



## **Stabilization of A-6 Lateritic Soil using Cold Reclaimed Asphalt Pavement**

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### **ABSTRACT**

Reclaimed Asphalt Pavement (RAP) was used for stabilization of a deficient lateritic soil, classified as A-6 and CL according to AASHTO and Unified Soil Classification System, respectively. The RAP, in a cold state, was mixed with the lateritic soil at varying percentages of 0, 5, 10, 15, to 100 %. California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS) were used as evaluation criteria for specimens of the soil-RAP mixtures, compacted at British Standard Heavy (BSH) energy level. The strength evaluation was carried out at 60 % RAP mixture which was found to be the optimum RAP content that gave the highest MDD. Extraction test result on the RAP gave 7.3 % bitumen content which is slightly higher than the 7.0 % maximum recommended. There was 12.7 % increase in MDD which occurred at 60 % RAP content. The Optimum Moisture Content (OMC) decreased by 31.3 %. The result of CBR on the soil and soil mixed with 60 % RAP showed slight increase of 7.2 %, while 9.9 % increase was recorded for the Unconfined Compressive Strength. The slight increase in strength was attributed to the cold state of the asphalt, which makes its adhesive (plastic) properties not pronounced.

**Keywords:** California Bearing Ratio; Lateritic soil; Reclaimed Asphalt Pavement; Stabilization; Unconfined Compressive Strength

### **1. INTRODUCTION**

Laterite is a soil group, which is commonly found in the leached soils of the humid tropics and is formed under weathering systems that cause the process of laterization [1]. It is a common construction material available in almost all the countries of the humid tropics of the world. Its formation is favoured by the factors encouraging laterization processes such as high intensity rainfall, high vegetation cover, permeable soil profile, alternating ground water movement, etc. Laterite soils can be used as base course for roads, in some cases, without any improvement. But there are other cases where laterization process is not complete and soil groups such as Laterite, lateritic and laterized soils are formed. These soils may contain substantial amount of silica in the form of clay silicate minerals and could affect the strength and the stability of the Laterite. In areas where deposits of these types of Laterite exist, sourcing for alternative suitable soil may be too expensive. Therefore stabilizing the available Laterite to meet the desired strength and stability is necessary.

Singh [2] define stabilization as a combination of soils and or additives in such a way that, when it is compacted under specified conditions and to specified extent, would undergo material change in its properties and would remain in its stable compacted state without undergoing any change under the effect of exposure to weather and traffic. Stabilization could be mechanical, bituminous, chemical (cement, lime etc.) or a combination of two or more of these materials depending on the nature of deficiency observed in a particular lateritic soil.

Bituminous road failure in form of wavy surface, corrugations, rutting and shoving which are commonly caused by poor sub-

grade condition, are very prevalent in most developing countries including Nigeria. Government at various levels, therefore, have constituted organizations to periodically respond to pavement surface failures. One of such organization constituted by the Federal Government of Nigeria is 'Federal Road Maintenance Agency' (FERMA). This organization is saddled with the responsibility of removing road asphalt surface of the sections that has failed completely. These materials commonly called Reclaimed Asphalt Pavement (RAP) which contains both gravel and bitumen at various proportions are thrown away indiscriminately and are mostly found littering the environment. The use of this material in the stabilization of lateritic soils will be cheap and also help in the protection of the environment. The use of lateritic soils, stabilized with this material, will substantially help in the provision and maintenance of durable unpaved roads, which constitutes vast percentage of access roads, especially to rural dwellers in Nigeria.

### **2. RECLAIMED ASPHALT PAVEMENT**

Reclaimed Asphalt Pavement (RAP) (waste asphalt removed from a failed pavement surface) is a mixture of aggregate coated by bitumen and is collected from failed asphalt pavement surfaces. RAP has been in use in most developed countries for more than 30 years [3]. It has been used as aggregate in the cold recycling of asphalt paving mixtures either by the method of cold mix plant recycling or cold in place recycling process. Some of the engineering properties of RAP that are of importance when used in cold recycled

applications include its gradation, asphalt content, and the penetration and viscosity of the asphalt binder. The aggregate gradation of RAP is somewhat finer than that of the virgin aggregate. This is due to mechanical degradation during asphalt pavement removal and processing. RAP aggregates usually can satisfy the requirements of ASTM D692 for coarse aggregate and ASTM D1073 for fine aggregates. According to Epps *et al* [4], the asphalt content of most old pavements will comprise approximately 3 to 7 % by weight of the pavement. Osinubi and Bajeh [5] carried out stabilization of lateritic soil using bitumen and discovered that the MDD of the mixture decreased with increase in the bitumen content. However, there was moderate increase in the CBR of the bitumen-lateritic mixture. Osinubi [6] conducted comparative studies on the stabilization of soil with anionic bitumen and cement and also observed reduction in both the MDD and OMC of the lateritic-bitumen mixtures with resultant increase in the CBR. Physically, RAP also contains crushed gravel which can be used in mechanical stabilization. Due to high specific gravity of gravel compared to Laterite, the combination of the two will result to increase in MDD of the Laterite-gravel mixtures. Therefore, addition of RAP to a deficient lateritic soil can improve the engineering properties of the deficient soil.

### 3. LOCATION AND GEOLOGY OF THE STUDY AREA

The soil sample used in this study was collected from a borrow pit along Minna-Kuta road in Niger State of Nigeria. The area lies between longitude 6°E and 7°E and latitudes 9°N and 10°N. According to Wright [7], the residual soil in this area is under laid by a granite basement and is surrounded to the north and south by 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 tributaries of River Niger. Soils in this area belong to ferruginous tropical soils derived from acid igneous and metamorphic rocks [8].

### 4. MATERIALS AND METHOD OF TESTING

Lateritic soil sample used for this study was collected using disturbed sampling method, while reclaimed asphalt pavement used was collected from failed sections of the paved road surfaces within Minna, in Niger State, Nigeria. The soil was air dried, and index properties test was conducted on the natural soil. Substantial amount of RAP was collected, pulverised and sieved through sieve 5.0 mm. The RAP specimen was added to lateritic soil at 0, 5, 10, 15, to 100 % by weight of the lateritic soil. For each mixture, compaction test was carried out at British standard Heavy compaction energy level to obtain the Maximum Dry Densities (MDD) and Optimum Moisture Contents (OMC).

The results of both the MDD and OMC were plotted against the percentage RAP to obtain the optimum RAP content to give the maximum MDD. The strength characteristics which include California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS) were then evaluated at this optimum RAP mixture with varied moisture contents. The maximum strength and the optimum moisture, where the strength was achieved were then recorded. The laboratory tests on the natural lateritic soil were carried out in accordance with BS 1377 [9], while the mixed specimens were tested in accordance with BS 1924 [10].

### 5. RESULT AND DISCUSSION

#### 5.1 Index Properties of Soil

The results of the index properties of the natural lateritic soil are summarised in table 1 while the grain size analysis for the natural lateritic soil is shown on fig 1. From table 1, the lateritic soil was classified as CL according to Unified Soil Classification System and A-6 according to AASHTO [11] soil classification system. This soil is considered not suitable for used as sub-base material for pavement structures.

Table 1: Index properties of the natural soil

Property	Quantity
Natural Moisture Content (%)	7.50
Percentage passing BS sieve 0.075mm (%)	56.0
Liquid Limit (%)	36.1
Plastic Limit (%)	22.5
Plasticity Index (%)	13.6
AASHTO Classification	A-6
USCS Classification	CL
Specific gravity	2.67
Maximum Dry Density (Mg/m <sup>3</sup> )	1.895
Optimum Moisture Content (%)	12.08
California Bearing Ratio (%)	45.1
Colour	Brownish

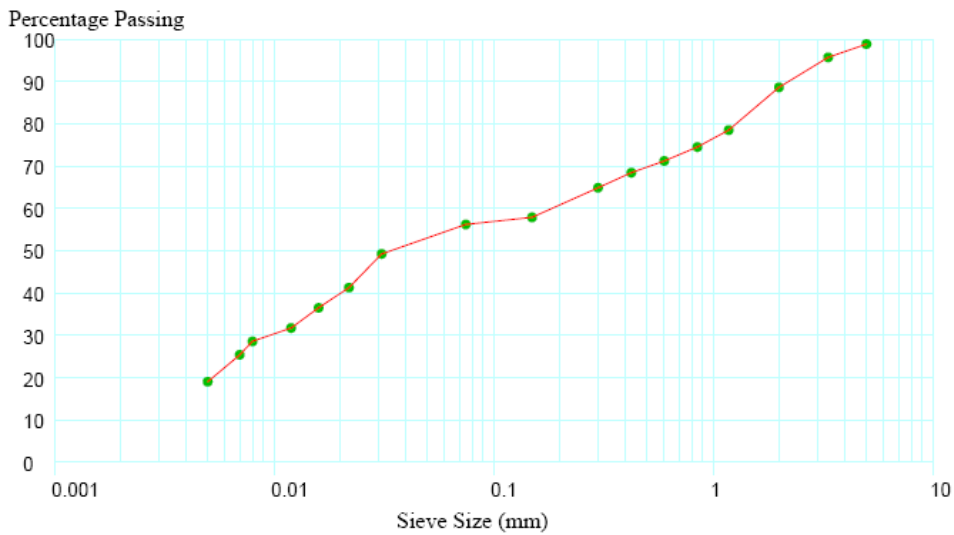


Fig. 1: Grain size analysis for natural lateritic soil

### 5.2 Bitumen Extraction Test

The result of the asphalt extraction test is shown on table 2 while the grain size analysis of the extracted aggregate is shown on fig. 1 below. From the results, the bitumen content

was observed to be 7.3 %. This is slightly above the 7.0 % maximum bitumen contained in asphalt mixture observed by Epps *et al* (1977).

Table 2: Summary of Results of Bitumen Extraction Test

Property	Quantity (%)
Coarse Aggregate	80.0
Fine Aggregate	12.7
Bitumen Content	7.3

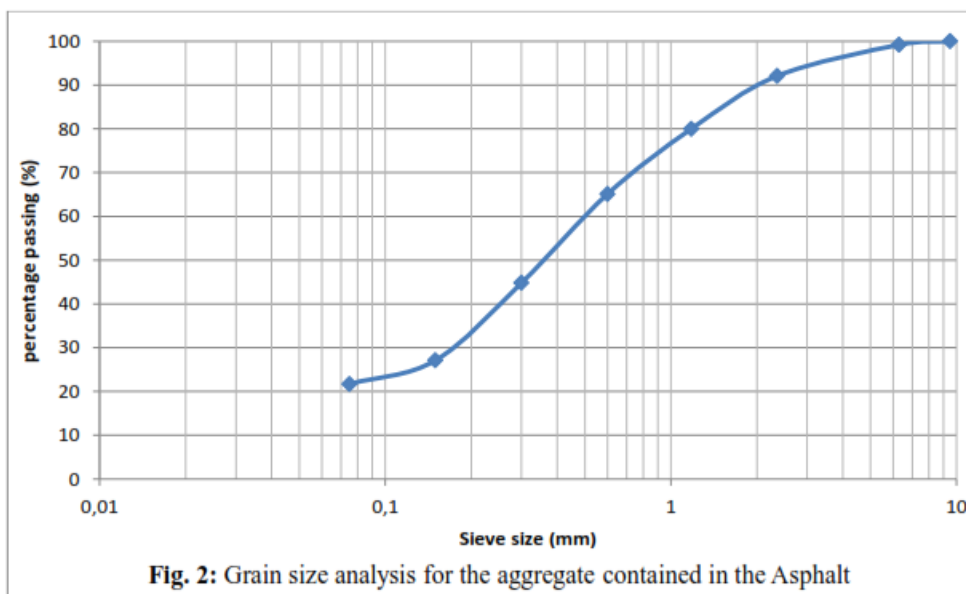
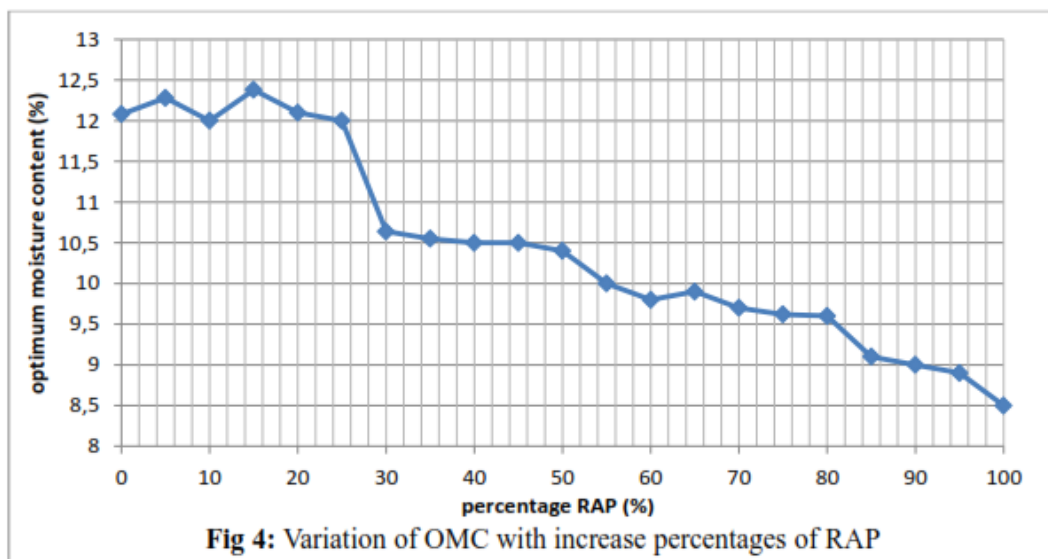
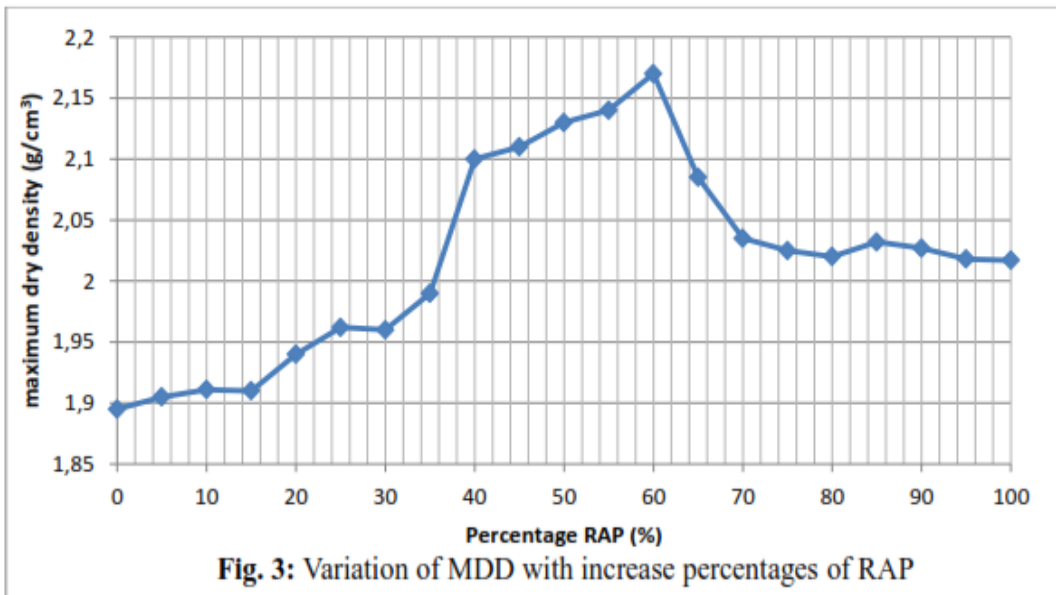


Fig. 2: Grain size analysis for the aggregate contained in the Asphalt

### 5.3 Compaction Characteristics

The variation of MDD and OMC with increase percentages of RAP are presented in figs 3 and 4 respectively. The MDD treated soil with varying percentages of RAP content, initially increases gently from 1.895 g/cm<sup>3</sup> at 0 % RAP to 1.990 g/cm<sup>3</sup> at 35 % RAP, and then increases sharply to 2.170 g/cm<sup>3</sup> at 60 % RAP, after which the MDD dropped to 2.017 g/cm<sup>3</sup> at 100 % RAP content. The initial gentle increase can be attributed to the mixture of low specific gravity bitumen and high specific gravity aggregates which are both present at very low

proportion. Subsequent increase in percentage of RAP increases the coarse aggregate which results in to increase in the density of the mix. Beyond 60 % RAP content, the composition of the coarse aggregates becomes high with fewer fines from the lateritic soil to fill the pore spaces hence reducing the MDD. The graph (fig. 4) shows continuous reduction in OMC with increase in RAP content to 100 %. This can be attributed to the fact that both the aggregate and bitumen which are the main components of asphalt have less affinity to water compare to the (clayey) lateritic soil. With increase in the bitumen and coarse aggregate, the soil content is reduced, and therefore reduction in the moisture content.

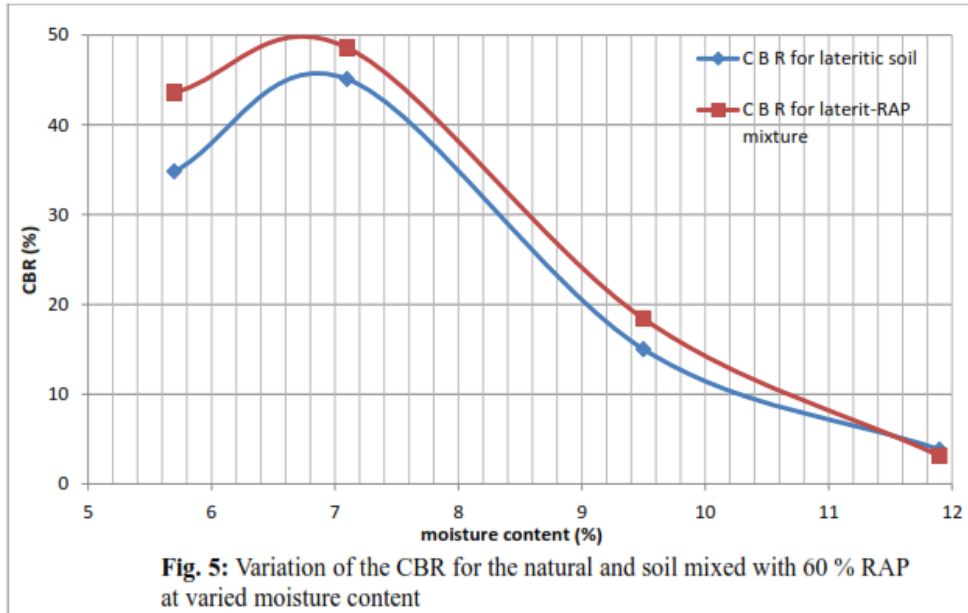


## 5.4 Strength Characteristics

### 5.4.1 California Bearing Ratio

The result of the California Bearing Ratio (CBR) test of the natural lateritic soil with varied moisture content, and the CBR of the lateritic soil mixed with 60 % RAP at varied moisture content are shown in fig 5. From the graph, it was observed that

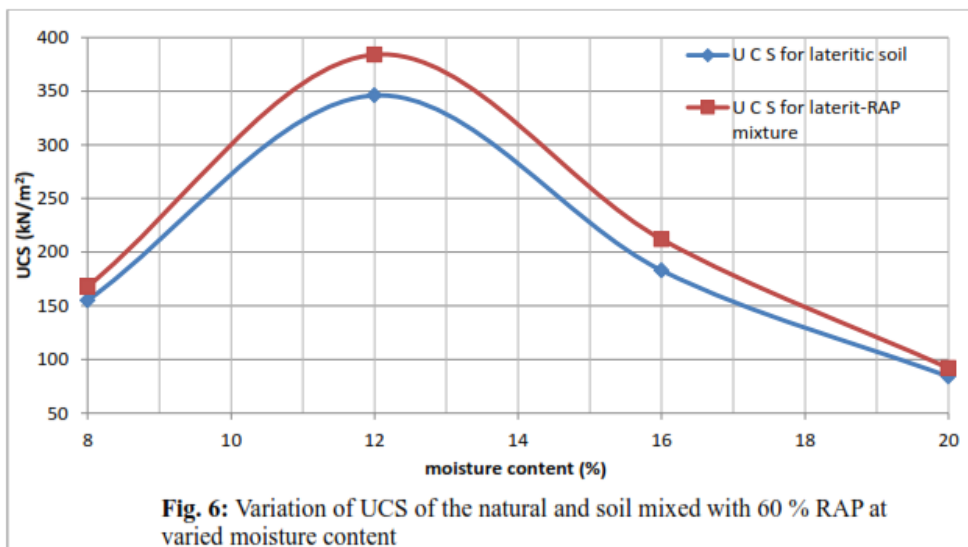
the maximum CBR increased slightly from 45.1 kN/m<sup>2</sup> for the natural lateritic soil to 48.6 kN/m<sup>2</sup> for the lateritic soil mixed with 60 % RAP. The OMC, where the maximum CBR occurred are 6.85 % and 6.68 % for the natural lateritic soil and lateritic soil mixed with 60 % RAP respectively. However, the OMC of the compaction carried out on the natural lateritic soil and lateritic soil mixed with 60 % RAP are 12.08 % and 9.80 % respectively. Therefore, lower moisture content below optimum is required to achieve maximum CBR.



### 5.4.2 Unconfined Compressive Strength

The variation of UCS with varied RAP content is shown in fig. 6 for the soil and soil mixed with 60 % RAP. From the graph, there is a slight increase in the maximum UCS from 346 kN/m<sup>2</sup> for the natural lateritic soil to 384 kN/m<sup>2</sup> for lateritic soil mixed

with 60 % RAP. These increases occurred at optimum moisture content of 12.2 %. It is observed that the optimum moisture content where the maximum UCS occurred is slightly higher than the optimum moisture content obtained from the compaction test.



## 6. CONCLUSIONS

From the result of the index properties of the lateritic soil used in this study, the soil was classified as A-6 according to AASHTO soil classification system and CL according to USCS. The extraction test result on the asphalt used in the study showed 7.3 % bitumen which is slightly above the 7.0 % maximum recommended by standard. The MDD of the soil mixed with varied percentages of RAP increased from 1.895 g/cm<sup>3</sup> at 0 % RAP to 2.170 g/cm<sup>3</sup> at 60 % RAP after which the MDD decreases. This represents a 12.7 % increase in MDD. The OMC on the other hand decreased from 12.38 % at 15 % RAP mixture to 8.5 % OMC at 100 % RAP mixture, which represents 31.3 % reduction in OMC. The CBR values increased slightly from 45.1 % for the natural soil to 48.6 % for the soil mixed with optimum 60 % RAP, which represents 7.2 % increase. The UCS also increased slightly from 346 kN/m<sup>2</sup> at 0 % RAP to 384 kN/m<sup>2</sup> at 60 % RAP mixture, representing 9.9 % increase. These low increases in strength are attributed to the nature of the asphalt treatment, i.e. cold during application. The bitumen, contained does not possess the plastic nature to adhere the soil particles together, rather it act as inert material which occupied pore spaces within the mixture.

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