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Research article

MODELING PERMEABILITY AND VELOCITY INFLUENCE ON FLOW RATE IN HOMOGENEOUS LATERITIC SOIL THROUGH CROSS SECTION AREA IN A VERTICAL COLUMN

Eluozo, S. N

[1]Subaka Nigeria Limited, Port Harcourt, Rivers State of Nigeria
Director & Principal Consultant, Civil & Environmental Engineering, Research & Development
E-mail: Soloeluozo2013@hotmail.com
E-mail: solomoneluozo2000@yahoo.com

Abstract

Structural deposition of soil developed lots of variation, the geological setting determine the position of the soil structure in any location, there are several conditions that influences the rate of flow in soil and water environment, the rate of fluid flow in soil are reflected on the deposition of the strata setting through the matrix of soil structural deposition of the formation in the study area. The flow rates of fluid are determine by the stated parameters in the system. The study has show the reflection of soil stratification of the formation including its variation of flow rate through permeability coefficient and velocity of fluid flow; the two parameters were found to establish a relationship, the study express their relation in terms of fluid flow rate in soil and water environment. This determine the rate of flow in the study area, mathematical approach were found necessary to establish a fundamental base line that will monitor the rate of fluid flow, the condition has express the various relations that influences the deposition of permeability and velocity of flow, the developed model will definitely determine various rate of permeability coefficient and its velocity including flow rate in soil vertical column.

Keywords: modeling permeability and velocity, flow rate, homogeneous lateritic soil and vertical column

1. Introduction

Soil water establishment is highly affected by soil formation and its steadiness. Various soil arrangement types may cause preferential flow or water immobilization (Kodešová et al., 2006, 2007, 2008, Eluozo 2013). Soil structure breakdown may initiate a soil particle migration, formation of less porous or even water-resistant layers and as a result of decreased water fluxes within the soil profile (Kodešová et al., 2009a). Soil aggregation is under managed of different mechanisms in different soil types and horizons (Kodešová et al., 2009b). Soil formation and consequently soil hydraulic properties of tilled soil varied in space and time (Strudley et al., 2008). The temporal variability of the soil aggregate stability was shown for instance by Chan et al. (1994), and Yang and Wander (1998). While Chan et al. (1994) documented that temporal changes of aggregate stability were not positively related to living root length density; Yang and Wander (1998) suggested that the higher aggregate stability was found due to crop roots, exudates microbial by-products and wet/dry cycles. The temporal variability of the soil hydraulic properties (mainly hydraulic conductivities, K) were investigated, for instance in following studies. Murphy et al. (1993) showed that K values at tensions of 10 and 40 mm varied temporally due to the tillage, wetting/drying, and plant growth. Messing and Jarvis (1993) presented that the K values decreased during the growing season due to the structural breakdown by rain and surface sealing. Somaratne and Smettem (1993) documented that while the K values at tension of 20 mm were reduced due to the raindrop impact, the K values at tension of 40 mm were not influenced. Angulo-Jaramillo, et al. (1997) discovered that only the more homogeneous sandy soil under furrow irrigation exhibited significant decrease in sorptivity. Petersen et al. (1997) documented using the dye tracer experiment that cultivation reduced the number of active preferential flow paths. Azevedo et al. (1998) measured tension infiltration from 0 to 90 mm and showed that macropore flow decreased from 69% in July to 44% in September. Bodner *et al.* (2008) discussed the impact of the rainfall intensity, soil drying and frost on the seasonal changes of soil hydraulic properties in the structure-related range. Finally, Suwardji and Eberbach (1998) studied both, aggregate stability and hydraulic conductivities. They documented the lowest aggregate stability during the winter and increased in spring. The *K* values decreased during the growing season. The goal of this study is to assess the seasonal variability of the soil structure, aggregate stability and hydraulic properties with respect to each other and to varying soil physical and chemical properties, soil management and climatic conditions (Eluozo, 2013).

Water is of fundamental importance to plants and animals particularly man. It is then very vital in maintaining life processes and growth (Ogbe, 2003). Potable drinking) water is not commonly found and its provision limits the setting up of villages and towns to the places where supply exist (Shankar, 1994 and Huisman, 1966). In most part of Niger delta like aboh and environs, the residence depend on the slow running water from river Niger and its tributaries such as Ase creak and hand dug wells for their domestic water needs but today, increased activities within the study area which includes gas flaring at Kwale/Okpai gas plant, dead and decayed organic matter in contact with the rivers, streams and lakes, the drilling activities and the effect of buried pipes (rust) as well as the numerous oil spillages especially that of August 2002 in River Niger, the Ashaka 1 location spills of 1978 and

1983 respectively and the recent fire and oil spillage at Abalagada in have drastically polluted the source of water supply to the region and rendered it unhygienic and unsafe for drinking (Oseji et al, 2005). Unfortunately, these were the only available source of water, despite the increased demand for potable water in the region due to increase in the population within the last few years A better knowledge of the near surface aquifer distribution, formation and type in this area is therefore important so as to ascertain whether the aquifer is prone to contamination or not since the surface water have been polluted. (Oseji et al 2006). Most of the side effects of oil production are the possible pollution of water and the destruction of aquatic lives. Water pollution occurs when rainwater combines with the by-products of gas flaring in the atmosphere, (Ebeniro et al 1996 Eluozo, 2013).

2. Theoretical Background

Modeling permeability and flow velocity influenced by flow rate in homogeneous lateritic soil has been expressed by lots of experts in the system, but most of the studies could not produce a better results that can determine the flow rate of fluid even with solute in vertical column, these conditions are expressed from observed flow rate of the fluid in the formation. The formation of the soil determined the flow rate level of the fluid, similarly solute that migrate from one formation to the other are base on the structural stratification of the soil in the study location. Flow of water in soil media takes place through void spaces which are apparently interconnected. Water can flow through the densest of natural soils. Water does not flow in a straight line but in a winding path (tortuous path). However, in soil mechanics, flow is considered to be along a straight line at an effective velocity. The velocity of drop of water at any point along its flow path depends on the size of the pore and its position inside the pore. Since water can flow through the pore spaces in the soil, hence soil medium is considered to be permeable. Thus, the property of a porous medium such as soil by virtue of which water can flow through it is called its permeability. In other words, the ease with which water can flow through a soil mass is termed as permeability. More so calibrating the velocity of solute transport in soil and water environment has been assessed, the solute velocity of transport established various rate of velocity at different depth in the study area. The study confirm the influence of the flow paths as one of the causes of variation in solute velocity of flow, few area were examined that confirms the influence of stratification of the soil formation, this has played some role on the rate of velocity flow at different depths, formation characteristics like porosity where also observed to have recorded some influence in the stratification of silty and fine sand, where an optimum level where recorded, the lower rate of velocity are where lateritic soil are predominant, few location experience an average mix of lateritic and silty formation as observed in average velocity of those depths. The study is imperative because it has assessed the rate of velocity of solute flow at different formation at vertical column, this concept determine the time of solute migration in the study area.

3. Governing Equation

$$q\frac{h}{\partial z} = K\frac{hA}{L}\frac{dh}{dz} - KV\frac{dh}{dt} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

The expression is the governing equation will determine the rate of flow under the influences of permeability in the study location, permeability influences are reflected from the geological setting of the formation, these determine the structural deposition of the formation, the rate permeability influences was confirmed through the stratification from the hydrological studies carried out in the study area. The rates of permeability in the soil were the focus of the study, to determine the impact; it has on the rate of flow in soil on vertical column.

$$\frac{dh}{dz} = S^1 h(z) - Sh(o) \quad \ldots\ldots\ldots\ldots \quad (2)$$

$$\frac{dh}{dz} = S^1 h(z) - Sh(o) \quad \ldots\ldots\ldots\ldots \quad (3)$$

$$\frac{dh}{dt} = S^1 h(t) - Sh(o) \quad \ldots\ldots\ldots\ldots \quad (4)$$

$$S^1 h(z) - (z) - q\left[S^1(z) - S^1 h(o)\right] - K\frac{hA}{L} - KV\left[S^1 h(t) - Sh(t)\right] \quad \ldots\ldots \quad (5)$$

$$S^1(z) - h(o) = qS^1 h(o) - qho \quad \ldots\ldots\ldots\ldots \quad (6)$$

$$K\frac{hA}{L} h(z) - K\frac{hA}{L} S\, h(o) \quad \ldots\ldots\ldots\ldots \quad (7)$$

$$dh(z) - S\, h(o) \quad \ldots\ldots\ldots\ldots \quad (8)$$

Let $h(o) = 0$

We have

$$S^1(t) - qS^1 h(o) - K\frac{hA}{L} S^1 h(z) - KVh(t) \quad \ldots\ldots\ldots\ldots \quad (9)$$

$$h(z) = \frac{1}{S}\left[qS^1 h(t) - K\frac{hA}{L} S^1 - KV\, S^1(t)\right] \quad \ldots\ldots\ldots\ldots \quad (10)$$

$$h(z) = \frac{1}{S^1}\left[qS^1 h(t) - K\frac{hA}{L} S^1 - KV(t)\right] \quad \ldots\ldots\ldots\ldots \quad (11)$$

$$\frac{h^1(z) = qS^1 h(t) - K\frac{hA}{L} h(z) - \alpha S^1}{S} \quad \ldots\ldots\ldots\ldots \quad (12)$$

$$h(z) = q^2 h(t) - K\frac{hA}{L} h^1(z) - KV h^1(t) \quad \ldots\ldots\ldots\ldots \quad (13)$$

$$h(z) = KV^2 S^1 h(t) = \frac{K\frac{hA}{L} h^1(z) \;\; KV h^1(t)}{S} \quad \ldots\ldots\ldots\ldots \quad (14)$$

$$h(z) = \left[q^2 - K\frac{hA}{L} - KV \right] h(t) \quad \ldots\ldots\ldots\ldots \quad (15)$$

$$S^1 h(z) = \left[q^2 - K\frac{hA}{L} - KV \right] h(t) \quad \ldots\ldots\ldots\ldots \quad (16)$$

$$h(z) = \frac{S^1 h(t)}{qS^1 - K\frac{hA}{L} - \alpha} \quad \ldots\ldots\ldots\ldots \quad (17)$$

$$\boxed{h(z) = \frac{S^1(z)}{qS^1 - K\frac{hA}{L} - KVS^1}} \quad \ldots\ldots\ldots\ldots \quad (18)$$

Furthermore, considering the boundary condition, we have the following

At $t = 0 \; h^1(o) = h(o) = 0$

$$qS^1 - h(z) - K\frac{hA}{L} h(z) - KVS^t h(t) = 0 \quad \ldots\ldots\ldots\ldots \quad (19)$$

$$h(z) = \frac{0}{q - K\frac{hAS}{L} - KVS} \quad \ldots\ldots\ldots\ldots \quad (20)$$

Considering the following boundary condition when

At $t = 0 \; h^1(o) = h(o) = 0$

Apply the condition into this equation

$$qS^1 - h(z) - qho - q - K\frac{hA}{L} h(z) - K\frac{hA}{L} ho - h(z) - \alpha KVh(t) - KVho + h(t) \quad \ldots\ldots \quad (21)$$

$$q(z) - K\frac{hA}{L}h(z) = qS\,h(o)\ \ qho - \ K\frac{hA}{L}ho - h(z) - KV\,ho \quad \ldots\ldots\ldots\ldots \tag{22}$$

$$h(z) = \left[qs + q + K\frac{hA}{L} + KV\right]ho \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \tag{23}$$

$$h(z) = qs - q - K\frac{hA}{L} - KV \ \ ho \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

(24)

$$h(z) = \frac{\left[qs - q - K\dfrac{hA}{L} - KV\right]ho}{qs - K\dfrac{hA}{L} - KV} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \tag{25}$$

Applying quadratic equation to determine denominator for the equation

$$qs - K\frac{hA}{L} - KV = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \tag{26}$$

$$S = \frac{-b \pm \sqrt{b^2 - 4ac}}{2ah} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \tag{27}$$

Where $\alpha = q,\ b = K\frac{hA}{L},\ -\ c\ =\ KV$

$$S = \frac{-K\dfrac{hA}{L} \pm \sqrt{K\dfrac{hA}{L}^2 - 4qKVho}}{2q} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \tag{28}$$

$$\left[S_1\ \frac{-K\dfrac{hA}{L} + \sqrt{K\dfrac{hA}{L}^2 - 4qKVho}}{2q}\right]\left[S_2\ \frac{+K\dfrac{hA}{L} - \sqrt{K\dfrac{hA}{L}^2 - 4qKVho}}{2q}\right]$$

$$\ell^{\left[\frac{K\frac{hA}{L} - 4qKVho}{2q}\right]t^2\ \left[K\frac{hA}{L} - \frac{\sqrt{K\frac{hA}{L}^2 - 4qKVho}}{2q}\right]t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \tag{29}$$

The Laplace inverse of the equation yield

$$h(z) = \left[\frac{q}{z} + q + K\frac{hA}{L}\right] ho \;\; \ell^{\left[K\frac{hA}{L} + \frac{\sqrt{K\frac{hA^2}{L} - 4qKVho}}{2q}\right]t} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (30)$$

$$h(t) = \left[\frac{K\frac{hA}{L}}{t^2} ho\right]\left[K\frac{hA}{L} + \frac{\sqrt{K\frac{hA^2}{L} - 4qKVho}}{2q}\right] \ell^{\left[K\frac{hA}{L}\frac{\sqrt{K\frac{hA^2}{L} - 4qKVho}}{2q}\right]}$$

$$\ell^{\left[K\frac{hA}{L}\frac{\sqrt{K\frac{hA^2}{L} - 4qKVho}}{2q}\right]t - \left[K\frac{hA}{L}\frac{\sqrt{K\frac{hA^2}{L} - 4qKVho}}{2q}\right]t} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (31)$$

At this point $ho = 0 \;\; t \neq 0$

For equation (30) at $t = 0 \; h(o) = h(o)$, we have

$$ho = (q + K\frac{hA^2}{L} - \alpha) ho \; (1-1-1) = 0 = (q - K\frac{hA}{L} - KV)$$

Hence $q - K\frac{hA}{L} - KV = 0$

Equation (31) becomes

$$h(z) = ho\left[\frac{q}{t} + 2\right]\left[K\frac{hA}{L} + \frac{\sqrt{K\frac{hA^2}{L} - 4qKVho}}{2q}\right]t\left[K\frac{hA}{L}\frac{\sqrt{K\frac{hA^2}{L} - 4qKVho}}{2q}\right] \ldots\ldots \quad (32)$$

We recall that $e^x + e^{-x} = 2Cos\, x$, so that equation (32) can be expressed as:

$$h(z) = \left[K\frac{hA}{L} + 2\right] ho\, Cos\left[K\frac{hA}{L}\frac{\sqrt{K\frac{hA^2}{L} - 4qKVho}}{2q}\right]t \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (33)$$

The expression in [33] is the final model that will determine the rate of flow through permeability coefficients in the stratification of the formation. The formation of the soil was investigated through the standard experimental analysis that determines the rate permeability of flow in soil and water environment. The derived governing equation expressed the structural deposition of the strata under the influences of geological setting in the study location. The expressed model showcase the proof of permeability and velocity of fluid flow within the intercedes of the formation, such deposition of soil structural setting reflecting the matrix of its deposition confirmed to expressed the rate of fluid flow in the formation.

4. Conclusion

The depositions of permeability in soil are base on the structural setting of soil in the study area, the formation of the soil are base on several factors in the system, the concern of the study focus on the velocity of flow that reflect much more in the coefficient of permeability in the formation, such formation characteristics are found to have develop much impact in the flow rate in soil and water environment, the study showcase the rate of flow considering several factors, these factors influence the degree of permeability through the influence found to increase the permeability and velocity of flow in the study area. The study has express several factors that influences the deposition of permeability in the soil, these include environmental influence under the pressure from climatic condition, high rain intensities are found to generate influences from change of climatic condition , this factors were considered when the rate of fluid flow and rate of velocity deposition are determined in the study area

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