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# Technological Characterization and Chemical Stabilization of Residues From Continuous Flight Auger (CFA) Piles Excavation For Use in Pavement Projects

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## ABSTRACT

The construction and demolition waste (CDW) make the civil construction sector be seen as one of the main responsible for the pollution of the urban environment. In this context, the large volume of waste generated in the process of continuous flight auger (CFA) piles excavation has been motivating the seek for more appropriate ways for its final disposal following the concept of sustainable development. Thus, this study aims to analyze the feasibility of strength improving (with hydraulic binders) the residues from CFA piles excavation, in order to used them as the base pavement material. For such, residues from the CFA piles excavation were collected – from a construction site located in Recife-PE, Brazil. The collected material was sent to the Soil Laboratory of the Polytechnic School of the University of Pernambuco for physical and mechanical characterization. After the geotechnical characterization of the waste, cylindrical specimens were molded with different contents of cement (3%, 6% and 9%) and underwent to unconfined compression tests at different curing times (7, 28 and 90 days). The results have showed that the residue can be classified as fine sand. The results of the unconfined compression test – carried out at the three curing times–have showed significant strength gains, which allow the percentages of 3%, 6% and 9% adequate for the use of such mixtures as pavement base material.

KEYWORDS: Construction waste, continuous flight auger pile, soil-cement, pavement

## INTRODUCTION

The solid residues generated by the Civil Construction Industry make this sector be recognized as one of the main responsible for the environmental pollution in great cities. The construction and demolition waste (CDW) cause environmental impacts when discarded at riverbanks, roads, empty lots and illegal disposal sites.

The inadequate disposal of CDW brings a series of environmental impacts such as visual pollution, the narrowing of river beds, floods, soil and water pollution, besides stimulating the disposal of organic wastes that attract pathogen vectors such as rats, cockroaches, worms, bacterium, fungi and viruses [1,2,3]. These impacts are caused due to the lack of waste management in the construction companies. Even though 90% of the CDW are recyclable, they are usually disposed inadequately and bring a series of economic, social and environmental problems [4]. In case of excavated soils, these materials are classified as CDW and call attention due to its large quantities.

Another fact worth mentioning is that the Civil Construction Industry also causes environmental impacts that come from the exploration of raw materials and the waste generated from this process. The growing mineral exploration has alerted the authorities and the population to the activities of exploration companies. In this scenario, the Civil Construction Industry must follow sustainable development principles up using technologies, which emphasize prevention, reduction, reuse and recycling of materials and the collection and disposal of its wastes [5].

On the other hand, the difficulty in obtaining materials that meet the technical standard specifications for the use in pavement base and sub-base layers in Brazilian roads represents a major problem for the local government departments. Frequently, the lack of granular materials or their great distance from the construction sites of the roads end up making them unfeasible to use in paving projects. Thus, it comes forth the need to use less noble soils, by stabilizing them with binders and residues that may improve their properties. The use of Portland cement to improve the soil properties is an alternative that has been commonly applied in Geotechnique [6].

Often, the use of traditional techniques in geotechnical engineering faces obstacles of economic and environmental nature. The addition of cement becomes an attractive technique when the project requires strength improvement of the local soil. The treatment of soils with cement finds application, for instance, in the construction of base pavement layers, in slope protection of earth dams, and as a support layer for shallow foundations [7].

In this context, the present study aims to evaluate the potential of the residue from the excavation process of continuous flight auger (CFA) piles after being strength improved with cement for the use as pavement base layers material.

## MATERIALS AND METHODS

The CDW used in this study was collected during the execution of 3 (three) continuous flight auger (CFA) piles at a construction site located in the metropolitan region of Recife, PE, Brazil (Figure 1). A total of 400kg of CDW were collected to be used in this study.

**Figure 1:** Execution of the continuous flight auger (CFA) pile at the construction site.

The CDW were dried in the open air and divided into small samples according to the recommendations presented by the Brazilian Association of Technical Standards (ABNT, in Portuguese) [8]. Then, all the material was fractionated into 3 (three) samples, which were underwent to the procedures and recommendations provided by ABNT technical standards listed below:

- Granulometric analysis [9];
- Determination of the specific gravity of grains [10];
- Atterber limits [11 and 12];
- Compaction tests [13].
- California bearing ratio [14].

Hydraulic binder – a cement composed with Pozzolana CP II Z 32 and bought locally – was used.for the chemical stabilization of CDW.

Unconfined compression tests were carried out on test cylindrical specimens with 128mm of height and 100mm in diameter. After the weighing of the materials (CDW, cement and water), the CDW and the cement were mixed together with a metal spatula, until the mixture acquired uniform coloring. The cement percentage used in the sample molding were 3%, 6% and 9% of cement relative to the dry mass of the residue. Then, a certain quantity of water was added according to the moistures obtained from the compaction test of each sample. The process was carried out until the targeted homogeneity was obtained.

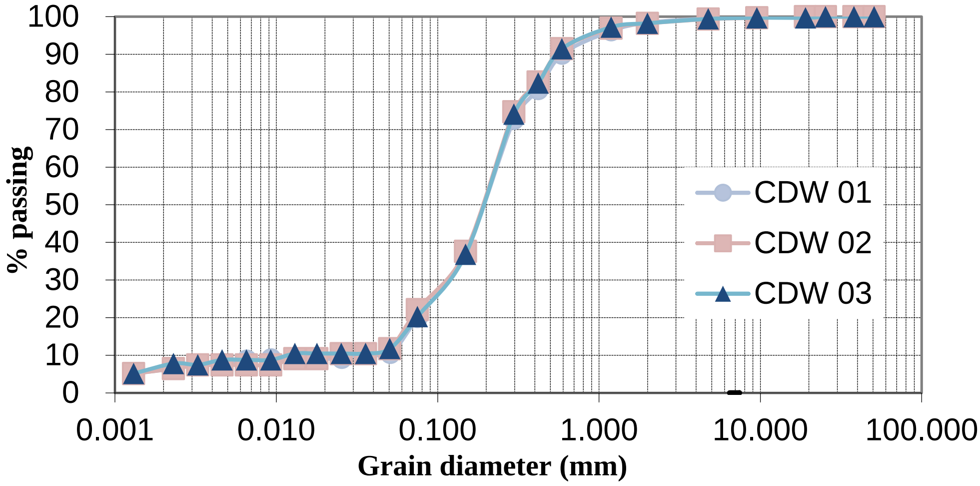
The curing and molding procedures of the specimens (Figure 2) were carried out according to the ABNT recommendations [15]. The total of 15 cylindrical specimens were molded for each cement dosage, which enabled the testing with 5 (five) specimens for each curing time. The curing process of the specimens consisted in storing them in a humid room at the temperature of 23 ± 2°C and relative humidity not inferior to 95%.

**Figure 2:** Cement-improved CDW specimens.

# RESULTS

## Granulometric Analysis

The particle size analysis of the CDW showed similar results for the 3 (three) tested samples (Figure 3). It was observed that the CDW is essentially composed by fine sand (around 71%) and medium sand (around 17%).




**Picture 3:** Grain size distribution curve of the CDW collected from continuous flight-auger pile driving.

## Grain Specific Gravity Test

The results of the grain specific gravity tests revealed mean value of 2.68 g/cm³, with coefficient of variation of 0.01%. This result is similar to the ones found in the literature for sands (from 2.65 to 2.68 g/cm³) [16] and for CDW (2,65 g/cm³) [17]. Table 1 shows the results of the tests to determine the actual density of the grains.

**Table 1**: Grain specific gravity of the CDW (particle diameter below 4.8 mm).

| Sample | Real Density of the grains (g/cm³) |
|---|---|
| CDW 01 | 2.70 |
| CDW 02 | 2.68 |
| CDW 03 | 2.65 |
| Mean value | 2.68 |
| Coefficient of variation | 0.01% |

## Atterberg Limit Determination Test

All the samples of the CDW present non-plastic behavior, which is a typical for essentially granular materials and a positive point to CDW.

## Highway Research Board (HRB) Classification

The Highway Research Board (HRB) classification is based on the soil granulometry and liquid and plastic limits. The results revealed that the CDW can be classified as a soil type A3.

## Proctor Compaction Test

The results of Proctor compaction tests of the CDW – without the addition of cement – presented mean values of the maximum unit dry weight of 19,49 kN/m$^3$, with coefficient of variation of 0%. The optimum water content presented mean value of 103.30%, with a coefficient of variability equal to 0%. (Table 2).

**Table 2:** Proctor compaction test results – CDW.

| Sample | Optimum water content (%) | Maximum dry unit weight (kN/m³) |
|---|---|---|
| CDW 01 | 10.40 | 19.43 |
| CDW 02 | 10.90 | 19.60 |
| CDW 03 | 9.70 | 19.45 |
| Mean value | 10.30 | 19.49 |
| Coefficient of variation | 0.05% | 0% |

The results of Proctor compaction tests of the mixtures (chemically stabilized CDW) showed that the addition of cement caused a gradual increase in the maximum dry unit weight in relation to the content of the cement added (Table 3). Similar results were reported in a previous study about compaction of silty-clay sand and clayey sand [18] and in a study about soil-cement stabilization for use in base pavement [17].

**Table 3**: Results of the compaction test with the stabilized RCC Proctor compaction test results7Mixtures.

| RCC Stabilized | Optimum water content (%) | Maximum dry unit weight (kN/m³) |
|---|---|---|
| Mixture 01 (addition of cement equal to 3%) | 9.3 % | 18.97 |
| Mixture 02 (addition of cement equal to 6%) | 9.9 % | 19.25 |
| Mixture 03 (addition of cement equal to 9%) | 10.6 % | 19.69 |

## Unconfined Compression Test

Unconfined compression test results of the mixtures at 7 days of age are presented in the Chart 1. Charts 2 and 3 show the results of the specimens at 28 and 90 days of age, respectively.
It was verified that the higher the addition of cement, the greater was the result of the unconfined compression tests (Figure 2).
According to ABNT [19], the soil-cement dosage for its use in base pavement must be investigated – at least 3 (three) contents of cement – in order to determine the one that addresses the criterion of minimum strength of 2.1 MPa. The results revealed that all of the mixture specimens – with cement contents of 3%, 6% and 9% –, presented higher values in comparison to the minimum value required by the Brazilian standard.

**Chart 1:** Unconfined compression test results – Specimens at 7 days of age.

| Mixture (addition of cement) | 7 days of age | | | | | | |
|---|---|---|---|---|---|---|---|
| | qu (MPa) | | | | | | |
| | 01 | 02 | 03 | 04 | 05 | Mean value | Coefficient of Variation |
| 01 (3%) | 2.21 | 2.28 | 2.19 | 2.24 | 2.48 | 2.28 | 5% |
| 02 (6%) | 7.06 | 6.94 | 7.55 | 6.90 | 7.59 | 7.21 | 5% |
| 03 (9%) | 9.65 | 9.32 | 8.87 | 9.87 | 9.53 | 9.45 | 4% |

**Chart 2:** Unconfined compression test results – Specimens at 28 days of age.

| Mixture (addition of cement) | 28 days of age | | | | | | |
|---|---|---|---|---|---|---|---|
| | qu (MPa) | | | | | | |
| | 01 | 02 | 03 | 04 | 05 | Mean value | Coefficient of Variation |
| 01 (3%) | 2.58 | 2.83 | 2.72 | 2.79 | 2.69 | 2.72 | 4% |
| 02 (6%) | 7.98 | 8.19 | 8.11 | 8.21 | 7.67 | 8.03 | 3% |
| 03 (9%) | 13.20 | 13.92 | 13.06 | 12.41 | 12.29 | 12.98 | 5% |

**Chart 3:** Unconfined compression test results – Specimens at 90 days of age.

| Mixture (addition of cement) | 90 days of age | | | | | | |
|---|---|---|---|---|---|---|---|
| | qu (MPa) | | | | | | |
| | 01 | 02 | 03 | 04 | 05 | Mean value | Coefficient of Variation |
| 01 (3%) | 3.35 | 3.43 | 3.63 | 2.95 | 3.22 | 3.32 | 8% |
| 02 (6%) | 10.03 | 9.06 | 9.70 | 8.57 | 9.25 | 9.32 | 6% |
| 03 (9%) | 14.88 | 15.40 | 15.98 | 13.43 | 13.52 | 14.64 | 8% |

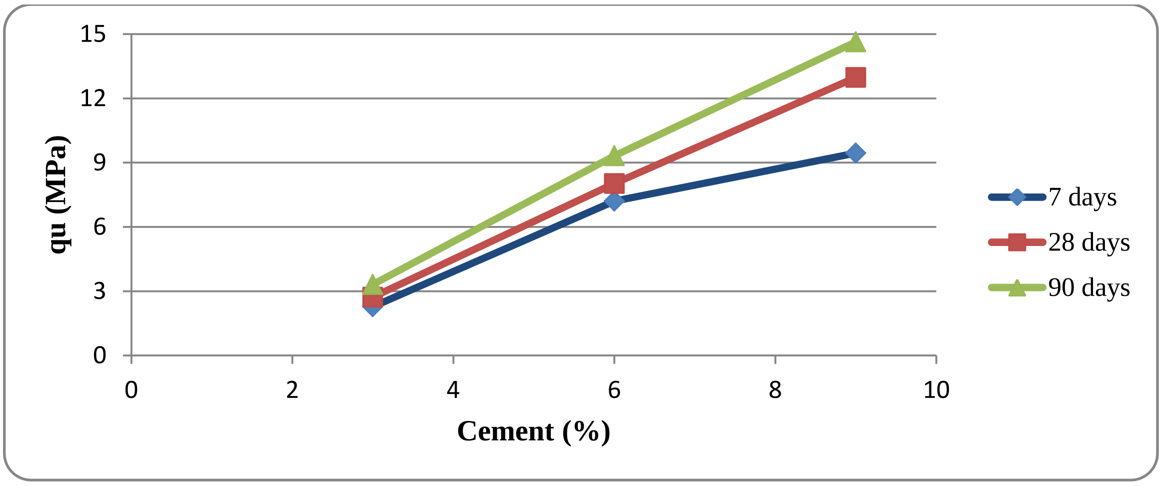



**Figure 2:** Unconfined compression strength vs. addition of cement addition.

## CONCLUSION

Based on the results and the comparison with the requirements of Brazilian standards, the following conclusions can be drawn:

● It was observed that CDW presented excellent geotechnical properties and can be classified as non-plastic fine sand. According to the HRB classification for soils, the CDW can be classified as a soil type A3.

● Addition of cement, even in small quantities, provided significant gains of strength to the samples. It was verified that higher the content of the cement added to the CDW, the greater is the strength gain.

● All the criteria, such as the HBR classification for soils, grain size distribution curve and the compression strength, achieved by all the mixture (CDW + cement). The investigated mixtures follow the Brazilian standards for the use of soil-cement as base pavement material. The results of unconfined compression test have shown that the excavated soil generated from continuous flight auger (CFA) piles driving can be use as base pavement material after its stabilization with hydraulic binder.

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