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Estimation of building waste flows and adequacy with resources

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Abstract. Today, the flows of materials in the French building sector are poorly known, both in terms of quantities or types of recovery (reuse, recycling, energy recovery, etc.). Therefore, the aim of this study is to increase the knowledge about recovery of building products in France. A methodology is developed to identify the flows of materials resulting from the deconstructions of buildings. The volume of demolished buildings for each typology (individual house, apartment building, office building...) and constructive system (brick, concrete, wood...) is known from the state of the art. Moreover, the quantities of demolished materials are estimated for each building typology from a French database of building waste diagnosis. Then, the volume of waste can be calculated for all the building sector and the deconstruction flows can be crossed with an analysis of the existing types of recovery (projects of close development, recycling channels, ...). This analysis will present the distribution of the different ways of recovery for each type of material and the associated costs. This capitalization of data on waste flows and building resources will allow to question the adequacy between material needs and available resources.

Keywords: waste flows, recovery, deconstruction, resources

1. Introduction

In France, the civil engineer and building sector is the first consumer in terms of raw material and the first waste producer [1]. With dwindling material resources, it became clear that C&D waste management should be improved and that the use of materials from recovering should grow. For a sound and adequate management of construction waste, their quantification is crucial [2]. Therefore, the research interest in C&D waste quantification and management is increasing over last years [3]. For example, generated and potential building waste streams in Bulgaria are studied to define the priorities of the waste management strategy [4]. A selective classification and quantification model of C&D waste is also developed and used in residential buildings in Seville (Spain) [5].



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Unfortunately, the flows of materials in the French building sector are poorly known, both in terms of quantities or types of recovery (reuse, recycling, energy recovery, etc.). It is therefore necessary to improve the knowledge concerning the flows of materials and to anticipate and develop new recovery channels.

The aim of this study is to estimate the quantities of waste resulting from the deconstruction of buildings in France and to evaluate the recovery rates of C&D waste in the different recovery channels. The study is based on a state of the art and on a database of waste management in demolition sites.

In this paper, we present the global methodology we defined to estimate both C&D waste quantities and their recovery rates. Then, the material description of the different building typologies is detailed in section 3. The next section is devoted to the analysis of a case-study: the estimation of material quantities contained in a concrete apartment building. Finally, the recovery rates of building waste are evaluated with the database and compared to the state of the art in section 5.

2. Methodology

A methodology is being developed to identify material flows resulting from the deconstructions of buildings. The main steps are the followings:

- Step 1:
The volume of demolished buildings for each typology and constructive system is stemming from a state of the art analysis. The main studied building types are: individual house, apartment building, office and administration, industrial building. If the state of the art is accurate enough, the typologies will be studied separately according to the constructive system (brick, concrete, wood or metal).
- Step 2:
The different building typologies are defined in terms of constituent materials. Their types (concrete, ceramic, brick, glass, wood, plastic, insulation ...) and quantities are estimated thanks to the analysis of a French data-base of building waste diagnosis. This step is developed in sections 3 and 4.
- Step 2bis:
The French data-base of building waste diagnosis is also used to determine the global distribution of the different recovery channels for each type of material. This step is presented in section 5.
A further analysis of the database will consist in estimating the average recovery rates for the different material flows and for each typology separately. Indeed, a ton of concrete is not valued in the same way according to its origin, individual house or large building of collective housing for example.
- Step 3:
The waste streams and global recovery rates for C&D wastes are known from a previous state of the art presented in section 5. There are compared with the results of the step 2bis.
- Step 4:
Then, thanks to the steps 1 and 2, the volume of deconstruction waste can be calculated for the whole building sector. Therefore, the deconstruction flows can be crossed with an analysis of the existing types of recovery (projects of close development, recycling channels, ...). This capitalization of data on waste flows and building resources will allow to question the adequacy between material needs and available resources.

This article focuses especially on building types development (step 2).

3. Development of typologies – step 2

In France, the article 3 of the decree of December 19th, 2011, relating to the diagnosis about the management of waste resulting from the demolition of buildings imposes to realize a waste diagnosis for the demolition of the following buildings:

- Buildings which have an area upper than 1000 m²;
- Professional buildings which have received hazardous substances.

Thanks to a collection file (CERFA 14498), ADEME (the French Environment & Energy management Agency), which is responsible to gather these waste diagnoses, collect data about demolished building projects. All these data constitute the database of building waste diagnosis, that is used in this case study.

The main data available in the database are presented in table 1.

Table 1. Data available in the database of building waste diagnosis.

General data	Number of buildings in the project
	Total area of the project
	Type of building: industrial building, shop, office building, housing, school building, hotel...
Quantification of waste	For each project, a quantification by waste type must be realized:
	Inert waste: concrete and stone, ceramic, bituminous mixture without tar, tile and brick, glass, inert waste mix...
	No-hazardous waste: wood without hazardous substances, window, insulation, metal, plastic, plaster, no-hazardous waste mix ...
	Hazardous waste: asbestos, wood with hazardous substances, bituminous mixture with tar, hazardous waste mix...
Ways of recovery	For each project, a quantification by waste management type must be realized. The categories of waste management are:
	- Reuse (on site or out site)
	- Sent to an eco-organization
	- Waste sent to a sorting center
	- Other material recovery
	- Incineration with energy recovery
	- Storage
	- Other elimination

} Material recovery

Some projects are composed of several building typologies (ex: a project can be composed of an industrial building and an office and administration building). One of the aims of this study is to analyze the projects by building typology. In order to simplify projects composed of several typologies, the following hypothesis has been adopted: when a building typology represents more than 90% of the total project area, this typology is used for the project. Thus, 209 projects were selected with 1 building typology and 31 projects contain between 2 and 5 types of building typology.

Considering this hypothesis, the distribution of deconstructed surfaces by building typology for these 209 projects is presented in figure 1.

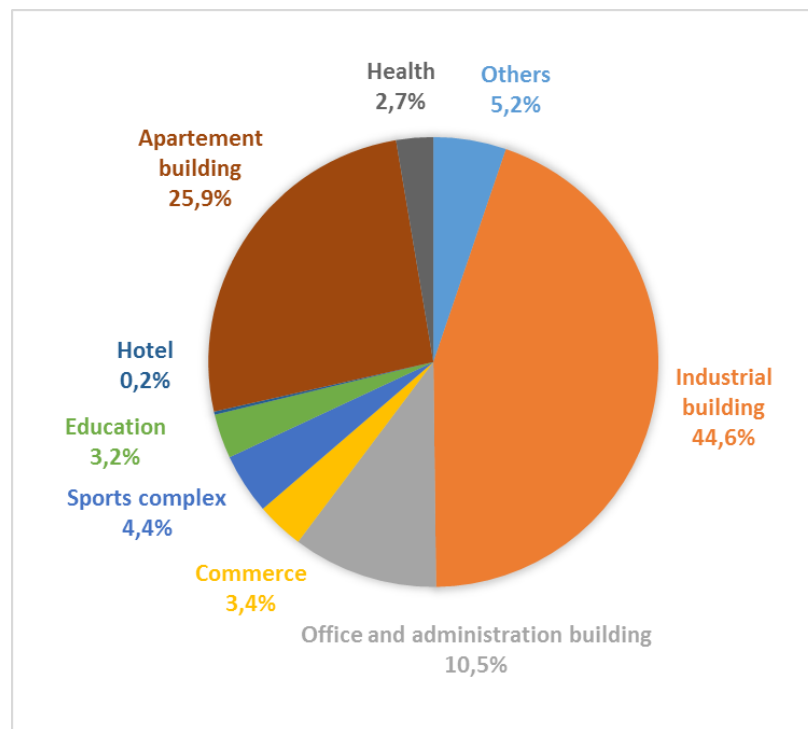


Figure 1. Deconstructed surfaces by building typology.

In 2018, the database gathers 240 projects, the main building typologies represented in the database are the followings:

- 80 projects of industrial building;
- 61 projects of apartment building;
- 29 projects of office and administration building.

The development of different building typologies consists in calculating the average quantity per square meter of each type of materials (concrete, ceramic, brick, glass, wood, plastic, insulation ...) that is constituent of a given typology. To determine the constructive system the different buildings, we focus on the quantities of brick, concrete, wood and metal.

The first typology that was defined is the concrete apartment building. The analysis is presented in the next section.

4. A case study: concrete apartment building

The goal of this case study is to determinate the average amounts of waste (concrete and stone, tile and brick, wood, plastic, plaster...) per square meter in an apartment building made of concrete in France. In this way, the database of building waste diagnosis was used.

The selected projects to establish these average quantities, had to meet the following criteria:

- The building type is apartment building;
- It is necessary that concrete/stone quantities are specified;
- The metal or tile/brick quantities (per m²) are not upper than concrete/stone quantity (per m²);
- The concrete/stone quantity (per m²) has not to be aberrant in comparison with the other projects;

- The quantities for the categories “no-hazardous waste mix” and respectively “inert waste mix” need to represent less than 5% of the total no-hazardous waste quantity waste and respectively of the total inert waste quantity;
- It is necessary that lots of types of waste are quantified (in order to select the projects which really sorted their waste).

With all the criteria, 23 projects have been selected. The results are presented in figure 2.

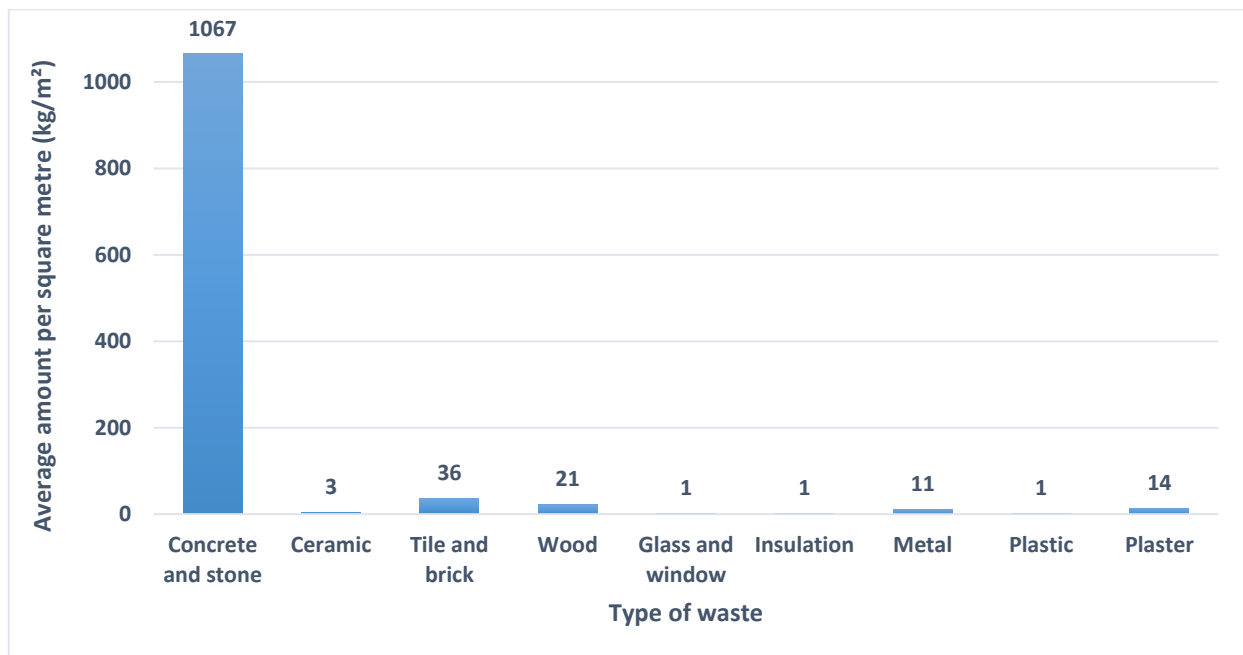


Figure 2. Average amount of waste per m² for an apartment building made of concrete.

In an apartment building made of concrete, one square meter produces 1155 kg of waste, 92% of this waste are concrete and stones (1067 kg/m²). This amount represents a quantity 100 to 1000 larger than for the other categories.

5. Recovery flux

5.1. State of the art

A state of the art has permitted to determine the recovery channels for building waste [6-8]. The recovery channels identified are the following: material recovery (reuse, recycling, used as career filling, used as road underlay), incineration with energy recovery, waste storage facility and incineration without energy recovery. The state of the art has also permitted to quantify the current recovery methods for different types of waste. In order to compare these results with those of the waste diagnosis database, only some types of waste were presented. For inert waste, table 2 presents the results for concrete, bricks, tiles/ceramics and glass and for no-hazardous waste, table 3 presents the results for wood, plastic, metal, insulation and plaster.

Table 2. Recovery rates for some types of inert waste (results from the state of the art).

Type of inert waste	Reuse	Recycling	Career filling	Road underlay	Energy recovery	Waste storage facility	Incineration without energy recovery
	Material recovery						
Concrete		Between 58 and 70%			/	Between 30% and 42%	/
Tiles and ceramics	20%	20%	55%	/	/	5% in inert waste storage facility 95% in no-hazardous waste storage facility	/
Glass	/	5%	/	/	/		/

Table 3. Recovery rates for some types of no-hazardous waste (results from the state of the art).

Type of no-hazardous waste	Reuse	Recycling	Career filling	Road underlay	Energy recovery	Waste storage facility	Incineration without energy recovery
	Material recovery						
Wood		40.2 %			34 %	25.1%	/
Plastic		From 0 to 5%			/	From 95 to 100% in no-hazardous waste storage facility	/
Metal	From 0 to 11%	From 87% to 98%	/	/	/	From 2 to 15% in no-hazardous waste storage facility	/
Insulation	/	From 0 to 40%	/	/	/	From 60 to 100% in no-hazardous waste storage facility	/
Plaster	/	From 0 to 5%	/	/	/	From 95 to 100% in no-hazardous waste storage facility	/

5.2. Results from the field

In order to compare these results with those of the state of the art, the same type of waste was selected in the database. These results have been obtained from all the projects referenced in the database (241 projects) and are presented in tables 4 and 5.

Table 4. Recovery rates for some type of no-hazardous waste (database of building waste diagnosis results).

	Reuse	Sent to a sorting center	Other material recovery	Incineration with energy recovery	Sent to an eco-organization	Waste storage facility	Other elimination
Concrete/Stone	64%	11%	19%	0%	0%	5%	1%
Tiles/bricks/Ceramics	59%	6%	0%	19%	0%	16%	0%
Glass	2%	12%	79%	0%	0%	7%	0%

Table 5. Recovery rates for some type of no-hazardous waste (database of building waste diagnosis results).

	Reuse	Sent to a sorting center	Other material recovery	Incineration with energy recovery	Sent to an eco-organization	Waste storage facility	Other elimination
Metal	1%	15%	80%	0%	0%	4%	0%
Insulation	5%	30%	7%	5%	0%	53%	0%
Plaster	6%	24%	17%	2%	4%	47%	0%
Plastics	0%	25%	65%	0%	0%	10%	0%
Wood	2%	23%	21%	34%	0%	20%	1%

Comparison between state of the art and waste diagnosis database is very contrasted. Indeed, for metal and wood categories, the results are very concordant. For brick/tiles/ceramics, plaster and insulation categories the results are quite similar, but some differences appear. Finally, for some types of waste (glass, plastic, plaster), the results are totally opposed. Indeed, according to the state of the art, the majority of these materials are sent to waste storage facility. But according to the database, most of them are valorized, in a material way. A deeper analysis of those differences based on other data sources will be undergone in further studies.

6. Conclusion and perspectives

This paper presents the methodology we defined to estimate both demolition waste quantities and their recovery rates. The French database of waste diagnosis is described and then used to develop building typologies. The example of the concrete apartment buildings illustrates the method to define a typology. In this type of building, one square meter produces 1155 kg of waste, 92% of this waste are concrete and stone (1067 kg/m²). Finally, the global recovery rates of building waste are estimated thanks to the state of the art and compared with the results given by the analysis of the database. For certain types of waste (metal and wood), the results fit well with the global estimation but, for other types of materials (glass, plastic, plaster), the difference is significant.

The other typologies are under development, as well as the estimation of the volume of demolished buildings for each typology and constructive system. Further analysis of the database and other data sources will be necessary to consolidate the knowledge about recovery rates.

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