Waste volume estimation tool for optimizing construction and demolition waste management in railway works.

A. de Guzmán[1], P. Villoria[2], J. García-Navarro[1] and M. del Río[2]

[1] Research Group: Sustainability in Construction and Industry, Technical University of Madrid, 28040, Spain
[2] Department of Architectural Constructions. Technical University of Madrid, 28040, Spain
Corresponding author email: ana.deguzman@upm.es
Telephone: +34 91 336 58 64

Abstract

The increase of construction and demolition (C&D) waste generation has raised new regulations for C&D waste prevention among the European countries, including the obligation to quantify the C&D waste expected to be generated during construction works. This has led to the development of many research works. However, almost none regarding civil engineering works.

Therefore, the aim of this research study is to provide a C&D waste estimation tool for railway works. For this purpose several Spanish railway roads have been analyzed in order to develop an equation to estimate in advance the volume of C&D waste likely to be generated, analyzing the category of C&D waste generated for each of the functional units considered.

From the analysis performed it has been proved a relationship between the amount of C&D waste generated and the functional units of railways. In short, the methodology presented can help in assigning an optimal and systematic management of the C&D waste produced and assist the construction agents in developing the waste management plans according to the existing legislation.

Keywords: Construction and Demolition Waste (C&D waste), Waste Management, Quantification, Railway Construction Works.

1. Introduction

During the last decades, the intense activity in the construction sector within the European Union (EU) has generated huge volumes of construction and demolition (C&D) waste, precisely 890 million tonnes per year. The latest ratios found for construction and demolition (C&D) waste generation and recycling in Spain are from 2006. This country generated roughly 47 million tons of C&D waste and only 13.6% of the C&D waste generated was recycled (Table 1).

Table 1. C&D Waste generation and recycling ratios for 2006 in the EU. [1] [2]

Countries	Total waste (tn)	CDW (tn)	% CDW of total	% CDW recycled	Countries	Total waste (tn)	CDW (tn)	% CDW of total	% CDW recycled
Austria	54,286,603	31,321,626	58	59.50	Latvia	1,858,551	19,339	1	45.80
Belgium	59,351,721	13,089,651	22	:	Lithuania	7,665,111	348,968	5	59.70
Bulgaria	242,488,634	1,023,303	0	:	Luxembourg	9,586,405	6,774,547	71	:
Cyprus	1,248,723	298,346	24	:	Malta	2,861,219	2,492,522	87	:
Czech Republic	24,745,752	8,379,849	34	23.00	Netherlands	93,808,094	56,609,823	60	98.10
Denmark	14,703,138	5,802,368	39	94.90	Poland	266,740,538	14,141,031	5	28.30
Estonia	18,932,903	717,105	4	91.90	Portugal	34,952,771	3,607,449	10	:
Finland	72,205,476	23,145,712	32	:	Romania	344,424,713	33,740	0	:
France	445,865,248	358,878,312	80	:	Slovakia	14,501,495	916,228	6	:
Germany	363,786,069	196,536,165	54	86.30	Slovenia	6,035,829	994,886	16	:
Greece	51,324,662	6,829,161	13	:	Spain	160,946,629	47,323,392	29	13.60
Hungary	22,287,476	3,045,335	14	15.50	Sweden	115,583,415	8,943,363	8	:
Ireland	29,599,175	16,599,466	56	79.50	Turkey	46,091,628	:	:	:
Italy	155,025,054	52,315,620	34	:	UK	346,143,765	109,545,987	32	6.80

In addition, a study from the European Environment Agency (EEA) estimated that 65% on average of the waste was recycled in 2006 in the 27 European State members. Spain showed a quite lower figure for

recycling than the EU average and was far from countries such as Denmark, Estonia and The Netherlands, with recycling indexes of over 90% [2]. However, this percentage is overrated because some countries consider mineral wastes, such as soil and stones not containing hazardous materials in their ratios.

Moreover, the official EU statistics for C&D waste generation do not distinguish between the waste generated in building works from those generated in civil engineering works [1]. In this sense, the 2nd Spanish National Plan on C&D waste (II PNRCD in Spanish acronym) makes a distinction claiming that 28% of the total C&D waste generated in Spain for the year 2006 was originated in civil works [3].

In short, EU State members are still far from achieving the quantitative target set by the Waste Framework Directive (WFD) for the year 2020 [4]. The reasons for this might include: high cost of C&D waste management, low cost of natural resources and landfill disposal, lack of knowledge regarding the consequences of waste, lack of interest by the clients for waste reduction or minimization, and lack of standards to regulate the inclusion of these wastes in the manufacturing of other materials.

In an attempt to correct the serious consequences this situation produces, several countries are stating specific laws to establish a legal frame for C&D waste production and management, including the obligation to quantify the C&D waste expected to be generated during construction works in a Waste Management Plan developed for each construction project [5].

Although these measures have been implemented by EU countries, the professionals of the construction sectors are reluctant to calculate the volume of waste generated and how it should be managed. In this sense, no tools or methodological instruments are available to help construction agents in estimating in advance the C&D waste to be generated in civil engineering works, needed in the Management Plan.

Moreover, this situation has not only worried EU governments, but it has been of great interest for researchers in the field. According to Yuan & Shen special attention to C&D waste management has been drawn in recent years [6], focusing in the quantification of the C&D waste generated in the building sector. Among these researchers, Mañà I Reixach et al. [7], Conchran et al. [8] and Kofoworola and Gheewala [9] can be highlighted. Specifically for the situation in Spain, Solís-Guzmán et al. [10] and Villoria Sáez et al. [11] studied models for C&D waste quantification and management based on budget data of building works. However, specific tools to quantify C&D waste generation in civil engineering works is still a research study to be analyzed.

Therefore, this study aims to define an equation to quantify in advance the C&D waste expected to be generated in railway construction works. This information will be necessary to fulfil the C&D waste estimation in the Management Plan.

2. Materials and methods

To develop this study, a total of 14.60 km of Spanish railway road has been analyzed in order to develop an equation to estimate in advance the volume of C&D waste likely to be generated, analyzing the category of C&D waste generated for each of the following functional units considered: km of railway (L_r); Number of intersections, junctions (N_j); Number of transversal drainage (N_{td}); Number of underpasses (N_u); Number of overpasses (N_o); km of viaduct (L_v); km of tunnel (L_t).

To estimate the volume of C&D waste generated, values for each waste category have been obtained from BEDEC database from the Instituto de Tecnología de la Construcción de Cataluña (ITeC) [12]. This database gives environmental parameters for each element of work in the bill of quantities of the projects. In this sense, volume (m^3) values for each European Waste Catalogue category (EWC code) for the analyzed railway works have been obtained [13]. C&D waste volume generated is thus calculated by an empirical equation, Eq. (1) and related to the functional units of the railway project to be analyzed.

$$V = x_1 \cdot L_r + x_2 \cdot N_j + x_3 \cdot N_{td} + x_4 \cdot N_u + x_5 \cdot N_o + x_6 \cdot L_v + x_7 \cdot L_t \qquad (1)$$

Where, V is C&D waste volume (m^3) and x_i are constant values for volume calculation (m^3/unit).

The functional units are determined by the railway project characteristics. In addition, Eq. (2) has been used to obtain the constant values:

$$x_i = V/Q_{fu} \qquad (2)$$

Where, Q_{fu} is the quantity of each functional unit.

In this study soil and rocks not containing hazardous substances have been excluded (EWC code: 17 05 04) because the 2008/98/EC Directive of 19 November on waste does not consider them as such [4]. An example of how the data is obtained can be seen in Table 2 which shows, a fragment from one of the analyzed substages for the quantification of C&D waste generated in a tunnel construction.

Table 2. Example of C&D waste quantification generated in the tunnel stage

Work item			Environmental parameters		
			Waste per Unit[a]		
Unit	Description	Quantity (Unit)	EWC Code	V per unit (m^3)	Total V per work item (m^3)
m^3	Mass concrete for leveling layers and cleaning	6334.56	170101	1.00×10^{-02}	63.3
kg	Reinforcement steel bars.	2 329 388.16	170405	8.03×10^{-06}	18.7
m^2	Wood works (formwork)	16688.64	170201	9.00×10^{-04}	15.0
			170405	6.20×10^{-06}	0.1
			150101	3.04×10^{-06}	5.1×10^{-02}
			150110*	4.41×10^{-05}	0.7
:	:	:	:	:	:
		Total waste generated in the whole construction project =			$\sum$ V per work item (m^3)

[a] Data obtained from BEDEC.

3. Results and discussion

From the relation between the amount of C&D waste obtained in the analysis of the studied projects and their functional units, seven empirical constants have been obtained (Table 3).

Table 3. Empirical constant calculation

				Vol (m^3/unit)	
Functional unit		Q_{fu}[a]	V	x_i	
L_r	(km)	14.60	$7.39 \cdot 10^4$	x_1	$5.06 \cdot 10^3$
N_j	(unit)	4	10.1	x_2	2.53
N_{td}	(unit)	11	47.1	x_3	4.28
N_u	(unit)	10	$1.94 \cdot 10^2$	x_4	19.4
N_o	(unit)	1	4.83	x_5	4.83
L_v	(km)	0.59	$2.53 \cdot 10^2$	x_6	$4.29 \cdot 10^2$
L_t	(km)	9.528	$5.49 \cdot 10^4$	x_7	$5.76 \cdot 10^3$

[a] Quantities of the functional units

These constant values can be used to estimate in advance the C&D waste generated in similar railway projects, by introducing them in Eq. (1) along with the particular functional units of the railway project to be studied. Although the constant values determined are derived from Spanish railway constructions works, this methodology can be applied to other similar areas or infrastructures in different scenarios.

In addition, wastes generated according to the EWC code were also identified:

- 15 01 01 paper and cardboard packaging
- 15 01 02 plastic packaging
- 15 01 03 wooden packaging
- 15 01 10* packaging containing remains of or contaminated by dangerous substances
- 17 01 01 concrete
- 17 01 03 tiles and ceramics

- 17 02 01 wood
- 17 02 03 plastic
- 17 03 02 bituminous mixtures containing other than coal tar and tarred products
- 17 04 05 iron and steel
- 17 04 07 mixed metals
- 17 09 04 mixed construction and demolition wastes other than those containing dangerous substances.

Once the total quantities in volume have been obtained, results show that the mixed C&D waste not containing hazardous substances (EWC code: 17 09 04) are the most generated ones in railway construction works (Figure 1), representing 85% in volume of the total. This is mainly due to the lack of C&D waste segregation onsite, despite the usual space available in railway construction works, to do so. This waste category is followed by the bituminous mixtures (EWC code: 17 03 02) that in turn, represent 7% in volume.

On the other hand, plastic (EWC code: 15 01 02) and wood (EWC code: 15 01 03) packaging wastes and empty hazardous waste containers (EWC code: 15 01 10*) are generated in smaller proportions not even reaching 0.1% in volume.

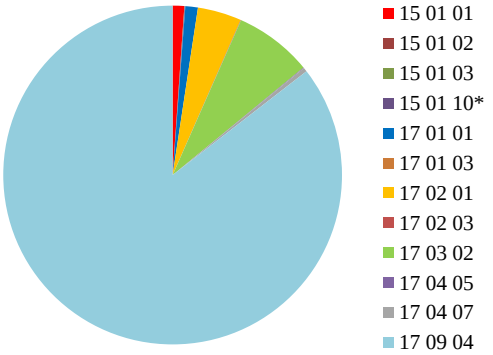

Figure 1. Percentage of C&D waste generated in volume (m3) in railway works, according to the category.

Furthermore, waste categories such us 17 09 04 or 17 02 01, occupy huge volumes in the construction site. In this sense, the use of mobile waste treatment plants for grinding and crushing or other measures could be considered.

4. Conclusions

From the analysis performed in this study the following conclusions can be drawn:

- The quantification tools for C&D waste generation presently being used in civil works are not detailed enough to answer to the increasing social pressure in relation to environmental concerns.
- A relationship between the amount of C&D waste generated and the functional units of the railway has been proved and stated in the following equation:

$$V=5.06\cdot10^{3}\cdot L_r+ 2.53\cdot N_j+ 4.28\cdot N_{td}+ 19.4\cdot N_u+ 4.83\cdot N_o+ 4.29\cdot10^{2}\cdot L_v+ 5.76\cdot10^{3}\cdot L_t$$

- The methodology provided can be applied to obtain new equations for other particular areas, with new constant values representing their specific characteristics.
- The most generated C&D waste category in railway works corresponds to mixed C&D waste (EWC code: 17 09 04). In this sense, if construction agents focus their efforts in the minimization C&D

waste generation (EWC code: 17 09 04), more than 85% of the total waste generated in railway works could be properly managed.

- In general, packaging wastes and empty hazardous waste containers are the less significant waste generated.

In short, the methodology presented can help in assigning an optimal and systematic management of the C&D waste produced and assist the construction agents in developing the waste management plans according to the existing legislation.

The implementation of these conclusions in railway construction projects will help in assigning an optimal and systematic management of the C&D waste produced, giving priority to treatments for reducing, reusing and recycling these wastes as opposed to a definite disposal, as well as anticipating good practices for their correct management throughout the construction process.

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