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Use of Crushed Concrete Aggregate Waste in Stabilization of Clayey Soils for Sub Base Pavement Construction

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Abstract

The research aimed at stabilizing lateritic soils, using crushed concrete aggregates from demolished buildings, foundations, roads and other structures, for use as sub-base for a paved road. Lateritic soils were sampled along the Mukono-Jinja Highway from a borrow pit owned by Stirling Company LTD. Crushed concrete aggregate wastes were fairly angular and strong as they showed comparative values to the fresh aggregates as earlier researched. The lateritic soils were blended with different percentages of waste aggregates 0%, 30%, 40% and 50%, chosen basing on previous studies. The study looked at properties such as grading and flakiness of the waste aggregates, grading, atterberg limits, Optimum Moisture Content, Maximum Dry Density and 4 day soaked California Bearing Ratio for the stabilized and un-stabilized material. Mix designs with 40 % and 50 % of the waste aggregates were considered suitable for use as sub base material. They had CBR of 46 and 59, respectively, at 95 % relative compaction and PI values of 13.64 and 11.40. These met the specified standards of a CBR equal or greater than 45 and PI equal or less than 14 according to the general specifications of Ministry of Works, Housing and Communications (2004).

Keywords: *Lateritic soils, Soil stabilization, Crushed concrete aggregate, Waste, Subbase*

1 Introduction

Use of crushed concrete waste is a process in which used-concrete is re-used for new construction. This is greatly due to the fast development of infrastructure of a country requiring huge amounts of construction material. This leads to many dangers to the environment including depletion of the natural aggregates, accidents in the quarries, noise pollution and the increasing rate of waste generated, (Abukettala, 2006). In order to reduce the usage of fresh aggregate and concrete wastes, recycled aggregates can be used as a stabilizing material in road construction. Stabilizing laterite soils, which do not meet the required engineering properties, with crushed concrete waste aggregates would increase the strength of the sub base. The major function of the sub base layer is to transfer wheel load to the subgrade, bear stresses occurring due to the wheel loads and resists wear due to abrasive action of traffic, (Tripathy & Mukherjee, 1997).

In this study, crushed concrete aggregate samples ranging from size 0.075 mm - 37.5mm mixed with lateritic soil was subjected to classification tests such as particle size distribution and plasticity, compaction and California Bearing Ratio tests to meet the required standards of the sub base layer. The results were be compared with those of the standard sub base material used in Uganda.

2 Materials and Methods

2.1 Lateritic Soil

The lateritic soil sample was obtained from a borrow pit along Mukono-Jinja road owned by Sterling Construction company. Random sampling was done at the borrow pit to obtain a representative sample. Shallow trial pits, dug by means of pick-axe and shovel, were utilized to study the soil profile in detail. Bulk samples were obtained from each pit for laboratory investigations. The sampling sites and sample specimen conditions are described below:

- Sample A: It was taken from the depth range of 0.2 – 1.0 m. It was light reddish brown, very dense sandy clayey gravel. It was underlain by yellowish brown, clayey gravel lateritic hardpan.
- Sample B: It was reddish brown clayey sandy gravel taken within a depth range of 0.3 – 0.8m. It was underlain by molted sandy gravelly clay.

According to AASHTO soil classification system, they were grouped as A-2-6(0), classified as gravels with clay good for sub base construction. A Group Index of zero (0) specifies gravel samples best for road construction. However, these gravels did not meet all the requirements for sub base construction according to the Ministry of Works, Housing and Communication (MWH&C) General Specifications for national roads of 2004, (Table 1) in reference to Maximum Dry Density (MDD), Optimum Moisture Content (OMC) and 4-days soaked California Bearing Ratio (CBR) hence the need to be stabilized

2.2 Crushed Concrete Aggregate Wastes

Concrete wastes were obtained from Kawempe, Kirinya and Namanve dumping centres owned by ROKO Construction Company. It involved crushing, pre sizing, sorting, screening and removal of contaminations. The obtained material was hand crushed using hammers to obtain a representative sample containing aggregate wastes of size ranging from 0.075mm - 0.375mm. The aggregates had an Aggregate Crushing Value (ACV) of 19.3%, Aggregate Impact Value (AIV) of 18.3%, Ten Percent Fine Value (TFV) of 11.2%, Flakiness Index (FI) of 16.3% and Los Angeles Abrasion value (LAAV) of 26.0%, hence highly resistant to crushing under applied loads.

2.3 Sample Preparation

The samples for the tests were prepared in accordance with BS 1377 Part1:1990. On account of the fact that some tropical soils are sensitive to pre-test drying methods, air-drying was undertaken. Other pre-test sample preparation methods included pulverization, sieving and subsampling (coning, quartering and riffling). After air-drying all the three bulk soil samples, index properties tests were carried out for classification.

In order to investigate the effect of crushed concrete waste aggregates on the properties of lateritic soils, specimens with specified amounts of crushed concrete waste aggregates added to the soil samples were prepared by mixing in quantities of 0%, 30%, 40% and 50% of weight. The mixing was done mechanically on a metal tray. For consistency, soil was mechanically blended before mixing with the waste aggregates. Tests of physical properties of the different soil/aggregate blends were conducted.

2.4 Tests

Sieve Analysis Test: The test was carried out in accordance with BS 1377:Part2:1990. In this test, representative samples of approximately 3 kg were used for the test. The sample was washed and oven dried before sieving. The sieving was carried out using an automatic shaker with a set of sieves stacked in order of decreasing sieve sizes. From the weights retained on each of the sieves, the percentage passing was obtained which was then plotted on semi log graph to give the particle distribution curve.

Atterberg Limits Test: The cone penetrometer method was used to determine the liquid limit of the gravel/aggregate mixtures. As the moisture content of the soil sample was increased by small amounts, the penetration of the cone was noted and plotted against the respective moisture content. From the same soil sample, a specimen was dried to near its plastic limit by air drying. It was then molded into a ball and rolled between the palms of the hand and glass plate to threads of nearly 3 mm in diameter. The soil was then considered to be at the plastic limit and its moisture content was determined.

California Bearing Ratio Test: The test was carried out for all design mixes in accordance with BS 1377:Part4:1990 for natural gravel and BS 1924:Part2:1990 for stabilized lateritic gravel. Fresh sets of 7000g air-dried soil are mixed with suitable amount of water to their OMC. Each layer was compacted with 65 blows using a 4.5kg hammer at a drop of 450mm. The compacted soil and mould were weighed and then soaked in water for four days. After the four days, of soaking, the samples were placed under the CBR machine following standard procedures. Load applied was recorded at varying penetrations to give a stress-strain curve from which the CBR was computed.

Proctor Compaction Test: The compaction tests were performed in accordance with BS 1377:Part4:1990 for natural gravel and BS 1924:Part2:1990 for stabilized lateritic gravel. Samples were crushed to pass through 20 mm British Standard sieve size and about 6 kg of material was used. The sample was mixed with suitable amount of water and compacted in five layers. Each layer was compacted with 4.5 kg rammer from a dropping height of 450 mm. Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) was determined from the graph of dry density against moisture content.

3 Results and Discussion

3.1 Introduction

The effect of different percentages of concrete aggregate wastes on the engineering properties of the soil are shown in Table 1. The results are further discussed graphically.

Table 1. Engineering properties of different soil blends

Percentages of waste aggregates	**GM**	**LL**	**PL**	**PI**	**LS**	**MDD**	**OMC**	**CBR**			**CBR SWELL**
								93%	**95%**	**98%**	
0 %	1.70	49.70	27.60	22.10	12.9	2.050	13.2	16	20	30	0.66
30%	2.13	37.10	21.50	15.60	7.5	2.076	10.7	19	34	56	0.50
40%	2.31	33.10	19.46	13.64	6.4	2.090	9.9	28	46	66	0.39
50%	2.40	29.70	18.30	11.40	5.4	2.132	7.9	36	59	76	0.23

3.2 Particle Size Distribution

The material was not suitable for sub-base since it did not meet the gradation requirements. Particle sizes of 2.00, 0.425 and 0.075 mm were out of the grading percentage limits. However, blending it with 30% waste aggregates improved the particle size distribution within the percentage limits.

The grading modulus improved gradually as the percentages of the waste aggregates increased. Blends of 40% and 50% waste aggregates met the grading requirements for a sub base specified by the grading envelope as per the MWH& C general specification for roads and bridges (2004), Table 2.

3.3 Atterberg Limits

The liquid limit of the resulting blends all decreased with addition of aggregates. That is from 49.70% for neat to 37.10%, 33.10% and 29.70% for 30%, 40% and 50% waste aggregate addition respectively. The addition of aggregates which are non-cohesive reduced the binding ability of the mixture and its capacity to retain moisture. In addition, increase in aggregates decreased the samples shrinkability. All the blends had a liquid limit less than 40%, evidence of lower plasticity, within limits of the MWH& C general specification for roads and bridges (2004) in Uganda.

Table 2. Requirements for Sub-base layers of G45 materials

Material properties	**Material class G45**	
	General requirements	**Calcrete or other pedogenic materials**
CBR: BS 1377: Part 4		
CBR (%)	Minimum 45 after 4 days soaking 1)	
CBR-swell (%)	Maximum 0.5 measured at BS-Heavy compaction	
Atterberg limits: 2)		
Max Liquid limit BS 1377: Part 2	40	45
Max Plasticity Index BS 1377: Part 2	14	16
Max Linear Shrinkage BS 1377: Part 2	7	8
Grading: BS 1377: Part 2		
Requirements:	Grading modulus, GM shall be minimum 1.5	

1) CBR values shall be measured at the specified field density for the layer.
2) It is emphasized that the Atterberg limits shall be measured according to BS 1377: Part 2. Other laboratory test procedures and equipment may not give comparable results and shall not be used unless proper correlation to BS has been carried out to the satisfaction of the Engineer.

3.4 Compaction Characteristics

MDD of the material increased with increase in the percentages of waste aggregates, Figure 1. As seen before increment in the percentages of waste aggregates led to an improvement in the grading of the material. Grading is directly proportional to MDD of the material. The MDD was in the range of 2050-2132kg/m^3 of the stabilizer contents of 30% to 50%. The coarse fraction of the mixture increases, natural micro clusters breakup, grains come close together with voids filled by the fines and on compaction the particles interlock each other thereby increasing dry density.

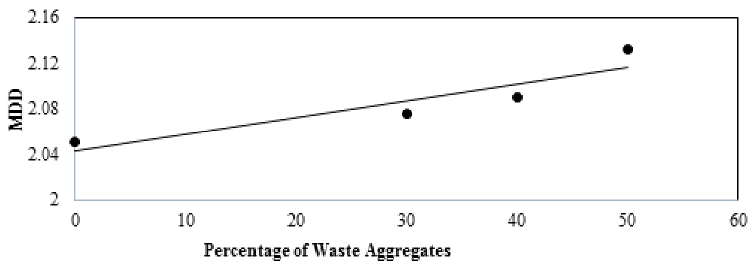

Figure 1. Relationship between MDD and % of waste aggregates

OMC is the maximum water content required to achieve maximum compaction of the material. According to the results, Figure 2, OMC reduced with increase in the waste aggregates used i.e. 13.2 for neat, 10.7, 9.9 and 7.9 for 30%, 40% and 50% of waste aggregates respectively. Addition of aggregates increases coarse fraction and reduces the proportion of fines in the mixture. As a result, less water is required to lubricate the fines thereby reducing the OMC.

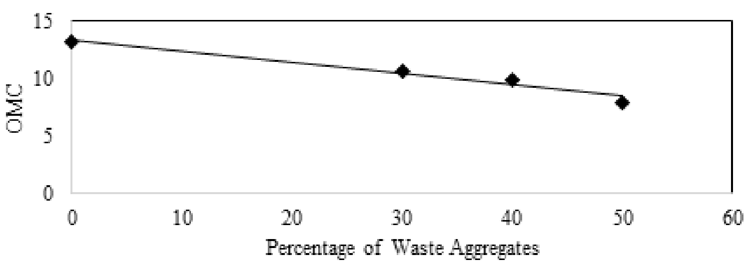

Figure 2. Relationship between OMC and % of waste aggregates

3.5 California Bearing Ratio

The CBR values increased from 20 for neat to 34, 46 and 59 for 30%, 40% and 50% of waste aggregates respectively considering CBR at 95% MDD. The increase in CBR was due to the increase in compaction (MDD) of the material. High compaction of the material renders it impermeable to water, expulsion of air voids and high densities which result to high bearing capacities. Only the CBR for 40% and 50% of waste aggregates at 95% MDD achieved the requirements for sub base material as per the MWH& C general specification for roads and bridges (2004) in Uganda.

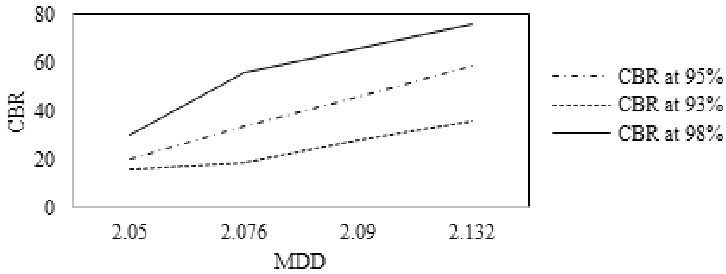

Figure 3. Relationship between CBR and MDD

4 Conclusion

Basing on the analysis of the results, with reference to the general specification for sub base material by Ministry of Works, Communication and Transport Uganda, mix designs of 40 % and 50 % of the waste aggregates and 60% and 50% of laterite soils respectively were considered suitable for use as sub base material as they showed CBR values of 46 and 59, respectively, at 95 % relative compaction and PI values of 13.64 and 11.40. These met the specified standards of a CBR equal or greater than 45 and PI equal or less than 14 according to the general specifications of Ministry of Works, Housing and Communications (2004).

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