Comparative Study of Models for Quantifying Waste in Finishes Phase of Residential Buildings

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Abstract— **Global concern about environmental impact caused by Construction and Demolition (C&D) waste has risen in recent years. C&D waste must be managed in an efficient way in order to reduce this environmental impact. For this reason, Governments are developing guidelines and control measures.**

In Spain, the regulatory framework for generation and management of C&D waste is the National Decree 105/2008, implemented in February 2008. Among other issues, it is required to quantify the amount of generated C&D waste and to separate each fraction when they exceed certain amount: concrete, ceramic, metal, wood, glass, plastics, paper and cardboard. Therefore, a reliable model for quantifying C&D waste in projects is needed in order to plan their subsequent management once they appear during the execution of the work.

Currently, there are several theoretical and statistic studies for quantifying C&D waste in the project stage. Their objective is to establish the real composition and quantity of C&D waste. However, as they are based in statistic data or general project information, the results obtained are approximate value. In fact, most of them would need to check their data in construction sites.

Given this shortcoming, this paper reveals the deviation between estimates from theoretical models applied to projects and the actual amount of C&D waste generated on site. This comparison is studied in a constructive system (finishes) in a residential building promoted by "Empresa Municipal de Vivienda de Sevilla, EMVISESA".

Results reveal that it is required a model for quantifying the expected amount of C&D waste to be generated on site: a) verified in construction sites, b) detailed by type and origin of waste.

Keywords: Models, Quantification, Waste, Construction.

I. INTRODUCTION.

Global concern about environmental impact caused by Construction and Demolition (C&D) waste has risen in recent years. In order to reduce this environmental impact, Governments are developing guidelines and control measures.

In Spain, generation and management of C&D waste are regulated by National Decree 105/2008, implemented in February 2008. One of the new obligations of the C&D producer is to include in construction projects a new document called Waste Management Study. Among other issues, this document has to contain an estimate of the amount of C&D waste expected to be generated on site, in tons and cubic metres. In order to fulfil this new requirement, a reliable model for quantifying C&D waste in projects is needed.

Currently, several theoretical and statistic studies help to estimate types and quantities of C&D waste from the project stage. However, as these methodologies are based on statistic data or rough coefficients that come from estimates and approximations from general information of the project, results obtained are approximate value. In fact, most of them would need to check their data in construction sites.

Given these shortcomings, the Department of Architectural Constructions I of the University of Seville is accomplishing the research Project ''-CDWs = + ECO-efficiency. Waste Reduction in the Design and Construction of Dwellings in Andalusia'', subsidized by Department of Housing and Spatial Planning of the Government of Andalusia. In this framework, the PhD thesis "On site verification of theoretical models for quantifying C&D waste in buildings" is being developed.

Current results from this research reveal that it is required a model for quantifying the expected amount of C&D waste generated on site: a) verified in construction sites b) detailed by type and origin of waste.

In this paper, results obtained during the construction stage are shown. Deviation between estimates from theoretical models applied to projects and the real amount of C&D waste

quantified on site is revealed. This comparison is studied in a building subsystem (finishes) in a 225 dwelling building promoted by Empresa Municipal de Vivienda de Sevilla, EMVISESA (Sevillian Municipal Housing Enterprise).

II. MODELS FOR QUANTIFYING C&D WASTE.

In recent years, to establish ranges and parameters in order to describe waste generated by construction activity has become a key challenge. For that reason, several authors have developed methodologies for quantifying C&D waste. Many of these initiatives are general approximations that can only be applied to a certain region or building typology (dwelling or non-dwelling); however, a number of methodologies include construction materials and techniques in their approach [1].

These methodologies use empirical factors to quantify the generated C&D waste. These factors have been defined by different entities: a particular industrial sector (e.g.: drywall or concrete), construction cost databases, environmental agencies, or theoretical studies. So far, any study developed on construction sites defining factors of waste production has been found.

A. Spanish legal framework for C&D waste.

In Spain, although the generation of C&D waste is regulated in general terms since 1998, the regulatory framework for generation and management of C&D waste appeared in February 2008 with the entry into force of the National Decree 105/2008. Among other issues, deposit without treatment of recoverable waste is forbidden and waste disposal fees to discourage landfilling are demanded; in addition, autonomous communities are encouraged to create control measures linked to building permission, as can be fees or similar.

This Decree introduces a number of obligations that must be fulfilled by agents involved in construction activities. For example, the C&D waste producer has to include in construction projects a Waste Management Study with an estimate of the amount of C&D waste expected to be generated on site, in tons and cubic metres, according to EWL codes (European Waste List). Furthermore, it is also required to separate C&D waste into different fractions when they exceed the following amounts: concrete: 80 t; bricks, tiles, ceramic: 40 t; metal: 2 t; wood: 1 t; glass: 1 t; plastics: 0.5 t; paper and cardboard: 0.5 t. [2].

B. Current models for quantifying C&D waste in Spain

Is Spain, a number of softwares for quantifying C&D waste have been developed, as BEDEC Database by ITeC. Based on on-site studies, its results are volume of waste by built or demolished area. This software provides total weight and volume of each type of waste according to the European Waste List (EWL), in all construction phases. ITeC has also developed the guide "Writing the C&D Waste Management Plan". Applying a number of waste production factors to the built area, this guide assists to obtain an approached amount of waste in weight and volume, according to the 7 fractions required in National Decree 105/2008.

Currently, in order to comply with National Decree 105/2008, several professional organizations have developed models and guidelines, which make it easier the quantification of C&D waste from the design stage. For example, in Seville, Foundation FIDAS has developed a model to estimate the 7 waste fractions, offering very simplified data.

Related to more specific methods, Ph.D Thesis "Waste generated in residential construction. Proposals and evaluation of procedures and requirements for its minimization" (Llatas 2001), develops a methodology for quantifying C&D waste in order to assess the waste generated in each construction process. Obtaining data from the measurements and budget document of the project, a universal and detailed calculation procedure is proposed, according to the origin of the waste generated in each building element. In this procedure, transformation factors and estimation factors are used according to the type of waste (soil, packaging and remains). The analytical expressions developed gives the volume and detailed composition of waste expected in each building element [3].

III. METHODOLOGY

A. Objective

The main purpose of this paper is to compare models for quantifying waste generated during the Finishes phase in dwelling buildings.

B. Phases

The proposed methodology has the following stages:

- Compilation of documents of the project under study (written, graphic …) Description and analysis of specific characteristics of finishes.
- Analysis of the Chapter of Finishes in the measurement and budget document of the project. Structure, organization and coding homogenization of building elements in the measurement document, according to the Andalusian Construction Cost Database. Identification of chapters and subchapters. Identification and analysis of building elements. Selection of building elements to study on site.
- Analysis and measurement of waste generated on site during the execution of each building element. Following parameters are studied: type, shape and packaging of materials; amount of material by built area; measurement of volume and weight of packaging waste; measurement of volume and weight of remains, etc.
- Types and quantities of waste generated during the execution of each building element are identified. On site C&D Waste Sheets are filled in with the collected data, one sheet is filled by building element.
- Application of the Detailed Model for Quantifying Waste to each building element in the chapter of Finishes. Unit Price Breakdowns are established for each building element according to Andalusian

Construction Cost Database. Applying the appropriate factors, types and quantities of waste generated by building element are estimated according to this model.

- Application of waste generation factors obtained from BEDEC Database to each building element in the chapter of Finishes. Types and quantities of waste by building element are estimated, according to this software.
- Comparative study of results.

C. On site measurement of waste

First, every building element to execute during the Finishes phase is identified, according to the systematic structure of the construction process. After analyzing this building subsystem (Finishes), building elements are identified. Then, working groups are organized to study and measure the generated C&D waste. These groups are made up of senior students and coordinated by the authors of this paper. Volume, area or length are delimited on site for each building element, in order to analyze the work carried out during its execution. After executing a delimited building element, the waste generated on site is measured and identified, as it is shown in figure 1, 2 and 3.

Figure 1. Waste of building elements separated and piled on the place of work or in containers.

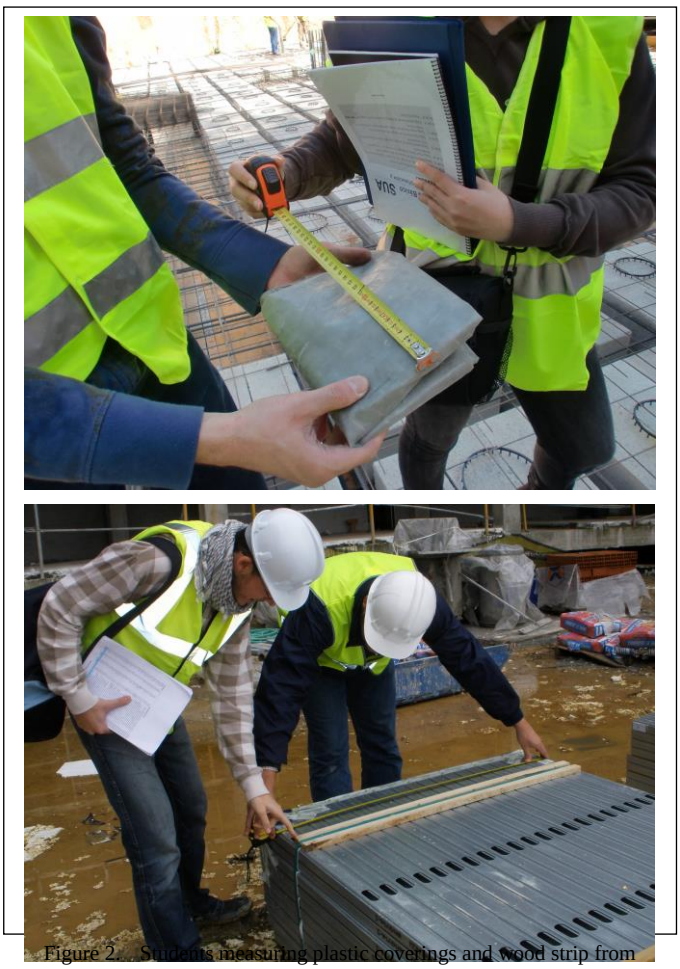

Figure 2. Students measuring plastic coverings and wood strip from packagings.

Subsequently, On Site C&D Waste Sheets are elaborated for each building element. In these tables, types of generated waste are identified, according to the European Waste List and grouped into three blocks: soil, packaging and remains. In Finishes phase, only packaging and remains are found. Next, volume and weight measurements of each type of waste are written down. The measurement of each group of waste is carried out as follows:

Packaging waste can be mixed with the contained material or other remains. They are usually generated in the place of material supply and stockpile (Figure 2). For each building element, types of generated packaging waste are identified and coded according to the chapter 15 of the European Waste List (Packaging Waste). Its volume and weight are quantified as well. Its recycling rate is quite high, in fact, most of them are re-used again, mainly the wood pallets, which have certain number of uses available.

On site measurement of waste generated during the execution of the building element is more complicated, due to waste is usually mixed and dispersed. A study area is delimited, and when operators finish the execution of that area, the generated waste is piled up and, if possible, stacked separately.

Figure 3. Students collecting and measuring paper remains. Student weighing and measuring marble tiles remains.

Types of waste are identified according to the European Waste List. In case of mixed fraction, each type of waste is estimated proportionally. Then, measurement is made (Figure 3), which can be in two ways:

- Waste of small size or with undefined shape (e.g: mortar, ceramic, cement, etc.) are introduced into a known volume container.
- Waste of big size or with defined shape (eg: plasterboard panels, sections, marble, etc.) are measured with tape after being stacked as a prismatic volume.

Finally, On Site C&D Waste Sheet for each building element is completed, filling in a section with incidents. An example can be seen in Figure 4, the On site C&D Waste Sheet for the unit of tiles. Although measurements have been made in volume and weight, tables are expressed in volume. Weight Conversion Table with data obtained on site is shown in Table 1.

ON SITE WASTE SHEET: PROJECT M.A.-3.1. API-DE-01(old SUNP-AE-1)

CHAPTER: 10:		FINISHES PHASE		
Andalusia Base Code: 10AAE00024		Tiles 20cm x 20cm, with adhesive.		
C&D Waste EWL Code	Amount executed	**7.213,38 m²**		
	On Site Information			
	C&D Waste measure-ment area	Tower B, stair 5, 7th flour: **2 big toilets and 2 small toilets: total: 31,55m²** Big toilets = (6,80X2,40m)+(0,30x0,75m)= 16,55m² Small toilets = (6,15x2,40m)+(0,30x0,75m)= 15m²		
15		**PACKAGING:**	**m³**	**m³/m²**
15 01 01	Cardboard:	Cardboard sacks and boxes out a volume of a +/- regular prism 0,65m x 0,9m x h:0,60m = 0,351m³. 0,351m³ x 7.213,38m² / 31,55m²= 80,250282m³. Plus handling loose of 5% is 4,012514m³ + 80,250282m³ = 84,262796m³.	84,262796	0,011681
15 01 03	Wood:	• Tiles pallets are 0,104728m³ with 72 boxes/pallet. Each box have 1,4m². 7.213,38m²/1,4m²/box = 5.152,42 boxes. 5% of the 5.152,42boxes are 257,62boxes, total require 5.152,42 + 257,62 = 5410boxes. 5410boxes / 72 boxes/pallets = 75,14 pallets x 0,104728m³= 7,869205m³. • Grout and adhesive comes in pallets of 0,114490m³ with 64 sacks by pallets (1600kg). Performance of 7kg/m². Then: 7213,38m² x 7kg/m² = 50.493,66kg. 50.493,66kg / 1600kg/pallets = 31,56pallets x 2(grout and adhesive)= 63,12pallets. Lost in handling: 1 sack by pallet = 63sacks/64sacks/pallets = 0,98pallets. 0,98pallets + 63,12pallets = 64,10pallets. 64pallets x 0,114490m³= 7,327360m³. Refer to use 5 times 7,869205m³ + 7,327360m³ = 15,196565m³. 15,196565m³/5uses = 3,039313m³	3,039313	0,000421
15 01 02	Plastic	Thick-plastic with 1.88% overrun. Original volume of the coating = 130,335520m³ (tiles 1 x 1,03 x 0,94m = 0,968m³/pallet x 75,14 pallet = 72,735520m³ and grout and adhesive sacks 1x1x0,9m= 0,9m³/palé x 64palés = 57,6m³) 130,335520m³ x 1,88% / 100% = 2,450308m³.	2,450308	0,000345
15 01 06	Other (1%) 89,752417 /100=		0,897524	0,000124
		Total Packaging	**90,649941**	**0,012567**
17		**REMAINS:**	**m³**	**m³/m²**
17 01 03	Ceramic Materials	Lost in handling: 5% are 258boxes with an approximate volume of 0,20 x 0,20 x 0,105m = 0,0042m³. 0,0042m³ x 258boxes =1,083600m³.	1,083600	0,000150
17 01 07	Mix Concrete Ceramic Materials	Measurement : 40lts baskets (h:33cm y d: 44cm) = 0,04m³ Remove Waste: 4,5 are drawn mixed waste baskets full of debris of tiles and blends. 0,04m³/container x 4,5container= 0,18m³. Total: 0,18m³ x 7.213,38m² /31,55m² = 41,153991m³.	41,153991	0,005705
17 09 04	Other (1%) 42,237591 / 100 =		0,422376	0,000059
		Total Remains:	**42,659967**	**0,005914**
		Total Tiles C&D Waste	**133,309908**	**0,018481**

Observations: Work done with little order, without great care to not generate unnecessary cuts or waste and spills. Some waste due to poor handling of pallets of tiles in the site, there are boxes scattered with several broken tiles, and some other entire pallet broken, so we estimated 5% of lost tiles and 1 sack/pallet in the paste adhesive and grout.
Comercial Brands: Tiles: KERAMEX, Concrete: CAPAFLEX, Grout: CAPACOLOR.

Figure 4. On site C&D Waste Sheet for the unit of Tiles

D. Theoretical models for quantifying C&D waste.

Subsequently, two methodologies for quantifying are applied to each building element: a) Detailed Model for Quantifying developed by University of Seville (3) b) waste generation factors from BEDEC Database, as a software for quantifying widely used in Spain (4).

The Detailed Model for Quantifying is selected for being the most specific method and having the greater degree of fragmentation. "This procedure is based on the fact that waste is simply the consequence of resources and packaging transformations, due to the construction process". Therefore, materials and their containers required for the execution of each building element are identified and quantified, according to the measurement and budget document.

In this Model, the total waste expected in the building is obtained by the sum of those expected in each building subsystem: excavation, foundation, drainage, structure, masonry, etc. Likewise, the waste expected in each building subsystem is obtained by the sum of those expected in the

execution of each building element (e.g., in Structure: columns, beams, sills, floors…).

TABLE I. WEIGHT CONVERSION TABLE WITH DATA OBTAINED ON SITE.

Weights Chart of Construction and Demolition Waste obtained on site.				
PACKAGING				
C&D Waste EWL Code	C&D Waste Tipe Names	On Site volume measured (m^3)	On Site weigth measured (kg)	kg / m^3
Paper or Cardboard				
15 01 01	Cardboard of Cement Sack	0,010080	0,75	74,40
15 01 01	Cardboard of Adhesive Paste bags	0,014700	1,00	68,03
15 01 01	Corrugated cardboard box	0,021206	1,00	47,16
15 01 01	Thin cordboard box	0,006158	0,50	81,20
Wood				
15 01 03	Pallet of 0.80 x 0.80 x 0.105m	0,067200	11,00	163,69
Plastic				
15 01 02	Thin plastic bag (screws)	0,013547	2,00	147,64
15 01 02	Thick coating of pallet	0,018900	2,00	105,82
Hazardous				
15 01 10*	Hard plastic container	0,028463	1,50	52,70
REMAINS				
C&D Waste EWL Code	C&D Waste Tipe Names	On Site volume measured (m^3)	On Site weight measured (kg)	kg / m^3
Physical or chemical transformation of non-metallic minerals				
01 04 13	Marble tile or threshold and veneer plinth of natural stone	0,010800	21,50	1990,74
Concrete, Brick and Ceramics				
17 01 01	Hardened mortar	0,015000	15,00	1000,00
17 01 01	Mortar of stony rendering monocapa	0,038906	12,50	321,29
17 01 01	Terrazzo paving tiles cut	0,005320	13,00	2443,61
17 01 02	Perforated brick	0,006930	6,00	865,80
17 01 03	Ceramic tiles cut	0,003600	5,50	1527,78
17 01 06*	Cellular Concrete (set)	0,007728	4,00	517,60
17 01 07	Double Hollow Brick and Mortar	0,008005	9,00	1124,33
17 01 07	Tiles with adhesive paste	0,022050	16,00	725,62
17 01 07	Perforated brick with mortar	0,018360	17,50	953,16
Wood, Glass and Plastic				
17 02 01	Wood from formwork	0,036666	13,00	354,55
17 02 03	Fiberglass mesh laminated and/or plastic lifeguards	0,027412	2,50	91,20
Metales				
17 04 05	Fine steel profiles for drywall	0,044800	10,00	223,21
17 04 02	Aluminum beading for stony rendering monocapa	0,000360	1,00	2777,78
Material with gypsum				
17 08 02	Plasterboard panels	0,023520	9,00	382,65
17 08 02	Dry plaster (mixture)	0,022050	20,00	907,03
17 08 02	Plaster (pasta and plates)	0,022050	17,50	793,65
Others (Mixed)				
17 09 04	Board tape for plasterboard corners of paper/metal	0,007069	0,85	120,25

To estimate the waste generated in each building element, a number of factors are applied to the total amount of each building element, in the unit of measurement of the project. These factors are used to transform these quantities into volume/weight of waste, differentiating between soil, remains and packaging waste. Obtained waste is coded according to the European Waste List.

IV. CASE STUDY

This research has been applied to social housing buildings promoted by the Empresa Municipal de Vivienda de Sevilla, EMVISESA (Sevillian Municipal Housing Enterprise). These are four to eight floors buildings with ground floor and basement, and their design features are normally used in Spain: reinforced concrete foundation; reinforced concrete structure; brick closings; plasterboard panels; ceramic, terrazzo or marble pavements; flat roof; aluminium carpentry on the exterior; wooden carpentry on the interior.

The case study selected is a building promoted by EMVISESA, located in the M.C.-1.2 block in Polígono Aeropuerto API-DE-01 (former SUNP-AE-1), called as well East district, in Seville, Spain (Figures 5 and 6). It is a 21.379,81 m² multi-family residential building in perimeter block, with 225 dwellings, garage, storage and commercial premises in the ground floor. It was designed in 2006 by the architect Manuel López García. Its construction was finished in early 2011 by Constructor SANJOSE.

Figure 5. External views of the M.C-1.2 perimeter block building, during its construction

Figure 6. Figure 6. View from the courtyard of the perimeter block Building MC-1.2, once its construction has finished

The two aforementioned theoretical models for quantifying are applied to this case study. Obtained data are compared with on site data. Each building element included in the subsystem of finishes is identified in the measurement document of the project. Elements with similarities in their execution are joined in order to make a simplification. Finally, 17 building elements are obtained to quantify their waste.

A. Discussion of results by building element

On Site Waste Sheet are filled in for each of this 17 building elements. Subsequently, comparative tables of coefficients are made, one by each building element in the Finishes phase, obtaining 17 tables in total. An example can be seen in Table 2, corresponding to the building element “m2 of tiles”. In this table, types and quantities of waste obtained on site are indicated and compared with results obtained from the Detailed Model for Quantifying by University of Seville (Llatas, 2001) and the BEDEC Database by ITeC.

TABLE II. C&D WASTE QUANTIFICATION SHEET FOR THE UNIT OF TILES

CONSTRUCTION WASTE QUANTIFICATION SHEET					
CHART 10.1	PROJETC: M.C-1.2 API-DE-01				
CHAPTER 10.	CONSTRUCTION PHASE: FINISHES				
CONSTRUCTION UNIT	**12.892,54**	**m2 of Tiles 20cm x 20cm, with adhesive.**			
C&D WASTE EWL CODE	C&D WASTE GENERATED	TOTAL VOLUME QUANTIFIED ON	GENERATION COEFFICIENTS		
			MEASUREMENT ON SITE	U.S. DETAILED MODEL	BEDEC SOFTWARE
15	**PACKAGING**	**m^3**	**m^3/m^2**	**m^3/m^2**	**m^3/m^2**
15 01 01	CARDBOARD	150,597760	0,011681	0,001900	0,001900
15 01 03	WOOD	5,427759	0,000421	0,001163	0,000891
15 01 02	PLASTIC	4,447926	0,000345	0,000621	0,000001
15 01 06	OTHER	1,598675	0,000124	0,000037	0,000037
TOTAL PACKAGING		**162,072120**	**0,012571**	**0,003721**	**0,002829**
17	**REMAINS:**	**m^3**	**m^3/m^2**	**m^3/m^2**	**m^3/m^2**
17 01 01	CONCRETE	-	-	0,000672	0,000095
17 01 03	CERAMIC	1,933881	0,000150	0,000534	0,001800
17 01 07	CONCRETE &CERAMIC	73,551941	0,005705	-	0,000090
17 09 04	OTHER	0,760660	0,000059	0,000012	-
TOTAL REMAINS		**76,246482**	**0,005914**	**0,001218**	**0,001985**
TOTAL TILES C&D WASTE		**238,318602**	**0,018485**	**0,004939**	**0,004814**

In this particular case, the ratio obtained on site is 0,018485 m3 per square metre of tiles. Comparing this value with results obtained by the Detailed Model (0,004936 m3/m2) or BEDEC Database (0,004814 m3/m2), the deviations observed are a percent decrease of 374% and 384% respectively. Applying this ratios to the total area of tiles, the results obtained are 63,68m3 (Detailed Model) and 62,06 m3 (BEDEC), when in fact, the real amount of waste generated is 238,32 m3.

B. Discussion of results on Finishes Phase

Ratios obtained in the C&D Waste Quantification Sheets are applied to the quantities of building elements on Finishes phase in the M.C-1.2 project. Total amount of generated waste in cubic metres is obtained according to the Detailed Model, BEDEC Database and on site measurement, as can be seen in Table 3.

Reviewing these results, values obtained by applying the two theoretical models don't correspond with on site data. In some cases, the difference between values is very high. Related to the total amount, deviations observed respect to on site data are a percent decrease of 193% in the case of the Detailed Model and 464% in the case of BEDEC Database. In most of the analyzed building elements, values obtained by applying the Detailed Model and BEDEC are lower than on site data. However, some exceptions are found:

- For four building elements, values obtained by the Detailed Model are higher than on site data.
- For the unit of "m of veneer plinth of natural stone", values obtained by BEDEC are higher than Detailed Model and on site data.
- In the case of "m2 of rendering mortar" and "m2 of concrete slab", on site data are lower than values obtained by applying the two theoretical models.

C. Discussion of results by Type of Waste in Finishes Phase

Results by type of waste generated in Finishes phase of the M.C-1.2 project, according to the Detailed Model, BEDEC and on site measurement are shown in Table 4.

As can be seen, according to on site data, quantities of remains are higher than quantities of packaging waste, unlike the results obtained by the Detailed Model and BEDEC. Related to packaging waste, the quantity obtained by the Detailed Model is 410,81m3, which is 155% lower than the quantity generated on site (636,81 m3). By applying BEDEC, the quantity is 361% lower (177,31 m3).

TABLE III. AMOUNT OF C&D WASTE BY BUILDING ELEMENT.

CONSTRUCTION WASTE GENERATED IN M.C-1.2 PROJECT ON FINISHES PHASE BY BUILDING ELEMENT: COMPARISON OF DETAILED MODEL FOR QUANTIFYING, BEDEC SOFTWARE AND ON-SITE MEASUREMENT.							
SUB-CHAPTER	ANDALUSIAN UNIT CODE	UNIT	Obra: M.C-1.2. API-DE-01. CHAPTER 10: FINISHES	AMOUNT EXECUTED	BEDEC SOFTWARE M3	U.S. DETAILED MODEL M3	MEASUREMENT ON SITE M3
APLAC	10AAL00003	m2	TILES 20CM X 20CM, WITH ADHESIVE.	12.892,54	62,06	63,68	238,32
CONTINUOUS	10CEE00003	m2	RENDERING MORTAR ON WALL	7.562,09	11,79	6,68	5,05
	10CGG00008	m2	GYPSUM PLASTER ON WALL	8.963,60	17,99	43,37	51,50
	10CGG00007	m2	GYPSUM PLASTER ON CEILING	10.462,25	26,65	49,56	44,46
	10CRR00080	m2	MONOCOUCHE RENDERING MORTAR, 10 MM.	19.354,28	69,13	50,95	451,77
STEPS	10PNP00003	m	MARBLE STEP, FOOTPRINT AND RISERS.	1.725,15	5,25	148,02	76,73
FLORING	10SCS00003	m2	FILOORING WITH CERAMIC TILES, 40X40CM	3.078,18	6,81	31,92	11,91
	10SHS00001	m2	PAVING WITH HYDRAULIC CONCRETE, 40x40cm. BEVELED	3.044,24	6,62	10,93	17,88
	10SNR00005	m	VENEER PLINTH OF NATURAL STONE	240,60	0,95	0,08	0,44
	10SNW00011	m	MARBLE THRESHOLD	48,09	0,04	0,54	1,12
	10SSS00003	m2	CONCRETE FLOOR, 15CM	5.104,50	8,13	43,47	7,40
	10STS00020	m2	FLOORING TERRAZZO PAVING, 40X40CM.	13.928,60	91,42	27,75	336,15
	10SWW00081	m2	SCREED OF FLOORS WITH BRICKS	41,28	0,13	0,68	8,06
	10SWW00100	m	TAPING OF PREFABRICATED CONCRETE VIBRATED 40X20X5CM	920,40	1,52	3,46	5,40
CEILINGS	10TET00003	m2	CONTINUOUS CEILING PLASTER PLATES, FIXING WITH RODS.	1.710,99	2,08	2,25	57,33
	10TWW00011	m2	CONTINUOUS CEILING WITH PLASTERBOARD PANELS, 10MM.	6.107,08	12,87	164,96	16,79
VARIOUS	10WAA00001	m	ARTIFICIAL STONE WINDOW SILL AND REMATE, 30 CM.	3.560,78	3,22	136,72	186,29
				Total:	**326,68**	**785,03**	**1.516,61**

TABLE IV. AMOUNT OF C&D WASTE BY TYPE OF WASTE

CONSTRUCTION WASTE GENERATED IN M.C-1.2 PROJECT ON FINISHES PHASE BY TYPE OF WASTE: COMPARISON OF DETAILED MODEL FOR QUANTIFYING, BEDEC SOFTWARE AND ON-SITE MEASUREMENT.				
PACKAGING				
C&D Waste EWL Code	TYPE OF WASTE	BEDEC SOFTWARE M3	U.S. DETAILED MODEL M3	MEASUREMENT ON SITE M3
15 01 01	CARDBOARD PACKAGING	48,55	50,15	317,96
15 01 02	PLASTIC PACKAGING	0,90	26,63	109,33
15 01 03	WOODEN PACKAGING	127,19	323,25	146,25
15 01 10*	HAZARDOUS PACKAGING	0,18	6,71	58,67
15 01 06	MIXED PACKAGING (OTHES)	0,48	4,07	6,34
	TOTAL PACKAGING	**177,31**	**410,81**	**638,54**
REMAINS				
C&D Waste EWL Code	TYPE OF WASTE	BEDEC SOFTWARE M3	U.S. DETAILED MODEL M3	MEASUREMENT ON SITE M3
01 04 13	STONE QUARRY	0,05	0,10	0,07
10 13 96	CEMENT	0,00	0,00	0,49
17 01 01	CONCRETE	79,47	94,18	573,71
17 01 02	BRICK	0,04	0,17	5,95
17 01 03	CERAMIC MATERIAL	24,13	6,89	3,11
17 01 07	MIX CONCRETE AND CERAMICS	1,16	0,00	116,49
17 02 02	WOOD	0,00	0,06	0,07
17 02 03	PLASTIC	0,01	11,97	5,71
17 04 02	ALUMINUM	0,00	0,03	0,04
17 04 05	IRON AND STEEL	0,00	0,13	0,29
17 05 04	SOIL, SAND & GRAVEL	4,26	11,55	0,00
17 08 02	MATERIAL WITH GYPSUM	40,26	245,44	124,90
17 09 03	MIXES (OTHER)	0,00	3,70	47,22
20 01 01	PAPER	0,00	0,00	0,01
	TOTAL REMAINS	**149,37**	**374,22**	**878,07**
	TOTAL	**326,68**	**785,02**	**1.516,61**

In the case of packaging waste, according to the Detailed Model, wood packaging are the highest value (410,81m3). 65% of this quantity corresponds to pallets from window sills and marble steps. According to BEDEC, the highest value corresponds to wood packaging as well.

According to on site data, 50% of packaging waste corresponds to cardboard packaging, which are the most voluminous: 317,56m3. 47% of this quantity corresponds to sacks of adhesive paste or cement and boxes of tiles, 29% corresponds to cement sacks from the terrazzo flooring, and 8% corresponds to sacks of gypsum for plastering.

Related to hazardous packaging, deviations obtained are a percent decrease of 874% in the case of the Detailed Model (6,71m3) and 32,594% in the case of BEDEC (0,18m3), being 58,67m3 the real volume generated. This difference has enormous consequences in the planning of the management of this type of waste.

With respect to remains data, according to the Detailed Model, the quantity generated is 374,22m3, which is 235% lower than the quantity measured on site (878,07 m3). According to BEDEC, the quantity generated is 326,68m3, which is 588% lower than on site data.

According to the Detailed Model, the highest quantity of remains corresponds to remains of gypsum materials from plasterboard ceiling (161,23m3) and plaster on walls and ceilings (83,76m3).

According to on site data, the highest quantity of remains corresponds to concrete (66,58%), followed by gypsum (14,31%) and concrete and ceramic mix remains (13,21%). These remains are generated by pre-cleaning of the work area and necessary small demolitions to fit pieces during the work.

V. CONCLUSIONS

As can be seen in the discussion of results, deviations observed between data from on site measurement and data obtained using the Detailed Model by University of Seville or the BEDEC Database by ITeC, are very high. The "mismatch" between quantities obtained from theoretical models and real quantities generated on construction sites implies a lack of reliable data during the design stage, which is needed to plan an optimal C&D waste management. This is a key challenge, especially since the National Decree 105/2008, in its article 5.5, requires to separate C&D waste into seven fractions if certain amounts are exceeded.

Deviations between theoretical results and real quantities of waste generated on site, confirm that current theoretical models for quantifying C&D waste, which are used as guidelines to planning C&D waste management, must be verified in construction sites

Using a model for quantifying verified in construction sites, more accurate data can be handled from early stages, as the design project. Identifying real amount generated of C&D waste, their management can be improved, reducing their generation and promoting recycling.

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