Leonardo Electronic Journal of Practices and Technologies
ISSN 1583-1078
Issue 11, July-December 2007
p. 47-58

Effect of Rice Husk Ash on Cement Stabilized Laterite

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Abstract

Laterite soil collected from Maikunkele area of Minna, classified as an A-7-6 on AASHTO classification, was stabilized with 2-8% cement by weight of the dry soil. Using British Standard Light (BSL) compaction energy, the effect of Rice Husk Ash (RHA) on the soil was investigated with respect to compaction characteristics, California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS) tests. Results obtained, indicate a general decrease in Maximum Dry Density (MDD) and increase in Optimum Moisture Content (OMC), all with increase in RHA Content (2-8%) at specified cement contents. There was also a tremendous improvement in the CBR and UCS with increase in the RHA content at specified cement contents to their peak values at between 4-6% RHA. The UCS values also improved with curing age. This indicates the potentials of using 4-6% RHA admixed with less cement contents for laterite soil stabilization.

Keywords

Laterite; Rice Husk Ash; Stabilization; Maximum Dry Density (MDD); Optimum Moisture Content (OMC); California Bearing Ratio (CBR); Unconfined Compressive Strength (UCS).

Introduction

A lot of Laterite gravels and pisoliths, which are good for gravel roads, occur in tropical countries of the world, including Nigeria [1]. There are instances where a laterite may contain substantial amount of clay minerals that its strength and stability cannot be guaranteed under load, especially in the presences of moisture. These types of laterites are also common in many tropical regions including Nigeria where in most cases sourcing for alternative soil may prove economically unwise but rather to improve the available soil to meet the desired objective [2]. Soil improvement could either be by modification or stabilization or both. Soil modification is the addition of a modifier (cement, lime etc) to a soil to change its index properties, while soil stabilization is the treatment of soils to enable their strength and durability to be improved such that they become totally suitable for construction beyond their original classification. Over the times, cement and lime are the two main materials used for stabilizing soils. These materials have rapidly increased in price due to the sharp increase in the cost of energy since 1970s [3].

The over dependent on the utilization of industrially manufactured soil improving additives (cement, lime etc), have kept the cost of construction of stabilized road financially high. This hitherto, have continued to deter the underdeveloped and poor nations of the world from providing accessible roads to their rural dwellers who constitute the higher percentage of their population and are mostly, agriculturally dependent. Thus the use of agricultural waste (such as Rice Husk Ash) will considerably reduce the cost of construction and as well reducing the environmental hazards they causes. It has also been reported by Sear [4] that Portland Cement, by the nature of it’s chemistry, produces large quantities of Co_2 for every tonne of it’s final product. Therefore, replacing proportions of the Portland Cement in soil stabilization with a secondary cementitious material like RHA will reduce the overall environmental impact of the stabilization process.

Rice Husk is an agricultural waste obtained from milling of rice. About 10^8 tonnes of rice husk is generated annually in the world. In Nigeria, about 2.0 million tonnes of rice is produced annually, while in Niger state, about 96,600 tones of rice grains is produced in 2000 [5]. Meanwhile, the ash has been categorized under pozzolana, with about 67-70% silica and about 4.9% and 0.95% Alumina and iron oxides, respectively [5]. The silica is substantially contained in amorphous form, which can react with the CaOH librated during the hardening of cement to further form cementations compounds. This will go a long way in actualizing the dreams of the Federal Ministry of works in Nigeria of scouting for readily cheap construction materials. The World Bank too has been spending substantial amount of money on research aimed at harnessing industrial waste products for further usage.

Location of Study Area

The soil sample used for this study was collected from Maikunkele area of Minna at a depth of between 1.5m to 2.5m using the method of disturbed sampling. A study of the soil map of Nigeria [6], shows that the sample taken, belongs to the group of ferruginous tropical soils derived from acid igneous and metamorphic rocks [7].

Methods of Testing

The laboratory tests carried out on the natural soil include particle size distribution, Atterberg limits compaction, CBR and UCS. The geotechnical properties of the soil were determined in accordance with B.S. 1377[8] while the stabilization tests were performed in accordance with B.S. 1924 [9]. Specimens for Unconfined Compressive Strength (UCS) and California Bearing Ratio (CBR) tests were prepared at the Optimum Moisture Contents (OMC) and Maximum Dry Densities (MDD)-British Standard Light of the soil-cement and Rice Husk Ash (RHA) mixtures. The CBR tests were conducted as specified by the Nigeria General Specifications [10], where the compacted specimens were cured for six days and soaked for one day before testing at a constant loading rate. The RHA was grounded and sieved through B S sieve No 200 (75μm) before usage.

Results and Discussion

Identification *of Soil and RHA*

The geotechnical index properties of the laterite before addition of stabilizers are shown in Table 1. The particle size distribution of the natural soil is shown in Figure1.

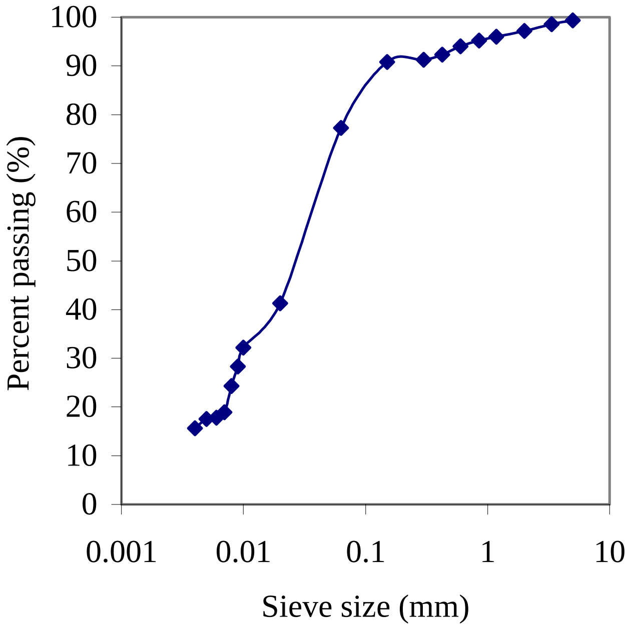

Figure 1. Particle Size Distribution for the Natural soil

Table 1. Properties of the Natural Soil before Stabilization

Characteristics	Description
Natural moisture content (%)	22.27
Percent passing B.S Sieve NO 200	77
Liquid Limit (%)	49.5
Plastic Limit (%)	24.4
Plasticity Index (%)	25.1
Group Index	20
AASHTO Classification	A-7-6
Maximum Dry Density (Mg/m^3)	1.482
Optimum Moisture Content (%)	18.38
Unconfined Compressive Strength (KN/m^2)	290
California Bearing Ratio (%)	8.5
Specific Gravity	2.69
Colour	Reddish-brown

The overall geotechnical properties of the soil classified as A-7-6 in the AASHTO [11] classification system, shows that it falls below the standards recommended for most geotechnical construction works and would therefore require stabilization.

The oxide composition of the RHA is shown in Table 2. The combine percent composition of silica, Al_2O_3 and Fe_20_3 is more than 70. This shows that, it is a good pozzolana that could help further promote the formation of cementitious compounds with cement hydration reaction products.

Table 2. Oxide composition of RHA (After Oyetola and Abdullahi, 2006)

Constituent	Composition (%)
SiO_2	67.3
Al2O3	4.9
Fe2O3	0.95
CaO	1.36
MgO	1.81
Loss On Ignition (LOI)	17.78

Effect of Treatment with Cement-RHA

Compaction Characteristics

The variations of MDD and OMC with stabilizers contents are shown in Figure 2 and 3 respectively. The MDD and OMC increased with increase in cement content. The increase in MDD with cement content is attributed to the relative higher specific gravity of cement (3.15) to that of the soil (2.69). The increase in OMC with cement content was as a result of water needed for the hydration of cement.

At specific cement contents, the results indicates a decrease in the MDD with increasing RHA contents, to the minimum at 6% RHA, after which there was a slight increase to 8% RHA. The initial decrease in the MDD can be attributed to the replacement of soil and cement by the RHA which have relatively lower specific gravity (2.25) compared to the soil and cement [12] and [13]. It may also be attributed to coating of the soil cement by the RHA which result to large particles with larger voids and hence less density [14] and [15]. The increase in density from minimum at 6% RHA content to 8% Ash content could be due to molecular rearrangement in the formation of "transitional Compounds" which have higher densities at 8% RHA content [16].

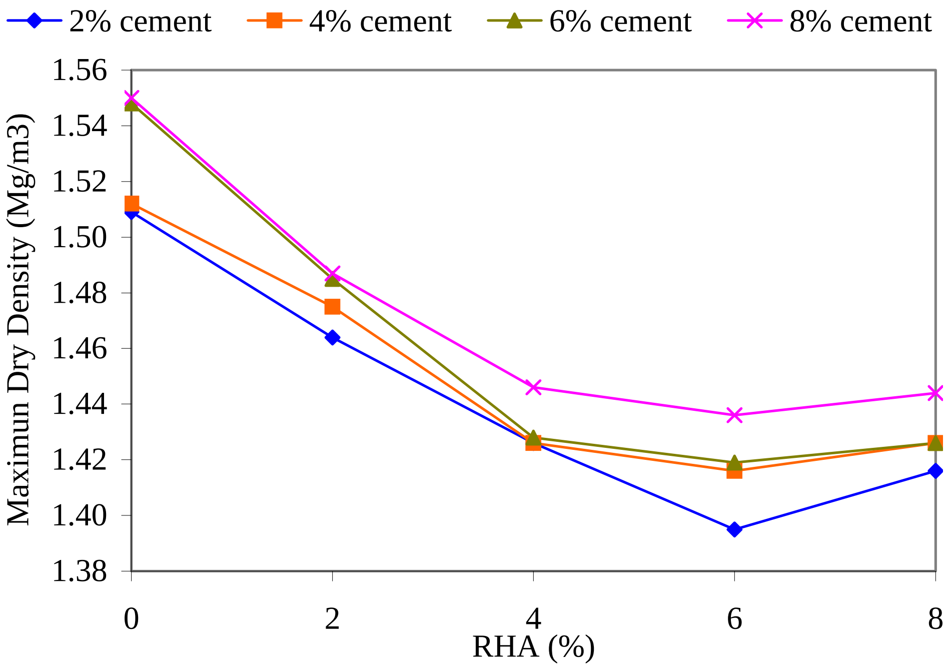

Figure 2. Variation of MDD with RHA content

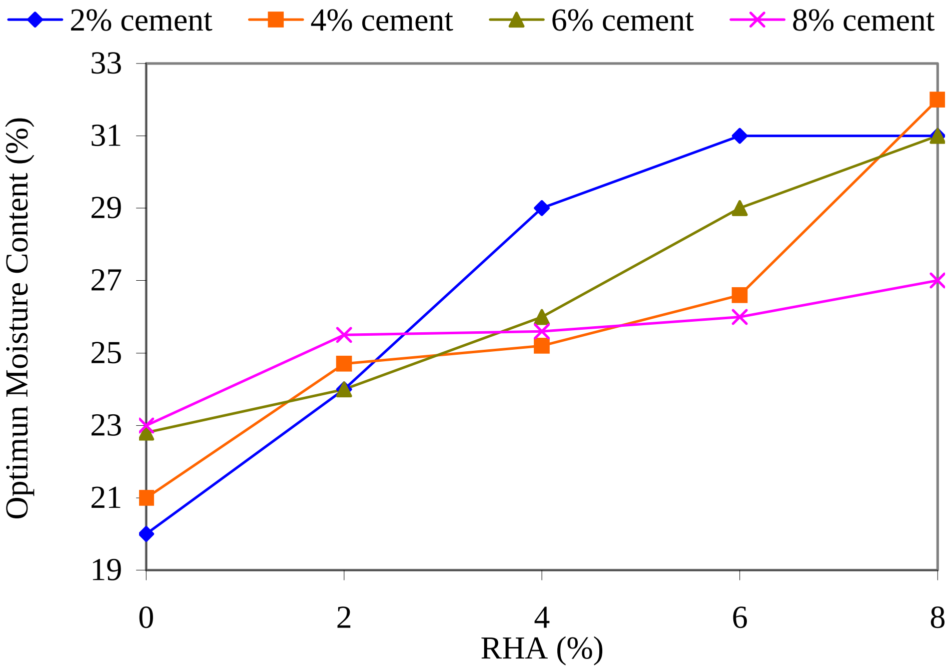

Figure 3. Variation of OMC with RHA content

The variation of OMC with increase in RHA for each of the various cement contents has relatively the same trend. There was increase in OMC with increase RHA for each of the cement contents. This trend is in line with [12], [17] and [18]. The increase in OMC was due to the addition of combined cement and RHA, which decreased the quantity of free silt and clay fraction and coarser materials with larger surface areas were formed (these processes need water to take place). This implies that, apart from the water needed for hydration of cement to take place, more water was needed in order to compact the soil-cement-RHA mixtures [18].

California Bearing Ratio

The CBR value of a compacted soil is an indicator of soil strength and bearing capacity and is widely used in the design of base and sub-base material for pavement. It is also one of the common tests used to evaluate the strength of stabilized soils.

The variations of CBR with increase in RHA from 0 to 8% with specific percentages of cement are shown in figure 4.

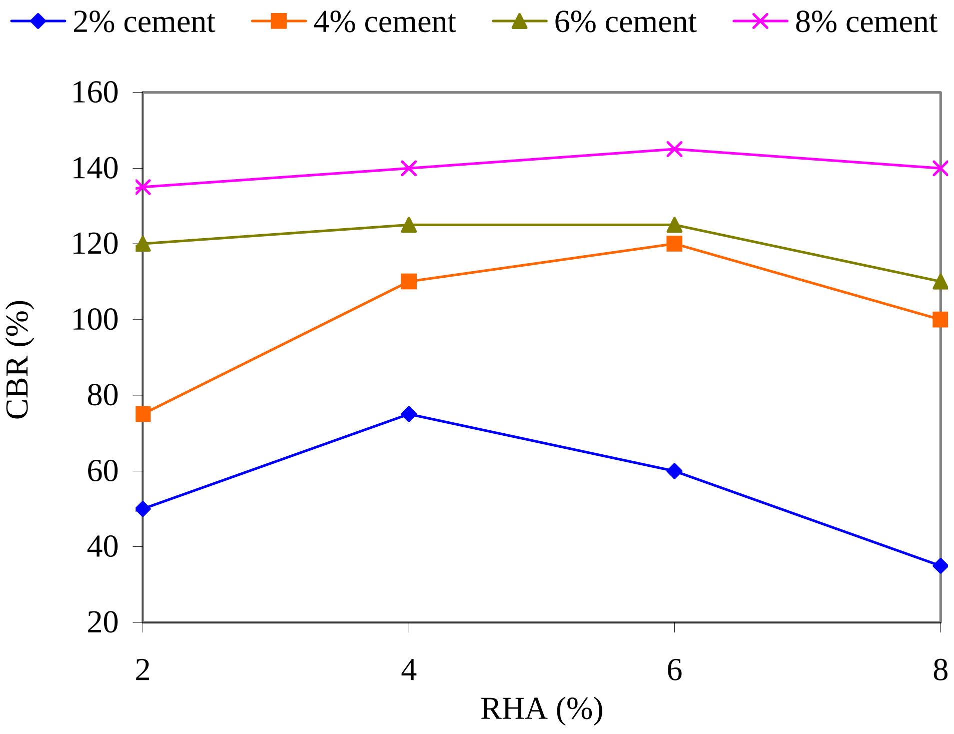

Figure 4. Variation of CBR with RHA content

Addition of cement and RHA to the soil, showed marked improvement in the CBR compared to the low CBR value of 8.5% recorded for the natural soil. CBR values increase with increased in RHA contents for specific cement contents. This increase was obvious from the increase in CBR from 35% recorded at 0% RHA to 75% recorded at 4% RHA for 2% cement, 50% at 0% RHA to 110% at 4% RHA for 4% cement, 95% at 0% RHA to 125% at 4% RHA for 6% cement content and 120% at 0% RHA to 140% recorded at 4% RHA for 8% cement content. These improvements resulted from the secondary cementitious materials resulted from the reaction between the lime librated from the hydration reaction of cement and the pozzolanic RHA. This reaction also contributed to interparticle bonding [2].

Unconfined Compressive Strength

Unconfined compressive strength (UCS) has being the most common and adaptable method of evaluating the strength of stabilized soil. It is the main test recommended for the determination of the required amount of additive to be used in stabilization of soil [19]. Variation of UCS with increase in RHA from 0% to 8% with specific cement contents at British Standard Light energy level and for 7 days, 14 days and 28 days curing period were studied and the results for the three curing periods are shown in figures 5, 6 and 7 respectively. There was a tremendous improvement in the UCS with addition of cement and RHA to the natural soil when compared with the low UCS value of 290KN/m^2 for the natural soil.

Apart from increase in UCS recorded with increase in cement content, there was also increase in UCS with increase in RHA content with specific cement contents up to the peak UCS value at 4% RHA after which it dropped. This trend was observed after 7 days curing period where the UCS increase from 300kN/m^2 at 0% RHA 400kN/ m^2 at 4% RHA both admixed with 2% cement, 700kN/m^2 at 0% RHA to 900kN/m^2 at 6% RHA both admixed with 4% cement, 715kN/m^2 at 0% to 1025kN/m^2 at 4% RHA both admixed with 6% cement and 975kN/m^2 at 0% RHA to 1300kN/m^2 at 4% RHA for 8% cement content. This trend was the same for the 14 and 28 days curing periods.

The UCS improvement due to increase in RHA must have resulted from the pozollanic reaction between the lime librated from the hydration reaction of cement and the pozollanic RHA to form secondary cementitious materials [20].

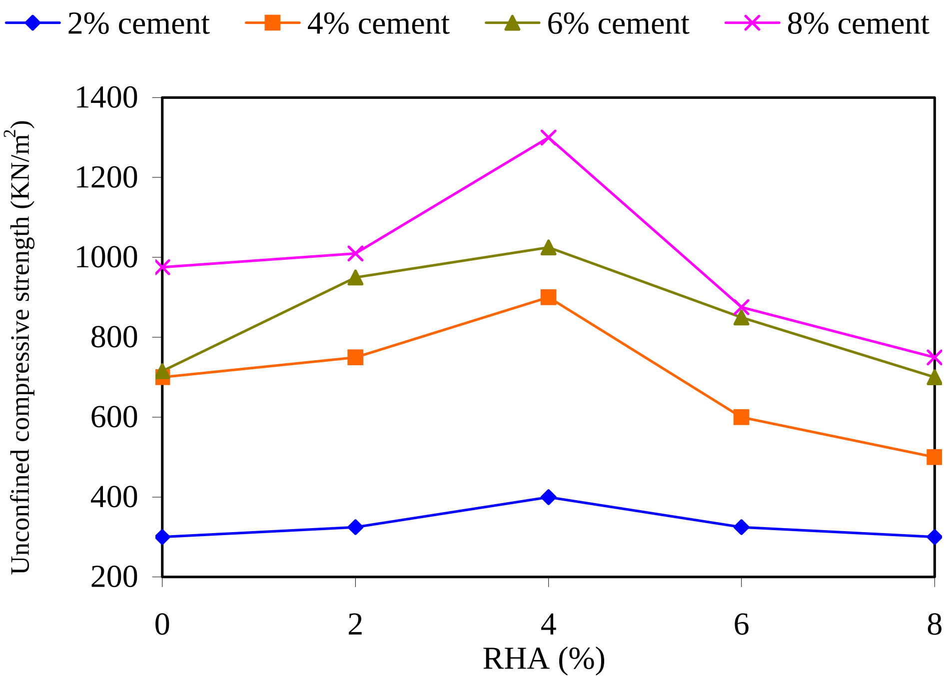

Figure 5. Variation of 7 days UCS with RHA content

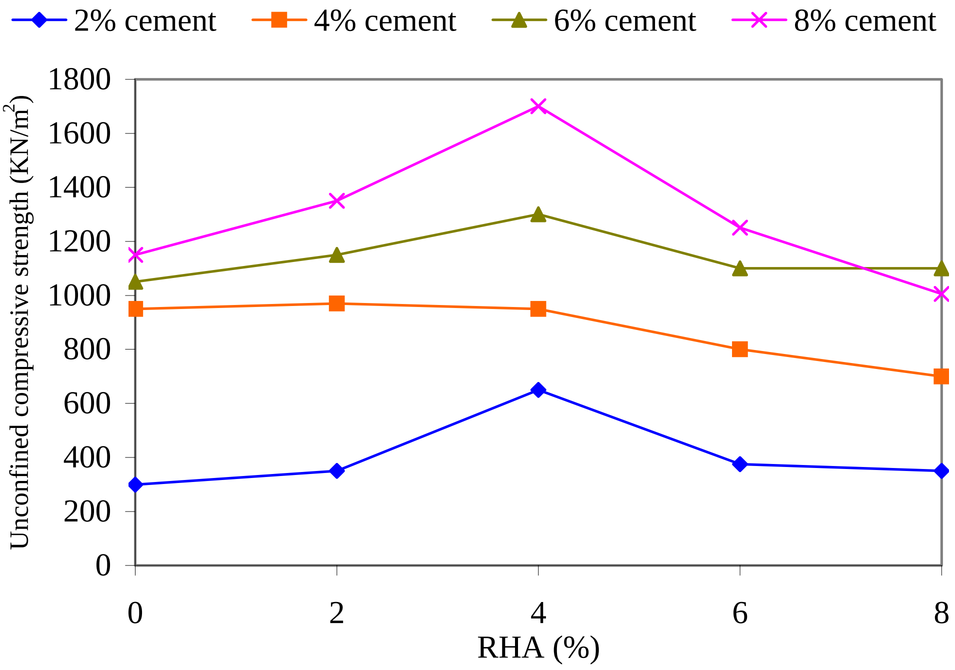

Figure 6. *Variation of 14 days UCS with RHA content*

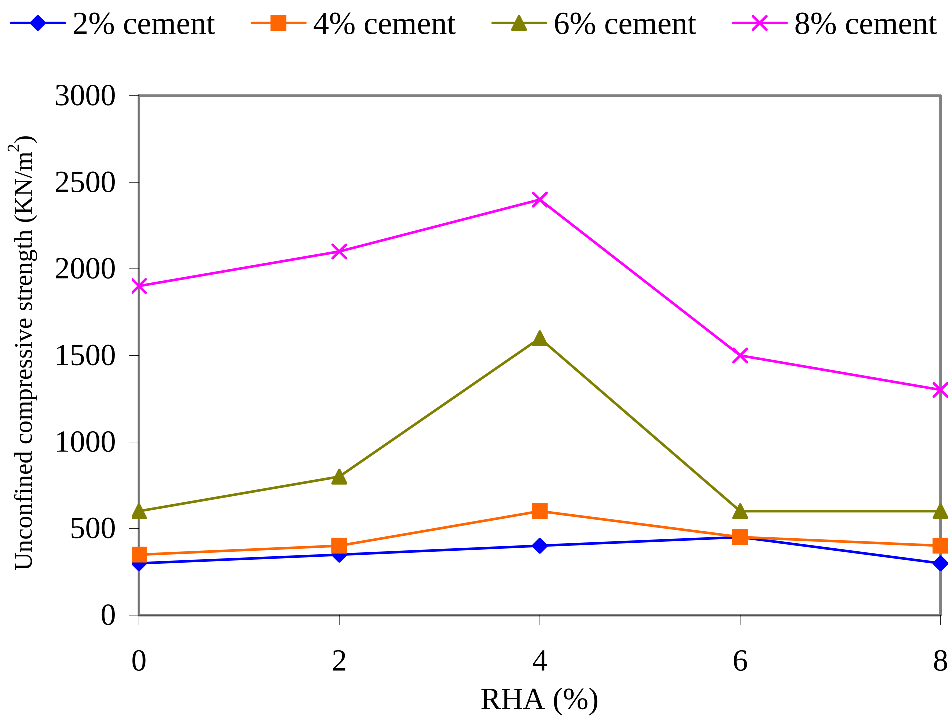

Figure 7. Variation of 28 days UCS with RHA content

Conclusion

From the results of the investigation carried out within the scope of the study, the following conclusions can be drowned:

1. The laterite was identified to be an A-7-6 soil based on AASHTO (1986) classification system.
2. At specified cement contents, treatment with RHA showed a general reduction in MDD with increase in the ash content to minimum values at 6% RHA content after there was a slight increase. The OMC generally increased with increased in the RHA content at specified cement contents.
3. There was also a tremendous improvement in the CBR compared with the CBR of the natural soil. There was increase in CBR with increase in RHA at specified cement contents with peak values between 4-6% RHA contents.

4. A similar trend of the CBR was obtained for UCS. There was enormous increase in UCS with increase in RHA at specified cement contents. The UCS of same mix ratios also increased with curing age.

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