Characterisation and Binder Stabilisation of Problematic Niger Delta Soils and Field Performance Evaluation in Nigeria

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ABSTRACT

This study offers an enduring solution to road failures in the Niger Delta. This was achieved by using different locally available additives and cement to improve the quality of the subgrade soils in the laboratory. The formulated blends were then used to construct trial stabilised sections in Sampou town, and their field performance were evaluated, while the potency of the stabilised soil composites was authenticated with micro-structural analysis.

The Niger Delta, Nigeria consists of deltaic layout of rivers and creeks with both fresh and salt water, the topography is flat, high intensity rainfall occurs almost throughout the year, and thus prone to persistent flooding. The intensity of weathering and the environment conditions have their toll on the soils, which makes them to be poor engineering materials especially for road construction. The norm in the region is to place huge dredged-sand as either fill or surcharge on the soft soil, for densification and consolidation purposes. Differential settlement usually occurs soon after pavement construction, resulting in massive road deterioration and failure. Inherent pavement failure causative factors were therefore linked to deficiency in soil properties, high moisture content in the environmental, and poor construction practice.

Laboratory analysis was performed on eight site soils obtained at both the subgrade levels and borrow-pit from five different sites across the coastal areas. The identified deficiencies in the soils were lack of coarse particles, fine-grains with high clay content, expansive clay minerals, and acidity. These deficiencies were reflected in the consistency limits of some of the soils, which had values above the specified limits: liquid limit (> 50%); plasticity index (> 30%); and linear shrinkage limit (> 6%). Therefore, with classification ranging A-2-4 to A-7-6 and ML – CH the soils were rated as good, fair, and poor subgrade. However, the ones rated as good or fair contained expansive or sulphate bearing clay minerals. These deficiencies were also reflected in the low MDD, high OMC, low CBR and UCS of many of the soils. While the ones with appreciable unsoaked CBR value (> 60%) would readily lose the strength in the presence of water, and prolong curing with adequate protection from water was required to development maximum UCS (~ 0.10 MPa). Model soils were patterned after two of the site soils, using sand, kaolin, and vermiculite, and ferrous sulphate was used to spike acidity. Variants of the model soils with different sand and clay mineral contents, and acidity were also prepared and these were characterised. The model soils were stabilised with blends of cement, hydrated lime, pulverised fly ash, and lateralite. Extensive data was generated which was used to explain the uniqueness and probable transition process that may occur in the site soils, and the effect of the binders on the geotechnical properties.

With this knowledge, locally available additives and binder in the Niger Delta were identified and used to stabilise a non-acidic fat clay namely: Drill cutting ash (DCA), lateralite, and cement (PC). Sand was used to supplement the deficient particle sizes, and the effect of saltwater on the cementation of the soil particles was investigated. The analysis revealed that more than 8% of the additives and PC was required to optimally stabilise the soils, when they were used in isolations. Also, continued cementation effect of saltwater on the soil particles could not be accounted for if used in the waterlogged areas. Hence, blends of the additives, sand, and PC were formulated and applied on the fat clay. These composites were found adequate to effectively stabilise the site soil namely: DCA-PC (1:1); lateralite-PC (2:1); and sand-PC (4:1). The following properties were improved and found commendable: plasticity (< 30%); densification; swelling (0.002 – 0.008); both 24 and 96 hrs soaked CBR (> 20% and > 10% respectively); permeability (8.89 x 10^{-8} - 9.66 x 10^{-8} m/s); CBR durability strength (24 – 41%) and UCS durability strength (0.11 – 0.18 MPa).

Trial sections were constructed on the Sampou site with these blends for field performance evaluations. The DCP CBR values for the stabilised sections and the unstabilised section were > 15%. However, the field plate loading test effected a substantial settlement in the unstabilised section, with 138% increase after the cyclic loading procedure. All the stabilised sections had minimal settlement, with percentage differences in settlement between each cyclic loading ranging -17% to 7%. Micro-structural analysis of the field stabilised samples using ESEM and SEM/EDX methods revealed that both soil-sand-PC and soil-lateralite-PC composites had stable structures after the flooding and drying procedures. While soil-DCA-PC composite revealed unstable structure with ettringite formed after the procedures. The performance evaluation of parts of the stabilised sections carried out 6 months after construction, revealed that the soil-DCA-PC had the highest natural moisture content of 18.91% compared with other sections, depicting that this section was highly susceptible to water.

Hence, this study shows that blends of sand-PC and lateralite-PC can be used for the stabilisation of the Niger Delta fat clay soil, while blend of DCA-PC should be used with caution. These results and application thus offer better adaptation of the subgrade soils in the region.