Quantitative analysis of mortar waste in civil construction in Brazil between the years 2009 and 2018

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Abstract
Civil construction is one of the main generators of economic and social development in Brazil. However, due to the way it is executed, it is also one of the sectors that causes the most environmental impacts. At all stages of its production chain, from the extraction of raw materials; industrialization; commerce and services; and the generation of waste that has the potential to cause damage to the environment. The inadequate final disposal of civil construction or demolition waste can generate major environmental impacts, such as soil, river, and air pollution. In this context, in the present research, a survey of the disposal of mortars collected on public roads in all Brazilian municipalities from 2009 to 2018 was conducted. The analysis used data from the Brazilian Association of Public Cleaning and Special Waste. It was found that, between 2009 and 2018, 1,142,065 T/day of RCC were collected and that the largest amount of this waste was mortars, with 719,501 T/day, which were discarded on public roads in Brazil. Recycling this waste would be a solution for the mitigation of environmental damage caused by improper disposal and, consequently, preservation of the environment.

Keywords: Environmental impacts. Waste. Mortar. Disposal.

Resumo
A construção civil é uma das principais geradoras de desenvolvimento econômico e social no Brasil. Entretanto, devido à maneira que é executada, também é um dos setores que mais causam impactos ambientais. Em todas as fases da sua cadeia produtiva, desde extração de matérias-primas; industrialização; comércios e serviços; e geração de resíduos que tem potencial de causar danos ao meio ambiente. A disposição final inadequada de resíduos da construção civil ou de demolição pode gerar grandes impactos ambientais, tais como a poluição do solo, rios e ar. Neste contexto, na presente pesquisa foi realizado um levantamento do descarte de argamassas coletadas em vias públicas de todos os municípios brasileiros, entre 2009 a 2018. A análise realizada utilizou dados da Associação Brasileira de Limpezas Públicas e Resíduos Especiais. Verificou-se que, entre 2009 a 2018, foram coletados 1.142.065 t/dia de RCC e que a maior quantidade deste resíduo foi de argamassas, com 719.501 t/dia, que foram descartados em vias públicas no Brasil. A reciclagem desses resíduos seria uma solução para a mitigação dos danos ambientais causados pelo descarte inadequado e, consequente, preservação do meio ambiente.

Palavras-chave: Impactos ambientais. Resíduos. Argamassas. Descarte.

1 Introdução

The civil construction sector has an important impact on economic and social development, being a source of job creation, and its activity is related to meeting basic needs, such as housing (RESENDE, 2007). However, besides the importance emphasized, works can cause impacts that influence the ecosystem and can alter it drastically or even cause its extinction, through the flooding of large areas, cutting of vegetation, sealing of the soil and its construction phase that ends up generating noise, waste, etc. (SPADOTTO, 2011).

Mesquita (2012) says the construction sector is one of the largest consumers of raw materials, corresponding to the consumption of 20 to 50 % of what the whole society consumes. Silva (2003) said it is the industry that causes more environmental impacts, considering the steps from extraction to the generation of its products.

According to Santoro and Kripka (2016), the production, extraction, use and transportation of materials contribute to the pollution of the planet. As the civil construction sector grows, more waste is generated. According to Teixeira (2010), the generation of waste is directly proportional to the growth and economic development of a society.

The environmental impacts caused by the improper disposal of waste are: degradation of spring areas and permanent protection, silting up of rivers and streams, obstruction of fishponds,
occupation of public areas and degradation of the urban landscape (LASSO, 2011).

Construction and demolition waste is considered the most important issue in the construction sector because of its environmental and economic influence (Aslam et al., 2020). For Sá et al. (2018) the waste is generated at the construction sites themselves where the sector's activities take place.

CONAMA Resolution No. 307/2002 (CONAMA, 2002, authors' translation) defined in Subsection I of Art. 2 the term Construction Waste:

"They are those coming from constructions, renovations, repairs and demolitions of civil construction works, and those resulting from the preparation and excavation of land, such as bricks, ceramic blocks, concrete in general, soils, rocks, metals, resins, glues, paints, wood and plywood, linings, mortar, plaster, tiles, asphalt sidewalk, glass, plastics, pipes, electrical wiring, etc., commonly called rubble works, trowels or bricks".

According to ABRECON (2020, authors' translation), "Civil Construction Waste (CCW) is all waste generated in the construction, refurbishment, excavation or demolition process".

The CCW presents a variety in its composition due to the diverse characteristics of construction, handling of raw materials, use of technologies, economic level of each region, among others. Oliveira et al. (2011) states that the composition of the CCW is also variable by some factors such as geographical region, time of year, construction method among other factors, Malia et al. (2011) state that the CCW has a heterogeneous constitution composed of fractions of various dimensions and Wu et al. (2014) says that there are some hazardous components found in this type of waste (e.g., asbestos, particulate matters, etc).

The CCW must be classified according to Resolution N° 307 which defines them as follows:

- Class A: recyclable materials or that can be recycled as aggregates;
- Class B: recyclable for another destination such as plastic, cardboard, glass, wood, plaster and paper;
- Class C: resources that have not been developed technologies or without economically viable recycling technology;
- Class D: hazardous waste (CONAMA, 2004).

Melo (2014) stated that the highest percentage of CCW is Class A because the residues of this class are related to the waste in the execution of the work (Figure 1).

Figure 1 – CCW generation percentage

Rosado and Penteado (2019) say that although there are guidelines for proper CCW management, classification is often ignored, making reuse and recycling impractical and causing waste containing mixed minerals and non-inert components to be sent to Class A and inert CCW landfills.

For Jacobi and Besen (2011), the CCW when disposed of in an irregular (illegal) way on public roads causes flooding and deprives the population of spaces for leisure and recreation. The CCW represents a major problem in Brazilian cities and represents 50% to 70% of the urban solid waste mass (MINISTÉRIO DAS CIDADES, 2005).

The inadequate management and disposal of solid waste cause social and environmental impacts, such as soil degradation, compromise of water bodies and springs, intensification of floods, contribution to air pollution and proliferation of vectors of sanitary importance in urban centers and collection in unhealthy conditions in streets and final disposal areas (BESEN et al. 2010).

Mortar residue is quite frequent due to the fact that mortar has a diversity in its purpose, being used from the construction site to the finishing part. It can be classified as laying mortar, wall and ceiling covering mortar, general-purpose mortar and decorative mortar.

Mortars can be defined as a mixture of binders, sand and water and may contain additives to improve performance. Petrucci (2003) mentions that construction materials consisting of the union of one or more binders, small aggregates (sand), and water are capable of even containing additives to improve characteristics.

The recycling of CCW according to Thomark (2001) would be an alternative for the preservation of non-renewable natural resources that were extracted by civil construction. Fagury and Grande (2007) also affirm that the recycling of CCW is an opportunity to transform expenses into a source of income, reducing costs with demolition and the amount of extraction of raw material.

John and Agopyan (2003) suggest some actions for the reduction of CCW generation, such as improvement of projects technological changes;
adequate selection of materials; improvement in stock; training of human resources; management of people; improvement in the quality of services; increase in the physical life of the structure and its components and incentives for modernization and not demolition.

According to Angulo, Zordan and John (2001), the recycling of construction waste causes a positive impact on the environment, reducing: consumption of non-renewable natural resources, when replaced by recycled waste; areas for landfill, since with recycling there is a reduction in the volume of final disposal; and energy consumption during production and extraction.

Lira (2016) states that the recycling of CCW has been presenting several environmental, economic and social advantages such as the decrease in energy consumption; decrease in distances of transportation of raw materials; decrease in the extraction of raw materials and environmental degradation; economy for municipalities, by reducing the volume of waste to be collected and deposited in appropriate locations; preservation of natural resources; new business opportunities; transformation and reuse of discarded materials that are used in civil construction in a new product.

CONAMA Nº 307/2002 (CONMA, 2002), amended by Resolution No. 348 of 2004 (CONAMA, 2002) determines that the waste generator becomes responsible for the management and is responsible for disposal. According to the Ministério do Meio Ambiente (2011), the CCW needs to have adequate management, that is, to avoid that they are abandoned and accumulate in the margins of rivers, wastelands or other inappropriate places. The Brazilian Association of Public Cleaning and Special Waste (ABRELPE) annually publishes the report Panorama of Solid Waste in Brazil, a document constituted as a data source that brings national figures as information and the five regions on urban solid waste and construction and demolition waste in Brazil (ABRELPE, 2018).

The study conducted by Tessaro, Sá and Scermin (2012), whose objective was to present the results of the qualitative and quantitative diagnosis of the production of construction and demolition waste (CCW) in the municipality of Pelotas-RS, prepared with the aid of software, showed that 88% of CCW generated refers to Class A, a mineral fraction composed of mortar, concrete and ceramic material and natural soil the material that showed the highest percentage in its gravimetric composition was the mortar and concrete representing 32% collected.

Leite (2001) in his study pointed out that the distribution of the average composition of construction and demolition waste collected at the Inertes Landfill in the South Zone of Porto Alegre is composed of Mortars (28.26%), Natural Rock (29.84%), Ceramic Material (26.33%), Concrete (15.18%) and Others (0.39%).

In the research made by Caetano, Selbach and Gomes (2016), referring to horizontal residential works of a constructive pattern of the Minha Casa Minha Vida housing program, they present that 92% of the residues can be passive of recycling and qualitatively, the wood residues represented 41.13% of the total generated residues, followed by 28.19% of recycled (plastic, metal and paper), 16.09% of concrete, mortar and ceramic residues, 8.38% of contaminated residues and 0.22% of wires.

According to Oliveira et al. (2011) mortar is the main material of the CCW of the city of Fortaleza, corresponding to 38% of the CCW mass, while concrete and ceramics correspond on average 14% and 13% respectively.

As pointed out by several authors, the results show that there is a high occurrence in the percentage of mortars in the average composition of CCW in the municipalities of Brazil, highlighting the study prepared by Santos (2009) which defined the average composition of CCW of constructions in Brazil.

Silva and Fernandes (2012) concluded that the municipality of Uberaba - MG needs to invest in inspection and sensitization of the population in addition to its own action regarding the CCW. Souza, Marques and Araújo (2019) also concluded in their study that the lack of a culture of environmental preservation is one of the variables for the misuse of the CCW, besides the lack of inspection.

In view of the above, it becomes relevant studies that identify and update the collaboration of civil construction activities to the inadequate disposal of the CCW, so this article aims to evaluate the disposal of mortars from construction or demolition in public roads in Brazil in 2009 to 2018.

2 Methodology

A numerical survey of mortar residues in Brazil was conducted. As it is not possible to quantify precisely all mortar waste, data published by ABRELPE - Associação Brasileira de Empresas de Limpeza Pública de Resíduos Especiais was considered. In addition, the last 10 years of publication carried out by the company has been adopted as the evaluation period in order to monitor the evolution of mortar waste.
For this research, the Panorama of Solid Waste in Brazil, published by ABRELPE, was adopted, such data were contemplated between 2009 and 2018. The data published by ABRELPE in its panoramas do not present the totality of CCW collected by the municipalities in Brazil, since most of the municipalities only record and disclose data that were collected by the public sector, generally limited to the collection of waste of this nature, that is, the forecast of such waste does not include the collection performed by the private sector.

The study conducted by Santos (2009) on the average composition of CCW in Brazil was also used. Based on the literature mentioned, it has been found that to obtain the number of mortars discarded in an irregular way in public roads, the annual sum of the projections of the CCW launched in each region of Brazil was performed. With the annual projections of each year was made the total calculation of the CCW launched on public roads in Brazil.

With the total amount of CCW launched in public roads in Brazil, referring to the years analyzed in this research, the Santos study (2009) has been adopted, which defines the average composition of CCW, so a percentage calculation was made to obtain the corresponding amount of each material according to the average composition.

3 Results and Discussions

Wu et al. (2014) state in their study that quantifying the generation of CCW can be considered a prerequisite for the implementation of successful waste management. According to the data presented in Table 1, the region in Brazil with the highest amount of CCW launched on public roads is the Southeast in all years.

Between 2009 and 2018, the Center-West, Northeast, North and South Regions presented low growth in the CCW launched on public roads. In contrast, the Southeast Region showed strong growth between 2009 and 2015. From 2015 onwards, these numbers stabilized in the Southeast Region (Figure 2).

Table 1 - Number of CCW launched on public roads in Brazil (T/day).

| Region    | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|-----------|------|------|------|------|------|------|------|------|------|------|
| Norte     | 3,405| 3,514| 3,903| 4,095| 4,280| 4,539| 4,736| 4,720| 4,720| 4,709|
| Nordeste  | 15,663| 17,995| 19,643| 20,932| 22,162| 24,066| 24,310| 24,387| 24,585| 24,123|
| Centro-Oeste | 10,997| 11,525| 12,231| 12,829| 13,439| 13,675| 13,916| 13,813| 13,574| 13,255|
| Sudeste   | 46,990| 51,582| 55,817| 59,100| 61,487| 63,469| 64,097| 63,981| 64,063| 63,679|
| Sul       | 14,389| 14,738| 14,955| 15,292| 16,067| 16,513| 16,662| 16,718| 16,472| 16,246|

Source: ABRELPE (2009 to 2018).

The CCW inspection is a factor that can increase or decrease the dumping of waste in an irregular way, however several authors point out that there is no efficient inspection or there is a lack of inspection in the municipalities.
Piovezan Junior and Silva (2006) in their study stated that in the municipality of Santa Maria (RS) one of the problems encountered in the management of the CCW is the lack of efficient inspection. In another study conducted by Pereira (2014), the management occurs incorrectly due to the lack of inspection in the municipality. The municipality of Santarém (PA) also reflects a lack of supervision in the management of its CCW (SOUZA, 2020).

Table 2 shows the per capita CCR generation (kg/hab/day) of the five regions of Brazil, noting that there was a decrease in all regions between the years 2016 and 2018. The South region corresponded to 3.87%, in the Southeast a decrease of 2.02%, in the Midwest a decrease of 6.58%, in the Northeast a decrease of 0.70% and in the North 2.63%.

Table 3 shows the population of Brazil separated according to the five regions of the country, the Southeastern region presenting the largest number of inhabitants per region, followed by the Northeast, South, North, and Center-West.

**Table 2 - CCW per capita generation (kg/hab/day)**

| Year | North | Northeast | Center-West | Southeast | South |
|------|-------|-----------|-------------|-----------|-------|
| 2009 | 0.297 | 0.412     | 0.918       | 0.632     | 0.63  |
| 2010 | 0.301 | 0.464     | 0.923       | 0.691     | 0.634 |
| 2011 | 0.33  | 0.502     | 0.966       | 0.742     | 0.638 |
| 2012 | 0.341 | 0.53      | 1           | 0.78      | 0.638 |
| 2013 | 0.252 | 0.397     | 0.896       | 0.728     | 0.558 |
| 2014 | 0.263 | 0.428     | 0.899       | 0.746     | 0.569 |
| 2015 | 0.271 | 0.43      | 0.901       | 0.748     | 0.57  |
| 2016 | 0.266 | 0.428     | 0.882       | 0.741     | 0.568 |
| 2017 | 0.264 | 0.429     | 0.855       | 0.737     | 0.556 |
| 2018 | 0.259 | 0.425     | 0.824       | 0.726     | 0.546 |

Source: ABRELPE (2009 to 2018).

**Table 3 – The population of Brazil by region**

| Region       | North Region | Northeast Region | Southeast Region | South Region | Central West Region |
|--------------|--------------|------------------|------------------|--------------|---------------------|
| Brazil       | 18,672,591   | 57,374,243       | 89,012,240       | 30,192,315   | 16,504,303          |
| Total        | 211,755,692  |                  |                  |              |                     |

Source: IBGE (2020).

Figure 3 shows the ratio of the quantity of CCW generated by region by population quantity. It is possible to note that the Northern Region is the fourth region in population number, but is the fifth in the collection of CCW on public roads.

**Figure 3 - CCW T/day x Population Ratio by Region of Brazil**

![Figure 3 - CCW T/day x Population Ratio by Region of Brazil](source: Elaborated by the authors)

The region with the greatest number of municipalities with CCW management was the Northeast region, being the second in the amount of CCW collection on public roads; the South region is
the second with municipalities that carry out CCW management, but it is the third with residue collection on public roads. The Southeast region is the last in the management of CCW and the first in the irregular disposal on public roads (Table 4).

Table 4 - Number of municipalities in Brazil with CCW management in 2008

| Region  | Total municipalities evaluated | Total of municipalities with services | Percentage (%) |
|---------|-------------------------------|--------------------------------------|----------------|
| North   | 449                           | 293                                  | 65,25          |
| Northeast | 1,793                         | 1,454                                | 81,09          |
| Center-West | 1,668                        | 1,272                                | 76,26          |
| Southeast | 1,188                         | 639                                  | 53,78          |
| South   | 466                           | 373                                  | 80,04          |

Note: A municipality may have more than one form of CCW ground layout.
Source: PNSB (IBGE, 2010).

Figure 4 shows the relationship between Brazil’s Gross Domestic Product (GDP) and the GDP of civil construction between the years 2009 to 2018. Through the data presented in Figure 4, it is possible to verify that both the GDP of Brazil and of the Civil Construction has started a fall from 2014, with recovery in 2017 and 2018, respectively. These analogous behaviors demonstrate the importance and influence of the Civil Construction market in the Brazilian economy.

Figure 4 - GDP of Brazil and the GDP of civil construction (% change) from 2009 to 2018

Through the data obtained by ABRELPE for the period from 2009 to 2018, Table 5 was elaborated, which showed the amount of CCW (T/day) collected in each of these years. After the sum was obtained, the amount of 1,142,065 T/day has been obtained. The total amount of CCW collected from public roads in Brazil showed a reduction of 1.3% between 2016 and 2018.

Table 5 - CCW collection T/day from 2009 to 2018
Table 6, presents the study by Santos (2009), regarding the average CCW composition in Brazil, mortars have the highest percentage 63% and organic components are only 1%.

Countries like the USA and China both are big economies but have problems in the management of CCW (Aslam et al, 2020), in the year 2014 the production of CCW from the U.S. was 534 million tons but China's production was 1.13 billion tons (U.S. EPA, 2016; LU et al. 2016).

Table 6 - Average CCW composition of works in Brazil

| Components          | Percentage (%) |
|---------------------|----------------|
| Mortar              | 63             |
| Concrete and blocks | 29             |
| Others              | 7              |
| Organic             | 1              |
| Total               | 100            |

Source: SANTOS (2009).

Figure 6 contains the CCW composition of the total of 1,142,065 T/day, the mortars correspond to the highest percentage has been collected material being 719,501 T/day, the concrete and blocks with 331,198.90 T/day other T/day and organic 11,420.60 T/day.
4 Conclusion

The information collected is useful for researchers or professionals in Brazil to help and understand the facts related to the CCW, such as the generation of waste according to the years, regions that have greater waste generation, waste vs. population ratio, waste production and GDP of the country, and may fill current gaps and contribute to future work on the subject. This article shows that there is an influence on waste generation by some factors such as population and GDP.

In addition, the article portrays that a large portion of the CCW is recyclable and can bring financial, economic and social advantages.

In Brazil the disposal in an irregular way occurs in all regions of the country, knowing the quantity and composition of the CCW is necessary to assist, administer, prepare and implement a waste management plan.

The present work shows that the amount of CCW that has been collected in public roads in Brazil a drop in all regions, the center-west region presented the biggest drop, exactly where the volume per inhabitant is the biggest. The northern region is the region with the smallest collection of CCW on public roads because it is a little developed region compared to other regions of Brazil.

The reduction in the amount of CCW collected on public roads in Brazil is related to the fall in the GDP of construction in recent years.

The results obtained show that in recent years approximately 1,142,065 T/day of CCW have been irregularly released and that the mortar represents the largest waste pore size of 719,501 T/day.

References

ABRECON. ASSOCIAÇÃO BRASILEIRA PARA RECICLAGEM DA CONSTRUÇÃO CIVIL E DEMOLIÇÃO. O que é entulho. Available at: https://www.abrecon.org.br/o-que-e-entulho/. Acesso em; mai. de 2020. In Portuguese.

ABRELPE. ASSOCIAÇÃO BRASILEIRA DE EMPRESAS DE LIMPEZA PÚBLICA E RESÍDUOS ESPECIAIS. Panorama dos resíduos sólidos no Brasil, 2009. In Portuguese.

ABRELPE. ASSOCIAÇÃO BRASILEIRA DE EMPRESAS DE LIMPEZA PÚBLICA E RESÍDUOS ESPECIAIS. Panorama dos resíduos sólidos no Brasil, 2010. In Portuguese.

ABRELPE. ASSOCIAÇÃO BRASILEIRA DE EMPRESAS DE LIMPEZA PÚBLICA E RESÍDUOS ESPECIAIS. Panorama dos resíduos sólidos no Brasil, 2012. In Portuguese.

ABRELPE. ASSOCIAÇÃO BRASILEIRA DE EMPRESAS DE LIMPEZA PÚBLICA E RESÍDUOS ESPECIAIS. Panorama dos resíduos sólidos no Brasil, 2013. In Portuguese.
ABRELPE. ASSOCIAÇÃO BRASILEIRA DE EMPRESAS DE LIMPEZA PÚBLICA E RESÍDUOS ESPECIAIS. Panorama dos resíduos sólidos no Brasil, 2014. In Portuguese.

ABRELPE. ASSOCIAÇÃO BRASILEIRA DE EMPRESAS DE LIMPEZA PÚBLICA E RESÍDUOS ESPECIAIS. Panorama dos resíduos sólidos no Brasil, 2015. In Portuguese.

ABRELPE. ASSOCIAÇÃO BRASILEIRA DE EMPRESAS DE LIMPEZA PÚBLICA E RESÍDUOS ESPECIAIS. Panorama dos resíduos sólidos no Brasil, 2016. In Portuguese.

ABRELPE. ASSOCIAÇÃO BRASILEIRA DE EMPRESAS DE LIMPEZA PÚBLICA E RESÍDUOS ESPECIAIS. Panorama dos resíduos sólidos no Brasil, 2017. In Portuguese.

ABRELPE. ASSOCIAÇÃO BRASILEIRA DE EMPRESAS DE LIMPEZA PÚBLICA E RESÍDUOS ESPECIAIS. Panorama dos resíduos sólidos no Brasil, 2018.

ÂNGULO, S. C.; ZORDAN, S. E.; JOHN, V. M. Desenvolvimento sustentável e a reciclagem de resíduos na construção civil. São Paulo: SP, 2001.

ASLAM, M. S.; HUANG, B.; CUI, L. Review of construction and demolition waste management in China and USA. Journal of Environmental Management, v. 264, p. 110445, 2020.

BESEN, G. R. et al. Resíduos sólidos: vulnerabilidades e perspectivas de insustentabilidade da geração excessiva de resíduos sólidos. In: SALDIVA, P. (ed.). Meio ambiente e saúde: o desafio das metrópoles. São Paulo: Saúde e Sustentabilidade, 2010. In Portuguese.

CAETANO, M. O.; SELBACH, J. B. O.; GOMES, L. P. Composição gravimétrica do RCD para uma etapa de acabamento em obras residenciais horizontais. Ambiente Construído, v. 16, n. 2, p. 51-67, junho de 2016. Available at: https://www.scielo.br/j/ac/a/YgnDNBqW633Y8nlF5pqLxc/. Accessed on: jun. 2020. In Portuguese.

CONAMA. Ministério do Meio Ambiente. Resolução Conama no 348, de 16 de agosto de 2004. Altera a Resolução Conama no 307, de 5 de julho de 2002, incluindo o amianto na classe de resíduos perigosos. Diário Oficial da União, Brasília. In Portuguese.

FAGURY, S. C.; GRANDE, F. M. Gestão de Resíduos de Construção e Demolição (RCD): aspectos gerais da gestão pública de São Carlos/SP. Exacta, v. 5, n. 1, p. 35-45, 2007. In Portuguese.

FREITAS, G. S.; BULBOVAS, P. Os avanços da conscientização a respeito da coleta dos resíduos sólidos na construção civil. Revista Geociências-UNG-Ser, v. 19, n. 1, p. 15-21, 2020. In Portuguese.

IBGE. INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. Estatísticas. Available at: https://www.ibge.gov.br/estatisticas/economicas/industria/9300-contas-nacionais-trimestrais.html?=&t=o-que-e. Accessed on: sep. 2020. In Portuguese.

IBGE. INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. Pesquisa nacional de saneamento básico, 2008. Rio de Janeiro: IBGE, 2010. In Portuguese.

IBGE. INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. Tabelas. Available at: https://www.ibge.gov.br/estatisticas/sociais/popolacao/9103-estimativas-de-popolacao.html?=&t=resultados. Accessed on: sep. 2020. In Portuguese.

JACOBI, P. R.; BESEN, G. R. Gestão de resíduos sólidos em São Paulo: desafios da sustentabilidade. Estudos Avançados, v. 25, n. 71, p. 135-158, 2011. Available at: https://www.scielo.br/j/ea/a/YgnDNBqW633Y8nlF5pqLxc/. Accessed on: may, 2020. In Portuguese.

JOHN, V. M.; AGOPYAN, V. Reciclagem de resíduos da construção. In: SEMINÁRIO REICICLAGEM DE RESÍDUOS DOMICILIARES, São Paulo. In Portuguese.

LASSO, P. R. O. Avaliação da utilização de resíduos de construção civil e de demolição reciclados (RCD-R) como corretivos de acidez e condicionadores de solo. 2011. Tese (Doutorado em Energia Nuclear na Agricultura e no Ambiente) -
Centro de Energia Nuclear na Agricultura, University of São Paulo, Piracicaba, 2011.

LEITE, M. B. Avaliação de propriedades mecânicas de concretos produzidos com agregados reciclados de resíduos de construção e demolição. 2001. Tese (Doutorado em Engenharia Civil) - Universidade Federal do Rio Grande do Sul, Porto Alegre, 2001. Available at: https://lume.ufrgs.br/handle/10183/21839. Accessed on: aug. 2021. In Portuguese.

LIRA, D. S. A reciclagem de resíduos da construção civil de classe a e o seu reuso na cadeia de suprimentos do setor. Revista Interface Tecnológica da FATEC Taquaritinga, v. 12, n.1, p. 80-92, jun. de 2016. In Portuguese.

MALIA, M.; BRITO, J.; BRAVO, M. Indicadores de resíduos de construção e demolição para construções residenciais novas. Ambiente Construído, v. 11, n. 3, p. 117-130, 2011. Available at: https://www.scielo.br/j/ac/a/8ghYt55DzJ4nkbmWTND3C3h. Accessed on: may, 2020. In Portuguese.

MELO, J. R. S.; FROTA, C. A. A situação dos resíduos sólidos oriundos de construção civil vertical na Cidade Manaus. In: V Congresso de Pesquisa e Inovação da Rede Norte Nordeste de Educação Tecnológica (CONNEPI 2010), 5., Maceió, 2010. Anais..., 2010. In Portuguese.

MESQUITA, A. S. G. Análise da geração de resíduos sólidos da construção civil em Teresina, Piauí. Holos, v. 2, p. 58-65, 2012. Available at: http://www2.ifrm.edu.br/ojs/index.php/HOLOS/article/view/835. Accessed on: apr. 2017. In Portuguese.

MINISTÉRIO DAS CIDADES. Ministro do Meio Ambiente. Área de manejo de resíduos da construção e resíduos volumosos: orientação para o seu licenciamento e aplicação da Resolução Comparta 307/2002, Brasília, 2005. In Portuguese.

MINISTÉRIO DO MEIO AMBIENTE. Guia para elaboração de Planos de Gestão de Resíduos Sólidos. Available at: http://www.mma.gov.br/estruturas/srhu_urbano/_arquivos/guia_elaborao_plano_de_gesto_de_resduos_re v_29nov11_125.pdf. Accessed on: nov. 2018. In Portuguese.

OLIVEIRA, M. E. D. et al. Diagnóstico da geração e da composição dos RCD de Fortaleza/CE. Engenharia Sanitária e Ambiental, v. 16, n. 3, 219-224, jul./set. 2011. Available at: https://www.scielo.br/j/esaa/xSQDpm6xPkwYBXLyMB3ZpWB. Accessed on: aug. 2021. In Portuguese.

OLIVEIRA, M. E. D. et al. Diagnóstico da geração e da composição dos RCD de Fortaleza/CE. Engenharia Sanitaria Ambiental, v. 16, n. 3, p. 219-224, 2011. Available at: https://www.scielo.br/j/esaa/xSQDpm6xPkwYBXLyMB3ZpWB. Accessed on: oct. 2020. In Portuguese.

PEREIRA, D. D. A. Estudo sobre os Resíduos da Construção Civil (RCC) no município de Mamborê-PR. 2014. Trabalho de Conclusão de Curso (Engenharia Civil) – Universidade Tecnológica Federal do Paraná, Campo Mourão, 2014. In Portuguese.

PETRUCCI, E. G. R. Materiais de construção. 12 ed. São Paulo: Globo, 2003. In Portuguese.

PIOVEZAN JÚNIOR, G. T. A.; SILVA, C. E. Avaliação dos resíduos da construção civil (RCC) gerados no município de Santa Maria–RS–BRASIL. In: XXX CONGRESO INTERAMERICANO DE INGENIERÍA SANITARIA Y AMBIENTAL 30., 2006, Punta del Este. Proceedings... 2006. In Portuguese.

RESENDE, F. Poluição atmosférica por emissão de material particulado: avaliação e controle nos canteiros de obras de edifícios, 2007. Dissertação (Mestrado em Engenharia de Construção Civil e Urbana) - Escola Politécnica, Universidade de São Paulo, São Paulo, 2007. In Portuguese.

ROSADO, L. P.; PENTEADO, C. S. G. Avaliação do ciclo de vida do sistema municipal de gerenciamento de resíduos da construção civil da Região Metropolitana de Campinas. Engenharia Sanitaria e Ambiental, v. 24, n. 1, p. 71-82, 2019. Available at: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1413-41522019000100071. Accessed on: oct. 2020. In Portuguese.

SÁ, A. C. C. et al. Construção e demolição civil na cidade de Espinosa, Minas Gerais: mapeamento dos pontos de disposição de resíduos. Revista Espinhaço, [S.I.], p. 49-58, 2018. Available at: http://revistaespinhaco.com/index.php/journal/article/view/226. Accessed on: oct. 2020. In Portuguese.
SANTORO, J. F.; KRIPKA, M. Determinação das emissões de dióxido de carbono das matérias primas do concreto produzido na região norte do Rio Grande do Sul. Ambiente Construído, Porto Alegre, v. 6, n. 2, p. 35-49, 2016. Available at: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1678-86212016000200035. Accessed on: nov. 2018. http://dx.doi.org/10.1590/s1678-86212016000200078. In Portuguese.

SANTOS, A. L. Diagnóstico ambiental da gestão e destinação dos resíduos de construção e demolição (RCC): análise das construtoras associadas ao Sinduscon/RN e empresas coletoras atuantes no município de Parnamirim - RN, 2009. Dissertação (Mestrado em Estratégia; Qualidade; Gestão Ambiental; Gestão da Produção e Operações) - Universidade Federal do Rio Grande do Norte, Natal, 2009. In Portuguese.

SILVA, V. G. Avaliação da sustentabilidade de edifícios de escritórios brasileiros: diretrizes e base metodológica. 2003. Tese (Doutorado em Engenharia de Construção Civil, Escola Politécnica, Universidade de São Paulo, São Paulo, 2003. In Portuguese.

SILVA, V. A.; FERNANDES, A. L. T. Cenário do gerenciamento dos resíduos da construção e demolição (RCD) em Uberlândia-MG. Soc. nat., Uberlândia, v. 24, n. 2, p. 333-344, Aug. 2012. Available at: http://www.scielo.br/j/sn/a/Q4Y9CTH5xLTNWSrBtBt5pwnB. Accessed on: jun. 2020. In Portuguese.

SOUSA, B. M. Gestão de resíduos da construção civil em Santarém-Pará. Brasil: realidades e desafios. Revista Gestão & Sustentabilidade Ambiental, v. 9, n. 1, p. 635-649, 2020. In Portuguese.

SOUSA, P. H. R.; MARQUES, M. S. P.; ARAUJO, M. C. P. Análise sobre a gestão de resíduos sólidos da construção civil. Multidisciplinary Scientific Journal. Núcleo do Conhecimento. Ano 04, Ed. 03, v. 07, p. 13-35, 2019. In Portuguese.

SPADOTTO, A. et al. Impactos ambientais causados pela construção civil. Revista Unoesc & Ciência, v. 2, n. 2, p. 173-180, 2011. In Portuguese.

TEIXEIRA, C. A. G. Jogando Limpo: estudo das destinações finais dos resíduos finais dos resíduos sólidos da construção civil no contexto urbano de Montes Claros. 2010. Dissertação (Mestrado em Desenvolvimento Sustentável) - Universidade Estadual de Montes Claros, Montes Claros, 2010. In Portuguese.

TESSARO, A. B.; SÁ, J. S.; SCREMIN, L. B. Quantificação e classificação dos resíduos procedentes da construção civil e demolição no município de Pelotas, RS. Ambiente Construído, Porto Alegre, v. 12, n. 2, p. 121-130, 2012. Available at: https://www.scielo.br/j/ac/a/pHnhNxX6CROPxN4m6NZq7dd/. Accessed on: jun. 2020. In Portuguese.

THORMARK, C. Conservation of energy and natural resources by recycling building waste. Journal of Resources, Conservation and Recycling, v. 33, p. 143-150, 2001.

U.S. EPA. UNITED STATES ENVIRONMENTAL PROTECTION AGENCY. Advancing Sustainable Materials Management. 2014 Fact Sheet United States Environmental Protection Agency Office of Land and Emergency Management. (5306P) Washington, DC 20460/ EPA530-R-17-01, p. 1–22, 2016. Available at: http://www.epa.gov/sites/default/files/2016-11/documents/2014_smmfactsheet_508.pdf. Accessed on: nov. 2020.

LU, W. et al. Estimating and calibrating the amount of building-related construction and demolition waste in urban China. International Journal of Construction Management, v. 17, n. 1, p. 13-24, 2017.

WU Z. et al. Quantifying construction and demolition waste: an analytical review. Waste Management, v. 34, n. 9, p. 1683-1692, 2014 DOI: https://doi.org/10.1016/j.wasman.2014.05.010. Available at: https://www.sciencedirect.com/science/article/abs/pii/S0956053X14002104. Accessed on: aug. 2021.