Use of construction and demolition wastes in compaction piles for soil improvement

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ABSTRACT
The increasing waste production in civil construction, whether in new constructions or demolitions, has become a growing concern. The purpose of this research was to investigate some physical and mechanical properties of construction and demolition waste – CDW, checking its performance when applied to improving soils using compaction piles to replace natural aggregate. With this in mind, laboratory characterisation, compaction and direct shear tests were carried out, as well as an experimental compaction mesh consisting of CDW and conventional piles on site, when it was possible to drill boreholes and perform plate bearing tests. Accordingly, it was possible to confirm the good performance of CDW when applied for this purpose, since both its laboratory and onsite results showed even better behaviour than the natural aggregate.

RESUMEN
El aumento de la producción de residuos en la construcción civil, ya sea en nuevas construcciones o demoliciones, se ha convertido en una preocupación creciente. El propósito de esta investigación fue investigar algunas propiedades físicas y mecánicas de los residuos de construcción y demolición - RCD, comprobando su funcionamiento cuando se aplica a la mejora de los suelos con pilotes de compactación para reemplazar materiales naturales. Con esto en mente, la caracterización de laboratorio, compactación y ensayos de corte directo se llevaron a cabo, así como una malla de compactación experimental que consiste en RCD y pilas convencionales en el lugar, cuando fue posible perforar pozos y realizar pruebas de placa de apoyo. En consecuencia, fue posible confirmar el buen desempeño de RCD cuando se aplica para este propósito, ya que tanto su laboratorio y los resultados in situ mostraron un comportamiento incluso mejor que los materiales naturales.

1 INTRODUCTION

The growing concern regarding the production of debris in general with regard to its disposal in increasingly confined urban spaces, and the exhaustion of natural resources and their close relationship with the cost of extraction and transport of materials from dumps even farther from the cities, causes concern in evaluating in more detail the question of waste produced in large urban centres.

This incurs several problems due to the negligence towards waste, such as obstruction of urban drainage elements, which causes risks of flooding; sedimentation and pollution of rivers, lagoons and other water sources; visual pollution of the city; a rise in the number of undesirable species and health hazards, namely rats and cockroaches; overspending with extraction of natural resources and their possible exhaustion; as well as extra costs from material wastage (Gusmão, 2008).

Carneiro (2005) goes farther when he says that one of the problems relating to waste generation is not only uncontrolled consumption of natural resources but also the possibility of the occurrence of even serious disasters.

Despite the risks and disturbances relating to solid waste in general, the data obtained on this matter are still very much in the early stages. Pinto (1999) has already warned about the major lack of knowledge regarding volumes produced; the impacts caused; social costs and unknown possibilities of re-using such waste. And the fact is that this situation has not improved satisfactorily over the past ten years.

It is worth recalling that a major step was taken in 2002 in relation to construction and demolition waste (CDW), when the Brazilian Environmental Council (CONAMA) Resolution no. 307 was approved, which determines generally the change in so-called corrective waste management (current reality of large urban centres) to sustainable management.

The aforementioned Resolution no. 307 recognises the need to adopt guidelines to reduce environmental impacts caused by civil construction; that inadequate waste disposal has a part to play in environmental degradation and that the generators must be liable for the waste from their construction activities (CONAMA, 2002).

Finding alternatives to put a stop to the impact that CDW causes on the environment, and adding this to the ceaseless search for cheaper inputs, a positive proposal emerges to use recycled aggregates, since a considerable quantity of recycled material is usable; its processing methods are simple and it uses several CDW component materials.

The purpose of this study was to analyse the technical feasibility of using recycled CDW aggregates as material to fill compaction piles for improving soil.

2 ANALYTICAL METHOD

2.1 Laboratory Tests

In order to obtain as many representative CDW samples as possible, since this is heterogeneous material, four jobsites were selected in the city of Recife, Pernambuco State (PE), Brazil, which were at the stages of structure, masonry, finishing and demolition.

Tests were carried out on gravimetric composition; optical microscopy; compaction and direct shear in the CDW samples from the different jobsites selected, as well as samples of stone dust.

2.2 On Site Tests

An experimental compaction mesh was undertaken consisting of CDW and stone dust piles which helped compare the performance between these two materials, and the original ground inside and outside the mesh.

A borehole of the Standard Penetration Test (SPT) type was drilled in original ground inside and outside the experimental compaction mesh, which allowed comparison of the performance between CDW material and stone dust.

Lastly, a plate bearing test was performed directly on CDW and stone dust piles; on CDW and stone dust piles and a portion of soil, as well as inside and outside the original ground. The test in question helps analyse the soil behaviour when applied stress is related to the maximum settlement obtained.

3 RESULTS

3.1 Gravimetric Composition of CDW Samples

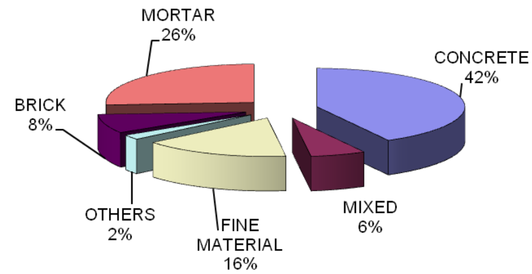
According to Figure 1a, the structure sample showed, as expected, a higher percentage of concrete (42%). This higher percentage was also diagnosed by Carneiro (2005) on a job at the same operating stage (53%). The author also found a higher percentage of brick waste in a job at the masonry stage, 39%, close to that found for the masonry sample assessed in this study, which was 43% for this material (Figure 1b).

For the finishing sample (Figure 1c), a larger quantity of fine material was found (material passing through no. 4 or 4.8mm sieve) of 53%. This fact is the result of the large quantity of soil existing in this material. It is also worth mentioning the small percentage of plaster waste (2%), although the sample was collected during the stage of applying the material. This fact is explained by the disposal of the plaster waste from the job being collected by an outsourced company for recycling.

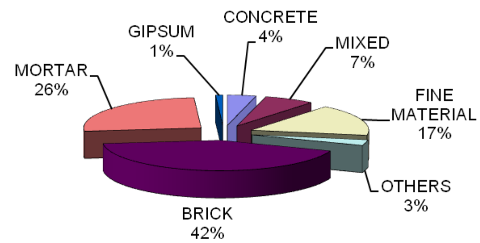
With regard to the demolition sample (Figure 1d) quite similar percentages were detected for the participation of its components, varying between 10% and 14%. The exception is the mortar component (25%), which in fact was the average value found for all samples. No Class B waste was found in this sample, since Class A waste was also collected during demolition, and therefore there is no mix with other graded waste

3.2 Optical Microscope Tests

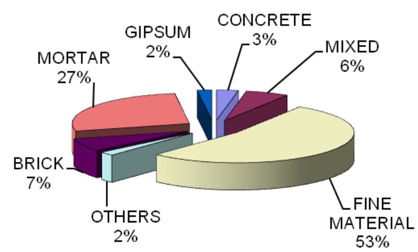
By analysing Figures 2a to 2e that were obtained using an optical microscope with binocular lens, the characteristics of mineralogical composition and shape of the particles could be identified.



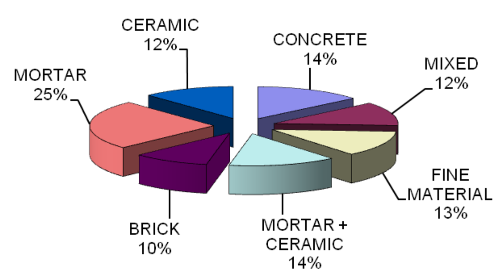
(a) Structure phase



(b) Masonry phase

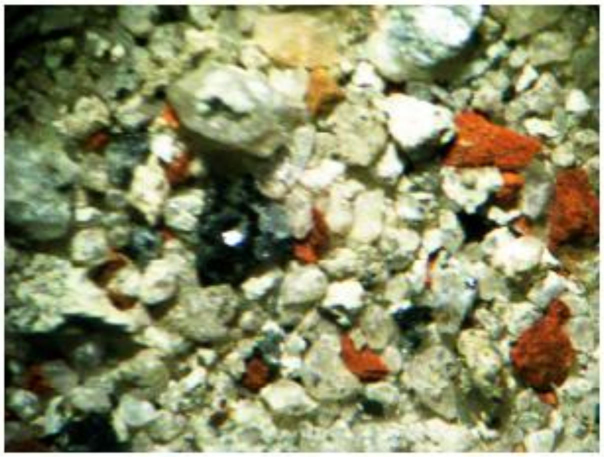


(c) Finishing phase



(d) Demolition phase

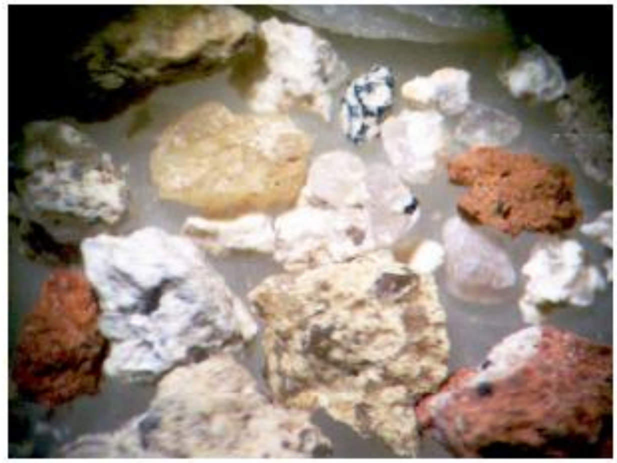
Figure 1. Gravimetric composition of components in the collected CDW samples.



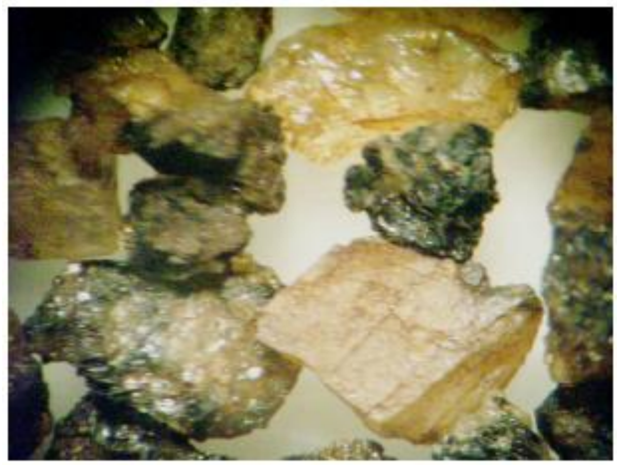
(a) Structure phase

(b) Masonry phase

(c) Finishing phase



(d) Demolition phase



(e) Stone dust

Figure 2. Optical microscope tests.

It was possible to find that the structure, masonry, finishing and demolition samples have quartz mineral as a common element. This was to be expected, since the samples in question come from elements that include sand in their composition. It is known that sand is the result of rock decomposition and, as Pinto (2006) points out, the quartz mineral is present in most of them. This mineral is also found in the stone dust sample, obviously because it was extracted directly from rocks.

The stone dust sample, besides the aforementioned quartz mineral, has the biotite mica mineral in common in relation to the other samples. An outstanding feature of this sample is the presence of the mineral feldspar, which is strongly affected by nature, giving origin to the clay minerals, which constitute the finest fraction of the soils (Pinto, 2006).

3.3 Compaction Tests

Figure 3 shows the compaction curves obtained for the compaction test by applying Normal Proctor energy.

The results of the compaction tests shown herein give an average value of maximum dry specific weight for the CDW samples of 16.52 kN/m^3 and an average value of optimum moisture content of 17.87%.

However, a greater dispersion is found in relation to the optimum moisture content of the samples, since the samples of waste from jobs at a structure and finishing stage showed values of around 14.25%, while the waste samples from jobs at a stage of masonry and demolition provides an optimum moisture content of 21.50%

3.4 Direct Shear Tests

The results presented in Figure 4 are for the direct shear tests.

Based on Figure 4, the findings from the samples from CDW processing at different stages of the job showed, for the non-flood test, higher values of shear strength and, consequently, greater angles of friction than the stone dust samples, whatever their gravimetric compositions may be.

3.5 The Experimental Compaction Mesh

Twenty-five compaction piles were driven, six consisting of CDW and crushed stone and the rest of stone dust and crushed stone (Figure 5).

The piles were driven by a tripod pile driver with 320mm pipe, 4m in length and a tamp of 18.5kN. All the plugs made have a volume of 72 Liters so that no difference in driving performance was found between the piles of different materials (CDW or stone dust), because of the plug.

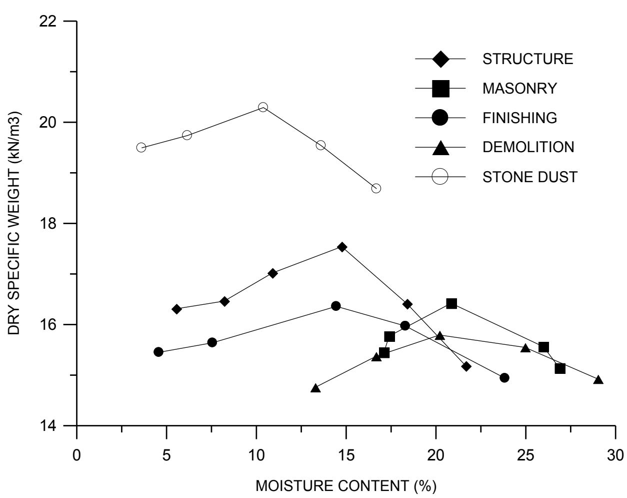


Figure 3. Compaction curves of samples tested.

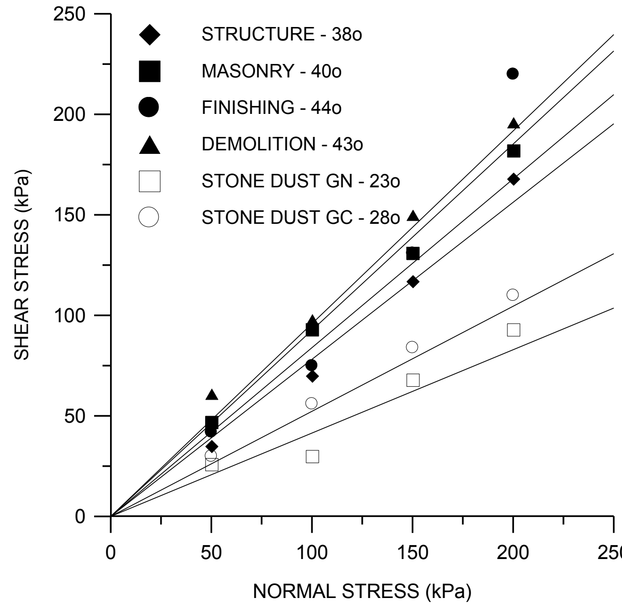


Figure 4. Strength envelopes of samples.

3.6 Boreholes

Four boreholes were drilled, two inside the compaction mesh (SP-01 and SP-02) and two outside it (SP-03 and SP-04), as shown in Figure 6.

It is important to stress that the SP02 borehole was drilled between compaction piles solely consisting of CDW and crushed stone, while borehole SP01 is located between CDW and stone dust piles. This fact makes obtaining such close results of soil improvement even more significant when comparing the aforementioned boreholes in Figure 6.

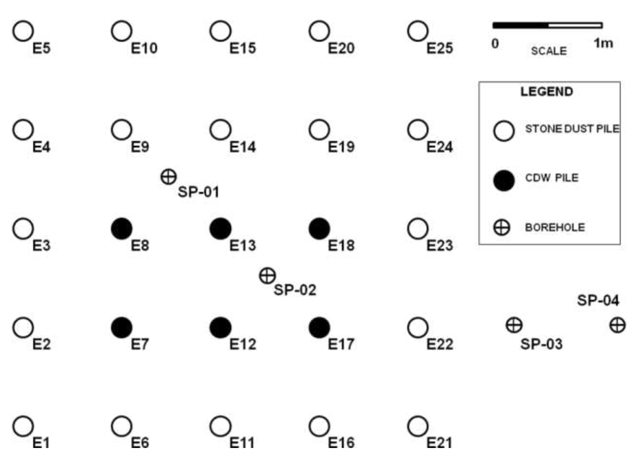


Figure 5. Experimental mesh and location of the boreholes.

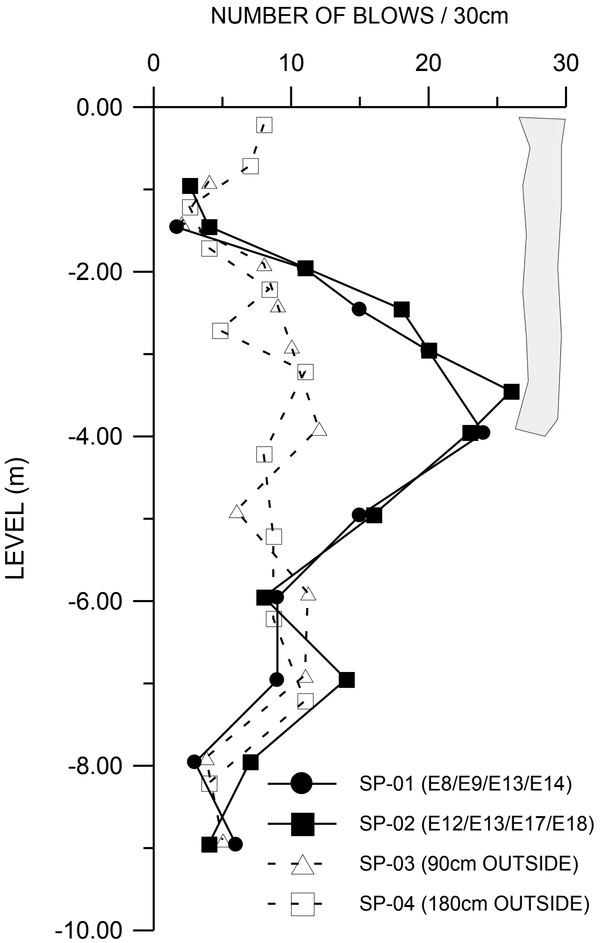


Figure 6. Comparison of boreholes.

3.7 Plate Bearing Tests

Fifteen bearing tests were carried out with variation in the plate used, plate elevation and location in relation to the mesh. The bearing tests were rapid, taken at 0, 2 and 5 minutes.

Figure 7 separates the tests applied only using a 300mm plate, which - except for the bearing test T11 - were performed directly on the piles. It is also necessary to point out that the bearing test T11 was the only one performed outside the compaction mesh.

A good performance of the CDW and stone dust piles was found in relation to the original ground outside the mesh (T-11). Emphasis must be given to bearing test of pile E07, which achieved slightly more than 3.5MPa, behaving very differently from the others

Another important analysis is that of bearing test of pile E09 (stone dust) and bearing test of pile E08 (CDW), since it is found that there is perfect compatibility of performance between these two bearing tests.

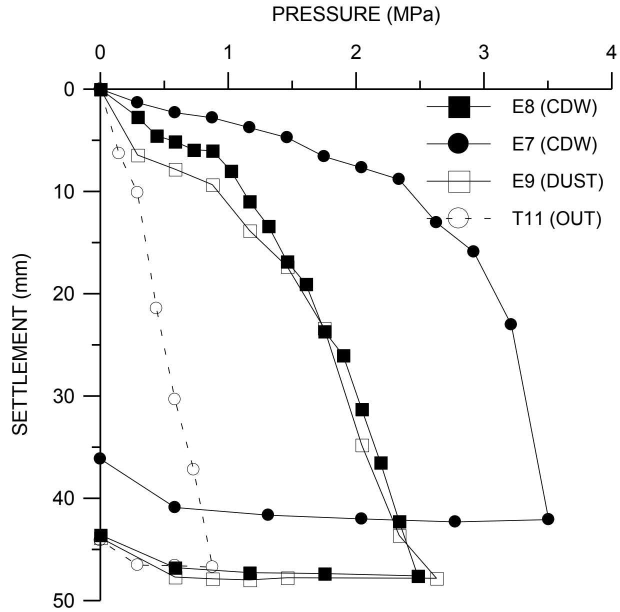


Figure 7. Bearing tests on a 300mm plate.

4 CONCLUSIONS

The direct shear tests recorded peak stress for all samples, which is a characteristic of rigid material. All CDW samples showed strength and consequently a greater friction angle than the stone dust samples.

The borehole and plate bearing tests made on the experimental compaction mesh helped confirm good performance on site of the piles with CDW compared to the conventional piles.

The conclusion is that CDW material, having been processed and regardless of its composition with elements from works at the stage of structure, masonry, finishing and demolition, is a satisfactory substitute for natural aggregate when using in compaction piles.

ACKNOWLEDGEMENTS

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