# Ⅲ－A324

## Using of tracer in the analysis of the pipe diameter distribution in soils

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**1-Introduction:** Many civil engineering problems concerned with soil mechanics require the knowledge of the pore size distribution of soils. Such characteristics of the voids distribution of soils are related in a direct manner with the permeability of soils. This papers aim to the obtention of voids distribution in soils by means of tracer.

**2-Pipe model:** Most soils are configurated in the form of layered deposits, mixture of two or more kind of soils and anisotropy of the soil grain properties. This particular characteristic makes erratic the void distribution of soils and almost impossible to predict. To analyze the permeability of soils through its real configuration is of no practical use. It is more expedient to consider a simplified configuration of voids (Pipe model) such as that showed in Fig.1. Briefly, this model is based on the assumption that voids in soil deposits are pipes aligned parallel to each other. On the basis that succesive values of radius, are very close to each other(continuity function), the void distribution curve of the sample may be drawed generically such as that in Fig.2. The horizontal axis represents the values of consecutive radius (r) in the soil sample, while the vertical axis m(r) , the number of pipes per unit length of a given radius. Thus, the number of pipes (N) enclosed by two determined radius $r_1$ and $r_2$ is

$$N = \int_{r_1}^{r_2} m(r)\, dr$$

If the sample is sujected to steady flow, for a given pipe, the flow velocity is $V(r)=(\gamma_w.r^2.i)/(8.\ \mu)$ where $\gamma_w$=Water density, i=Hydraulic gradient and $\mu$ is the dynamic viscosity. The time for the water to flow through the length L of the sample is $t(r)=(8.L.\mu)/(\gamma_w.r^2.i)=L/C_1.r^2.i)$. Rate of flow for a given pipe is an ascending function with increasing values of radius. It is expressed by means of the equation $Q(r)=C_1.i.\pi.\ r^4$ Finally, the accumulated discharge, which is conceptually the summation of the succesives discharges of all pipes within the range r-rmax in the period of time tmin -t is

$$Q_A(r) = \pi \quad i \quad C_1 \int_{r}^{r_{max}} m(r) \quad r^4 \quad dr$$

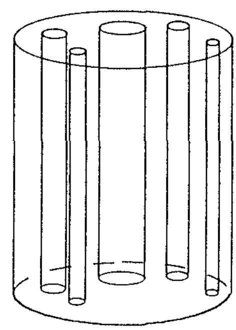

Fig.1 Pipe model in soils.

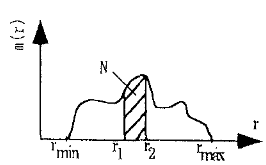


Fig.2 Voids distribution function in soils.

**3-General description of the saline water density test:** Principal features of this test, by means of which it is possible to obtain the voids distribution of soils are shown in Fig 3. A soil sample of length L is placed inside a container with a permeable cap at the bottom, then, water is poured from the top until the distance from the water level to the soil surface reaches the value $H_{TOP}$. Keeping constant the volume of water($V_{TOP}$) above the water surface, rate of flow is adjusted to steady. The quantity of discharge per unit time in the second recep-

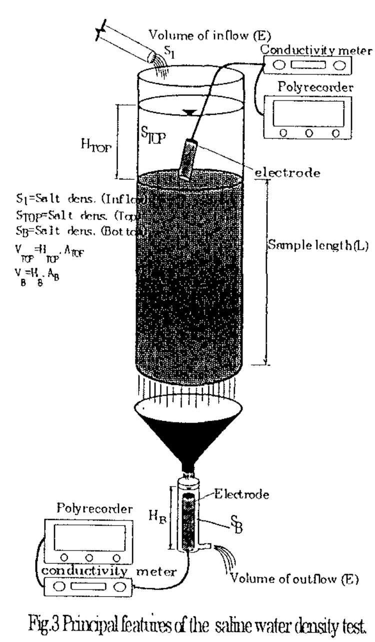


Fig.3 Principal features of the saline water density test.

Voids distribution. Pipe model. Tracer.

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tacle is regulated, so that $V_B$ (Bottom volume) experiments no variation. Since the flow is steady, volume flow is the same for both containers. At a given time $T_0(T=0)$ , established at zero for convenience, supply of water is stopped and replaced on the instant by saline water maintaining the initial conditions of steady flow. Salt water density for the inflow is constant with time and designated by $S_1$.

**3-1 Variation of salt concentration in top volume ($V_{TOP}$):** Changes in the values of salt concentration are measured in practice by means of a conductivity meter which consists of an electrode connected to an electronic box that receives the output signal. Finally, the connection of the set to a polyrecorder allows data recording with time.

As it would be expected, salt concentration varies from zero ($T_0$) to the final value of $S_1$ ($T_{S1}$), where $T_{S1}$ is the time for the top volume to attain $S_1$. For elapsing time greater than $T_{S1}$, salt concentration remains stationary in the value $S_1$. Outflow and inflow are equal and designated by E. The quantity of salt at the time T is $Q_{TOP}$ and the corresponding variation with time can be evaluated as $dQ_{TOP}/dT$. The volume of the saline solution experiments no variation with time, hence salt concentration as a function of time is $Q_{TOP}/V_{TOP}$; Salt inflow is at the rate of $S_1.E$ and salt outflow at the rate of $E.(Q_{TOP}/V_{TOP})$. The preceding problem is governed by the following differential equation

$$\frac{dQ_{TOP}}{dT} + \frac{E}{V_{TOP}} Q_{TOP} = S_1 \quad E$$

Solving for the time , the variation of salt density at $V_{TOP}$ with time can be expressed as

$$S_{TOP} \quad (T) = S_1 \quad (1 \quad e^{-\frac{E}{V_{TOP}} T})$$

**3-2 Variation of salt density in bottom volume ($V_B$):** The same analysis used for the top volume is valid for the bottom volume, however the salt density for the inflow in $V_B$ is variable with time, hence:

$$V_B \quad \frac{dS_B}{dT} + E \quad S_B = \frac{\gamma_w \quad \pi \quad i}{8 \quad \mu} \int_r^{r_{max}} S_{TOP}\,(T - t) \quad m(r) \quad r^4 \quad dr$$

in which m(r) can be obtained by means of the finite difference method. Figures 4(a-b) shows an example of calculus for a sample of sand.

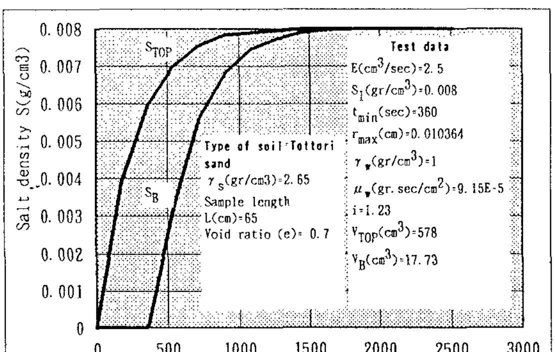


Fig. 4-a Variation of $S_{TOP}$ and $S_B$ with time t(sec)

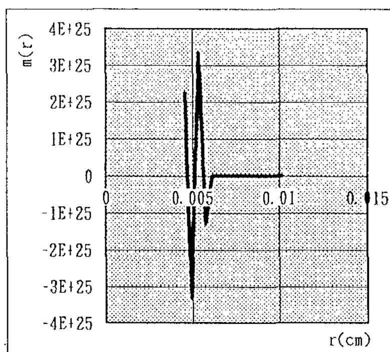


Fig. 4-b Function m(r) for Tottori sand

**4-Conclusion:**. Results of the experiments shows that it is no possible a transparent analysis of results. Negatives values for the m(r) curve (number of pipes per unit length) could be attributed to the followings: 1-Real configuration of voids in soils cannot be liken to the pipe model assumed in this investigation. 2-If from the m(r) curve, salt density in top or bottom volume is calculated (Assuming the negative values of m(r) zero or positive) some points are very close to the experimental curve. Therefore accuracy of observational data could be not enough to avoid the negative values of the m(r) curve. Knowledge of the voids distribution of soils allows the obtention of the coefficient of permeability. As the frequency and size of every pipe is pretendedly known it is possible to obtain both the average permeability and the permeability for every pipe.