World Journal of Soil, Water and Air Pollution
Vol. 1, No. 2, December 2014, pp. 1- 13
Available online at http://www.wjswap.com

Research article

MODELLING AND SIMULATION TO MONITOR DEGREE OF SATURATION IN LATERITIC AND SILTYCLAYEY FORMATION IN IGBO ETCHE RIVERS STATE OF NIGERIA

Eluozo, S N.

Subaka Nigeria Limited Port Harcourt Rivers State of Nigeria
Director and principal consultant Civil and Environmental Engineering, Research and Development
E-mail: soloeluozo2013@hotmail.com
E-mail: solomoneluozo2000@yahoo.com

Abstract

The behaviour of water penetration into soil and its volume content has been describes by experts in various dimensions, the deposition of water content are base on several factors, the mechanic of soil has express degree of saturation to be when water has filled up the void ratio of the soil, the degree of saturation definitely depend on the factors, there are other formation characteristics which includes porosity and permeability of the formations, these variable also influences degree of saturation, the deposition of lateritic and silty clayey formation was monitored through developed model the study were determined various percentage of saturation at different depths, these were observed through simulation results compared with experimental values, both parameters expressed faviourable fits validating the developed model. The behaviour of lateritic soil shows other factors that may have cause it to deposit low water content, most of these formation may also implies that there plasticity are very low thus expressing those soil classification to be a good material for subgrade, while those silty clayey formation express high plasticity that will definitely developed serious challenges in constructions.

Keywords: modelling, simulation, saturation, lateritic, and silty clayey formation

---

1. Introduction

The formation of lateritic soils occurs through the pedological alteration processes that act later or together with the mechanisms of disaggregation and decay caused by physical and chemical weathering, with a more intense chemical action. The pedagogical alteration process that contributes most significantly to lateritic soil formation is leaching, which is the intense migration of particles under the action of infiltration and evaporation, resulting in a layer of porous soil (high permeability), consisting of more stable minerals (quartz, kaolinite and magnetite) and a low degree of saturation. Since this process is very slow, it occurs in the well-drained superficial layers, located above the water level, therefore, not saturated [1]. This variable is called suction and can be matric or total. First, in order to evaluate changes in the suction of a stress state in an unsaturated soil, it is necessary to determine the soil-water characteristic curve (SWCC). This curve is a graphical representation of the suction (matric or total) and the quantity of water that can be represented by the gravimetric moisture content (w), volumetric moisture content (θ) or the degree of saturation [11]. SWCC describes a different pathway in terms of soil drying or wetting. Because of this, the curves obtained by the drying or wetting paths do not coincide, giving rise to a phenomenon called curve hysteresis and which is a characteristic of soil suction [2]. Hysteresis caused by drying and wetting paths can be attributed to non-uniformity of the voids, to the air bubbles captured by the voids of the soil during the wetting and structure alteration due to the expansion or contraction of the soil [3]. According [9], the real value of suction depends not only on the degree of saturation, but also on the initial state of the soil and the whole history of drying and wetting until that moment. The test consists of placing a filter paper with its known retention characteristics in a hermetic environment along with a soil sample. Due to the contact of the paper with the soil, which is able to retain moisture content, there is water migration until potential equilibrium is reached, thus obtaining matric suction [7]. If water in the soil is not in direct contact with the filter paper, total suction can be obtained after the potential equilibrium. This equilibrium time is being studied by several authors. [5] Suggests a seven day equilibrium time for suction values above 10,000 kPa and four days for values lower than 10,000 kPa. [7] [Argues that equilibrium time is related to the type and level of suction. This author suggests a seven day period when measuring matric suction, regardless of the level of suction. [1], the minimum equilibrium time between the filter paper and the soil is seven days. Equilibrium time is a very important factor to obtain the correct suction value. The procedure of this method is quite simple; however, it requires great care in determining the filter paper moisture content. [6], filter paper weighing time should be approximately 30 seconds to prevent gains or losses of moisture to the atmosphere. According to [8], the filter paper transfer time for a closed capsule or a zip lock plastic bag must be 5 seconds at most. According to [10], the elimination of the cavitations nucleons demands a special technique that the majority of the commercial tensiometers cannot withstand. To minimize the problem, distilled and de-aired water is used, when the tensiometer saturation is done. Some procedures must be performed with care during the tensiometer saturation and calibration, according to [7 and 8]. The saturation of the porous element can be done by simple immersion, when the porous stone used has capacity of the up to 100kPa of air-entry. However, caution must be taken due to the possibility of air bubbles forming on the walls of the pipe.

2. Developed Governing Equation

$$Vt\frac{\partial s}{\partial L} = \frac{Vw}{V}\frac{\partial s}{\partial t} + Kt\frac{\partial s}{\partial L} \quad \text{...............................} \quad (1a)$$

Nomenclature

Vt	=	Velocity of flow [LT^{-1}]
$S = \frac{Vw}{V}$	=	Degree of saturation [-]
Kt	=	Permeability [LT^{-1}]
L	=	Depth

T = Time

Simplifying the expression, let $\frac{Vw}{V}$ denote as τ so that the equation can be written as:

$$Vt\frac{\partial s}{\partial L} = \tau\frac{\partial s}{\partial L} + Kt\frac{\partial s}{\partial L} \quad \text{.................................} \quad (1b)$$

$$Vt\frac{\partial s}{\partial L} - \frac{\partial s}{\partial t} = \frac{\partial s}{\partial t} + \tau + Kt \quad \text{.................................} \quad (2)$$

$$(Vt-1)\frac{\partial s}{\partial L} = \frac{\partial s}{\partial L} + \tau + K \quad \text{.................................} \quad (3)$$

$$(Vt-1)\frac{\partial s}{\partial L} = \frac{\partial s}{\partial t} \quad \text{.................................} \quad (4)$$

$$0 = \frac{\partial s}{\partial L} + \tau + K \quad \text{.................................} \quad (5)$$

i.e. $\frac{\partial s}{\partial t} = -\tau - Kt$ .... (6)

From (5) integrate directly, we have

$$S = (-\tau - Kt)t + S_1 \quad \text{.................................} \quad (7)$$

From (6)

$$\frac{\partial s}{\partial L} = \frac{\partial s}{\partial t}$$

Let $S = LT$ .... (8)

$$\frac{\partial s}{\partial L} = Z^1T \quad \text{.................................} \quad (9)$$

$$\frac{\partial s}{\partial L} = ZT^1 \quad \text{.................................} \quad (10)$$

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

$$(Vt-1)Z^1T = (\tau - Kt)ZT^1 \quad \text{.................................} \quad (11)$$

$$(Vt-1)\frac{Z^1}{Z} = (\tau - Kt)\frac{T^1}{T} = \phi \quad \text{.................................} \quad (12)$$

$$(Vt-1)\frac{Z^1}{Z} = \phi \quad \text{.................................} \quad (13)$$

$$(\tau - Kt)\frac{T^1}{T} = \phi \qquad \text{..............................} \qquad (14)$$

From (13) $\frac{Z^1}{Z} = \frac{\phi}{(Vt-1)} z$ ....

$$Ln Z = \frac{\phi}{(Vt-1)} z + S_2 \qquad \text{..............................} \qquad (16)$$

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

From (14)

$$(\tau + Kt)\frac{T}{T} = \phi$$

$$T = \frac{\phi}{(\tau + Kt)} \qquad \text{..............................} \qquad (19)$$

$$Ln\, T = \frac{\phi}{(\tau + Kt)} t + S_3 \qquad \text{..............................} \qquad (19)$$

$$T = B\ell^{\frac{\phi}{\tau + Kt} t} \qquad \text{..............................} \qquad (20)$$

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

$$S_2 = A\ell^{\frac{\phi}{(Vt-1)} z} \bullet B\ell^{\frac{\phi}{\tau + Kt} t} \qquad \text{..............................} \qquad (21)$$

$$S_2 = AB\ell^{\left(\frac{z}{(Vt-1)} + \frac{t}{\tau + Kt}\right)^{\phi}} \qquad \text{..............................} \qquad (22)$$

Hence general solution becomes:

$$S\,[LT] = S_1 + S_2$$

$$S\,[LT] = AB\ell^{\left(\frac{z}{(Vt-1)} + \frac{t}{\tau + Kt}\right)^{\phi}}$$

3. Materials and method

Standard laboratory experiment where performed to monitor the degree of saturation different formation, the soil deposition of the strata were collected in sequences base on the structural deposition at different locations, this samples collected at different location generate variation at different depth producing different migration of salmonella concentration through pressure flow at different strata, the experimental result are applied to compare with the theoretical values to determined the validation of the model.

4. Result and Discussion

Results and discussion are presented in tables including graphical representation of salmonella concentration

Table: 1 Degree of Saturation at Different Depth

Depth[m]	Degree of saturation
3	1.12E-03
6	1.35E-03
9	1.70E-03
12	2.14E-03
15	2.69E-03
18	3.39E-03
21	4.27E-03
24	5.37E-03
27	6.75E-03
30	8.49E-03
33	1.10E-02
36	3.60E-02

Table: 2 Degree of Saturation at Different Time

Time	Degree of saturation
10	1.12E-03
20	1.35E-03
30	1.70E-03
40	2.14E-03
50	2.69E-03
60	3.39E-03
70	4.27E-03
80	5.37E-03
90	6.75E-03
100	8.49E-03
110	1.10E-02
120	3.60E-02

Table: 3 Comparisons of Predicted and Experimental Values at Different Depths

Depth[m]	Predicted Degree of saturation	Experimental Degree of saturation
3	1.12E-03	1.18E-03
6	1.35E-03	1.41E-03

9	1.70E-03	1.78E-03
12	2.14E-03	2.25E-03
15	2.69E-03	2.77E-03
18	3.39E-03	3.45E-03
21	4.27E-03	4.45E-03
24	5.37E-03	5.45E-03
27	6.75E-03	6.89E-03
30	8.49E-03	8.55E-03
33	1.10E-02	1.19E-02
36	3.60E-02	3.77E-02

Table: 4 Comparisons of Predicted and Experimental Values at Different Times

Time	Predicted Degree of saturation	Experimental Degree of saturation
10	1.12E-03	1.15E-03
20	1.35E-03	1.42E-03
30	1.70E-03	1.88E-03
40	2.14E-03	2.25E-03
50	2.69E-03	2.74E-03
60	3.39E-03	3.47E-03
70	4.27E-03	4.44E-03
80	5.37E-03	5.46E-03
90	6.75E-03	6.88E-03
100	8.49E-03	8.66E-03
110	1.10E-02	1.24E-02
120	3.60E-02	3.66E-02

Table: 5 Degree of Saturation at Different Depth

Depth[m]	Degree of saturation
3	2.47E+00
6	3.13E+00
9	3.97E+00
12	5.03E+00
15	6.37E+00
18	7.73E+00
21	9.79E+00
24	1.30E+01
27	1.64E+01
30	1.99E+01
33	2.63E+01
36	3.34E+01

Table: 6 Degree of Saturation at Different Time

Time	Degree of saturation
10	2.47E+00
20	3.13E+00
30	3.97E+00
40	5.03E+00
50	6.37E+00
60	7.73E+00
70	9.79E+00
80	1.30E+01
90	1.64E+01
100	1.99E+01
110	2.63E+01
120	3.34E+01

Table: 7 Comparisons of Predicted and Experimental Values at Different Depth

Depth[m]	Predicted Degree of saturation	Experimental Degree of saturation
3	2.47E+00	2.55
6	3.13E+00	3.23
9	3.97E+00	4.11
12	5.03E+00	5.24
15	6.37E+00	6.56
18	7.73E+00	7.98
21	9.79E+00	9.89
24	1.30E+01	13.11
27	1.64E+01	16.66
30	1.99E+01	20.12
33	2.63E+01	29.55
36	3.34E+01	33.45

Table: 8 Comparisons of Predicted and Experimental Values at Different Times

Time	Predicted Degree of sat	Experimental Degree of sat
10	2.47E+00	2.55
20	3.13E+00	3.23
30	3.97E+00	4.11
40	5.03E+00	5.24
50	6.37E+00	6.56
60	7.73E+00	7.98
70	9.79E+00	9.89
80	1.30E+01	13.11

World Journal of Soil, Water and Air Pollution
Vol. 1, No. 2, December 2014, pp. 1- 13
Available online at http://www.wjswap.com

90	**1.64E+01**	**16.66**
100	**1.99E+01**	**20.12**
110	**2.63E+01**	**29.55**
120	**3.34E+01**	**33.45**

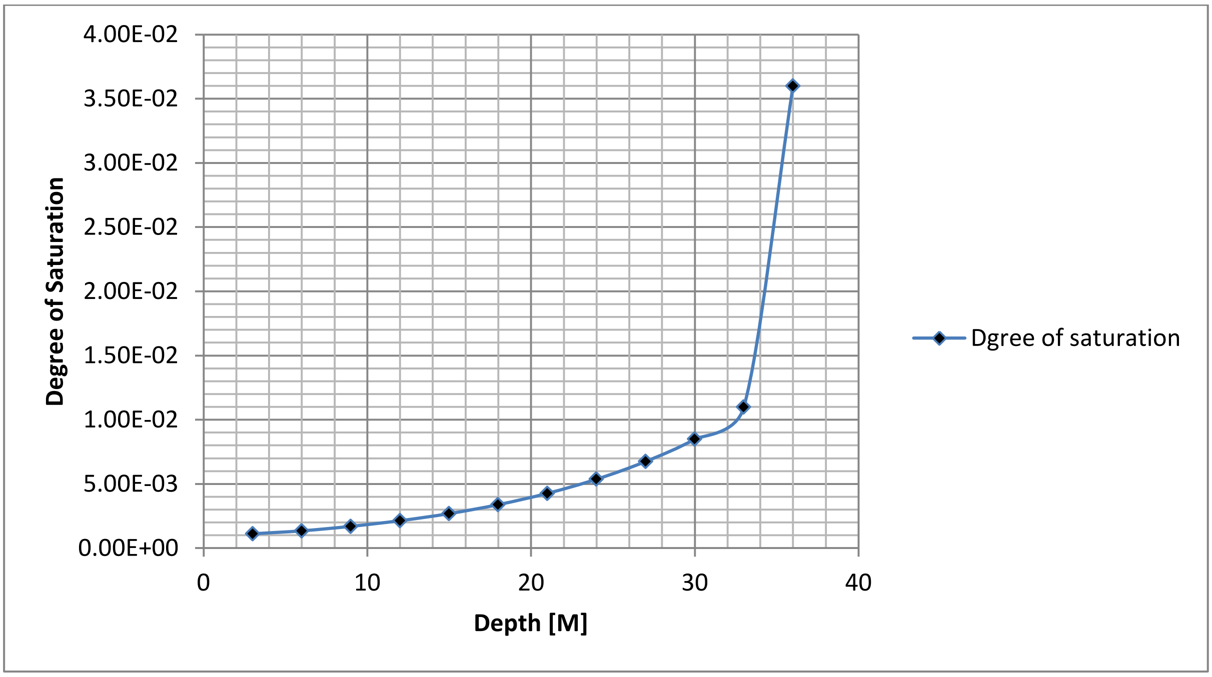

Figure:1 Degree of Saturation at Different Depth

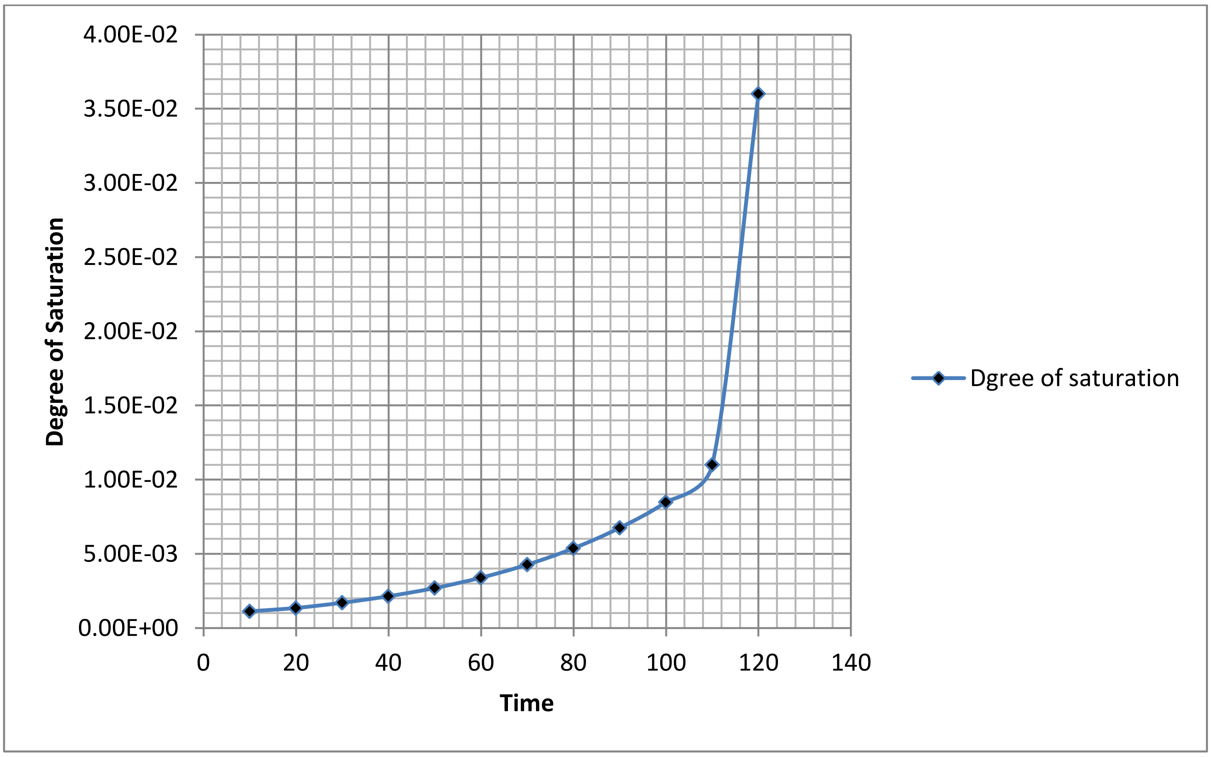

Figure: 2 Degree of Saturation at Different Time

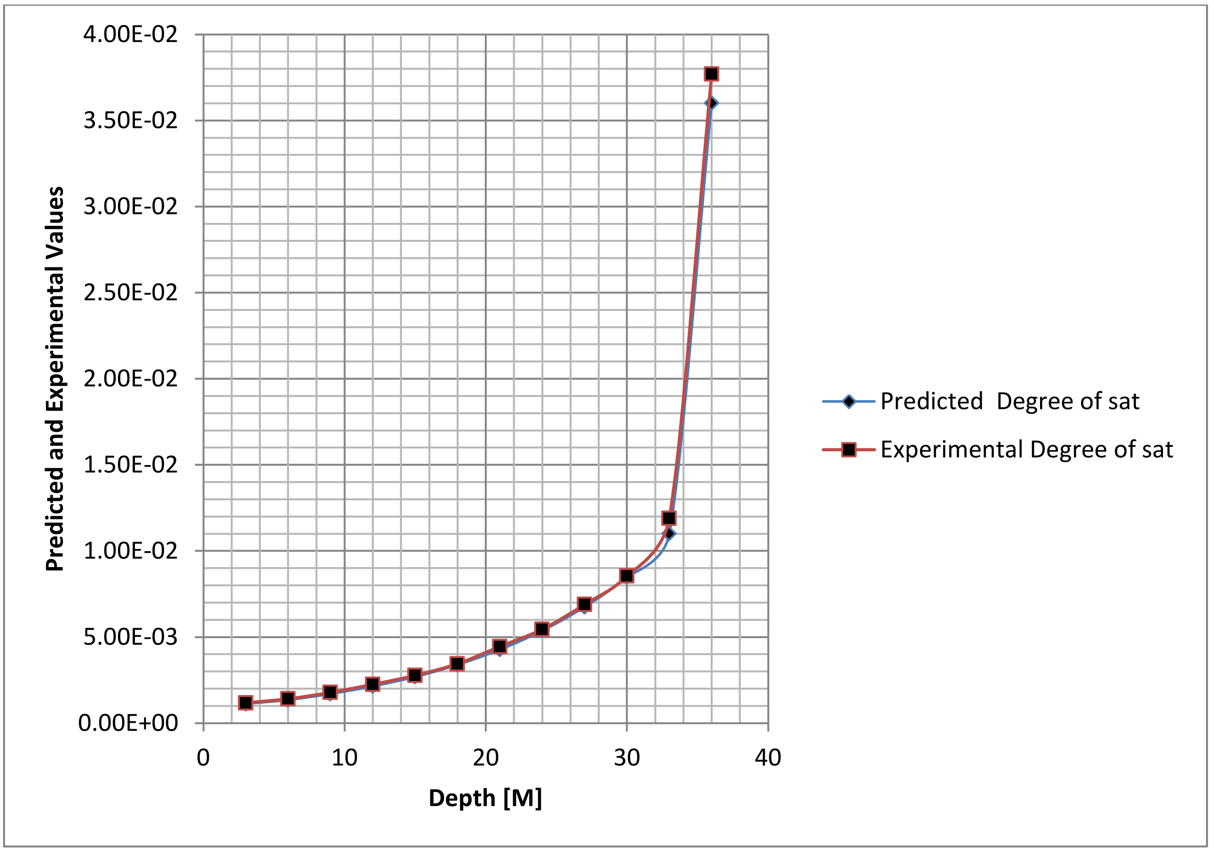

Figure: 3 Comparisons of Predicted and Experimental Values at Different Depth

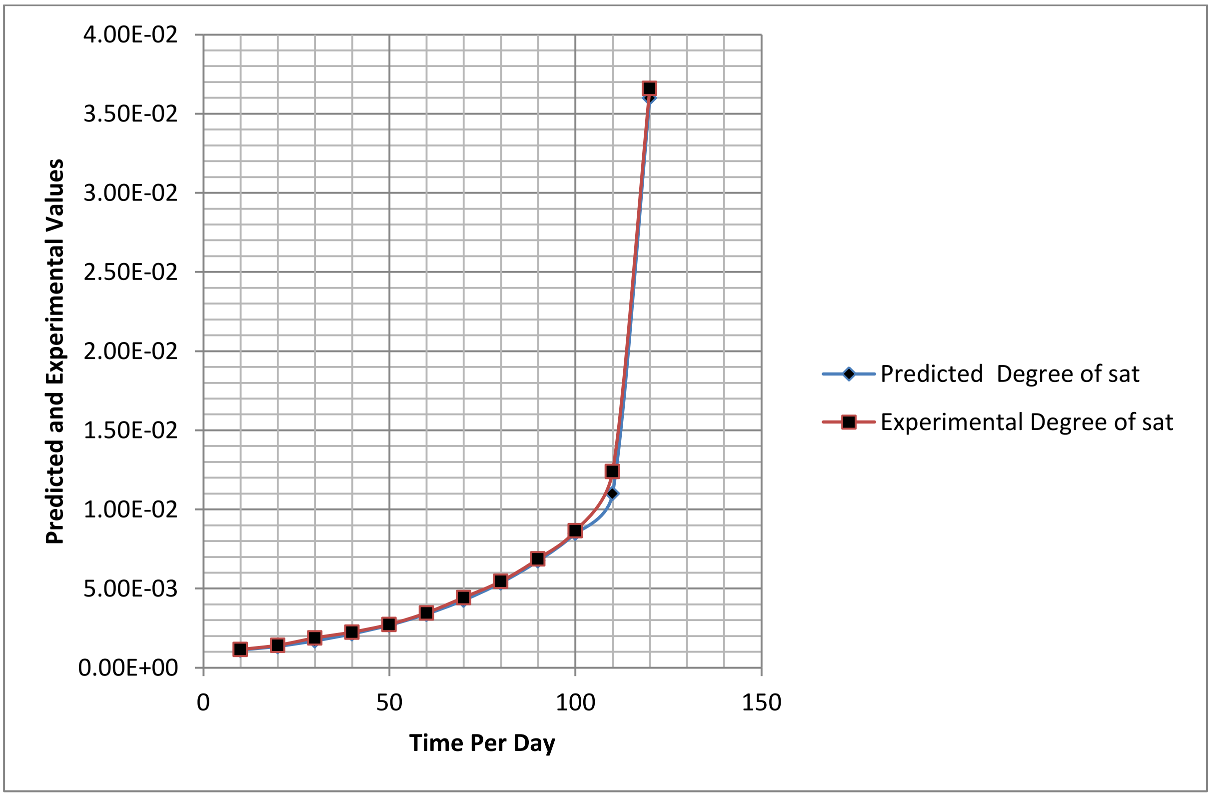

Figure: 4 Comparisons of Predicted and Experimental Values at Different Times

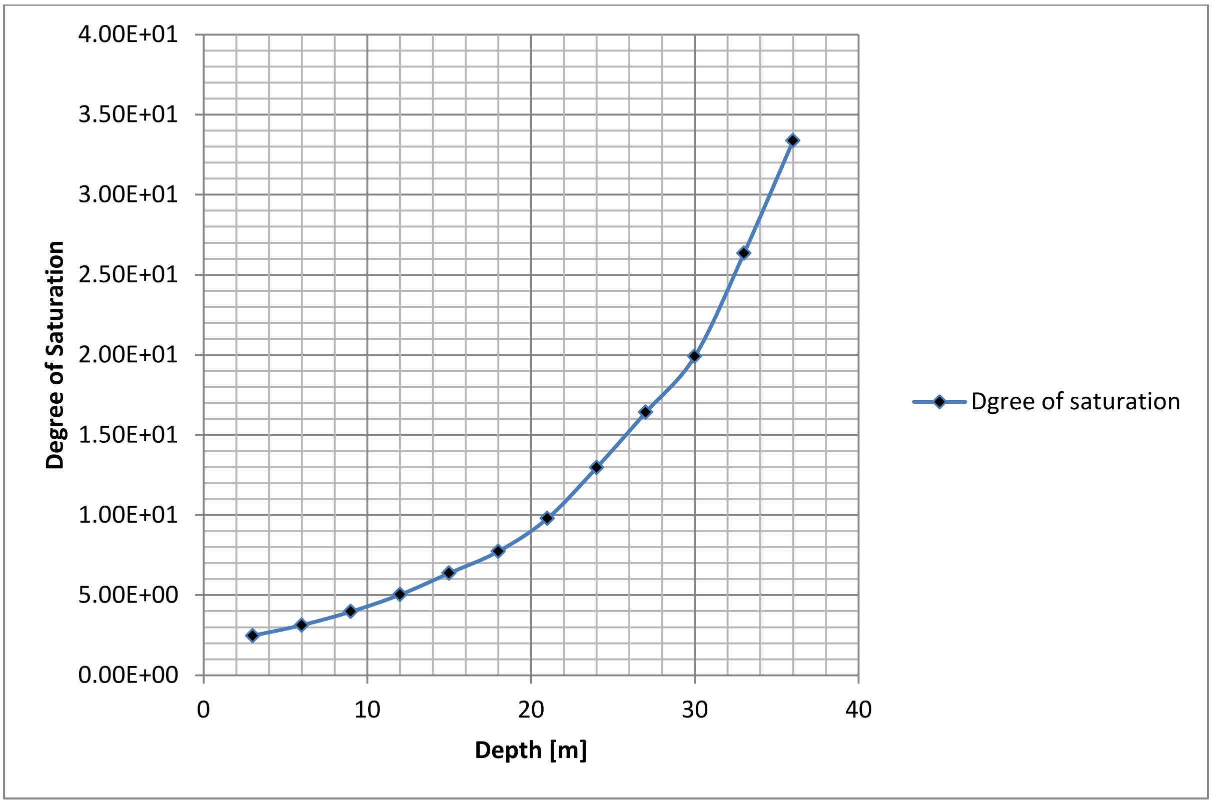

Figure: 5 Degree of Saturation at Different Depth

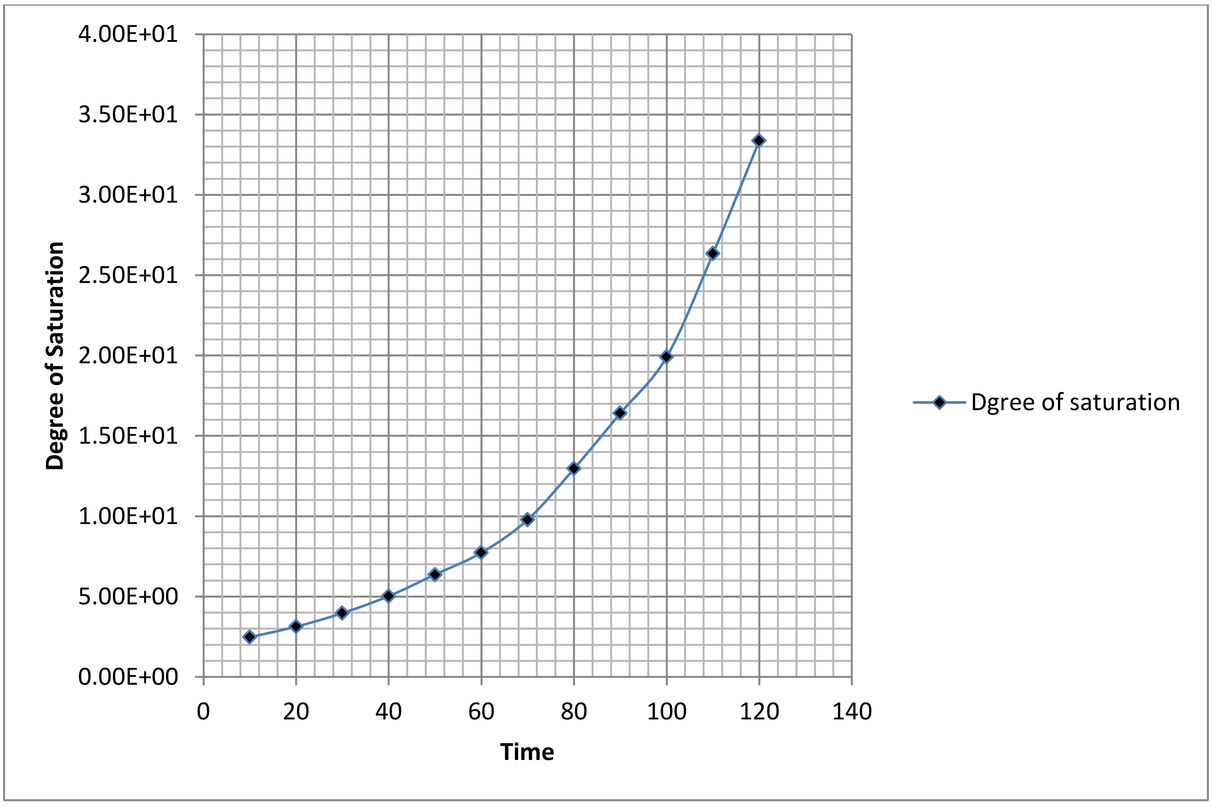

Figure:6 Degree of Saturation at Different Time

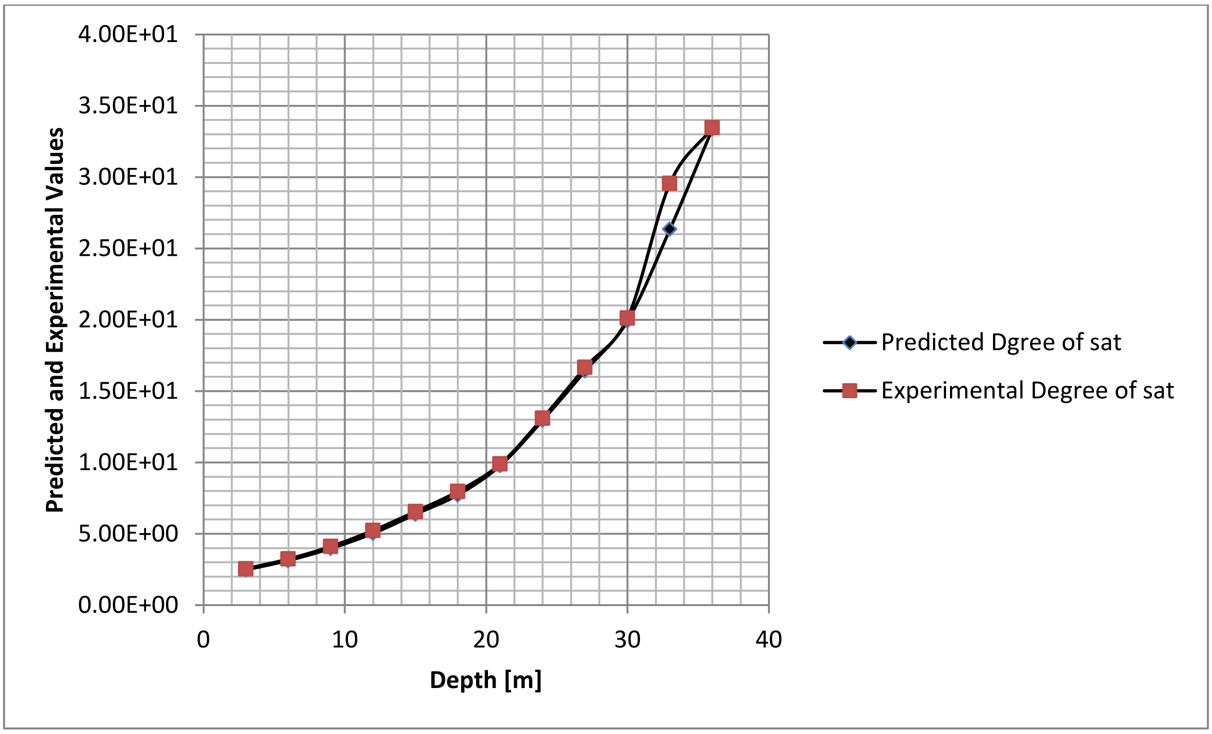

Figure: 7 Comparisons of Predicted and Experimental Values at Different Depth

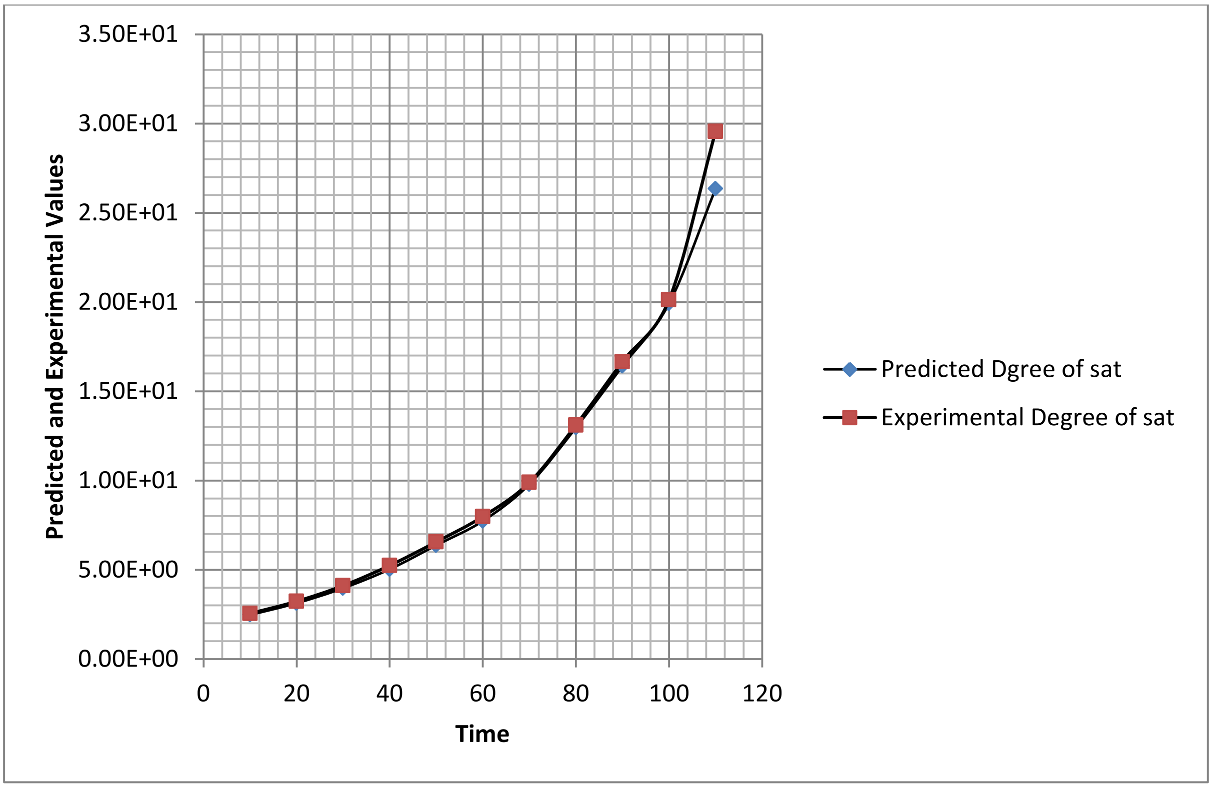

Figure: 8 Comparisons of Predicted and Experimental Values at Different Times

The study expresses the degree of saturation from figure one to eight how the behaviour soil the increasing in moisture under exponential condition, the study from figure one to four establish gradual increase from three to thirty three metres, sudden rapid increase were observed to the point where the optimum degree of saturation was recorded, these condition implies that the soil deposited some strata that the degree of saturation were very low base on the nature of the soil, more so the formation in the study location displayed low degree of saturation base on volume of void between the intercedes of soil formation, low degree of saturation may be as a results of the level temperature, the rate of porosity and permeability may also determine deposition saturation content of the soil base on their various degree of deposition. Furthermore figure five to eight express high deposition of degree of saturation in silt clayey formation, the express figure shows that the silty clayed formation may deposit more percent of degree of saturation at these formations, deltaic predominance's influences were observed at the location of the soil, permeability and porosity including void ratio were experiences to deposit low percentage pore distribution are very low that result volumetric water content were observed to deposit high degree, the Water Content Significantly affects properties of Silt and Clayey soils (unlike sand and gravel). Plasticity property describes the response of a soil to change in moisture content. Strength decreases as water content increases–Soils swell-up when water content increases. Fine-grained soils at very high water content possess properties similar to liquids. As the water content is reduced, the volume of the soil decreases and the soils become plastic. If the water content is further reduced, the soil becomes semi-solid when the volume does not change.

4. Conclusion

The developed model has expressed various level of degree of saturation in different deposition of the soil, the simulation results show various degree of saturation cause by several factor in the formation, the degree of saturation were found to be influenced by low deposition of void ratio between the intercedes of the formation, these implies that those location that degree of saturation are very low shows that the porosity and void rate percentage are very high, these also implies that permeability in those region may experiences high degrees also. There is other location that observed high degree of saturation; these are formation were high degree of porosity permeability and void ratio experiences low deposited content, deltaic influences were observed to have predominantly deposition of the formation, theses implies that lateritic and silt clayey formation simulated from the developed model has expressed the behaviour of the formation compared with the experimental results, both parameters generated faviourable fits validating the developed model for the study.

References

[1]ASTM D 5298-03. 2004. Test method for measurement of soil potential suction using filter paper, Volume 04.08.

[2] Bonder, B.H. 2008. Curvas de retenção de água de um solo coluvionar de Campinas obtidas mediante técnicas de laboratório e de campo. Dissertação de Mestrado. Universidade Estadual de Campinas, Brasil. 130p. (in Portuguese).

[3] Calle, J.A.C. 2000. *Análise de ruptura de talude de um solo não saturado*, Tese de Mestrado, EESC-USP/ São Carlos. (in Portuguese).

[4] Cassel, D.K. and Klute, A. 1986. A. Water potential: tensiometry. In: Klute, A. (Ed.) Methods of soil analysis. Madison: American Society of Agronomy and Soil Science Society of America, p.563-596. Second Edition.

[5] Feuerharmel, C.; Gehling, W. Y. Y.; Bica, A. V. D. 2006. The use of filter-paper and suction-plate methods for determining the Soil-Water Characteristic Curve of undisturbed colluvium soils. *Geotechnical Testing Journal*, 29 (5): 419-425.

[6] Gardner, W.R. 1937 A method of measuring the capillary tension of soil moisture over a wide moisture range, *Soil Science*, 43 (4), 277-283.

[7] Marinho, F.A.M. 1994. Técnica do papel filtro para medição de sucção. *Encontro sobre Solos Não Saturados*. Porto Alegre/RS. 1, 112-125. (in Portuguese).

[8] Marinho, F.A.M. 1997. Medição de sucção em solos. *III Simpósio Brasileiro de Solos Não Saturados*. Rio de Janeiro/RJ, 1, 373-397. (in Portuguese

[9] Rojas, E. 2002. Modeling the Soil Water Characteristic Curve during wetting e drying cycles, *Proc. of the Third International Conference on Unsaturated Soil*, 1, 215-219, Recife, Brazil

[10] Vieira, A.M. 1999. Variação Sazonal de Sucção em um Talude de Solo Residual de Gnaisse. Dissertação de Mestrado, Escola Politécnica, Universidade de São Paulo, São Paulo (in Portuguese)

[11] Brunno H B& Miriam G M 2011 Hysteresis phenomenon of a tropical soil profile observed by means of soil water characteristic curves obtained in laboratory and field geotechnical Pan Am CGS conferences