II-79 A SIMPLIFIED METHOD OF ESTIMATING INFILTRATION RATES FROM TRENCHES

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INTRODUCTION

Recently, infiltration trenches, some as wide as 10 - 15 m, are being widely used as urban drainage facilities, and as a result, increasing attention is being focussed on methods to estimate their infiltration capacity. In this paper a practical method to estimate the infiltration from trenches based on a small scale in-situ infiltration test is presented.

1. FORMULATION OF THE PROBLEM

Results from a number of field and laboratory experiments can be summarized as follows. The influence of the variation of θ - ψ relation in a given site is small enough to permit the use of a representative θ - ψ relation for that soil. The important parameters of more sensitive k-ψ relation are the saturated hydraulic conductivity K_0 and the slope of k-ψ curve. For Kanto Loam soil this can be adequately represented by the k-ψ relation (Mualem 1978)

$$k = K_0 \; Se^n$$

where $Se = (\theta - \theta r)/(\theta_0 - \theta r)$; $n = .015 \; w + 3.0$; $w = \int_0^{\psi_a} \gamma_w \; \psi \; d\theta$

As a representative θ-ψ relation is used, n, the slope of the k-ψ curve is predetermined. It was observed that a small variation of this value does not affect the final infiltration rate much. Therefore K_0, the saturated hydraulic conductivity emerges as the significant parameter to be determined by a small scale in-situ infiltration test. The θ-ψ relation and n, are taken as the characteristic values for that soil established by laboratory tests on small field samples.

2. ESTIMATION OF Ko

Richards' equation governing the flow is

$$c(\psi) \; \partial\psi/\partial t = \nabla \{ k \; \nabla(\psi - z) \}$$

By introducing K_0 = 1cm/s * Ko this equation can be scaled down with respect to the value of saturated conductivity.

Since k = Ko Kr where Kr = Se^n ; and defining t* = t Ko

$$c(\psi) \; \partial\psi/\partial t^* = \nabla \{ Kr \; \nabla(\psi - z) \} \quad \text{-- (1)}$$

Above equation can be used to simulate the infiltration from a source such as a borehole or a small trench which is used in the in-situ infiltration test. From the simulation, a curve is established between q/Ko and t*. Using observed infiltration rate q at a given time, Ko is determined from this curve by a trial and error method.

3. STEADY STATE SOLUTION FOR DESIGN CURVES

The relation between the trench geometry and the infiltration rate is nonlinear and it is not possible to extrapolate the results of a particular case to general. Thus it is necessary to use numerical simulation to obtain design curve of q/Ko, for different combinations of trench widths and water heads. During the infiltration, flow conditions in the neighborhood of the source achieves a steady state in a short time permitting steady state simulations to obtain the final infiltration rates from trenches. The governing equation then becomes,

$$0 = \nabla \{ Kr \, . \, \nabla(\psi - z) \} \quad \text{-- (2)}$$

The flow rates computed from the steady state solution and from unsteady simulations corresponding to t*=100 were very close. As the computer requirements for the solution of (2) is much smaller than that for (1), the steady state solution is adopted for the preparation of design curves.

4. APPLICATION

The method is tested with results of the experiments carried out in Kiyose city, Tokyo, with trenches of 60, 120 and 180 cm widths. For each trench the infiltration rates were obtained for water heads of 45 and 60 cm. The θ-ψ data were measured from 24 soil samples collected from the site. The data were fitted to the equation,

$$\theta = \{ \theta_0 - \theta r \} \alpha \; / \; [\; \alpha + \{ \ln(\psi) \}^{\beta} \;] + \theta r$$

The curve with an average $\theta_0 - \theta r$ value was selected to be the representative curve for the site. The parameters of the curve are,
θ_0 = .7419, θr = .6432, α = 14.8, and β = 2.6.
The q/Ko vs. t* using this values for trench 60 cm wide is shown in fig. 1. The observed infiltration rate for 60 cm trench at 60 cm head after 30 min was 2.325 cm³ /cm /s. From the figure value of q/Ko is 281.2 at t*=100.
Ko = 2.325/281.2 = .00827 cm/s.
For this Ko the t* value corresponding to 30 min was, t*=30*60*.00827 = 14.88. An improved Ko value is given by q/Ko corresponding to t*=14.88
Ko = 2.325/290 = .00796 cm/s.
This Ko value can be used to predict the infiltration rates from other trenches using the final infiltration values computed according to 3. Results are shown in fig. 2 denoted by circles. It is seen that the predicted value is on the higher side for the 120 cm and 180 cm trenches while the prediction is very good for the 45 cm head of the same trench. This shows that there might be some variation between the trenches. The predictions based on Ko computed from 120cm width trench for 60 cm head is shown by squares in the same figure.

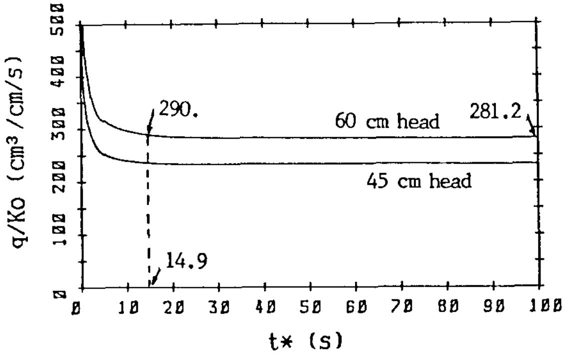

Fig 1. q/Ko vs. t* Curve for 60 cm Width Trench.

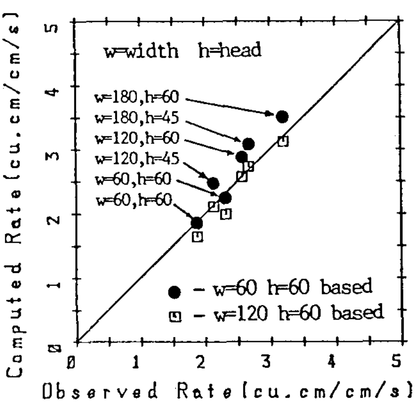

Fig 2. Observed and Predicted Infiltration Rates.

5. RESULTS

For larger trenches predictions and observations are in very good agreement.The discrepancy of 60 cm trench values can be attributed to the three dimensional effect of the actual flow in experiment compared with two dimensional analysis used in the predictions. In the experiment buffers of 50 cm length were installed on either side of 3m long middle compartment to ensure two dimensional flow from the middle part of the trench. However, still a part of the flow takes place in the direction parallel to the trench length, and the fraction of this flow from the side walls will be largest for the smallest trench while it becomes relatively smaller with increasing width. Therefore we can expect a higher computed/observed ratio for smaller trench than the larger trenches.

6. CONCLUDING REMARKS

1) The method described is adequate for field design purposes.
2) The pilot test should be conducted carefully as the errors will be magnified when applied to large systems. Provisions should be made to make the flow as close to the two dimensional flow as possible. Long buffer length, short middle compartment and wide trenches seem to be the most suitable form for the pilot test with trenches.
3) An easier method would be to conduct a borehole test to determine the Ko value.
4) Even though the analysis was carried for isotropic conditions these ideas can be easily extended for the anisotropic soils.

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