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Models development for the determination of plastic limits for improved construction and design of roads

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ABSTRACT

This paper explains the assessment of plastic limit of soil and model development that can be applied to examine the impact of plasticity of soils on the design and construction of roads in the study location. Samples collected from nine locations were subjected to laboratory analysis and the results from these location produced the following model equations: $y = -2.51x^2+9.881x+14.95$ *and* $R^2 = 0.978$, $Y= -3.957x^2+11.85x+14.34$ *and* $R^2 = 0.816$, $Y =2.967x^2 -12.53x+30.76$ *and* $R^2 = 0.878$, $Y =8.816x^3-37.12x^2+35.90x+18.42$ *and* $R^2 =0.975$, $Y = 0.163x^3-2.625x^2 +7.609x+18.84$ *and* $R^2 =0.971$, $Y = 0.713x^3-5.095x^2+8.506+16.42$ *and* $R^2 = 0.968$, $Y=6.647x^3-34.45x^2+51.74x+2.040$ *and* $R^2 = 0.97$, $Y= -3.098x^2+13.11x +11.68$ *and* $R^2=0.876$ *and* $Y =5.304x^3-28.43x^2+45.10x+3.030$ *and* $R^2 = 0.96$. *The model equations were developed from the results obtained and can be resolved to generate other theoretical values that can be applied in design and construction of roads. The generated model equations will produce a predictive model for plastic limit of soil in the study locations. Hence, this model will solve the problem from clay and lateritic earth materials for sub grade in road construction, considering the deltaic environment, the geologic history and predominance of some clays and lateritic soils depositing medium and high plastic limit in the study area.*

INTRODUCTION

Soil with the exemption of peat is produced by the breakdown of rock masses, either by weathering or erosion. Soils that are deposited in most area are base on the amount of transport [7]. The soils characteristics may also have been affected by its geological past, i.e. being covered by ice, disproportionate heat, wind & rain, etc. There are many dissimilar types of soils, in most condition experience different tribulations linked with various transportation of different type of soil. Certain soils may shrink, expand, collapse or show a lack of Strength/stiffness. Soils are usually made up of a mixture of four different groups of differing particle size: Certain changes in clay soils can be a major concern for the construction industry, since this transformation may result in widespread amounts of reduction (drying out) or swell (water absorption) which could cause destructions of so many highway roads, building or construction project in general. It was predicted that in Britain in a distinctive 10 years period between 1995-2005 swelling and shrinkage in clay soils had caused over 3 billion pounds worth of damage. This problem has develop lots of construction failure. Quantity change in soils is generally as a result of its moisture content, density, void ratio, stresses applied or released, along with the internal soil formation and mineralogy. The principle source of development in natural soils is the presence of swelling clay minerals such as montmorillonite [8], set out two types of enlargement characteristics in clay soils, namely intercrystalline and intracrystalline swelling [7]. Intercrystalline is when the uptake of water is limited to the exterior crystal surfaces and the void spaces between the crystals. Intracrystalline is when water enters not only between the crystals, but also between the unit layers which comprise the crystals.The different types of clay minerals present, dictate the materials capability to take up (adsorb) water. Each clay mineral possibly will have a comparable structure to another clay mineral i.e. be made up of tetrahedral (Silicon atom-Si) and octahedral sheets (aluminium atom-Al), but it is the way that they are arranged that dictates their type: Plastic clays termed as expansive soils or active soils exhibit volume change when subjected to moisture variations. In most case soil found in most case studies is over-consolidated with the significant amount of expansive clay minerals (montmorillonite), mainly darkish grey to reddish grey in colour. The case study being in the coastal belt of the tropics in the semi-arid regions of East Africa even West African like Nigeria, it experiences two main seasons, the rainy and the dry seasons. During the rainy season, the Expansive clay minerals attract water molecules resulting into massive change in volume. This condition increase the plasticity of soil in some deposition were it contain high percentage of plastic. Numerous masonry houses especially lightweight structures on these expansive soils in Kibaha have met with damages originating from differential heave [9]. While the presence of expansive soil in the area can cause significant problem, the mere presence of it does not alone cause all the defects Apart from the expansive soil, the defects may originate from inadequate design, poor materials, poor job-site construction or multiple of the factors [9]. In order to understand fully the problem behind the poor performance of construction like roads and buildings in this study, a top agenda item is to build-up facts of expansive soils both as an entity in its own right, but particularly as a critical component with myriad linkages (Soil-Structure Interaction) to the whole structure, namely road constructions, foundation design and construction that include superstructure in most cases slow infiltration can develop in sandy loam soils with low organic matter content [12,13,19]. Low penetration in medium and coarse textured soils are capable of been caused by restrictive layers at the surface (crusts, seals) or underneath the surface (compacted layers, hard pans, fine- turned strata, cemented layers). It can also result from scattering of the fine particles due to sodicity, or lack of enough divalent cations such as calcium [12, 13]. Many soil properties are known to influence the HC and IR of soils. Organic matter and iron oxides, clay mineralogy, texture, and exchangeable cation composition have all been studied. With regard to the latter, the consequence of adsorbed potassium on the hydraulic properties of soil is controversial, because of results vary or conflict, possibly due to differences in clay mineralogy and sample preparation procedures [21, 22 ,7] establish that assessment of the differences in texture, transferable sodium percentage (ESP), organic matter and pH of different soils could not give details the differences in the final IR values connecting the stable and the unstable soil groups. This led to the imperative conclusion that it was the mineralogy of the clay portion that was the deciding factor that decrease IR between the soils studied. [5] Showed that penetration processes measured in the field are reliant on the soil salinity and sodicity and the salinity of the applied water. This leads to the conclusion that the permeability of a soil to water depends both on its ESP and on the salt concentration of the percolating solution. The permeability tends to decrease with increasing ESP and decreasing salt concentration [15, 19]. IR is much more sensitive to the ESP of the soil than is the hydraulic conductivity [2] IR decreases because the clay disperses and clogs the soil pores and aids in sealing the soil. Another important soil property disturbing IR is the structure of the soil and aggregate stability. These two factors are listed among the most important soil quality indicators in part because of their relation to IR [10]. Poor soil structure and aggregate steadiness can lead to numeral problems, most importantly soil sealing or crusting. [1] Found that the decrease in IR was due to the structure of a surface seal caused by the physical breakdown of aggregates and clay dispersion. Deterioration in soil structure may take place even when irrigating non-sodic soils with waters of low sodium absorption ratio (SAR) and salinity. Due of crust structure, the resultant IR tends to decrease to a minimum value irrespective of the initial soil moisture content [1]. [23, 23] confirmed that a decrease in IR at the surface was due to seal formation. As distinguished by [12], water-repellent soils are found throughout the world and their repellency affects IR. They defined a water-repellent soil as one that does not wet spontaneously when a drop of water is placed upon the surface. A positive Pressure (water-entry pressure head, hp) must be applied to force water into the soil [12]. [10] Emphasized that soil moisture content is also an important factor explaining water repellency. They explained that it would be expected to be higher in aridic or dry soils than in humid soils. There are also many other factors that can lower IR. [11] found that the temperature of infiltrating water is related to IR because its viscosity changes by ~2% per degree Celsius. This leads to an estimated 40% change of IR between summer and winter in arid zones [11]. [1, 3, 4] emphasized the receptive nature of IR to any trouble in surface soil structure. This would comprise compaction, planting patterns, crop, and cultivation. [20] Found that for a clay soil the final IR is not a function of initial IR, representing that the surface layer is not the zone controlling the IR. This implies that the detailed properties of the clay mineralogy may transform with exposure to water and lower IR – such as swelling steatite clay. Low IR can make irrigation more difficult and expensive [16]. Low penetration on level exterior irrigated fields can result in crop damage due to standing water or insufficient aeration in the root zone, and can consequence is algae growth that is on the soil Surface that further lowers permeation. Dropping sprinkler or micro irrigation application rates usually increases system costs. Water standing on the soil surface increases evaporation losses [16, 17, 18,]. [14] Give details in order to decrease the destructive effects of low IR, irrigation should be stopped when ponding or runoff begins. This is aimed to prevent erosion and deep pools that will take even longer to evaporate. If final IR increases, the credibility factors decrease exponentially due to less runoff [7]. [12,13,] also give details that as a rule all water should infiltrate within 24 to 48 hours. Longer periods of ponding increase the potential for disease and poor aeration. Because penetration varies from place to place, within a field, more water must be applied than is needed by the crop to assure adequate irrigation [13]. Application of about 20% more water than needed by the crop compensates for infiltration variability. However, this increase may cause ponding in areas where IR is lowest. As emphasized by [17, 18], slow IR can make irrigation more difficult and expensive. This is because IR slower than sprinkler or drip emitter application rates results in water ponding and reduced application uniformity. Water standing on the soil surface can increase evaporation losses. Wet surface soil increases weed growth, changes the weed species mix, and delays access to the field [2,3,4,].

MATERIALS AND METHODS

This test was conducted in accordance with Bs 1377 1975 test 3. The plastic limit of a soil is the water content expressed as a percentage of the mass of the oven dried soil at the boundary between the plastic and semisolid states. The water content at this boundary is arbitrarily defined as the lowest water content at which the 5011 can be rolled into 3.0mm diameter threads without breaking into pieces. The plastic limit was determined by measuring the water content of the soil when threads 3.0mm diameter made from that particular soil just starts to crumble and can be taken as the smallest or minimum moisture content at which the soil can be rolled into 3.0mm diameter thread without breaking up.

Procedure

About 50gm of laboratory air dried soil sample was ground to the consistency of powder and sieved with a sieve (300mm). 20gm of this sieved soil was then taken and mixed thoroughly with some quantity of distilled water with the aid of a spatula until it formed a ball. This soil bail was now placed on top of a flat glass plate and rolled continuously with the palm until 3.0mm soil threads was obtained. Part of this soil was then put into the oven for its moisture content to be determined. The process was repeated with further addition of sieved soil until the 3.0mm diameter threads just starts to fumble. Part of this last soil and water mixture was removed and installed in the oven for is moisture content determination like for others. R plasticity index (P1) was calculated from the expression; P1 LL -PL, utilizing tile reading obtained after each water addition. The results generated from the experiments were subjected excel programs plotted each location result at the study area, the results plotted generated a model that that can be resolved to solve problem in other location were the experimental results are not available.

RESULTS AND DISCUSSION

Result and discussion to for plastic limit of soil examination and model development on the impact of construction and design of roads are presented in tables and figures.

Table 1 plastic limit of soil at different depth

Depth	Plastic Limit
0.2	17
0.4	18
0.8	22
1	22
1.5	24
2.5	24

Table 2 plastic limit of soil at different depth

Depth	Plastic Limit
0.2	18
0.4	17
0.8	20
1	23
1.5	24
2.5	19

Table 3 plastic limit of soil at different depth

Depth	Plastic Limit
0.2	27
0.4	28
0.8	24
1	19
1.5	19
2.5	18

Table 4 plastic limit of soil at different depth

Depth	Plastic Limit
0.2	25
0.4	26
0.8	28
1	27
1.5	18
2.5	14

Table 5 plastic limit of soil at different depth

Depth	**Plastic Limit**
0.2	20
0.4	22
0.8	23
1	24
1.5	25
2.5	24

Table 6 plastic limit of soil at different depth

Depth	**Plastic Limit**
0.2	18
0.4	19
0.8	20
1	21
1.5	20
2.5	17

Table 7 plastic limit of soil at different depth

Depth	Plastic Limit
0.2	12
0.4	16
0.8	25
1	27
1.5	24
2.5	20

Table 8 plastic limit of soil at different depth

Depth	Plastic Limit
0.2	13
0.4	19
0.8	18
1	22
1.5	25
2.5	25

Table 9 plastic limit of soil at different depth

Depth	Plastic Limit
0.2	12
0.4	15
0.8	24
1	26
1.5	24
2.5	21

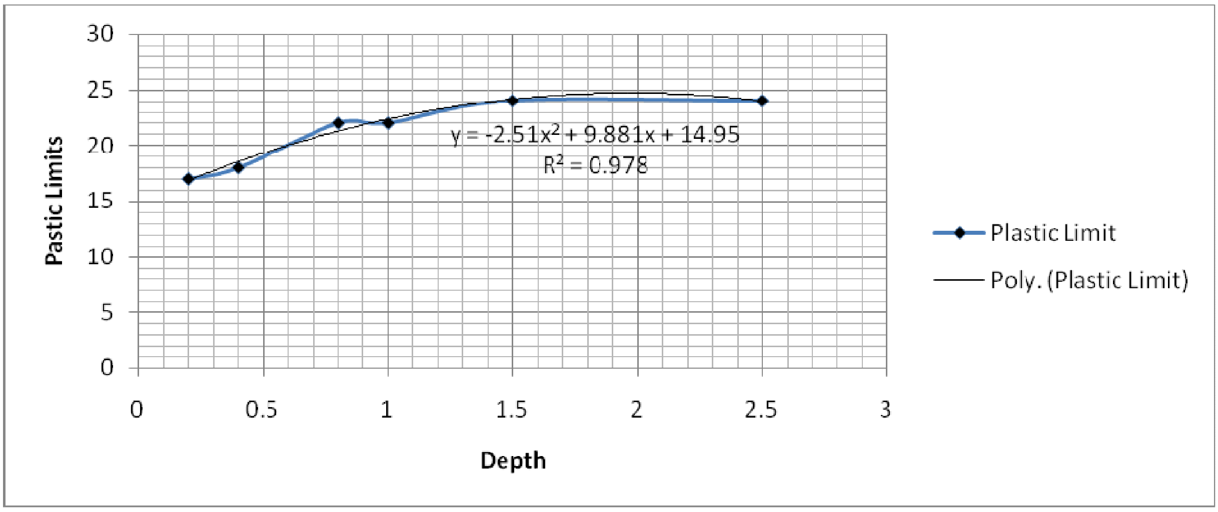

Figure: 1 Plastic limit of soil at different Depth

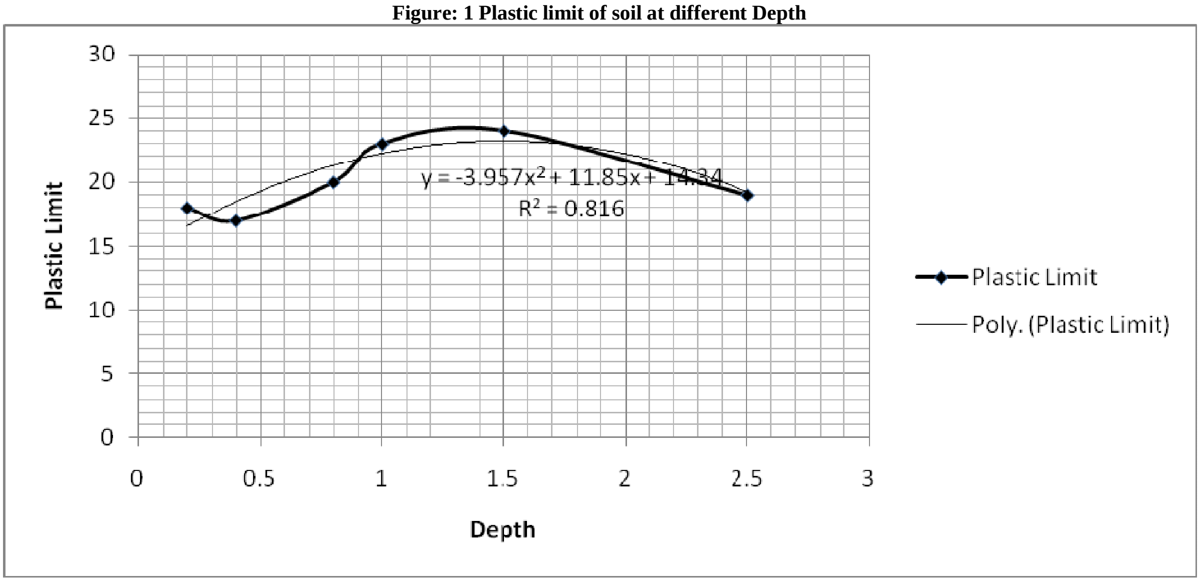

Figure: 2 Plastic limit of soil at different Depth

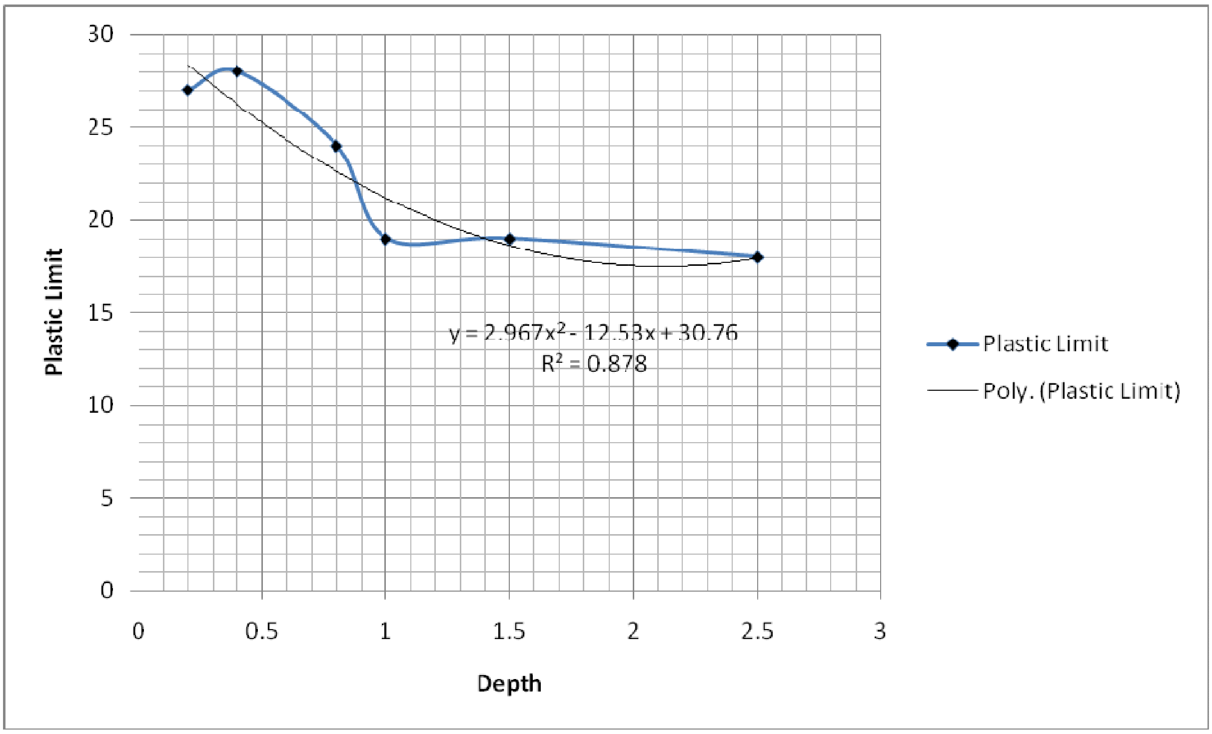

Figure: 3 Plastic limit of soil at different Depth

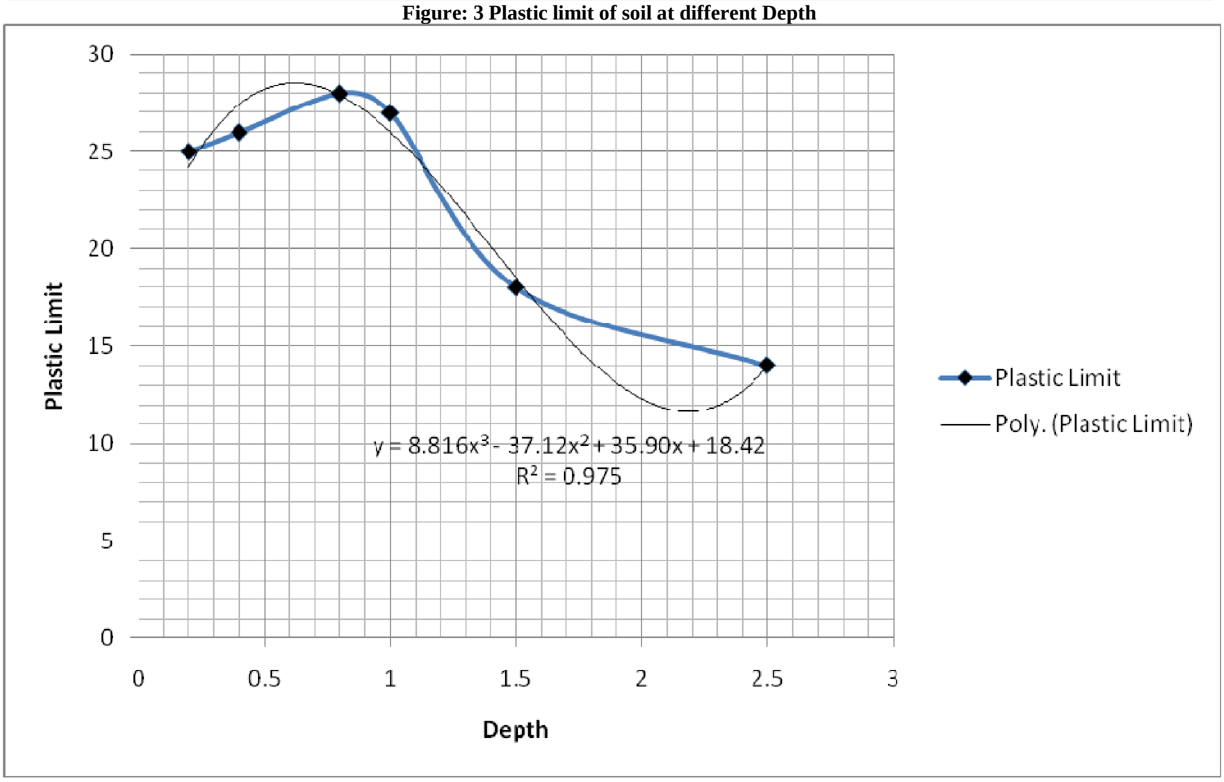

Figure: 4 Plastic limit of soil at different Depth

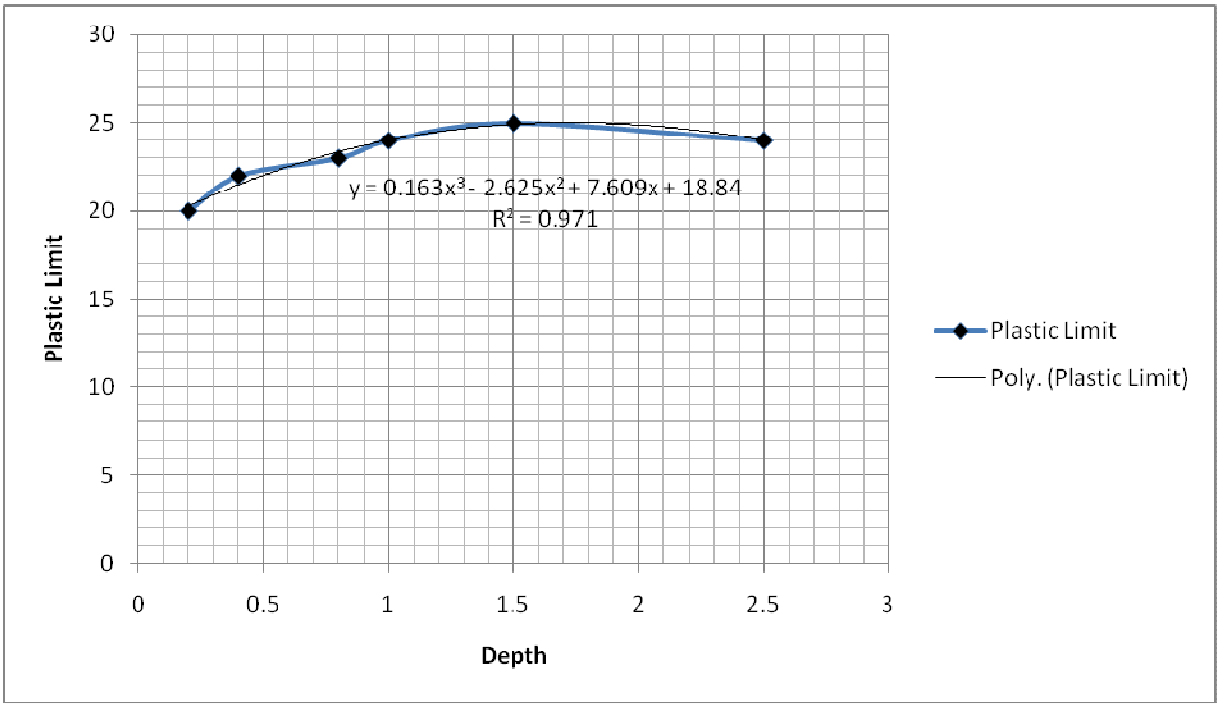

Figure: 5 Plastic limit of soil at different Depth

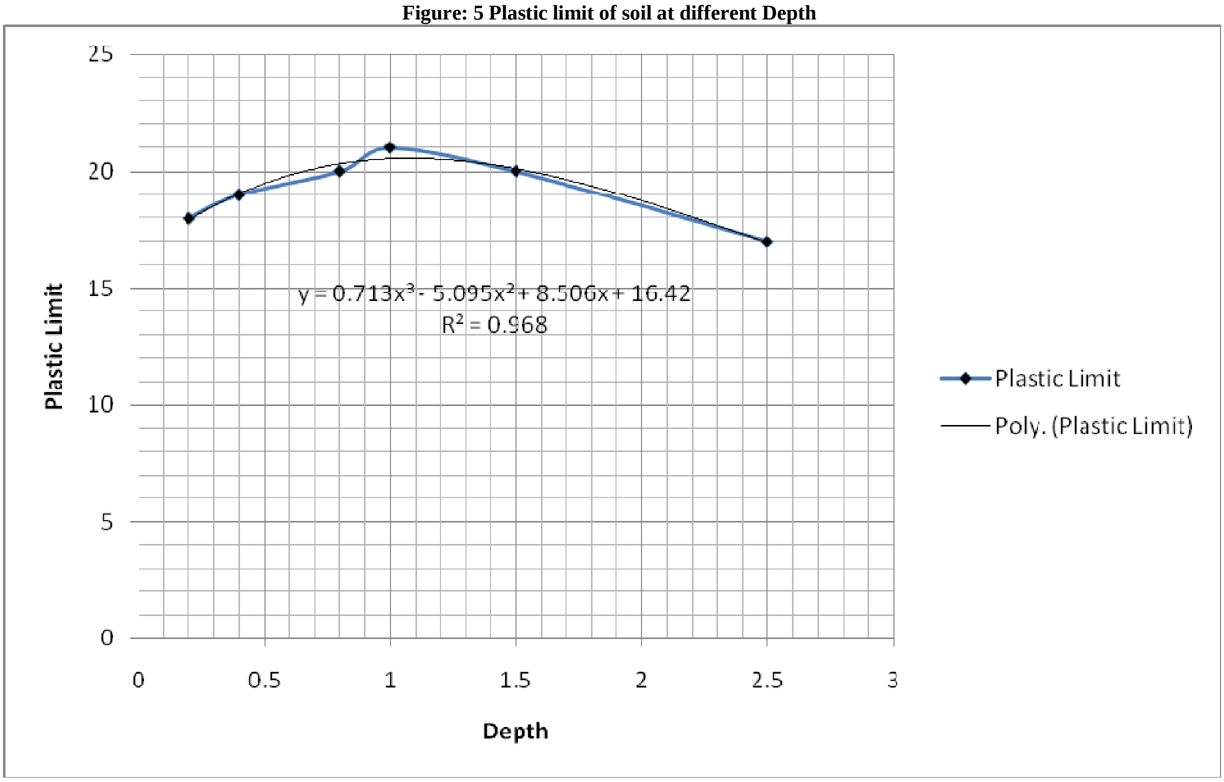

Figure: 6 Plastic limit of soil at different Depth

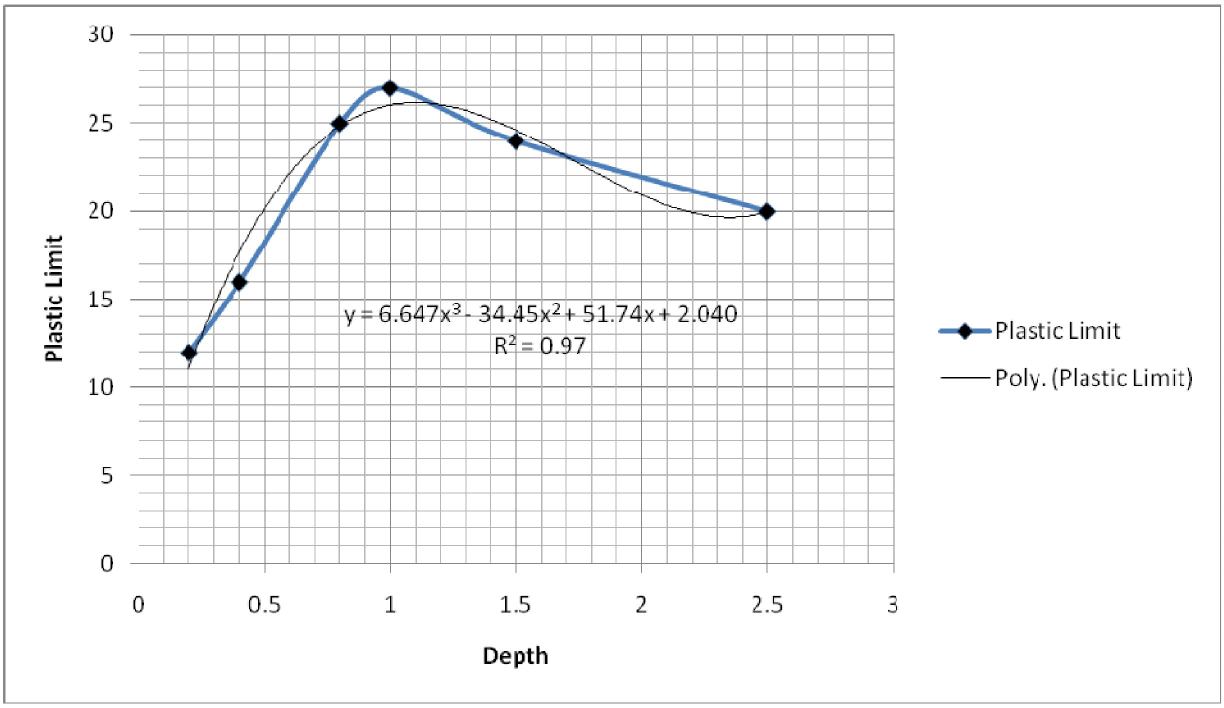

Figure: 7 Plastic limit of soil at different Depth

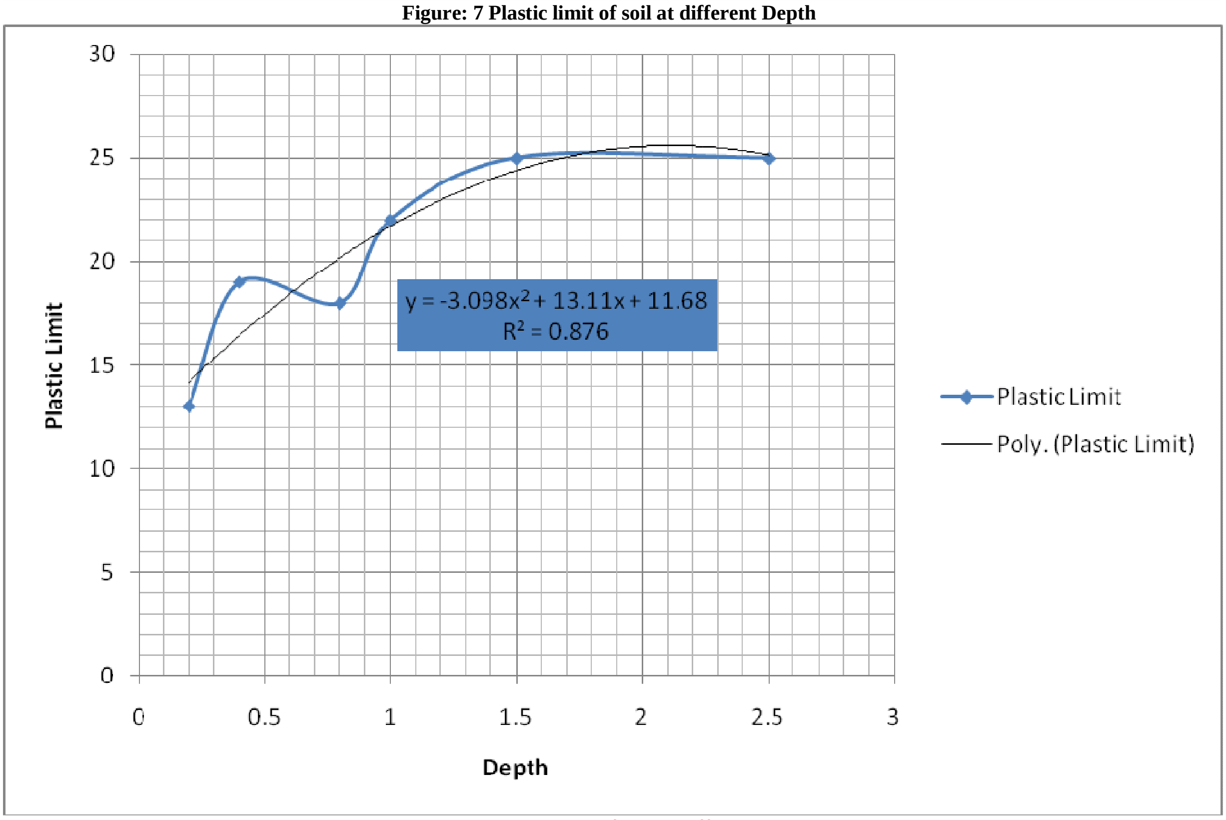

Figure: 8 Plastic limit of soil at different Depth

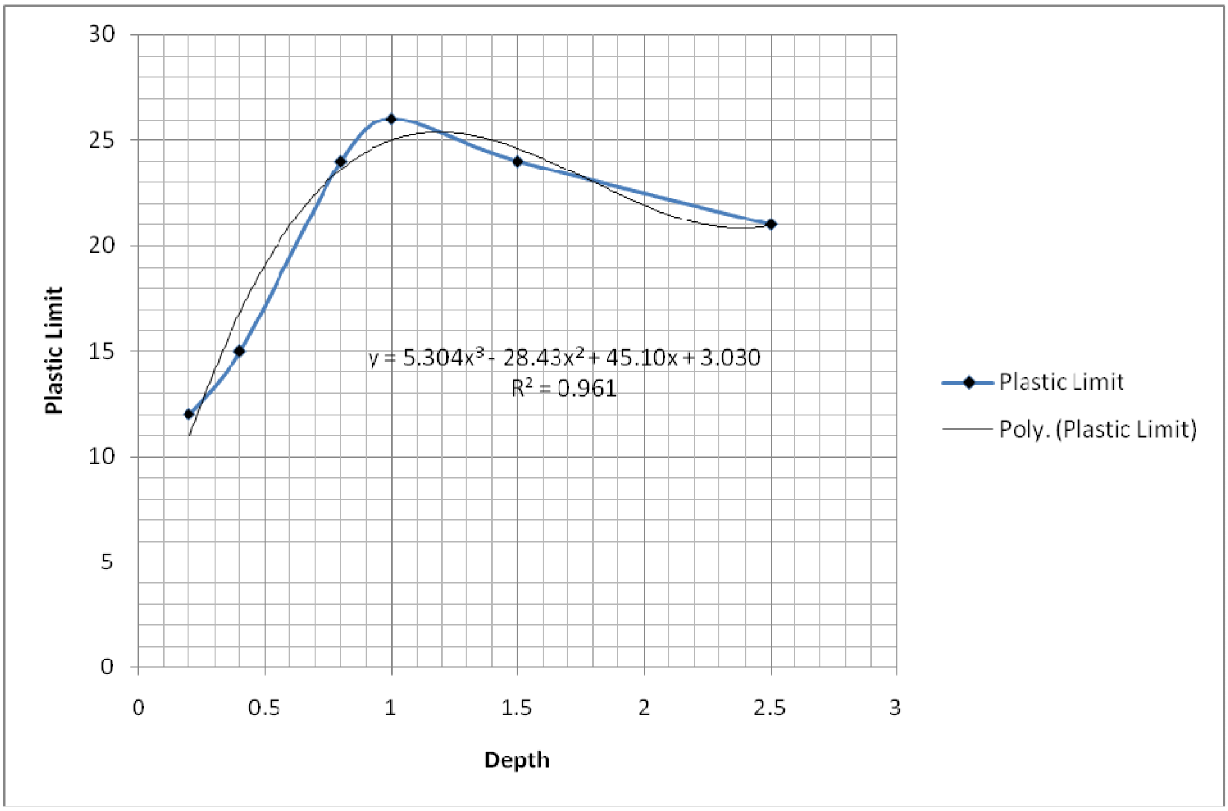

Figure: 9 Plastic limit of soil at different Depth

Figure 1 from the results, the level of plasticity of the soil gradually increase with depth, to a point where the optimum value were recorded at 25 2.5m deep, it generated a model equation as $Y = -2.51x^2 + 9.88x + 14.95$ and $R^2 = 0.975$. The level of plasticity of the soil at the optimum level shows that the deposited formation produced high. Plasticity. Figure 2 develop its level of plasticity in a fluctuation form, the same as figure 1 at 1.5m deep and suddenly declination were observed where the lowest level of plasticity were achieved at 19 2.5 metres deep, this implies that at 2.5m deep the deposited formation are classified to be medium plasticity, it develops a model equation as $Y = -3.957x^2 + 11.85x + 14.34$ with $R^2 = 0.816$. Figure 3 displayed its rate of plasticity at the optimum level of 28 at 0.4m and suddenly decline in an oscillation form, where the lowest plasticity were recorded at 19 2.5m deep, this condition shows that the formation that deposited the plasticity of the soil developed allots of variation, this influence is from the geological deposition and deposited minerals, but in engineering properties of soil, it is confirmed to be a homogenous formation. It displayed a model equation as $Y = 2.967x^2 – 1253x + 30.76$ as $R^2 = 0.878$. Figure 4, the plastic limit displayed its level of plasticity in fluctuation form, the optimum value are recorded at 28 0.8m deep suddenly decreasing to the lowest level of plasticity at 14 2.5m deep, the model equation displayed as $Y = 8.816x^3 – 37.12x^2 – 35.90x + 18.42$ and $R^2 = 0.975$. Figure 5 deposited its plasticity in a gradual process, the optimum value were recorded at 25 at 1.5m deep and finally decreased slightly at 2.5m at 24. It developed a model equation as $Y = 0.163x^3 – 2.625x^2 + 7.609x + 18.84$ and $R^2 = 0.975$.Figure 6 shows that the rate of plasticity gradually obtained its optimum value at 21.1.0m deep and decreased with increase in depth where the lowest level of plastic limit were recorded at 17 2.5m deep. It produced a model equation as $Y = 0.713x^3 – 54.45x^2 + 51.744x + 2.040$ and $R^2 = 0.968$.figure 7 rapidly increase its plasticity and deposited its lowest rate at 12; finally develop its optimum value at 27 at 1.0m deep and suddenly decreased with depth. It produced a model equation as $Y = 6.647x^3 – 34.45x^2 + 51.74x + 2.040$ and $R^2 = 0.97$.Figure 8 displayed its lowest level of plasticity12 0.4m deep it increase with depth in an oscillation form to a point where the optimum value was observed at 25 2.5m deep generating a model equation as $Y = -3.099x^2 + 13.11x + 11.68$ and $R^2 = 0.875$. Figure 9 developed its rate of plasticity in gradual process and generated its optimum plastic deposition at 26 1.0m deep and slightly decreases were the lowest rates were observed at 0.4m. It generated a model equation as $Y = 5.304x^3 – 28.43x^2 + 45.10x + 3.030$ and $R^2 = 0.962$.Results from the plastic limit of soil were found to develop lots of variations, some of the results were confirmed to be medium and high plastic, such conditions in Road design should be put into consideration when the organic soil is remove, the introduction of the earth material as subgrade, the rate of plastic limit of soil should be investigated since most of the soil deposited high plasticity and affects the subgrade including the base course of the Road. This study is imperative due to the study location that is deltaic environment and the geologic formation that influences the deposition at the study area, it deteriorate the live span of these roads.

CONCLUSION

From every point of indication, the plastic limit of soil should be investigate to known the level of plasticity of the soil, before it can be applied as earth material for construction of roads in deltaic environment. This study has confirmed that the level of plasticity of the soil in the study location varies between medium and high plasticity and hence the rate of variation at different location can be obtained. From the foregoing the developed models for plastic limit of soil materials would aid design that will ensure standard live span of the road in the study area.

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