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Research Article

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Relative Study of Effect of Waste Ceramic and Quarry Dust on Geotechnical properties of Shrink-Swell Soils

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Abstract A lot of research work has been done worldwide in the direction of utilizing various industrial wastes in the soil stabilization technique. However, from the available literature it is found that little research has been done to compare their effect on shrink-swell soils. This paper therefore presents the results of a laboratory study undertaken to investigate and compare the effect of waste Ceramic dust (WCD) and Waste Quarry dust (WQD) on the geotechnical properties of shrink-swell soil. The laboratory tests carried out on the natural and stabilized soils includes Atterberg limits, Compaction, California Bearing Ratio (CBR) and swell pressure. For conducting different tests, the soil was mixed separately under the same conditions with WCD and WQD from 0 to 30% at an increment of 5% by dry weight of the soil. Mixes were prepared and the above mentioned tests were conducted on the samples/mixes according to the standards of the American Society for Testing and Materials. From the analysis of the test results it was found that the liquid limit of the soil decreased from 67% to 35% when WCD was added from 0 to 30% and from 67% to 27% when WQD was increased under the same condition. The result of free swell characteristics of the investigated soil revealed a decrease in swell from 111% to 45% and 111% to 40% for WCD and WQD respectively. The soaked CBR increases from 1.6% to 4.1% when WCD was increased from 0 to 30% and from 1.6% to 4.5% when WQD was added in the same manner. Based on the analysis of the study, it can be inferred that both materials gave satisfactory results however; WQD shows more potentials than WCD on the Geotechnical properties of Shrink- Swell soils.

Keywords Waste Ceramic Dust (WCD), Waste Quarry Dust (WQD), Geotechnical Properties, Shrink- swell soil, Stabilization

Introduction

Shrink–swell soils are soils which swell significantly when they come in contact with water and shrink when the water squeezes out. They are extremely problematic soils and cause a wide range of problems to a geotechnical engineer.

In recent years, there is rising social concern about the problem of waste management in general, and industrial waste and waste from the construction industry in particular. This problem is becoming increasingly acute due to the growing quantity of industrial, construction and demolition waste generated.

It has been estimated that about 30% of daily production in the ceramic industry goes to waste [1]. The disposal of which creates soil, water and air pollution.

Utilizing industrial wastes such as ceramic dust, quarry dust, marble dust, e.t.c as a soil replacement or stabilizer in the stabilization of shrink-swell soils will not only solve environmental problems but will also provide a new resource for construction industry.

A lot of research work has been done worldwide in the direction of utilizing various industrial wastes like waste ceramic and Quarry dusts in the soil stabilization technique. The test results revealed that both materials provide a significant improvement in the geotechnical properties of the soil.

Chen and Idusuyi (2015) [2] studied the effect of waste ceramic dust (WCD) on index and engineering properties of shrink-swell soils mixed with waste ceramic dust from 0 to 30% at an increment of 5%. From their investigation the liquid limit, plastic limit, plasticity index, optimum moisture content, free swell and swelling pressure decreased with increase in WCD. They also reported that the maximum dry density, unconfined compressive strength and California bearing ratio increased with an increase in waste ceramic dust content.

Koyuncu et al.(2004) [3] had added ceramic tile dust wastes up to 40% to study its effect on swelling pressure and swelling potential of Na –bentonite and found that swelling pressure and swelling potential decreased by 86% and 57% respectively at 40% addition of ceramic tile dust waste.

Sabat (2012) [84] conducted series of tests and concluded that addition of quarry dust decreases Liquid limit, Plastic limit, Plasticity index, Optimum moisture content, Cohesion and increases shrinkage limit, Maximum dry density, Angle of internal friction of expansive soil.

Satyanarayana et al. (2013) [5] conducted plasticity, compaction and strength tests on gravel soil with various percentage of stone dust and found that by addition of stone dust plasticity characteristics were reduced and CBR of the mixes improved. Addition of 25-35% of stone dust makes the gravel soil meet the specification of sub-base material.

Ali and Koranne (2011) [6] presented the results of an experimental programme undertaken to investigate the effect of stone dust and fly ash mixing in different percentages on expansive soil. They observed that at optimum percentages, i.e., 20 to 30% of admixture, the swelling of expansive clay is almost controlled and there is a marked improvement in other properties of the soil as well. It is concluded by them that the combination of equal proportion of stone dust and fly ash is more effective than the addition of stone dust/fly ash alone to the expansive soil in controlling the swelling nature.

Bshara et al. (2014) [7] reported the effect of stone dust on geotechnical properties of poor soil and concluded that the CBR and MDD of poor soils can be improved by mixing stone dust. They also indicated that the liquid limit, plastic limit, plasticity index and optimum moisture content decrease by adding stone dust which in turn increases usefulness of soil as highway sub-grade material.

From the available literature it is found that no research has been done in the area of relative study of these industrial wastes. This work therefore is aimed at comparing the effect of Waste Ceramic and Quarry Dusts on Geotechnical Properties of Shrink - swell Soil.

Materials and Methods

Materials

The materials used in the experiment were shrink-swell soil, waste ceramic and Quarry dusts.

Shrink-Swell Soil

The Shrink-swell soil used in this study was obtained from Baure, Yelmatu Deba Local Government Area, Gombe state, North-Eastern Nigeria. The top soil was removed to a depth of 0.5m before the soil samples were taken by disturbed sampling. X-ray diffraction analysis was performed on the clay fraction of the tested soil to identify its mineralogical composition. The X-ray diffraction indicates that the soil consist primarily of montmorillonite, which is mainly responsible for the expansive characteristics of the soil.

Waste Ceramic Dust (WCD)

Ceramic products are produced from natural materials containing a high proportion of clay minerals. Following a process of dehydration and controlled firing at temperatures between 700ºC and 1000ºC, these minerals acquire the characteristic properties of fired clay.

Broken/waste ceramic tiles were collected from construction and demolition sites within Bauchi Metropolis. These tiles were broken into smaller pieces with a hammer and fed into a Los Angeles abrasion testing machine to make it further smaller.

Waste Quarry Dust (WQD)

Quarry waste is a general term for any material that is generated from the processing of stones at quarries. About 20-25% of the total production in each crusher unit is left out as the waste material-quarry dust. The quarry dust for this study was obtained from Triacter Quarry site at Bayara, Bauchi State, Nigeria.

Experimental Methods

The experimental study was carried out on soil samples collected at a depth of 0.5-1.0m below ground level. The laboratory tests carried out on the natural and stabilized soils includes Atterberg limits, compaction, and swell pressure. For conducting different tests, the soil was mixed separately under the same conditions with waste ceramic and Quarry dust from 0 to 30% at an increment of 5%. Mixes were prepared and the above mentioned tests were conducted on these samples/mixes according to the standards of the American Society for Testing and Materials (ASTM, 1992) [8].

Compaction Characteristics

The Standard Proctor tests were conducted according to the standards of the American Society for Testing and materials on the natural soil and soil stabilized with WCD and WQD mixtures to determine its compaction characteristics, namely, the optimum moisture content (OMC) and maximum dry density (MDD). The soil was mixed with various amounts of WCD and WQD at 5%, 10%, 15%, 20%, 25% and 30% by weight of soil and standard proctor test were conducted on these mixtures.

Testing of soil Samples for California Bearing Ratio (CBR).

The soaked California bearing ratio test was conducted in accordance with British standards (1990) [9]. Soil samples were prepared by dynamic compaction method and placed on the bottom plate of the loading device and load was applied at a strain rate of 1.25 mm/min. Penetration was measured by strain gauge. Load was recorded at the penetration of 0.0, 0.5, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 7.5, 10.0 and 12.5 mm. CBR value is expressed as a percentage of the actual load causing the penetrations of 2.5 mm or 5.0 mm to the standard loads. The greatest value calculated for penetrations at 2.5mm and 5.0mm was recorded as the CBR**.** The California bearing ratio is calculated as follows:

California bearing ratio (CBR) = $\frac{p_t}{p_s}$ x 100

Pt = corrected test load corresponding to the chosen penetration from the load penetration curve

Ps = standard load for the same depth of penetration.

Free Swell Characteristic of the Soil.

10cm^3 of initial volume (v_i) of dry soil passing through No.40 ASTM sieve was poured into 100cm^3 graduated cylinder containing distilled water. The volume of the soil increases on coming in contact with water. The increased volume of settled soil in the cylinder was measured directly after 24 hours, which gives the final volume swelled volume of soil (v_f). The soil was mixed separately under the same condition with various amounts of waste ceramic and marble dusts at varying percentages of 5%, 10%, 15%, 20%, 25% and 30% by weight of soil and free swell test was conducted on these mixtures. The free swell (s_f) was then computed as:

$$s_f = \frac{v_f - v_i}{v_i} \times 100$$

where:

s_f = free swell, (%)

v_i= initial volume of dry poured soil, (cm^3)

v_f= final volume of poured soil after 24hours contact with water, (cm^3)

Results and Discussion

Tables 1 and 2 shows the results of index and Engineering properties of natural Shrink-Swell Soil and quarry dust respectively. The results of soil stabilized with waste ceramic and quarry dust are shown in tables 3 and 4.

Table 1: Index and Engineering properties of Natural Shrink-Swell Soil

Property	**Quantity**
Grain Size Analysis	
Sand, %	3.0
Silt, %	27.0
Clay, %	70.0
Specific gravity	1.9

Natural moisture content, %	35.0
Liquid limit, %	67.0
Plastic limit, %	34.0
Plasticity index, %	33.0
Linear shrinkage, %	17.0
Free swell, %	107.0
Swelling pressure kN/m^2	131.0
Maximum dry density, g/cm^3	15.6
Optimum moisture content, %	20.4
california bearing ratio(CBR)%	1.6
Colour	Greyish black

Table 2: Index and Engineering properties of Quarry dust

Property	Value
Natural moisture content	9.11
Particle Size distribution	
Sand (%)	97.1
Silt %	2.9
Specific gravity	2.76
Liquid limit %	NP
Plastic limit %	NP
Plasticity index %	NP
OMC %	11.5
MDD (g/cm^3)	1.97
Angle of internal fiction (^{0})	35
Cohesion kN/m^2	0.07
CBR soaked%	11.5

Table 3: Index and Engineering Properties of Soil Stabilized with WCD

WCD (%)	LL (%)	PL (%)	PI (%)	FS (%)	SP (kN/m^3)	MDD (kN/m^3)	OMC (%)	CBR (%)
0	67	34	33	111	131	15.6	20.4	1.6
5	65	29	36	105	121	15.8	19.8	1.8
10	54	26	28	98	115	16.1	19.4	2.1
15	51	24	27	75	83	16.5	19.0	2.5
20	47	22	25	65	60	17.2	18.5	2.8
25	43	20	23	58	51	17.5	18.2	3.5
30	35	18	17	45	42	18.1	17.6	4.1

***Key**: **WCD**: Waste Ceramic Dust, **LL**: Liquid Limit, **PL:** Plastic Limit, **PI:** Plasticity Index, **FS**: Free Swell, **SP**; Swell Pressure, **MDD**; Maximum Dry Density, **OMC**: Optimum Moisture Content, **CBR**: California Bearing Ratio*

Table 4: Index and Engineering Properties of Soil Stabilized with WQD

WCD (%)	LL (%)	PL (%)	PI (%)	FS (%)	SP (kN/m^3)	MDD (kN/m^3)	OMC (%)	CBR (%)
0	67	34	33	111	131	15.6	20.4	1.6
5	60	27	33	99	116	16.0	19.8	1.8
10	51	22	29	93	110	16.3	19.6	2.3
15	48	20	28	71	76	17.1	19.2	2.7
20	42	17	25	60	55	17.8	18.9	2.9
25	38	15	23	52	46	18.2	18.4	3.8
30	27	13	14	40	37	19.0	17.8	4.5

Effect of Waste Ceramic Dust and Waste Quarry Dust on Liquid Limit

The result of liquid limit tests on expansive soil treated with different percentages of ceramic and quarry dust is shown in fig.1. From the results it can be seen that with increase in different percentages of the admixtures from 0 to 30% at an increment of 5%, the liquid limit of the soil goes on decreasing. It decreases from 67% to 35%

when waste ceramic dust was added from 0 to 30% and from 67% to 27% when quqrry dust was increased from 0 to 30%. It can be inferred from the results that waste quarry dust is more suitable in the treatment of shrink-swell soil than waste ceramic marble.

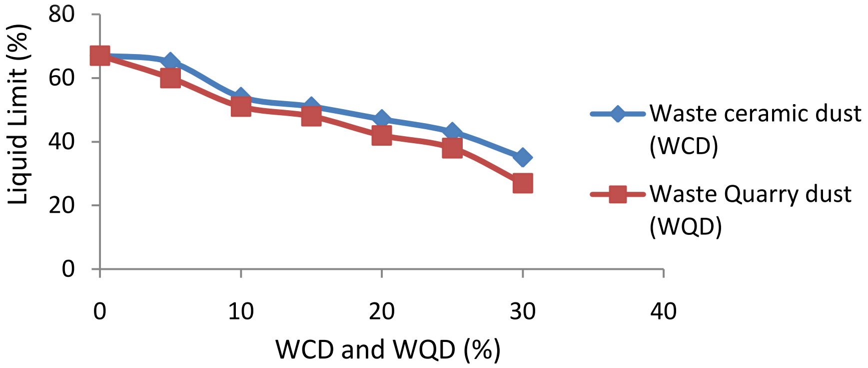

Figure 1: Variation of Liquid limit with percentage of waste ceramic dust and waste marble dust

Effect of Waste Ceramic Dust and Waste Quarry Dust on Plastic Limit

The result of plastic limit tests on expansive soil treated with different percentages of ceramic and quarry dust is shown in fig.2. From the results it is observed that with increase in different percentages of the admixtures from 0 to 30% at an increment of 5%, the Plastic limit of the soil goes on decreasing. It decreases from 34% to 18% when waste ceramic dust was added from 0 to 30% and from 34% to 13% when quarry dust was increased from 0 to 30%.From the comparative point of view,waste quarry dust improved the plastic characteristics of the shrink- swell soil more than waste ceramic dust.

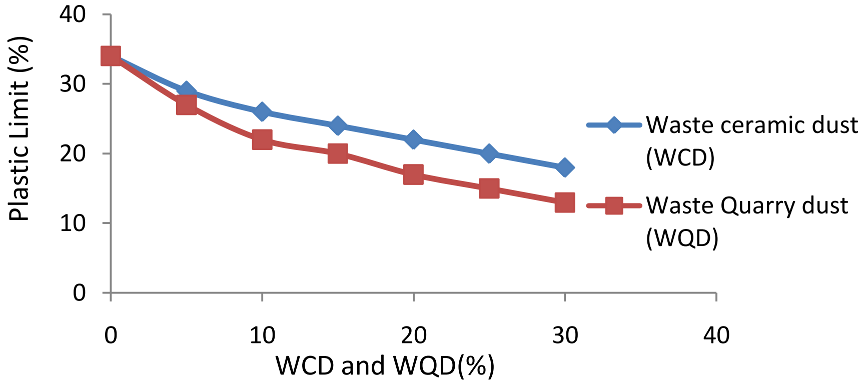

Figure 2: Variation of Plastic limit with percentage of Waste ceramic dust and waste Quarrydust

Effect of Waste Ceramic Dust and Waste Quarry Dust on Free swell Characteristics

The result of free swell characteristics of the investigated soil is shown in fig 3. From the result it can be seen that the percentage of free swell goes on decreasing with the addition of ceramic and quarry dust, from 0 to 30% at an increment of 5% for each stabilizer. It decreases from 111% to 45% and 111% to 40% for waste ceramic and quarry dust respectively. It can therefore be seen that waste quarry dust has more positive effect on swell characteristic of shrink-swell soil than waste ceramic dust

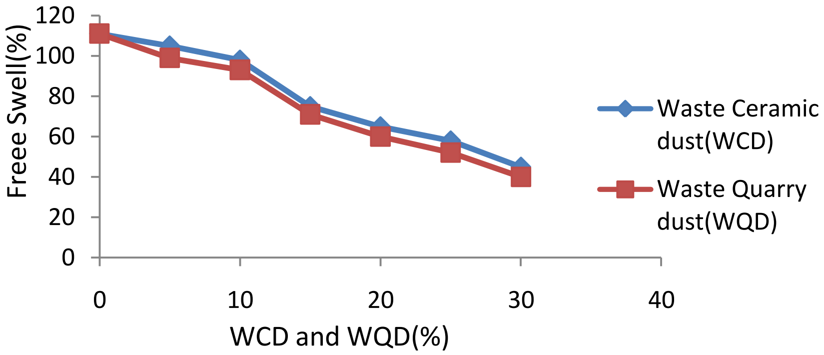

Figure 3: Variation of Free Swell with percentage of waste ceramic dust and waste Quarry dust

Effect of Waste Ceramic Dust and Waste Quarry Dust on Compaction Characteristics

Figure 4 shows the variation of maximum dry density (MDD) with percentages of WCD and WQD. With increase in percentage of WCD and WQD, the MDD of soil goes on increasing. The MDD increases from 15.6kN/m^3 to 18.1 kN/m^3 when WCD were increased from 0 to30% and WQD increases from15.6 kN/m^3 to 19.0 kN/m$^{3.}$ From the results it can be seen that WQD has more potential in the improvement of shrink swell soil the WCD.

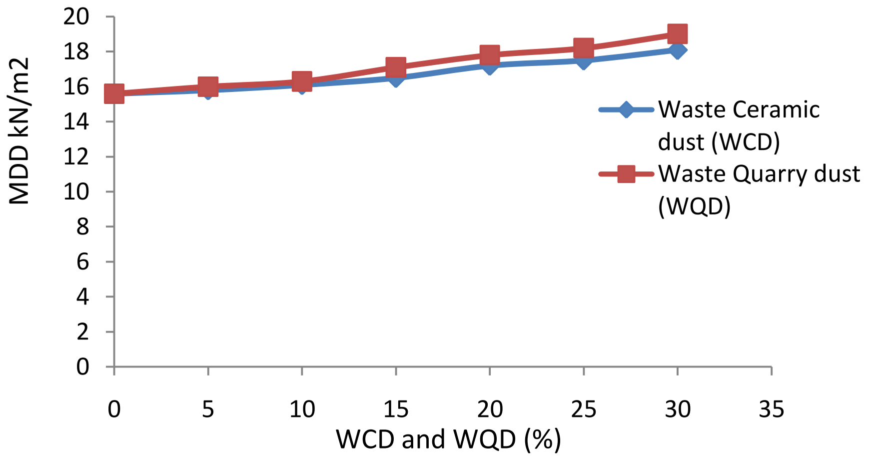

Figure 4: Variation of Dry Density with percentage of waste ceramic and waste Quarry dust

Effect of Waste Ceramic Dust and Waste Quarry Dust on CBR characteristics

The results of soaked CBR tests on shrink- swell soil treated with different percentages of WCD and WQD are shown in Figure 5. From the figure it can be seen that with increase in percentage of WCD and WQD, the soaked CBR of soil goes on increasing. The soaked CBR increases from 1.6% to 4.1% when WCD was increased from 0 to 30% and from 1.6% to 4.5% when WQD was added in the same manner. It is evident from the result that waste quarry dust has more positive effect on CBR characteristic of shrink swell soil than waste ceramic dust.

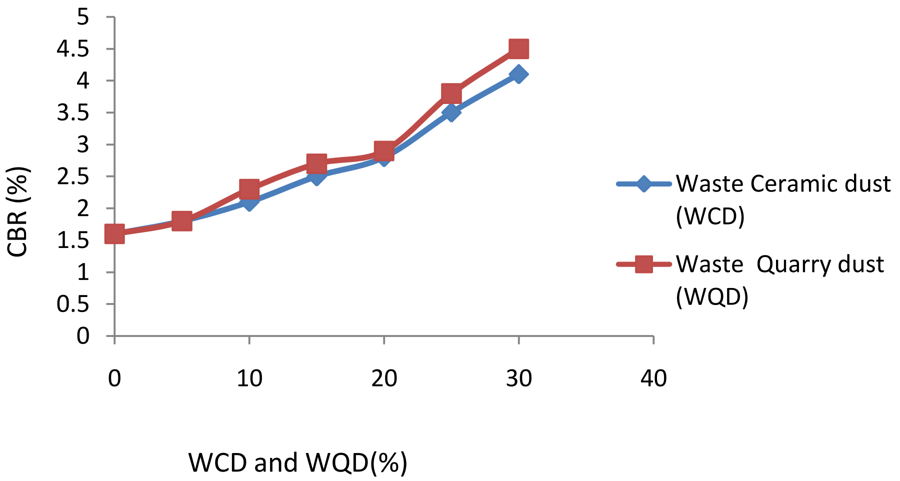

Figure 5: Variation of CBR with percentage of waste ceramic dust and waste Quarry dust

Conclusion/Recommendation

From the analysis and comparative study, it can be inferred that both materials gave satisfactory results however; WQD shows more potentials than WCD in the stabilization of shrink–swell Soils.

The study can be expanded by including other soil property parameters such as permeability, consolidation, strength characteristics etc.

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