METHOD OF TEST FOR
DETERMINATION OF PERMEABILITY OF GRANULAR SOILS

1. SCOPE

1.1 This method covers the determination of the coefficient of permeability of soils (granular materials) by means of the constant head test apparatus.

2. REFERENCE

2.1 ASTM D 2434

2.2 AASHTO T 215

3. FUNDAMENTAL TEST CONDITIONS

3.1 Ideally, the flow of water through a test specimen should be laminar, that is to say there is no turbulence. Conditions to obtain laminar flow are a function of the void structure of the test specimen and the hydraulic gradient.

3.2 There should be no volume change in the test specimen during the test.

3.3 The voids in the test specimen must be saturated with water.

4. APPARATUS

4.1 The apparatus is selected on the basis of the material under test. It consists of a permeameter to contain the specimen with porous disks or screens at the top and bottom and filter paper covering the disks or screens to restrict migration of fines from the sample.

4.2 CONSTANT HEAD PERMEAMETER: The constant head test is carried out in a modified CBR mold, which is adapted by the addition of special top and bottom plates with rubber sealing rings to prevent water from leaking out during the test. The top and bottom plates are provided with inlets for water lines and are generally provided with valves to control the flow (Figure 1).

4.3 CONSTANT HEAD TANK: The supply of water to the permeameter must be maintained under a constant head. This is accomplished by means of a cylinder with a water inlet from the tap or storage tank and an overflow such that a constant stream of water is supplied. An outlet from the base of the cylinder is attached to the inlet on the bottom plate of the mold\ (Figure 1).

Note 1: Water flow through the specimen should be from the bottom to the top. This will aid in preventing build up of air, as bubbles will be carried with the water flow to the outlet.

4.4 SPECIMEN COMPACTION EQUIPMENT: For compacting samples, a Proctor or CBR mold may be used along with RAMMER EQUIPMENT as detailed in Test Method LS 706.

4.5 VACUUM PUMP: It may be necessary to apply a vacuum to the specimen prior to the test in order to evacuate any air present. This may be done with a vacuum pump, but the vacuum applied must be carefully monitored in order to avoid the creation of drainage channels by piping in the specimen, which may lead to erroneous results. Alternatively, a water-faucet aspirator may be most appropriate for this purpose.

4.6 MISCELLANEOUS APPARATUS: Appropriate balances, ovens, containers and tools required for sample preparation as may be necessary.

5. TEST SAMPLES

5.1 Samples of material for permeability must be representative of the original material. In some cases the material may be oven dried and pre-screened in order to produce a specimen of the appropriate gradation. More often, samples are tested as submitted and compacted into the mold at an acceptable water content.

6. PREPARATION OF SPECIMENS

6.1 The sample must be prepared to the required water content (optimum moisture) and compacted in the permeameter. The water content and density are required as data for reporting purposes.

6.2 Initial measurements are made of the inside diameter (D) of the permeameter, the distance (L) between the outlets, and the height (H) of the test specimen.

6.3 ASSEMBLY OF PERMEAMETER: Before placing the specimen on the base plate of the permeameter, a porous disk or screen covered by filter paper is inserted in the base plate. The apparatus is assembled with a porous disk or screen on top of the specimen separated by filter paper, and any required surcharge such as required for CBR data. The specimen is then very slowly irrigated with de-aired water by opening the valves in the top and bottom plates of the apparatus until free flow is observed. This observation depends to some extent on the grain size of the test specimen.

6.4 SATURATION OF SPECIMEN: In the majority of cases, it is desirable to apply a vacuum to the specimen to ensure removal of entrapped air. Connect the outlet on the top plate of the apparatus to a vacuum line and apply a vacuum of less than 50 cm Hg for 15 minutes to remove entrapped air. The vacuum may be varied according to the material under test. Coarse materials will in general de-air at a lower vacuum than those of finer grain size. Also, the construction of the apparatus may not withstand high vacuum levels without leaking air, which defeats the operation.

Note 2: If using tap water (non-de-aired) air bubbles may cause varying degrees of obstruction of pipe elbows, etc. Tapping very lightly with a small wood dowel may dislodge these bubbles.

7. TEST PROCEDURE

7.1 CONSTANT HEAD TEST: Ensure that water is flowing into the constant head cylinder and open valves on the apparatus, the bottom valve first. Monitor the water levels in the cylinder until a stable head condition is reached, i.e. no fluctuations in the water level. The quantity of water (Q) flowing through a sample of a certain area (A) is measured for any required time (t). The temperature (T) of the water discharged should also be measured. Modify the head to establish the required hydraulic gradient. This is calculated as:

$$i = \frac{h}{L}$$

where: i = hydraulic gradient
h = height of head
L = length of sample

If necessary, tests may be run at different hydraulic gradients to ensure that the testing is being performed in the range of laminar flow. This may be checked by plotting velocity of flow v (where $v = \frac{Q}{At}$) against the gradient (i). A linear relation should occur between some points on the graph, indicating the region of laminar flow.

Note 3: In general, much lower values of hydraulic gradient are required than generally recognised in order to ensure laminar flow.

7.2 Upon completion of the test, drain the water from the apparatus, remove the mold containing the specimen and perform a CBR test, if required. The water content of the sample should be measured before it is discarded.

7.3 When the test has been completed, drain the specimen and inspect for streaks or layers (evidence of segregation of fines). The calculation procedures outlined in 8.1 should then be followed.

8. CALCULATIONS

8.1 Coefficient of Permeability is calculated as follows: $k = \frac{Q}{iA}$

where: k = coefficient of permeability

$$Q = \frac{\text{quantity of water discharged (cc)}}{\text{time (s)}}$$

i = hydraulic gradient $\frac{h = \text{head (cm)}}{L = \text{length of specimen (cm)}}$

A = cross-sectional area of specimen (cm^2)

Correct the value of permeability to that of 20°C by multiplying k by the ratio of the viscosity of water at the test temperature to the viscosity of water at 20°C (Figure 2).

9. REPORTING OF RESULTS

9.1 The report of the test shall include the following information:

9.1.1 Value of permeability (k) at 20°C

9.1.2 Initial and final water content

9.1.3 Compacted wet and dry density

9.1.4 Void ratio (if required)

9.2 WORKED EXAMPLE:

Head (h) (cm)	1.0	1.0	1.0	2.0	2.0	3.0	3.0
Water Flow (cc)	98.1	198.0	328.4	207.6	411.1	352.0	707.6
Time t (s)	180	360	600	180	360	180	360
$Q = \frac{cc}{t(s)}$	0.545	0.550	0.547	1.153	1.142	1.956	1.966
Length of Specimen L (cm)	11.4	11.4	11.4	11.4	11.4	11.4	11.4
Hydraulic Gradient $i = \frac{h}{L}$	0.088	0.088	0.088	0.175	0.175	0.263	0.263
Area of Specimen A (cm^2)	182.65	182.65	182.65	182.65	182.65	182.65	182.65
$k = \frac{Q}{iA}$ (cm/s)	$3.4x10^{-2}$	$3.4x10^{-2}$	$3.4x10^{-2}$	$3.5x10^{-2}$	$3.5x10^{-2}$	$4.1x10^{-2}$	$4.1x10^{-2}$
Temp. of Water °C	15°	15°	15°	20°	20°	25°	25°
Viscosity of Water at Test Temp. (X)	1.140	1.140	1.140	Not Required	Not Required	0.894	0.894
Viscosity of Water at 20°C (Y)	1.005	1.005	1.005	Not Required	Not Required	1.005	1.005
$Ratio = \frac{X}{Y}$	1.134	1.134	1.134	Not Required	Not Required	0.889	0.889
Temp. Corrected k = (k x Ratio)	$3.9x10^{-2}$	$3.9x10^{-2}$	$3.9x10^{-2}$	$3.5x10^{-2}$	$3.5x10^{-2}$	$3.6x10^{-2}$	$3.6x10^{-2}$

Comments:
- Constant Head Method on open graded drainage layer (OGDL) material
- Fast penetration of water through sample
- Average of tests using various heads is 3.7×10^{-2}

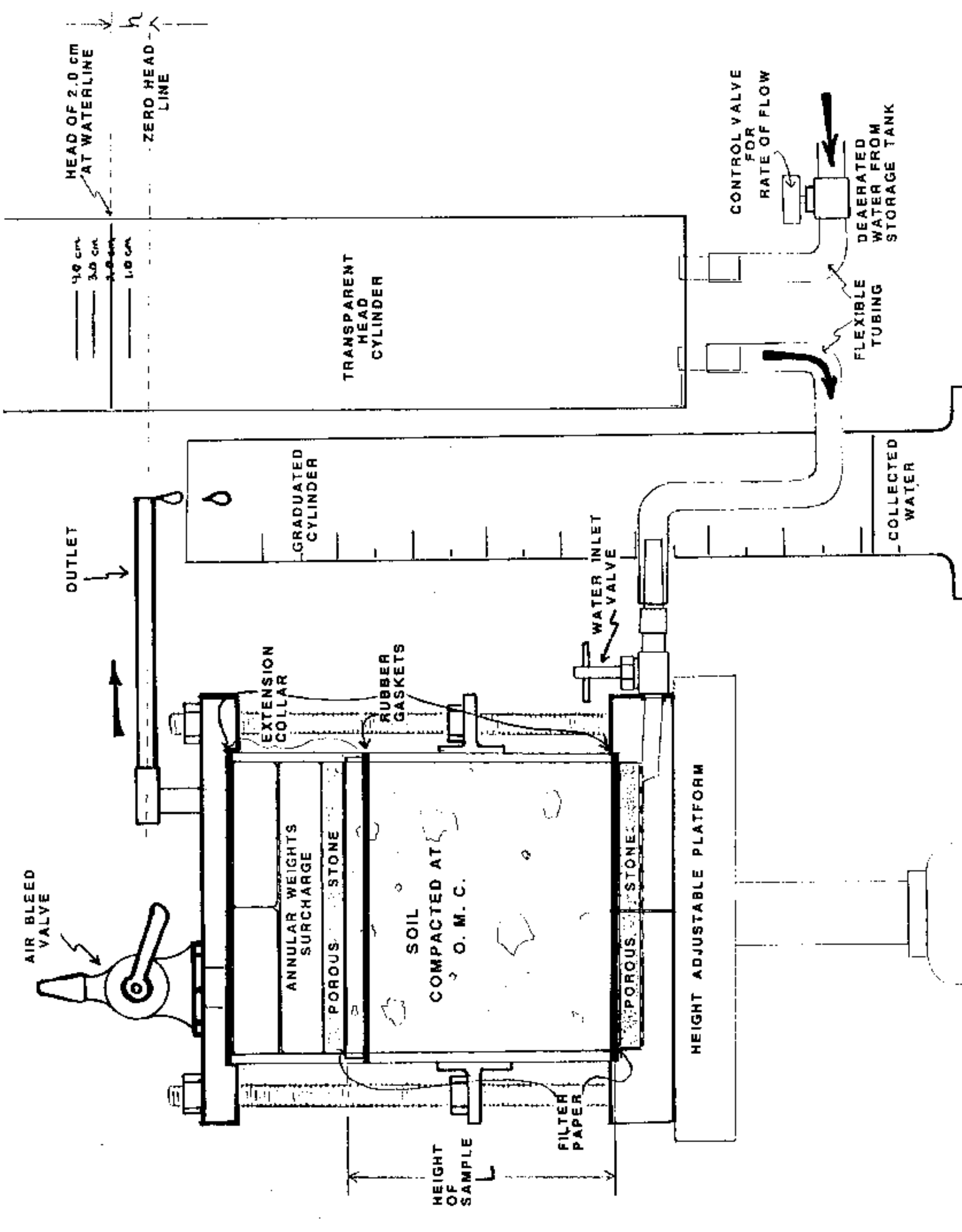

Figure 1 – **CONSTANT HEAD PERMEAMETER**

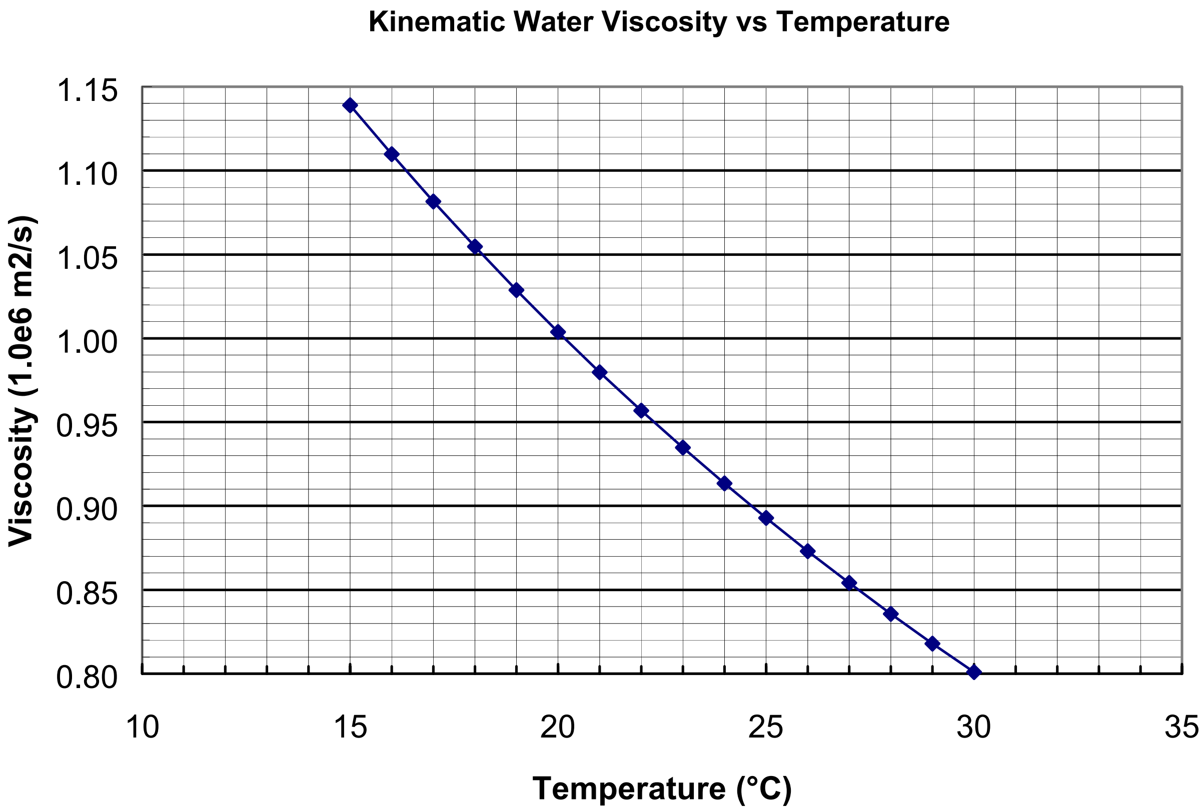
Kinematic Water Viscosity vs Temperature
Viscosity (1.0e6 m2/s)
1.15
1.10
1.05
1.00
0.95
0.90
0.85
0.80
10
15
20
25
30
35
Temperature (°C)

Figure 2