POTENTIAL REPLACEMENT OF CONVENTIONAL AGGREGATE BY RECYCLED AGGREGATE IN CONSTRUCTION WORKS IN THE CITY OF SALVADOR-BA.

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Abstract: Two of the main issues in the civil construction industry concerns how to mitigate the extraction of natural resources for the production of supplies and how to reduce the sector's generation of waste in urban regions. The main objective of this article is to estimate the potential for replacing natural aggregates with recycled aggregates in construction works in the city of Salvador. A bibliographic review of articles, dissertations, book chapters and journalistic articles available on the Internet was carried out in the search for data that could support the calculation of the sought estimate. The results indicate a probable substitution potential, as well as the existence of a market niche to be explored by construction waste recycling companies.

Keywords: Construction. Recycled aggregate. Construction and demolition waste (CDW).

POTENCIAL DE SUBSTITUIÇÃO DE AGREGADO CONVENCIONAL POR AGREGADO RECICLADO EM OBRAS DE CONSTRUÇÃO NA CIDADE DE SALVADOR-BA.

Resumo: Duas das principais questões da indústria da construção civil dizem respeito a como mitigar a extração de recursos naturais para a produção de insumos e, como diminuir a geração de resíduos do setor nas regiões urbanas. Este artigo tem como objetivo principal estimar o potencial de substituição de agregados naturais por agregados reciclados em obras de construção da cidade de Salvador. Foi realizada uma revisão bibliográfica de artigos, dissertações, capítulos de livros e matérias jornalísticas disponíveis na Internet na busca de dados que pudessem subsidiar o cálculo da estimativa procurada. Os resultados indicam provável potencial de substituição, bem como a existência de um nicho de mercado a ser explorado por empresas de reciclagem de resíduos da construção civil.

Palavras-chave: Construção. Agregado reciclado. Resíduo de construção e demolição (RCD).

1. INTRODUCTION

Aggregates play a fundamental role in the execution of any kind of construction, once they give the concrete characteristics such as mechanical resistance, fluidity and workability. However, just as any other mineral, aggregates are finite resources, leading to a need for sustainable use to guarantee their disponibility in future. One of the options to extend the availability of these resources is by replacing common aggregates for recycled aggregates.

From the explanation above, this paper raises the following issue: what volume of common aggregate could be replaced by recycled aggregates in Salvador-BA construction's? Based on this question, data on the consumption of aggregates for civil construction in Salvador-BA were sought, as well as the production of recycled aggregates in the city.

The objective is to estimate the potential of substitution of the common aggregate by the recycled one, considering technical limitations of the use of the recycled aggregate, especially for structural purposes.

Relevance of this research is based on the hypothesis that the reuse of civil construction waste can represent the opening of new productive and commercial chains linked to civil construction in Salvador, and also subsidize sustainable solutions to decrease the environmental impact of such an industry.

1.1. Theoretical Foundation

As reported by Valverde (2001), the term "agregados para a construção civil" is used in Brazil to identify a segment of the mineral sector that produces raw or processed feedstock for instant use in civil construction. On the other hand, according to ABNT NBR 7211, aggregates can be classified as "fine" (grains smaller than 4,75 mm and larger than 0,15 mm) and "coarse" (grains smaller than 75 mm and larger than 4,75 mm). [1,2]

Sand is the most used fine aggregate and can be found in different granulometries. It is widely employed in production of mortar, concrete and other materials, due to its capability of fulfilling and grant workability to the mixtures.

The most utilized coarse aggregate in civil construction is the gravel. These are produced from the crushing of rocks of varied sort, as granite, basalt and calcareous, being used in the production of the concrete, becoming essential in high resistance concrete and large construction.

The mixing of cement plus sand and gravel arises to concrete and prefabricated artifacts. In their natural state, aggregates can be find in railways, pavings and coatings. In concrete, aggregates represent 70 to 80% of the total mix volume. [3]

According to Guandagnini (2018), concrete is the second most consumed material by humankind. Available information on the National Association of Construction Aggregate Producers (ANEPAC) indicates a global mineral production of 65 billion tons, of which 45 billion tons were aggregates for construction, during 2014. In Brazil that was the year of greatest production of these materials: 741 million tons

of aggregates were produced in that year. In Brazil 741 million tons were produced in that year with 21% headed to construction in the country's northeastern region, totalyzing about 154 million tons. [4, 5]

Once mineral resources are finite and society's demand for construction is rising, the scenario becomes paradoxical. Based on a report by the Cimento Itambé portal the global between now and 2060, the global demand for sand could increase up to 45% in relation to the current consumption of this material. As a result, there is a real risk of scarcity of this material, which makes it a priority for the civil construction industry to search for solutions that delay the depletion of the mineral deposits from which its inputs are extracted. [6]

From the point of view of Luz and Almeida [7]:

> *The application of alternative aggregates are justified in case of conventional aggregate exhaustion, especially those of an alluvial nature, or when its exploitation promotes environmental impacts, or when rises the distances among the queries or sand harbors to consumer market, contributing to raise the costs with aggregates' transportation to metropolitan regions in the country. (Luz and Almeida, 2002, our translation)*

The above-mentioned authors draw attention to economic impacts resulting from the scarcity of natural resources (*e.g.*, the rise of costs with aggregates' transportation). A possible solution is to replace conventional aggregates with alternative ones, such as civil construction waste, blast-furnace slag and polymers, once they can be found in industrial hubs close to metropolitan regions.

Recycled aggregates are obtained from the use of specialized equipment for the processing of class A construction waste (CDW) (CONAMA, 2002). Those waste is collected, separated, crushed and classified according to its granulometry, being able to partially or completely replace the conventional aggregate in the concrete or mortar. However, there is a lot of resistance from engineers in the use of non-conventional aggregates. [8]

Metropolitan region of Salvador has CDW recycling plants, designated and equipped industrial area where Class A waste is transformed into three distinct product defined as Concrete Recycled Aggregate (ARCO)[1], Cement Recycled Aggregate (ARCI)[2] and Mixed Recycled Aggregate (ARM)[3] (MELO, 2011). This fact presupposes that there is availability of recycled aggregates to meet local demand without compromising the costs related to the material transportation. [9]

Salvador Urban Cleaning Company reported a collection of 748.182,22 tons of CDW during 2022 in the city. Of this total, 727.042,84 tons were sent to CDW recycling plants for sorting and processing or disposal in a suitable landfill. These relevant numbers do not include CDW improperly discarded or collected by a private company. [10]

As explained by Paulino *et al.* (2023), the effective production of recycled aggregates has been lower than the maximum capacity of the plants, not breaking the

[1] Recycled aggregate consisting predominantly of concrete waste. (ABNT, 2022)

[2] Recycled aggregate consisting predominantly of cementitious materials (concrete, mortar, precast concrete blocks, etc.), which may include reduced levels of red ceramic. (ABNT, 2022)

[3] Recycled aggregate consisting of a mixture of cementitious materials (concrete, mortar, precast concrete blocks, etc.) and ceramic materials (red ceramic blocks and tiles, etc.). (ABNT, 2022)

mark of 20 million tons per year, which is less than 50% of their maximum capability, which is about 45 million tons per year. [11]

Table 1 - Construction and demolition waste index and brazilian recycling plants productive capacity.

Índice	2013	2014/2015	2017/2018	2019/2020
Geração de resíduo anual (t)	100.516.000	102.225.000	103.830.000	105.073.500
Produção de AR extrapolada (t/ano)	19.830.064,50	20.712.000,00	15.679.980,00	16.944.692,00
Índice de reciclagem (AR produzido/RC gerado) – extrapolado	19,7%	20,3%	15,1%	16,1%
Capacidade máxima de produção de AR – extrapolada (t/ano)	42.191.626,60	46.026.666,67	44.799.942,86	50.487.520,00
Capacidade máxima de reciclagem (Cap. Máx./Geração RCD) – extrapolada	42,0%	45,0%	43,1%	48,0%

Fonte: PAULINO, R. S. et al, 2023, p. 93.

The table above demonstrates that the recycling rates of Construction and Demolition Waste (CDW) and the production capacity of Brazilian recycling plants have been similar over the last years of the detailed historical series. However, the number of CDW recycling plants has shown variations.

Data obtained from the sectoral survey carried out by the Brazilian Association for Recycling of Civil Construction and Demolition Waste (ABRECON) show that the association surpassed the number of 300 members, of which around 100 are public. Considering non-associated plants, it is estimated that in Brazil the total number of plants currently reaches approximately 360 recycling units. [12]

2. METHODOLOGY

From the bibliographic review of the previously cited sources, an attempt was made to define a methodology to estimate the potential for replacing conventional aggregate by the recycled one in construction located in Salvador, knowing that conventional coarse aggregate can be substituted by recycled one just for non-structural purposes or partly for structural purposes.

First factor to be calculated to reach the target was the total mass of traditional aggregate consumed annually in the defined region. For these purposes, it was considered data about the consumption *per capita* available in the bibliography and by the most recent Brazilian Censo's stat about Salvador's population, that indicates 2.418.005 inhabitants (IBGE, 2023). [13]

Then it was necessary to appraise the generated mass of CDW annually in Salvador, as well as the use rate of recycled aggregate production. This information was brought in this paper from documents by Limpurb and the paper by Paulino *et al*.

Finally, a complicating factor was presented for an accurate conclusion on the expected estimate: construction works that use conventional construction systems do not follow a single standard regarding the amount of concrete used, as it depends on the project, the terrain, and the techniques and professionals employed in the execution. Therefore, how can we identify the masses of fine and coarse aggregates used in the production of non-structural concrete in construction works carried out in Salvador annually?

This information was not located in the searched bibliography. Then, a hypothetical index was used: of the total mass of aggregates used in a work, it is assumed that 15% of sand and 10% of gravel are used in the production of non-structural concrete. This hypothesis was raised from the proportions of fine (60%) and coarse (40%) aggregate produced in Brazil, in relation to the total production of natural aggregate.

3. RESULTS AND DISCUSSION

The per capita consumption of natural aggregate in the Northeast region of Brazil in 2014 was 2.7 tons per person. Projecting this rate to 2022 and considering the population of the city of Salvador as determined in the latest census, the current consumption reaches approximately 6,626,965 tons of natural aggregate annually in the capital of Bahia, with 3,976,179 tons of sand and 2,650,786 tons of gravel.

By estimating, based on the chosen method, the possibility of substituting 15% of sand and 10% of gravel with recycled aggregates, it would be possible to save 861,505.45 tons per year of natural resources (596,426.85 tons of sand and 265,078.60 tons of gravel annually). This, therefore, would be the estimated potential for replacing natural aggregate with recycled aggregate in construction projects in the city of Salvador.

It remained to be seen whether the annual production of recycled aggregate in the region would be sufficient to meet this demand. Then, the average of the “Recycling index (produced AR/generated RC) – extrapolated” was used, according to Table 1 of this work, which corresponds to the rate of 17.8% of recycled aggregate produced in relation to the total RCC generated in the city. Given that 727,042.84 tons of CDW were sent to recycling plants in Salvador in 2022, the result is 129,413.62 tons of recycled aggregate being produced annually in the capital city. This indicates the potential for increasing the current production of recycled aggregate in the Metropolitan Region of Salvador by at least 5 times, either through the implementation of new CDW recycling plants or by promoting a culture of recycling and reusing these waste materials on construction sites.

It is worth mentioning that this result aligns with what was shown in the researched bibliography regarding the national scenario, where an increasing number of CDW recycling plants are being established. This denotes the development of this sector, represented not only by the number of companies and/or the volume of recycled aggregate produced but also by the growing amount of financial resources invested in innovations to improve production processes, standardization, and the quality of the aggregate produced. As evidence of this progress, the update to NBR 15.116b in late

2021 brought a significant change regarding the possibility of partially replacing natural aggregate with recycled concrete aggregate (ARCO) in the production of structural concrete as well. [14]

4. CONCLUSION

This study presents relevant data from both an economic and environmental perspective regarding the chain of generation and recycling of Construction and Demolition Waste (CDW) in the metropolitan region of Salvador. However, further in-depth research and field studies are needed to confirm the estimations made here.

It is evident that the substitution of natural aggregates with recycled aggregates in the construction industry is a sustainable approach that contributes to reducing the extraction of natural resources, minimizing waste, and preserving the environment. Moreover, the local production of recycled aggregates can promote the development of a circular economy, stimulating job creation and sustainable growth.

Nevertheless, there are challenges to overcome, and proper awareness and regulation must be promoted to ensure the quality and reliability of recycled aggregates. Case studies and successful examples from around the world demonstrate that the use of recycled aggregates is a viable and efficient alternative in the construction industry.

The adoption of a sustainable approach in the construction industry, with the utilization of recycled aggregates, is essential to promote a more responsible sector and contribute to a more sustainable and balanced future.

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