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EXPERIMENTAL ANALYSIS OF THE REUSE OF WASTE FROM PREFABRICATED CONCRETE PILES: CASE OF A PORT WORK

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ABSTRACT

Construction waste in large works is poorly studied. Port works have peculiar characteristics and it is interesting that designers have indicators of waste generation. In this work, the generation of waste from the activity of logging concrete piles and their reuse process was analyzed, generating indicators for the project. The research methods covered the quantification of the reuse of piles in the activity itself and the quantification of waste intended for disposal. Results showed that 49.2% of piles used leftovers, which represented 12.98% of the total length driven (242210 m). The study showed that the average apparent density of concrete waste from piles comminution is 0.47 ± 0.02 tons.m-1 on average. For the metal scrap 0.70 tons m-³. The results showed the great potential for reuse of materials that has the activity of driving concrete piles, which is environmentally desirable. It is concluded that the indicators obtained are an important instrument for waste area designers, especially in the area of port buildings, where there are few data available in the literature.

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INTRODUCTION

Over the last thirty years, both researchers and practitioners have paid growing attention to the negative environmental impacts (air pollution from factories and traffic, marine pollution and industrial wastewater, ship-generated pollution such as oily wastes, numerous solid wastes, underwater noise, and ballast water) of port operations and development (Di Vaio et al., 2019; Mohee et al., 2012). Ports tend to assume environmentally sustainable and energy-efficient behavior, allowing some authors to introduce the concept of "green ports" as one of the first frameworks for aware and sustainable port strategies (Di Vaio et al., 2019). Green ports thus develop, implement and monitor practices for preventing and reducing their environmental impacts above the requirements for regulatory compliance (Acciaro, 2015). The literature on green ports and their strategies and duties is still scarce (Di Vaio et al., 2019). Pollution management with regards to solid waste management, in particular, requires that a comprehensive and updated knowledge of the several solid wastes streams be obtained from as many as of the waste generators (Zuin et al., 2009). The construction industry, a major generator of direct and indirect jobs, has a significant participation in global economic development. It is estimated that the volume of construction and demolition waste (CDW) in Brazil represents approximately 67% of the total municipal solid waste (MSW) generated in the country (Schamne and Nagalli, 2018). This situation stems from the low efficiency of the management process of the CDW, which ultimately provides inadequate treatment and disposal of waste (Schamne and Nagalli, 2018). Research on construction and demolition waste has been increasing significantly (Yuan, 2013). As the generation of construction and demolition waste is inevitable, in urban environments, during the consolidation of cities, during periods of population expansion efforts need to be permanent and necessary to carry out further management in the construction and demolition sector (De Melo et al., 2011). One of the strategic sectors for the economy of a country is the port, responsible for the flow of materials and goods. Some

factors that contribute to the waste generation are projects with lack of detailed specifications, materials with little quality that are adopted by low cost, lack of care with storage and transportation of materials inside and outside the work, lack of skilled labor, little control and supervision of executive processes, among others. Knowledge of the waste index generated is important to define a waste management strategy. It allows, for example, to define the size of collection containers, the best form of internal and external transport, i.e. waste logistics (Nagalli, 2014). In this context, we emphasize the need for studies and tools that help in the quantification of solid waste to be generated in all types of works, considering the various variables that influence the generation of solid waste and densities (Da Paz, 2019). In the construction industry, port works are among the least studied in terms of waste generation and management. The objective of this research was to investigate the generation of waste resulting from the activity of logging concrete piles, considering the process of reuse of leftovers. It was intended to obtain generation indicators that could be used in waste management projects and systems in future port works.

MATERIALS AND METHODS

Case description: The port infrastructure work whose waste was studied is the construction of cradle 218, dolphins and retroarea of cradle 217 (Figure 1), in the far east of the Container Terminal of Paranaguá (TCP), in the municipality of Paranaguá, Brazil. This is the largest and most important port work carried out in Brazil from 2016 to 2019. This is a complete port work, which covered the usual services of service sites (carpentry, frame center, concrete machining, cafeteria, outpatient clinic, offices, etc.), production of precast concrete parts for use in the work, pile stake/metal dressing, concrete piles, ferries, land cranes, etc., and related services.

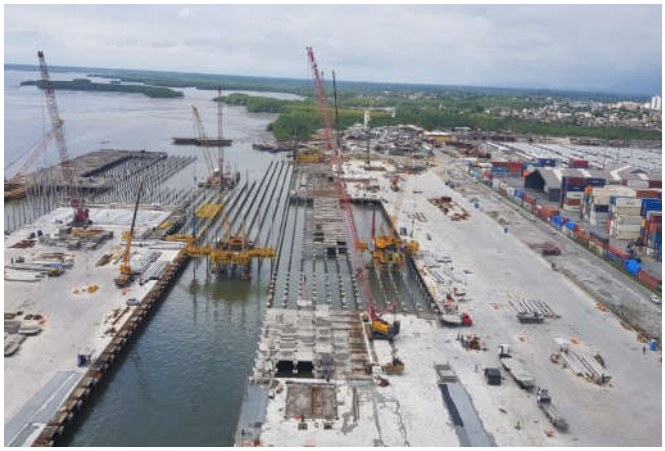

Figure 1. Overview of the work during its execution

The retroarea in which the concrete piles were spiked was 150018.70m², with 7424 reinforced concrete piles with an average length of 32.63m. In the expansion work, there was a very large variation in relation to the length of the piles, which even measured between 23.0m to 49.0m deep. The elements had 11.0m, so it took scrap cuts in the stakes so that they could reach the project quotas. Only the first longitudinal line of the work had a different crushing dimension, the rest of the stakes had the same crushing dimension.

The swings were performed through cutters, using discs specially designed for this type of operation.

Methodological approach: Aiming at the generation of quantitative indicators of waste applicable to the concrete pile stake mine service, the reuse of pile pieces was studied; (ii) the generation of waste from unused pile pieces. Centrifugal concrete piles were prefabricated with a standard length of 11.0 meters. Metal gloves were used as tips, with a height of 80cm, thickness of 5mm and with locking pins for better fixation. As the total length of the piles ranged from 23.0 to 49.0m, these were amended as needed, razing them in the project quota. The research consisted of evaluating the technical criteria for reusing these piles and their impact on waste generation. An engineer and two quality officers performed the sorting of pile leftovers, using various methods to verify the integrity of elements and piles with less than two meters were automatically discarded. The second research front consisted of assessing the quantity and characteristics of construction waste generated when pile pieces could not be reused. The technique adopted in the work was to break up such pieces of piles and turn them into concrete aggregates for landfilling and steel for recycling. In this stage, 20 samples of pile remains were selected. The samples were measured and then ruptured separately with the aid of a hydraulic backhoe with a breaker. For each pile, concrete steel was separated. By means of a backhoe, the broken material was introduced into a 5m³ stationary bucket. Then the stationary bucket containing the waste was hoisted through a Model SANY 70t crane and weighing through the crane's own scale was performed. The weight of the cables, lifting straps and the weight of the bucket were discounted and equated to 2t. The sequence of activities in this stage of the survey can be seen in Figure 2.

Figure 2. The sequence of activities of the second stage of investigation: A) breaks; B) load; C) weighing and D) discharge

Table 1. Results of the second stage of the investigation

Stationary Bucket ID	1	2	3	4	5
Length of the pile leftover (m)	3.65	3.09	3.34	2.90	3.15
	2.79	4.25	3.39	2.68	3.61
	3.16	4.35	2.70	2.79	3.48
	3.25	3.07	2.95	3.89	3.06
∑ Length (m)	12.85	14.76	12.38	12.26	13.3
Waste Mass (tons)	6.2	6.5	5.6	5.8	6.4
Mass / Length relation (tons / m)	0.48	0.44	0.45	0.47	0.48

As the waste volume of a stake overstock was lower than the volume of the stationary bucket, as many piles were ruptured as necessary for the complete filling of stationary buckets.

About 4 leftover piles per bucket were necessary to perform the procedure. The same procedure was adopted for scrap metal.

RESULTS AND DISCUSSION

The first investigative line showed that the use of pile leftovers in the work was 49.2%.

Of the 7,424 were spiked, 3656 used leftovers from other stakes. The total length of piles spiked in the work was 242210.0 m. Of these, 12.98% (31436.7 m; 3888 pieces) were reused piles. In other words, half of the piles were composed of 11m pieces devastated in the design quota and the other half of the piles consisted of pieces of piles reused from the razing process. The second line of investigation obtained the results presented in Table 1. From the analysis of Table 1 it is observed that in each of the stationary buckets, waste of 4 pile pieces was introduced, whose total lengths ranged from 11.26 to 13.3m. Thus, the apparent density of concrete waste of the piles ranged from 0.44 to 0.48 tons.m-1 (0.47 ± 0.02 tons.m-1 on average). The indicator of apparent density per pile linear meter is convenient to the designer, as it allows to predict the waste regardless of the size of the work. The broken concrete waste presented sizes ranging from 0.05 to 0.45m on average. The results of the metal scrap measurement showed an average bulk density of 0.70 tons m-³ (3.48 tons per 5m³ bucket). According to design data, the linear weight by pile meter was composed of steel and concrete was 0.45 tons / m. Considering the results of the measurements, it is noted that concrete waste sometimes exceeded this projected value. This is attributed to the incorporation of water (dampness) by waste since they have been stored in the open.

Conclusion

The study showed that the generation of residues in the activity of the concrete pile stake in the analyzed work is significant. However, it was observed that a significant part of the potential waste of the activity is reusable in the process itself. It was possible to calculate indicators of waste generation for the activity, values that can assist designers in future port works. We see the need for further studies to be carried out for other activities of port buildings, and other large works, since they have characteristics of generating waste quite different from buildings, living up to specific indicators.

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