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A Method for Determining Permeability and Specific Capacity from Effective Grain Size

by

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Particles and Permeability

A METHOD OF DETERMINING PERMEABILITY AND SPECIFIC CAPACITY FROM EFFECTIVE GRAIN SIZE

by H. Glen Rose * and H. F. Smith **

Due to recent and rapid developments of ground-water resources in recent years, there is a growing need for a simplified method for determining permeability and well yield of a water-bearing sand and gravel formation when only a log and sieve analysis of the formation are available. The purpose of this paper is to give a simple procedure for rapidly determining the approximate permeability of the formation when only the particle sizes are known; and a method of determining the specific capacity of a proposed well when the permeability or transmissibility is known.

In general, laboratory determinations for permeability do not distinguish between vertical and horizontal permeability of lenticular formations such as are encountered in unconsolidated water-bearing formations.

The laboratory methods for determining permeability consist of indirect and direct methods. Permeability is determined by the indirect methods from analyses of samples of material for such physical properties as grain size and porosity and by the direct methods from observations on the percolation of water through samples of the material.

The methods of Hazen,[1,2] Slichter,[3] and Terzaghi[4] are similar in that the formula for each contains the square of the effective grain size. Hazen makes no allowance for particle shape and compactness of similar material having different porosities except through the selection of his equation constant. Slichter and Terzaghi have included factors to compensate for the degree of compactness.

Fraser[5] states that the equations of Hazen, Slichter and Terzaghi give reasonably satisfactory values for the coefficient of

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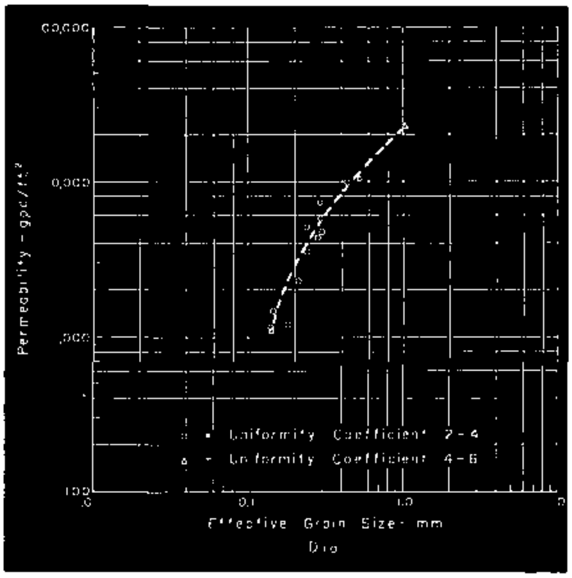

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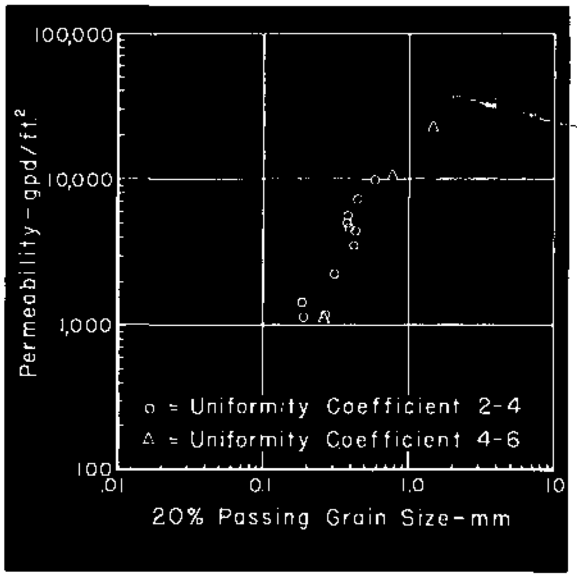

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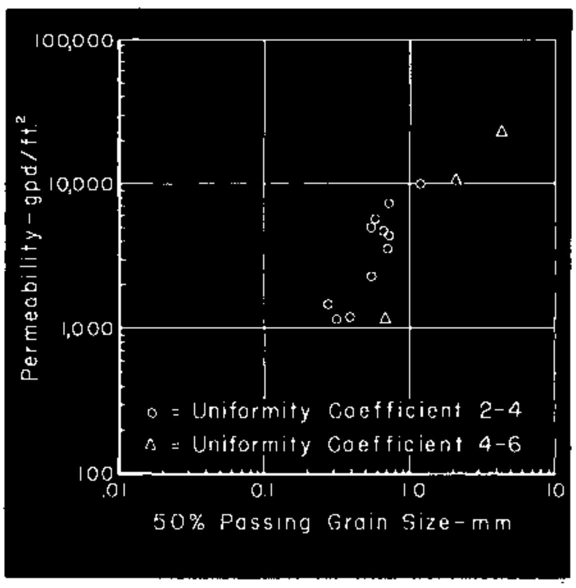

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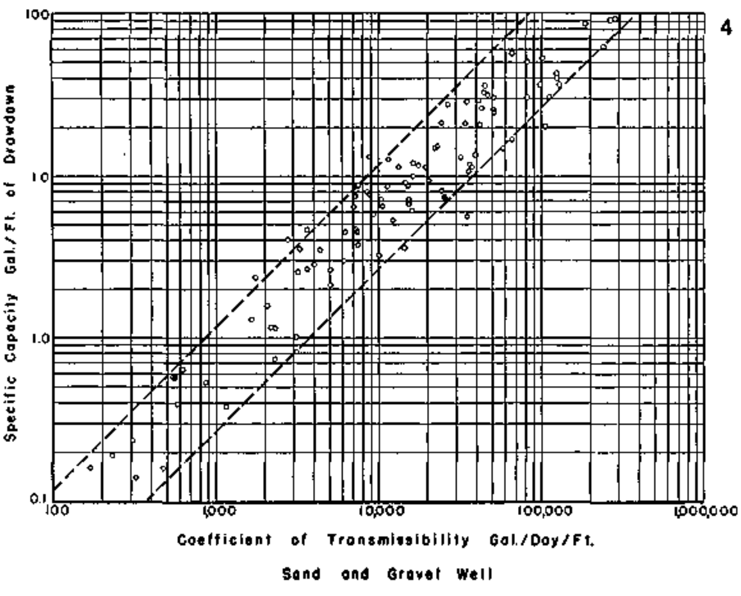

permeability of columns of uniformly sized spheres but that the equations are unsatisfactory for mixed sizes.

Mansur and Kaufman[6] found a correlation between the effective grain size and the coefficient of permeability during their studies of underseepage along the Mississippi River levees in the St. Louis area.

They found little agreement between permeabilities as determined in the laboratory on remolded samples and those obtained from the field pumping tests. They concluded that there is no reason why the permeabilities should agree since the aquifer is stratified and lenses of coarse sand and fine gravel exist.

Emrich and Mansur[1] found a correlation between permeability and the effective grain size during studies in Mississippi and Louisiana.

Some controversy seems to exist among experimenters as to what grain size actually controls the flow in a sand and/or gravel formation. Many of them use the 10 per cent size as the effective grain size. These percentages are expressed as per cents finer or per cents passing. Fancher and Lewis[8] in their work use the average grain diameter.

In an attempt to determine the controlling grain size the authors plotted the 10 per cent, 20 per cent, and the 50 per cent grain sizes against the permeability of the water-bearing formation. The sieves used for determining sand grain sizes were of the Tyler series.

Of the three plots, 10, 20, and 50 per cent grain sizes against permeability, the plot of the 10 per cent size gave the least scatter and therefore the best curve (Figs. 1, 2, 3). In the beginning it was believed that the uniformity coefficient might have some effect on the permeability. In other words, those formations having the same effective grain size but different uniformity coefficients would have different permeabilities. The uniformity coefficients of the formations used in this study were grouped in the ranges of 2 to 4 and 4 to 6. The plot using the 10 per cent size showed no scatter or banding due to different ranges in the uniformity coefficient. From the data available, it was concluded that the uniformity coefficient had little or no effect on the permeability when using the 10 per cent grain size.

Coefficients of transmissibility were determined from controlled pumping tests of 14 wells by the non-equilibrium method "Type Curve" solution and by the modified non-equilibrium "Straight Line" method. The coefficients were then divided by the aquifer, thicknesses, as determined from the well log, to give coefficients of permeability.

The collection of good representative drill cuttings and keeping good well logs are essential if satisfactory results are to be obtained. An accurate well log is used to obtain the aquifer thickness, and from this the coefficient of permeability can be obtained. The necessity of a good sampling technique is obvious since an accurate determination of the effective grain size is needed.

The data used for this study were obtained from water well pumping tests; water temperatures averaged between 50° and 60° Fahrenheit. The results obtained in this study would need correction if water of different temperatures were percolating through a system.

In addition to the effective grain size permeability study, the authors have investigated the relationship between the coefficient of transmissibility and the specific capacity of a well.

Coefficients of transmissibility and specific capacity have been determined from many well tests conducted by the Illinois State Water Survey. Only those tests where adequate data were available were used for determining the coefficients. Transmissibility was calculated by the non-equilibrium method "Type Curve" solution and by the modified non-equilibrium "Straight Line" method. The specific capacity was determined after sufficient time had elapsed to stabilize the rate of drawdown.

Coefficients of transmissibility were plotted along the abscissa on log-log paper and values of specific capacity along the ordinate (Fig. 4). The plot shows a definite relationship by the straight line banding of the plotted points.

The reasons for this banding are many and should be carefully studied when investigating an area. Any factor which will affect the drawdown will also affect the specific capacity of the well. Some of the items to study and determine are the pumping of other wells in the area, the presence of hydrologic boundaries, proper methods of well construction, and adequate well development. Certainly a carefully conducted well test of sufficient duration to allow for reliable results is of utmost importance.

To illustrate the use of these two studies, a hypothetical problem will be discussed. Let it be assumed that a groundwater supply is being considered for some specific locality. A small diameter test hole is drilled, with care being taken to record an accurate log and to collect good samples of the formation penetrated. A sieve analysis is then run on these samples to determine the 10 per cent passing or effective grain size. From this value of the effective grain size, a value of permeability may be selected from the curve (Fig. 1). A study of the well log will denote the aquifer thickness which, when multiplied by the permeability, will give a coefficient of transmissibility. This value of transmissibility will give a range of values for specific capacity (Fig. 4). A further study of the well log and the static water level will give a value of available drawdown. This available drawdown multiplied by a value of specific capacity would give a production rate that might be expected from a well finished in the aquifer.

To obtain this production rate, well diameter, screen selection, and other well construction features are some of the items to be considered.

It is believed by the authors that this study will make possible the rapid determination of approximate permeability and specific capacity values for a formation. A careful consideration and investigation of all the limiting factors discussed must be incorporated in the final results.

It must be remembered that an actual pumping test with observation wells is the best known method for determining the formation coefficients. This study would be applicable where a pumped well and observation wells are not used for reasons of economy, etc. This method could also be used for a rapid determination where approximate values will suffice.

The authors are indebted to the engineers of the Illinois State Water Survey Division who have collected data from many pumping tests and who helped compute the formation coefficients needed for this paper.

The writers are also indebted to the geologists of the subdivision of Groundwater Geology and Geophysical Exploration of the Illinois State Geological Survey Division who have furnished well logs and conducted grain size determinations.

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