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Integrated Approach to the Environmental and Socio-Economic Impact of Social Housing Companies in Versailles and Guyancourt, Paris, France

RAFIDIARISON Harilala[1], SAMIR Allal[1], ANDRIANARIMANANA Jean Claude Omer[2], ANDRIANJARY Myriam[3]
[1]University of Versailles Saint-Quentin-en-Yvelines, Paris, France (2014)
[2]Doctoral School of Natural Resource Management and Development, University of Antananarivo, Madagascar
[3]University of Vakinankaratra, Madagascar

Abstract— *The Construction and Public Works (CPW) sector is a major economic driver at the national level, but it is also the primary source of waste by volume. The current management of this waste is still inefficient, as approximately 98% of CPW waste is simply dumped in inadequate or uncontrolled landfills across large areas, wasting resources and polluting the environment. This problem is exacerbated by the lack of specific regulations for managing this type of waste and the lack of treatment infrastructure to accommodate it. It is in this context that this study was conducted to develop an integrated waste management strategy for CPW, based on the principles of the circular economy and eco-design. The main objective of this research is to propose a sustainable CPW waste management strategy by identifying potential recovery channels and suggesting eco-design measures to reduce waste production at the source. The methodology adopted was mixed, combining a literature review, semi-structured interviews with sector professionals, and the physical characterization of waste collected in the field. The data was then analyzed to evaluate the cost-benefit of the proposed solutions. The study results showed that inert waste (concrete, bricks) represents 75 to 80% of the total volume and constitutes a significant resource for recycling. The study also highlighted the main obstacles to recovery, particularly the high cost of transport and the mistrust of local stakeholders regarding the quality of recycled materials. It was demonstrated that the application of eco-design, such as the use of modular materials, could reduce waste production by 20%. In conclusion, the proposed strategy, which includes the creation of mobile sorting platforms and the establishment of local standards, is technically and economically feasible for a transition towards a circular economy in the CPW sector.*

Keywords— *Construction waste, Management, Recovery, Circular economy, Ecodesign.*

I. INTRODUCTION

Research on the quantification and characterization of construction sector waste has revealed that, over the past decade, waste generation has ranged between 300 and 350 million tons (ADEME, 2007). These quantities are closely linked to the economic context, infrastructure planning, and urban development policies. According to available data on waste management, this volume represents nearly eight times that of household waste. The management of such waste falls under the dual responsibility of the producer—the project owner—and the holder—the contractor operating on site.

Over time, the composition of construction waste has evolved as a result of changes in building techniques and materials, as well as regulatory developments in the construction sector. Approximately 85 to 90 percent of this waste is generated by building construction sites and 10 to 15 percent by public works projects (ADEME, 2007).

Recent awareness of the non-renewable nature of certain natural resources, combined with tensions in raw material and energy markets and increasing regulatory pressure from European institutions, has led to the gradual establishment of specialized recycling and recovery channels within the sector.

Waste generation in the C*onstruction and Public Works* (CPW) sector is now widely recognized by industry stakeholders as a major issue. Beyond its environmental impact, it also represents a significant economic loss due to high management costs. Consequently, local waste prevention initiatives have been developed to promote new approaches to design, renovation, and construction that minimize waste production.

While the building and public works subsectors differ in the nature and volume of their waste, they share a common commitment to the recovery and reuse of materials, taking into account technical, economic, environmental, and social criteria.

This paper seeks to provide updated data and insights on waste management in the French construction and public works sector. Its objective is to present an overview of the current state of CPW waste—its generation and characteristics—in order to propose a sustainable management framework that integrates economic and environmental considerations, emphasizing the critical importance of sustainability in waste management practices.

II. CONTEXT OF THE STUDY

1.1 Construction and public works waste management

C*onstruction and Public Works* (CPW) waste originates from projects managed by public authorities (the State, local communities) or private entities (companies, individuals). Their management differs between the building and public works sectors, mainly due to the number of stakeholders involved in each project, the nature of the waste produced, the locations of production, and the possible treatment methods. In 2000, following a circular issued on February 15, the Ministers of the Environment and Infrastructure entrusted the prefects with the

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task of developing the first departmental plans for the management of construction and public works site waste.

This marked the first initiative aimed at building consensus, primarily intended to define and then increase the capacity of facilities for handling construction site waste across the territory. It also sought to change the practices of stakeholders to promote on-site sorting and recycling.

Several strategic action areas were identified in this circular, namely:

- Comply with existing regulations and continue programs to close illegal dumping sites;
- Establish a network of treatment facilities;
- Promote the recovery and recycling of waste;
- Encourage the use of recycled aggregate;
- Promote tools that allow for the specific consideration of the "*waste*" component in the cost of building or road infrastructure projects.

It also defined the content of the plans, outlining their objectives to:

- Quantify the waste generated;
- Inventory the existing treatment channels;
- Identify the new treatment facilities to be established;
- Prepare an assessment of material resource management and the use of recycled materials.

These initial initiatives helped structure the management of construction and public works site waste by contributing to the creation of numerous treatment facilities and raising initial awareness of the BTP waste issue.

More than ten years after the launch of these efforts, although the number of facilities needed to meet industry demands has significantly increased, the situation remains unsatisfactory in some areas, where certain categories of waste lack appropriate treatment solutions. This is compounded by practices such as burning, landfilling, and uncontrolled waste dumping. In this context of insufficient facilities to handle this waste, priority was given to reducing the treatment capacity deficit. However, some more qualitative recommendations were overlooked, such as:

- Improving on-site sorting;
- Ensuring traceability of waste flows.

In response to these shortcomings, the *Grenelle Environment Forum* sought to initiate a new generation of CPW waste prevention and management plans, more structured, with the responsibility for their development and monitoring entrusted to the departmental councils, or the regional council for Île-de-France. These new CPW waste prevention and management plans are intended to:

- Give special priority to the issue of waste prevention, focusing on reducing the quantities of waste produced and limiting their hazardous nature;
- Adopt specific, contextual objectives and an action plan to achieve them;
- Equip themselves with tools for monitoring and validating the policies thus implemented.

The new plans will be subject to a public inquiry in order to ensure their compatibility with public decisions, particularly regarding work orders and authorizations to operate specific construction waste management facilities. Each year, a progress report must be presented to the Plan's evaluation and monitoring committee, which will decide every six years on the need for a revision.

1.2 Stakeholders and priorities in construction waste management

The General Council, which plays an advisory role in environmental legislation, is entrusted with new responsibilities regarding the development of the waste prevention plan. It must set an example in its roles :

- As the planning and coordinating authority for the plan and its monitoring;
- As a major project owner in the region for public works projects and, to a lesser extent, for building projects;
- As a potential funder for local authorities, which are also clients of construction projects.

To address concerns regarding behavioral change and thereby ensure the success of the new planning approach, a more operational methodology has been implemented according to the points below:

- Engage public and private project owners;
- Establish a territorial consultation bringing together all relevant stakeholders;
- Conduct a thorough assessment incorporating a qualitative approach to waste management in the plan area;
- Propose operational and incentive-oriented measures to be developed through the consultation and territorial coordination process;
- Initiate a system for observation, implementation, and monitoring.

1.3 Regional feedback

An example of success in the development of departmental plans was approved in 2003 and 2005. These are the departmental plans of Languedoc-Roussillon, which can serve as a reference to a certain extent, as they all include:

- A quantification of waste sources;
- An inventory of existing facilities and those yet to be created;
- Recommendations for the various stakeholders, which led to the signing of "*good practice charters for construction waste management*";
- Minimum monitoring provisions as specified in the circular, namely an annual report submitted to the development committee.

These plans achieved some undeniable progress, even though the recommendations often lacked operational scope and incentive value, particularly in the following areas:

- Creation of new treatment facilities;
- Opening of municipal waste collection centers to a greater number of artisans' waste;
- Development of material recycling, reaching up to 10% of the total waste stream in 2011.

In a context where the implementation of coherent and operational waste management at the local level remains complex, it is important to attempt a concise analysis of the main factors influencing the development of the sector in order to focus actions on the lack of coordination among stakeholders in managing this waste.

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III. Construction waste

1.1 Construction waste sources

Construction waste encompasses waste generated from CPW including demolition, maintenance, rehabilitation, and new construction. According to a study by the General Commission for Sustainable Development published in October 2010, the total construction and public works waste generated in France in 2008 (the reference year in most publications) amounted to 254.5 million tonnes, with 38.2 million tonnes from building and 216.3 million tonnes from public works. It is important to note that materials reused on the same site (for example, as backfill) are not included in the tables below, which report the quantification and distribution of waste produced by construction activity. These data come from the survey conducted by Department for Observation and Statistics (SOeS) of the French Ministry for Ecology and Sustainable Development. Ministry for Ecology, Sustainable Development and Energy (MEDDE)

TABLE 1: Quantification of the different types of waste generated by each sector of CPW in 2008 (CGDD, 2010).

Sector	**Total waste quantity (million tonnes)**	**Distribution by waste type (%)**			Total
		Inert waste	Non-hazardous non-inert waste (NIW)	Hazardous waste (HW)	
Building	38.2	72.4	26.1	1.5	100
Structural work	28.1	80.8	18.0	1.2	100
Finishing work	10.1	49.0	48.6	2.4	100
Public works	216.3	97.6	1.5	0.9	100
Total	254.5	93.8	5.2	1.0	100

TABLE 2: Distribution of different types of waste generated by each sector of the construction and public works in 2008 (CGDD, 2010).

Sector	**Distribution of total waste by type (%)**	**Distribution by waste type (%)**		
		Inert waste	Non-hazardous non-inert waste (NIW)	Hazardous waste (HW)
Building	15	11.6	75.3	22.5
Structural work	11.0	9.5	38.2	13.2
Finishing work	4.0	2.1	37.1	9.5
Public works	85.0	88.4	24.5	76.5
Total CPW	100.0	100.0	100.0	100.0

These tables show that public works account for a very large proportion of total waste production (85%), with the majority of this waste being inert (97.6%). Similarly, across the entire building sector, inert waste is also the most produced, representing 93.8% of sector waste, or 238.7 million tonnes. However, these figures should be considered with caution, as surplus soil and natural materials from earthworks, which are easily reusable, are often poorly tracked according to the survey. Non-inert, non-hazardous waste (DIB) represents 5.2% of BTP sector waste, the majority of which (75.3%) comes from building sites. Regarding hazardous waste, production is very low, accounting for only 1% of sector waste.

1.2 Analysis of construction waste sources

The proportions given in the tables above come from the notes of the General Commission for Sustainable Development published in July 2011 on building and public works waste. According to the information made available, these results do not include, in particular, site surpluses, that is, excavation material reused on the same site where it was produced. However, they will serve to establish projections of waste quantities to be managed in the short and medium term (6 and 12 years), which will obviously determine the required treatment or recovery capacity.

This is necessary for the General Council responsible for developing the planning approach and highlights the difficulty of this task due to the relative lack of monitoring of production and flows, and of knowledge regarding construction and public works waste sources.

The General Council in charge of preparing this Plan must therefore find the right balance between time and financial resources, as well as the precision of the information, which must be sufficient to continue the planning process and propose ambitious objectives and actions capable of improving the technical and environmental management of construction and public works waste. In this approach, the General Council will need to carry out a relatively comprehensive assessment of construction site waste sources. This approach requires distinguishing the public works sector from the building sector, as they involve very different quantities and types of waste. Given the difference in waste quantities produced by the two activities, the methods for improving management practices will differ accordingly. However, a particular issue arises with waste from building artisans, as it often consists of small, dispersed sources, generated across the territory and frequently passing through municipal waste collection centers.

Example of possible outlets for inert waste

The study commissioned by ADEME on the cost of inert waste collected survey results from construction sector stakeholders (local authorities, companies, unions, federations, and associations), as illustrated below.

These graphs show the distribution of the types of waste managed and their destinations, as reported by the sector's producers.

Overall, half of the producers deliver their waste to a sorting or transit site, while the other half take it to a final disposal site. The network of public waste collection centers represents a significant share of the chosen disposal sites (16%); indeed, these sites play a complementary role, helping to densify the network of possible outlets. Private collection centers reserved for professionals remain a limited outlet for this type of waste. Improving knowledge of these facilities was, in fact, a focus of ADEME's 2012 study.

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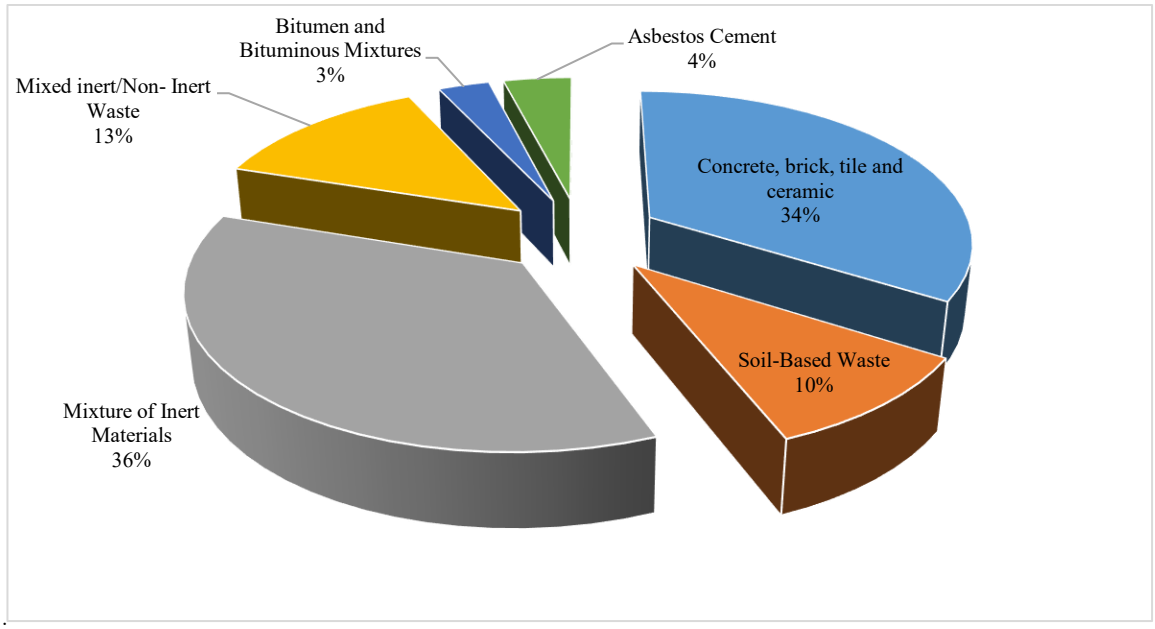

Figure 1: Waste primarily managed by producers

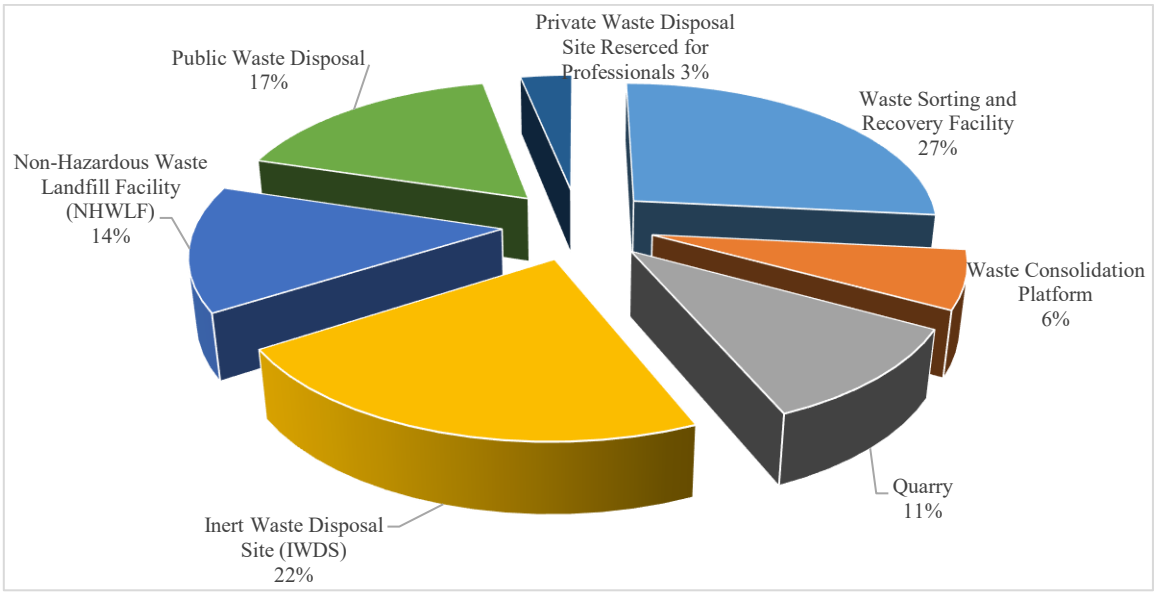

Figure 2: Distribution of the different handlers of waste primarily managed by producers

It should be reiterated that, given the limited number of responses and the pronounced bias toward certain respondent categories, the resulting distribution cannot be regarded as fully representative of overall practices. To advance understanding and support the development of a coherent waste management framework within the construction sector, further characterization of these waste streams is necessary to identify potential management strategies and perspectives.

II. Characterization of each type of construction waste

2.1 Types of waste produced by the construction sector

For reference, construction waste from the building and CPW results from activities related to the construction, demolition, and rehabilitation of buildings, as well as from activities involving the construction and maintenance of public infrastructures (roads, bridges, distribution networks, etc.).

Three categories are commonly used to describe all construction and demolition waste: inert waste, non-hazardous industrial waste, and hazardous waste. These are defined as follows according to Article R. 541-8 of the French Environmental Code (*see Annex 1 for the list of waste types Page 11*)

- *Inert waste*: Three categories are commonly used to describe all construction and demolition waste: inert waste, non-hazardous industrial waste, and hazardous waste. These are defined as follows according to Article R. 541-8 of the French Environmental Code (*see Annex 1 for the list of waste types Page 11*)

Examples of inert waste include concrete, concrete blocks, bricks, tiles, ceramics, natural stones, cement and mortar bases, clays and fired earth, ordinary glass, earthworks materials, as

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well as unsullied mixed inert materials from excavations, uncontaminated soil, and aggregates, etc.
Approximately two-thirds of this type of waste is recycled — it is reused as backfill or as aggregates after crushing.

- *Non-hazardous, non-inert waste – Ordinary Industrial Waste (OIW):* a waste is considered "ordinary industrial waste" when, by its nature or composition, it is neither hazardous to the environment or human health nor inert.

These wastes are similar to household waste and can therefore be treated and stored in the same facilities.

- *Recyclable OIW* includes plumbing components made of copper or PVC, electrical components, plastic materials (PVC, expanded polystyrene and extruded polystyrene), ferrous and non-ferrous metals, clean packaging, clean cardboard, and untreated wood.
- *Non-recyclable OIW* generally consist of heterogeneous assemblies, such as complete joinery elements combining difeerent materials (wood, steel, aluminum, etc.), metals mixed with insulation, fibers bound with natural glues or bitumen, inert materials mixed with insulation, treated glass, hollow partition walls, plastics, artificial mineral wools, synthetic and natural organic fibers, as well as all mixed ordinary industrial wastes.

In 2008, 13 million tonnes of non-hazardous, non-inert waste were produced. Nearly half of this amount consisted of mixed waste. The remainder was mainly composed of plaster waste, wood waste (Approximately 1.8 million tonnes per category), and ferrous or non-ferrous metals (1.2 million tonnes).

- *Hazardous waste*: hazardous waste includes *Special Industrial Waste (SIW)* and *Toxic Waste in Dispersed Quantities (TWDQ)*. This category notably comprises wood treated with heavy metals, coating products such as paints and varnishes containing organic solvents, used oils, and inert or ordinary waste mixed with toxic substances.

These wastes pose certain risks to humans and the environment and therefore require specific disposal and treatment channels. The table below provides a few examples of waste produced from building sites and public works projects, categorized into the three types of waste (inert, ordinary industrial waste and hazardous).

TABLE 3: Examples of waste generated by building sites and public works sites (DDE, 2002)

	Building	Public works
Inert Waste	○ Mineral demolition materials (uncontaminated rubble) ○ Concrete, bricks, tiles, ceramics, and floor tiles ○ Mineral wool	○ Soil, natural stones, and uncontaminated earthwork materials ○ Mortars and concrete ○ Bituminous concrete and poured asphalt (tar-free)
Non-hazardous Industrial Waste (NIW)	○ Cardboard, plastics, packaging ○ Metals ○ Untreated wood ○ Glass, plaster ○ Textiles, rubber	○ Cables, scrap metal, electrical wires ○ Concrete posts, used panels, street furniture ○ Plastic pipes, polystyrene ○ Untreated wood
Hazardous waste	○ Paints, varnishes ○ Oils ○ Solvents, stripping acids, and various chemical products ○ Treated wood ○ Asbestos and asbestos-containing construction materials ○ Contaminated accessories and equipment	○ Hydrocarbons, tars ○ Coatings or bituminous concrete containing tar ○ Soils mixed with tar ○ Soils contaminated by chemicals or other pollutants ○ Adhesives, resins, additives ○ Treated wood ○ Transformers and electrical panels

2.2 Volume and recovery of waste

The construction industry generated 254 million tonnes of waste in 2008. This volume represents a significant management cost. This total amount of construction and demolition waste is distributed as follows: 38.2 million tonnes from the building sector and 216.3 million tonnes from public works.

The table below provides a detailed overview of the different types of waste. It presents combined data, thereby facilitating the analysis of economic opportunities for the recovery of reusable materials.

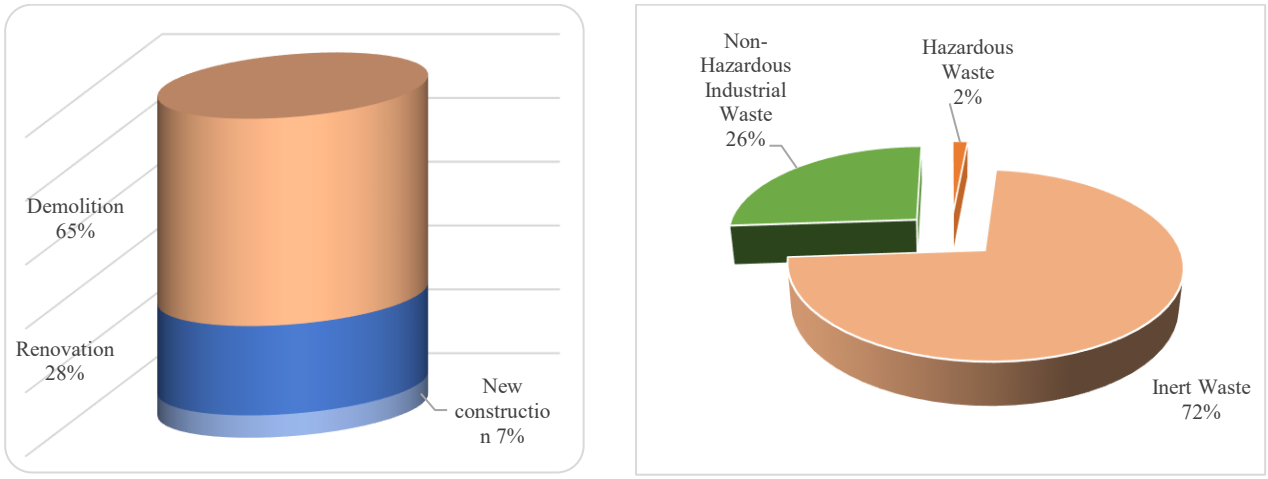

Figure 3 : Distribution of building waste. Source: Department for Observation and Statistics of the Environment (SOeS)

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TABLE 4: Detailed quantification of waste generated by the CPW sector in 2008 and their material recovery rates (CGDD, 2010).

	Type of waste	Quantity (million tonnes)	Percentage of the category (%)	Material recovery rate (%)
Inert Waste	Concrete	17.84	7.47	79.9
	Bricks, ceramic tiles, slates	2.87	1.20	59.2
	Glass	0.10	0.04	19.4
	Bituminous mixtures and products not containing tar	9.30	3.89	78.9
	Uncontaminated soil and stones	175.11	73.30	45.2
	Other road demolition materials	11.82	4.95	85.4
	Uncontaminated railway ballast	0.97	0.41	61.6
	Uncontaminated dredging and cleaning sludge	2.60	1.09	50.0
	Other types of inert waste	1.18	0.49	56.3
	Mixtures of inert waste	17.09	7.15	21.7
	Total	**238.89**	**100.00**	**49.7**
Non-hazardous, non-inert waste (NIW)	Untreated or treated wood with non-hazardous substances	1.835	13.92	11.3
	Plastics	0.435	3.30	3.9
	Ferrous or non-ferrous metals	1.201	9.11	42.4
	Insulating materials: fiberglass, rock wool	0.118	0.90	4.0
	Plaster	1.844	13.99	0.5
	Green/Vegetable waste	0.651	4.94	53.5
	Used tires	0.018	0.14	39.1
	Other types of non-hazardous non-inert waste	0.542	4.11	5.9
	Mixed NIW	1,119	8,49	3,8
	Mixtures of inert waste and NIW	5.421	41.12	1.3
	Total	**13.183**	**100.00**	**9.4**
Hazardous Waste	Wood treated with hazardous substances	0.066	2.63	3.7
	Bituminous coatings, bituminous mixtures, and products containing tar	0.891	35.51	62.4
	Contaminated soil and stones	0.967	38.53	13.9
	Contaminated dredging and cleaning sludge	0.016	0.62	28.1
	Contaminated railway ballast	0.000	0.02	4.3
	Friable asbestos	0.019	0.76	21.0
	Asbestos bound with non-hazardous vinyl materials	0.023	0.90	0.9
	Asbestos bound with inert materials	0.099	3.94	12.8
	Hydraulic oils, vehicle oils	0.266	10.59	39.8
	Contaminated packaging or packaging that contained hazardous substances	0.056	2.,24	7.9
	Refrigerant gases (CFCs, Freon)	0.001	0.03	47.3
	Batteries and cells	0.012	0.48	28.7
	Fluorescent tubes (neon), compact fluorescent lamps, LEDs	0.017	0.68	48.1
	Other electrical and electronic equipment (WEEE/DEEE)	0.014	0.56	21.3
	Waste contaminated with PCBs or PCTs	0.003	0.12	39.2
	Other types of hazardous waste	0.019	0.76	22.4
	Mixtures of these waste types, unsorted waste	0.040	1.61	43.6
	Total	**2.510**	**100.00**	**34.4**

The table shows that:

- Inert waste is mainly composed of uncontaminated soil and stones, which account for 73.3% of this type of waste.

Nearly half of this waste is reused on other sites as backfill, road sub-bases, or for filling quarries.

This material recovery rate is even higher than 75% for concrete, asphalt not containing tar, and other road demolition materials, with recycling rates of 79.9%, 78.9%, and 85.4%, respectively.

- For non-inert, non-hazardous waste, mixed ordinary industrial waste (OIW), either alone or combined with inert materials, constitutes the pajority of waste produced at 49.6%, followed by plaster at 14% and raw or non-hazardously treated wood at 13.9%.

Only 9.4% of the total amount of this waste undergoes material recovery. This recovery mainly concerns green waste (recovered at 53.5%), metals (recycled at 42.4%), and used tires (recovered at 39.1%).

- Hazardous waste is primarly composed of "*contaminated soil and stones*" and "*asphalt, bituminous mixtures, and tar-containing products*", with respective proportions of 38.5% and 35.5%

The recycling rate for this hazardous waste is 34.4%, notably including asphalt, bituminous mixtures, and tar-containing products (recycled at 62.4%), fluorescent tubes, compact fluorescent lamps, and LEDs (recycled at 48.1%), as well as refrigerant gases (recycled at 47.3%).

2.3 Limits of an optimal variation

According to the commission of November 18, 2011, the recovery rate should reach 70% by 2020. Recycling possibilities are limited, depending on the source, when there is a large quantity of mixed waste.

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This situation is particularly common in deconstruction activities (of older infrastructures), where elements are often difficult to separate (for example, plaster or toxic substances). To increase the recovery rates of this waste, and thereby reduce the environmental and economic impact of the construction sector, it is essential to change current construction practices and implement selective deconstruction of buildings and structures. An assessment to evaluate the total waste generated is used to calculate recycling or recovery rates. The methodology for evaluating these rates often involves conducting surveys with the professionals concerned.

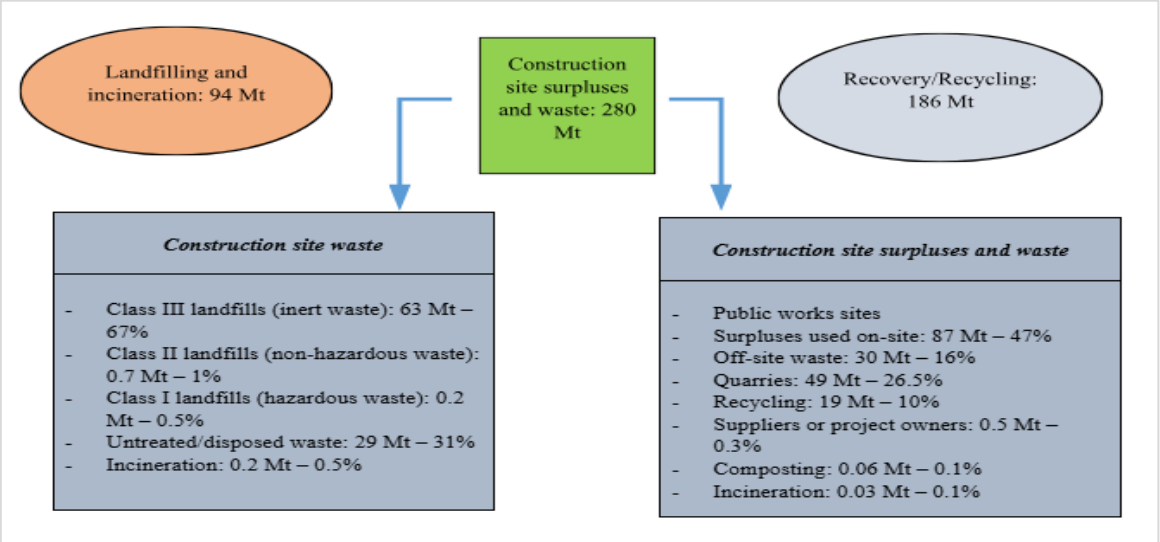

Figure 4: Quantification des déchets des Travaux Publics

However, this methodology is frequently subject to a certain degree of inaccuracy, especially in the case of road sector waste, where waste flows are substantial. The figure above shows that public works projefcts dispose of one-third of their waste and recover two-thirds, either on-site or off-site, with or without processing at a suitable facility. Among the 94 million tonnes of construction waste that are disposed of, two-thirds are sent to final landfill.

III. Economic analysis of construction waste management

3.1 Cost of construction waste disposal

An ADEME study on the implementation of a construction waste management guide estimated that the annual cost of disposing of construction waste amounted to €2.54 billion in 1999. The distribution of the disposal cost of building construction waste (excluding transport and skip rental) according to the chosen management methods is as follows:

TABLE 5: Distribution of CPW Waste Disposal Costs by Management Method

Without sorting	***With sorting***	***Sorting + 30% inert material recycling***
2.5 billion euros	1.31 billion euros	1.27 billion euros

Evidence highlights that disposal costs are significantly reduced when on-site sorting and recycling systems are implemented. This demonstrates that stakeholders in the construction sector have a clear incentive to include explicit clauses addressing on-site waste management in project contracts.

3.2 Evolution of construction and public works waste production

The analysis of the data provided by INSEE (*National Institute of Statistics and Economic Studies*) reveals a strong correlation between the economic context, the construction market, and waste generation in the construction sector.

The figure below illustrates the trends in waste production throughout the construction and public works (BTP) sector over the period 1999–2008.

A marked decrease in construction site waste generation can be observed between 2006 and 2008, amounting to nearly 30%. This decline is partly attributed to the economic and financial crisis. According to INSEE studies on the waste market, new construction activity fell significantly in 2008, with overall construction decreasing by 5%, housing construction by 6.1%, while maintenance and renovation activities remained relatively stable. The construction of individual houses declined by 16% in volume. New non-residential building projects were also affected, with nearly 19% fewer construction starts. Only office buildings and industrial facilities showed resilience to the downturn, whereas cultural and leisure buildings experienced a pronounced decline, largely linked to the municipal electoral cycle, as municipalities constitute the main clients for these types of facilities. Public works activity similarly decreased by 34%, reflecting both the post-election lull in municipal contracts and the broader slowdown in new construction (INSEE, 2010).

These figures, however, should be interpreted with caution, as methodological changes in the assessment of construction sector waste prior to 2008 may affect data reliability. In studies conducted before 2008, waste directly reused on-site was

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included in total waste counts, whereas in 2008, this category was excluded. To correct for this, previously uncounted waste — amounting to 87 million tonnes of inert materials in 1999 for public works, representing nearly 31% of all waste (Florio et al., 2006) — was added back. Assuming a similar proportion in 2008, the quantity of reused waste would amount to 97 million tonnes, resulting in a total of 313 million tonnes of waste generated by public works activities and 351.5 million tonnes for the entire construction and public works sector. The corrected evolution of construction and public works waste between 1999 and 2008 is presented in the figure below.

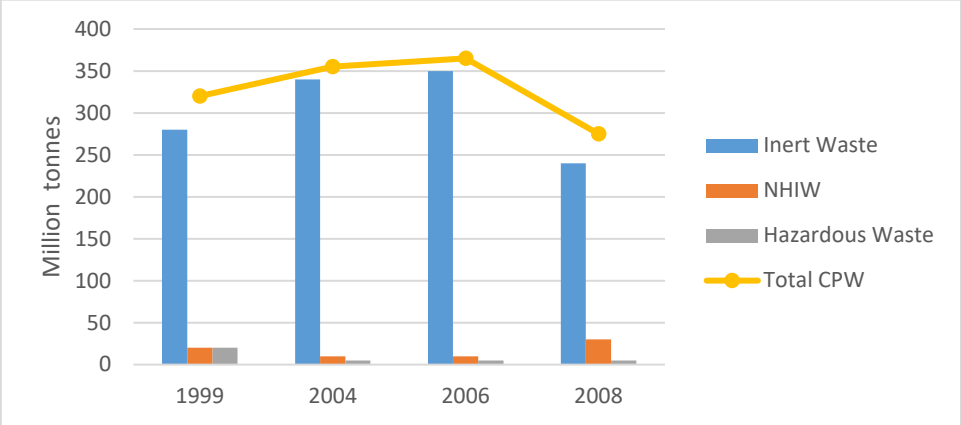

Figure 5: Evolution of construction and public works waste production between 1999 and 2008 (Florio et al. 2006; IFEN, 2008; CGDD, 2009; CGDD, 2010).

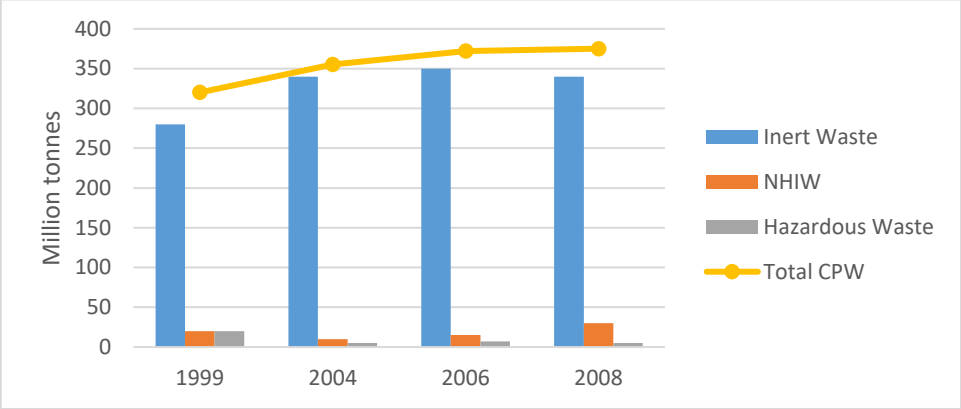

Figure 6: Evolution of construction and public works between 1999 and 2008 (Florio et al. 2006; IFEN, 2008; CGDD, 2009; CGDD, 2010).

The amount of waste produced would then have decreased by 2% instead of 30%, which remains consistent with the evolution of the market in this sector. Waste generation in the construction industry is therefore closely linked to the economic context, infrastructure planning, and urban development policies.

3.3 Initiatives to improve waste management

To assist building professionals in forecasting the generation, disposal, and potential recovery of construction site waste, ADEME provides guides containing data on waste generation ratios by type. Examples of these ratios for new construction and demolition sites are presented in Tables 5 and 6 (ADEME, 2001; ADEME, 2002; FFB and Ademe, 2007). The composition of waste generated during construction activities varies according to the nature of the site. Demolition waste is primarily composed of inert materials, whereas rehabilitation works produce a significant proportion of hazardous waste. Construction activities generate a mix of materials, predominantly inert waste along with non-hazardous industrial waste (NIW).

TABLE 6: Quantification of waste generated during new housing construction (ADEME, 2001; FFB et ADEME, 2007)

Types of Waste	Production en t/m² de SHOB
Inert Materials (mixed)	All types: 13.5 (from 1 to 36)
Metals	Collective: 0.45 (from 0.1 to 0.9) Individual: little or no metals
Wood	All types: 1.3 (from 0.6 to 3.2)
CIW en mélange	Collective: 5.7 (from 1.3 to 9.5) Individual: 7.7 (from 0.8 to 12.6)
Plaster and partition walls	All types: 1.8 (from 0.75 to 2.6, mostly around 2.3)
Cardboard	Tous types : 0.25 (de 0.03 à 0.35)
« Gestion sélectives des déchets sur les chantier de bâtiment. Bilan de 40 opérations » ADEME, Octobre 2001	

Given the volume of waste and the fluctuations in the construction and public works waste market, an analysis of the regulatory framework for waste management proves useful to

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support efforts aimed at changing stakeholder behavior, limiting illegal dumping, and focusing actions on prevention.

IV. Analysis of the regulatory framework

4.1 Legislative and regulatory framework at the European level

At the European level, Framework Directive 75/442/EEC of 15 July 1975 on waste establishes the "*polluter pays*" principle and defines the concepts of waste, disposal, and recovery by reference to a list of waste types or activities.

TABLE 7: Quantification of waste generated during building demolition/deconstruction
(ADEME, 2002; FFB et ADEME, 2007)

Types of Waste	Production
Overall	0.5 to 1.1 t/m² of GFA (Gross Floor Area)
Mineral Waste (inert)	From 80% to 99%* (social housing buildings constructed in the 1950s to 1970s: over 95%)
CIW	From 1% to 20% (mainly originating from the finishing works)
Hazardous Waste	Less than 1% (mainly asbestos) for residential, office, warehouse, and school buildings, and more generally for all buildings that have not housed industrial activities.
Figures come from deconstruction projects subsidized by ADEME and completed between 1999 and 2001. The waste originates almost exclusively from the building structures, with percentages depending on the construction system. « Déconstruire les bâtiments ». ADEME first term 2002.	

Thus, waste is defined as "any substance or object which the holder discards or intends or is required to discard." The categories of such waste are listed in Annex I of this directive.
Annex I classifies *different categories of waste*, including, in particular, expired products, unusable items, machining/forming residues (e.g., turning or milling chips), and any material, substance, or product not covered by the categories listed in Annex I but which the holder discards or intends or is required to discard.
Annex II A of the directive lists the *disposal operations*, including deposition on or in the soil (such as landfilling), incineration, permanent storage, treatment in a terrestrial environment, and so on.
Annex II B defines the *recovery operations*, including main use as a fuel or other means of generating energy, recycling or recovery of metals and metal compounds, and so on.

Thus, the directive aims for Member States to promote the prevention or reduction of waste generation, as well as its recovery. It requires Member States to establish waste management plans. The directive has been transposed into national regulations to be implemented in each waste-producing sector, including the construction and public works sector.

It is through this same directive that the measures, procedures, and guidelines for landfilling construction and public works waste have been classified into three categories of landfill.
The directive classifies landfills into three categories:

- Landfills for hazardous waste;
- Landfills for non-hazardous waste;
- Landfills for inert waste.

For each type of landfill, the text specifies which wastes are admissible in order to prevent or minimize the negative environmental impacts of these activities.

4.2 Legislative and regulatory framework at the French level

The definition provided in the legislative framework for waste is: "any residue from a production, transformation, or use process, any substance, material, product, or, more generally, any movable property that is abandoned or that its holder intends to abandon" (*Article L. 541-1-II of the Environmental Code*).

a) *Concerning public works waste, an approach is proposed based on the responsibility* assigned to the designer (the project owner or the project manager). Waste management for the following activites fall under their responsibility:
   - In new works:
     - Stumps and wood ;
     - Topsoil ;
     - Natural materials: sand, silt, clay, rocks, etc. ;
     - Demolition materials from various structures, in small quantities ;
     - Sludge from underground structures.
   - In maintenance works:
     - Reinforced or plain concrete ;
     - Asphalt;
     - Pavement and railway sub-base materials.

b) *Predominantly non-hazardous waste (sometimes including some hazardous waste) generated during the execution of the work* is the responsibility of the contractor. This includes:
   - Offcuts of manufactured products: PVC, or stoneware pipes, curbs, etc.;
   - Residues from maintenance of various equipment on site (oils, batteries, greases, filters, etc.);
   - Packaging materials such as cardboard, PVC film, wood, etc.;
   - Waste related to personnel presence on site, similar to household waste, greasy paper, food, etc.)

c) *The circular of 15 February 2000 regarding the planning of construction and public workds site waste management* provides for the establishment of departmental waste management plans for CPW.

It aims to achieve the following objectives:
   - Ensure compliance with regulations by combating illegal dumping and applying the "*polluter pays*" principle;
   - Establish a treatment network and organize financial flows so that costs are integrated and clearly allocated;
   - Enable public works to participate in the principle of waste reduction at the source;
   - Reduce landfilling and contribute to the overall effort of waste recovery and recycling ;
   - Promote the use of recycled materials in construction and public works projects;
   - Better involve public project owners in the disposal of waste generated by the execution of their contracts.

d) Management of construction site waste in contracts

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Project owners are encouraged to provide construction companies with the financial means and the necessary organizational time to manage site waste in compliance with environmental protection legislation. Recommendations regarding this consideration are provided in the annex.

Professionals are responsible for setting up the necessary infrastructure as part of the plans (collection, transfer centers, sorting and consolidation, recycling centers, and storage facilities). In this context, local authorities have a clear interest in the proper management of construction and public works waste:

- As project owners, they themselves generate construction site waste, which they must manage;
- Under their general policing authority, mayors must combat illegal dumping of materials and waste.

e) Use of recycled materials

To raise awareness among public decision-makers of the benefits of using recycled materials (as long as these processes meet technological, environmental, and public health requirements), the Plan recommends the development of "*framework agreements*."

These initiatives mainly concern public works, which offer numerous opportunities for implementation. For example, pilot framework agreements provide for:

- Optimization of material choices from an environmental perspective according to intended uses;
- Determination of a minimum proportion of recycled materials to be used in public works contracts;
- "*Eco-variant*" clauses and environmental variants through which project owners could encourage contractors to use recycled materials in their bids.

It can therefore be advantageous for construction companies to check the existence of such contractual tools in their region.

V. Disposal of construction site waste in the interest of the environment

The disposal of construction site waste is a major issue, as it accounts for a significant portion of site management costs.

Depending on whether a sorting system is implemented on-site, disposal determines the outlet used for the waste. As noted in previous sections, the choice of facility receiving the waste makes storage the most costly alternative.

From a regulatory standpoint, when different categories of waste are mixed, the most restrictive category determines the classification of the mixture.

Thus, whenever Common Industrial Waste (CIW) or inert waste is mixed with Special Industrial Waste (SIW), the entire mixture is classified as SIW.

This example highlights the importance of sorting and specifically storing at least SIW on-site, to avoid unnecessarily increasing disposal costs.

To optimize the sorting system, recommendations are provided to project owners or project managers, including:

a) Avoid mixing the following types of waste:

- Inert waste;
- Household and similar waste;
- Special industrial waste;
- Packaging waste.

b) Identify specific dispoasal routes for each waste category.

TABLE 8: Destination infrastructures by type of construction and demolition waste

Inert Waste	- Recycling facility - Class 3 landfill
Household and similar waste (CIW)	- Recycling of recyclable materials - Recycling of recyclable materials - Sorting center - Class 2 landfill
Special Industrial Waste (SIW)	- Class 1 landfill

To reduce the disposal costs of construction site waste, many departmental and regional federations participate in the establishment of waste consolidation platforms (with or without sorting) in partnership with the French Environment and Energy Management Agency (ADEME) and local authorities.

VI. Waste reduction at the source

Limiting waste generation at the source remains the most effective way to reduce disposal costs in any sector and is particularly true for the construction and public works sector. Solutions exist to minimize waste production and, consequently, the challenges of disposal. The success of such initiatives depends primarily on good coordination among site stakeholders: between trades, with suppliers, and so on.

Although not mandatory, sorting becomes essential to reduce disposal costs, as waste processors increasingly refuse mixed waste. This requires:

- Reorganizing the construction site,
- Informing and training personnel,
- Placing multiple bins simultaneously on-site,
- Planning the upstream transport of waste to optimize personnel movement on-site,
- Using a sealed container for hazardous and liquid waste.

To optimize space on-site, compartmentalized bins are available, which is particularly useful for sites located in urban areas. For each waste category, a minimum of three sorting bins can be installed on-site, provided sufficient space is available. Regarding collection, the management method depends on the type of work performed: new construction, rehabilitation, or demolition. The frequency of bin collection can vary from one site to another and from one type of waste to another, depending on the quantities produced. Implementing an on-site sorting approach is closely aligned with quality management practices, which an increasing number of construction companies are adopting.

IV. Conclusion

The analysis of CPW waste management in France has highlighted the inseparable link between this sector, the economic context, and prevailing urban planning policies. Studies conducted to provide data on waste generation in this sector have proven particularly useful for focusing stakeholders' efforts on better on-site sorting practices. This is reflected in the assessment of quantities handled by collective waste treatment and disposal facilities, which allows estimation

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of facility utilization rates across the territory and the potential for local treatment capacity shortages.

However, progress in waste management remains limited and results more from localized initiatives than from the coordinated and concerted implementation of departmental plan orientations, which are often difficult to operationalize. Poor practices persist because a significant portion of waste is still disposed of without traceability, through non-compliant procedures, and illegal dumping remains. Certain areas still lack facilities to manage these wastes. The potential for recyclable materials remains underutilized, and charters of good practice or management guidelines are largely unknown.

Most construction waste currently has the potential for recovery, yet some materials are still incinerated or landfilled due to technical limitations or the difficulty of disassembly and sorting during demolition. These disposal methods have a considerable environmental impact (air pollution, risks of soil or water contamination, etc.) and are often costly. It is therefore in the interest of CPW stakeholders to optimize on-site sorting, seeking the most appropriate management methods that integrate the overall dynamics of a construction site.

Alignment between current regulations and the CPW waste market—which remains active—should lead to reduced extraction of natural resources, lower landfill costs, and decreased nuisances associated with landfills and incineration facilities. The evolution of construction methods should further promote recycling techniques, as the construction market today increasingly responds not only to renovation due to wear and tear but also to aesthetic and functional trends.

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