revista principia
Vol. 59, N. 4
REVISTA DE DIVULGAÇÃO CIENTÍFICA E TECNOLÓGICA DO INSTITUTO FEDERAL DE CIÊNCIA, EDUCAÇÃO E TECNOLOGIA DA PARAÍBA

SUBMITTED February 24, 2021
APPROVED August 1, 2021
PUBLISHED ONLINE August 29, 2021
PUBLISHED December 30, 2022
ASSOCIATE EDITOR
Fábio Gomes Ribeiro

DOI: *http://dx.doi.org/10.18265/1517-0306a2021id5484*

ORIGINAL ARTICLE

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: extraction of raw materials; industrialization; commerce and services; and generation of waste that can 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. Considering this context, in the present research, a survey was conducted on the disposal of mortars collected on public roads in all Brazilian municipalities from 2009 to 2018. The analysis used data from Associação Brasileira de Empresas de Limpeza Pública e Resíduos Especiais. It was discovered that, between 2009 and 2018, 1,142,065 T/day of civil construction waste were collected and that the largest amount of this waste was mortar, with 719,501 T/day 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, would contribute to the preservation of the environment.

Keywords: disposal; environmental impacts; mortar; waste.

Análise quantitativa dos resíduos de argamassa na construção civil do Brasil entre os anos de 2009 e 2018

RESUMO: *A construção civil é uma das principais geradoras de desenvolvimento econômico e social no Brasil. Entretanto, devido à maneira como é executada, também é um dos setores que mais causam impactos ambientais em todas as fases da sua cadeia produtiva: extração de matérias-primas; industrialização; comércios e serviços; e geração de resíduos com o 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. Nesse contexto, na presente pesquisa, foi realizado um levantamento do descarte de argamassas coletadas em vias públicas de todos os municípios brasileiros entre 2009 e 2018. A análise realizada utilizou dados da Associação Brasileira de Empresas de Limpeza Pública e Resíduos Especiais. Verificou-se que, entre 2009 e 2018, foram coletadas 1.142.065 t/dia de resíduos da construção civil e que a maior quantidade desse resíduo foi de argamassas, com 719.501 t/dia descartadas em vias públicas no Brasil. A reciclagem desses resíduos seria uma solução para a mitigação dos danos ambientais causados pelo descarte inadequado e, consequentemente, uma contribuição para a preservação do meio ambiente.*

Palavras-chave: *argamassas; descarte; impactos ambientais; resíduos.*

1 Introduction

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

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

According to Santoro and Kripka (2016), 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 areas, 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 impact (ASLAM; HUANG; CUI, 2020). For Sá *et al*. (2018), the waste is generated at the construction sites themselves where the sector's activities take place.

The *Conselho Nacional do Meio Ambiente* (CONAMA) in its Resolution No. 307 (CONAMA, 2002, authors' translation) defined in Subsection I of Art. 2 the term Construction Waste:

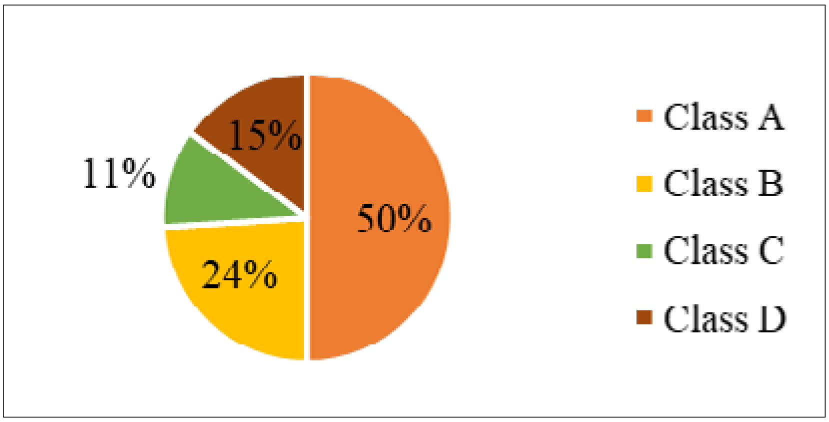
> They are those coming from constructions, renovations, repairs and demolitions of civil construction works, and those resulting from the preparation and excavation of land, such as bricks, ceramic blocks, concrete in general, soils, rocks, metals, resins, glues, paints, wood and plywood, linings, mortar,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

According to *Associação Brasileira para Reciclagem de Resíduos da Construção Civil e Demolição* (ABRECON, 2014, authors' translation), "Civil Construction Waste (CCW) is all waste generated in the construction, refurbishment, excavation or demolition process".

The CCW composition is variable depending on due to the diverse characteristics of construction, handling of raw materials, use of technologies, and economic level of each region, among others. Oliveira *et al*. (2011) state that the composition of the CCW is also variable by some factors such as geographical region, time of year, construction method, among other factors. Mália, Brito and Bravo (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 CONAMA Resolution No. 307, which defines them as follows: Class A: recyclable materials or materials that can be recycled as aggregates; Class B: recyclable for other destinations, such as plastic, cardboard, glass, wood, plaster, and paper; Class C: resources for which technologies have not been developed or without economically viable recycling technology; Class D: hazardous waste (CONAMA, 2004). Melo and Frota (2010) 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.
Source: Melo and Frota (2010)



Rosado and Penteado (2019) say that, although there are guidelines for proper CCW management, classification is often ignored, making reuse and recycling impractical, 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 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 from 50% to 70% of the urban solid waste mass (BRASIL, 2005).

Inadequate management and disposal of solid waste cause social and environmental impacts, such as soil degradation, jeopardizing of water bodies and springs, intensification of floods, augmentation of air pollution, increase in health vectors in urban centers, and collection under unsanitary 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 of purposes, 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 can even contain additives to improve characteristics.

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

John and Agopyan (2003) suggest some actions for the reduction of CCW generation, such as improvement of technological change projects; 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 Ângulo, 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 recycling reduces the volume of final disposal; and energy consumption during production and extraction.

Lira (2015) states that the recycling of CCW has presented several environmental, economic and social advantages such as decrease in energy consumption; decrease in distances of transportation of raw materials; decrease in the extraction of raw materials and environmental degradation; expense reduction for municipalities by reducing the volume of waste to be collected and deposited in appropriate locations; preservation of natural resources, among others.

CONAMA Resolution No. 307/2002 (CONAMA, 2002), amended by Resolution No. 348 (CONAMA, 2004), determines that the waste generator becomes responsible for management and disposal. According to Brazil's Ministry of the Environment (BRASIL, 2011), the CCW needs to have adequate management, that is, to avoid their dumping and accumulation in the margins of rivers, wastelands or other inappropriate places. *Associação Brasileira de Empresas de Limpeza Pública e Resíduos Especiais* (ABRELPE) annually publishes the report "Panorama of Solid Waste" in Brazil, a document that provides information on national numbers on solid urban waste and construction waste in Brazil (ABRELPE, 2018).

The study conducted by Tessaro, Sá and Scremin (2012), whose objective was to present the results of the qualitative and quantitative diagnosis of construction and demolition waste production (CCW) in the municipality of Pelotas-RS, prepared with the aid of software, showed that 88% of CCW 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 mortar and concrete, representing 32% of the collected materials.

Leite (2001), in his study, pointed out that the distribution of the average composition of construction waste collected at the 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) on horizontal residential works of a constructive pattern of *Minha Casa Minha Vida* housing program, they present that 92% of the residues can be suitable for recycling, and qualitatively, the wood residues represented 39.13% of the total generated residues, followed by 23.19% 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 in the city of Fortaleza, corresponding to 38% of the CCW mass, while concrete and ceramics correspond, on average, to 14% and 13%, respectively.

As pointed out by several authors, results show 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 in Brazilian constructions.

Silva and Fernandes (2012) concluded that the municipality of Uberaba-MG needs to invest in inspection and population sensitization in addition to its 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, studies that identify and update the collaboration of civil construction activities to the inadequate disposal of the CCW are relevant. Therefore, this article aims to evaluate the disposal of mortars from construction or demolition in public roads in Brazil from 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 e 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, as its contemplated data corresponds to the years between 2009 and 2018. The data published by ABRELPE in its overviews do not present the totality of CCW collected by the municipalities in Brazil. This is because 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 detected that, to obtain the number of mortars discarded in an irregular way on public roads, the annual sum of

CCW projections launched in each region of Brazil was evaluated. Through the annual projections of each year, it was made the total calculation of CCW launched on public roads in Brazil.

Considering the total amount of CCW launched on public roads in Brazil during the years analyzed in this research, Santos (2009)'s study has been adopted, since it defines the average composition of CCW. Thus, a percentage calculation was made to obtain the corresponding amount of each material according to the average composition.

3 Results and discussion

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, 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).
Source: ABRELPE (2009 to 2018)

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
North	3,405	3,514	3,903	4,095	4,280	4,539	4,736	4,720	4,727	4,709
Northeast	15,663	17,995	19,643	20,932	22,162	24,066	24,310	24,387	24,585	24,123
Center-West	10,997	11,525	12,231	12,829	13,439	13,675	13,916	13,813	13,574	13,255
Southeast	46,990	51,582	55,817	59,100	61,487	63,469	64,097	63,981	64,063	63,679
South	14,389	14,738	14,955	15,292	16,067	16,513	16,662	16,718	16,472	16,246

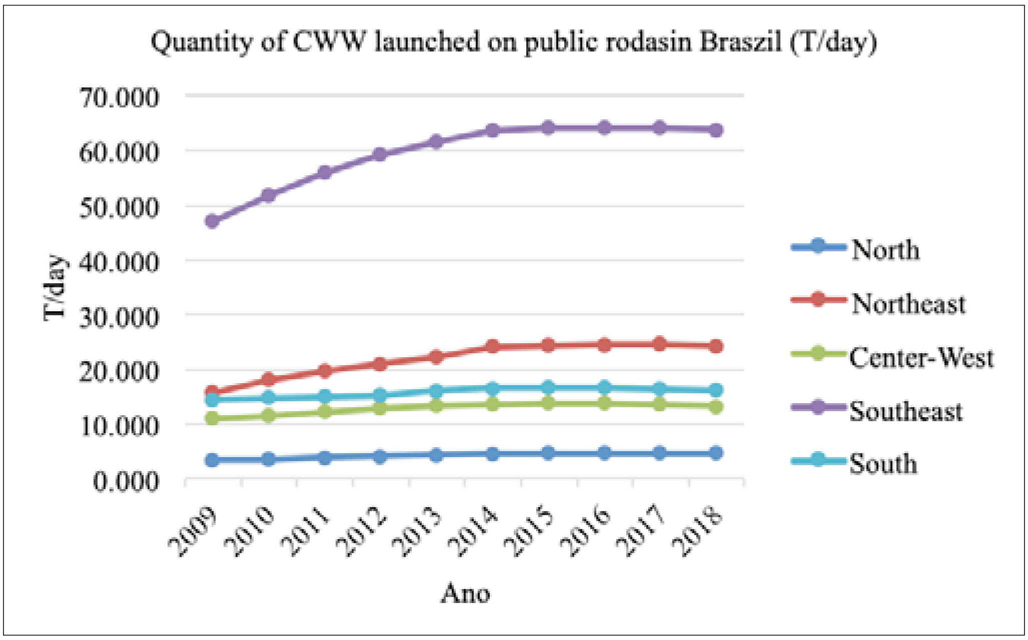


Figure 2 ▶
Evolution of CCW disposal in public roads between 2009 and 2018.
Source: ABRELPE (2009 to 2018)

The CCW inspection is a factor that can increase or decrease the dumping of waste in an irregular way. However, several authors have pointed 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 occurred 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 (SOUSA, 2020).

Table 2 shows the per capita CCR generation (kg/inhab./day)in Brazil's five regions, noting that there was a decrease in all of them between the years 2016 and 2018. The South region corresponded to 3.87%, whereas the Southeast showed a decrease of 2.02%; the Center-West, a decrease of 6.58%; the Northeast, a decrease of 0.70%, and the North, 2.63%.

Table 2 ▼
CCW per capita generation (kg/inhab./day).
Source: ABRELPE (2009 to 2018)

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
North	0.297	0.301	0.33	0.341	0.252	0.263	0.271	0.266	0.264	0.259
Northeast	0.412	0.464	0.502	0.53	0.397	0.428	0.43	0.428	0.429	0.425
Center-West	0.918	0.923	0.966	1	0.896	0.899	0.901	0.882	0.855	0.824
Southeast	0.632	0.691	0.742	0.78	0.728	0.746	0.748	0.741	0.737	0.726
South	0.63	0.634	0.638	0.648	0.558	0.569	0.57	0.568	0.556	0.546

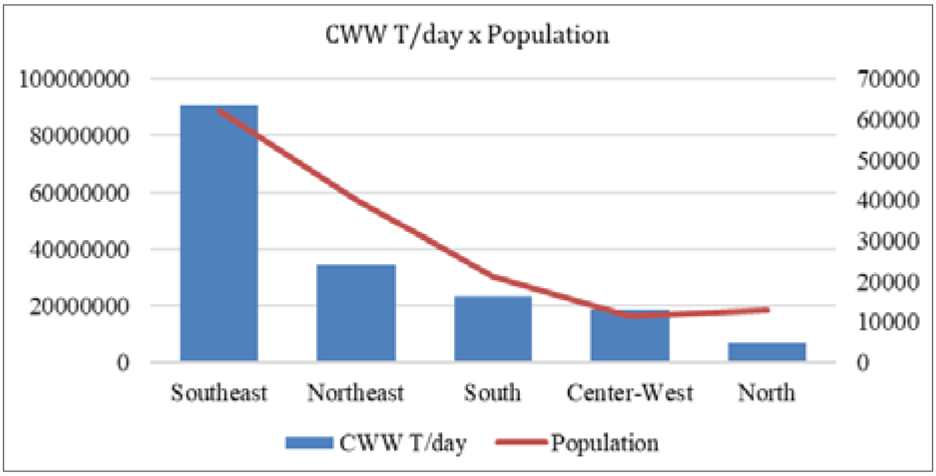
Table 3 shows the population of Brazil separated according to the country's five regions, where the Southeastern region presents the largest number of inhabitants per region, followed by the Northeast, the South, the North, and the Center-West.

Table 3 ▼
The population of Brazil by region.
Source: IBGE (2020)

	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		

Figure 3 shows the ratio of the quantity of CCW generated by region in relation to population quantity. It is possible to note that the Northern Region is the fourth 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.
Source: IBGE (2022) adapted 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 is the second among municipalities that carry out CCW management, but it is the third with reference to residue collection on public roads. The Southeast region is the last in the management of CCW and the first in irregular disposal on public roads (Table 4).

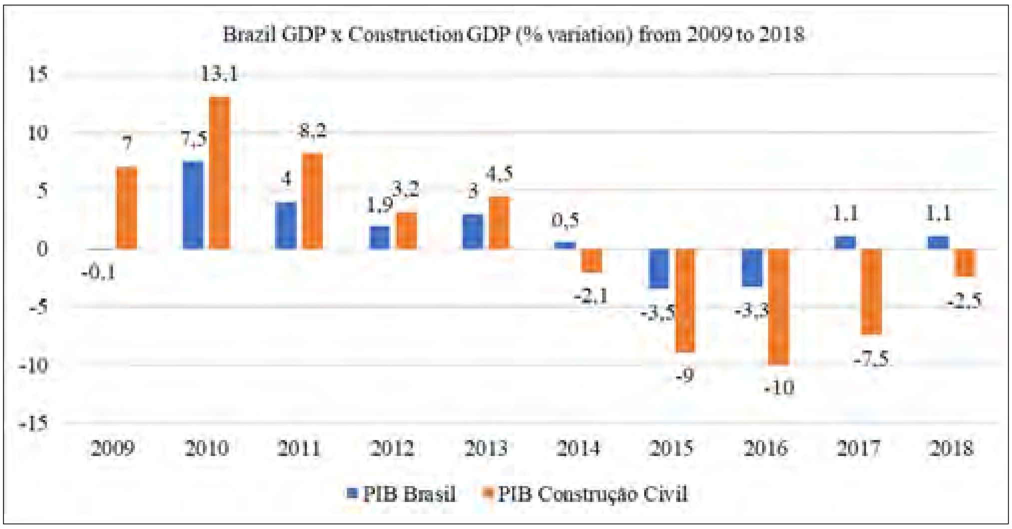
Table 4 ▼
Number of municipalities in Brazil with CCW management in 2008.
Source: Pesquisa Nacional de Saneamento Básico (IBGE, 2010)

Region	Total municipalities evaluated[1]	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[1] A municipality may have more than one form of CCW ground layout

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 Civil Construction has begun to fall after 2014, with some recovery in 2017 and 2018, respectively. These analogous behaviors demonstrate the importance and influence of Civil Construction market in Brazilian economy.

Figure 4 ▶
GDP of Brazil and the GDP of civil construction (% change) from 2009 to 2018.
Source: IBGE (2020)



Through the data obtained by ABRELPE for the period from 2009 to 2018, Table 5 was elaborated, showing 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.
Source: ABRELPE (2009 to 2018)

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
(t/day)	91,444	99,354	106,549	112,248	117,435	122,262	123,721	123,619	123,421	122,012

Through Figure 5, it can be verified that the management of the CCW occurred in an incorrect way, and we notice that the disposal happened in a public way, without any compliance with the law or separation of the material. Freitas and Bulbovas (2020) stated that, despite the existence of standards and legislation for the CCW, the disposal occurs on Brazil's public roads in an irregular way.

Figure 5 ▶
Irregular CCW disposal on public road, Avenida Gualtar, São Paulo-SP.
Source:authors' archive

Table 6 presents the study by Santos (2009) regarding the average CCW composition in Brazil, and it shows that mortars have the highest percentage (63%), whereas organic components represent only 1%.

Countries like the USA and China are both big economies but have problems with the management of CCW (ASLAM; HUANG; CUI, 2020). In the year 2014, the production of CCW by the U.S. was 534 million tonnes, and China's production was 1.13 billion tonnes (LU *et al.*, 2016; USEPA, 2016).

Table 6 ▶
Average CCW composition of works in Brazil.
Source: Santos (2009)

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

Figure 6 contains the CCW composition of a total of 1,142,065 T/day. Mortars correspond to the highest percentage of collected materials, 719,501 T/day, whereas concrete and blocks to 331,198.90 T/day. Still, in the graph of Figure 6, other components correspond to 79,944.60 T/day and organic components to 11,420.60 T/day.

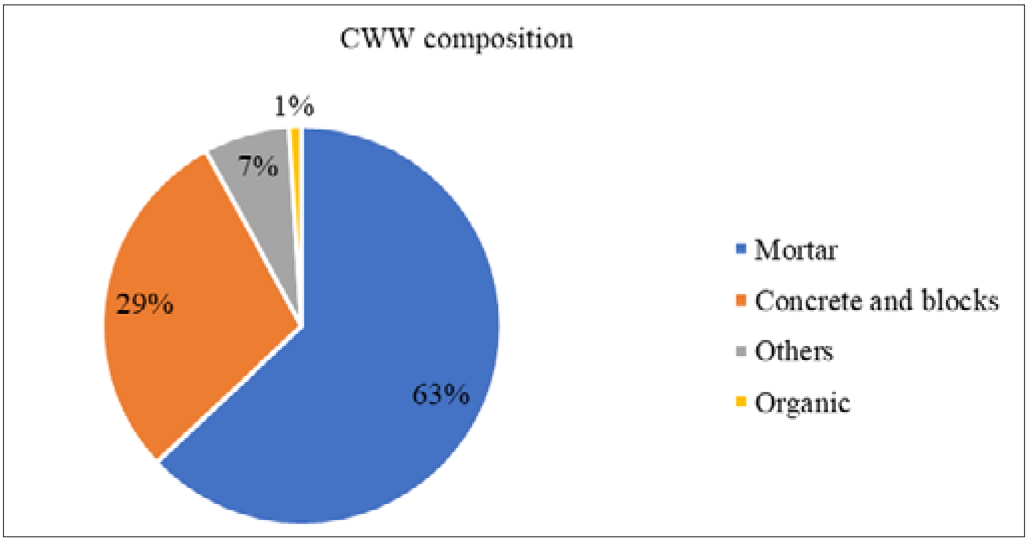


Figure 6 ▶
Composition of CCW (T/day) launched on public roads from 2009 to 2018.
Source: elaborated by the authors

4 Conclusion

The collected information is useful for researchers or professionals in Brazil to understand the facts related to the CCW, such as generation of waste according to the years, regions that have greater waste generation, waste vs. population ratio, and waste production in relation to the country's GDP. These data may fill current gaps and contribute to future work on the subject. This article shows that some factors influence waste generation, 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, irregular disposal occurs in all regions of the country. For this reason, 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 collected on Brazil's public roads have dropped in all regions, whereas the Center-West region presented the most significant drop, exactly where the volume per inhabitant is the biggest. The northern region is the one with the smallest collection of CCW on public roads because it is less developed than other regions of Brazil. Furthermore, 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.

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