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Characterizing the Engineering Properties of Residual Soils of Migmatite and Charnoakite Precursor for Infrastructural Development

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Abstract: ***The study is an investigation into the engineering properties of Migmatite and Charnockite precursor soils with a view to determining their suitability for sustainable infrastructural development. Six disturbed soil samples were sampled and used for the study. The results of the investigations showed that the soils from both locations have the same degree of laterization and they are fairly graded being rich in fines. Cassagrande chart classifies soils from both locations as inorganic intermediate plastic soils (CI). The results obtained further revealed that all the soil samples exhibit good compaction parameters; high water retention capacities and poor drainage characteristics. The California bearing ratios (CBR) of all the soil samples are generally suitable in comparison with the recommended standard values. It is concluded from the integrated results that though both derived soil samples from the study areas are safe and fairly competent for any engineering work, the Migmatite residual soil samples possess better engineering properties and is thereby recommended as more suitable material for all civil engineering construction projects.***

Keywords: *Migmatite, Charnockite, Engineering Construction, Laterization, Infrastructural.*

1. Introduction

Residual soil materials are produced by in-situ rock weathering and can be commonly found in the surface and subsurface profiles across the Nation. **R**esidual soils are commonly referred to as lateritic soils especially in the tropics. According to Osinubi and Bajeh, (1994), Lateritic soils have been identified as the most common material that is routinely used in civil engineering works in the tropics as a result of its availability and cost effectiveness. Its usage as reported by Uche and Abubakar, (2010) has led to development of its potentials as reliable and durable construction material that is readily available. Due to their in-situ formation, residual soils generally possess significant microstructure (rock fabric) and material characteristics closely related to those of their parent rock. The engineering properties of residual soils will reveal their suitability for construction work. Investigating the properties will also show the variability of selected parameters in the area under study. Hence, paper recommendation can be made. Geotechnical properties of the subsoil along a section of a realigned Igbaraodo-Ikogosi highway were investigated. Field mapping revealed an underlying basement rock suite. The road was realigned as a result of the windy nature of the road along a particular section in order to prevent frequent motor accidents. The geotechnical test results of subsoils in the new alignment showed soil geotechnical properties. The liquid limit range from 24% to 66% while the soil is well graded silty sandy clay. The specific gravity values range from 2.60 to 2.65, the maximum dry density range from 1850 kg/m^3 to 2040 kg/m^3, the linear shrinkage values are below 7 while kaolinite predominate the soil clay mineral. Akintorinwa and Adeusi, (2009) say that soils that are largely made up of fine particles are likely to have poor geotechnical properties as foundation materials than soils that are largely made up of coarse particles. In their study to determine the factors responsible for road failure along Ilorin-Ajase Ipo road, Kwara State, soil samples were collected to determine particle size distribution (PSD), atterberg limit, compaction test and California Bearing Ratio (CBR). The result indicated that, the soil has 50% sand, Coefficient of curvature (CC) 28% and coefficient of Uniformity 14.1%. These combinations contributed to the failure of the road. Consequently, it is essential that proper selection be made of the type of soil to be used as subbase material for all construction works especially in road construction along with good understanding of the geological formation of the terrain.

2. Study Area

The study area lies within latitude 07˚17" N, longitude 05˚07"'E and latitude 07˚ 35" N, longitude 05˚ 12 E. The area is underlayed by charnockitic rocks and Migmatite-Gneiss complex. The Charnockitic rocks constitute one of the important petrologic units within the Precambrian Basement Complex of Nigeria. They usually contain quartz + plagioclase + alkali feldspar + orthopyroxene + clinopyroexen + hornblende + fayalite. Accessory minerals are usually zircon, apatite and iron ores (Olarewaju, 2006). Migmatite rock constitute a mixture of metamorphic rock and Igneous rock. Migmatite form under extreme temperature conditions during prograde metamorphism, where partial melting occurs in pre-existing rocks. Migmatites is one of the heterogeneous assemblages of the migmatite-gneiss complex, generally considered as the basement complex *sensu stricto* (Rahaman, 1988; Dada, 2006).

3. Materials and Methodology

Materials

The following materials were used in the collection and analysis of samples; measuring tape, sampling bags, digger, shovel and GPS equipment.

Methodology

Three disturbed soil samples for each of the two different lithologies were collected at an average depth of 1.0m from trial pits designated A to F. A – C samples were collected for Charnockite derived soil while D – F were for Migmatite derived soils. The pre-treatment was done after the Moisture content was determined for each sample. This involves air-drying of soil sample for four (4) days, and were later subjected to the following geotechnical tests; Grain size analysis, Atterberg limit, Compaction test in accordance with the BS 1377 [BS 1377: 1990]. However, to ensure effective segregation of soil grains, the soils were soaked and regularly agitated in water for a period of 24hrs before wet sieving grain size analysis. The results of the geotechnical analyses were interpreted and presented. Mineral identification was done using plasticity chart developed by Cassagrande data [Mitchell, 1976]. The properties and grading curve of the lateritic soil are shown in Table 1 and Figure 4 respectively.

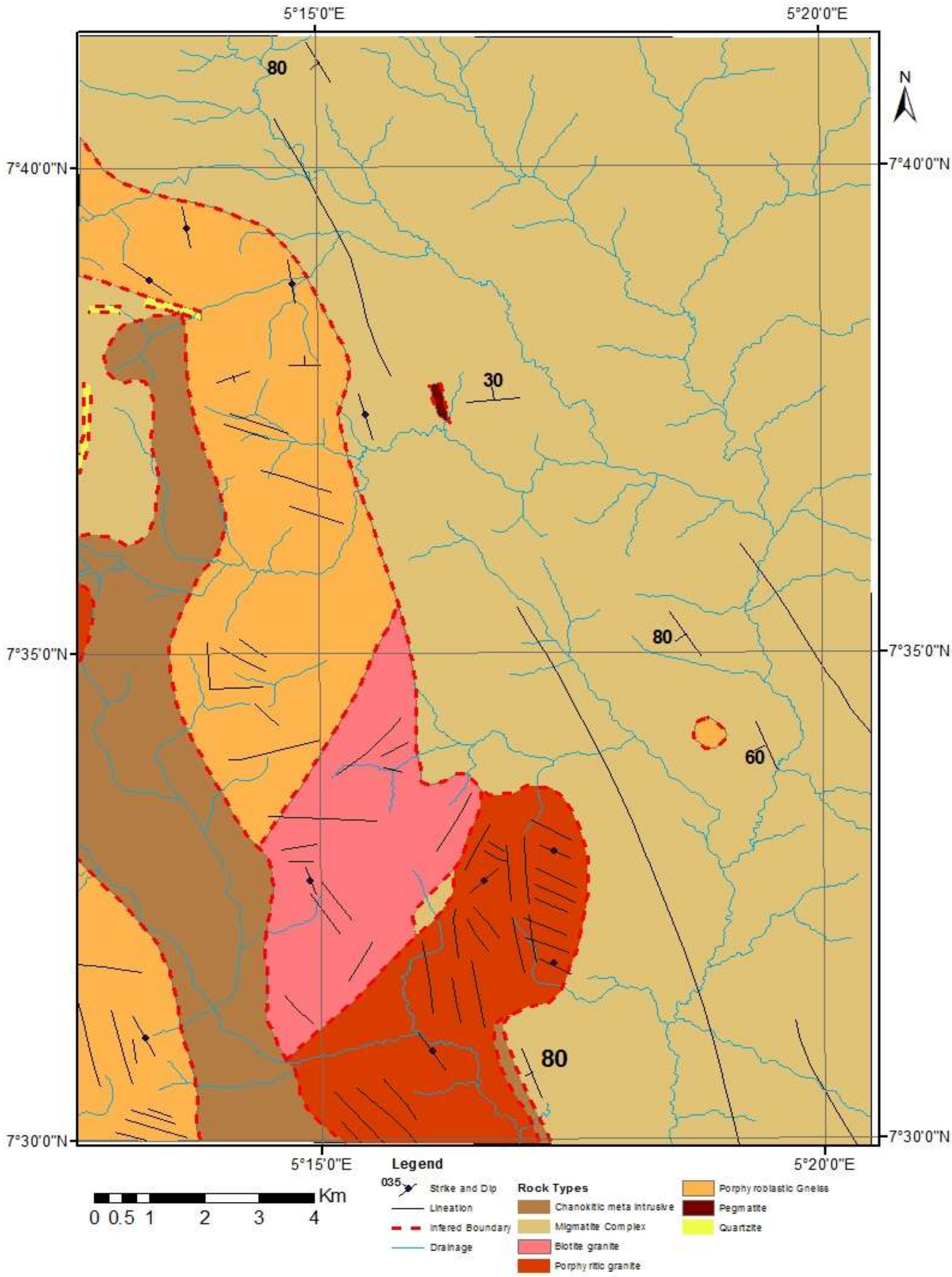

Figure 1: Geological Map of the Study Area
Source: Nigeria Geological Survey Agency

Table 1: Engineering Properties of Migmatite and Charnoakite.

	CHARNOCKITE				MIGMATITE		
% /Test Co-ordinates Lg Lat.	TPA – N - 07^{0}18” 05˚08” TPB – N - 07˚17” 05˚07” TPC - N - 07˚17” 05˚08”				TPD - N 07˚.31” E 05˚ 13” TPE - N 07˚ 34” E 05˚ 12” TPF - N 07˚ 35” E 05˚ 12		
M.C	7.2	7.6	8.3		8.2	6.5	6.1
Gs (%) BS NO 200 sieve							
FINES (%)	40.6	39.4	39.0		40.7	40.4	41.3
SAND (%)	52.3	52.6	59.7		58.0	57.1	57.5
GRAVE (%)	7.1	8.0	1.3		1.4	2.4	1.2
AASHTO/USCS Symbols	/SC-SM	CI/SC-SM	CI/SC-SM		CI/SC-SM	CI/SC-SM	CI/SC-SM
CONSISTENCY LIMITS							
Liquid Limit, LL (%)	38.6	39.6	40.8		38.8	36.2	38.5
Plastic Limit, PL (%)	23.4	23.7	23.4		23.3	24.4	24.3
Plasticity Index, PI (%)	15.2	16..0	17.5		15.5	11.8	14.3
Linear Shrinkage	8.6	8.6	9.3		8.6	7.9	8.6
Shrinkage Limit	9.6	9.6	9.1		9.6	10.1	9.6
Cassagande Chart	CI	CI	CI		CI	CI	CI
Degree of Expansion	Critical	Critical	Critical		Critical	Marginal	Critical
COMPACTION							
OMC (%:)	14.2	13.4	16.0		16.7	16.6	17.5
MDD (kg/m3)	1910	1914	1840		1812	1800	1763
CBR (%)	SK :USK	SK :USK	SK : USK		SK : SK	SK : USK	SK : USK
CBR (%) Values	23 :34	26 : 36	16: 22		17 : 25	17 : 24	16 : 23
STRENGTH RATING	GS; SB	GS : SB	EXL: SG		GS; SB	GS : SB	EXL: SG
CONSOLIDAION (M2/YR)	0.01270	0.01241	0.01042		0..01249	0..01255	0..01259
FRICTIONAL ANGLE (0’)	32.6	32.1	27.3		26.9	26.6	25.9
COHESION (KPa)	77.0	80.6	93.2		94.8	96.5	99.5
UNDERAINED SHEAR STRENGTH (KPa)	115.3	118.2	124.2		125.2	126.6	128.6
STRENGTH CHARACTER	HIGH	HIGH	HIGH		HIGH	HIGH	HIGH

Legend: SK: USK : Soak and Unsoak SCH :Soil of High Compressibility and Plasticity NS : Normal Subgrade Strength GS : Good Subgrade Strength PS :Poor Subgrade Strength CBR :Canifolial Bearing Ratio
OMC: Optimal Moisture Content MDD : Maximal Dry Density

4. Results and Discussion

Moisture Content

The natural moisture content of the tested soil samples values ranges from 7.2% to 8.3% and from 6.1% to 8.2% for Charnockite and Migmatite soils respectively Table 1. The result shows that at its natural state, the natural moisture content of the soil in the area is relatively very low. Jegede (2000) reported moisture variation is generally determined by intensity of rain, depth of collection of sample and texture of the soil.

Grain Size Distributions

The results of the six studied soil samples are presented in Table 1 and the curve distribution in Fig.4.. The residual soils posses percentage fines ranging from 39.0% to 40.6%, and 40.4% to 41.3% for both migmatite and charnockite repectively. Most of the soils have percentage passing No. 200 (0.075 mm) of more than 35%, hence, the soils range in group classification from A-4 to A-7 and are generally rated as fair to poor sub-grade highway materials. Based on USCS, the soil can be classified as clayey silty sand (SC-SM). This implies that both samples may be rated as fair to good sub-grade highway materials.

Consistency Limits

The liquid limit, the plastic limit and the plasticity index (Liquid Limit- Plastic Limit) of the soils from the Charnockite residual soil ranges from 38.6% to 40.8%, 23.4% to 23.7% and 15.20 % to 17.45% respectively while that of the Migmatite derived soils have liquid limits, plastic limit and plasticity index values ranging from 36.2% to 38.8%, 23.3% to 24.4% and 11.80% to 15.50% respectively. These values indicated that the soil have intermediate plasticity according Cassagande Chart Fig. 2. Thus, the soil samples are safe for foundation structures and construction purposes. The maximum plasticity index value of 17.45% recorded in the study area is less than 20%. Thus, the tested soil samples are of low consistency limits indicating low percentage of clay content in the soil. Hence, it shows a good engineering property, since the higher the plasticity index of a soil, the less the competency of the soil as a foundation material.

Brink *et al.* (1992) suggested that soils with linear shrinkage below 8% would be inactive, inexpensive and are good as foundation material. The linear shrinkage of all tested soils are greater than 8%, hence the soils are likely to be subjective to swelling and shrinkage during alternate dry and wet seasons of the humid tropical climatic condition of the south western Nigeria. This must be taken into cognizance in the design of the foundation in the study areas.

Compaction

The results of the relationship between the Moisture Content and Dry density of the soil samples are presented shown in Fig. 3. The values of the moisture content ranges from 13.4% to 16% and MDD values ranges from 1840kg/m^3 to

1941kg/m³ for the Migmatites soil samples while that of Charnockite derived soils range from 16.6% to 17.5%. The MDD ranged from 1763 kg/m³ to 1812 kg/m³ (Fig. 3). The results indicate that Migmatites possess higher compaction values with lower moisture content compared to the charnockite residual soil samples. However, both soils respond favorably to compaction. The importance of compaction is to improve the desirable load bearing properties of soil as a foundation material. Hence, the engineering properties of both lithologies can be upgraded to the desired values.

Califonia Bearing Ratio

The results of the unsoaked California Bearing Ratio (CBR) values for the migmatite derived soil samples ranges from 22% to 34%, while those from the charnockite soil samples ranges from 23% to 25% see table 1. It is apparent that soils from the migmatite complex have a higher unsoaked CBR value compared with those from charnockite complex terrain. The result also shows that CBR of the soils reduce greatly as a result of soaking, and the amount of water absorbed is more than 20% for both locations A and B. This further stresses the fact that these soils in these two locations have high water retention capacity and that adequate drainage is required in order to prevent ingress of water below the pavement, which could result in a significant loss of strength of the sub grade soils and hence failure of the overlying pavement. However, it is apparent that soils from the migmatite complex have a higher unsoaked CBR value compared with those from charnockite complex terrain. (Table.1)

Shear Strength

The triaxial compression test is used to measure the shear strength of soil the samples under controlled drainage conditions. The shear strength parameters are; angle of internal friction, from 25.9^o to 32.6 ^{o}, cohesion ranges from 77.0Kpa to 99.5Kpa and the undrained shear strength, from 115.3Kpa to 128.64Kpa. According to the Unified Soil Classification System (USCS), the result obtained from the triaxial shear strength test can be used to classify the soils based on angle of internal friction. Since all the angle of internal friction is above 25^o, the soils are classified as hard, and will be reliable and suitable to sustain any construction and infrastructure projects.

Consolidation

Consolidated drained (CD) under a constant net confining stress and consolidated drained direct shear tests were performed to determine saturated and unsaturated shear strength parameters of residual soils from the two lithologies formations. The consolidation properties determined from the consolidation test are used to estimate the magnitude and the rate of both primary and secondary consolidation settlement of a structure. Estimates of this type are of key importance in the design of engineered structures and evaluation of their performance especially in terms of differential settlement. The coefficients of consolidation values for both rock type derived residual soils is very moderate and shows that they are suitable to accommodate any engineering infrastructure load. Table 1.

5. Conclusion

The investigation revealed that the six locations fall under group A-7 of (AASHTO., 1986). classification and classified as CI under the USCS classification system. They are rated as good sub base and excellent sub-grade materials with low material moisture content. The soils sample exhibited favorable compaction tendency and low settlement rate with high undrained shear strength values. Stabilization of the residual soils in the study areas to further enhance its engineering properties of the material is very possible. However, Migmatite residual soil sample showed a higher CBR values while the charnockite residual soil exhibited better shear strength values. It is concluded from the integrated results that the subsoil from the study areas is safe and fairly competent for any civil engineering infrastructural work, most especially as foundation materials, refill in road construction work, and in dam construction project.

References

[1] AASHTO: (1986) “Standard Specifications for Transportation Materials and Methods of Sampling and Testing, 14th Edition.” American Association of State Highway and Transportation Officials, Washington D. C., USA.
[2] Akintorinwa, O.J., and Adeusi, F.A (2009). Integration of Geophysical and Geotechnical Investigations for a Proposed Lecture Room Complex at the Federal University of Technology, Akure, SW, Nigeria. Jour. Of Applied Sciences 2(3), pp 241-254.
[3] Brink, A.B.A., Partridge, J.C and Williams A.A.B (1982). “Soil Survey for Engineering. Clardon, Oxford, 375.
[4] British Standard Institution (BSI) 1377 (1990). “Methods of testing soils for civil engineering purposes”. British Standards Institution, London.
[5] Cassagrande, A. 1948. Classification and Identification of Soil Transaction ASCE, Vol. 113 New York.
[6] Dada, O .O (2006): Proterozoic evolution of Nigeria. In: Oshio (ed). The basement complex of Nigeria and its mineral resources (A Tribute to Prof. M.A.O. Rahaman). Akin Jinad & Co. Ibadan, pp. 22-44.
[7] Jegede, G. (2000). Effect of Soil properties on Pavement Failures along the F 209 Highway at Ado-Ekiti, Southwestern Nigeria. Construction and Building Materials Elservier, Oxford 14, 311 – 315.
[8] Mitchell J. K.(1976); “Fundamentals of Soil Behaviour. “ John Wiley & Sons, Inc., New York, USA.
[9] Mustaphas M.A,(2005) . Effects of Bagasse ash on Cement Stabilized Laterite. Seminar paper presented at the Department of Civil Engineering Ahmadu Bello University, Zaria, Nigeria.
[10] Rahaman, M.A., (1988): Recent advances in the study of the basement complex of Nigeria. In: Geological Survey of Nigeria (Ed) Precambrian Geology of Nigeria. pp. 11-43.
[11] Rahaman, M.A., (1989): Review of the basement geology of southwestern Nigeria. In: Kogbe, C.A., (ed) Geology of Nigeria, Rock View (Nig.) Limited, Jos, Nigeria, pp. 39-56.
[12] Uche O.A.U and Abubakar, M.N (2010): Influence Of Neem Seed Husk Ash (NSHA) On Engineering

Properties of Residual Lateritic Soil, Journal Engineering and Technology, Vol. 4 No 2 Pp38 - 44.

Appendix

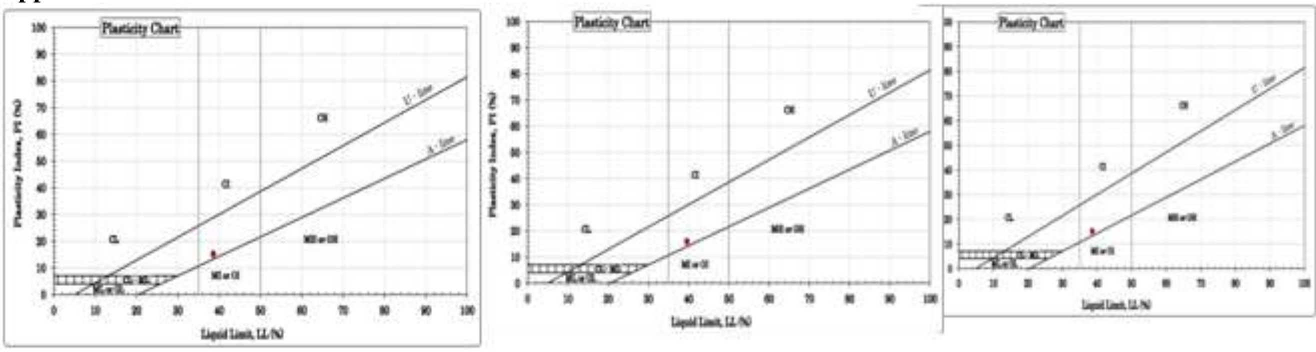

Figure 2(i): Plasticity of soil samples A – C

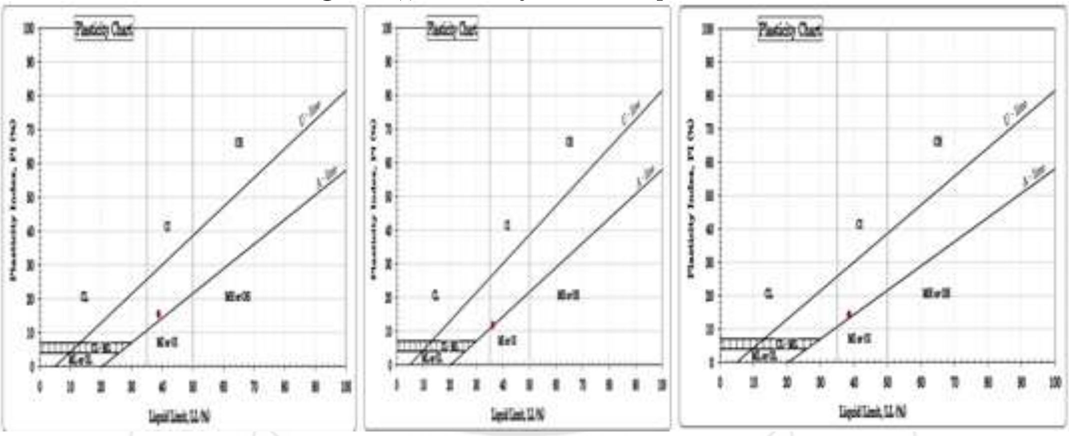

Figure 2 (ii): Plasticity of soil samples D – F

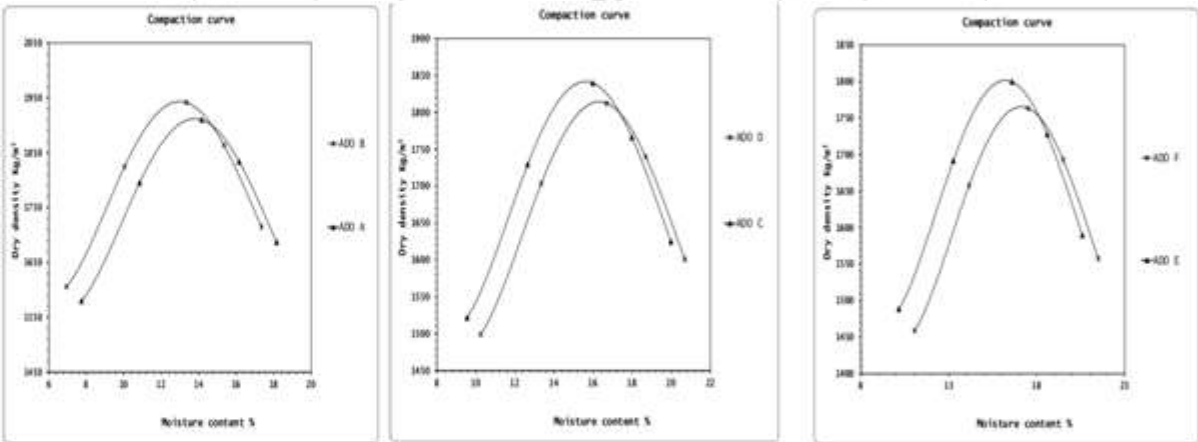

Figure 3: Result of compaction test for all samples

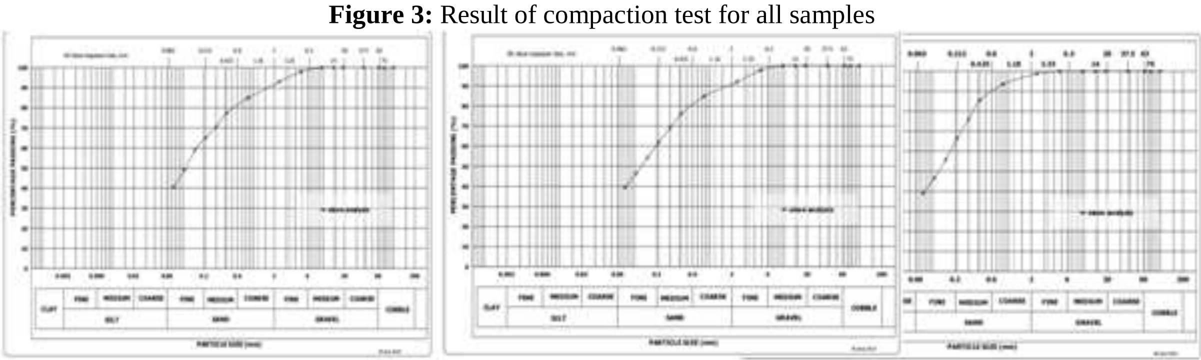

Figure 4(i): Grain size distribution for samples A – C respectively

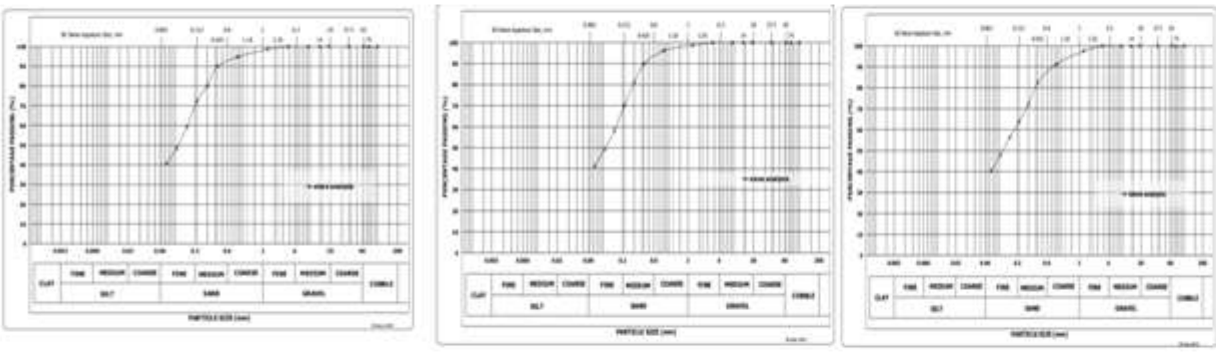

Figure 4(ii): Grain size distribution for samples D – F respectively