International Journal of Advanced Geotechnic and Impact Engineering
(ISSN: 2545-5559)
Akinola Johnson OLAREWAJU
Open Access Volume 1, Issue 1, Dec., 2017, Pp 1-11

CBR Strength Characteristics of a Laterite Stabilized with 2% to 10% (Low Dosage) Thermoplastic

Akinola Johnson OLAREWAJU
Civil Engineering Department, Federal Polytechnic Ilaro, Ogun State, Nigeria

Abstract: *This study is aimed at investigating the usability of thermoplastic as an alternative for construction materials with a view to reducing environmental hazard caused by plastic waste. The lateritic soil used was taken at Ajegunle, Abalabi* (6^0 53' 13.758"N, 3^0 7' 59.994"E) *along Papa-Ilaro road, Ogun State, Nigeria while the solid thermoplastic wastes were taken from plastic recycling plant at Papalanto* (6^0 53' 26.406"N, $3^0$10' 21.788"E), *Ogun state, Nigeria. The quantity of water which was used to obtain optimum moisture content and maximum dry density for lateritic soil (control, 0%) was determined. This water was then used to run CBR (soaked and unsoaked) tests for all thermoplastic substitutions. The thermoplastic waste were grounded into pellets passing through 5mm sieve and then substituted for lateritic soil from 2% to 10% (low dosage) at 2% interval for California Bearing Ration (CBR) test while 0% served as control experiment. The tests conducted in line with BS 1377 (1990) are sieve analysis, plasticity index determination, compaction, soaked and unsoaked CBR. From the results, it was observed that plastic pellet stabilized soil exhibit the same strength characteristic as lateritic soil while CBR value increases as percentage of plastic pellet increases for both soaked and unsoaked from 2% to 10% substitution. Consequently, plastic pellet could be used as a substitute as well as stabilizing agent in lateritic soil for construction material. Therefore, environmental risk and hazard caused by plastic waste could be reduced if not completely eliminated.*

Keywords: *Thermoplastic, Laterite, Soil, Strength, Plasticity, CBR, Soaked, Unsoaked.*

Introduction

There are various types of polymers that could be made from hydrocarbons derived from coal, natural gas, oil and organic oils which are transformed into materials with desirable properties. Plastics are made up of long chain molecules called polymers. Plastics that can be readily recycled are Thermoplastics which means they will soften when heated. Thermosetting plastic that hardens when heated are often used in electrical applications and are not suitable for recycling. Thermoplastics are light, durable, mouldable, hygienic and economic, making them suitable for a wide variety of applications including food and product packaging, car manufacturing, agriculture, housing products, to mention but a few. Thermoplastics can be repeatedly reformed into new products and this requires significant quantities of fossil fuels, a non-renewable resource. Plastics have their impact on the environment through all stages of their existence from manufacture to utilization and disposal (Sophie, 2009).

Background Study

In many metropolitan cities in developing nations the amount of plastic waste generated amount to 20% of the total amount of the household waste. Together with the increased complexity of many plastics, plastic waste is becoming a major headache for waste management officials. Most of the plastic wastes are disposed into the running streams, flowing rivers, gutters, channels, drainage systems, etc. Choked drainage systems cause flood in urban areas after rainfall causing health related problems such as malaria and other water borne diseases. Cities, littered with plastic waste suffer serious visual nuisance, and this constitute a major reason for tourists avoiding the place. Sophie (2009) suggested that to prevent countries from choking on plastic waste and to prevent further pollution of the oceans, innovative solutions are needed. Recycling of plastic waste is the answer to the problem of health hazard caused by plastic waste. Plastic waste recycling conserves natural resources, saves energy, and contributes to the green economy and by so doing provide many job opportunities. By recycling plastics, the environments get cleaner and waterways will be less polluted. In addition, local governments benefit from the recycling activities as less waste needs to be collected and disposed of at landfills (Sophie, 2009; Verma, 2008; Jean-Piera, 2004; Olarewaju, 2016a; 2016b; 2016c and 2016d).

Methodology

The lateritic soil used in this study was taken at Ajegunle (Figure 1), Abalabi *(6^0 53' 13.758"N,* 3^0 *7' 59.994"E)* along Papa-Ilaro road, Ogun State, Nigeria and the solid thermoplastic wastes were taken from plastic recycling plant (Figure 2) at Papalanto *(6^0 53' 26.406"N,* 3^0*10' 21.788"E),* Ogun state, Nigeria. The quantity of water which was used to obtain optimum moisture content and maximum dry density for lateritic soil (control, 0%) was determined. This water was then used to run CBR (soaked and unsoaked) tests for all thermoplastic substitutions into the lateritic soil. The thermoplastic were grounded into pellets passing through 5mm sieve and then substituted for lateritic soil from 2% to 10% at 2% interval for California bearing ration (CBR), soaked and unsoaked tests while 0% served as control experiment. The tests conducted in line with BS 1377 (1990) are; sieve analysis, plasticity index, compaction, soaked and unsoaked CBR (Brian, 1980; Bowles, 1981).

Figure 1: Location of lateritic soil sample *(6^{0} 53' 13.758"N,* 3^{0} *7' 59.994"E)*

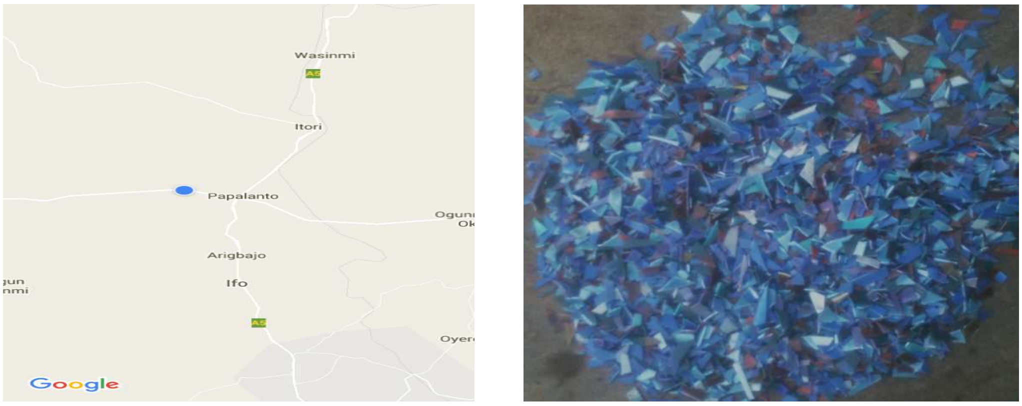

Figure 2: Location of plastic waste *(6^{0} 53' 26.406"N,* 3^{0}*10' 21.788"E)*

Results and Discussion

Sieve analysis results for control experiment used to determine the particle size distribution is hereby graphically presented in Figure 3 while the results of liquid limit, maximum dry density and optimum moisture content used to determine the quantity of water used in the study are graphically presented in Figure 4 and 5 respectively. In addition to this, the results of load against penetration for soaked control and 2% plastic pellet substitution are graphically presented in Figure 6 while the results of load against penetration for soaked control and 4% plastic pellet substitution are graphically presented in Figure 7. Furthermore, the results of load against penetration for soaked control and 6% plastic pellet substitution are graphically presented in Figure 8 while the results of load against penetration for soaked control and 8% plastic pellet substitution are graphically presented in Figure 9. In addition, the results of load against penetration for soaked control and 10% plastic pellet substitution are graphically presented in Figure 10 while the results of load against penetration for unsoaked control and 2% plastic pellet substitution are graphically presented in Figure 11. The results of load against penetration for unsoaked control and 4% plastic pellet substitution are graphically presented in Figure 12 while the results of load against penetration for unsoaked control and 6% plastic pellet substitution are graphically presented in Figure 13. The results of load against penetration for unsoaked control and 8% plastic pellet substitution are graphically presented in Figure 14 while the results of load against penetration for unsoaked control and 10% plastic pellet substitution are graphically presented in Figure 15. Finally, the CBR values for soaked and unsoaked CBR tests for 0% to 10% (at interval of 2) are graphically presented in Figure 16.

International Journal of Advanced Geotechnic and Impact Engineering
(ISSN: 2545-5559)

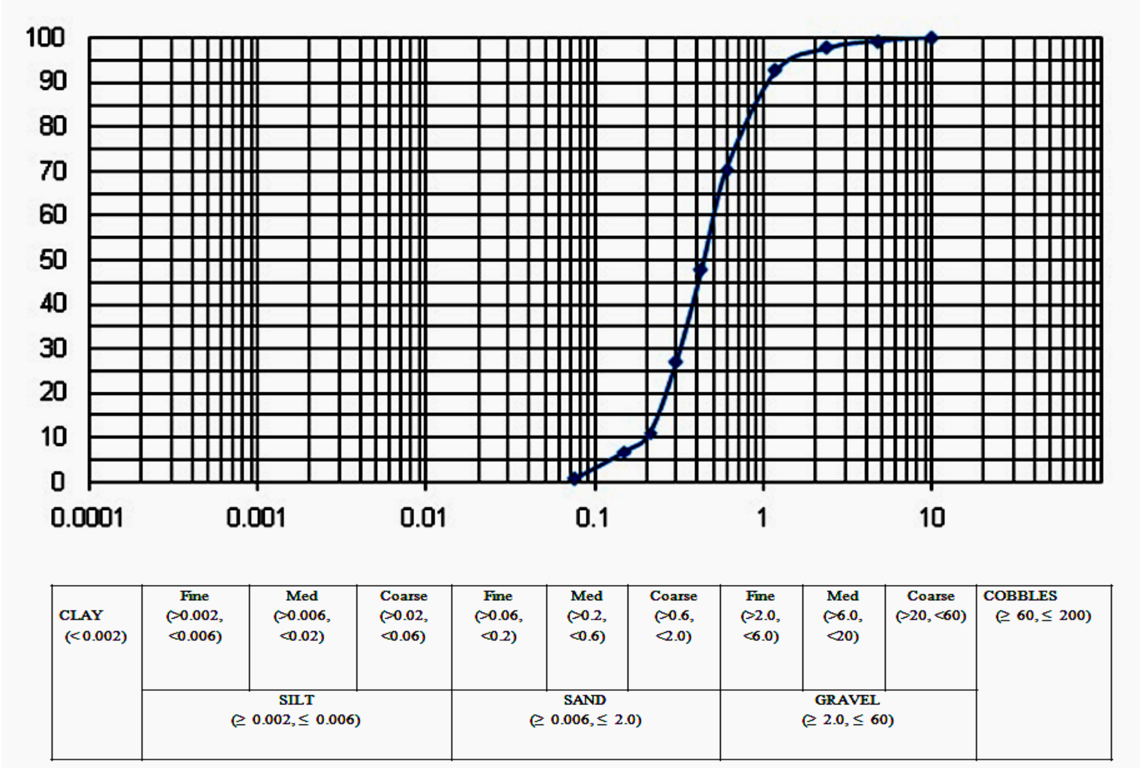

Figure 3: Results of sieve analysis of control experiment (0% subtitution)

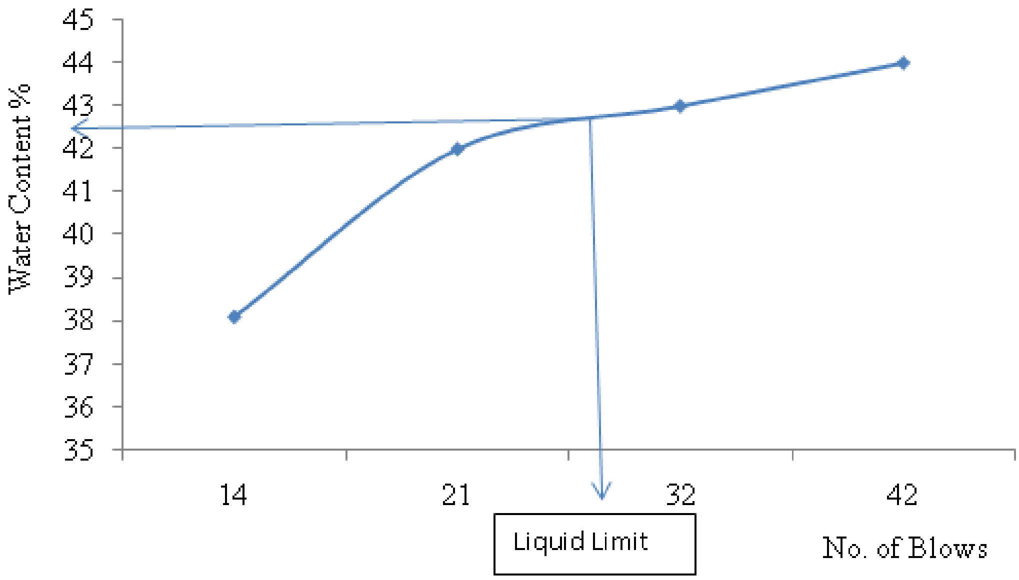

Figure 4: Results of liquid limit test for control experiment.

http://perfectengineeringassociates.com

International Journal of Advanced Geotechnic and Impact Engineering
(ISSN: 2545-5559)
Akinola Johnson OLAREWAJU
Open Access Volume 1, Issue 1, Dec., 2017, Pp 1-11

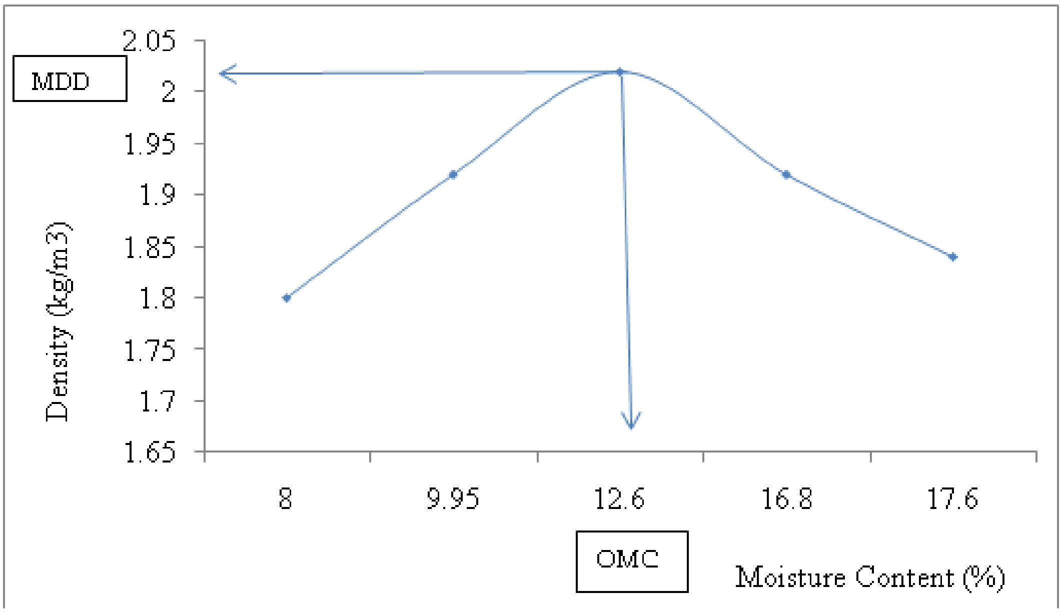

Figure 5: Results of dry density against moisture content for quantity of water content used

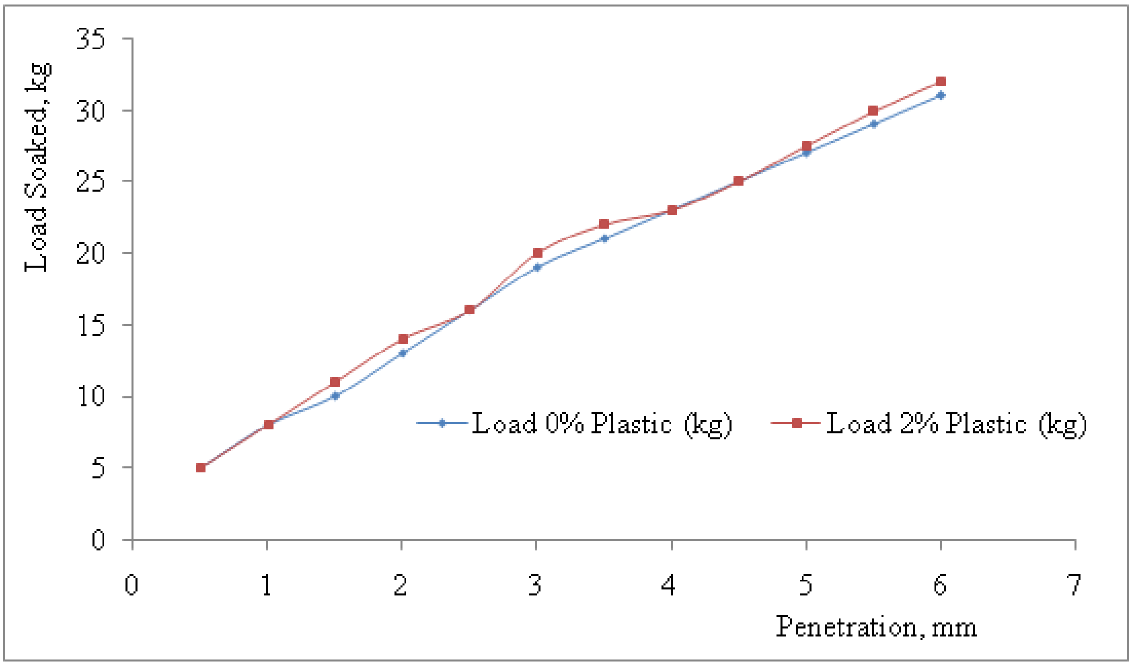

Figure 6: Results of load against penetration for soaked control and 2% plastic pellet substitution

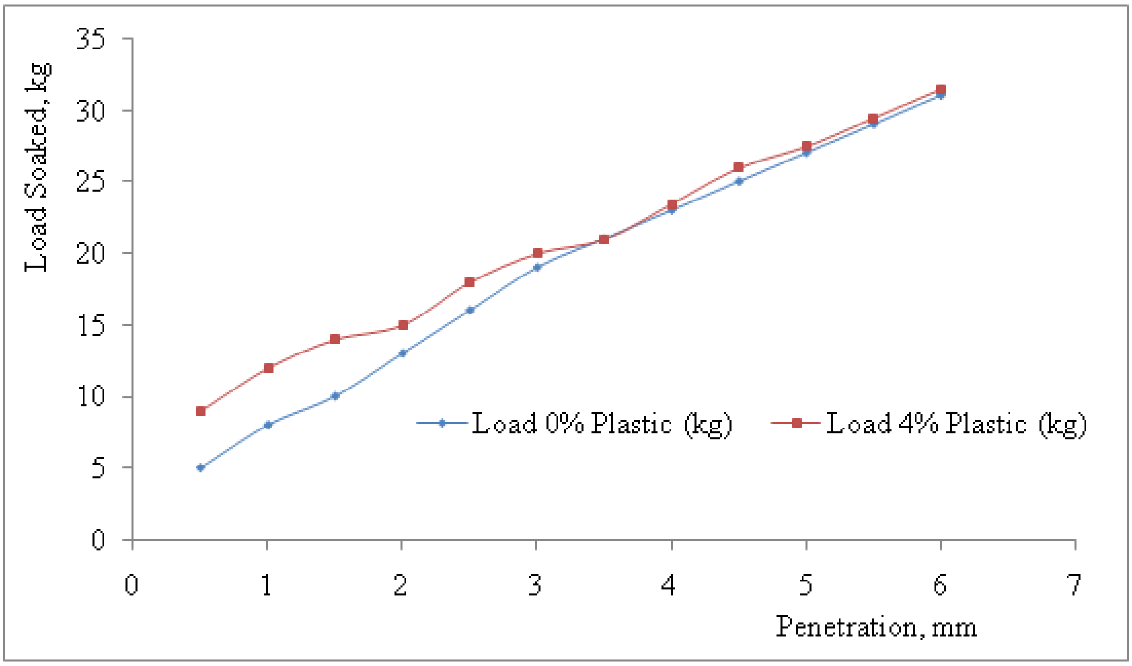

Figure 7: Results of load against penetration for soaked control and 4% plastic pellet substitution

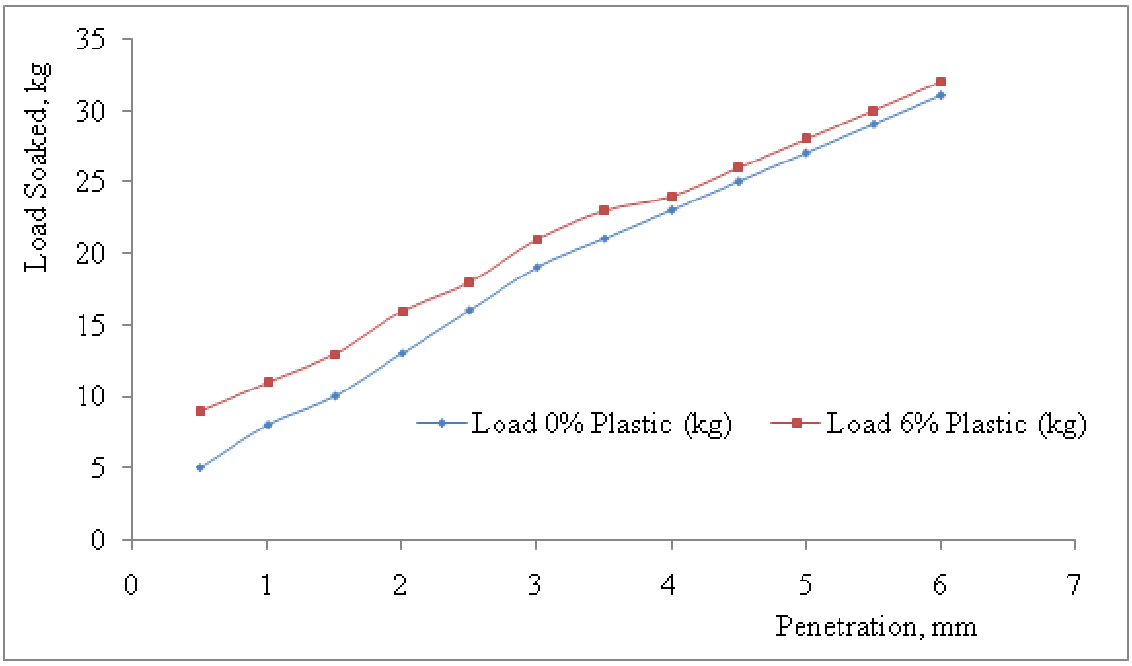

Figure 8: Results of load against penetration for soaked control and 6% plastic pellet substitution

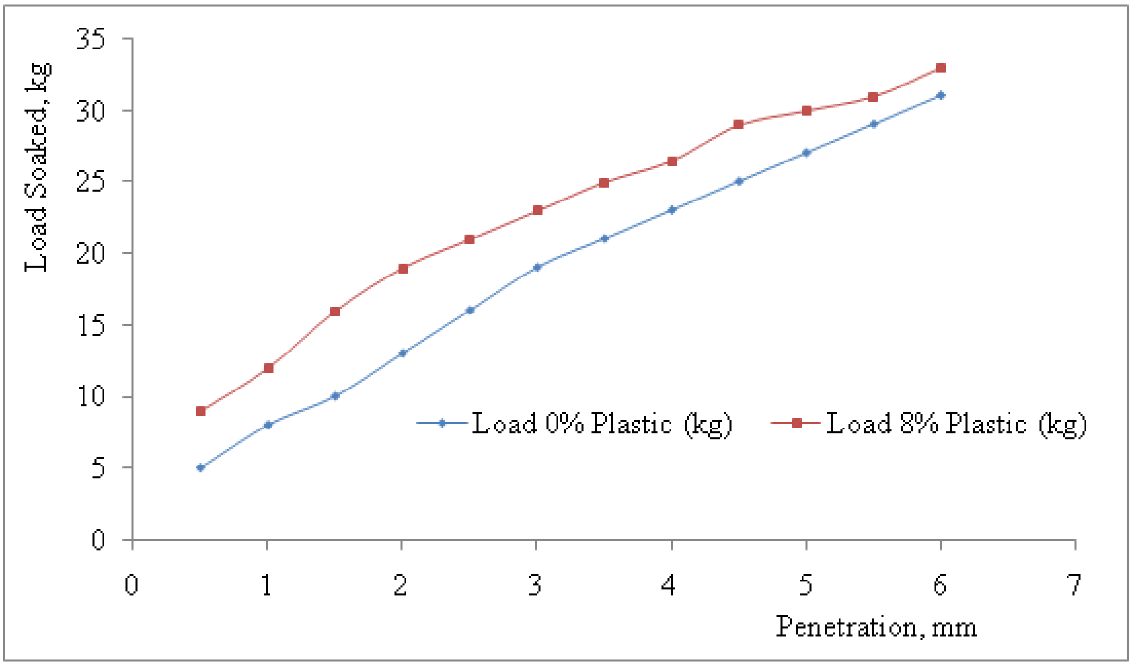

Figure 9: Results of load against penetration for soaked control and 8% plastic pellet substitution

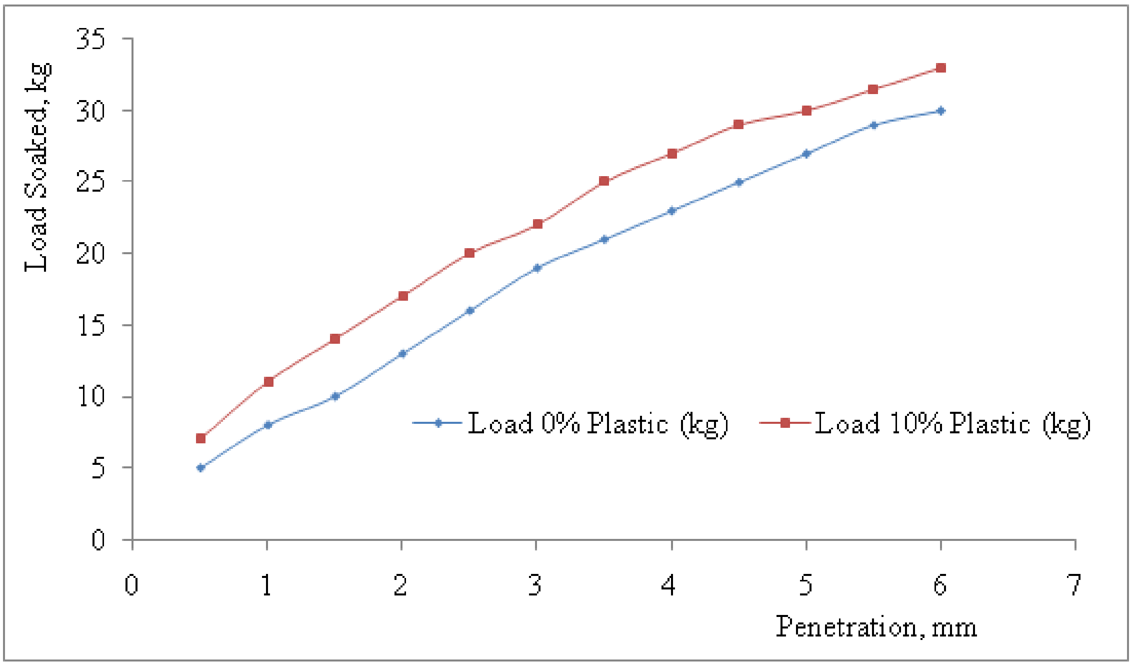

Figure 10: Results of load against penetration for soaked control and 10% plastic pellet substitution

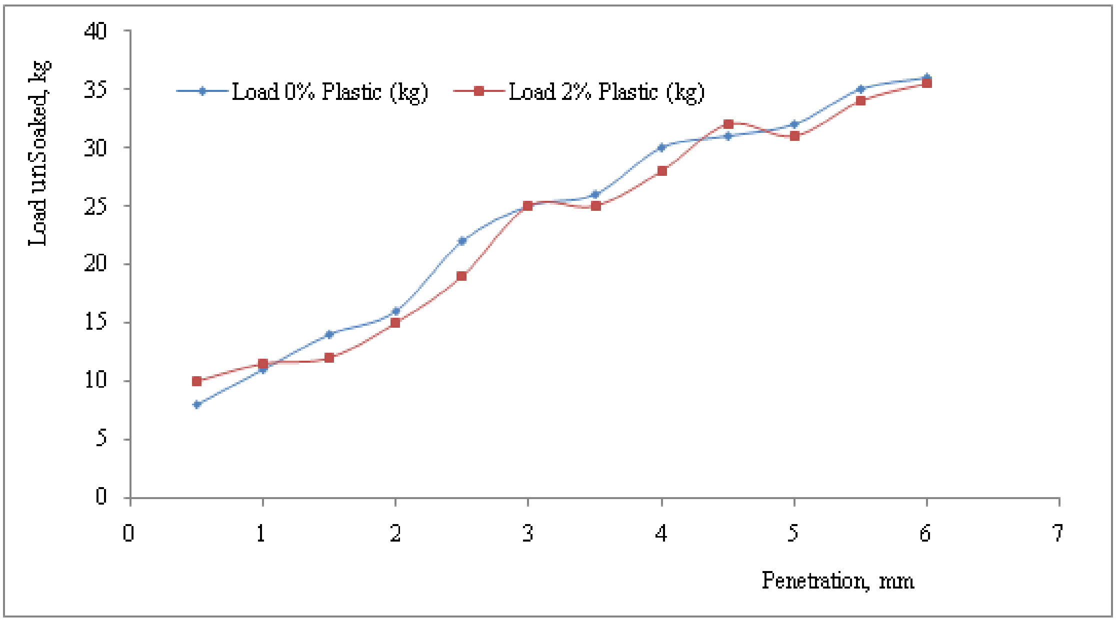

Figure 11: Results of load against penetration for unsoaked control and 2% plastic pellet substitution

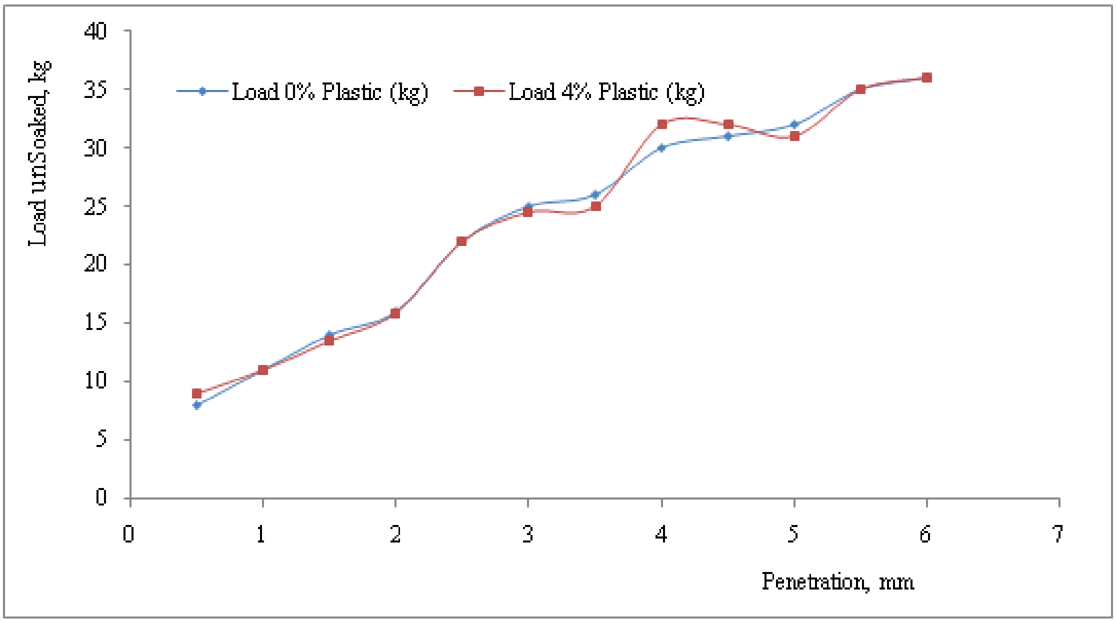

Figure 12: Results of load against penetration for unsoaked control and 4% plastic pellet substitution

International Journal of Advanced Geotechnic and Impact Engineering
(ISSN: 2545-5559)
Akinola Johnson OLAREWAJU
Open Access Volume 1, Issue 1, Dec., 2017, Pp 1-11

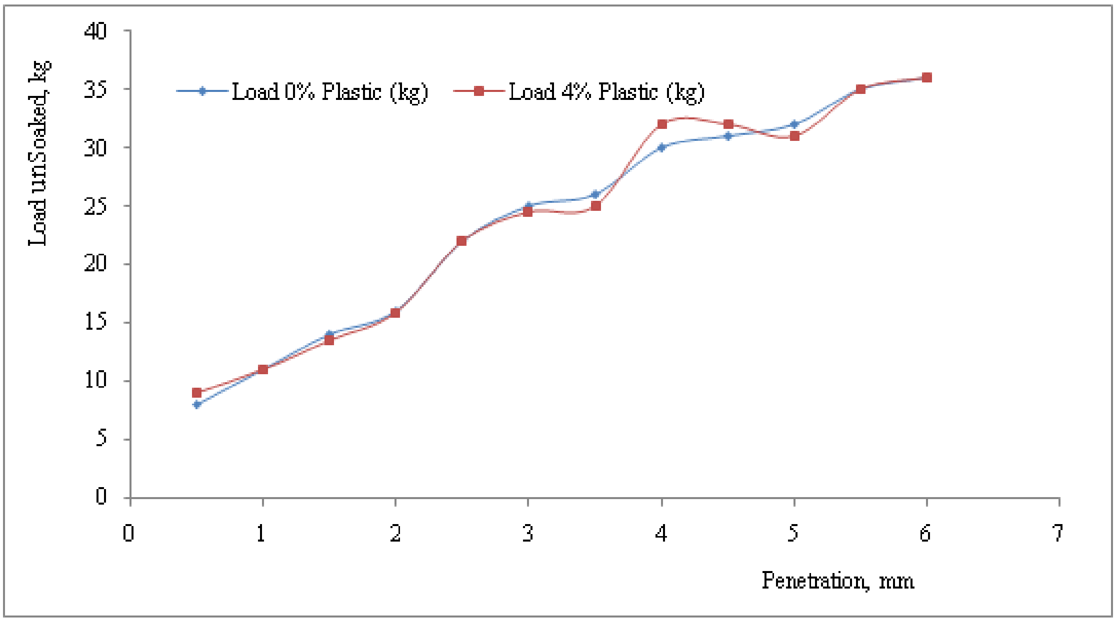

Figure 13: Results of load against penetration for unsoaked control and 6% plastic pellet substitution

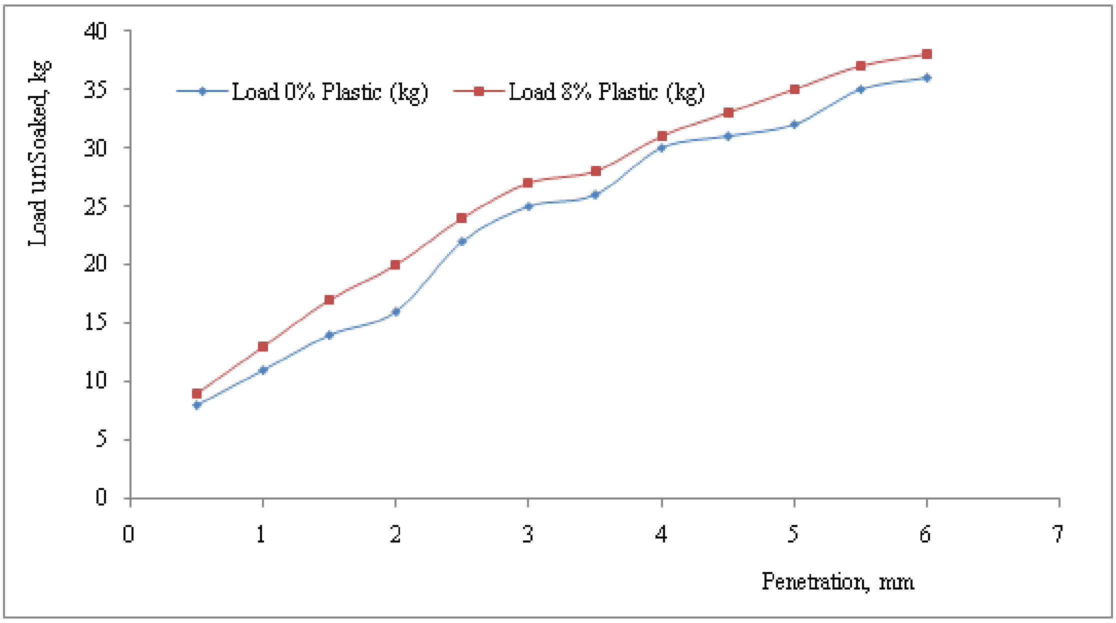

Figure 14: Results of load against penetration for unsoaked control and 8% plastic pellet substitution

International Journal of Advanced Geotechnic and Impact Engineering
(ISSN: 2545-5559)

Akinola Johnson OLAREWAJU
Open Access Volume 1, Issue 1, Dec., 2017, Pp 1-11

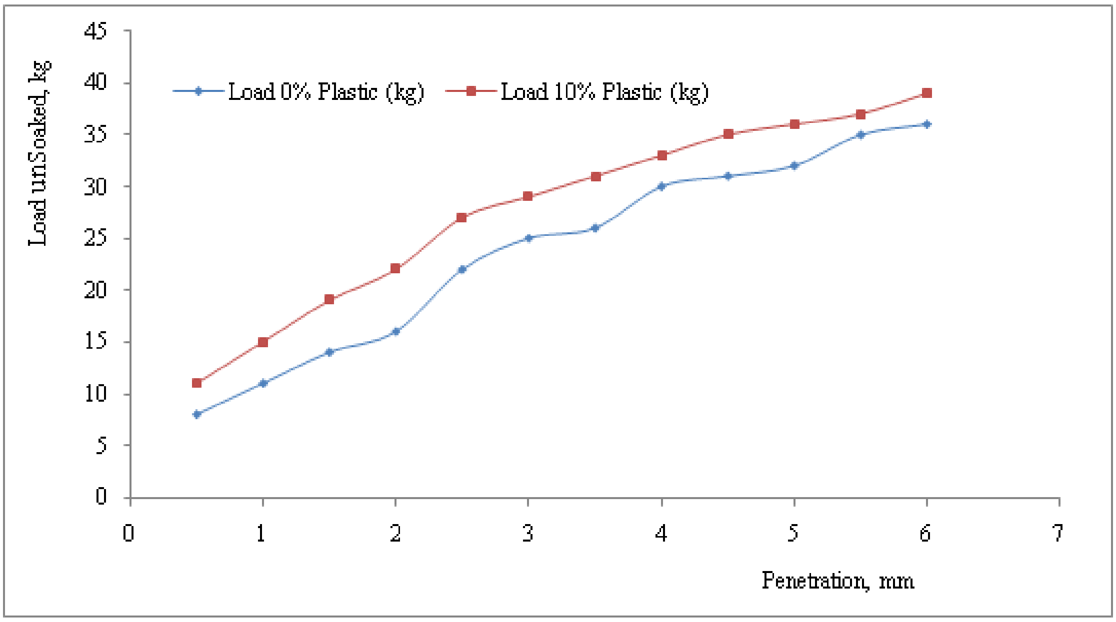

Figure 15: Results of load against penetration for unsoaked control and 10% plastic pellet substitution

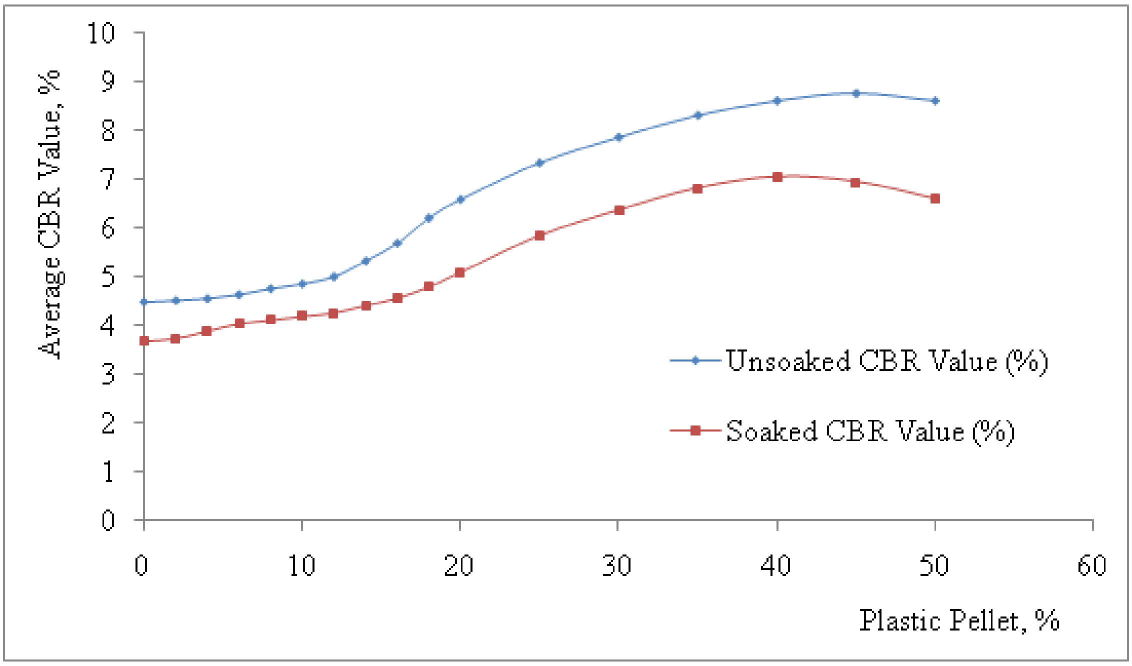

Figure 16: Average CBR values against % plastic pellet subtitution

Using unified soil classification system, soil can be classified into uniform soil and well graded soil. According to BS 1377 (1990), the coefficient of uniformity (Cu) greater than 5 indicate a well graded soil and from the results presented (Figure 3), the coefficient of uniformity (Cu) is 2.5 which is less than 5, therefore the soil sample is not a well graded soil. According to the same source, the coefficient of curvature (Cc) less than 3 indicate a uniform soil and from the results presented (Figure 3), the coefficient of curvature Cc is 1.6 which less than 3, therefore the soil sample is a well graded soil. According to the same source, water content at 25 blows represents the Liquid limit. From the result presented in Figure 4, the Liquid Limit is 42.5%.

Using this expression:

Plastic Index, PI = LL - PL Equation 1

where PI is the Plasticity Index, LL is the Liquid Limit and PL is the Plastic Limit.

Therefore Plasticity Index is 42.5 – 30.77= 11.73, approximately 12. Atterberg limit test have close relationship with stress parameters like compressibility, permeability and shear strength and also used to distinguish between different types of silt and clay. Plasticity Index between 7 and 17 are classified as medium plastic. According to Road Note 29 (1970), plasticity index between 10 and 20 with CBR value between 6 and 7 for unsoaked CBR and 4 and 5 for soaked CBR are classified as Sandy clay. Therefore lateritic soil which was taken along Papa-Ilaro road at Ajegunle ***(Lat. 6^0 53' 13.758"N, Long. 3^0 7' 59.994"E)*** is a sandy clay since it possesses all those aforementioned strength characteristics From the results presented (Figure 5), the water quantity used during the compaction test of the control experiments to achieve optimum moisture content of 12.6% and maximum dry density of 2.02 kg/m^3 is 12% of 6000g. This quantity of water was used to prepare the materials used for soaked and unsoaked California Bearing Ratio experiment of the plastic pellet substituted for lateritic soil in the range of 2% to 10% at interval of 2. From the results of plastic pellets substitution ranges from 0% to 10% at interval of 2 (soaked and unsoaked) with 0% serving as control experiment (Figures 6 to 15), it was observed that the plastic pellet substituted lateritic soil behaves just like control experiment (0% substitution) but there is slight increase in the load values during the CBR test, with CBR value of 3.0% for control experiment and 3.02% for 2% plastic pellets substitution (Figure 16). Lateritic soil contains voids which can take moisture while plastic pellets cannot absorb moisture. The water absorbed by lateritic soil normally act as lubricant between the soil particles whereas plastic pellets cannot retain such moisture. Therefore there is bound to be rearrangement of soil skeletons which will eventually account for the lower value of strengths compared to lateritic soil mixed with plastic pellets. The more the amount of substituted plastic pellets, the more the strengths characteristics (Olarewaju, 2016a, 2016b, 2016c, and 2016d).

The average CBR value of 3.928 was recorded for the soaked low dosage while 4.678 was recorded for unsoaked low dosage. The strength parameters used to determine the characteristic strength of a lateritic soil includes, compaction test results, California Bearing Ratio test results, shear strength test results and consolidation test results. Low dosage of plastic pellets substituted (2% to 10% at interval of 2) for lateritic soil using strength parameter of California Bearing Ratio test follows the same trend with the work by (Olarewaju, 2016). The results of low dosage (0% to 10%) of densified plastic stabilized lateritic soil have the same behaviour with 0% to 10% for CBR value of plastic pellet substituted for lateritic soil. From the CBR value result presented in Figure 16, this CBR value is related to the CBR value for sub grade materials used to design other component of highway pavement (Road Note 29, 1970). If the CBR value results (unsoaked experiment) falls between 0% and 3% within an elevated surface (i. e. depth of water-table below the formation level is more than 600mm) is regarded as heavy clay and can be used to design sub base of 350mm to 400mm thickness depending on the expected traffic wheel load, provided there is permanent and adequate drainage. According to the same source, this sub base thickness is therefore used to design other components of the highway. From the results of soaked CBR test presented in Figures 16 it was observed that CBR value increases as plastic pellets substituted for lateritic soil increases, 0% (control experiment) have same CBR values with 2% plastic pellets substituted for lateritic soil, but the CBR value of 4% to 10% plastic pellet substitution is greater than that of control experiment (Hans et al., 1951; Sophie, 2009; Verma, 2008; Jean-Piera, 2004; Olarewaju, 2016a; 2016b; 2016c and 2016d).

The strength characteristics in term of density (Olarewaju, 2016) of plastic pellets that is allowed to pass through 5mm sieve substituted for lateritic soil is greater than non-stabilized lateritic soil. According to Road Note 29 (1970), lateritic soils with CBR value above 3% and in water logged area is regarded as soaked CBR. This category of soil may be regarded as sandy clay and the expected traffic load must be determined before other components of a highway pavement can be designed. To estimate the expected traffic load for highway pavement design, life span of the pavement must be known as well as a constant growth. Once the expected axle load is determined, then Road Note 29 (1970) can be used to determine the thickness of the sub-base layer. For instance, the average CBR value of low dosage plastic pellet substitution is 3.928 and if the expected traffic load is 0.01 x 10^6 cumulative number of standard axle, therefore, the sub-base thickness will be 180mm with rolled asphalt road base of 60mm and surfacing (i. e. base course + wearing course) of 50mm while ensuring adequate and permanent drainage is provided (Hans et al., 1951; Sophie, 2009; Verma, 2008; Jean-Piera, 2004; Olarewaju, 2016a; 2016b; 2016c and 2016d)..

Lateritic soil with CBR value above 4% and elevated surface is regarded as unsoaked CBR. This category of soil may be regarded as silty clay and the expected traffic load must be determined before other components of a highway pavement can be designed. To estimate the expected traffic load for highway pavement design, life span of the pavement must be known as well as a constant growth. Once the expected axle load is determined, then Road Note 29 (1970) can be used to determine the thickness of the sub base layer. For instance, the average CBR value of low dosage plastic substitution is 4.678 and if the expected traffic load is 0.01 x 10^6 cumulative number of standard axle, therefore, the sub-base thickness will be 110mm with rolled asphalt road base of 60mm and surfacing (base course + wearing course) of 50mm while ensuring adequate and permanent drainage is provided. Lateritic soil with heavy clay content needs to be stabilized so as to mitigate the effect of swelling or expansion in clay when wet and shrinkage when dry (Sophie, 2009, Verma, 2008, Jean-Piera, 2004, Olarewaju, 2016a, 2016b, 2016c, and 2016d)..

Conclusions

Based on the result of this study, it has been established that using uniform soil classification system the Lateritic soil used as control experiment is a well graded soil. In addition, plasticity index of the control experiment shows that the soil sample is a medium plastic soil as well as sandy clay. The quantity of water required for compaction test to achieve optimum moisture content at 12.6 percent and maximum dry density of 2.02 kg/m3 is 12% of 6000g. Low dosage plastic substitution ranges from 0% to 10% plastic pellet substitution and it behaves just like control experiment of 0% plastic pellet substitution. There is increase in CBR value of 2% to 10% plastic pellet substitutions. Plastic pellets can be partly used as replacement for lateritic soil since the CBR value of reinforced soil conforms with specifications in Road Note 29 (1970), hence it could be used as a construction material when it is well compacted. Recycling plastic into plastic pellet for construction purpose will help mitigate problem of pollution to bearable limit.

Acknowledgement

The author acknowledges the contributions of Ogunola K. G. and Toriola M. A. in data collection as well as Adeyinka A. O. and Aro M. O. for technical assistance in the laboratories.

References

BS 1377, (1990): *Methods of test for soils for Civil Engineering purposes*, British Standard Institution.

Brian V. (1980), *Laboratory works in civil Engineering*, New York, USA, Granada Publishing.

Chakole A. (2015), Plastic roads: *Presentation on plastic roads*. Smart City, Nagpur, India. Retrieved on February 2, 2017, from https://www.smartcitynagpur.com/pdf/plasticroads

Highways Department (2013): Guidance Notes on Pavement Design for Carriageway Construction, Research & Development Division RD/GN/042, Hong Kong, September, pp 1 – 43.

Joseph Bowles, 1981, *Engineering soil properties*, (2nd edition), London, England, McGrew-Hill International.

Jean-Pierre, H. (2004). Waste recycling a good practice guide by and for local and regional authorities. Report 2004. *The association of cities and regions for recycling (ACRR). Belgium.*

Olarewaju A. J. (2016). Geotechnical properties of plastic stabilized lateritic soil, American Journal of Engineering Research (AJER)**,** Vol. 5, Issue-9., pp 146-149

Olarewaju, A.J., (2016). Effects of compaction on lateritic soil stabilized with low dosage of cement and fly ash, International Journal of Applied Research, Vol. 2, Issue 9, Sept., pp 290-295.

Olarewaju, A.J., (2 016). Characteristics of densified plastic pellet stabilized lateritic soil to reduce the impact of blast loads on underground structures, International Journal of Academic Research and Innovation, IJARI, Vol. 1, Issue-1, Nov, pp 1-7.

Olarewaju, A.J., (2016). characteristics of lateritic soil stabilized h plastic pellets, International Journal of Applied Research, ISSN (print): 2394-7500 / ISSN (online): 2394-5869, Vol. 2, Issue-9, Sept., pp 300-305.

Pragyan Bhattarai, A. V. A Bharat Kumar, K. Santosh, T. C. Manikanta & K. Tejeswini, (2013). *Engineering behavior of soil reinforced with plastic strips*, International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development ISSN 2249-6866 Vol. 3, Issue 2, Jun 2013, pp 83-88.

Road Note 29, (1970), A *guide to the structural design of pavement for new road*, (3rd edition), London, England, Her majesty's stationery office.

Sophie, V. (2009).Technical brief. Recycling of plastic. *Practical action*. Retrieved on February 2nd, 2017. From http://practicalaction.org/practicalanswers

Verma. S., (2008): Roads from plastic waste. *The India Concrete Journal, P43-44*.