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Research article

MOEDELING AND SIMULATION OF PLUG FLOW APPLICATION ON FLOW NET INFLUENCED BY VARIATION OF VELOCITY AND PERMEABILITY IN HETEROGENEOUS GRAVEL FORMATION IN COASTAL AREA OF PORT HARCOURT, NIGER DELTA OF NIGERIA

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Abstract

Flow net are one of the formation influences that interact with the geophysical properties of soil in design of foundation including ground water exploitation and exploration, these depend on the type of construction that is been carried out. The study under normal condition express the behavioral influences of flow net in design of foundation and ground water system, the study were able to determined various influences of from various direction of flow, including variation in the structural strata in deltaic formation, more so, system that express the condition of flow net were developed, these generated the governing equation that will monitor the rate flow in the strata, the influences from deltaic formation were expressed in the system, these parameters developed various way in the derived solution on how they influences the flow direction in different strata, the derived solution generated model for the flow net, the developed model were simulated, these produced theoretical values from the simulation, the values were compared with experimental values and both parameters developed a favuorable fits validating the model. Experts will applied this generated model as a tool to monitor flow net in any construction that they are carrying out in the study location.

Keywords: modeling and simulation, flow net velocity, permeability and gravel formation

1. Introduction

It has been state by Liu Jianjun, Liang Bing, Zhang Mengtao [2] and others had established the gas flow models of coal seam in non-isothermal situation, bearing in mind the adsorption or desorption of coal seam gas with variation of temperature. Both Liu Jianjun [3] and Wang Ziming [4] had studied the trouble of three field joined in the procedure of in water, oil and gas field development, but had not known a precise solving method of other structure influences such as heat field model and the decoupling idea of three field coupled, these had no example of simulates temperature field. Based on the study of Zhao Yangsheng, Bruel and Zhongjing Renyan and others, Liang Bing etc [5] (2001), Wang Ruifeng etc [6] (2002) developed the mechanical -hydro- hermo coupling equations of three-dimensional fracture network block fractured media and high-temperature rock. Wu Yanqing [7] had established disseminated parameter model of continuous medium for three coupled of the seepage field, stress field and temperature field by applying the device assessment and hybrid analysis method. Kong Xiangyan [8] and others based on linear thermo elasticity theory of porous materials small deformation, bearing in mind the changes of fluid density, solid compactness and porosity in relation to pressure and temperature, changes of liquid viscosity in relation to temperature, giving a full and easily thermo-hydro-mechanical coupling equations. Since some of the coupling process (such as nuclear waste repository safety assessment) need to simulate several decades or even longer, the equations highlighted the differential of strain on time, discussed the solving methods, emphasis on the results in different engineering applications, also discussed briefly to other more complex situations. Xue Qiang [9] based on theory of porous media, variety of mechanics and multiphase seepage mechanics, initial research of contaminants transports, change in porous media problem, established mathematical mode of pollutant migration under multi-field coupling, to provide theoretical basis for the prediction problem of solving ecological pollution. Song Shaoyun[10] had given differential equations control by a number of field, modelled for the multi-field coupling issues, and proceeding detailed study for coupling relationship, giving 14 kinds of coupling relationship about displacement field, flow field, electric field, magnetic field and temperature field, analyzed it by using tables of phase diagram. Xu Hehua, Zhou and, Chenglong [14, 15]. And others major considered coupling between temperatures, flow rate, pressure, established of a multi-field non-linear mathematical model of the interactional coupling. Ignored the impact of sediment compaction items, also had not considered the temperature and pressure source term. Li Ning [12] and others based on frozen multiphase medium static equilibrium equation, conservation of mass and conservation of energy, soil structure and ice pieces as accepted, the transfer mechanisms between water and water ice phase transition mechanism, derived differential governing equations for temperature field, deformation field, and moisture field coupled problem in turkey frozen, ice and water medium systematically. Sheng Jinchang [13] assumed that the phase fluid is midphase flow, solid medium is non-boiling saturated and thermoelastic porous media, given fully coupled mathematical model of hydro-mechanical-thermo of porous rock; the model consisted of mutual coupling equations of fluid mass conservation equation, the mechanical balance equation and the energy equation, which contains a number of coupling terms, and define a series of constitutive and coupling variables Zhou and, Chenglong [14, 15].

2. Governing equation

$$V\frac{\partial q}{\partial z}\quad K\frac{\partial q}{\partial t}+\frac{N_f}{N_d}\frac{\partial q}{\partial z} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (1)$$

$$V\frac{\partial q}{\partial z}-\frac{\partial q}{\partial z}=\frac{\partial q}{\partial z}+K+\frac{nf}{Nd} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (2)$$

$$(V-1)\frac{\partial q}{\partial z} = \frac{\partial q}{\partial z} + K + \frac{nf}{Nd} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (3)$$

$$(V-1)\frac{\partial q}{\partial z} = \frac{\partial q}{\partial t} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (4)$$

$$0 = \frac{\partial q}{\partial z} + K + \frac{nf}{Nd} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (5)$$

i.e. $$\frac{\partial q}{\partial z} = -K + \frac{nf}{Nd} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (6)$$

From (5), integrate directly

$$q = \left(-K - \frac{nf}{Nd}\right)t + q_1 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (7)$$

From (6) $(V-1)\dfrac{\partial q}{\partial z} = \dfrac{\partial q}{\partial t}$

Let $q = ZT$ $\qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad$ (8)

$$\frac{\partial q}{\partial z} = Z^1 T \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (9)$$

$$\frac{\partial q}{\partial t} = ZT^1 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (10)$$

Substitute (9) and (10) into (3), we have

$$V-1\,Z^1 T = \left(K + \frac{nf}{Nd}\right)ZT^1 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (11)$$

$$V-1\frac{Z^1}{Z} = \left(K + \frac{nf}{Nd}\right)\frac{T^1}{T} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (12)$$

$$V-1\frac{Z^1}{Z} = \phi \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (13)$$

$$\left(K + \frac{nf}{Nd}\right)\frac{T^1}{T} = \phi \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (14)$$

From (13) $\dfrac{Z^1}{Z} = \dfrac{\phi}{V-1}Z$ $\qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad$ (15)

$$\text{In } Z = \frac{\phi}{V-1} Z + q_3 \qquad \text{………………………..} \qquad (16)$$

$$Z = A\ell^{\frac{\phi}{V-1} Z} \qquad \text{………………………..} \qquad (17)$$

From (14) $\left(K + \frac{nf}{Nd} \right) \frac{T^1}{T} = \phi$

$$T = \frac{\phi}{K + \frac{nf}{Nd}} \qquad \text{………………………..} \qquad (18)$$

$$\text{In } T = \frac{\phi}{K + \frac{nf}{Nd}} t + q_3 \qquad \text{………………………..} \qquad (19)$$

$$T = B\ell^{\frac{\phi}{K + \frac{nf}{Nd}} t} \qquad \text{………………………..} \qquad (20)$$

Put (17) and (20) into (8) yield:

$$q_2 = A\ell^{\frac{\phi}{V-1} Z} \bullet B\ell^{\frac{\phi}{K + \frac{nf}{Nd}} t} \qquad \text{………………………..} \qquad (21)$$

$$q_2 = AB\ell^{\left(\frac{Z}{V-1} + \frac{t}{K + \frac{nf}{Nd}} \right)\phi} \qquad \text{………………………..} \qquad (22)$$

Hence general solution becomes

$$q[Z,T] = q_1 + q_2 \qquad \text{………………………..} \qquad (22)$$

$$q[Z,T] = AB\ell^{\left(\frac{Z}{V-1} + \frac{t}{K + \frac{nf}{Nd}} \right)}\phi \qquad \text{………………………..} \qquad (23)$$

3. Materials and Method

Falling-head test method is the method applied. This method is usually employed to determine a coefficient of permeability for fine grain soil. The soil sample is usually undisturbed and very often the u 4 sampling tube can be used as container during the test. A coarse filter screen is placed at the upper and lower ends of the sample tube. The base of the sample tube is connected to the water reservoir, to the top of the sample tube is connected a glass stand pipe of known cross section area. This pipe is filled with water as the water seeps down through the soil sample; observations are taken of time versus height of water in the standpipe above base reservoir level. Series of tests are performed, using different sizes of stand pipe and the average value of the coefficient of permeability is taken. Note must be taken of the unit of weight of the sample's moisture content.

Furthermore, falling-head permeability test using the standard mild parameter, a substantial head loss can occur through the thick porous stone in the base. The small water entry orifice through the cap may produce a sample cavity from local flow condition. Care is required to produce a water tight system. Use a mater stick to obtain the hydraulic head h1 and h2. In the falling test, since water flow through the sample as the level of water in the stand pipe drop over a time interval at the rate of flow can determine the value of *k* by plotting in pole against it and finding the gradient. Notice that in a falling head test, the effective stresses change because the pore pressure change as the level of water in the standpipe falls. Any volume changes that occur as a result of these changes of effective stress have to be neglected. Value of the coefficient of permeability measured in laboratory permeability test are often highly inaccurate, for a variety of reasons such as autotrophy (i.e. value of *k* is different for horizontal and vertical flow) and small sample being unrepresentative of volume of soil in the ground and in practice value of *k* measure from insitu test are much better. Its sample are collected from bore hole drilling site (i.e. aquifer material) through insitu method of sample collection on a sequence of 3 metres interval in several locations, but notice is taken on the dynamics of the sample based on the type of deposition. Other tests include void ratio and porosity for all the study area.

4. Result and Discussion

Results and discussion are presented in tables including graphical representation of flow net in a Batch system conditions

Table 4.1: Plug Flow Method on Flow Net at Different Depth

Depth [M]	Flow Net
2	1.62E-03
4	1.62E-03
6	1.62E-03
8	1.62E-03
10	1.63E-03
12	1.63E-03
14	1.63E-03
16	1.63E-03
18	1.63E-03
20	1.63E-03

Table 4.2: Plug Flow Method on Flow Net at Different Time

Time per day	Flow Net
2	1.62E-03
4	1.62E-03
6	1.62E-03
8	1.62E-03

10	**1.63E-03**
12	**1.63E-03**
14	**1.63E-03**
16	**1.63E-03**
18	**1.63E-03**
20	**1.63E-03**

Table 4.3: Plug Flow Method on Flow Net at Different Time

Time per day	**Flow Net**
2	**1.62E-03**
4	**1.63E-03**
6	**1.63E-03**
8	**1.64E-03**
10	**1.64E-03**
12	**1.65E-03**
14	**1.65E-03**
16	**1.66E-03**
18	**1.66E-03**
20	**1.67E-03**
22	**1.67E-03**
24	**1.68E-03**
26	**1.68E-03**
28	**1.69E-03**
30	**1.69E-03**

Table 4.4: Plug Flow Method on Flow Net at Different Depth

Depth [m]	**Flow Net**
0.2	**1.62E-03**
0.4	**1.63E-03**
0.6	**1.63E-03**
0.8	**1.64E-03**
1	**1.64E-03**
1.2	**1.65E-03**
1.4	**1.65E-03**
1.6	**1.66E-03**
1.8	**1.66E-03**
2	**1.67E-03**
2.2	**1.67E-03**
2.4	**1.68E-03**
2.6	**1.68E-03**
2.8	**1.69E-03**

3	**1.69E-03**

Table: 4.5 Comparison of Theoretical and Measured Values of Plug Flow Method on Flow Net at Different Depth

Depth [M]	Theoretical Values	Measured Values
2	**1.62E-03**	**1.01E-03**
4	**1.62E-03**	**1.00E-03**
6	**1.62E-03**	**1.00E-03**
8	**1.62E-03**	**1.01E-03**
10	**1.63E-03**	**1.01E-03**
12	**1.63E-03**	**1.01E-03**
14	**1.63E-03**	**1.01E-03**
16	**1.63E-03**	**1.01E-03**
18	**1.63E-03**	**1.01E-03**
20	**1.63E-03**	**1.02E-03**

Table: 4.6 Comparison of Theoretical and Measured Values of Plug Flow Method on Flow Net at Different Time

Time per day	Theoretical Values	Measured Values
2	**1.62E-03**	**1.01E-03**
4	**1.62E-03**	**1.00E-03**
6	**1.62E-03**	**1.00E-03**
8	**1.62E-03**	**1.01E-03**
10	**1.63E-03**	**1.01E-03**
12	**1.63E-03**	**1.01E-03**
14	**1.63E-03**	**1.01E-03**
16	**1.63E-03**	**1.01E-03**
18	**1.63E-03**	**1.01E-03**
20	**1.63E-03**	**1.02E-03**

Table: 4.7 Comparison of Theoretical and Measured Values of Plug Flow Method on Flow Net at Different Depth

Depth [m]	Theoretical Values	Measured Values
0.2	**1.62E-03**	**1.00E-03**
0.4	**1.62E-03**	**1.00E-03**
0.6	**1.62E-03**	**1.00E-03**
0.8	**1.62E-03**	**1.00E-03**
1	**1.62E-03**	**1.00E-03**
1.2	**1.62E-03**	**1.00E-03**
1.4	**1.62E-03**	**1.01E-03**
1.6	**1.63E-03**	**1.01E-03**
1.8	**1.63E-03**	**1.01E-03**
2	**1.63E-03**	**1.01E-03**

2.2	**1.63E-03**	**1.01E-03**
2.4	**1.63E-03**	**1.01E-03**
2.6	**1.63E-03**	**1.01E-03**
2.8	**1.63E-03**	**1.01E-03**
3	**1.63E-03**	**1.01E-03**

Table: 4.8 Comparison of Theoretical and Measured Values of Plug Flow Method on Flow Net at Different Depth

Time per day	Theoretical Values	Measured Values
2	**1.62E-03**	**1.00E-03**
4	**1.63E-03**	**1.01E-03**
6	**1.63E-03**	**1.01E-03**
8	**1.64E-03**	**1.02E-03**
10	**1.64E-03**	**1.02E-03**
12	**1.65E-03**	**1.02E-03**
14	**1.65E-03**	**1.03E-03**
16	**1.66E-03**	**1.03E-03**
18	**1.66E-03**	**1.04E-03**
20	**1.67E-03**	**1.04E-03**
22	**1.67E-03**	**1.04E-03**
24	**1.68E-03**	**1.05E-03**
26	**1.68E-03**	**1.05E-03**
28	**1.69E-03**	**1.06E-03**
30	**1.69E-03**	**1.06E-03**

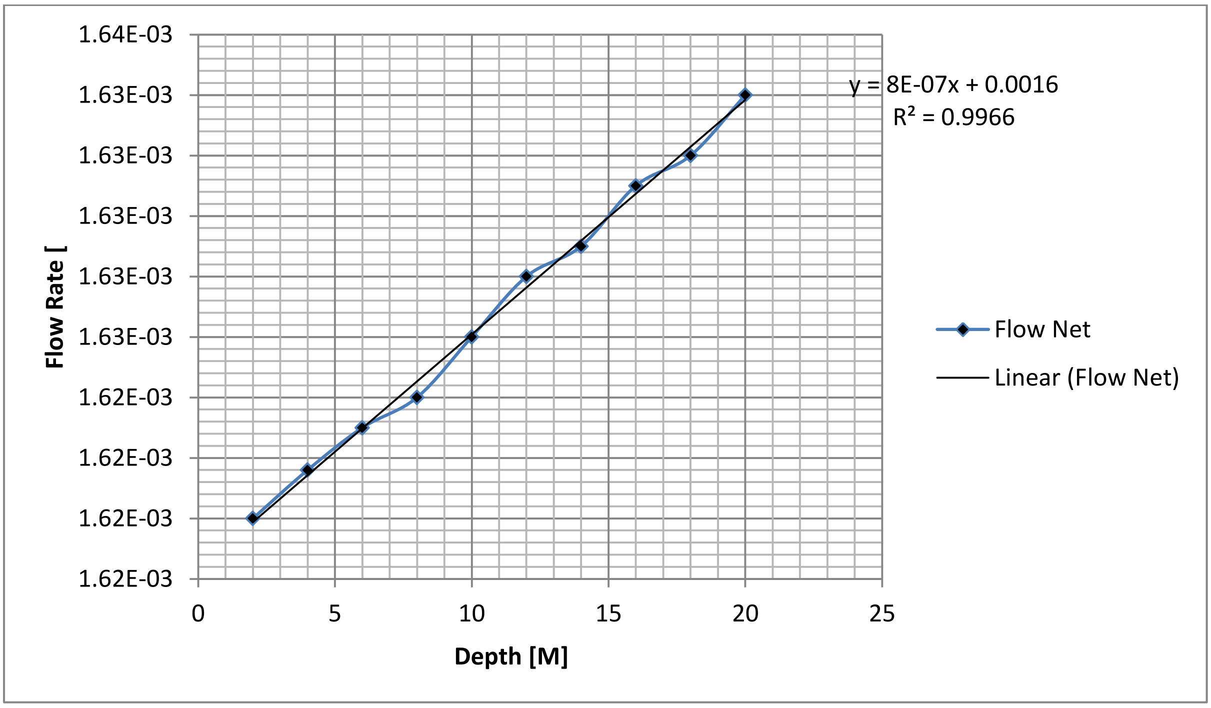

Figure 1: Plug Flow Method on Flow Net at Different Depth

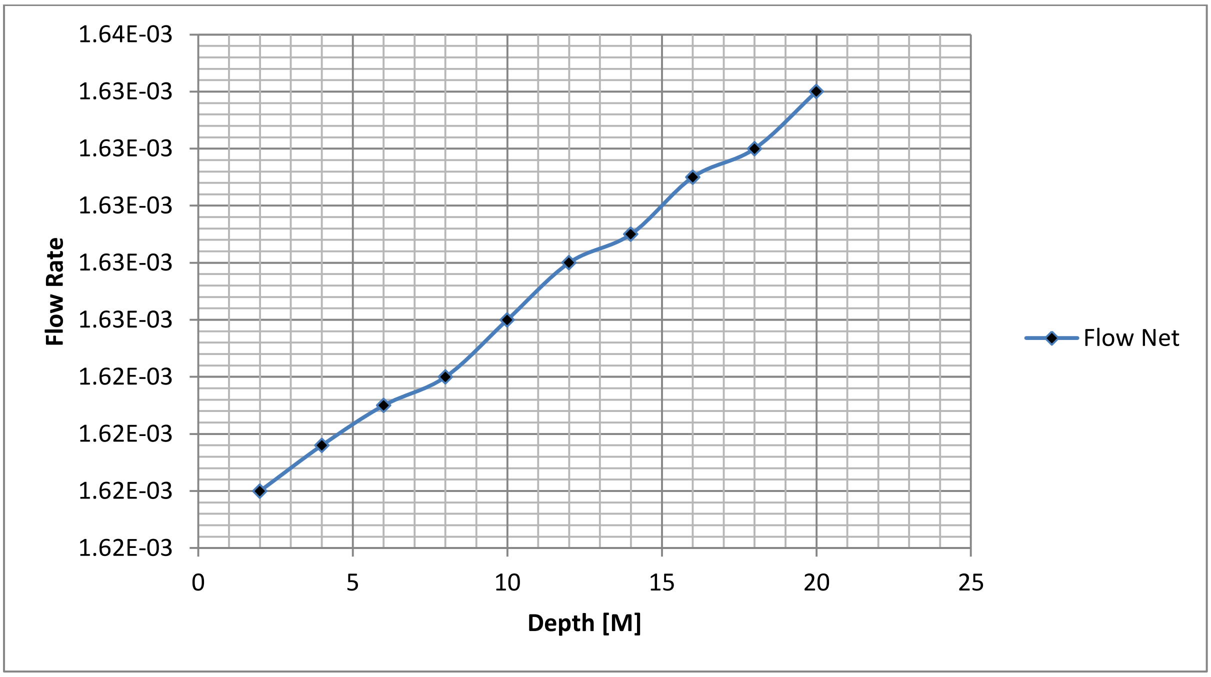

Figure 2: Plug Flow Method on Flow Net at Different Depth

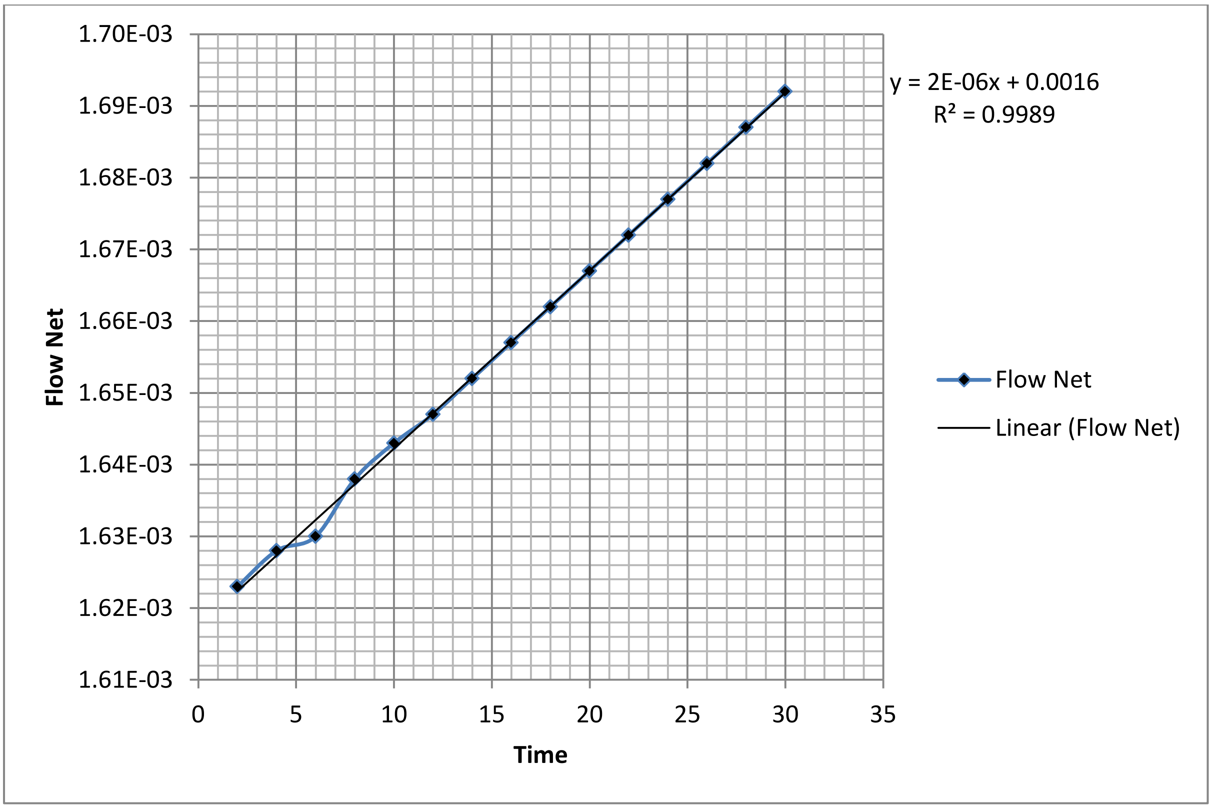

Figure 3: Plug Flow Method on Flow Net at Different Time

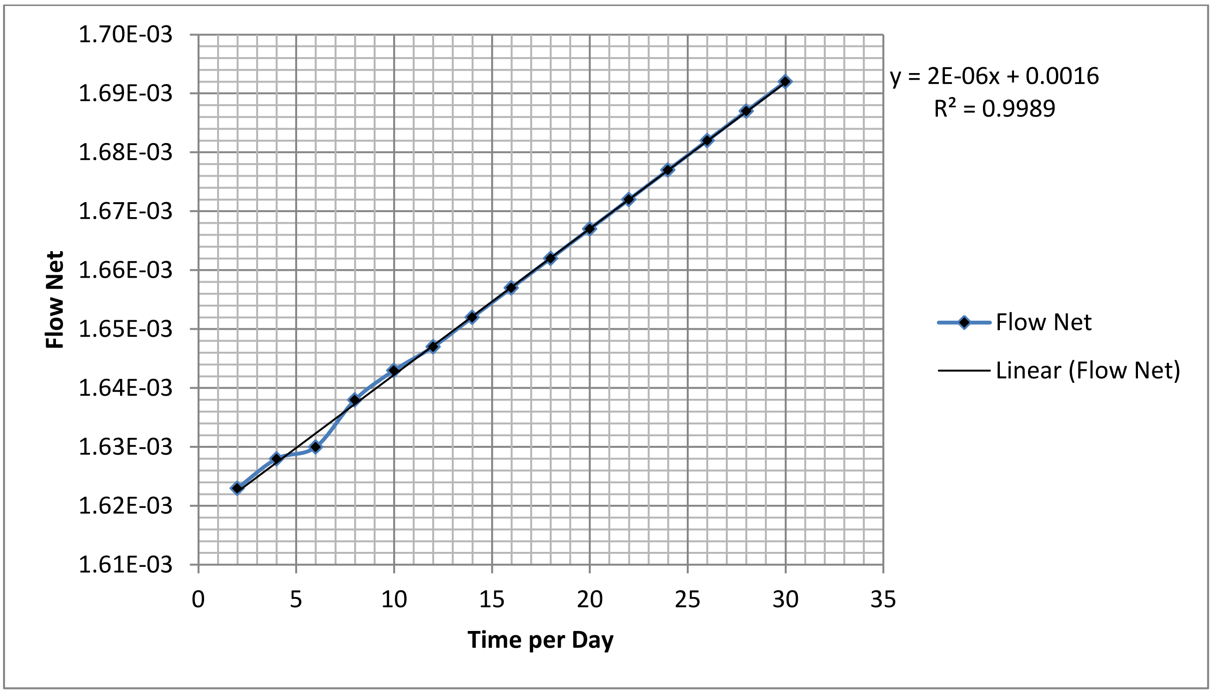

Figure 4: Plug Flow Method on Flow Net at Different Time

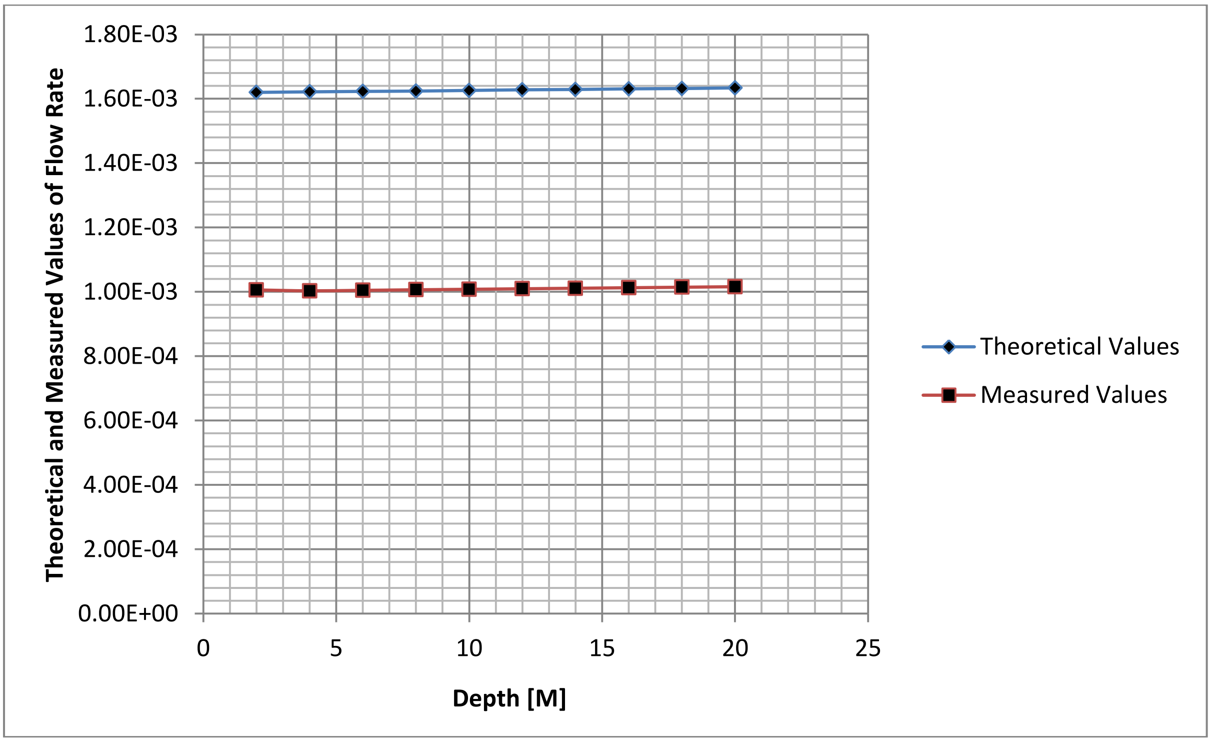

Figure: 5 Comparison of Theoretical and Measured Values of Plug Flow Method on Flow Net at

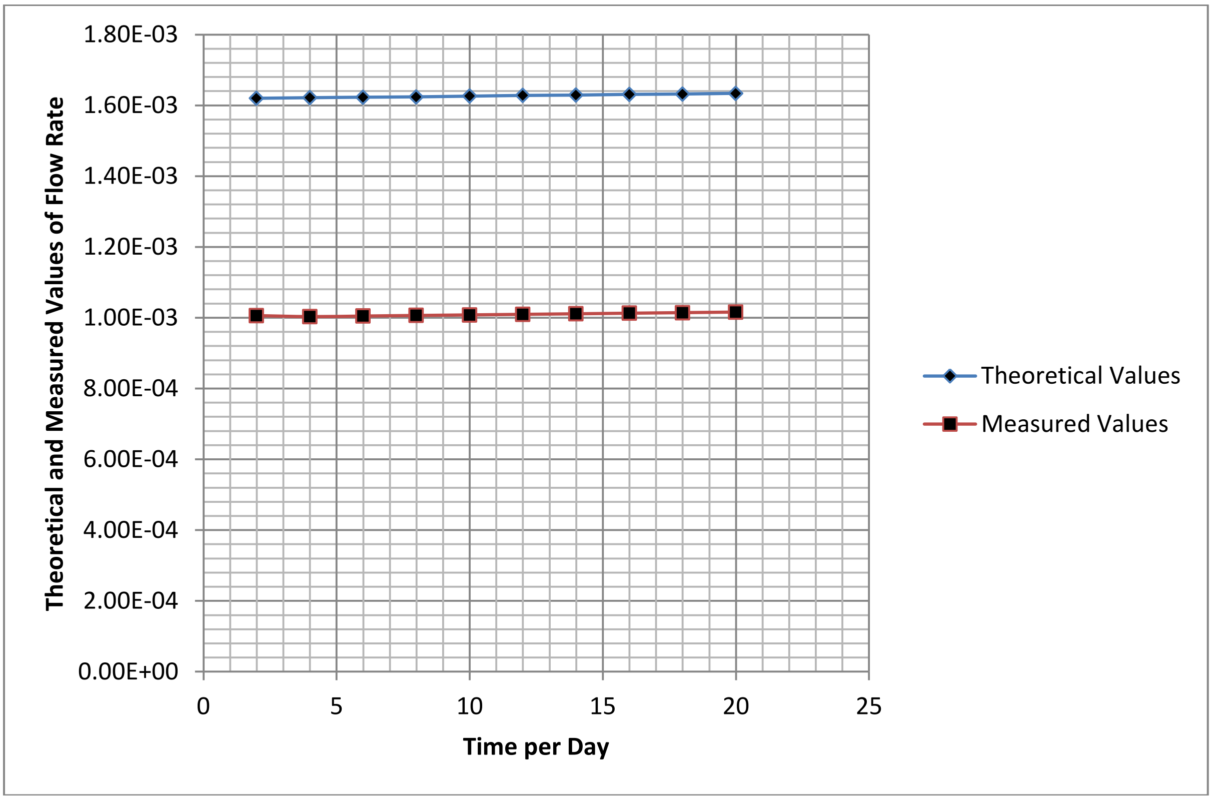

Figure: 6 Comparison of Theoretical and Measured Values of Plug Flow Method on Flow Net at Various Time

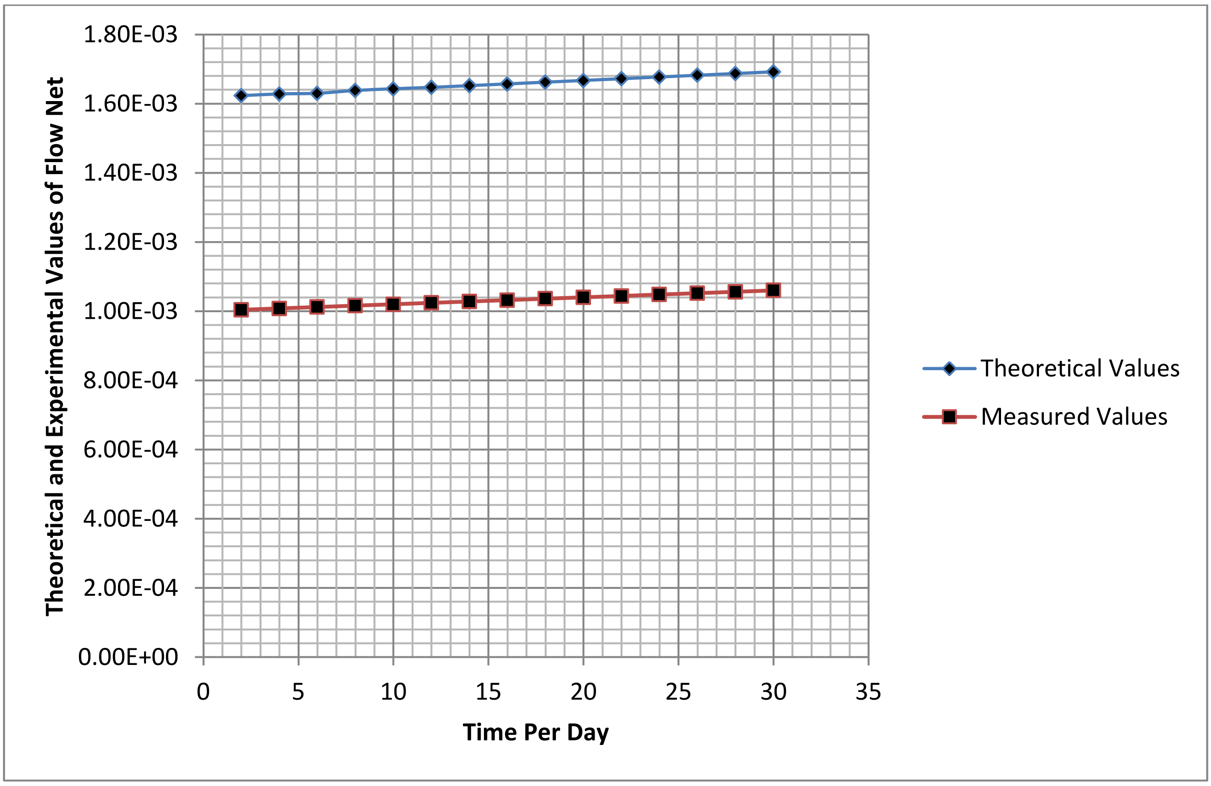

Figure: 7 Comparison of Theoretical and Measured Values of Plug Flow Method on Flow Net at Various Time

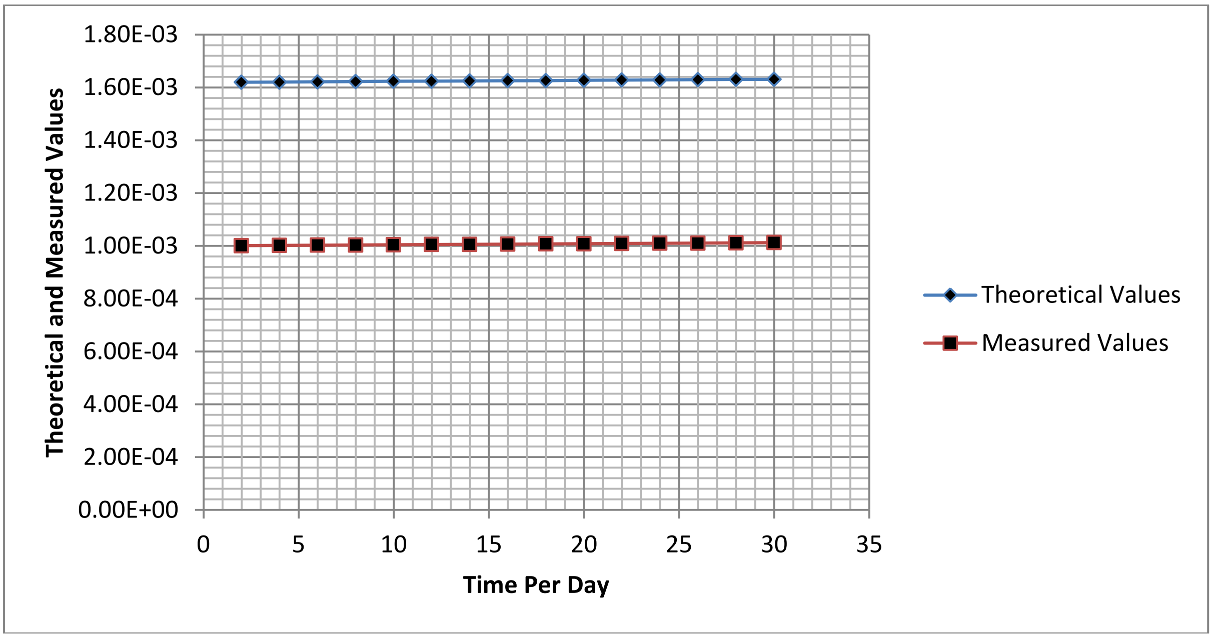

Figure: 8 Comparison of Theoretical and Measured Values of Plug Flow Method on Flow Net at Various Time

The express figures shows the migration of flow within the formation under several influences from geological formation of the area, the rate of flow in figure one to four express the rate of flow in an exponential level as presented in the figures, the expression implies that the rate flow within the pore distribution of the strata are influenced by some predominant formation characteristics, the depositional structure of the strata within the intercedes are deposited under the influences of these predominant formation characteristics expressing rapid migration of flow in exponential state. Such development influences the direction of flow net in the study as area expressed in figure one to four. While figure five to eight are the comparison between the theoretical values from model simulation and the experimental values that determine the rate of flow at any formation, both parameter in there graphical representation express best fit in exponential linear direction, this implies that there rapid increase of flow under the influences of porosity, this formation characteristic as early stated above is the predominant influential parameters that pressure the flow net deposition in the study location.

5. Conclusion

The behaviour of flow net in the study area expresses lots of influences from formation characteristics, flow net are monitored by application of this concept that determine the actual velocity of flow including pore distribution of the strata within the formation, predominant formation characteristics like porosity were found to influences the velocity of flow to be very high rate, the behaviour of fluid flow in the strata are base on the geological setting reflecting on the structural deposition of the formation between the intercedes, such condition are express in the developed model including other influential deposition that were not focus of the study such as thermo-hydro-mechanical coupling, this means the interaction between fluid, solid and changing temperature field in the system composed by them. In the question of thermo-hydro mechanical coupling, thermal effect and of fluid pore pressure are base on rock deformation; this deformation and fluid seepage lead to changes in temperature field. Rock deformation and thermal effects lead to changes of reservoir permeability characteristics and pore fluid pressure, thus affecting the seepage of fluid; the above three affects concurrent.

The reservoir has large temperature field fluctuations, especially the implementation of thermal recovery, which was located in the deep underground, having great stress and pore fluid pressure and severe temperature changing; reservoir rock shows complex deformation characteristics, combined with regular injection mining disturbance, leading to reservoir seepage, deformation, temperature in a complex interaction and constantly changing with time and space, so, The reservoir that large temperature field fluctuations, especially the implementation of thermal recovery that is typically thermo-hydro-mechanical coupling system. The state parameters are other influences in the system, but were not predominant as early stated above, the study is imperative because flow net has under geophysical characteristics must interact with other parameters in the formation, such condition developed variation in the deposition of flow net in the soil.

References

[1]. Liu Jianjun; Lin Xiangui. Mathematical model for three fields matching in development [J],Special Oil & Gas Reservoirs,2001,8 (2): 31-37(in Chinese).

[2]. WANG Zi ming; DU Zhi min. The Fluid-Solid-Heat Coupled Math s Model in the Multiphase Flow Porous Media of Elastic Reservoir [J],Petroleum Geology & Oilfield Development in Daqing,2003,22 (1): 29-31,37(in Chinese).

[3]. Huang Tao Yang Lizhong. A Mathematical Model for the Coupling among Groundwater Seepage Stress Temperature in Engineering Rock Mass [J]. journal of southwest jiaotong university,1999,34 (1):11-15(in Chinese).

[4]. Liang Bing,Liu Jianjun,Fan Houbin,Zhang Mengtao.the mathematical model and its numerical solution of gas flowunder unequal temperatures[J]. Chinese Journal of Rock Mechanics and Engineering,2000,19(01):1-5(in Chinese).

[5]. Liang Bing,Sun Keming,Xue Qiang.The Research of Fluid-solid Coupling in the Ground Engineering[J].Journal of Liaoning Technical University,2001,20(02):129-134 (in Chinese).

[6]. Zhao Yangsheng,Wang Ruifeng,Hu Yaoqing,Wan Zhijun,Xie Yaoshe.3d numerical simulation for coupled thm of rock matrix-fractured media in heat extraction in hdr[j].chinese journal of rock mechanics and engineering ,2002,21(12): 1751-1755(in Chinese).

[7]. Wu Yanqing. Principles of rock mass hydraulics[J],Hydrogeology and Engineering Geology,1997,(02): 54-57(in Chinese).

[8]. Kong Xiangyan,Li Daolun,Xu Xianzhi,Lu Detang.Study on the mathematical models of coupled thermal-hydrological-mechanical (THM) processes[J].Journal of Hydrodynamics,2005,20(02): 270-274(in Chinese).

[9]. Xue Qiang, Liang Bing, Wang Qixin. application of multi-field coupling theory to the process of contaminant transport[J].Chinese Journal of Rock Mechanics and Engineering,2002,21(S2): 2318-2321(in Chinese).

[10]. Song Shaoyun. modeling of multiphysics problem and research of coupling relation[j],Journal of Wuhan Polytechnic University, 2005,24(04): 21-23(in Chinese).

[11]. Xu Hehua ,Zhang Jian Xiong ,Liangping . the numerical simulation of coupling flow,temperature and pressure in yinggehai basin[j].china offshore oil and Gas, 1999,13(04): 297-300(in Chinese).

[12]. Li Ning ,Chen Bo, Chen Feixiong . heat - moisture - deformation coupled model for composite foundation in cold zone[j].china civil engineering Journal,2003,36(10):66-71(in Chinese).

[13]. Sheng Jinchang. fully coupled thermo-hydro-mechanical model of saturated porous media and numerical modelling[J]. Chinese Journal of Rock Mechanics and Engineering, 2006,25(S1): 3028-3033(in Chinese).

[14]. Liu Quansheng, Zhang Chengyuan, Liu Xiaoyan. numerical modelling and simulation of coupled thm processes in task_d of decovalex_iv [J].Chinese Journal of Rock Mechanics and Engineering,2006,25(04): 709-720(in Chinese).

[15] zhou Zhijun, YU Chenglong Mathematical Model of Stress- Seepage - Temperature Three Field Coupled in Heavy Oil Reservoir