INTRODUCTION

One of my working fields (I am a professional Geologist) is about rain- and storm water plants projecting when dealing with buildings for residential and industrial projects. Very briefly this involves assessing the rainwater volume falling into the area interested by the project and disposing it through some plant infiltrating it into the soil, into municipal wastewater sewers or into rivers and streams. Usually in Northern Italy (the area where I work the most) rainwaters are drained and infiltrated into the soil through so-called "draining pits", a sort of cylinder made of concrete rings assembled accordingly to the project made by an engineer or a professional geologist. Ring diameter and depth in projecting the pits may vary, according e.g. the soil permeability values typical about the specific area involved. Usually the soil permeability value is measured on site or may be estimated from the pertinent literature data, the second method usually to be adopted for smaller projects.

Permeability assessing methods may vary from laboratory tests, performed on representative soil samples (e.g. drilled into the project site) or may be performed on the field. This secondo one is preferred, because it is more representative about the actual site soil behavior, due to the very limited disturbance induced into the soil volume to be tested.

Field permeability test methods may vary widely on the basis of the soil permeability value to be expected. When dealing with low permeability soils more sophisticated devices and longer test times are adopted (e.g. double ring permeameters, Mariotte tubes, etc..).

On the opposite, when dealing with medium-high permeability soils (e.g. sands and gravels) a more sturdy and faster test method is required.

Very simply speaking, the field test method requires to infiltrate a given amount of water through a given soil area in a given amount of time. The shorter the time, the greater the permeability value will be.

The ability of a given soil type to be infiltrated obeys the so-called Darcy's Law. Very simply it stated that there is a relationship between the total amount of water crossing a given soil volume, the area to be crossed and the water head. The equation should be written as

$Q = s\ k\ i$

Etc…

When dealing with projecting storm water runoff system, one of the most important parameters to be assessed is the soil infiltration capacity (so called also "hydraulic conductivity" or "permeability"). Usually its value is expressed as mm/hour units and it is determined through a so-called "infiltration test". There are different kinds of tests, described in the literature based on the specific aim of the test itself and the nature of soils to be tested. The reader is referred to the available textbooks for more details about his topic.

In this paper we describe a method that could be adopted on the field in assessing the value of soil permeability when carrying out a variable-head infiltration test with the aid of a common Slide Rule. On the field this approach would be useful, because it is not requiring electronic devices (so no batteries needed!) and the instrumentation is very handy and suitable, especially when working in area with difficult access.

The results performed with the aid of a Slide Rule are consistent until the third decimal figure, so they would be suitable to be used directly in every calculation involved in engineering the storm water plant parts.

HOW TO CARRY OUT AN IINFILTRATION TEST ON THE FIELD

We describe here only the field method named “variable-head infiltration test”, used mainly when testing sandy and gravelly soils with permeability values between 10^{-2} and 10^{-6} m/s). Different field and laboratory testing methods are widely described in the pertinent literature.

Permeability test methods should be roughly grouped as:

- Constant-head tests. The hydraulic head is kept constant, adding a tantamount of water. You have to measure the water added (in mc/s or l/s). usually it is adopted when assessing low-permeability soils (k between 10-11 and 10-6 m/s)
- Variable-head tests. A given amount of water is introduced at the beginning of the test and let I flow. You have to measure the time elapsed or the water volume difference. Usually this kind of test is adopted when assessing medium to high-permeability soils (k between 10-6 and 10-m m/s)

Usually the test is carried out digging a 2 x 2 meters trench on the field with the aid of a digging machine, digging depth depending on the specific soil level to be tested, based on field inspection.

Basically the test consists in measuring the time-span elapsed in absorbing a given water volume (usually between 1 and 10 liters each test) inside a standard test tube made of steel and driven inside the soil strata to be tested.

In our test device the test tube is approximately 30 cm diameter and 80 cm tall, made with stainless steel. On the inner wall of the test tube a graduated scale is labelled from 1 until 10 liters.

Before carrying out the test, water’s temperature is measured to assess the viscosity correction constant described herein after.

The operator pours 10 liters of water inside the test tube, switching on the chronometer and writing down on a field table the timings corresponding to every drawdown step labeled on the inner tube scale.

The test is carried out twice: a first run in dry soul condition and a second run after saturating the soil with tap water, simulating the operative conditions at the beginning and at the end of the rainfall event.

Usually, when making calculations, it is assumed to choose the smaller calculated permeability value between the two above described conditions (e.g. dry and saturated soil).

FORMULAS INVOLVED- SOME THEORY

Soil infiltration tests are used in assessing the mono dimensional (usually the vertical one) soil hydraulic conductivity.

First of all water movement throughout the soil is assumed to obey Darcy’s Law written as:

$$Q = s\ K\ i$$

Where

Q= Water discharge volume

S= testing tube diameter

K= permeability constant

I= hydraulic gradient

Accordingly to ASTM field testing method, soil hydraulic conductivity should be determined with the aid of the following equation:

$$HC\ (m/s)\ =\ \left|\frac{(Volume)}{(T\ \pi\ R^2)}\ Rt)\right|$$

$$HC\ (mm/h)\ =\ \frac{HC\ (m/s)}{3600000}$$

Where

HC = soil hydraulic conductivity

Volume = water volume for a given drawdown step (in cubic meters)

T = time elapsed (in seconds)

R = test tube inner radius (in meters) = 0.148 m

Rt= temperature correction factor

A correction factor must be applied to the value calculated with the above equation because the water's viscosity changes with temperature, according to the following equation

$$Rt = \left|2.2902\ *\ \left(\frac{0.9842^{Temp}}{Temp^{0.102}}\right)\right|$$

Where

Temp = tap water temperature in Celsius degrees

HOW TO ANALYSE FIELD DATA

In order to carry out the calculations, you need to record some parameters on the field:

- Tap water temperature
- Timings corresponding to drawdowns at 1,2, etc… up to 10 liters.

Usually at office you can carry out the calculations using a simple Excel worksheet and a laptop. Unfortunately on the field this approach would be something difficult to adopt, so we developed a simple method involving a simple table (I printed it on a transparent adhesive film and glued on the back of a Darmstadt Slide rule) and a basic Slide Rule.

The method yields the permeability value to be used in calculation when dealing with engineering projects about storm water drainage systems.

The whole label measure approximately 130 x 40 mm.

USING SLIDE RULES IN MAKING CALCULATIONS

To carry out calculations we simply arranged all the constant values in the above equations on the basis of the field device we described. So we assumed the following values:

Volume = varying from 1 to 10 (liters)

R = 0.148 m

Thence we are left with only three variables: time, drawdown step value and water's temperature.

This way we could rearrange the above equations as a very simple expression like

$$K = (\frac{C}{T})\, Rt$$

Where

K = Soil permeability value (in mm/h)

C = Soil coefficient. We calculated as many C values on the basis of the specific drawdown step (from C^1 to C^{10}) C= Volume/ (πR^2)

T = Time elapsed (in seconds)

R_t = Temperature correction factor. We calculated as many as Rt factors for water temperatures between 10 °C and 30 °C

So, first of all you only have to divide C value (on the basis of how many water liters were absorbed) by the proper recorded timing. Then you have to multiply the result by Rt value and that's all!

VOLUME (LITRES)	1	2	3	4	5	6	7	8	9	10
C (TO BE DIVIDED BY T)	52	105	157	209	262	314	367	419	471	523

Water temperature (in °C)	10	11	12	13	14	15	16	17	18
Rt	1.319	1.278	1.239	1.203	1.169	1.137	1.107	1.079	1.051
Water temperature (in °C)	19	20	21	22	23	24	25	26	27
RT	1.025	1.000	0.976	0.953	0.931	0.910	0.889	0.869	0.850

Water temperature (in °C)	28	29	30		$HC = \frac{C}{Time} Rt$
RT	0.832	0.814	0.796		

Table 1.

SUGGESTIONS IN DESIGNING A DEDICATED SLIDE RULE

Obviously the method described is a highly simplified one and the constant values to be adopted are changing when using different-sized field tools (e.g. test tube diameter, water temperature scale, etc..) but there are two important assets to be considered

- It doesn't require any electronic device (so no batteries) and it is very easy to carry along with you when working on the field (we use a pocket Slide Rule that fits easily in any coat or jacket)
- It yields the results in a matter of seconds and in a very straightforward way, allowing the field personnel to have a working value at hand just after the permeability test was carried out.

What would be desirable would be to develop a specific Slide Rule's design trying to set up different test settings (e.g. tube diameter, etc.…) but this requires some extra effort.

The method described here would be suitable on any commercial Slide Rule (even the most basic ones), so it is definitely cheaper than making a new specialized Slide Rule!