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Good Practices To Investigate The Effect Of Cure Time On Mechanical Strength Of Soil-Cdw Mixtures

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Abstract

The generation of construction and demolition waste (CDW) has been recognized as a problem in large urban centers, causing problems of preservation of the environment and increase of financial costs. This waste comes from constructions, renovations, repairs and demolitions of civil construction works, resulting from the preparation and excavation of land. This paper shows the good practices to investigate the application of soil stabilization technique with two different CDW granulometric fractions in three different porosities and three cure times (30, 60 and 90 days). The main parameters of resistance control of soil samples (control) and soil-CDW mixtures were dry maximum specific gravity (γd), optimum moisture (ω), CBR, unconfined compression strength (qu) and split compression tensile (qt) for different curing times and porosity. The results indicate that the higher the CDW addition to the soil and the longer the curing time, the greater the resistance increments. The resistance values presented in this research are acceptable for paving works.

Keywords: Good practices, CDW, soil, CBR, cure time

1. INTRODUCTION

The use of reused materials such as Construction and Demolition Waste (CDW), rice husk ash, heavy ash, among others (Moreira et al., 2017; Jiménez, 2013; 2016; Leandro, 2005; Prabakar et al., 2004) has been successfully used in geotechnical engineering for the stabilization and mechanical improvement of soils, mainly clays and silts. In a recent period, with the economic leap experienced by Brazil, there is a need for infrastructure and constructions that are technically and economically viable, with the lowest possible environmental impact, are required. Faced with this, there is a need for studies on materials and techniques little used regionally, as is the case of soil stabilization with CDW. The use of CDW presents itself as an interesting alternative to conventionally used materials, to promote an increase in the supply of paved roads characterized mainly by low traffic volume (Moreira et al., 2017). The main attractions of recycled aggregates are the economic and environmental aspects, as these materials usually have a lower market value than natural materials, in addition to being a useful destination for waste that is normally deposited in landfills, thus reducing the environmental impact. Research on CDW recycling has been carried out in other countries for some time. The mixture of these environmentally recyclable materials helps to solve the problem of scarcity of natural material and solves and/or minimizes the problem of irregular disposal of CDW.

CDW aggregate is an attractive alternative for base and sub-base materials for pavements due to its high mechanical strength and non-expansive behavior (Leite et al., 2011).

The soils of the Geological Formation of Guabirotuba, located in the city of Curitiba-PR, Brazil, and the metropolitan region, have, by their granulometry, the majority of fines. To a large extent, the soils of the Guabirotuba Formation cannot be used in the sub-base and paving base layers, to support surface foundations such as footings and to protect slopes. The soil improvement technique can also be used in the foundations of small buildings, in soils with low bearing capacity or that have low volumetric stability (Baldovino et al., 2017).

In any technique for using materials from recycling, it is essential to carry out preliminary studies, mainly covering aspects of the pavement geometry, the nature and ways in which the necessary maintenance will be carried out during the useful life of the pavement, the characterization of the materials recycled materials, the intervention thickness used as a base and the delimitation of the final mixture of materials to be applied for the type of flooring (Moreira, 2005). Within this perspective, this research was developed approaching the use of CDW mixed with a soil from the Guabirotuba Geological Formation as material for paving layers, having as control parameters the maximum dry specific weight (γd), the optimum humidity (ω), percentage of CDW and soil (mixtures), the Proctor Normal (EN) compaction energy, and response parameters CBR (in the immersed condition), simple compression (qu) and diametral compression tensile (qt) for different curing times (30, 60 and 90 days).

2. MATERIALS

2.1 Soil

The soil used for the study was collected at a construction site near the city of Curitiba, in the municipality of Fazenda Rio Grande (PR), Brazil, at a construction site for low-income housing with geographic location 25°41'03.9"S and 49° 18'32.5"W. The third layer of the Guabirotuba Formation was chosen, which is composed of 35.5% clay (diameter < 0.002 mm), 39.5% silt (0.002 to 0.075 mm) and 25% sand (diameter > 0.075 mm). Figure 1 shows the soil granulometric curve.

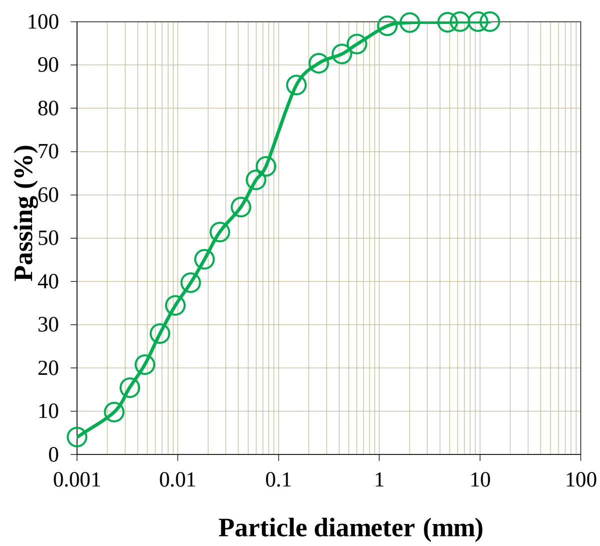


Figure 1. Particle size distribution curve of soil

The physical properties of the soil are shown in Table 1. Tests were carried out to determine the limits of liquidity and plasticity; the soil has a high liquidity limit (53.1%), as the plasticity index indicates that the clay is highly plastic with 21.3% (IP>15), making it impossible to use it in base and sub-layers. road pavement base according to the Paving Manual (DNIT, 2006), as shown in Table 1. Based on the granulometry and the result of the physical indices, the soil classification was carried out, according to the Unified Soil Classification System – SUCS – being classified as an elastic silt with sand (MH) and, according to the HRB Classification System, the soil is A-7-6 (clayey soil). The soil classification test was performed according to ASTM D2487 (ASTM 2000), the Atterberg limits of soils according to ASTM 4318 (ASTM 2010) and the actual specific gravity of soil grains according to ASTM D854 (ASTM 2014).

Table 1. Physical properties of soils

Property	Value
Liquid Limit	53.1%
Plasticity Limit	31.8%
Plasticity index	21.3%
Sand (0.075 mm < ϕ < 4.8 mm)	25%
Silt (0.002 mm < ϕ <0.075 mm)	39.5%
Clay (ϕ < 0.002 mm)	35.5%
Real specific mass of the grains (Gs)	2.71 g/cm^3

2.2 CDW

The construction and demolition waste used was collected at the recycling plant in the city of Almirante Tamandaré, metropolitan region of Curitiba. The type of waste chosen is mixed, that is, composed of gray (concrete, mortar, etc.), red (ceramic) and white (lime, gypsum, etc.) waste. Two granulometries of CDW were chosen: sand (material ≤ 4.8mm) and gravel (material ≤ 19.1mm); the granulometry of the CDW being carried out, represented in Figure 2.

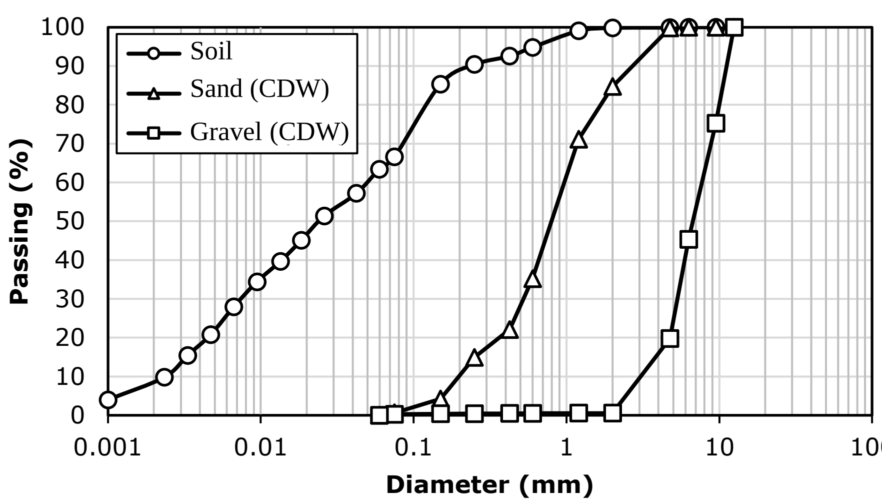


Figure 2. Particle size distribution curve of CDW

The CDW collected has less than 1% sulfates, more than 90% cement and rock-based fragment content, less than 2% non-mineral materials, gravel absorption less than 8% and sand less than 13%, and specific weight of 13.84 kN/m³ for gravel and 13.23 kN/m³ for sand (USIPAR, 2018).

2.3 Water

The water used for both the soil characterization, compaction and CBR tests was distilled, in accordance with the specifications of the standards, being free of impurities, avoiding unwanted reactions.

3. METHODOLOGY

3.1 Dosage of mixtures

A granulometric stabilization was carried out to determine the optimal content of the mixture of soil with CDW, considering different research on reinforcement of soils with CDW, 4 contents of soil-CDW mixtures were defined for the present study. To facilitate the study, the nomenclatures were adopted: M0, M1, M2, M3 and M4; according to Table 2.

Table 2. Input dosage

Mixture	Percentage		
	Soil	**Sand**	**Gravel**
M0	100%	0%	0%
M1	60%	30%	10%
M2	60%	20%	20%
M3	50%	30%	20%
M4	40%	30%	30%

3.2 Compaction Tests

Soil compaction tests were carried out at Proctor Normal energy, according to the norm according to NBR 7182/16.

3.3 California Bearing Ratio Tests – CBR

For the CBR tests, specimens were molded according to the DNIT - 172/2016 - ME standard. Three specimens were molded by CBR in order to have a statistical result. The test was carried out with the molding of the specimen at the optimum moisture content (ωot) and maximum dry specific weight (γd) found in the compaction test (Normal Proctor), only with normal compaction energy, using 12 blows of the standard socket to the soil and for the soil-CDW mixtures. The final result of the CBR is the greater value between the two penetrations in the specimen (0.1' and 0.2').

3.4 Expansion Tests

The expansion test followed the DNIT – 172/2016 – ME and DNIT – 160/2012 – ME standards. This test was carried out while the CBR specimens were submerged for 4 days, in which readings were taken to see the daily expansion.

3.5 Simple compression and tensile strength tests by diametral compression

For the simple compression and tensile tests by diametral compression, specimens measuring 100mm in height and 50mm in diameter were molded. The soil was completely dried in an oven at 100±5°C and then placed in uniformly distributed portions to be mixed with the different CDW contents. The amount of dry CDW was placed with reference to the dry weight of the soil sample. Next, mixing was carried out so that the final mixture became as homogeneous as possible. A weight percentage of water was added to the soil sample with CDW and mixed again to achieve optimum moisture.

The samples for molding the specimens were statically compacted in two layers in a stainless steel mold with an internal diameter of 50 mm, height of 100 mm and thickness of 5 mm, in order to reach the maximum apparent specific weight. After being compacted, the sample was removed from the mold with the help of a hydraulic extractor, weighing it in sequence on a 0.01g precision scale; taking its dimensions with the use of a caliper. Soon after, they were wrapped with transparent plastic to ensure moisture conservation. Finally, the specimens were taken to the humid chamber for the curing process for 30 days, with an average temperature of 25°C.

The procedures for the simple compression tests followed the American standard ASTM D 5102/96 and the tensile ones followed the ASTM C 496/C 496M - 04 standard.

4. RESULTS

4.1 Compaction, CBR and Expansion Tests

Figure 3 shows the soil compaction curves and the studied soil-CDW mixtures.

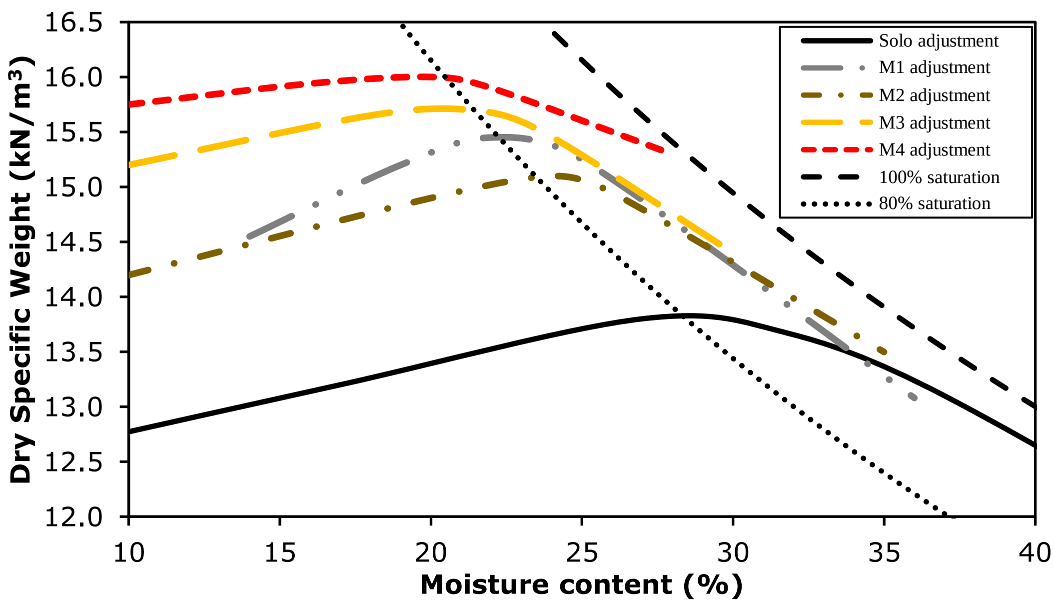


Figure 3. Clay compaction curves

Thus, compaction tests were also carried out with each mixture used at normal energy.

Table 3 presents the variation of the maximum dry specific weight and the optimal moisture for different CDW mixtures.

Table 3. Compaction properties of soil and soil-CDW mixtures

Mixture	Maximum dry specific weight, $\gamma dmax (kN/m^3)$	Optimum humidity, ωot (%)
M0	13.58	32.5
M1	15.21	25.2
M2	15.12	24.0
M3	15.81	21.3
M4	16.13	20.2

It is noticed that with the addition of CDW in the mixtures the maximum dry specific weight also increases, this happens because of the recycled aggregates forming a matrix with the soil.

4.2 CBR tests

Figure 4 shows the CBR results of the soil and soil-CDW mixtures studied.

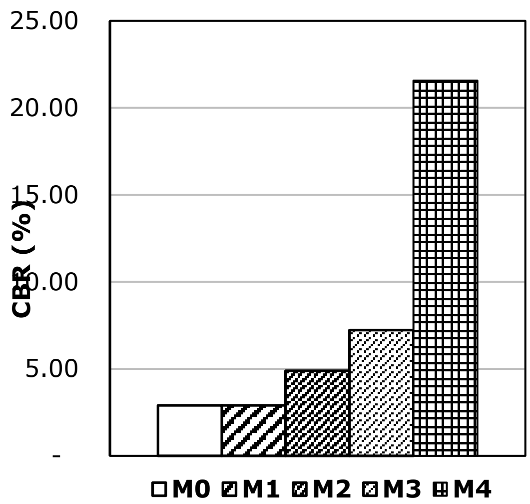


Figure 4. Influence of CDW on CBR results

It was observed that as the CDW content increases, the CBR increases, with the exception of one point, as shown in Figure 5. Between the mixture M0 and M1, a plateau is observed, demonstrating that there were no changes. In the CBR test, there were no significant changes between Soil (M0) and the M1 mixture, with an increase in the maximum dry specific weight. An increase in CBR is observed as the granulometry of the CDW in the mixture increases. Between M3 and M1, there was an increase of 147.85%, and 298.34% between M4 and M3. The increase of M4 in relation to the M0 mixture was 743.79%. The CBR value above 4% can be used for subgrade reinforcement, and the M4 mix, with CBR greater than 20% and 1% expansion for subbase.

4.3 Expansion Tests

In Table 4, the results of the expansion are shown.

Table 4. Expansion Results

Mixture	Expansion
M0	5.61
M1	3.27
M2	2.60
M3	1.18
M4	1.00

Based on the data presented in Table 4, Figure 5 was created to analyze the expansion behavior with the addition of CDW in the mixtures.

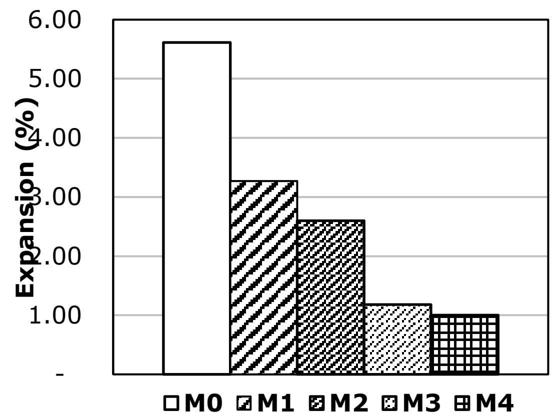
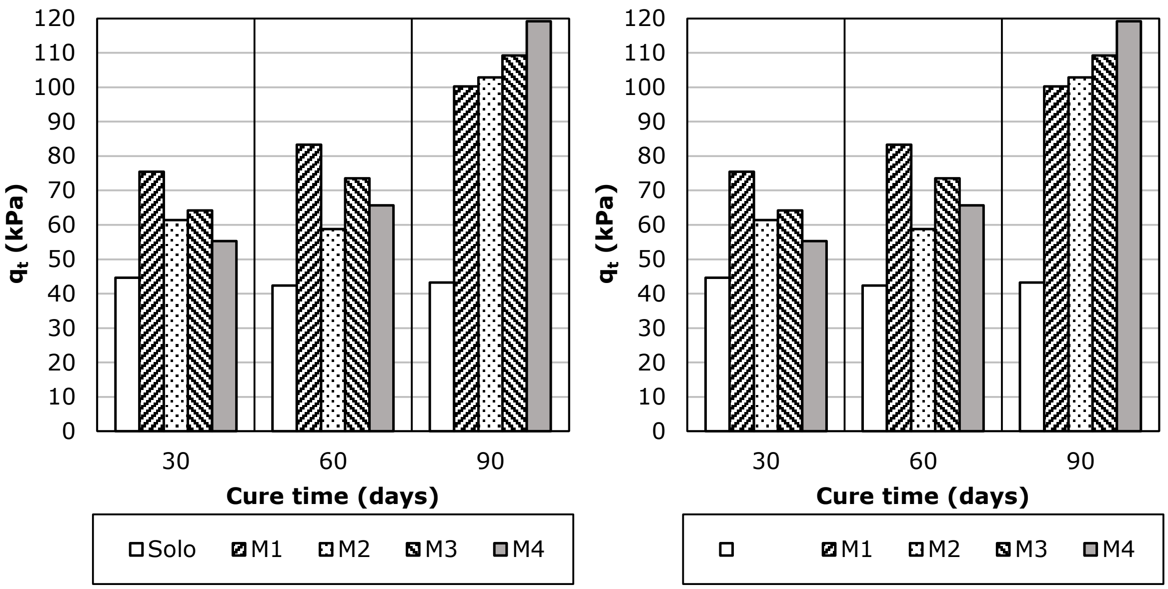


Figure 5. Influence of CDW on Expansion results

A decrease in the expansion is observed as CDW is added, making the mixture more stable in the presence of water, obtaining a decrease of up to 82.17% of the initial expansion of the soil. Based on the Brazilian norms for pavement layers, it is observed that from the M1 mixture, it becomes feasible to use the mixture for pavements, since with the reduction of the expansion to 3.27% and the CBR greater than 2%, the M1 mixture can be used as a subgrade.

4.4 Simple Compression Test (qu)

Figure 6a and 6b shows the results of qu and qt, respectively, of soil samples and soil-CDW mixtures with the variation of CDW contents. It is observed that with the increase in the dry specific weight of the samples, their resistance to simple compression and traction increases.



a) Simple compression b) Split tensile

Figure 6. Influence of CDW on strength qu and qt

The simple qu compressive strength of a compacted fine-grained soil at optimum moisture content can range from 170 kPa to 2100 kPa, depending on the nature of the soil. It is observed that there is an increase in resistance of mixtures M1, M2, M3 and M4 over time, so it is concluded that the CDW reacts with the soil over time, this is due to reactions of non-inert materials of the CDW, such as cement and lime present in residues from works with the soil, that is, the curing time has an influence on the resistance to simple compression. The mean single compressive strength increments for mixtures M1, M2, M3 and M4 over time was 26%. Note that there was an increase in resistance with the addition of CDW in the soil for a curing time of 30 days. This increase in resistance is due to the resistance matrix created between the soil and the CDW through granulometric stabilization.

For the qt results, it can be seen that the highest average strength increment over time was 67%, and the strength increment after 30 days of curing was 43%, very close to the results for simple compression strength.

5. CONCLUSIONS

The use of CDW in fine soils improves the support capacity, given that the CDW matrix with the soil forms a new material, altering the original characteristics of the soil. Thus, the use of CDW in the soil decreases its expansion due to the reduction of fines in the mixture and the reaction between the constituent components in the residue, such as cement and non-inert lime.

Also, it is concluded that the greater the incorporation of CDW into the soil, the greater the specific weight of the final mixture, therefore the greater the CDW and the lower its expansion. It is concluded that the addition of CDW in the soil increases the resistance to simple compression (qu) and to traction (qt) in approximately 50% and the curing time also influences the final resistance of the soil-CDW mixtures, increasing approximately 26% of simple compressive strength and 67% increase in tensile strength. Within these findings, its use in subgrade reinforcement layer and pavement subbase is permitted. It should be noted that it is essential to carry out preliminary studies, both on the type of soil and on the quality and composition of the CDW, given the heterogeneity of the CDW.

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