Rational Method for In-Situ Prediction of the Vertical Saturated Hydraulic Conductivity of Soils

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Description of the test method:

- Double Ring Infiltrometer is a common field test used to determine the infiltration rate and saturated hydraulic conductivity of the soils.
- The test apparatus consists of an inner and outer ring inserted into the ground.
- Each ring is supplied with a constant head of water either manually or from mariotte bottles.
- Hydraulic conductivity can be estimated for the soil when the water flow rate in the inner ring is at a steady state.
- The rate of infiltration is determined by the amount of water that infiltrates into the soils per surface area, per unit of time.
- Infiltration can be measured by either a single or double ring infiltrometer, with preference usually lying with the double ring because the outer ring helps in reducing the error that may result from lateral flow in the soil.

Test equipment:

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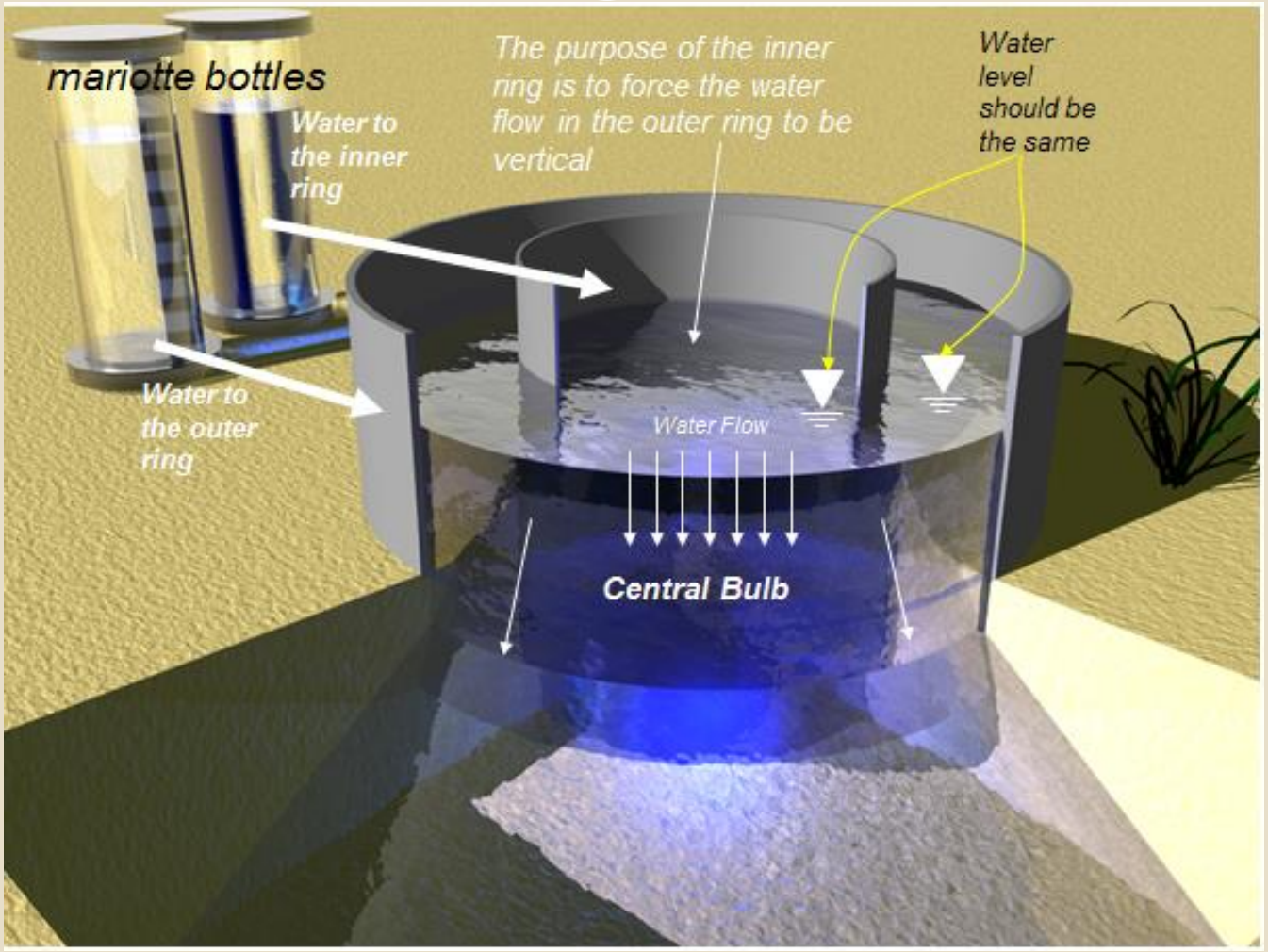


Test restrictions:

- Based on ASTM D 3385, running double ring infiltrometer requires continuous surveillance for a minimum of six hours.
- Based on ASTM, DRI test cylinders should have the diameter of 12 in. for the inner cylinder and 24 in. for the outer one which require 200 liter (55 Gallon).
- Because of the weight and size of the test equipment and also the time needed to run this test, it may not always be performed by the exact procedure required by ASTM.
- Rings sizes affect the estimated infiltration rate from the test. There is a need to evaluate the effect of diameter changes on the infiltration rate.
- Empirically, the steady state infiltration rate is multiplied by 1.45 to predict K_S. This method is not a reliable way to predict the Saturated Hydraulic Conductivity.

Literature Review:

- Lai and Ren in 2010 conducted a total of 7224 numerical simulations to investigate the optimum combination of inner and outer ring sizes for reliable saturated hydraulic conductivity measurements. They recommended inner ring diameter greater than 80 cm and buffer indexes higher than 0.33 to obtain reliable in situ measurement of soil field saturated hydraulic conductivity.

- In 2007, Lai and Ren performed 28 DRI tests for 4 different infiltrometers. They also conducted a series of numerical experiments using two-dimensional model HYDRUS-2D. They recommended use of large-diameter infiltrometers with inner ring diameter of minimum 80 cm to minimize the effects of lateral divergence due to capillary gradients.

Literature Review continue:

- In 2005, Gregory and his colleagues compared two different sizes of double ring infiltrometer test. They run total number of 26 field tests in three different groups. They concluded that the test using a constant head with a double-ring infiltrometer of 15-cm inner diameter and 30-cm outer diameter would be suitable for infiltration research on the sandy soils generally found in North Central Florida.

- Chowdary et al. In 2005 stated that the accuracy of infiltration data depends on various parameters such as head of ponding, ring diameter, initial soil moisture content and saturated hydraulic conductivity. They developed relationships for cumulative infiltration based on the diameter of the infiltrometer, head of ponding, depth of penetration, elapsed time, saturated hydraulic conductivity, and initial moisture content.

Literature Review continue:

- Youngs in 1987 concluded that the results were consistent from site to site when the ring size was at least 0.15 m.

- Ahuja in 1976 reported that when a buffer ring of 0.9m diameter was employed for an inner ring of 0.3m diameter, the lateral flow was practically eliminated. Further, he reported that even when a buffer ring of 0.6m diameter was used, its effect on final infiltration rate was negligible.

- In 1961, Swartzendruber and Olsen reported that 0.6m of outer ring radius and 0.5m of inner ring radius was the most satisfactory concentric ring size throughout all the various conditions studied in a sand model.

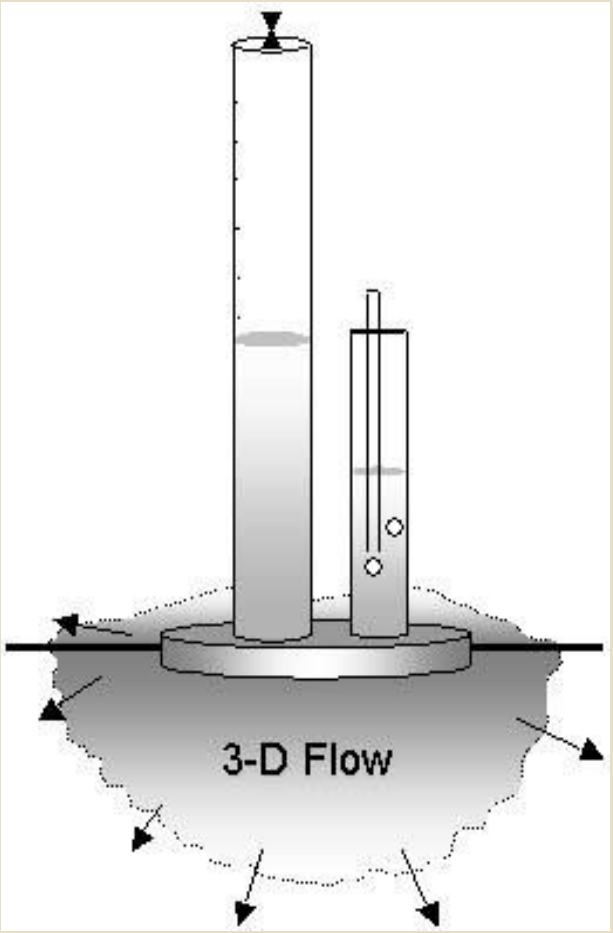
Scope of the research:

- By finding the ring size effect on the calculated infiltration rate, different ring sizes can be used without the need for using a specific size. Smaller rings are preferred because they are lighter in weight and easier to employ. They also require less volume of water to perform the test.

- For that purpose, 30 DRI lab and field tests with different ring diameters are performed. Inner Rings sizes were ranging from 1 inch to 6 inches in the lab tests and 6 inches to 12 inches in the field tests. The infiltration rate from each test was calculated. The ring diameters and their respective infiltration rates were used to predict the actual K_S of the soil. Values of Ks were calculated from the Falling head permeability and the Tension disk infiltrometer testing methods. The accuracy of the prediction method was then calculated.

Tension Disk Infiltrometer

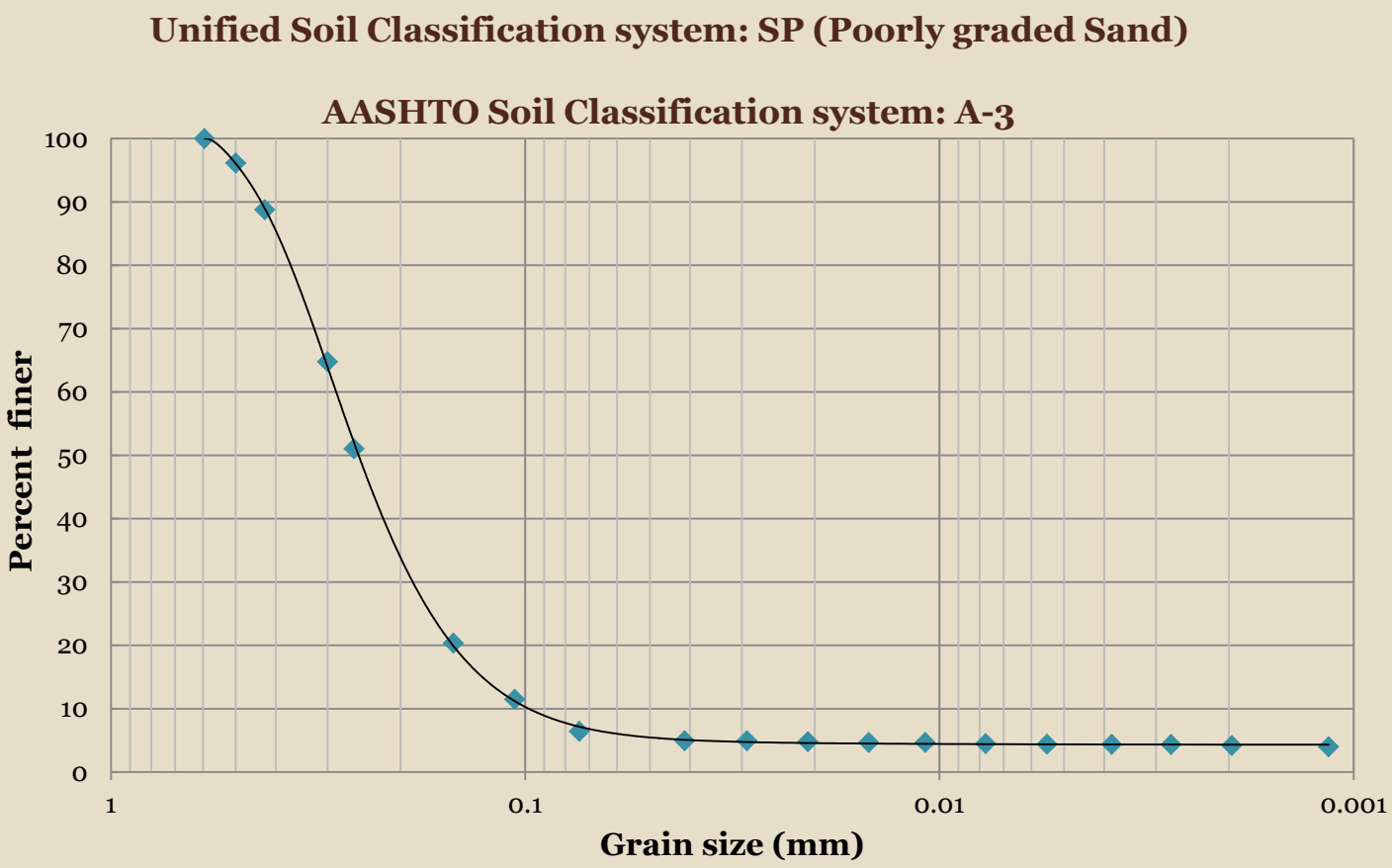
- Tension disc infiltrometers have become an increasingly popular device for in-situ measurement of K close to natural saturation.
- Many authors have attempted to create a negative potential (tension) on the water flow. This excludes macropores from the flow process, hence only measuring flow in the soil matrix.
- There exists several methods to calculate the Hydraulic Conductivity of the soil from the observed infiltration rate. Simunek-Wooding method is used in this research.



Lab tests:

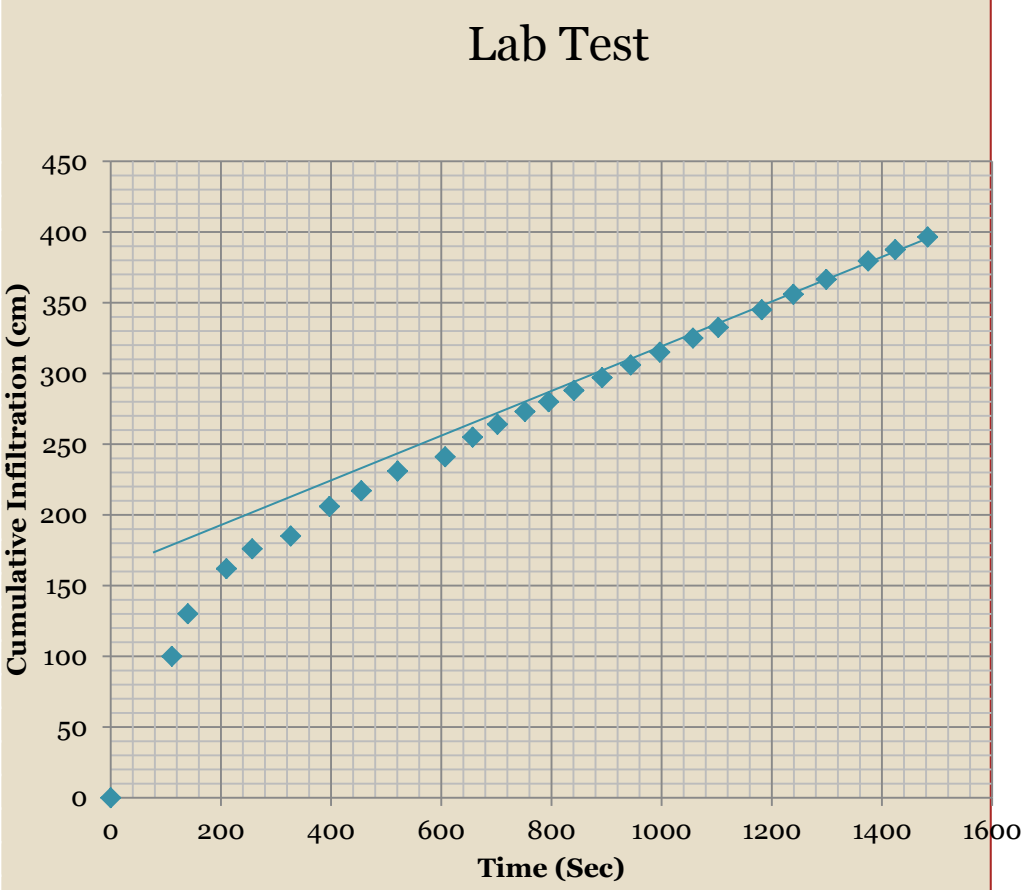
Field tests:

Soil type:


Unified Soil Classification system: SP (Poorly graded Sand)
AASHTO Soil Classification system: A-3
Percent finer
100
90
80
70
60
50
40
30
20
10
0
1
0.1
0.01
0.001
Grain size (mm)

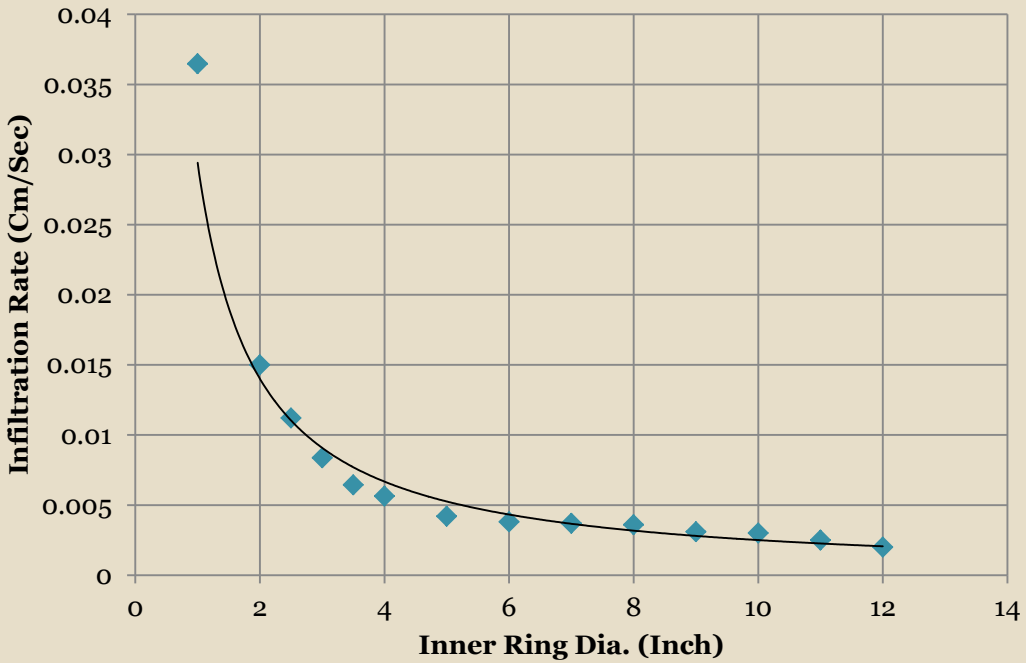
DRI test results sample:

Test 6I R, Di=3.5, Do=7.0, H=0.25, Depth=1.0, Thickness=1.125 inch			
Time (Sec)	Cumulative Water Head in Centimeter (ML)	Inner ring Diameter=	3.5 inch
0	0	Outer Ring Diameter=	7 inch
111	100	Ring Depth=	1.0 inch
140	130	water head=	0.25 inch
210	162	Thickness=	1.125 inch
257	176	Inner Half ring Area (in^2)=	3.9375
327	185	Inner Half ring Area (cm^2)=	25.403175
397	206		
455	217		
521	231		
607	241		
657	255		
702	264		
752	273		
795	280		
841	288		
892	297		
944	306		
997	315		
1057	325		
1103	332.5		
1182	345		
1239	356		
1299	366.5		
1375	379.5		
1424	387.5		
1483	396.5		
Infiltration Rate=0.006434691			



Results:

- The Infiltration values Vs. DRI diameter (Inner cylinder):



$$I = 0.0337D^{-1.184}$$

D: Inner ring diameter (inch), I: Calculated infiltration rate(cm/sec),

Results cont.:

- Linear Regression Model is used to find an equation for predicting saturated hydraulic conductivity of the soil from the ring diameter and the calculated infiltration rate:

$$\mathbf{0.02}(\boldsymbol{D} \times \boldsymbol{I}) - \mathbf{0.038} \times \boldsymbol{I} = \boldsymbol{K}$$

D: Inner ring diameter (cm), I: Calculated Infiltratin rate (cm/sec), K: Saturated vertical hydraulic conductivity (cm/sec)

- RMSE of this equation is 0.0045 which shows the acceptable performance of the result.

Conclusion

1. Based on the power relation of the Infiltration rate and cylinder diameter, inner cylinder diameter of 24 inches and outer cylinder of 48 inches will have infiltration rate equal to the saturated hydraulic conductivity.

2. Based on the derived equation from the Linear Regression Model , inner cylinder diameter of 20 inches and outer cylinder of 40 inches will have infiltration rate equal to the saturated hydraulic conductivity.

3. By using the derived equation, different ring sizes can be used without the need for using a specific size.

4. From the derived equation we can see that for the standard size of 12 and 24 inches, the infiltration can be multiplied by 1.75 (and not 1.45) to predict Saturated Hydraulic Conductivity.

THANKS FOR YOUR ATTENTION