .0972cc/hr for i=20 and A = 81cm^2

  (small amount of flow quantity and longer duration time)

  $\Rightarrow$ Accurate measurement of flow quantity with some provisions to control evaporation is required.

- The equation applicable to falling head permeability test

$$k = \frac{aL}{A\Delta t}\ln\frac{h_1}{h_2}$$

Where A = cross-sectional area of sample

a = cross-sectional area of burette

h_1 = hydraulic head across sample at beginning of test (t=0).

h_2 = hydraulic head across sample at end of test ($t=t_{test}$)

1.5.4 <u>*k* from a consolidation test</u>

1) Estimate *k* using the coefficient of consolidation c_v, from the equation below,

$$k = \frac{a_v \gamma_w c_v}{1+e}$$

2) Perform the falling head test on the loaded sample in the oedometer at the end of primary loading : Can consider the effect of the effective stress.

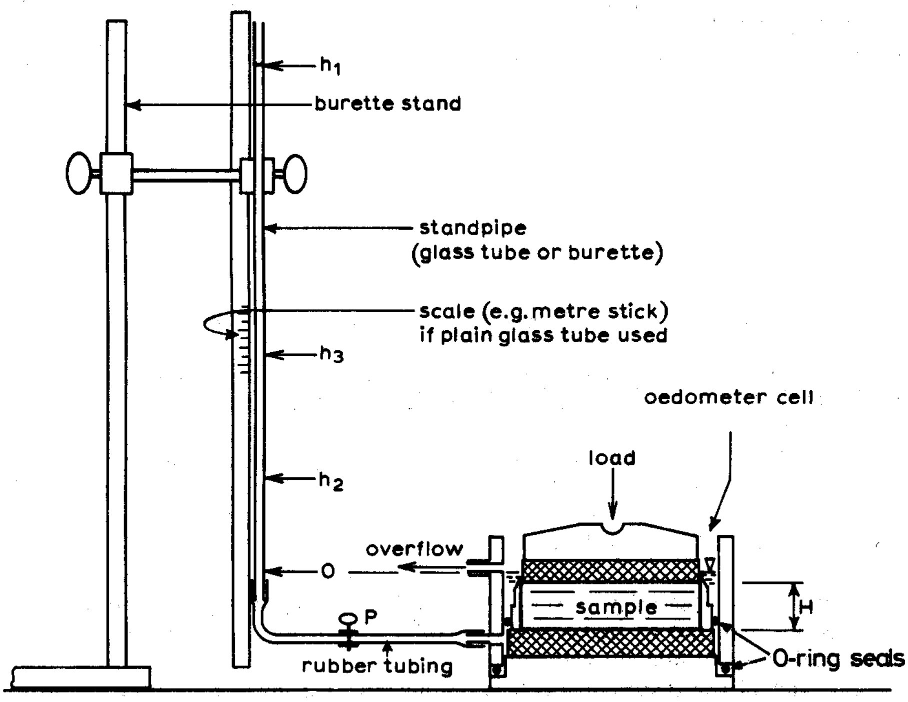

Fig. 10.41 Falling head permeability test in oedometer consolidation cell

1.5.5 <u>k from a triaxial cell (Flexible Wall Test)</u>

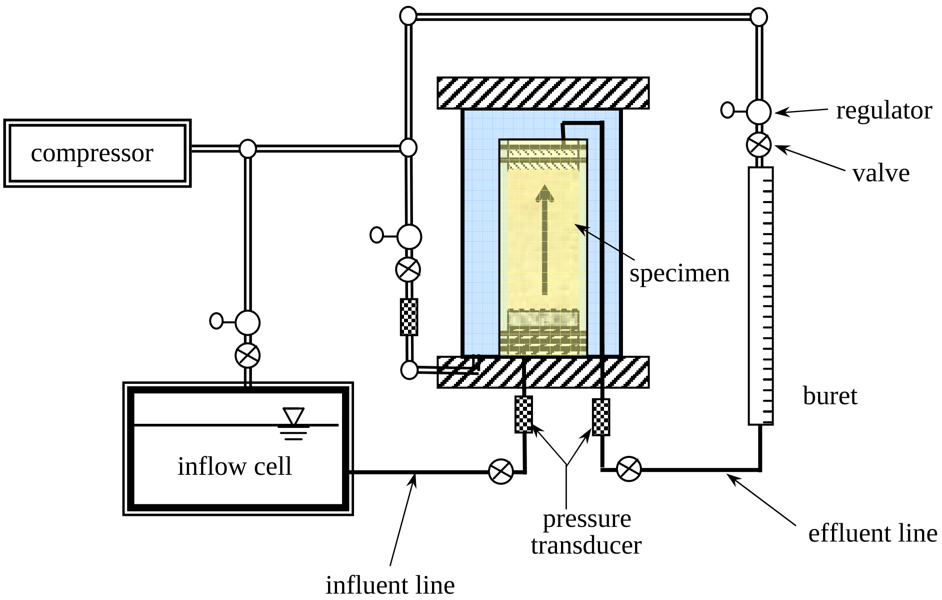

Figure. Schematic diagram of Flexible wall test set up for evaluation the coefficient of permeability of soils

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