California Bearing-Ratio Characteristics of Palm Kernel Shell Stabilized Sedimentary Formation

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Abstract: *There is increase in demand for safe, durable and economical roads, especially in the rural areas. The high cost of stabilizing agent, environmental effects of dumping of agricultural waste such as palm kernel shell and implications involved in the process of transporting materials from borrow pit pose serious threats to human and the environment. Therefore, there is need to look for affordable alternatives. The lateritic soil used in this study was taken from the sedimentary formation located at Abalabi (6^0 53' 13.758"N, 3^0 7' 59.994"E), Ajegunle, along Papalanto-Ilaro road, Ogun State, Nigeria and palm kernel shell wastes were taken from oil palm producing plant at Iweke along Ilaro-Owode Road, Ilaro, Ogun State, Nigeria. The palm kernel shells were broken into pieces passing through 5mm sieve and then substituted for lateritic soil in the range of 0% to 50% at 5% intervals with 0% palm kernel shell substitution serving as control experiment. In line with BS 1377 (1990), pressure loads were applied on the composite materials and California Bearing-Ratio tests conducted at different test water contents for all the substitutions. From the results, California Bearing-Ratio value increased gradually as palm kernel shell substitution increases while 25% palm kernel shell substitution has the maximum CBR value at both top and bottom. In addition, for the 40% to 50% palm kernel shell substitutions, maximum CBR values were observed from their initial test water content. The composite material with palm kernel shell at 25% can be used for road base and sub base. Finally, recycling of palm kernel shell wastes is an alternative solution of safe disposal of the agro waste called palm kernel shell. There environmental risk and hazard caused by palm kernel shell wastes could be greatly reduced if not completely eliminated.*

Keywords: *CBR, Stabilization, Sedimentary, Formation, Composite, Material.*

Introduction

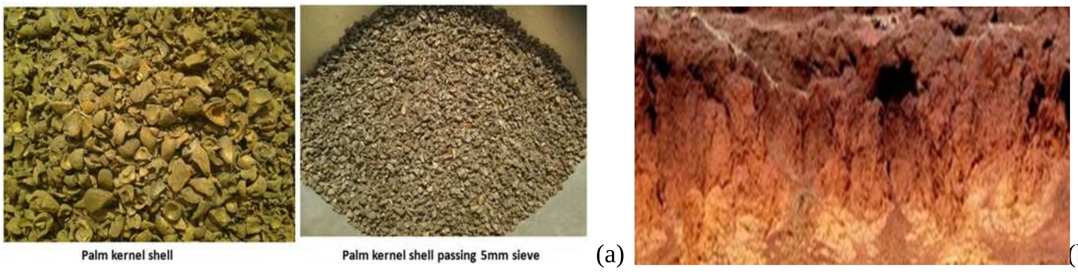
Palm kernel shells are waste generated from the processing of crude palm oil. This is the shell parts that remained after the nut has been removed and after crushing in the palm oil mill and is obtained as residual waste in the extraction of the kernel from the nut. Oil palm is cultivated in plantations of rotational farming followed by removal and replanting. The PKS can be obtained by crushing into sections then separating to remove the palm seed during the processing of palm kernel oil (Amu et al., 2008; Nnochiri et al., 2017; Olutaiwo et al., 2018; Omolayo and Esther, 2018; Olarewaju, 2018a, b and c; Olarewaju, 2021). During the process of removing or extracting ripe, fleshy and fresh fruit from bunches at the mills, residues and waste are generated in form of solid and liquid. These residues and waste include fibers, empty fruit bunches, shells and liquid waste in form of sewage with several uses, and these include prevention of the fibres from insect and pest attack, also in weaving baskets and most especially for domestic use as a means of energy generation during cooking (Amu et al., 2008; Nnochiri et al., 2017; Olutaiwo et al., 2018; Omolayo and Esther, 2018; Olarewaju, 2018a, b and c; Olarewaju, 2021).

Background Study

Soils are formed from the gradual breakdown of rocks through weathering which could be physical or chemical. Soil is the thin layer of material covering the earth's surface and is formed from the weathering of rocks. It is made up of mineral particles, organic materials, air, water and living organisms all of which interact slowly yet constantly. Most plants get their nutrients from the soil and they are the main source of food for humans, animals and birds. Therefore, most living things on land depend on soil for their existence (Amu et al., 2008; Nnochiri et al., 2017; Olutaiwo et al., 2018; Omolayo and Esther, 2018; Olarewaju, 2018a, b and c; Olarewaju, 2021). Soil is a valuable resource that needs to be carefully managed as it is easily damaged, washed or blown away by erosion and other agents of denudation. If soil is managed properly, destroying one of the essential building blocks of environment and food security could be avoided. The main interacting factors affecting the formation of soil include parent material, minerals forming the basis of soil, living organisms, climate also affect the rate of weathering and organic decomposition, topography which have to do with the grade of slope affecting drainage, erosion and deposition, time which influences soil properties and finally interactions between these factors produce an infinite variety of soils across the earth's surface (Amu et al., 2008; Nnochiri et al., 2017; Olutaiwo et al., 2018; Omolayo and Esther, 2018; Olarewaju, 2018a, b and c; Olarewaju, 2021). There is increase in demand for safe, durable and economical roads, especially in the rural areas. The high cost of stabilizing agent, environmental effects of dumping of agricultural waste such as palm kernel shell and implications involved in the process of transporting materials from borrow pit pose serious threats to human and to the environment. Therefore, there is need to look for affordable alternatives (Amu et al., 2008; Nnochiri et al., 2017; Olutaiwo et al., 2018; Omolayo and Esther, 2018; Olarewaju, 2018a, b and c; Olarewaju, 2021).

Methodology

The lateritic soil used in this study was taken on the sedimentary formation located at Abalabi (6^0 53’ 13.758”N, 3^0 7’ 59.994”E), Ajegunle (Figure 1), along Papalanto-Ilaro road, Ogun State, Nigeria and palm kernel shell wastes were taken from oil palm producing plant at Iweke along Ilaro-Owode Road, Ilaro, Ogun State, Nigeria. The palm kernel shells were broken into pieces passing through 5mm sieve and then substituted for lateritic soil in the range of 0% to 50% at 5% intervals for responses due to pressure load variations of California Bearing-Ratio test while 0% palm kernel shell substitution serving as control experiment. In line with BS 1377 (1990), pressure loads were applied on the composite materials and California Bearing-Ratio tests conducted on the composite material at different test water contents for all the substitutions (Knappett and Craig, 2012; Craig, 1994; Brian, 1980; Bowles, 1981).



(a) (b)

Figure 1: (a) Palm kernel shells and palm kernel shells passing 5mm sieve; (b) Sedimentary formation (lateritic soil) at Abalabi, Ajegunle, Papalanto-Ilaro Road, Ogun State *(6^0 53’ 13.758”N, 3^0 7’ 59.994”E)„*

Results and Discussion

The results of California Bearing Ratio (CBR) for top and bottom penetrations against test moisture content for 0% to 50% palm kernel shell substitution in lateritic soil with 0% serving as control experiment are graphically presented in Figures 2 to 12 respectively. From Figure 2 which is the control experiment (i. e. 100% lateritic soil), the CBR values is around 20% at the top and 14% at the bottom at 6% test water content while in the case of 5% palm kernel shell substitution (Fig. 3) the CBR value is in the range of 18% at the top and 16% at the bottom at 6% test water content. Figures 4, 5 and 6 shows 10%, 15% and 20% palm kernel shell substitutions respectively and it was observed that the CBR value is around 25% at the top and 16% at the bottom at average test water content of 6%. Figures 7, 8 and 9 shows the 25%, 30% and 35% palm kernel shell substitutions respectively where the CBR value increases in the range of 25% to 28% with test water content ranging from 6% to 8% for the top penetration and CBR value of penetration at bottom fall within the range of 15% to 20% with test water content ranging from 6% to 8%. The bottom penetration for 30% and 35% palm kernel shell substitutions have CBR value within the range of 14% to 20% with test water content ranging from 6% to 8%. Figures 10 and 11 shows the 40% and 45% palm kernel shell substitutions and it was observed that the CBR value decreases after the first test water content. This is because water absorption rate of palm kernel shell is low compared to lateritic soil (Amu et al., 2008; Nnochiri et al., 2017; Olutaiwo et al., 2018; Omolayo and Esther, 2018; Olarewaju, 2018a, b and c; Olarewaju, 2021). In the case of 40% palm kernel shell substitution, CBR value around 18% was observed at 4% test water content and decreases gradually to around 8% for both top and bottom penetrations at 10% test water content. In addition to this, in the case of 45% palm kernel shell substitution, the CBR value observed was 23% and decrease gradually to about 10% at test water content of 12% for top penetration. At 50% palm kernel shell substitution (Fig. 12), the CBR value from the first water content is within the range of 14% and 16% and later reduces at 8% test water content to CBR value of 8% and increase again to 14% and 16% for top penetration. At the bottom penetration, the CBR value observed was 7% at first test water content of 4%. Immediately after its peak CBR value of about 10% to 12%, it become constant until the last test water content of 14% (i.e. it has the same CBR value at 10%, 12%, and 14% test water content respectively). From the above results, it could be concluded that 25%, 30% and 35% palm kernel shell (PKS) substitutions have the highest CBR values among all the substitutions but 25% palm kernel shell substitution at both top and bottom penetrations compared very well with 0% palm kernel shell substitution (100% lateritic soil - control) (Amu et al., 2008; Nnochiri et al., 2017; Olutaiwo et al., 2018; Omolayo and Esther, 2018; Olarewaju, 2018a, b and c; Olarewaju, 2021).

According to Olarewaju (2021), the results showed that PKS could be used to stabilize lateritic soil although there is decrease in the value of Maximum Dry Density (MDD) as the percent of PKS substitution increases. The minimum CBR specification for sub grade and sub base layers of the highway surface is 5% and 20% respectively (Bowles, 1981). This research establishes that addition of PKS as a material for stabilization of lateritic soil for use as sub grade or sub base will be effective especially in areas that are not susceptible to effects of groundwater or surface. There is good adhesion between the soil and PKS thereby promoting an increase in strength. There is better mixing, dispersion and likely diffusion of the PKS particles within the lateritic soil aggregates thereby leading to the stabilization process (Amu et al., 2008; Nnochiri et al., 2017; Olutaiwo et al., 2018; Omolayo and Esther, 2018; Olarewaju, 2018a, b and c; Olarewaju, 2021).

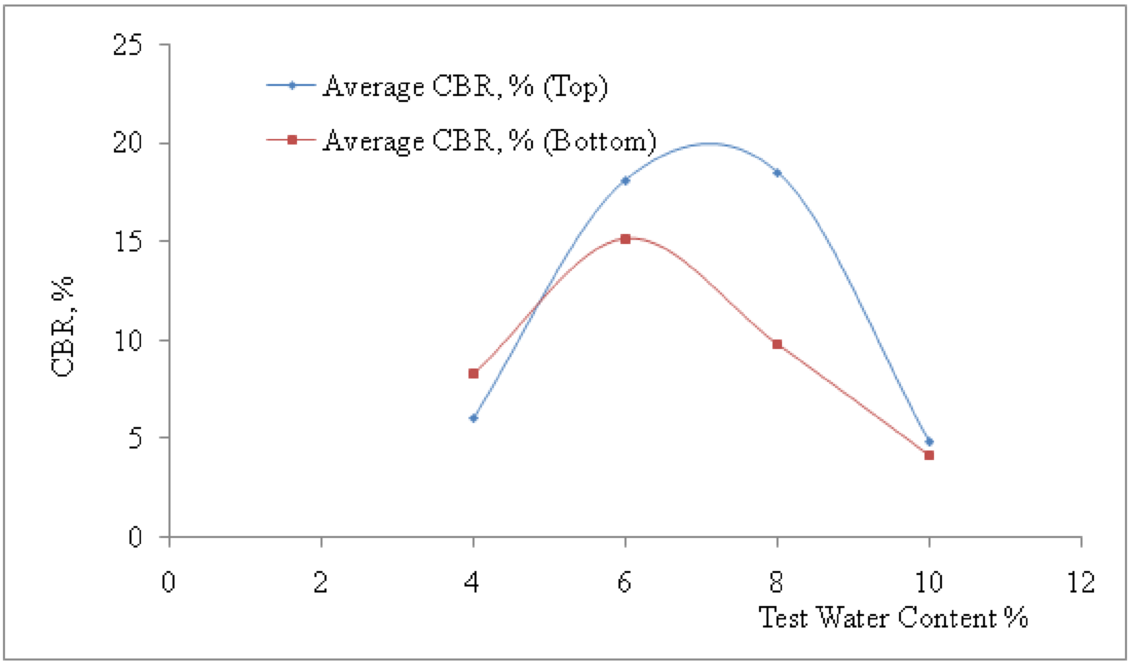


Figure 2: Results of CBR for top and bottom against test moisture content for 0% palm kernel shell substitution in lateritic soil (control experiment)

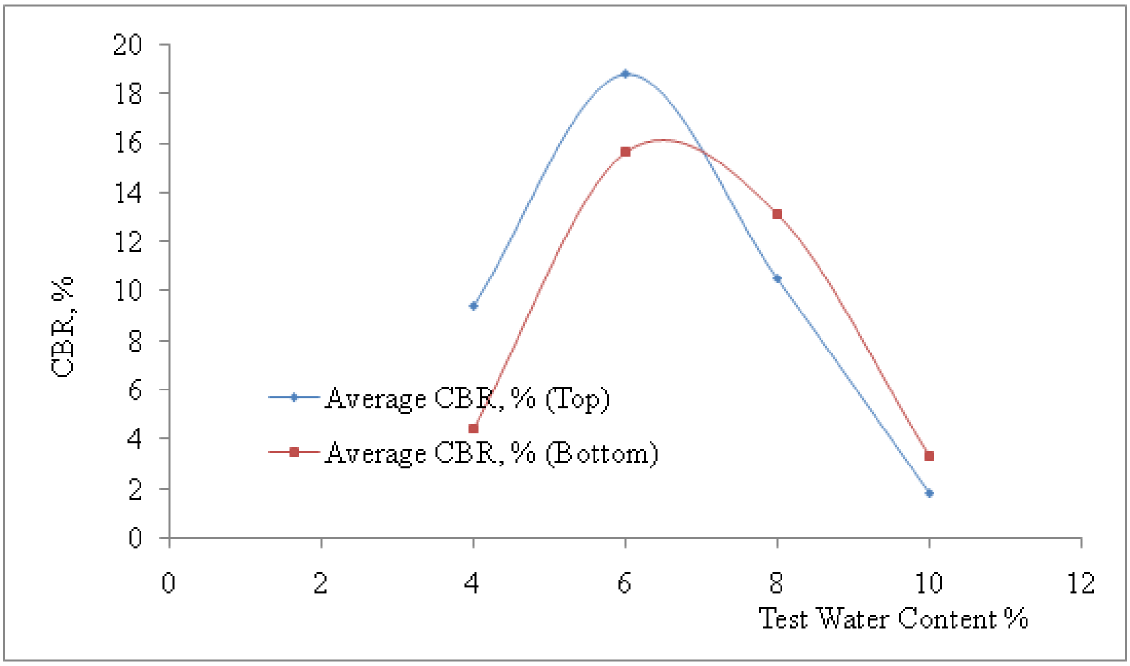


Figure 3: Results of CBR for top and bottom against test moisture content for 5% palm kernel shell substitution in lateritic soil

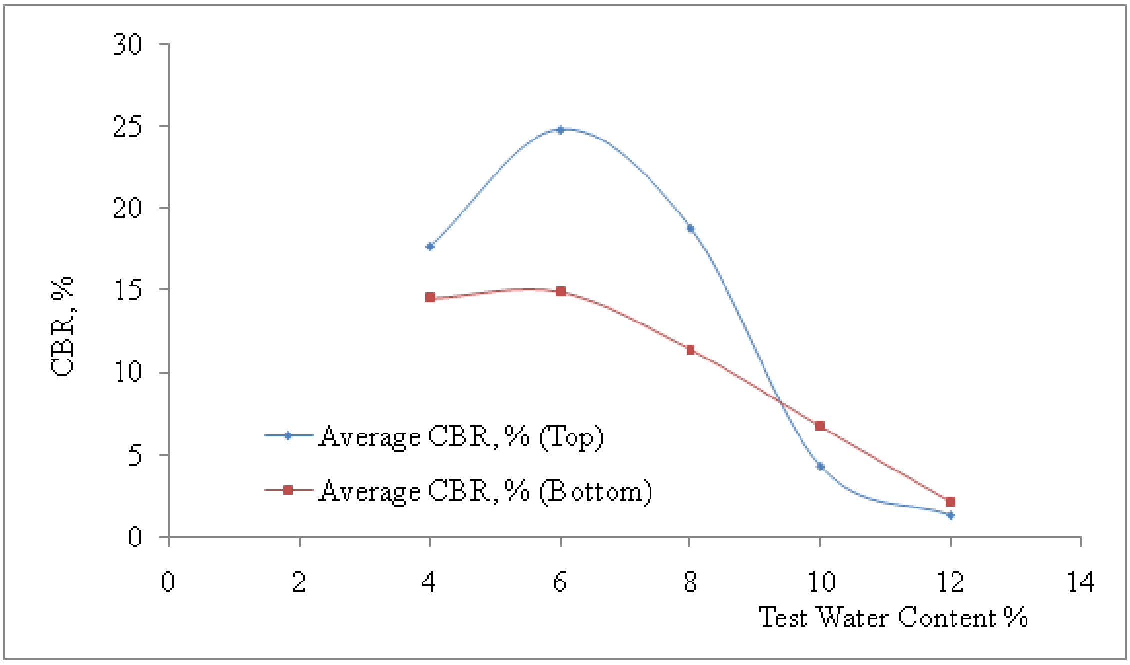


Figure 4: Results of CBR for top and bottom against test moisture content for 10% palm kernel shell substitution in lateritic soil

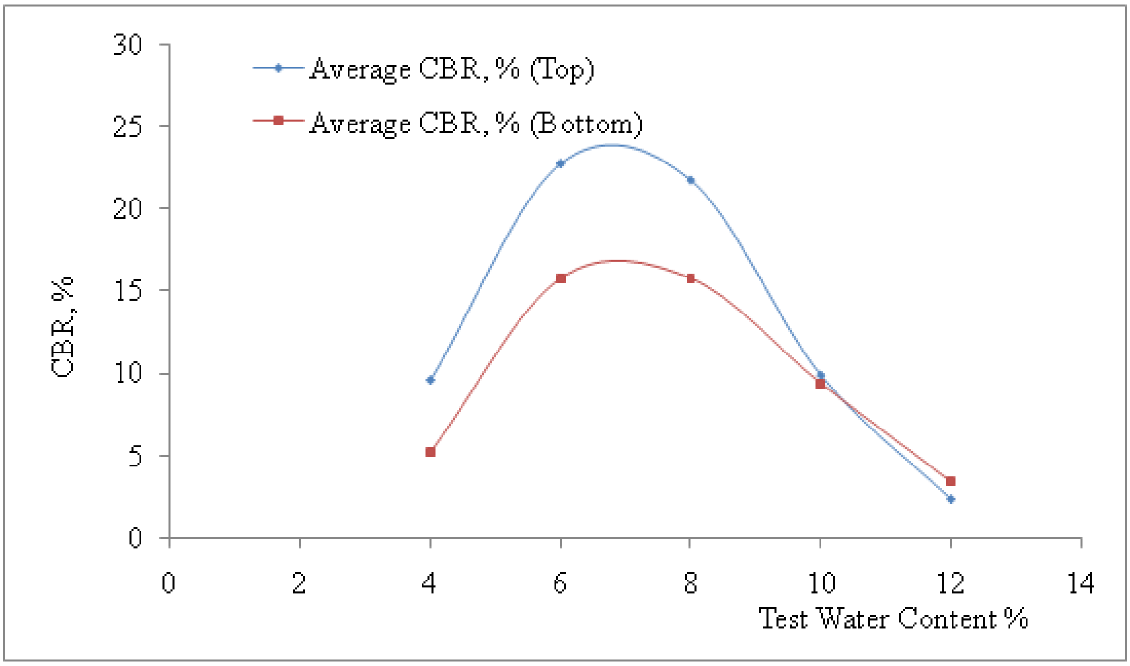


Figure 5: Results of CBR for top and bottom against test moisture content for 15% palm kernel shell substitution in lateritic soil

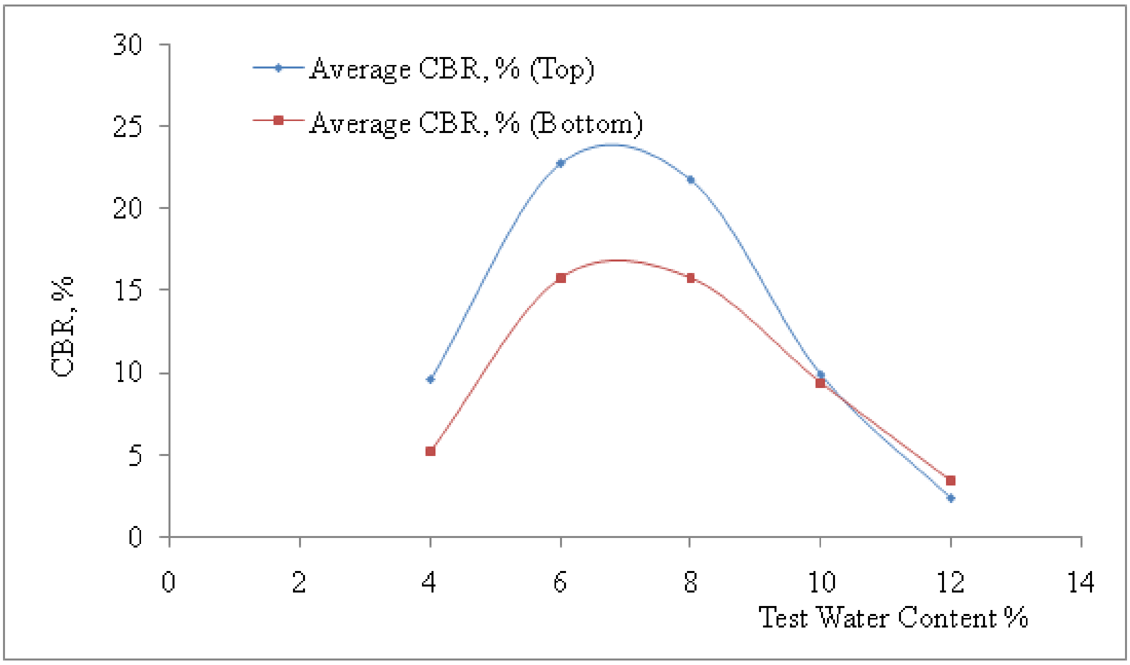


Figure 6: Results of CBR for top and bottom against test moisture content for 20% palm kernel shell substitution in lateritic soil

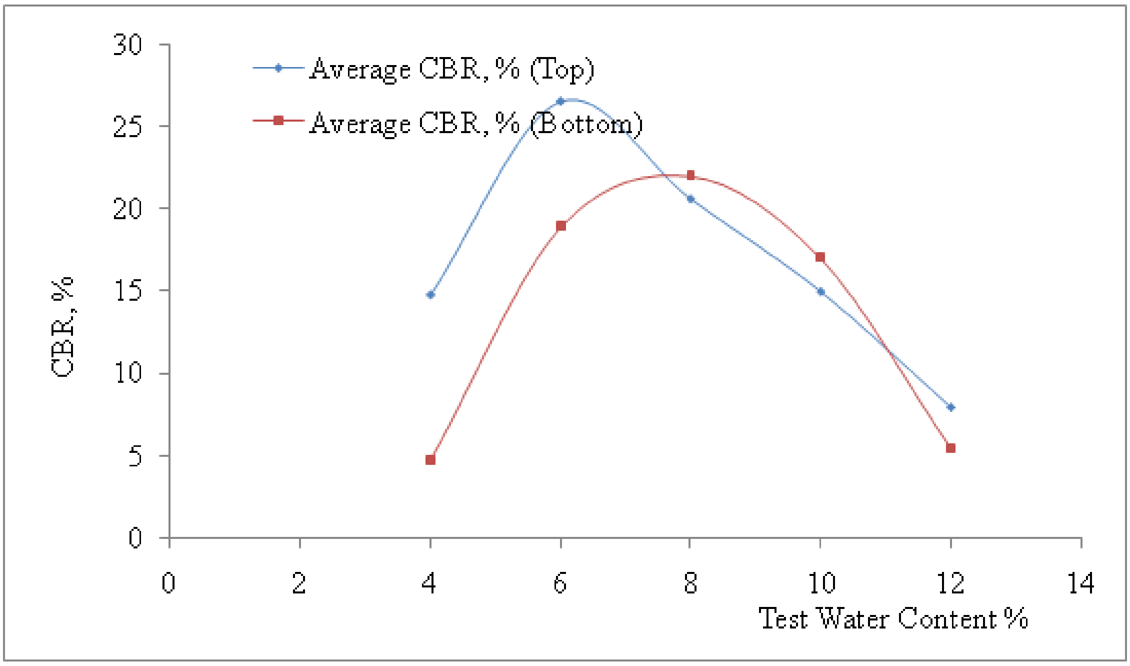


Figure 7: Results of CBR for top and bottom against test moisture content for 25% palm kernel shell substitution in lateritic soil

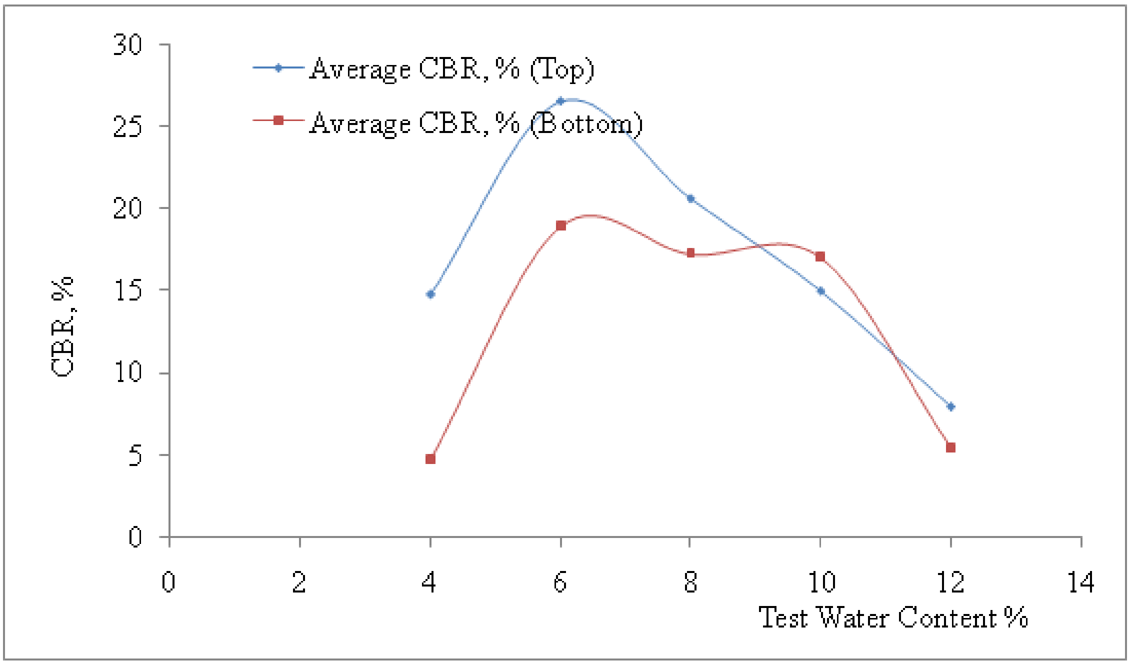


Figure 8: Results of CBR for top and bottom against test moisture content for 30% palm kernel shell substitution in lateritic soil

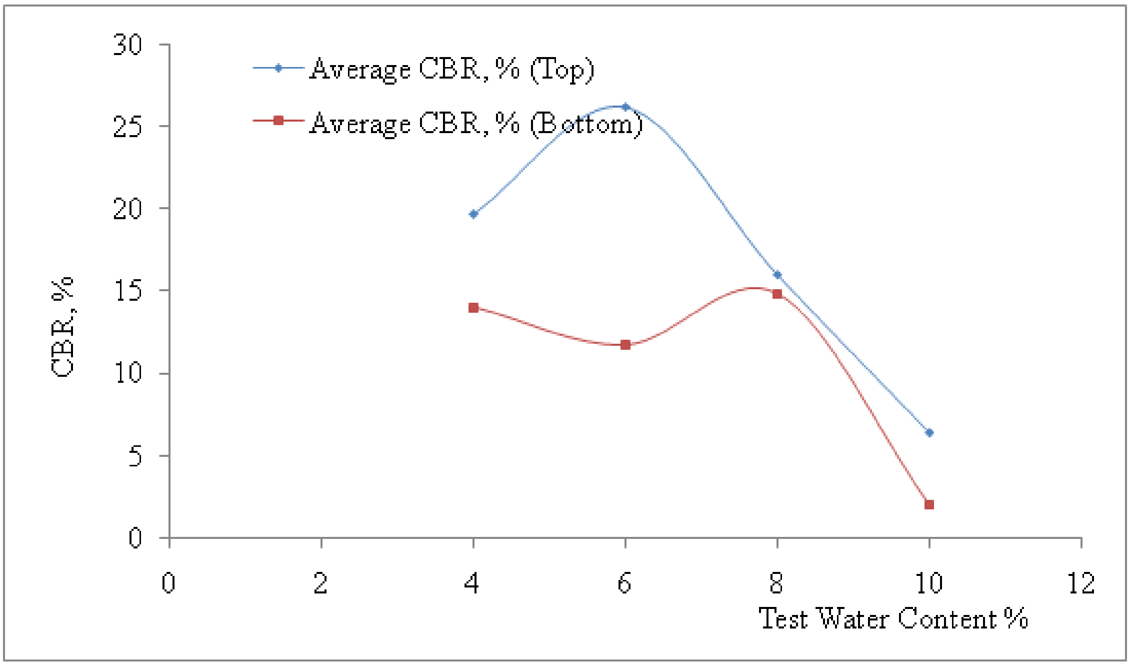


Figure 9: Results of CBR for top and bottom against test moisture content for 35% palm kernel shell substitution in lateritic soil

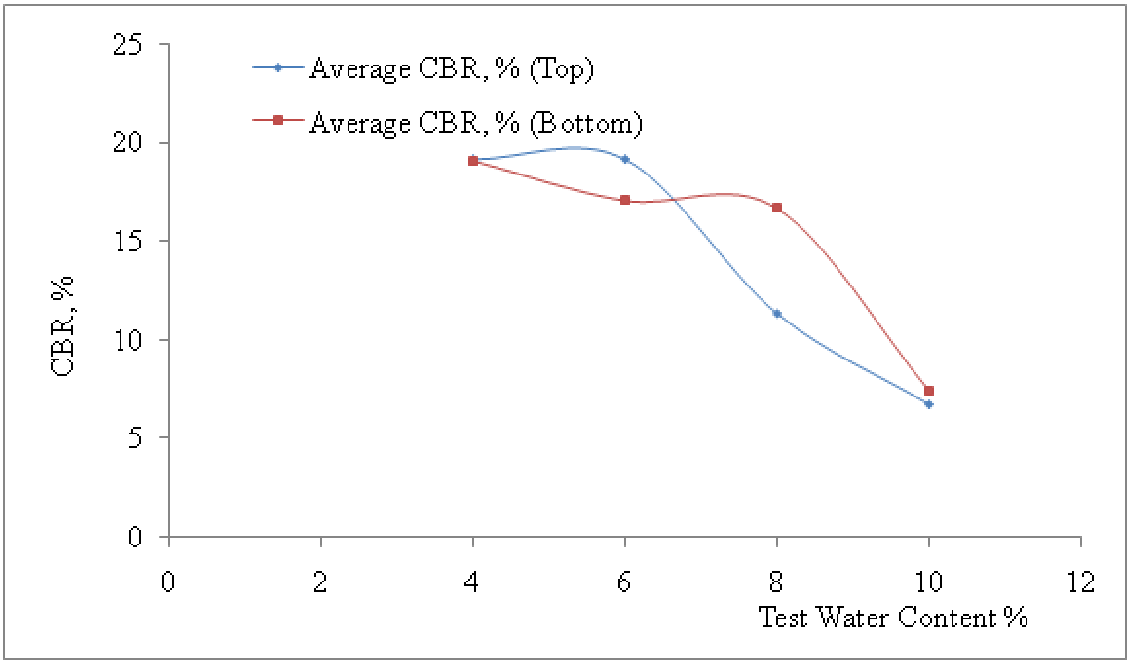


Figure 10: Results of CBR for top and bottom against test moisture content for 40% palm kernel shell substitution in lateritic soil

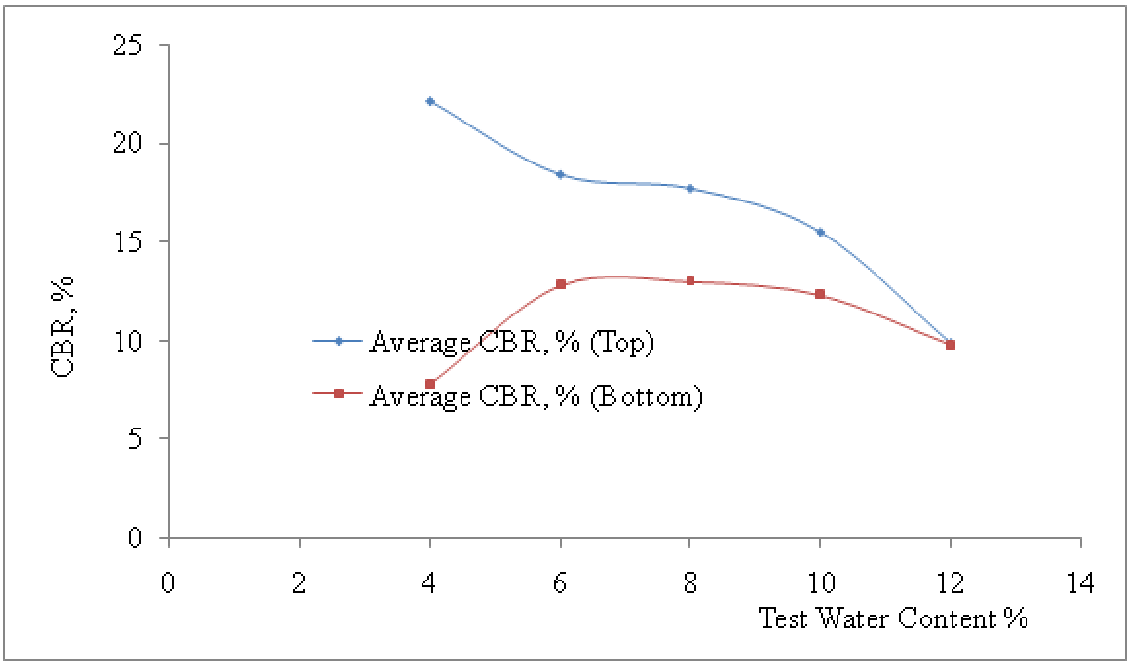


Figure 11: Results of CBR for top and bottom against test moisture content for 45% palm kernel shell substitution in lateritic soil

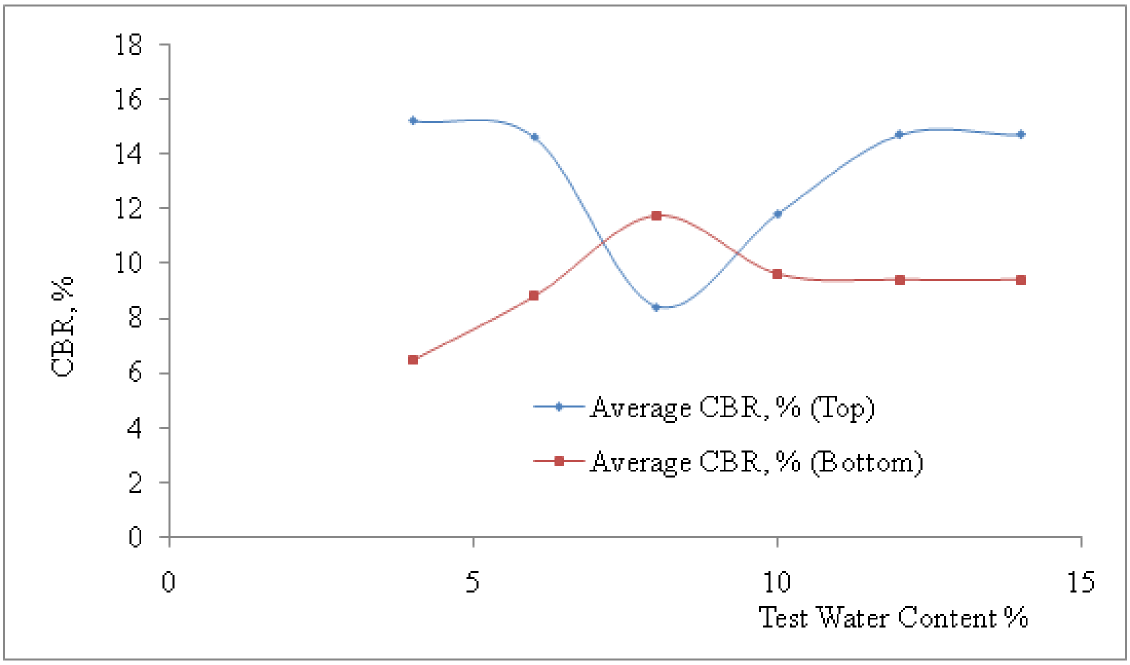


Figure 12: Results of CBR for top and bottom against test moisture content for 50% palm kernel shell substitution in lateritic soil

Conclusion

Study on CBR characteristics of palm kernel shell stabilized sedimentary formation were conducted on 0% to 50% palm kernel shell substitutions in lateritic soil. The CBR values of composite materials (5% to 50% palm kernel shell substitutions at 5% intervals) at different percentages of test water content were compared to lateritic soil (i. e. 0% palm kernel shell substitution, i. e. 100% lateritic soil). Based on the results of this study, California Bearing-Ratio value increased gradually as palm kernel shell substitution increases while 25% palm kernel shell substitution has the maximum CBR value at both top and bottom. In addition to this, from 40% to 50% palm kernel shell substitution, maximum CBR values were observed from their initial test water content. The composite material with palm kernel shell at 25% can be used for road base and sub base. Finally, recycling of palm kernel shell wastes is an alternative solution of safe disposal of the agro wastes. Therefore environmental risk and hazard caused by palm kernel shell wastes could be greatly reduced if not completely eliminated. Details of applications of various CBR values and compaction characteristics for all the palm kernel shell substitutions in lateritic soil for different road thicknesses (i. e. pavement design and construction guidelines – sub base, sub grade, etc.) could be found in Olarewaju (2021) (Amu et al., 2008; Nnochiri et al., 2017; Olutaiwo et al., 2018; Omolayo and Esther, 2018; Olarewaju, 2018a, b and c; Olarewaju, 2021)..

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