International Journal of Sustainable Energy and Environment
Vol. 1, No. 8, September 2013, PP: 167 -175, ISSN: 2327- 0330 (Online)
Available online at www.ijsee.com

Research article

MODELING THE BEHAVIOUR OF FLUID PRESSURE INFLUENCED BY VELOCITY AND MASS SOLUTE FRACTION IN POROUS MEDIUM, RIVERS STATE OF NIGERIA

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Abstract

The behaviour of Fluid pressure influence by velocity and mass solute fraction in porous medium has been evaluated. Expression from fluid pressure and mass fraction of solute are under the influence of porosity of the soil in the study location. Fluid pressures from this dimension are influenced by these paramount parameters that are reflected from stratification of the formation. Breakdown of the porous rocks is deposited in heterogeneous and homogeneous grain size reflecting the micropores and hydraulic conductivity that generates different degree of soil porosity thus influences fractional velocity of solute through these sources of depositions. But the focus of this study centred on velocity of mass fraction of solute found to be predominant through the geologic setting in the study location. Based on these factors, mathematical model were institute appropriate to monitor fluid rate variation under the influence of soil porosity in the study area. The systems were developed based on these variables that prearranged governing equation to express fluid rate pressure in the study area. The study is imperative because fluid depositions and its rate of variations were not evaluated, this also reflect the rate of velocity of mass fraction of solute, Moreso it showcase the determinants of fluid flow reflecting the yield of aquifers which will definitely influences the rate of concentration of solute thro mass velocity of fraction in the system. The expressed model will definitely be applied as a conceptual framework to predict fluid pressure and predict the velocity of mass fraction solute in the study location.

Keywords: river, Nigeria, Fluid,

Introduction

Direct measurement of pore pressure and hydrologic properties will strengthen our understanding of fundamental geological processes. We continue to debate the relationship between pore pressure and faulting in accretionary prisms [Davis, et al., 1983; Dahlen, et al., 1984; Saffer and Bekins, 2002]. Pore pressure is thought to have a role in the earthquake cycle [Sibson, 1981]. In hydrate systems, pore pressure may control how free gas is trapped and migrates [Hyndman and Davis, 1992; Holbrook et al., 2002; Flemings, et al., 2003]. Pore pressure is known to have an effect on the potential for submarine landslides [Dillon, et al., 2000; Dugan and Flemings, 2000; 2002]. Despite its importance, we are only beginning to learn how to directly measure pressure in low permeability sediments. In the Ocean Drilling Program, two techniques have been used. Permanent borehole installations (CORKs, ACORKs) have isolated parts of the formation to monitor pressure [Davis, 1992; Davis and Becker, 1994; Becker, et al., 1997] and penetrometers have been developed [Davis, 1997; Taylor, et al., 2000].

The induced pore pressure and its subsequent dissipation are constrained by the strength of the sediment and its consolidation coefficient. The initial excess pore pressure after penetration can be used to estimate the shear modulus of the sediments if conditions are undrained [*Randolph and wroth*, 1979a]. The pressure dissipation is used to infer in situ pore pressure and the coefficients of consolidation [Randolph and Wroth, 1979a; Gupta and Davidson, 1986], which can be used to infer permeability.

2. Theoretical back ground

Velocity and mass solute fraction in porous medium has been observed in such structural deposition to influence the flow net in soil and water environment. This condition has been confirmed through hydrological studies on the determination of different hydro flow net in different strata including their discharge rate to express the rate of yield coefficient at different strata in deltaic environment. It was confirmed that velocity of flow determines various fractional solute deposition under the influence of structural stratigraphy influenced by geologic setting expressed by the deltaic nature of the formation. In line with this conceptual framework, it is obvious that the influence of velocity of solid fraction under natural condition reflects the stratification that develops different flow pressure in soil and water environment. Such geological setting could be noted that formation characteristics may have reflected the velocity of fractional solute that structured the dynamic flow variations at every formation. Heterogeneous velocity of flow could be observed in this dimension through the structural stratification that express disintegration of the porous rock mass as its expressed on the velocity of fractional solute. It is obvious from this angle, that the pressure of fluid in soil structure express different influences depending on the structural strata setting based on the rate of structural grain size variations found to deposit in different horizons. In line with this conceptual framework the study of fluid pressure influenced by velocity of mass fractional solute are determined by hydraulic conductivity of the soil which express various variations of fractional solute under the influence of this paramount parameters described in the study. Based on these factors, fractional solutes will express different behaviours especially when it is a living organism. The behaviour of solute migrations is reflected on the deposition influence from the disintegration of porous rocks. In line with this conceptual development, fluid pressure dynamics are expressed by the rate of unit cross sectional area of an aquifer under a unit hydraulic gradient which is also known aquifer permeability or coefficient of permeability. In line with fluid pressure dynamic the intrinsic permeability of an aquifer is dependent on this liquid involved. Therefore, the characteristic of an aquifer alone is related to hydraulic conductivity which reflects the rate of velocity of solute in soil and water environment. Further more the reflection of hydraulic conductivity in this dimension is expressed as an intergraular aquifer that will depend on the grain size and sorting of the aquifer material including the degree of cementation. in fractional velocity of solute in fluid pressure .in fissured aquifer the intensity of fissuring and the openness and continuity of individual fissures will control the hydraulic conductivity, therefore the rate fluid pressure deposition in soil are reflected through the hydrogeological condition under the influence formation characteristics.

Nomenclature

P	=	Fluid density [ML^{-3}]
P	=	Fluid pressure [$ML^{-1} T^{-2}$]
QP	=	Fluid mass [$ML^{-3} T^{-1}$]
Kij	=	Intrinsic permeability of the porous medium
		a second-order Tensor [L^2]
U	=	Dynamic fluid viscosity [$ML^{-1} T^{-1}$]
g	=	Gravitational acceleration [LT^{-2}]
w	=	Solute mass fraction
		Mass of solute/mass of fluid [Dimensionless]
v	=	Velocity [LT^{-1}]
x	=	Distance [L]
T	=	Time [T]

$$Sop\frac{\partial^2 p}{\partial t^2} + \left[\varepsilon w\frac{\partial p}{\partial t}\right] w\frac{\partial p}{\partial t} - V\frac{\partial p}{\partial x_1}\left[\frac{K_1 p}{\mu}\right]\left[\frac{\partial p}{\partial x_j} + pg\frac{\partial p}{\partial x_i}\right] = QP_z \qquad \ldots\ldots \quad (1)$$

Equation (1) is the governing equation to monitor fluid pressure under the influenced velocity of fractional solute in the study location. Velocities of fractional solute depositions are determined through structural stratification of the formation under geological setting which express the variables in the system. Subject to this relation, void and permeability are structured to deposit in soil depending on the disintegration of the porous rock at different strata. The micropores between intercedes of the soil express the rate of porosity in the formation while the rate of hydraulic conductivities are expressed based on the rate of flow from one stratum to the other. Such conditions were considered in modifying the governing equation as expressed in equation (1).

Taking Laplace transformation of (1)

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$$\frac{\partial^2 p}{\partial t^2} = S^2 P_{(t)} - SP - P_{(0)} \quad \text{..} \quad (2)$$

$$\frac{\partial p}{\partial t} = SP_{(t)} - P_{(t)} \quad \text{..} \quad (3)$$

$$\frac{\partial p}{\partial t} = SP_{(t)} - P_{(t)} \quad \text{..} \quad (4)$$

$$\frac{\partial p}{\partial x} = SP_{(x)} - P_{(x)} \quad \text{..} \quad (5)$$

$$\frac{\partial p}{\partial x} = SP_{(x)} - P_{(x)} \quad \text{..} \quad (6)$$

$$P = P_{(0)} \quad \text{..} \quad (7)$$

Velocities of fraction solute are reflected including fluid pressure depositions are paramount in the system that is transformed to Laplace. These influential variables that formulate derivative functions were transformed into Laplace to express their relationship in the system the application of these mathematical methods. Such expression will detail their relations with respect to their functions on the modified equations that determine fluid pressures influenced by void ratio and permeability at different strata.

Submitting equation (2), (3), (4), (5), (6) and (7) into equation (1), yields

$$Sop\left[S^2 P_{(t)} - SP_{(t)} - P_{(0)}\right] - \varepsilon w\left[SP_{(t)} - P_{(t)} - wSP_{(t)} - P_{(x)}\right] - \left[\frac{Kp}{\mu}\right] - \left[SP_{(x)} + Pg\frac{\partial p}{\partial x_j} + pgP_{(x)}\right] = QP_z \quad (8)$$

$$SoP_{(x)} - SoSP^1{}_{(t)} - P_{(0)} - \varepsilon w\, SP_{(0)}\, \varepsilon wP_{(0)} - wSP_{(t)} - P_{(0)} - \left[\frac{Kp}{\mu}\right] - \left[SP_{(0)} - P_{(x)} + Pg\, SP_{(x)}\right] = QP_z \quad \text{.....} \quad (9)$$

Equation (9) expresses the breakdown of the variables into Laplace transform. This is to modernize the functional parameters in the classification on the direction of expressing their functions in details to platform the fluid variables depositions in different formations. The expression of these variables in this mathematical conception develop the behaviour of fluid depositions at different pressures under persuade of formation characteristics denoted as dominant variables that is in the system. Equations (6) to (9) are derived solution to incorporate these variables and also to express their functions in the system, subject to their relations to each other as modified from the governing equation.

Considering the following boundary condition at

$$t = 0, P^1{}_{(0)} = P_{(0)} \quad \text{..................} \quad (10)$$

$$P_{(t)}\left[Sop\,S^{2} - Sop - \varepsilon w - w - \frac{Kp}{\mu} + Pg\right] = 0 \quad \text{.................. (11)}$$

But considering the boundary condition

At $t > 0,\ P^{1}{}_{(0)} = P_{(0)} = P_{(0)}$ .... (12)

Equation (12) expresses the integration of various variables in the system being transformed to Laplace. These functional parameters were developed to form a mathematical equation that is expressed through this conceptual mathematical method. The expression of the variables reflects the condition of fluid pressure influenced by velocity of fractional solute through formation characteristics such as porosity. Solute fractions in this condition are found by man-made activities that are integrated into natural fluid that deposits in the formation migrating with the aid of micropores in the structural stratification of the formation to aquiferous zones, this where hydraulic conductivities display their roles. This reflects intrinsic permeability of an aquifer independent of the fluid involved. It is found to be characteristics of an aquifer alone, which reflect hydraulic conductivity equation, but the focus of the study is fluid pressure deposition that is being reflected on velocity of fractional solute in the system. Therefore, the expressed parameters denoted mathematically are parameters that influence the fluid pressure deposition in the system. Subject to this relation, the expressed functions of this parameter are applied to develop the boundary values that determine the time of flow reflecting the variation of the soil stratification, including fluid pressure depositions under the influence of hydraulic conductivity of the formations in the strata.

$$P_{(x)} - Sop\,S_{(t)} - \varepsilon w\,S_{(t)} - w\,S_{(t)} - \frac{Kp}{\mu}\,S_{(x)}\,QPz = Sop\,P_0 + SoPPo + \varepsilon wP_0 + wP_0 + \frac{Kp}{\mu}P_0 \quad \text{... (13)}$$

$$\left[Sop - \varepsilon w - w - \frac{Kp}{\mu} - QPz\right]P_{(t)} = \left[Sops + Sop + \varepsilon w + w + \frac{Kp}{\mu}\right]P_0 \quad \text{................. (14)}$$

$$\frac{P_{(t)} = Sop + \varepsilon w + w - \frac{Kp}{\mu}}{Sop - \varepsilon w - w - \frac{Kp}{\mu} - QPz}\,P_0 \quad \text{.................................. (15)}$$

Applying quadratic equation, we have

$$S = \frac{-b \pm \sqrt{b^{2} - 4ac}}{2a} \quad \text{.................................. (16)}$$

Concerning the derived solution from Laplace transformation, quadratic equation was found suitable to structure the derived solution prepared to consider different situations under the influence of formation variations in soil and water environment. Such perception, if introduced will definitely display the pressure of fluids in details in view of several variations from formation characteristics such as void ratio and permeability. Fluctuations from the formations depositions are reflected in the systems, subject the fluid pressure to deposit diverse disparity in diverse strata.

Where $a = Sop\varepsilon w, \quad b = \dfrac{wKp}{\mu}, \quad c = QPz$

$$\frac{-\dfrac{WkP}{\mu} \pm \sqrt{\dfrac{WkP^2}{\mu} + 4Sop\varepsilon w\; QPz}}{2Sop\varepsilon w} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (17)$$

$$C_{(t)} = A\exp^{\left[\frac{-\frac{WkP}{\mu} + \sqrt{\frac{-WkP^2}{\mu} + 4Sop\varepsilon w\; QPz}}{2Sop\varepsilon w}\right]_t} - \exp^{\left[\frac{-\frac{WkP}{\mu} + \sqrt{\frac{-WkP^2}{\mu} + 4Sop\varepsilon w\; QPz}}{2Sop\varepsilon w}\right]_t} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (18)$$

Subjecting equation (18) to the following boundary condition and initial value condition.

$$x = 0\; C_{(0)} = 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (19)$$

Boundary values were expressed to incorporate the inverse Laplace conditions that were applied in the system. The boundary condition shows the time limit, initial and final pressure rate of flow within the intercedes of the formation under the influence of the micropores, this that reflect void ratio and the hydraulic conductivity. This to express permeability of the formation in the system. This boundary formation shows the limit of pressure flow with respect to time and distance. The study specifically focuses on the dominant variables, but never undermined other dependent variables that also influence pressure rate of fluid at different strata in the system.

We have *B = -1 and A = 1* ……………………………… (20)

So that our particular solution, will be in this form

$$C_{(t)} = A\exp^{\left[\frac{-\frac{WkP}{\mu} + \left(\frac{-WkP^2}{\mu} - 4Sop\varepsilon w\; QPz\right)^{1/2}}{2Sop\varepsilon w}\right]_t} = \exp^{\left[\frac{-\frac{WkP}{\mu} + \left(4Sop\varepsilon w\; QPz\right)^{1/2}}{2Sop\varepsilon w}\right]} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (21)$$

Applying inverse Laplace in equation (21) were focused on the relation of variation of the soil structural deposition influenced by breakup of the porous rock, it reflects the variation of the fluid pressure at diverse strata. These displays the condition of fluid flow, expressing disparity of flow net influenced by permeability and void ratio. In line with this relation, it is clear that the pressure of fluid at diverse strata will be varied. Therefore, inverse Laplace transformation applications were found essential so that the variation of fluid pressure can be reflected on the derived solution.

But $e^{x} = e^{-x} = 2Sinx$

Therefore, the expression of (22) can be written in this form

$$C_{(t)} = 2\ Sin\left[\frac{WkP}{\mu} + \left(\frac{WkP^2}{\mu} + 4Sop\varepsilon w\, QPz\right)\right]^{1/2} t \qquad \text{..................} \quad (22)$$

But if $t = \frac{x}{v}$

Therefore, the model can be expressed as:

$$C_{(x)} = 2\,Sin\left[\frac{WkP}{\mu} + \left(\frac{WkP^2}{\mu} + 4Sop\varepsilon w\, QPz\right)^{1/2}\right]\frac{x}{v} \qquad \text{..................} \quad (23)$$

But if $\frac{x}{v} = t$, we have

$$C_{(t)} = 2\ Sin\left[\frac{WkP}{\mu} + \left(\frac{WkP^2}{\mu} + 4Sop\varepsilon w\, QPz\right)^{1/2}\right]^{t} \qquad \text{..................} \quad (24)$$

Considering equation (24) and (25) yield

$$C_{(x,t)} = 2\,Sin\left[\frac{WkP}{\mu} + \left(\frac{WkP^2}{\mu} + 4Sop\varepsilon w\, QPz\right)^{1/2}\right]x + 2\,Sin\left[\frac{WkP}{\mu} + 4Sop\varepsilon w\, QPz\right]^{1/2} \qquad \text{.........} \quad (25)$$

The expression in (25) is the final model equation. This expression mirrors all the situations that were considered to influence the fluid pressure deposition at diverse strata in the system. Dominant parameters were prearranged in the system to extensively express their functions on the deposition of fluid pressure rate in soil and water environment. Such situations were considered to rationalize the behaviour of fluid pressure under the influence of formation characteristics in the study area. It is noted to be dominant variables that determine the deposition of fluids in soil and water environment. The study focuses on the fluid rate as it determines the increase of aquiferous yield coefficient of groundwater system under the influence of the micropores deposition that reflect the structure of variation of void ratio as expressed in the stratification of the formation.

4. Conclusion

Fluid pressure variation influenced by velocity of fractional solute and porosity has been thoroughly evaluated, this based on the geological formation in the study location. These situations were experienced from hydrogeological and desk studies that reflect dissimilar yield coefficient at different formations in the study area. Reflecting this situation are expressed on the rate of fluid deposition based on breakdown of the stratification of the porous rock that deposits different particle grain sizes showcasing velocity of fractional solute and porosity. Subject to this relative, it was observed that fluid pressure are developed at different rate are reflected on the structural stratification between intercedes of the strata reflecting velocity of fractional solute and porosity. Other relevant parameters were also considered in the system, but were made immaterial due to the two foremost parameters which are independent variables that reflect every other influence of fluid flow and its pressure rate in soil and water environment. The study is essential because the fluid flow determine the yield rate mostly at aquiferous zone and lack of information of fluid pressure which express the yield rate of aquiferous zone were not made available. This predictive model from the derived governing equation, have developed a model which is a conceptual framework that can be applied to monitor the flow of fluid and its pressure rate in the study location. Experts in this profession will definitely apply this concept to determine the best yield aquiferous zone in construction and design of water wells.

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