WATER FLOW NET CHARACTERIZATION BY USING A TANK MODEL: PRELIMINARY OUTCOME

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INTRODUCTION

The work being reported was conducted to experiment and gain understanding of how groundwater flows. This experiment was expressed with a tank model filled with sand. The sand used was collected at Jones Beach (Long Island, NY) away from shore to avoid moisture *(Figure 1)*. The sand was carried to the lab to explore the effective grain size. Based on the effective grain size, permeability, k, was found and applied to the Laplace equation to estimate the amount of flow through a flow channel. It became evident that the water flow underground (shown as sand) occurred due to the difference in total head between the two locations on either side of the model boundary. As water was pumped in the tank, water began to flow downwards and back up as well due to the frictional drag and gravity on the soil particles. The boundary condition implies an impervious obstruction that water cannot flow through, it must flow around. For groundwater to flow, a change in total head is necessary. Therefore, an obstruction was applied to the model to suit this. The flow lines show symmetry. Percolating through the pore spaces of the soil, the water follows through channel from one end and travels to the opposite side of the boundary at the same level.

METHODS AND MATERIAL

Experimental Method: The method to the experiment consisted of 3 applications of dye at the sand interface on one side of a model boundary *(Figure 2)*. Water is then pumped from one side to observe the development of flow lines perpendicular to the sand interface (equipotential lines). As time passes it is evident that flow lines follow curved paths and are perpendicular to EP lines. A flownet was constructed to display the consistency of the set of equipotential lines and flow lines which create a linear curve; when intersecting form perpendicular lines.

Mathematical method: A sieve analysis was conducted to observe the effective grain size to support the *k* value, permeability, which was then included in the Laplace equation to compute the flow through a flow channel q_{channel} per unit width.

Material: A tank model built with acrylic glass sheets as the sides and base along with a sheet in the center to represent a boundary *(Figure 3)*. All sheets were welded together by acrylic glue. Prior to the sheets being welded together, three holes were created; two on one side of the boundary and one on the other. This allows for vinyl tubes (*Figure 8*) to pass water in and out of the tank with the help of an aquarium generator *(Figure 6)*. The tank was leak tested prior to the experiment. Dry sand was collected from Jones Beach, New York and poured into the tank just below the midpoint of the boundary. When beginning the experiment, enough water was carried in through the tubes to submerged the sand, but not over flow. Purple dye was added to three spots at the top of the sand on one side of the model *(Figure 4)*. The dye spots were then covered by sand and the generated was turned on.

Figure 6-8:
6 Aquarium generator- used to pump water
7 Rit Dye- used as an indicator
8 Vinyl Tube- tubing for water passage

Abstract

A study was conducted to observe and characterize the flow of water. Water beneath the surface may have an impact on structures by causing uplift, seepage and altering the strength characteristics of soil. One of the most relevant tools used for characterizing groundwater flow is the flow net. This consists of a combination of flow lines and equipotential lines. Flow lines, which are the lines indicating where a water particle will travel from upstream to downstream and equipotential lines (EP) which are lines where the potential head at all points are equal. Both lines come together to form two perpendicular lines which create a curved linear grid. One set of curves being equipotential that connect points with the same pressure. Assuming that water is incompressible and there is zero volume change in the soil mass, it is known that the total rate of inflow is to equal the total rate of outflow. Thus, introducing the idea of flow continuity, we use the Laplace equation of continuity, to observe the concept of the flow net. Using the flow net method, it is hypothesized: does a flow net reflect the way groundwater flows? The tank model crafted has been designed to display the flow of groundwater around an obstruction. This model illustrates the morphology and velocity of the flowing groundwater. It was constructed with sheets of glass glued together to weld and prevent leakage. A submersible pump was connected to a clear vinyl tube, which is attached to the apparatus with silicon sealing glue, allowing for a constant level of pressure on one side while the water flows from one side to the other. The apparatus was leak tested prior to the soil being added. The pumps on each side are attached to a bucket of water below to prevent water from over flowing or drying out the soil. As the groundwater flows, traces of the dye which represent the flow lines provides evidence of the habit in which water flows.

Figure 2: Initial start of the experiment

Figure 3: Leak Test

Figure 1: Sand being collected from Jones Beach

Figure 5: After one hour and 20 minutes, this is the result of water flow from one side of the boundary to the other.

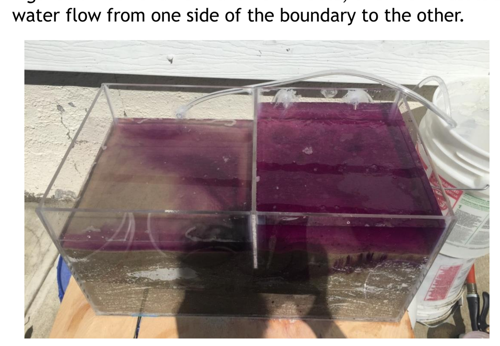

Figure 4: Overview showing in and out flow of water through vinyl tubes. (differential pressures of water)

RESULTS

With the idea of flow continuity, the Laplace equation seemed to justify the mathematical explanation of this experiment. Computing the flow through a flow channel, we observe the total head difference from the first equipotential line to the last equipotential line divided by the number of equipotential lines between the first and last head drop $q_{channel}l=(k)(\Delta H)N_f/N_d$. This resulted in multiplication of the permeability by the head difference *1.9 inches,* converted to 4.8 cm, by the number of flow channels *4* divided by the number of equipotential line drops *6*. Then multiplied by *k*. The uniformity coefficient $Cu=d_{60}/d_{10}$ determined the ratio of the grain size. Using the Hazen method $K=C(d_{10})^2$ the permeability was found to be k=0.117cm/s. Carrying the value of k to the Laplace equation, it is discovered that for every retained inch there is 0.386 cm of flow moving per second. The two-dimensional graph below represents the steady state of water flow through an obstruction (*Figure 10)*. These graphs were constructed to help visualize the passage of water through porous material and solve continuity equations (*Figures 9-10)*.

	Sample			
Sieve	***Soil (g)***	***Cumulative Retained***	***% Retained***	***% Pass***
Lid				
25	2.6	2.600	1.002	98.998
35	21	27.600	10.636	89.364
45	106	133.600	51.484	48.516
60	112.1	245.700	94.682	5.318
80	16.9	262.600	101.195	-1.195
120	0.8	263.400	101.503	-1.503
170	0.1	263.500	101.541	-1.541
200	0		0.000	100.000
Pan	0	0.000	0.000	100.000
Sum	259.5			

Figure 9: Effective Grain size Analysis

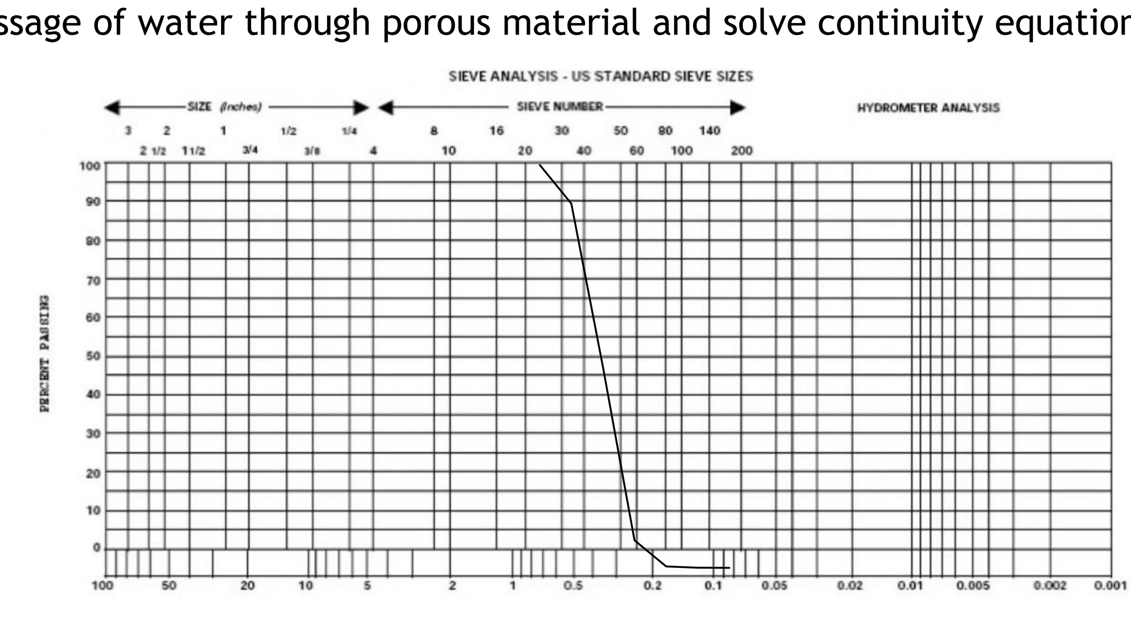

Figure 10: Graph of the grain size analysis

CONCLUSION

When experimenting with the flow net method, it was hypothesized whether a flow net reflects the way ground water flows in porous medium. The differential pressure expressed by the purple dye served as a potential aquifer representing ground water flow around an obstruction.

It was hypothesized that as water begins to fill one side of the tank, the pump and buckets where the water flows from and to will allow for maintaining a constant head pressure. This is the force, represented as the purple dye, that carried the water from one side of the boundary to the other. Realistically, the difference in pressure and frictional drag from the downward flow through soil particles are causing for the water to move from one side of the boundary to the other. Over a limited number of hours, the traces of dye and currently used mathematical methods from Laplace and Hazen's equations supported this hypothesis to be representative of groundwater flow through porous medium.

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