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California Bearing-Ratio Characteristics of Plastic Pellet Stabilized Sedimentary Formation

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Abstract: *Improving the engineering properties of lateritic soils by including stabilizing agent, such as cement, lime, bitumen, etc. helps to reduce settlement underneath the engineering structures. Plastic pollution is the accumulation of plastic objects and particles in the Earth's environment that adversely affects wildlife, and human. Living organisms, particularly marine animals, can be harmed by problems related to ingestion of plastic waste or through exposure to chemicals within plastics that interfere with their physiology. 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 plastic wastes were taken from different location in Ilaro, Ogun State, Nigeria. The plastic wastes were cut into pieces passing through 5mm sieve and then substituted for lateritic soil in the range of 0% to 50% at 5% intervals with 0% plastic pellet substitution serving as control experiment. In line with BS 1377 (1990), California Bearing-Ratio tests were conducted on the composite materials at different test water contents for all the substitutions. From the results, California Bearing-Ratio value increased gradually as plastic pellet substitution increases. In addition to this, 5% and 10% substitutions have the maximum CBR value at both top and bottom. Furthermore, between 25% to 50% plastic pellet substitutions, CBR values are highest from their first test water content. The composite material at 5% to 10% plastic pellet substitution could be used for road base and sub base, most especially rural roads. Therefore, environment risk and hazard caused by plastic waste could be greatly reduced, if not completely eliminated.*

Keywords: *CBR, Pressure, Loads, Variation, Stabilization, Sedimentary, Formation Composite, Material*

Introduction

The California Bearing Ratio (CBR) test was developed by the California Division of Highways to classify the suitability of a soil for use as a sub-grade or base course material in highway construction. During World War II, according to Bowles (1981), the U.S. Corps of Engineers adopted the test for use in airfield construction. The CBR test which American Society for Testing Materials (ASTM) terms simply a bearing ratio test measures the bearing resistance of a soil under controlled moisture and density conditions. The test yields a bearing ratio number, but it is evident this number is not a constant for a given soil but applies only for the tested state of soil. The test can be performed in the field on an in-situ soil, and the CBR number is obtained as the ratio of the unit load required to effect a certain depth of penetration of the piston into a compacted specimen of soil at a particular water content and density to the standard unit load required to obtain the depth of penetration on a standard sample of crushed stone (Chen, 1995; Knappett and Craig, 2012; Craig, 1994; Brian, 1980; Bowles, 1981). The CBR number is usually based on the load ratio for a penetration of 2.5mm, if however, the CBR value at a penetration of 5.0mm is larger, the test should be repeated. If a second test yields also a larger CBR number at 5.0mm penetration, then the CBR value for 5.0mm should be used. CBR tests are usually made on test specimen at the optimum moisture value for the soil as determined using the standard or modified compaction test, using method 2 or 4 of ASTM D698-70 or D1557-70, the specimen are made up using the concentration energy (Chen, 1995; Knappett and Craig, 2012; Craig, 1994; Brian, 1980; Bowles, 1981). Two moulds of soil are often compacted; one for immediate penetration testing and one for testing after soaking for a period of 96 hours. The second specimen is soaked for a period of 96hrs with a surcharge approximately equal to the pavement weight used in the field but in no case is the surcharge weight less than 5.5kg. Swell reading are taking during this period at arbitrary selected times and at the end of the soaking period, the CBR penetration test is made to obtain a CBR value for the soil in a saturated conditions. In both penetration tests for the CBR values, a surcharge of the magnitude as for the swell test is placed on the swell sample. The test on the soaked sample accomplishes two things; (1) it gives information concerning expected soil expansion beneath the pavement when the soil becomes saturated and (2) it gives an indication of strength loss from field saturation. Penetration testing is accomplished in a compression machine using a strain rate of 1.27 mm/min. Readings of load versus penetration are taken at each 0.5 mm of penetration to include the value of 5.0mm, and then at each 2.5mm increment thereafter until the total penetration is 12.7mm. The CBR number is used to rate the performance of soils primarily for use as bases and sub-grades beneath pavement of roads and airfields (Chen, 1995; Knappett and Craig, 2012; Craig, 1994; Brian, 1980; Bowles, 1981).

Background Study

Laterite, a sedimentary rock deposit arising from the weathering of rocks, is one of the most common and readily available road construction materials that can be sourced locally. Laterites as a soil group instead of well design material are mostly found in the leached soils of the humid tropics. These soils are formed under weathering conditions productive of the process of laterization, the most important characteristic of which is the decomposition of ferro-alumino silicates materials and permanent processes that produced lateritic soils. Lateritic soils are used in the construction of roads, highways, airfield, and earth dams and for foundation of structures. In natural state, it has a low bearing capacity and low strength due to its high clay content. When it consist of high plastic clay, the plasticity of the soil may cause cracks and damage to pavement, roadways, building foundations or any other engineering projects (Chen, 1995; Knappett and Craig, 2012; Craig, 1994; Brian, 1980; Bowles, 1981). The improvement in the strength and durability of lateritic soil in recent time has becomes imperative, which has encouraged researchers to use stabilizing materials that can be sourced locally at very low cost, in this case, plastic pellets. Settlement underneath foundation, embankment, and road involve an exceptional test to engineers. Improving the engineering properties of the soils (i. e. laterites) by including stabilizing agent, for instance, cement, lime, bitumen, etc. helps to reduce settlement beneath engineering structures. On the other hand, plastic pollution is the accumulation of plastic objects and particles (e.g. plastic bottles, bags, and microbeads) in the Earth's environment that adversely affects wildlife, wildlife habitat, and human. Living organisms, particularly marine animals, can be harmed either by mechanical effects, such as entanglement in plastic objects, problems related to ingestion of plastic waste, or through exposure to chemicals within plastics that interfere with their physiology (Chen, 1995; Knappett and Craig, 2012; Craig, 1994; Brian, 1980; Bowles, 1981).

Methodology

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 (Figure 1), along Papalanto-Ilaro road, Ogun State, Nigeria and plastic wastes were taken from different location in Ilaro, Ogun State, Nigeria. The plastic wastes were cut 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 with 0% plastic pellet 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 (Chen, 1995; Knappett and Craig, 2012; Craig, 1994; Brian, 1980; Bowles, 1981).

(a) **(b)** (c)

Figure 1: (a) Plastic Waste (b) Plastic Pellets (c) Sedimentary Formation at Abalabi, Ajegunle, Papalanto-Ilaro Road, Ogun State, Nigeria

Results and Discussion

The results of California Bearing Ratio (CBR) for top and bottom penetrations against test moisture content for 0% to 50% plastic pellet substitutions in lateritic soil with 0% serving as control experiment are graphically presented in Figures 2 to 12 respectively. In addition to this, typical pavement design for 0% (Control), 45% and 50% plastic pallet substitutions are presented in Tables 1, 2 and 3 respectively. Details of applications of various CBR values and compaction characteristics for all the plastic pellet 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). 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% plastic pellet substitution (Fig. 3) the CBR value is in the range of 25% at the top and 10% at the bottom at 6% test water content, the CBR values reduces as the test water content increases. Figures 4, 5 and 6 shows 10%, 15% and 20% plastic pellet substitutions respectively and it was observed that the CBR values reduces as the test water content increases. As the plastic pellet substitutions in lateritic soil increases as shown in Figures 5 to 12 for 15% to 50% plastic pellet substitutions respectively, CBR values reduces and further reduction in CBR values were observed as the test water content increases. The study shows that 5% and 10% plastic pellet substitutions in lateritic soil has the highest value of CBR similar to control experiment (i. e. 0%), meaning that plastic pellets have smooth surfaces and due to low dosage of plastic pellets in 5% and 10% substitutions, the high percentage of lateritic soil makes the plastic pellet content almost insignificant. But contrary to this, in high dosage of plastic pellet substitutions (like 30% to 50%), it slides against each other instead of supporting each other to carry the load. As the plastic pellets and test water content increases but reduction in lateritic soil, the composite material dissipates the water and slide against each other because of its smooth surfaces instead of cohesion among each other to support load. The water increase in the composite material acts as lubricant and also plastic does not absorb water which means at high dosage of plastic pellets and test water content, plastic pellets will slide against each other with the help of the increase in test water content which act as lubricant. Instead of supporting each other to support loads to eventually affect the CBR values to be increased, the increase in penetration of the load the lesser the CBR value because of its inability to absorb water.

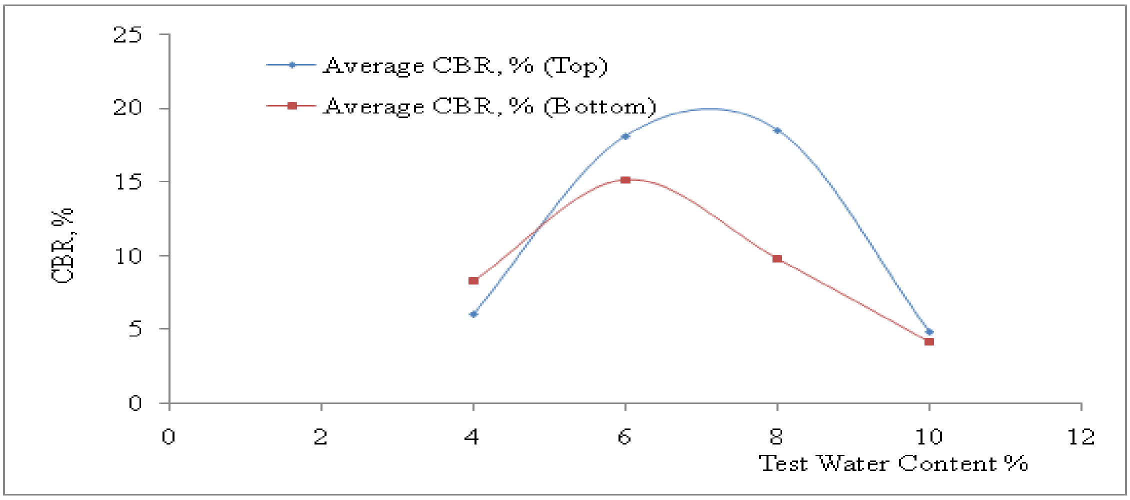

Figure 2: Results of CBR for top and bottom against test moisture content for 0% plastic pellet substitution in lateritic soil (control experiment)

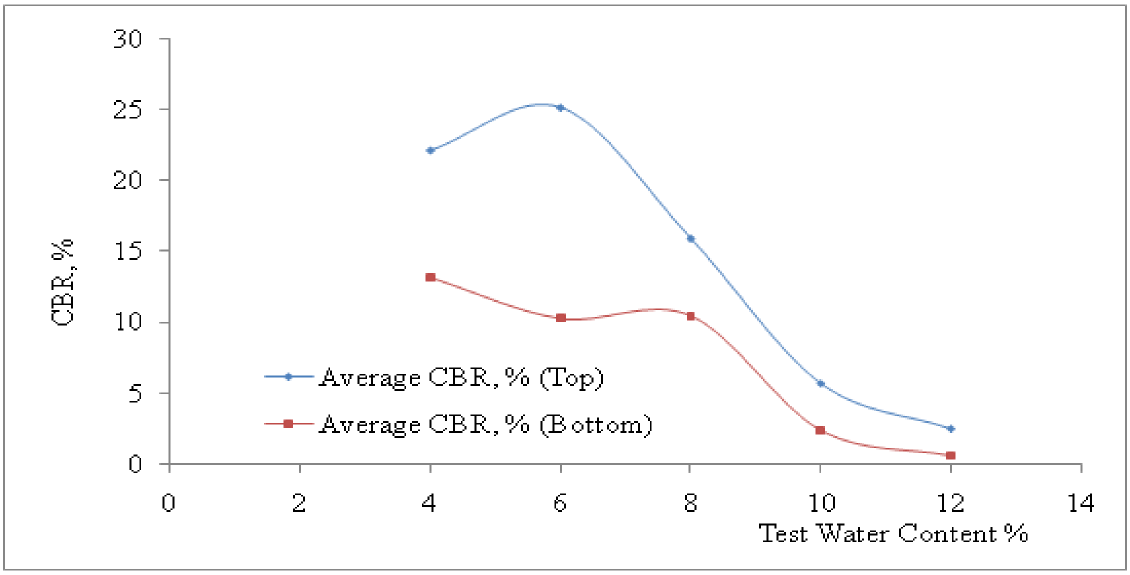

Figure 3: Results of CBR for top and bottom against test moisture content for 5% plastic pellet substitution in lateritic soil

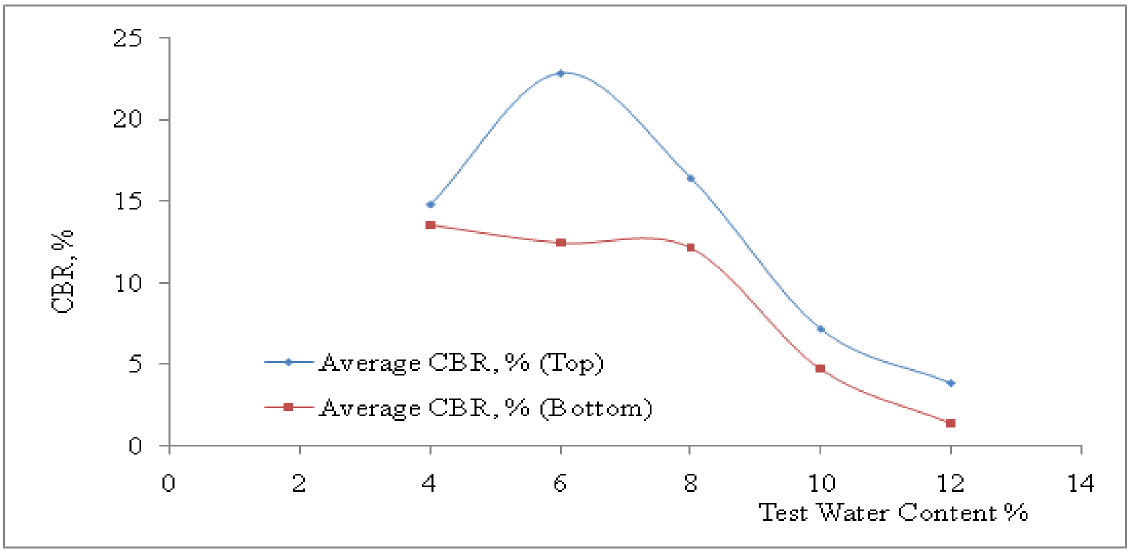

Figure 4: Results of CBR for top and bottom against test moisture content for 10% plastic pellet substitution in lateritic soil

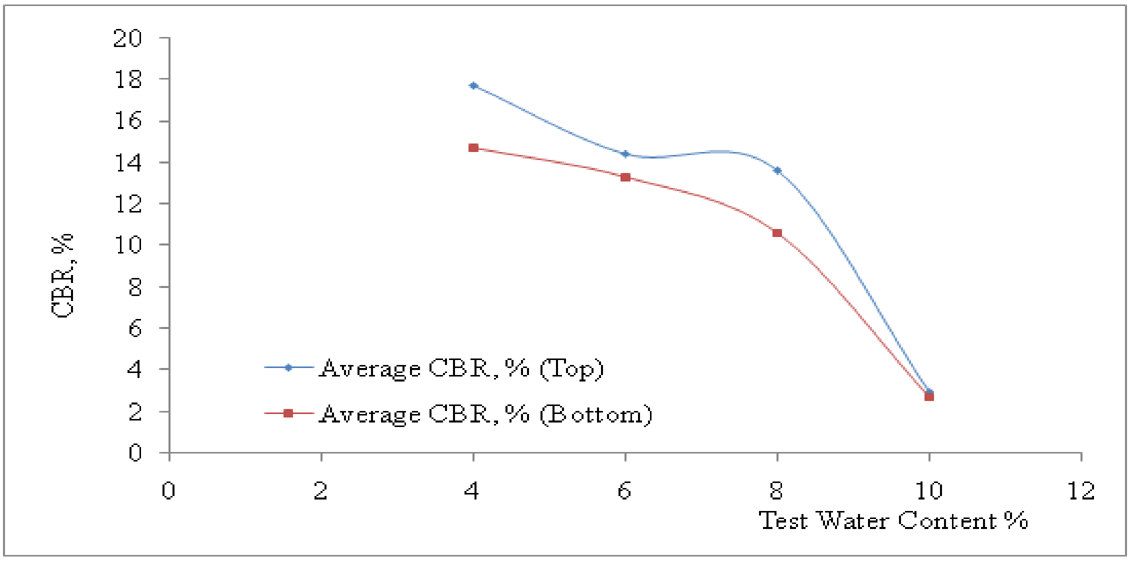

Figure 5: Results of CBR for top and bottom against test moisture content for 15% plastic pellet substitution in lateritic soil

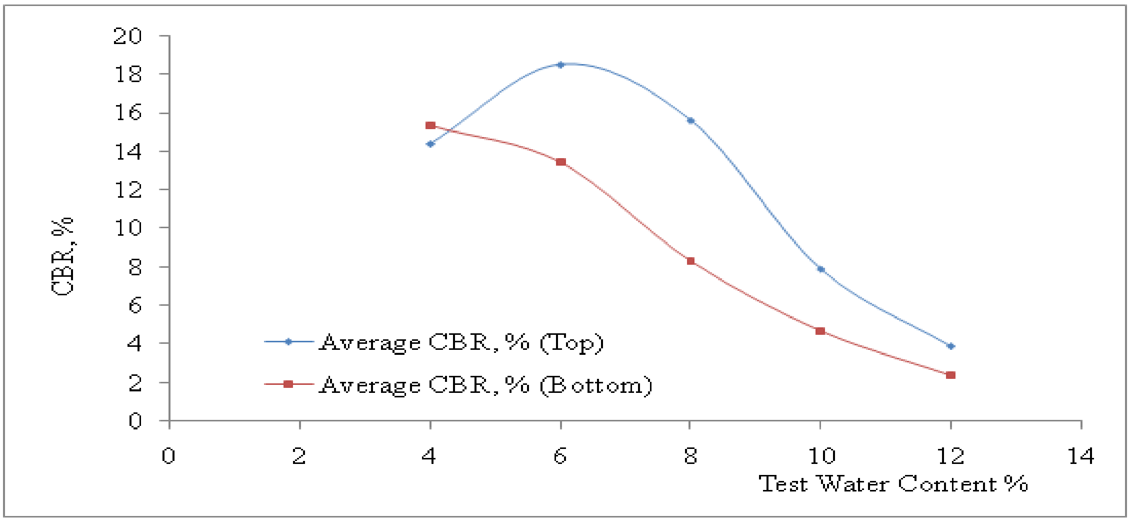

Figure 6: Results of CBR for top and bottom against test moisture content for 20% plastic pellet substitution in lateritic soil

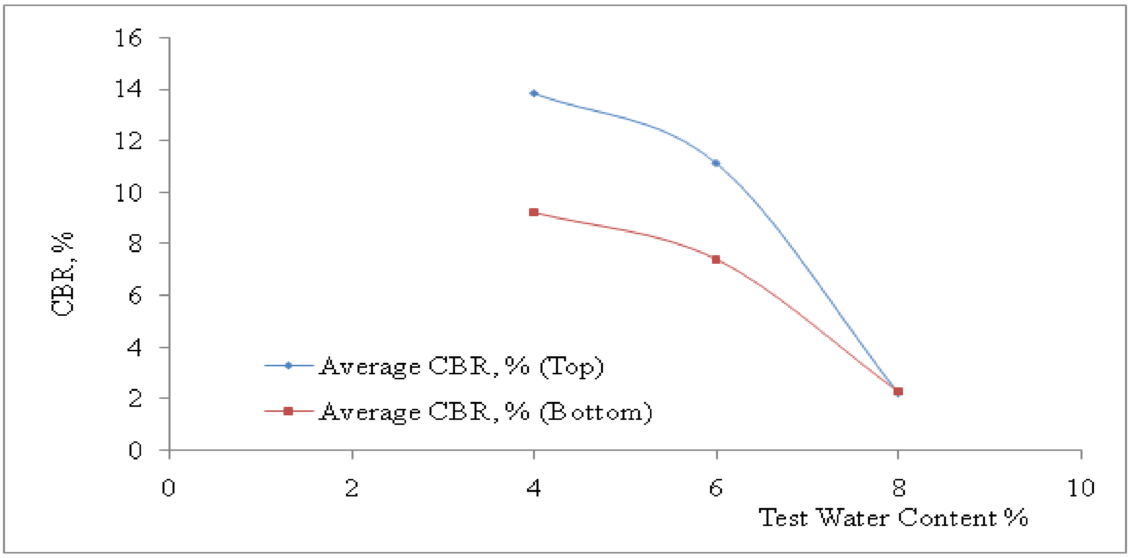

Figure 7: Results of CBR for top and bottom against test moisture content for 25% plastic pellet substitution in lateritic soil

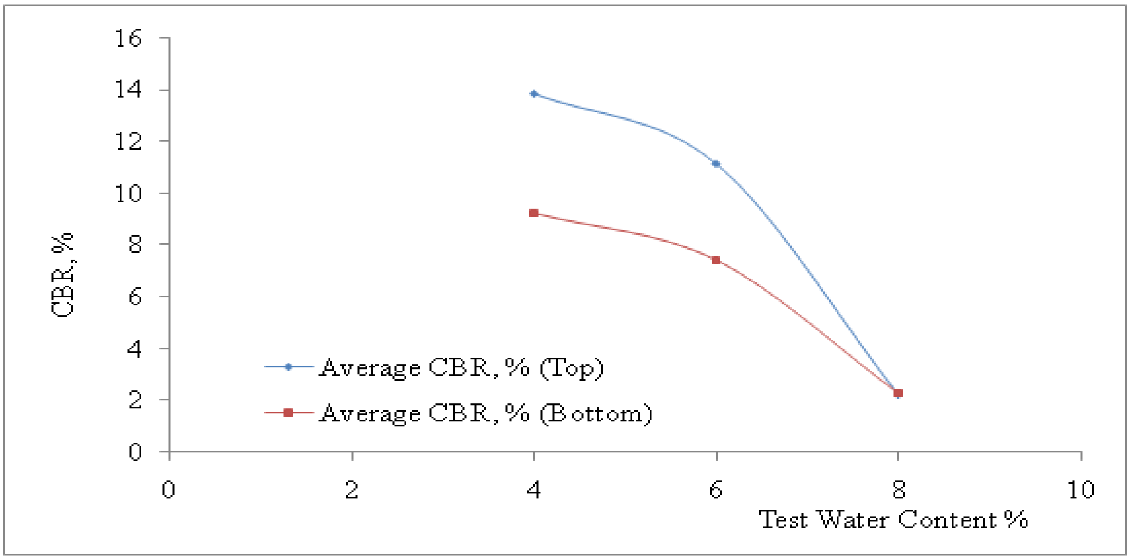

Figure 8: Results of CBR for top and bottom against test moisture content for 30% plastic pellet substitution in lateritic soil

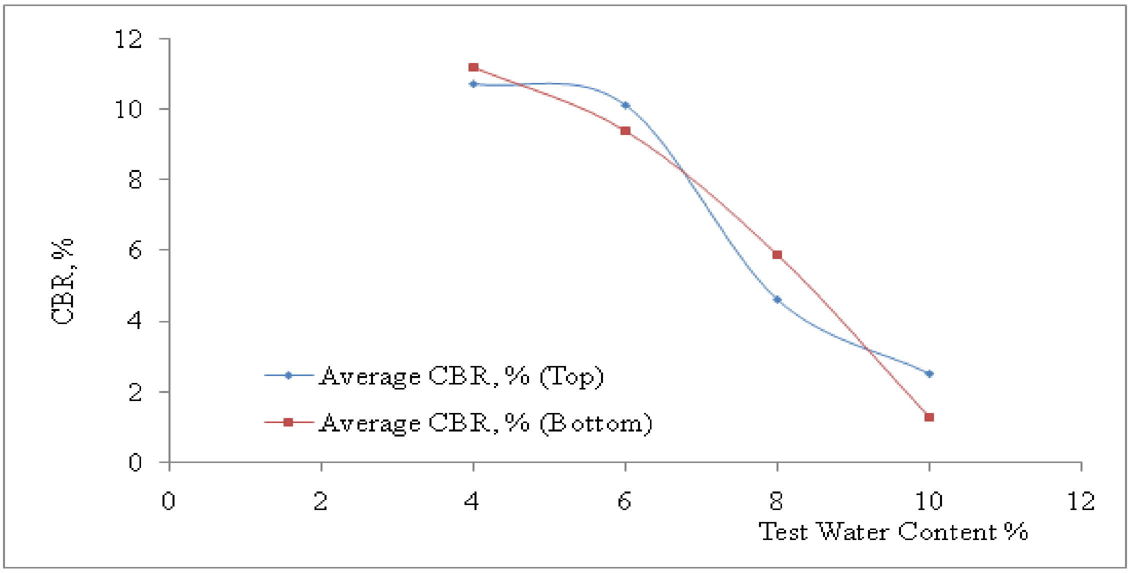

Figure 9: Results of CBR for top and bottom against test moisture content for 35% plastic pellet substitution in lateritic soil

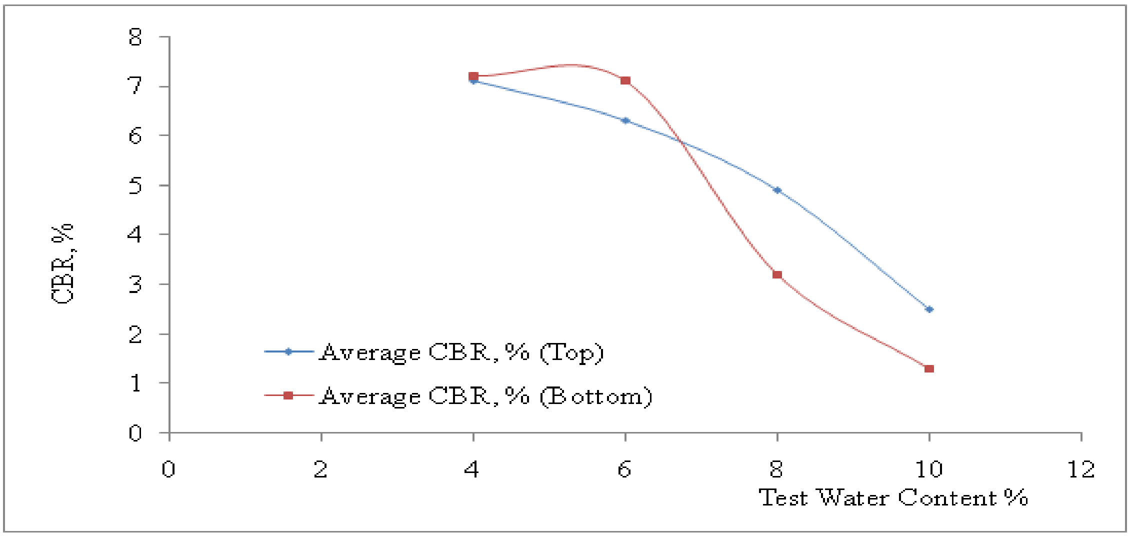

Figure 10: Results of CBR for top and bottom against test moisture content for 40% plastic pellet substitution in lateritic soil

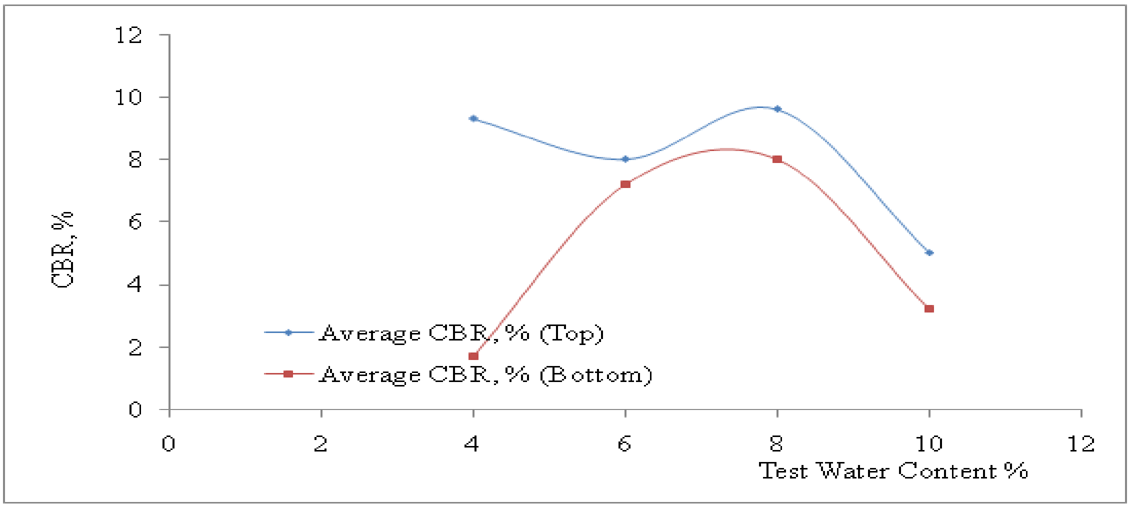

Figure 11: Results of CBR for top and bottom against test moisture content for 45% plastic pellet substitution in lateritic soil

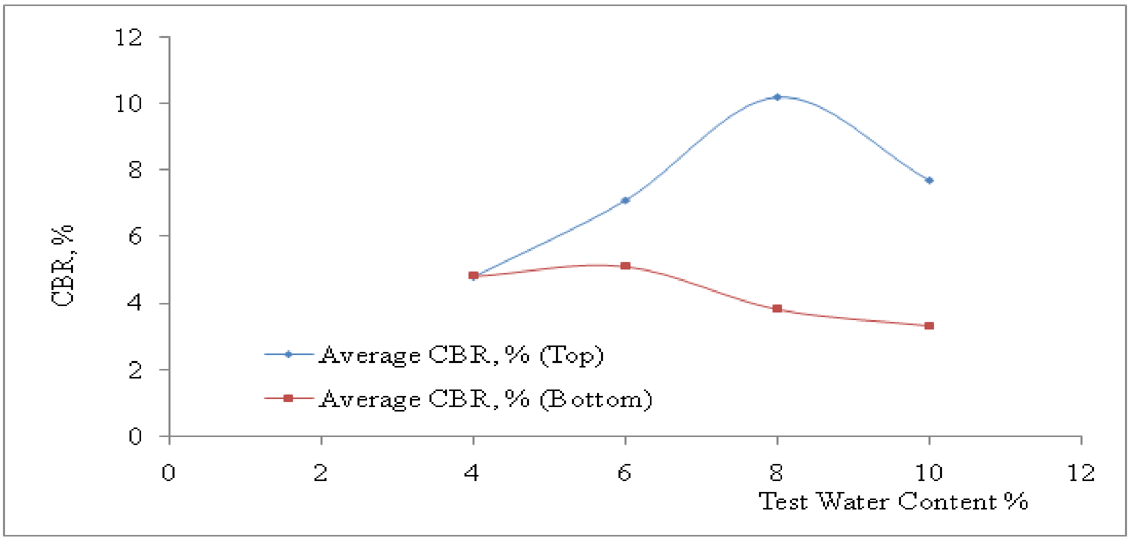

Figure 12: Results of CBR for top and bottom against test moisture content for 50% plastic pellet substitution in lateritic soil

Table 1: Pavement design for 0% plastic pellet substitution

	Average CBR (%)	Wheel Load (Ib)	Thickness (mm)
Surfacing			100
Base	18	70000	400
Sub base	18	70000	400
Total thickness			900

Table 2: Pavement design for 45% plastic pellet substitution

	Average CBR (%)	Load (N)	Thickness (mm)
Surfacing			100
Base	(10+8)/2 =9	311380	600
Sub base	(10+8)/2 =9	311380	600
Total thickness			1300

Table 3: Pavement design for 50% plastic pellet substitution

	Average CBR (%)	Load (N)	Thickness (mm)
Surfacing			100
Base	(10+5)/2 =7.5	311380	688
Sub base	(10+5)/2 =7.5	311380	688
Total thickness			1475

Conclusion

Studies on CBR characteristic of plastic pellet stabilized sedimentary formation had been conducted for 5% to 50% plastic pellet substitutions in lateritic soil at 5% intervals with 0% serving as control experiment. From the results, California Bearing-Ratio value increased gradually as plastic pellet substitution increases. In addition to this, 5% and 10% substitutions have the maximum CBR value at both top and bottom. Furthermore, between 25% to 50% plastic pellet substitutions, CBR values are highest from their first test water content. The composite material at 5% to 10% plastic pellet substitutions could be used for road base and sub base. The possible alternative solution to safely dispose plastic wastes from causing environmental pollution is to use it to stabilized lateritic soil in the construction of roads, most especially rural roads. Therefore, environment risk and hazard caused by plastic waste could be greatly reduced, if not completely eliminated.

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