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Effect of Zeolite on Clay Modified with Calcium Carbide Residue (CCR) Using Compaction as Evaluation Criteria

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ABSTRACT

Soil is used as construction material in various building and civil engineering projects to provide structural supports to foundation. It is important to state that not all soils are suitable for construction in their natural states. Problematic soils could either be expansive soil or collapsible soil which in return causes low bearing capacity in building foundation, breaking and creaking of road structures.). Building on these types of soils requires the development of techniques, such as soil stabilization, to enhance the soil. The cost of introducing these additives for stabilization of soil has also risen in recent years which opened the door widely for the development of other kinds of soil additives such as Zeolite, kaolinite, plastics etc. In this study, the effect of zeolite on clay modified with calcium carbide residue (CCR) using Compaction as evaluation criteria were investigated. Tests to determine the grain size distribution, specific gravity, liquid and plastic limits, compaction of the natural soil and its stabilization with varying percentages of 0%,5% and 10% CCR and 0%, 2%, 4% and 6% zeolite were carried out. Result showed general increase in liquid limit and plasticity index with increase in zeolite addition. The maximum dry densities were observed to be generally reducing with increase in zeolite for varied calcium carbide residue additions.

Keywords: Calcium Carbide Residue (CCR), California bearing ratio (CBR), Clay, Stabilization, Zeolite.

1 INTRODUCTION

In geotechnical engineering approach, soil deposits may not have the desired features and qualities to be used for construction. These soils can exist in a weak, dispersive and highly compressible nature and can be highly impermeable. Building on these types of soils requires that the soil be improved to increase the desired properties.

Clay is among the world's most important soil but always a problem for civil and geotechnical engineers (Skempton, 1953). The clay minerals are of high necessity in construction where they are major constituents in brick and tiles. However, any structure constructed on clayey soils are prone to failure due to its expansion, compression and shrinkage. It is then essential, to identify clay soils and its significance as related to engineering applications (Ural, 2018). Clay minerals are called mostly secondary silicates, because they are formed from weathering of primary rock-forming minerals. Clay minerals occur in small particle sizes (<0.002 mm) and are very fine grained and flaky shaped (Ural,2018), they are different from sand, gravel and silt due to the negative electrical load on the crystal edges and positive electrical load on the face. clays are fine grained soils, which signifies that they have more than 50% passing the No. 200 sieve as defined by the Unified Soil Classification System (USCS) and they are different from the silt soils based on their liquid limit and plasticity index (Holtz, 1981). Generally, this soil type has various problems due to its low strength, high compressibility and high level of volumetric changes. Clay needs to be improved before it can be used in road construction, dams, slurry walls, airports and waste landfills.

Soil stabilization enhances the strength, control soil dust and ensure soil water proofing. Clay soil stabilization is the process of elimination of swelling properties of soils to enhance its shear strength and improve its load bearing capacity. Quite often soils are stabilized for road construction to Improve the strength (stability and bearing capacity) for subgrade, subbase and base courses of low-cost road surfaces. Soil stabilization can be accomplished by several methods, all these methods fall into two broad categories namely mechanical and chemical stabilization. Mechanical stabilization entails mixture of two or more soils of different gradation in other to achieve optimal mixture which when compacted will result in to most dense state. Some of the mechanical stabilizations includes the work of Ibrahim (1983) who stabilized black cotton soil with sharp sand found as deposit below the superficial black cotton soil deposit. The mixture was used for the construction of Maiduguri-Gamburu road in north-eastern Nigeria. Another mechanical stabilization is the stabilization of clay soils using non-plastic silt (Alhaji and Sadiku, 2015). The unconfined compressive strength (UCS) was observed to increase from 272 and 770kN/m^2 for British Standard Light (BSL) and British Standard Heavy (BSH) compaction energy levels at 0% replacement to 295 and 795kN/m^2 for BSL and BSH compaction energy level respectively at 10% replacement after which the values reduced to 22 and 60kN/m^2 for BSL and BSH compaction energy levels respectively at 70% replacement. Stabilization of clay soil using cold reclaimed asphalt pavement (RAP) is also a form of mechanical stabilization (Alhaji *et al.,* 2014). The result showed 7.2% increase in UCS and 9.2% increase in California Bearing Ratio (CBR). Chemical stabilization entails mixture of chemical substance like cement, lime, or mixture of both, to a deficient soil in other to improve its strength and durability. Stabilization of soils using cement or mixture of cement and pozzolana has become a common phenomenon and has yield positive result in many instances. Portland cement alone have been used to stabilize soil for road base (Ismail *et al.,* 2014). Tremendous improvement in strength and durability was recorded with the addition of Portland cement. Some other works include the stabilization of lateritic clay using cement and bagasse ash as pozzolana (Osinubi and Alhaji, 2009), variation of compressive strength of cement-treated marine clay with water content (Tsuchida and Tang, 2015), effect of sodium silicate and promoter on the strength of cement stabilized clay (Ma *et al.*, 2015), cohesive soil stabilized with a mixture of cement and rice husk ash (Prasad *et al.,* 2017), improvement of weak residual soil using cement and rice husk ash (Basha *et al.,* 2005). All these studies recorded higher strength compared to the use of cement alone

Pozzolanic reaction, which is time dependent, involves interactions between soil silica and/or alumina and cement to form various types of cementitious products, thus enhancing the strength, (Turkoz and Vural, 2013). A pozzolan is a siliceous or siliceous/aluminous material that do not form cementitious material on its own but when mixed with cement, can react with resultant calcium hydroxide to form cementitious compound. Zeolites as a pozzolan are aqueous aluminum silicates containing alkali and alkaline earth elements. Their structure is made up of a framework of SiO_4 and AlO_4 tetrahedrons linked to each other's corners by sharing oxygen atoms. Zeolites have been recognized for more than 200 years, but only during the middle of the twentieth century they have attracted the attention of scientists and engineers who demonstrated their technological importance in several fields (Cincotti *et al.*, 2006). It is known that Turkey has millions of tons of zeolite reserves. The work of Shi (2013), Salamatpoor *et al.,* (2018), Yadav and Kushwaha (2018), Turkoz and Vural (2013) and Mola-Abasi and Shooshpasha (2016) are clear indications that zeolite has the potential to be used as pozzolana which can only form cementitious compounds in the presence of another chemical.

CCR contains large amount of lime and is a major waste from acetylene factory which constitutes serious nuisance to environment (Horpibulsuk *et al.,* 2013). In developing countries like Nigeria, a lot of local welding exercises by individuals and few groups of people are very common. This action has led to generation of wastes calcium carbide residue. Various researchers have worked on the utilization of CCR in addition to Pozzolanic materials to stabilize deficient soils. The study by Du *et al* (2016) was a good presentation of the potential of CCR for use as material for subgrade stabilization of weak clay soil. Field CBR, plate load test, Benkelman beam deflection test and dynamic cone penetration (DCP) tests were used as evaluation criteria to evaluate the potential of CCR for stabilization of weak subgrade clay soil. Results showed that treatment of soft subgrade with CCR increased the value of CBR and resilient modulus and resulted in to a low construction cost. Binary blending of CCR and palm oil fuel ash were used to stabilize fine grained soils (Majeed *et al.,* 2018). Atterberg limits and UCS strength were used to evaluate the effect of CCR and palm oil fuel ash on the fine-grained soils. It was concluded that UCS showed very high increase for clay treated with binary mixtures compared to those treated with CCR only. a lot of to stabilize clay soils. There has been a little effort devoted to the study on the use of pozzolans such as natural zeolite with Calcium carbide residue (CCR).

The main objective of this study is to investigates the effect of Zeolite on clay modified with calcium carbide residue (CCR) using compaction characteristics as evaluation criteria.

2 METHODOLOGY

2.1 MATERIALS

Soil sample: The soil sample used in this study is clay collected behind the Library complex of Niger State Polytechnic, Zungeru of Niger State, Nigeria. The clay soil was air-dried and pulverized as specified in BS 1377 (1992).

Calcium carbide residue: The CCR used in this study was collected from local welders at Keteren-Gwari mechanic site, Minna, Nigeria. The sludge was then air-dried, crushed and sieved through British Standard sieve with 0.075mm aperture before use.

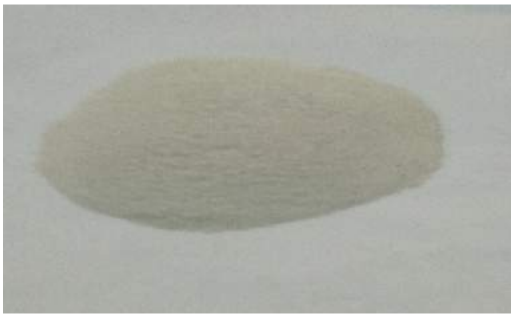
Figure 1: Calcium carbide residue

Zeolite: The zeolite used in this study was purchased from a commercial market in Kaduna in Kaduna State of Nigeria.

Figure 2: Zeolite sample

The zeolite was observed to be powdered smooth and was used as supplied.

2.2METHODOLOGY

The method used in this study involves characterizing the untreated clay soil by determining its index properties. Atterberg limit tests were conducted on the clay mixed with 0, 5 and 10% CCR which was admixed with 0, 2, 4 and 6% zeolite. This is to evaluate the effect of zeolite on the Atterberg limits of the CCR modified clay soil. These mixtures were then compacted at standard proctor compaction energy level to determine the effect of zeolite on the compaction characteristics of CCR modified clay soil. All tests on the untreated clay soil was carried out according to the method highlighted in BS 1377 (1992). Meanwhile, for all these tests, appropriate amount of water was mixed with the clay mixed with appropriate chemicals, kept in a polythene leather and allowed for 24 hours before conducting the tests.

Figure 3: Compaction test on the clay soil

3 RESULTS AND DISCUSSION

Index Properties

The result of the index properties of the untreated clay soil is shown on table 1.

Table 1: Summary of Index Properties of the clay

Description	Quantity
Sand	32.2
Silt	29.2
Clay	38.6
Liquid limit	44.8
Plasticity Index	19.4
Specific Gravity	2.76
MDD (Standard Proctor compaction)	1.815
OMC (Standard Proctor compaction)	18.8
AASHTO soil classification	A-7-6
Unified Soil classification	CL

From the table above, the clay soil classified under clay of low plasticity (CL) according to unified soil classification system. This clay can only be used for any component of a road structure when modified to increase its workability.

Effect of Zeolite on Liquid Limits of Clay

The effect of zeolite on liquid limit (LL) of CCR modified clay soil is shown on figure 4. The results showed that, for 0% CCR, the LL decreased from 44.8% at 0% zeolite to 41.5% at 4% zeolite. Beyond 4% zeolite, the values increased to 42.2% at 6% zeolite. The first decrease in LL is probably due to ion exchange between the sodium ion and ions around the clay particles. This must have resulted to flocculation of the particles thus improving the workability of the clay.

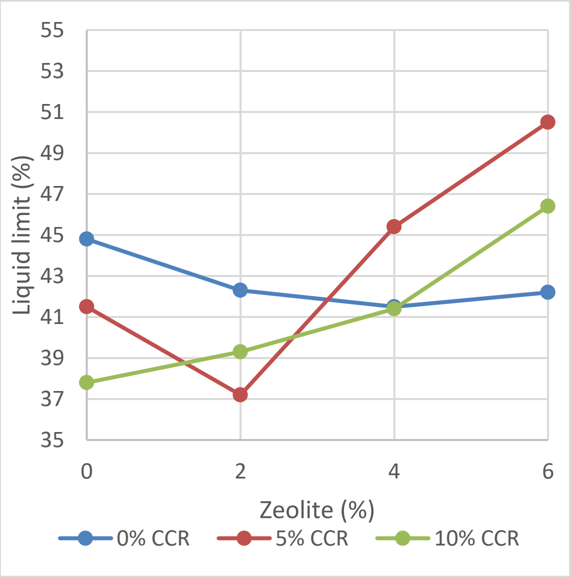

Figure 4: Variation of Liquid limit with zeolite

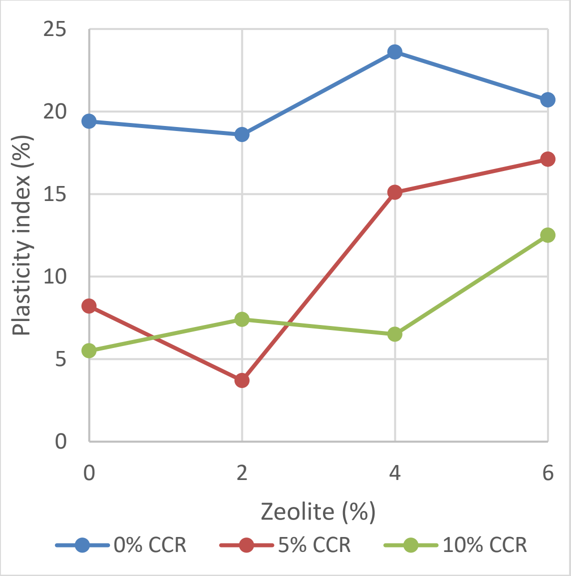

Figure 5: Variation of Plasticity Index with zeolite

For 5% and 10% CCR, the LL values tend to increase with increase in zeolite to 6% zeolite.

The variation of plasticity index with varied composition of zeolite for 0, 5 and 10% CCR is shown on figure 5. For 0% CCR, the trend showed decrease in plasticity index from 19.4% at 0% zeolite to 18.6% at 2% zeolite addition. At 4% zeolite, the value increased to 23.6%. This trend was repeated for 5% CCR where the plasticity index decreased from 8.2% at 0% zeolite to 3.7% at 2% zeolite. At 6% zeolite, the values increased to 17.1%. The trend is different for 10% CCR where the plasticity index values increased from 5.5% at 0% zeolite to 12.5% at 6% zeolite.

Effect of Zeolite on Compaction Characteristics

The effect of zeolite on the maximum dry densities are presented on figure 6. The trend for 0% CCR showed decrease in MDD from 1.815g/cm^3 at 0% zeolite to 1.761g/cm^3 at 2% zeolite. The values thereafter, increased to 1.805g/cm^3 at 4% zeolite. The trend in MDD for 5% and 10% CCR are similar and showed continuous decrease in MDD with increase in zeolite addition. This is probably due to the lower specific gravity recorded for the CCR and zeolite.

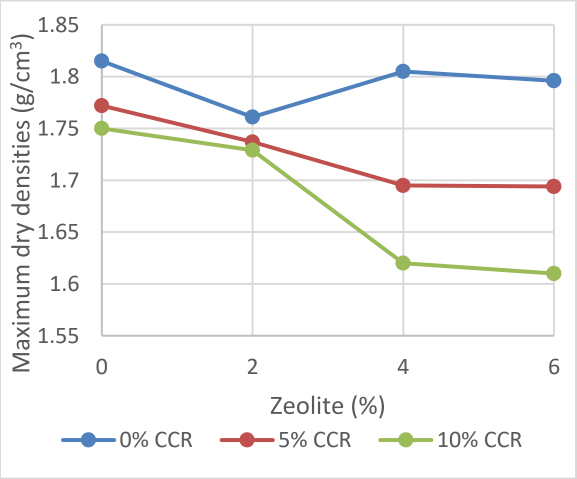

Figure 6: Variation of MDD with zeolite

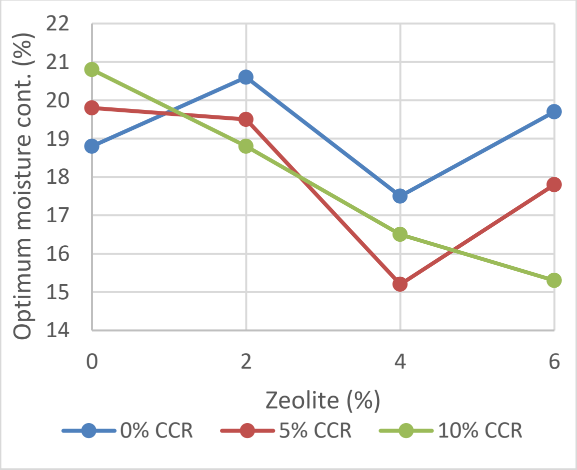

Figure 7: Variation of OMC with zeolite

The trend in OMC with varied composition of zeolite is shown on figure 7. Generally, the trend showed decrease in OMC with increase in zeolite to 4% zeolite. Beyond 4% zeolite addition, the OMC values increased to 6% zeolite.

4 CONCLUSION

The clay used in this study classified as clay of low plasticity (CL) based on unified soil classification system.

For 5% and 10% CCR, the liquid limit generally increased with increase in zeolite addition.

For 5% and 10% CCR, the plasticity index generally increased with increase in zeolite addition.

For 5% and 10% CCR, the MDDs generally increased with increase in zeolite addition. While the OMCs reduces with increase in zeolite addition,

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