

Study of the Technical Feasibility of the Usage of Waste from Electric Posts as Coarse Aggregate in the Mixture of Concrete for Structural Purposes

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Abstract—This work aims to analyze the technical and economic feasibility of using concrete post waste as coarse aggregate for the manufacture of new electricity posts. In order to carry out the experimental study, waste processing, characterization and finally concrete dosage were carried out. The adopted methodology consists in the partial substitution of the natural aggregate by recycled aggregate originated from damaged concrete electricity posts collected in the city of Palmas - TO. In order to obtain the results, specimens and new concrete posts were tested with the replacement of the aggregate, respecting the approval guidelines for concrete post for electric power networks. The results obtained point to the use of waste from unusable posts as a potential alternative in removing the residue from the environment, replacing natural aggregates in the manufacture of new posts that meet the mechanical resistance specifications.

Keywords— concrete electric post, concrete electric pole, construction waste, electrical resistance.

I. INTRODUCTION

The construction industry currently represents one of the largest consumers of natural resources in the world [1]. In addition, it is the largest generator of waste, in mass and volume, in urban environments. The lack of policies and guidelines related to this waste, culminates to its inadequate disposal on urban and natural environments, causing significant impacts to the environment, both on urban and rural [2].

According to the data from the National Department of Environmental Sanitation, construction and demolition waste (CDW) represents an amount of 40 to 70% of all solid waste generated in the country. The cleaning of this material improperly disposed in urban environments, generates a high cost for the municipalities, since they cannot be disposed in common sanitary landfills [3], a resource that could be used to benefit society and to improve urban infrastructure.

In this way, the recycling of construction waste is an effective alternative in reducing the extraction of natural resources for construction supplies, maintaining a healthy urban environment, decreasing municipal spending and increasing job creation [2].

Despite presenting itself as a viable alternative to all of the aforementioned problems, recycling is not a simple process and the product generated needs to undergo strict quality control so that this product can reach the market competitively enough to generate all the benefits that promises. In other words, it is not enough to adopt CDW recycling, it is necessary to meet market requirements [4].

Thus, in order of obtaining viability of the recycling of CDW, aspects such as technical performance of the recycled product, environmental impacts caused by the recycling process itself and disposal of the recycled waste at the end of the production chain and market viability must be taken into account [5].

Several studies have been developed to make the use of these recycled aggregates feasible in the constitution of concrete, among them, studies of evaluation of specific mass of aggregates from CDW and its reactions on the properties of concrete [6], use of steel fibers in concretes produced with recycled coarse aggregates [5], use of recycled CDW aggregates on the basis of paving structure [7], studies of the effects of the use of coarse and fine aggregates from CDW on the properties of structural concrete [8] and [9].

All of these work generate an important framework for studies on the use of recycled CDW materials in the constitution of structural concretes. Many of them show positive results in this area, such as the study by [6] that deals with the use of CDW residues separated by density in the concrete composition. In this study the author verified the direct relationship between the aggregate density and the ultimate strength range of the developed concrete.

These are the one works that motivate the study of the technical viability of the use of CDW obtained from concrete posts, in the composition of a concrete for structural purposes, since the source of the aggregate guarantees a homogeneity of its characteristics, both in relation to the density and the constituent materials and other features.

The viability of using this aggregate also enables the sustainability of posts production chain that grows every year along with urbanization, since the steel obtained from the demolition of the posts is already recycled and used for other purposes.

According to data provided by the company of electricity distribution in the state of Tocantins, [10], in 2019 3,940 reinforced concrete posts were discarded. According to the company, the main factor in the demolition of electricity distribution poles is the collision of cars, which damages completely the posts. Table 1 shows the number of posts lost in 2019 per month and the monthly average.

Table 1. Number of damaged posts during 2019.

Month	Quantity of posts
January	124
February	218
March	297
April	222
May	293
June	243
July	371
August	270
September	277

October	515
November	630
December	480
Total	3,940
Monthly Average	328

II. METHODOLOGY

In order to achieve the proposed objectives, the applied experimental methodology compared the results of resistance to compression and flexion of samples from posts dosed with conventional concrete and concrete posts with the substitution of natural coarse aggregate for recycled aggregate.

2.1 Sample preparation and crushing

In this phase, the preparation of the post residues was carried out, with the separation of the concrete from the steel bars. The removal of the bars was made manually in the company that manufactured the posts, with the aid of mallets and pneumatic hammers.

After the separation, the demolished concrete was sent for crushing in a jaw crusher, in order to obtain a similar granulometry to that of the natural aggregate, with a maximum characteristic length of 19 mm, the same maximum characteristic length of the natural aggregate with the removal of the fine material.

2.2 Characterization of the aggregate

Following the parameters of [11], the granulometric compositions of the coarse aggregate were determined, both natural and recycled, as well as the granulometry of the coarse aggregate.

To determine the specific mass and unit mass of the fine aggregate, the guidelines of [12] were adopted, it should be noted that only natural fine aggregates were used. For coarse natural (pebble) and replacement aggregates, the same determinations were made based on [13].

2.3 Concrete dosing

In this stage, the concrete was produced with the reference mix design, dosed by the method of the Brazilian Portland Cement Association (ABCP) and with the replacement of the coarse aggregate crushed concrete from the discarded posts.

This method consists of collecting data in the laboratory of the materials used in the production of concrete, they are: fineness modulus (MF), maximum characteristic length (MCL), humidity (h%), specific (γ) and unitary (δ) mass. From the data obtained, tables and graphs were used to

support obtaining the appropriate proportions for the mix design.

The f_{ck} (characteristic strength at 28 days) of 25 MPa was defined for an aggressiveness class II [14], a moderate aggressiveness class and a low risk of deterioration of the structure. Another characteristic adopted was a concrete slump equal to 50 ± 10 mm.

Based on the mix mass, it was calculated the consumption of the inputs needed to make 6 specimens for each mixture, in percentages of 0%, 25% and 50% of replacement.

2.4 Characterization of dosed concrete

In the fresh state, for the determination of the slump of the material, the criteria presented in [15] were used, which determines the consistency by slump of the cone trunk, known as slump test.

In the hardened state, tests were carried out to determine water absorption, void ratios and specific mass, resistance to axial compression and, finally, bending tests on posts manufactured with the new concrete matrix.

The determination of water absorption, void ratios and specific mass were made based on [16], for this assay, two specimens were molded for each mixture, totaling 6 (six) specimens.

Three mixtures were performed, 6 specimens per mixture, totaling 18 specimens which, according to [17], were molded with 10x20 centimeters for each sample. After 28 days of normal curing, the samples were taken to the hydraulic press and broken according to [18], in order to obtain their compressive strength.

2.5 Bending Test on electric posts

The last and main test performed is the bending test on posts, which seeks to verify the resistance of the posts when subjected to bending efforts. 6 poles with a height of 7.5m were molded and tested according to the standard requirements of [19].

The procedure consists of the following stages:

The setting of the base of the post to the test bench, with the length provided by the following equation:

$$e = \frac{L}{10} + 0,60$$

Where: "L" is the nominal pole length in meters and "e" is the footing length in meters. With the footing measure thus obtained, the post is fixed to the bench.

The distance from which the effort should be applied to the top of the post must be 200mm. The application and

withdrawal of effort should always be slow and gradual, avoiding sudden sweeping of the load during the tests.

With the post set, the effort R_n , corresponding to its nominal resistance, was applied at a distance of 200mm from its top, for at least 1 (one) minute, to allow the accommodation of the footing.

After the setting, an effort is applied at 1.4 times the R_n , corresponding to the minimum rupture load of the pole, for a minimum of 5 (five) minutes. After the time of the first application, the load is progressively increased until the rupture load of the part is obtained.

III. RESULTS AND DISCUSSIONS

3.1 Granulometry

The results of the granulometric characterization test of the natural fine aggregate revealed the fineness modulus of 3.39mm and the maximum characteristic length and 4.8mm.

In the analysis of the results collected in the granulometric characterization of the recycled aggregate (Figure 1 1), it was found a better distribution among the fractions retained on the sieves when compared to the natural aggregate.

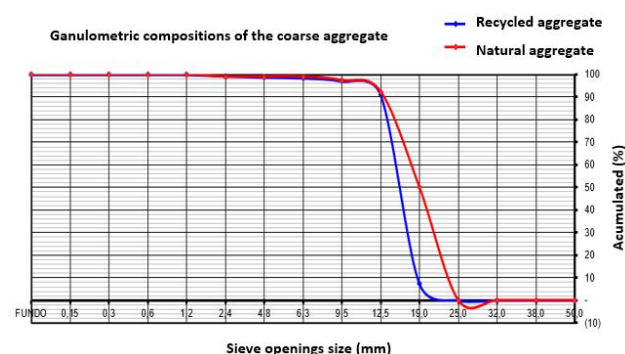


Fig.1: Granulometric distribution of coarse aggregates.

The result of this is a higher percentage of material with a diameter of less than 12.5mm as well as a greater amount of powdery material in the sample, which can affect the slump and resistance of the dosed concrete, since this material can subtract hydration water and kneading of the cement.

3.2 Water absorption, specific and apparent mass.

The specific mass, apparent mass and water absorption values of recycled and natural coarse aggregates can be observed in the table below.

Table 2. Results of water absorption, specific and apparent mass of the aggregates.

Properties	Natural Aggregate	Recycled Aggregate
Water Absorption (%)	1.19	2.88
Specific mass (kg/m ³)	2,650	2,560
Unit Mass (kg/m ³)	1,360	1,270

The percentage of water absorption by the recycled aggregate is much higher than that of the natural aggregate, a common situation when it's about demolition material. The presence of fine aggregate and the porosity of the demolished concrete are the main responsible for the absorption of the mixing water, which ends up impairing the workability of the dosed concrete.

For the fine aggregate used, the specific and apparent mass values found are shown in the table below.

Table 3. Values of specific and unit mass of the fine aggregate.

Properties	Natural Aggregate
Specific Mass (kg/m ³)	2,630
Unit Mass (kg/m ³)	1,670

3.3 Concrete mix design in mass

The dosages elaborated according to the ACI method, to resist the compression of 25 MPa, which is the adequate strength for the manufacture of new concrete posts, with slump of 100mm for reinforced parts, with a deviation of 4.0 for reasonable control, resulted in the mass proportions shown in table 04

3.4 Slump

The dosage made with natural aggregates showed good workability and consistency within satisfactory standards, observing the standards established by [20] and [21]. The table 4 shows the results obtained for both mix designs.

Table 4. Slump values for different dosages.

Properties	Reference	25%	50%
Slump	110mm	100mm	85mm

What is observed is that the dosage with 25% recycled coarse aggregate did not show a substantial change in its workability when compared to the reference mix design. However, on the second mix design, with a 50% substitution, there was a reduction in the concrete slump,

even though, within the tolerance limits of +/- 2.0 mm of the slump test.

3.5 Concrete in the hardened state

According to the adopted methodology, tests were carried out on cylindrical shape specimens and on molded posts. At 28 days of curing, axial load and water absorption tests were made on the cylindrical specimens, at *CEULP / ULBRA materials and structures laboratory, in Palmas - TO*.

The results of resistance and absorption can be seen in table 5.

Table 5. Values of compressive strength and water absorption by concrete.

Concrete Specimen	Rupture Stress Average (MPa)	Average Absorption (%)
Reference	28.05	3.85
25%	26.40	3.59
50%	25.65	4.54

Both results of compressive strength and water absorption remained within the adopted reference values. [22] fixes the average absorption of the specimens by up to 5.5% and the individual limit of water absorption by concrete, for electric posts, up to 7%.

3.6 Bending resistance

The bending tests (Figure 2) were carried out at the company *Concreto Artefatos de Cimento in Araguaína Tocantins*, with 6 posts of 5m length, two specimens of each mix design, all with an approximate age of 28 days of cure.



Fig.2: Bending test on molded posts.

Deflection results were obtained with the project load (150 kgf), residual deflection, number of cracks, in addition

to the modulus of rupture. Table 6 shows the results obtained during the experiment.

Table 6. Deflection values, rupture load and number of cracks in posts tested on bending.

Post	Deflection (cm)	Residual Deflection (cm)	Number of Cracks		Modulus of Rupture (kgf)
			Face A (Minor inertia)	Face B (Major inertia)	
Reference – Post 1	24	3,5	17	14	350
Reference – Post 2	23	3,5	23	17	350
25% - Post 1	22	3,5	26	21	330
25% - Post 2	23	3,5	19	20	300
50% - Post 1	24	2,0	33	27	300
50% - Post 2	24	2,0	38	29	300

As noted in the table above, the deflections for the nominal load of 150 kgf applied in the direction of lower inertia did not exceed the limit established by [19]. The deflections of all evaluated posts were within the range of 5% of their height, which corresponds to 37.5 cm.

The residual deflections measured after the removal of the load were below the established limit, 0.5% of the post nominal length

The posts with 25% replacement showed residual deflections identical to those of the posts with a reference mix design, while the posts molded with 50% replacement showed a reduction in their residual deflections, which may be an indication of an increase in their elasticity module (less plastic deformation), still, meeting the parameters of the standards for concrete posts.

The number of cracks when applying the force of 140% of the nominal load value was accentuated in posts with 50% replacement, however, with their holes remaining below the limit of 0.30mm. After the load ceased, the cracks closed,

becoming capillary pores, meeting the requirements of the standard, as shown in Figure 3.



Fig.2: Identification of closed cracks after bending test.

As for the rupture load, all posts reached similar results ranging from 300 and 350 kgf, both meeting the minimum of twice the nominal load value (150 kgf) established by the standard for concrete posts.

IV. CONCLUSION

The results obtained in this study were confirmed when compared with the concepts used in the research and through experimental tests.

It can be said that the use of recycled concrete aggregates, originating from the crushing process of waste posts, presents itself as a potential solution for the manufacture of new concrete electric posts. Its quality allows a satisfactory behavior from the point of view of its mechanical resistance, the main aspect observed in the approval and acceptance of a concrete pole.

It is verified that the use of recycled concrete aggregates contributes to the removal of a significant volume of waste per discarded unit, thus contributing to a reduction in the amount of material that could be discarded. Not least, there would be a decrease in the extraction of natural aggregates obtained from mineral deposits.

REFERENCES

- [1] JOHN, V. M.; ANGULO, S. C.; KAHN, H. Controle da qualidade dos agregados de resíduos de construção e demolição reciclados para concretos a partir de uma ferramenta de caracterização. 2006.
- [2] ANGULO, Sé. C.; JOHN, V. M. Normalização dos agregados graúdos de resíduos de construção e demolição reciclados para concretos e a variabilidade. IX Encontro Nacional de Tecnologia do Ambiente Construído, p. 1613-1624, 2002.

- [3] PINTO, T.P. Metodologia para a gestão diferenciada de resíduos sólidos da construção urbana. São Paulo.189p. Tese (Doutorado) – Escola Politécnica, Universidade de São Paulo. 1999.
- [4] MOREIRA, L. H. H. Avaliação da influência da origem e do tratamento dos agregados reciclados de resíduos de construção e demolição no desempenho mecânico do concreto estrutural. 2010. Tese de Doutorado. Universidade de São Paulo.
- [5] PIETRA, L. Avaliação do concreto com agregados graúdos reciclados e resíduos de construção e demolição reforçado com fibras de aço. 2005. 129 p. Dissertação (Mestrado). Escola Politécnica da Universidade de São Paulo, São Paulo, 2005.
- [6] CARRIJO, P. M. Análise da influência da massa específica de agregados graúdos provenientes de resíduos de construção e demolição no desempenho mecânico do concreto. São Paulo: USP, 2005. Dissertação (Mestrado em Engenharia Civil), Escola Politécnica da USP, Universidade de São Paulo, 2005.
- [7] MIRANDA, L. F. R.; ANGULO, S. C.; CARELI, E. D. A reciclagem de resíduos de construção e demolição no Brasil: 1986-2008. Ambiente Construído, v. 9, n. 1, p. 57-71, 2009.
- [8] TENÓRIO, J. J. L. et al. Avaliação de propriedades do concreto produzido com agregados reciclados de resíduos de construção e demolição visando aplicações estruturais. 2007.
- [9] GOMES, S. C.; PIMENTEL, L. L. Análise da viabilidade de incorporação de agregados reciclados provenientes do beneficiamento de resíduo classe A na produção de concretos c20 e c30. 2015.
- [10] ENERGISA. Relatório interno de geração de resíduos sólidos. Palmas, Tocantins. 2016.
- [11] ABNT. NBR NM 248. Agregados - Determinação da composição granulométrica. Rio de Janeiro 2003.
- [12] ABNT. NBR NM 45. Agregados - Determinação da massa unitária e do volume de vazios. Rio de Janeiro 2006.
- [13] ABNT. NBR NM 52. Agregado miúdo - Determinação de massa específica e massa específica aparente. Rio de Janeiro 2009.
- [14] ABNT. NBR 6118. Projeto de estruturas de concreto – procedimento. Rio de Janeiro 2014.
- [15] ABNT. NBR NM 67. Concreto - Determinação da consistência pelo abatimento do tronco de cone. Rio de Janeiro 1998.
- [16] ABNT. NBR 9778:2009 Argamassa e Concreto Endurecidos: Determinação da Absorção de Água, Índice de Vazios e Massa Específica. Rio de Janeiro, 2009. 3 p.
- [17] ABNT. NBR 5738:2015. Concreto – Procedimento para moldagem e cura de corpos de prova.. Rio de Janeiro, 2015.
- [18] ABNT 5739:2018. Concreto – Ensaio de compressão em corpos de prova cilíndricos. Rio de Janeiro 2018.
- [19] ABNT. NBR 8451-3. Postes de concreto armado e protendido para redes de distribuição e de transmissão de energia elétrica - Parte 3: Ensaio mecânicos, cobrimento da armadura e inspeção geral. Rio de Janeiro 2020.
- [20] ABNT. NBR 11172 Tb 371 - Aglomerantes de Origem Mineral. Rio de Janeiro 1990.
- [21] ABNT. NBR 12655. Concreto de cimento Portland — Preparo, controle, recebimento e aceitação — Procedimento Rio de Janeiro 2015.
- [22] ABNT. NBR 8451-4. Postes de concreto armado e protendido para redes de distribuição e de transmissão de energia elétrica - Parte 4: Determinação da absorção de água. Rio de Janeiro 2020.