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Physical Properties of Residual Profile Found in Minna

Alhaji Mohammed Mustapha

Civil Engineering Department, Federal University of Technology, Minna, Nigeria
<mustpelemi@yahoo.com>

Abstract

Two trial pits, 6Km apart, were dogged to a depth of 5.0m each and both disturbed and undisturbed samples taken at the depths of 0.5, 1.0, 2.0, 3.0, 4.0 and 5.0m. Tests including natural moisture content (NMC), liquid limit (LL), plastic limit (PL), mechanical sieve analysis, hydrometer analysis, specific gravity and Standard proctor compaction, were carried out on the disturbed samples while Insitu dry density and permeability tests were conducted on the undisturbed samples to evaluate the physical properties of the residual soil with depth. It was observed that the profile consists of a reddish lateritic soil layer having a thickness of about 0.8 to 1.7m, between a light reddish silty to sandy soil from the top and a whitish decomposed granite base rock below the layer. In area where water table was encountered before base rock, the NMC decreased to the reddish lateritic layer after which it increased down to the water table. But where otherwise, the NMC increased to the clay layer and decreased down to the base rock. The particle size distribution generally showed higher percentage of coarse soils at the reddish lateritic layer and higher percentage of clay size fractions at the layer just below the lateritic layer. The dry densities showed variation with depth but recorded higher values at the lateritic layer in both trial pits. Therefore, the physical property of the residual soils in Minna varies with depth and should not be treated as uniform.

Keywords: *Soil profile, residual soil, hydrometer, undisturbed soil.*

Introduction

Residual soils occur in different forms in Nigeria and throughout tropical Africa (Madu, 1975). In the northern part of Nigeria, perhaps the largest group of residual soils occurs as laterite and has been used for low-cost and medium trafficked roads. According to Madu (1975), among the residual soils occurring in West Africa, laterites are assumed by many engineers to be the best material for medium trafficked roads. Though some categories of laterite soils are not suitable to be used as road bases, a lot of lateritic gravels and pisoliths occur which are good for gravel roads (Osinubi and Bajeh, 1994).

Many soil workers in Nigeria may treat laterite weathering products and other residual soils as uniform with depth. This is the main reason why single or few soil test results carried out on a soil in a trial pit at the beginning of excavation is used to represent soils at deeper depth of the borrow pit. They are not mindful of the composite and complex nature of the weathering materials and the variation in the morphological, geotechnical, mineralogical and chemical properties of the materials with depth of the weathering profile (Adekoya, 1987). According to Zonn (1986), all tropical and subtropical soils can be grouped in terms of their profile as:

a. Soils whose profile depends on textural or structural differentiation.
b. Soils whose profile are mainly differentiated by texture and
c. Soil that can further be differentiated by the morphology of the individual generic horizons.

Therefore, to neglect the change in the physical properties of residual soils with depth may lead to misleading results and consequently, serious failure to geotechnical structures. Adekoya (1975) has carried out study on the geological and geotechnical lateritic weathering profile derived from banded gneiss in Ibadan area of south-west Nigeria but same has not been done on the residual profile derived from the young granite of Minna and its environs. This work is therefore aimed at determining the variation of the physical properties of residual soils derived from granite in Minna.

Location, Climate and Geology of Study Area

The two trial pits studied are located in Minna, Niger State of Nigeria. The area lies between longitudes 6^0E and 7^0E and the latitudes 9^0N and 10^0N. According to Wright (1989), the residual soil in this area is under laid by a granite basement and is surrounded to the north and south by the older basement rocks of the Precambrian to upper cambrian age and Illo-group formation to the north-west. The area is drained by several rivers which are tributries of River Niger.

Rainfall in this area varies considerably from station to station. The maximum rainfall per year varies from 1000mm to 1500mm for different locations.

Materials and Methodology

Two trial pits were dugged to a depth of 5m and soil samples collected at 0.5m, 1.0m, 2.0m, 3.0m, 4.0m and 5.0m depths in each of the trial pits. Trial pit ‘A’ was dugged at the southern end of Minna, along Minna-Bida road while trial pit B was dugged at the Bosso Campus of Federal University of Technology, Minna, a distance of about 6km away from trial pit A. During the digging, the soil profile was visually inspected and both undisturbed and disturbed soil samples collected at the above mentioned depths. The disturbed samples were air dried and tests including natural moisture content (NMC), Mechanical sieve analysis, Hydrometer analysis, liquid limit, plastic limit, specific gravity (S.G) and compaction tests were carried out on them. Permeability and insitu bulk density tests were also conducted on the undisturbed soils. All these tests were conducted according to the procedure highlighted in BS1377 (1997) with some modifications where necessary.

Results and Discussion of Results

Visual Inspection:

The profile of trial pit ‘A’ showed a light blackish top soil with a thickness of 0.3m. the soil below this layer is a light brown silty soil to a depth of 0.8m. A reddish fine laterite soil with occasional pisoliths was observed below 0.8m depth to a depth of 2.5m. Below this level, the soil gradually changed to whitish colour maintaining the structure of the base rock. The decomposed base rock gets whiter with depth to about 4.5m where water table was encountered and whiter more below the water table.

The profile of trial pit B is similar to that of trial pit A except that the thickness of various layers differs from one another. The top soil in this profile is 0.2m thick underlain by a sandy soil to a depth of 0.65m. The sandy layer is underlain by a reddish latentic soil with undecomposed rocks to a depth of 1.45m. Below the latentic layer, a whitish soil with the structure of the base granite rock was encountered to a depth of 5m where digging became almost impossible.

From the discussion thus far, the residual profile is generally composed of a latentic layer of varied thickness between a silty or sandy soil and a decomposed granite base rock with water table at a depth of between 4.5 to 5m in some areas. This arrangement is shown on the sketch in Fig. 1 below.

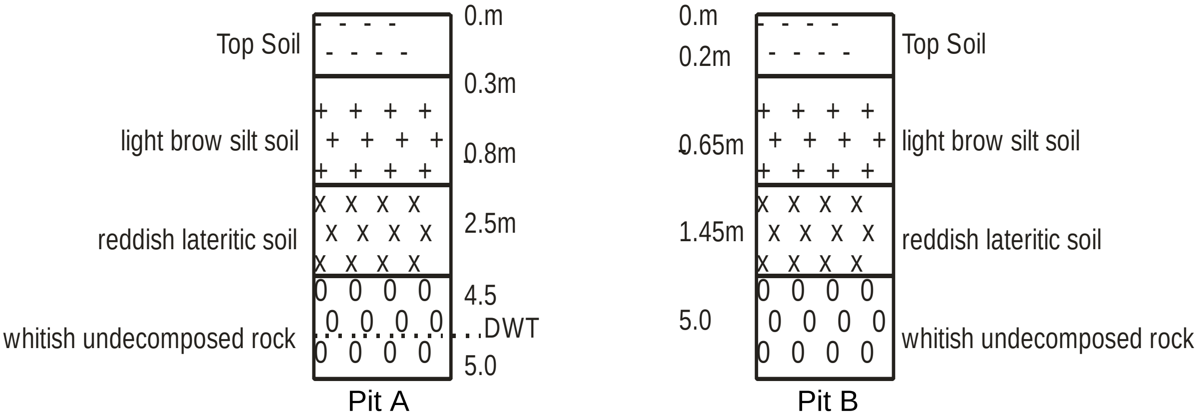

Fig. 1. Soil profiles for trial pits A and B.

Natural and the Optimum Moisture Content

The natural moisture content of samples from trial pit A decreased from 11% at 0.5m depth to 10% at 1.m depth after which it increased to 38% at 5.0m depth. This is not the same with the recompacted optimum moisture content (OMC) which increased from 17.6% at 0.5m depth to 20.5% at 1.0m depth. The value decreased again to 16.39 at 2.0m depth after which it increased to 20.1% at 4m depth. The trend of the natural moisture content (NMC) with depth is an indication of the presence of water table before the hard rock base.

The trend of the natural moisture content for samples in trial pit B showed an increase from 8% at 0.5m depth to a maximum of 17% at 2.0m depth after which it decreased to 11% at 5.0m depth. The recompacted optimum moisture content also increased from 10.5% to a maximum of 15.6% at 3.0m depth after which it decreased. The trend of the natural moisture content is indicative of the absence of water table before the base rock. Therefore, it is pertinent to note that no special correlation exists between the natural moisture content and the recompacted optimum moisture content. These trends are shown on Fig. 2 below.

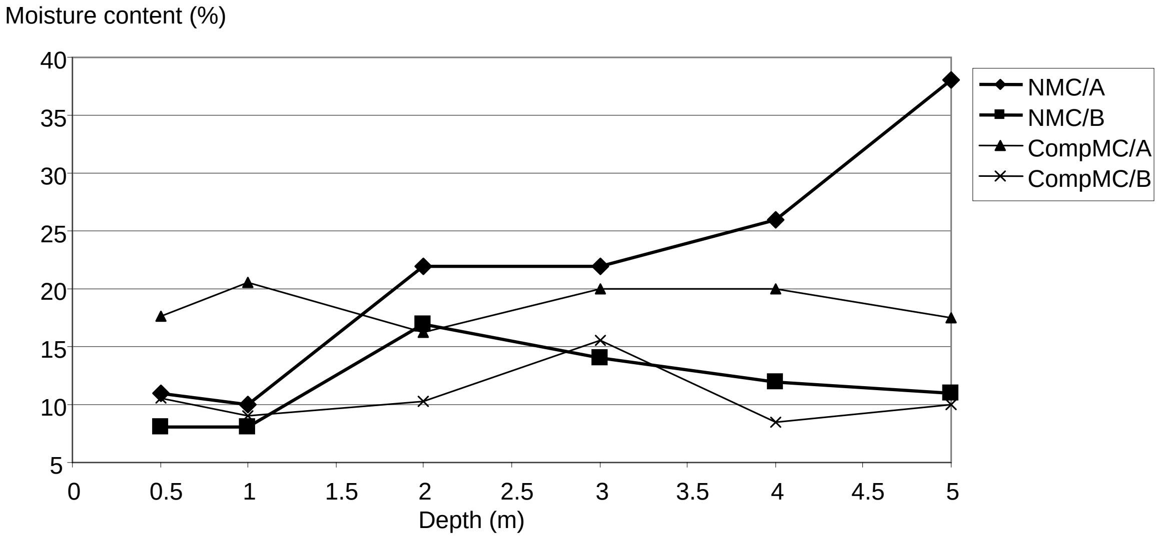

Fig. 2. Variation of natural and compacted moisture content with depth for samples from trial pits A and B.

Particle Size Distribution and Hydrometer Tests

The particle size distribution for samples in trial pit A showed high percentage of fine soil fraction of 72% at 0.5 depth after which the value decreased to 44% at 1.om depth. The fine soils increased again to 68% at 2.0m depth. Below this depth, the value decreased to

61% at 5m depth. The clay size fractions on the other hand, decreased again to 24% at 2.0m depth and finally decreased to 0% at 4 and 5m depths. This implies that the 65% and 61% fines recorded at 4m and 5m depths respectively are all silty size particles. This is probably because soil formation at this depth is still at its early stage and clay size particles are yet to be formed. Also, the rapid decrease of fine fraction at 1.0m depth was due to the high percentage of latentic gravels of 24% recorded at that depth. The high proportion of clay size particles encountered at 2.0m depth is in agreement with Zonn (1986) who argue that, in residual soil profile, clay particles are leached to the layer just below the latentic layer.

The trend is similar in trial pit B where the proportion of fine particles decreased from 23.6% at 0.5m depth to 18.8% at 2m depth. Below this depth, the proportion of fine soils decreased to 28% at 5.0m depth. The proportion of clay size particles also decrease from 15% at 0.5 and 1.0m depth to 5% at 3m depth and 0% at 5m depths respectively. Therefore, the residual profile derived from the granite base rock in Minna is characterised by the absence of clay size fractions at 4m and 5m depths. It was also observed that the clay size fractions are maximum just below the latentic layer. The trends are shown on Figs. 3 and 4, respectively.

Atterberg Limits

The liquid limits for samples in trial pit A increased from 36% at 0.5m dept to 46% at 3.0m depth after which the values decreased to 38% at 5.0m depth. The plastic limits on the other hand increased from 28% at 0.5m depth to 30% at 1.0m depth. The values reduced to 21% at 3m depth and increased to 32% at 5m depth. The highest liquid limit, 46% recorded at 2m depth is probably due to accumulation of clay size particles that was leached from the latentic profile.

In trial pit B, the liquid limit increased from 16% at 0.5m depth to 39% at 3.0m depth after which it decreased to 36% at 0.5m depth. The samples from 0.5m to 1.0m depth and those from 4.0m to 5.0m depths are non plastic. The reason for this non plasticity might have stemmed up from coated particles at 1.0m depth. The plastic limit 20 and 21% recorded for samples at 2 to 3m depth confirmed the accumulation of clay size particle just below the latentic soil profile. The trend is shown on Fig. 5 below.

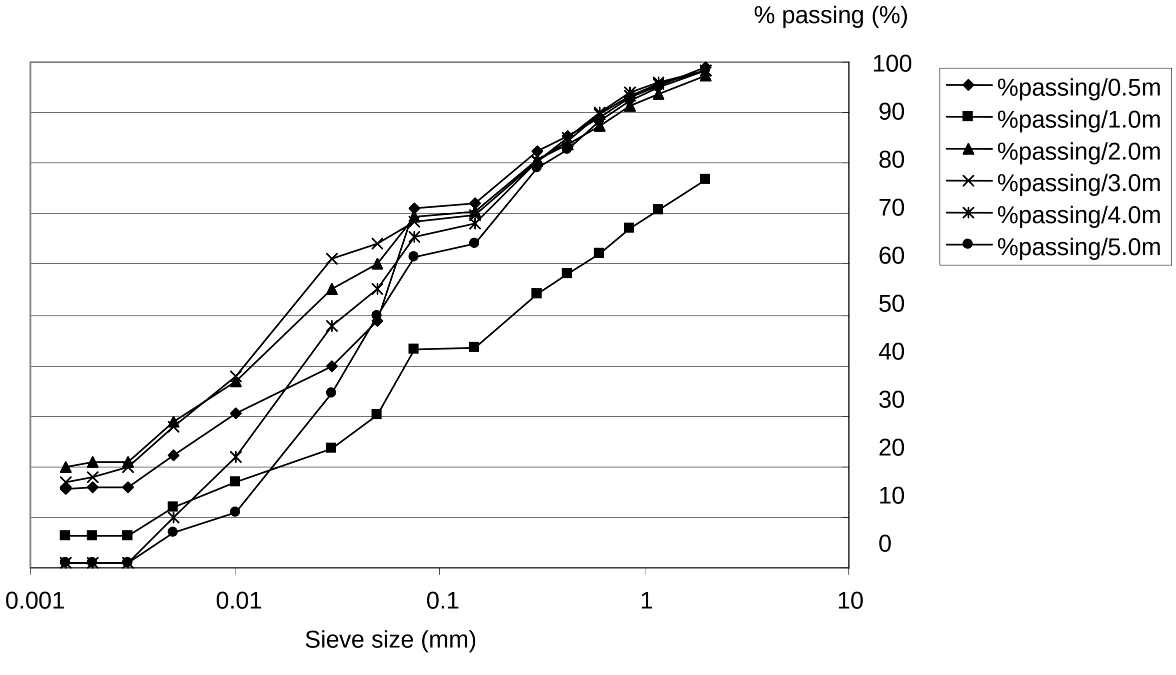

Fig. 3. Variation of particle size distribution with depth for sample from trial pit A.

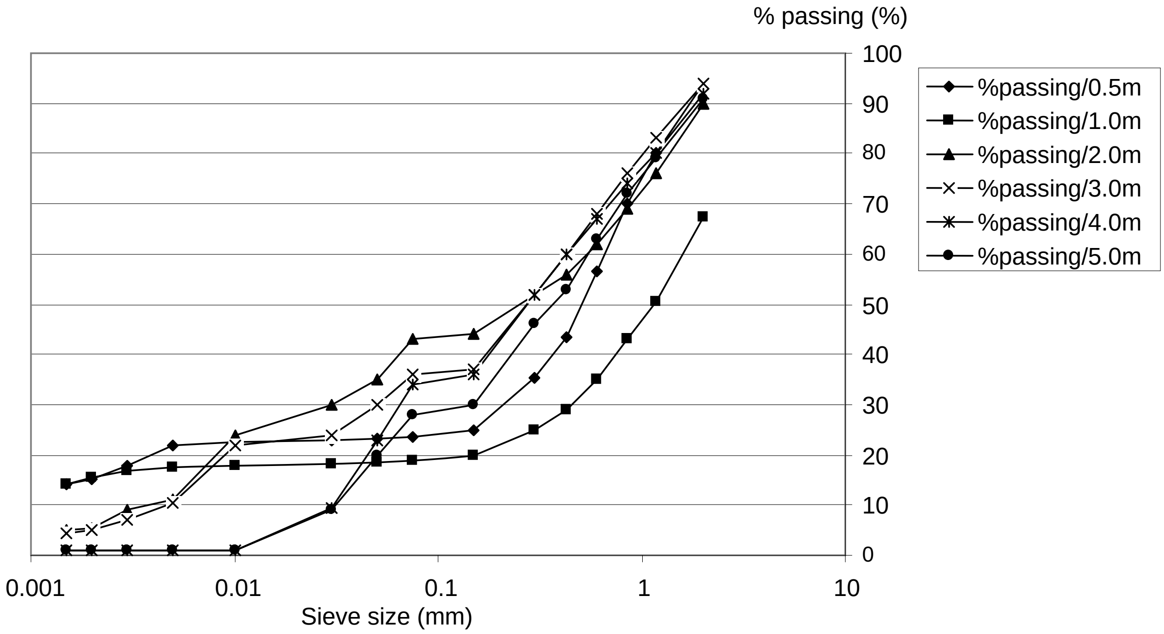

Fig. 4. Variation of particle size distribution with depth for samples from trial pit B.

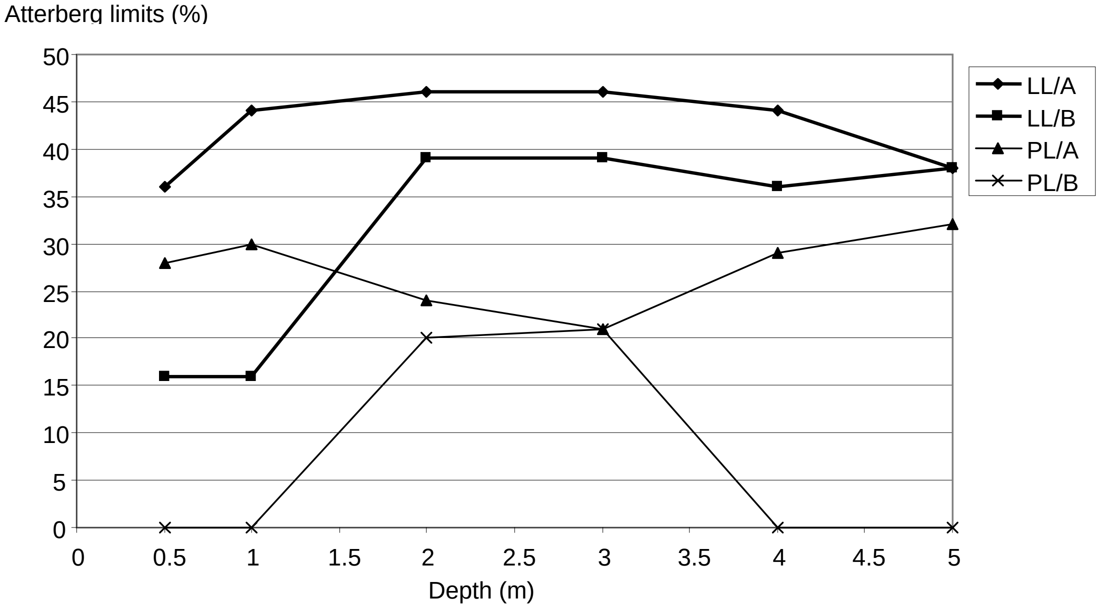

Fig. 5. Variation of Atterberg limits with depth for samples from trial pits A and B.

Specific Gravity

In trial pit A, the specific gravity increased from 2.53 at 0.5m depth to 2.64 at 3.0m depth. The value decreased once more to 2.60 at 4m depth and finally increased to 2.64 at o.5m depth. The higher value recorded at 2 and 3m depths were probably due to presence of free irons in this depth which are heavier than ordinary soil particles. The value of 2.64 also observed at 5.0m depth may be due to the undecomposed base rock. Trial pit B however, showed decrease in specific gravity from 2.66 at 0.5m depth to 2.52 at 2.0m depth after which the values increased to 2.64 at 5.0m depth. The least value of 2.52 recorded at 2.0m depth is due to the dominance of clay size particles at this depth which poses low specific gravity. The variation of specific gravity with depth is shown in Fig. 6 below for the two trial pits.

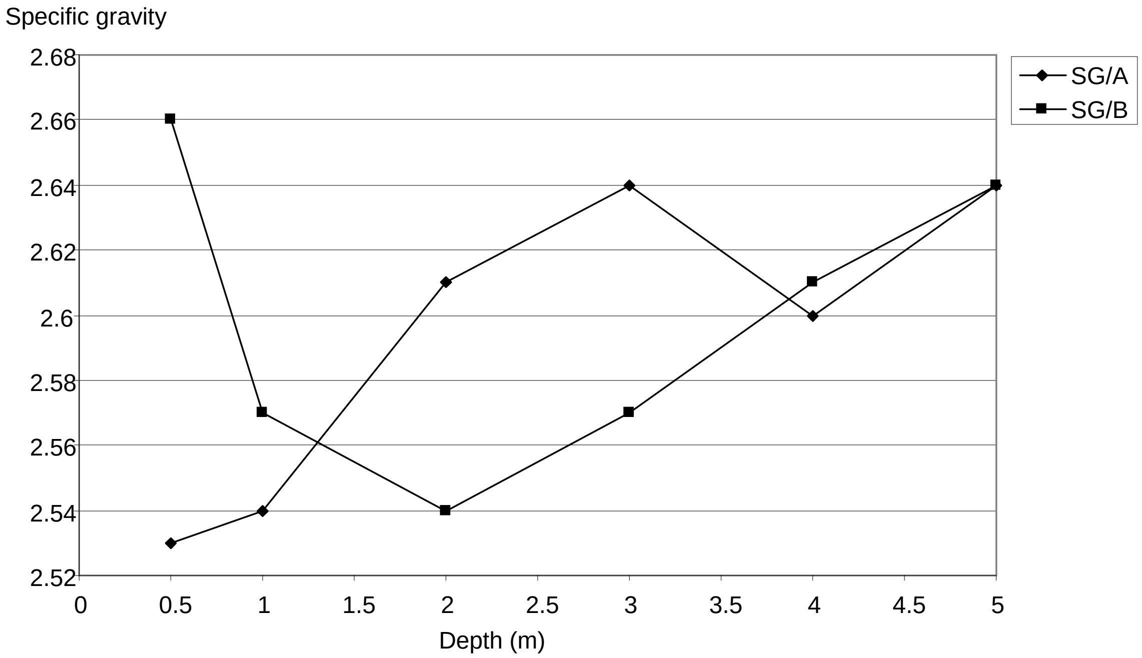

Fig. 6. Variation of specific gravity with depth for samples from trial pits A and B.

Undisturbed and Recompacted Dry Densities

The insitu densities of samples from trial pit A increased from 1.866Mg/m^3 at 0.5m depth to 1.928Mg/m^3 at 1.0m depth. The value then reduces to 1.598Mg/m^3 at 2.0m depth after which the value increased to 1.669Mg/m^3 at 4m depth. The trend of the insitu dry densities with depth from 0.5m to 2.0m depth is in agreement with the findings of Gidigasu and Kuma (1987) who studied a residual profile to a depth of 1.5m.

The dry density of samples recompacted at British Standard light (BSL) compaction energy level however, decreased from 1.805mg/m^3 at 0.5m depth to 1.635Mg/m^3 at 2.0m depth. The values then increased to 1.802 Mg/m^3 at 4m depth and decreased again to 1.745Mg/m^3 at 5.0m depth. The maximum insitu dry density observed at 1.om depth is probably due to the accumulation of free iron at that layer resulting from laterization.

The undisturbed dry densities from trial pit B decreased from 1.786Mg/m^3 at 0.5 depths to 1-605Mg/m^3 at 2.0m depth. Below this depth, the values increased to 1.756Mg/m^3 at 5.0m depth. The recompacted dry densities on the other hand, increased from 2.040Mg/m^3 at 0.5m depth to 2.050Mg/m^3 at 0.1m depth. Below this depth, the MDD values decreased to 1.925Mg/m^3 at 4.0m depth after which the value increased again to 1.998Mg/m^3 at 5.0m depth. The higher dry density values recorded at 1.0m depth for both trial pits indicate presence of denser particles which is suspected to be iron oxides synthesized from the process of laterization. The variation of undisturbed and recompacted dry densities with depth is shown in Fig. 7 below.

Permeability

The co-efficient of permeability for samples from trial pit A decreased from 2.8x10^{-4}cm/s at 0.5m depth to 1.72x10^{-5}cm/s at 4.0m depth. This is perhaps due to the fact that successive sub surface layers down the soil profile has under gone higher surcharge from the upper layers and have been compressed proportionately, hence decrease in permeability down the profile irrespective of the composition of the grain sizes down the profile. Also, despite the co-efficient of permeability for samples in trial pit B are generally higher, the trend also showed decrease from 6.65x10^{-3}cm/s at 0.5m depth to 7.72x10^{-4}cm/s at 5.0m depth. The graph is shown on Fig. 8 below.

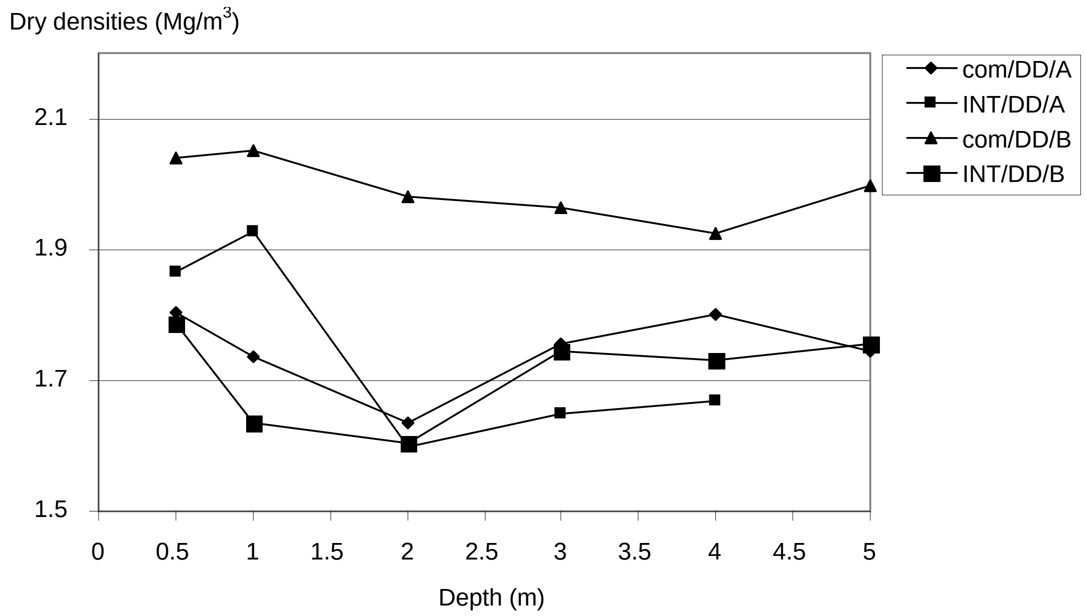

Fig. 7. Variation of insitu and compacted dry densities with dept for trial pits A and B.

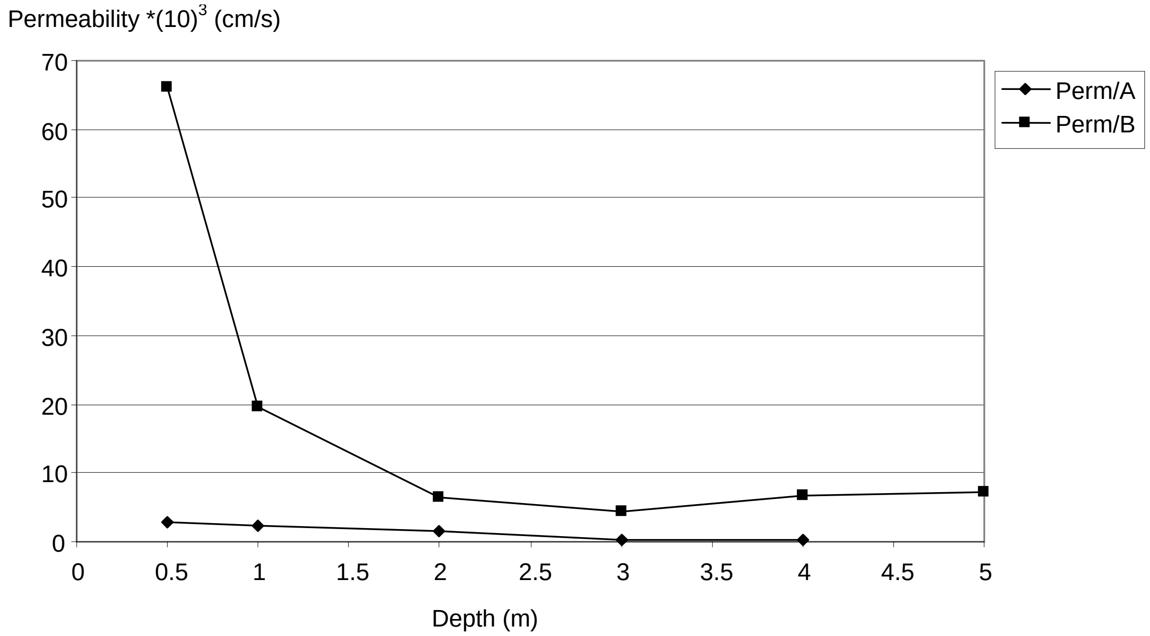

Fig.8. Variation of undisturbed soil permeability with depth for samples from trial pits A and B.

Conclusions

In conclusion, it was visually observed that the residual profile in Minna and it's environ consist of a reddish lateritic soil profile having a thickness of about 0.8 to 1.7m, between a light brownish silty to sandy soil from the top and a whitish decomposed granite base rock below the profile. Where water table was encountered before the base rock, natural moisture contents decreased to a depth of about 1 to 2m after which the N.M.C increased down to the water table. In the area where water table was not encountered before base rock however, NMC increased to a depth of about 2 to 3m after which the value decreased to base rock.

The particle size distribution generally, showed higher percentage of coarse soils at the reddish lateritic layer and higher percentage of clay size fractions at layers just beneath the lateritic layer. Also, both the undisturbed and recompacted dry densities showed increase and decrease at various layers down the profile but recorded higher values at the lateritic layer in both trial pits. The permeability of the undisturbed samples decreased from top down to the base rock in both trial pits.

It is therefore, clear that all physical properties of residual soils studied varied with depth and results obtained for soils at one layer should not be used to represent the result of soils at other layers for the avoidance of in accurate design of soil structures which may lead to its failure on application of the first load.

References

Adekoya, J.A. 1987. A preliminary geological and geotechnical study of lateritic weathering profiles derived from banded gneiss in the Ibadan area, SW Nigeria. Proceedings of the 9th Regional Conference for Africa on Soil Mechanics and Foundation Engineering, Akinmusuru, J.O.; Malomo, S.S.; and Sesida, E.A. (Eds.), Lagos, Nigeria, 15-17 September, A.A. Balkema, Rotterdam, The Netherlands. pp. 21–30.

British Standard BS1377. 1990. Methods of testing soil for civil engineering purposes. British Standards Institute (BSI), London, UK.

Gidigasu, M.D.; and Kuma, D.O.K. 1987. Engineering significance of laterization and profile development processes. Proceedings of the 9th Regional Conference for Africa on Soil Mechanics and Foundation Engineering, Akinmusuru, J.O.; Malomo, S.S.; and Sesida, E.A. (Eds.), Lagos, Nigeria, 15-17 September, A.A. Balkema, Rotterdam, The Netherlands. pp. 3-21.

Madu, R.M. 1975. Some Nigerian residual soils – there characteristics and relative road building properties on a group basis. Proceedings of the 6th Regional Conference for Africa on Soil Mechanics and Foundation Engineering, Pells, P.J.N.; Caldwell, J.A.; Robertson, A.M. (Eds.), Durban, South Africa, 8-12 September, A.A. Balkema, Cape Town, South Africa. pp. 121–29.

Osinubi, K.J.; and Bajeh, I. 1994. Bituminous stabilization of laterite. Spectrum Journal 1(2): 104-12.

Wright, J.B. (1989). Volcanic rocks in Nigeria. In: Geology of Nigeria. 2nd Revised Edition, Kogbe, C.A. (Ed.), Rock View (Nig.) Ltd., Jos, Nigeria. pp. 125-75.

Zonn, S.V. 1986. Tropical and Subtropical Soil Science. Mir Publishers, Moscow, USSR. pp. 31-32.