PAPER #8.10

CONSTRUCTION AND DEMOLITION WASTE MANAGEMENT: FROM OBLIGATION TO NECESSITY. NEW TRENDS AND SOME TOOLS FOCUSED ON ARCHITECTURAL PROJECTS

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How to cite
López Mateu, Vicente, and Teresa María Pellicer. "Construction and demolition waste management: from obligation to necessity. New trends and some tools focused on architectural projects." In *Proceedings of 3rd Valencia International Biennial of Research in Architecture. Changing priorities*. Valencia. 2022. https://doi.org/10.4995/VIBRArch2022.2022.15306

ABSTRACT

The construction of a building is an activity that generates a considerable use of materials and diverse resources. Likewise, new materials and supplies are used to maintain or renovate buildings, some of which are historically reused, partially or entirely. These processes generate a series of residues or waste materials C&DW, especially at the end of the building's useful life with its demolition. These elements are becoming increasingly important from the point of view of new approaches to the circular economy. Therefore, these elements previously discarded are now considered valuable resources. The agents involved in the building process are becoming increasingly aware of these issues. There is an evolution from the obligation imposed by the regulations toward new perspectives and trends. For that purpose, current tools will be discussed and compared, helping to understand the additional challenges and possibilities for architecture.

KEYWORDS

C&D Waste management; building reused materials; recycling in architecture.

1. INTRODUCTION

In recent years, sustainable development objectives have analyzed several resources in different areas. Particularly in architecture, the construction, maintenance and, finally, dismantling or demolition of the buildings. The focus has been placed on materials used in building activity: Construction and Demolition Waste (C&DW).
In 2018, this accounted for about 36% of the volume of waste generated in the EU (Eurostat 2021). This situation is a significant problem due to waste management, storage, reuse, treatment, and rejection or disposal. Therefore, a change in approach and priorities is essential, based on reducing and reusing this waste in different areas, starting with the construction itself. From the initial design to the final stages, it should be possible to evaluate its impact and introduce measures to achieve these goals.
This paper is organized into four sections, summarizing and updating the different approaches regarding the reuse and management of C&DW. These approaches go from the general EU framework to the recent Spanish regulations. The primary documents and the successive contributions are briefly cited, synthesizing the consecutive changes they have entailed. This paper presents the general overview

and perspective of C&DW regulations and a forecast of future approaches and trends in light of the current circumstances.

2. THE REUSE OF MATERIALS IN ARCHITECTURE

2.1. A brief historical overview of the current situation

In ancient buildings, it is common to see partially or entirely reused elements that have remained up to the present day. The structure of these buildings was mainly made up of walls and columns: the masonry work used on them came from different locally accessed materials. The reuse of elements or materials from previous constructions was frequent. Some building components, such as ashlars or capitals, were sometimes reused just as they were in another place (Fig. 1). Notwithstanding, they were sometimes "reused" to produce filler concrete, union mortars or coatings.

Construction technology has dramatically evolved, especially since the 19th century, due to industrialization and the development of new materials. These products acquired more convenient features during the 20th century, whereas fuel consumption, especially non-renewable energies, grew in manufacture, transport, installation, and subsequent demolition. The 21st c. challenge is to maintain or even improve quality and comfort standards while reducing C&DW and the energy involved in different processes.

Until the end of the 20th c., most building construction materials were obtained or manufactured from new raw materials. Gradually, traditional and "reused" elements were replaced by the latest materials due to their economic performance. This approach followed the "linear economy": produce, use and discard.

However, since the 1980s, the "circular economy" and "life cycle analysis" have introduced different architectural strategies for reusing construction elements, components or materials. (Fig. 2) Over time, this idea has become a beneficial possibility aligned with sustainable development goals. Nevertheless, it has become necessary to return to the reuse of materials not only for environmental reasons but also as a response to the raw materials, import-export crisis, and high energy prices.

Figure 1. Benavites Tower (Valencia) 14-16th c. South corner detail with reused materials. Source: VLM

2.2. Key aspects to consider in C&DW reuse, advantages and drawbacks

The possibilities for reusing in architecture are considerable, from directly reusable parts that require some modification, to auxiliary components or support and to those elements that need mechanical or physical-chemical transformations. The advantage of these actions is preservation of the environment by keeping the old elements in the useful life cycle, allowing the conservation of embodied energy (Akanbi et al. 2019).

Proper disassembly planning is essential for reuse (Sanchez and Haas 2018). Depending on the project and the new use, the transformation or adaptation of the pieces will be more or less significant. To evaluate reusability, it will be necessary to correctly identify the different features, such as the shape and dimensions, components and origin (Kozminska 2019).

In the case of transformation, the materials' identification, composition, and characterization are critical to ensure compliance with statutes and benefits established by the different regulations. Compared to the usual or recognized design, a new system or material that totally or partially reuses the previous ones requires preliminary analyses, controls, and some experience (Kozminska 2019).

For this reason, in areas such as civil engineering, some materials are becoming more usual, those whose characteristics are well known. These materials can be used in large areas such as landfills, pavements and roads, installations and urban furniture. Similar behaviour or improvement of some features allows the replacement of the previously used components in large volume or quantity.

Nevertheless, some buildings' elements become diverse and specific, providing solutions for different features. From the structure, and the envelope, to the interior finishes and furniture, they are made up of multiple materials, which can interact in different ways. This situation implies more significant complexity when considering and analyzing their identification and reuse possibilities.

At the same time, it is also an advantage to provide opportunities for the application of recovered or recycled elements or materials in these different areas. Therefore, we need the effective separation and preparation of multiple construction elements and materials. A proper dismantling management process in order to classify everything (as far as possible) is key to retrieving or producing new materials.

2.3. The reuse of materials in new projects and constructions

Faced with this favorable though emerging situation, identifying or locating constructions with the prevalence of reused materials is still challenging. It is also tricky to find buildings with components obtainable to reuse once the construction's useful life has ended. As a result, many of these projects and works are considered "experimental", temporary or provisional (Fig. 3)

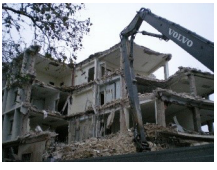

Figure 2. Non-selective demolition works, Pl. America, Valencia (2010), a container with different materials mixed and a recycling plant, where C&DW is sorted and classified. Source VLM

Figure 3. Constructions with ship containers. Source: https://casascontenedores.es/

Figures 4 and 5. Container restaurant. Source: Murad Garcia architects

These works are published in journals, technical papers, or websites as prototypes or models to follow (Fig. 4 & 5) Accordingly, they require verification or studies that involve an initial investment, generally from their promoters and "self-builders", research on their behavior in the medium and long term. These constructions are scattered over many private and public countries, mainly in homes and small collective facilities.

Hence, a primary classification according to their shared characteristics can be established. Firstly, those projects made from elements with little transformation and which took advantage of maritime containers, ships, planes, and vehicles; secondly, those built with pieces and parts of these elements. Finally, more "conventional" constructions using recycled or transformed materials.

Fortunately, different companies and manufacturers are investing and, progressively, offering more products that can be used in projects, individually or as a complete system. In product catalogues or exhibitions, it is common to find those alternative recycled products from construction materials or other industrial sectors. Many coatings, installations, partitions, and even structural concrete admit a percentage of recycled aggregate with certain limitations.

2.4. Construction EU regulations: obstacles with the reuse of C&DW and new proposals

Up until recent decades, regulations relating to building construction in some European countries, such as Spain, had changed from prescriptive to performance-based. Nowadays, codes do not specify using a limited number of constructive solutions or materials. They are centered on the achievement of certain behavior regarding basic requirements: reaction to fire, thermal and acoustic insulation, or health standards. This possibility opens the door to innovation and improvement of construction systems

and materials. However, this evolution is slow, and the previous standard solutions are maintained with some adaptations.
Furthermore, the new proposals require documents that certify the European Technical Assessment (ETA), a favourable technical evaluation of a product's suitability for assigned uses. European Regulations on Construction Products such as EU 305/2011, amendments EU 568/2014 and 578/2014 must be compulsorily followed on performance evaluation of construction products. Specialized institutions carry out this assessment by way of technical means and adequate funding. Likewise, there are Commission Delegated Regulations, which establish conditions for a large number of products and materials. A series of harmonized CEN-EN standards are published in the European Official Journal to complement them.
This situation makes implementing reused or recycled materials challenging, as they require one or more evaluation processes. This lack of specific standards for C&D recycling materials has led to compliance with the essential requirements and use in low-quality applications or "downcycling" (Allwood 2014), recycled aggregates for road base and infill. Therefore, alternative solutions for recycling higher-quality C&DW are urgently needed (Di Maria, Eyckmans, and Van Acker 2020). For this reason, the European Commission has recently approved the proposal COM (2022)144-*Harmonized conditions for the marketing of construction products* (European Commission 2022) to develop standards including outcomes with a significant impact on the environment and CO2 capture.
In this sense, the Platform on Sustainable Finance, an advisory body subject to the Commission's rules for expert groups, has recently presented a report about this matter. The annexe establishes proposals on technical screening criteria to determine how the activities of the construction sector contribute to the circular economy. The Commission will need to analyze the document in order to elaborate on new directives since they propose new measures. Among its goals, two aspects affect architecture projects:

- The proposal concerning construction designs and techniques must support circularity criteria and demonstrate that they are more resource efficient, adaptable, flexible, and easy to dismantle, enabling reuse and recycling. It must be verifiable according to indicators following ISO 20887:2020 (ISO 2020), EN 15643 (CEN 2021), and EN 16309 (CEN 2014).
- In new and refurbished buildings, at least 50% of their elements (either by weight or surface) must be made of reused or recycled materials, including facades, roofs, and internal walls and floors. Of that 50%, at least 15% must be reused components, another 15% recycled content, and the remaining 20% reused, recycled, or from responsible sources or renewable materials.

There is a recent European Construction Industry Federation (FIEC) reaction (FIEC 2022), with some comments and proposals for amending the Platform report. Therefore, these new proposals are under debate and will establish the following architectural trends.

3. THE EU AND SPANISH FRAMEWORK ON C&DW MANAGEMENT

3.1. EU and Spanish C&DW management framework: common guidelines

Since the Mid-1970s, a series of documents and directives in the EU, such as 75/442/CEE (The Council of European Communities 1975), established the legal framework for treating waste. They were considered in order

to protect the environment and human health and progressively improved and itemized the conditions. Proper management, recovery techniques, and waste recycling are necessary for construction and demolition to reduce resource pressure and improve their subsequent use.

Directive 91/156/EEC (European Council 1991) established shared definitions and first measures in this area. Later, Decision 2000/532/EC (Commission of the European Communities 2000) set up the harmonized *List of Waste* that allows waste identification with six-digit codes, also assigned to C&DW. Waste Framework Directive 2008/98/CE (European Parliament 2008) unified and modified previous regulations, establishing the "waste hierarchy," five key points in waste policy: prevention, preparing for reuse, recycling, energy recovery and the final disposal. About C&DW introduced the 70% recycling and recovery objective to be achieved by 2020. The subsequent decision, 2014/955/EU (European Commission 2014), updated and adapted the previous list of waste to this regulation.

The following Directives EU 2018/850 (European Parliament 2018a) regarding waste disposal and EU 2018/851 (European Parliament 2018b) support sustainable production and consumption models aligned with circular economy principles. This regulation aims to promote the design, manufacture, and efficient products, which are durable, repairable, reusable, and upgradeable. The ones containing "Critical raw materials" (CRMs) were considered a key objective to prevent them from becoming waste. It also promoted the availability of spare parts, technical information, and product repair, maintaining quality and safety. This matter affects many goods and devices, including those employed in buildings, especially installation components.

Another essential document in EU construction and demolition waste management was the reference protocol entitled *Guidelines for the waste audits before demolition and renovation of buildings* (GROW.DDG1.C.4 2018). It is a non-binding guideline but establishes the general processes and steps that should be considered before demolition and renovation work in buildings.

The idea was to help the different actors or parts involved: practitioners, public authorities, certification agencies and recycled materials clients to properly handle the waste stream. It promotes the management of CDW aligned with the "waste hierarchy"; therefore, it contributes to resource efficiency. The Protocol is intended to raise awareness about legal requirements.

3.2. Spanish regulations background and recent updates

Spanish environmental regulations were developed 30 years ago. They started with hazardous waste RD 833/1988 (Ministerio de Obras Públicas y Urbanismo 1988), which includes codes and activities related to construction materials. However, the RD 105/2008 (Ministerio de la Presidencia 2008) was the main change, binding C&DW Studies and Plans with Projects. The client or "producer" should provide them, but generally, they are drafted by practitioners, estimating the C&DW and providing measures to minimize it. The Project's Budget includes an economic study, which is required to constitute the deposit and Planning Permission.

This regulation established the role of the different agents involved in the C&DW management: the producer, identified with the owner of the property to be built or demolished, the waste holder who executes the work, and the waste manager who is responsible for the waste documentation. Subsequently, other agents involved in the processes were determined, such as transport, storage, treatment or recovery, etc.

Figure 6. Current general waste management scheme in projects and works Source: VLM

The subsequent regulations, such as L 22/2011 (Jefatura del Estado 2011), follow the EU Directives. It systematized the agents' obligations involved in the C&DW management simplifying the administrative tasks. It focused on preparation for reuse and recycling, setting objectives for implementing the collection of different materials. It also replaced the pre-administrative control with a final check to avoid slowing down economic activities. This approach has changed, requiring previous administrative compliance. In the Spanish housing rehabilitation plans RD 853/2021 (Ministerio de Transportes y Movilidad Urbana 2021), projects must follow the adaptability and deconstruction criteria (ISO, UNE) and the 70% reuse of C&DW.

Finally, the new L 7/2022 (Jefatura del Estado 2022) concerning Waste and Circular Economy has introduced the mentioned criteria in a mandatory manner. It adds new definitions and relationships between the agents involved in C&DW management waste (Fig. 6).

The significant changes are:

- A minimum amount of 70% of non-hazardous construction (excluding uncontaminated land reuse onsite) and demolition waste must be prepared for reuse, recycling and recovery, including landfills. This was already established by the EU Directive of 2008, but new goals point to 90%.
- The classification of non-hazardous C&DW into the following fractions: wood, mineral fragments (concrete, bricks, ceramics and stone), metals, glass, plastic and plaster. Also, elements, such as tiles, toilets or structural parts will be classified as reusable (mandatory from July 2022).
- Preferential onsite waste classification, including previous mandatory hazardous waste separate collection. The demolitions will preferably be performed by selecting materials to be removed (mandatory from early 2024).
- The use of materials "digital books" records in new construction, following the EU regulations on the circular economy. Therefore, the development of new specifications will implement "eco-design" requirements.

In this last issue, there is still a long way to go in the monitoring and traceability of all processes. Generally, the administrative control is under the auspices and final guardianship of the municipalities, but they have to carry this out with unequal and non-unified means and resources.

3.3. The requirements accomplishment: software apps and future objectives

The processes related to the management of CDWs represent a significant challenge, especially as regards their assessment. Many methodologies exist in different countries (Wu et al. 2014). Still, adapting to EU regulations requires recognizing particular data (Llatas 2011), adapting calculation methodologies and implementing new software, and obtaining indicators, quantities, and the annexes of project documents.

Some architects' professional associations, public entities such as the IVE (Fig. 7), IHOBE or ITEC, or commercial companies such as CYPE Engineers, Graitec-Arktec, or Urbicad, have developed helpful software for Waste Management Studies. Nowadays, the estimation of the amount of waste generated uses three different methodologies:

- The first is based on "statistical data" from waste plants and different studies research. It is a quick process, requiring the input of little data. The Guide with the "ratios" of C&DW in Spain (CSCAE-CGATE, 2020) allows calculation according to climatic zones and construction typology (Fig. 8).
- The following is based on the project's measurements and budget, drafted with different software and associated with a particular database. It means that each construction system and material have an individual evaluation. Therefore, the design project data must define detailed construction characteristics and measurements.
- The third way, related to the previous, although more complex, would involve getting the C&DW studies from the BIM data models and complementary applications (Mercader-Moyano et al. 2017). In this case, it will be necessary to establish how far into the detail it is necessary to go in the architectural models.

These options are viable in new construction but require a complex audit in rehabilitation, dismantling or demolition cases, where all the construction components are not precisely known. All these possibilities allow recent decisions based on the results but require weighing up the resources used.

The more complex the input, the more information will be obtained. Similarly, along with the rating of sustainability, energy certification and evaluation of improvement measures would be desirable. The more knowledge and experience available, the better the assessment and comparison of methodologies. Following these procedures and considering new requirements, material selection or even the whole construction system can change; therefore, it is necessary to consider this matter right from the start of the project in order to improve C&DW.

Figure 7. IVE online C&DW assessment. Source: www.five.es

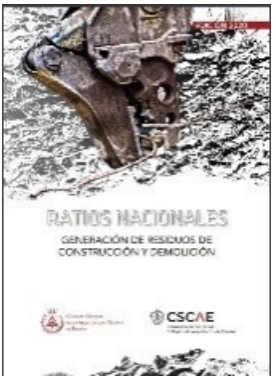


Figure 8. C&D Ratios report, areas and related data. Source: www.cscae.com

4. THE PRICE OF CONSTRUCTION MATERIALS AND ENERGY: AN UNCERTAIN FUTURE

According to reports and statistics recently published by the INE (Fig. 9), raw materials prices have suffered hyperinflation since the end of 2021, with increases of around 20% and "stock breaks". The increase in the price of supply chains is due to the interruption of supply channels caused by Covid-19 and recent restrictions on export-import due to the military conflict and the subsequent rise of energy and transport.

This situation is especially pronounced in energy, with increases of 110%. Materials such as copper, steel and aluminium have suffered increases of more than 30%. On the other hand, these materials are among the most recyclable or reusable, so their necessary recovery is unquestionable, more as a necessity than as a legislative imposition or an opportunity to benefit from subsidies.

Accordingly, global problems are already being transferred directly to projects and constructions differently. These approaches to the correct use of waste can evolve from purely an environmental issue to an opportunity to dispose of resources and save energy in their production and transformation. This situation raises new perspectives in construction and architecture for the future.

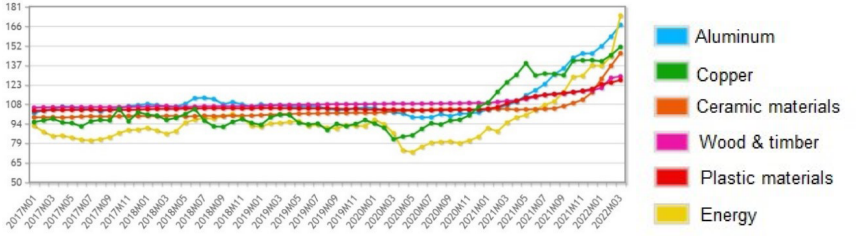

Figure 9. Evolution of materials & energy price index 2017-2022. Source: INE 2022

5. CONCLUSIONS

In view of the study, the following conclusions may be drawn:

1. The current general and theoretical approaches to reduction, reuse and recycling preparation follow a more detailed and improved process as regards the objectives established some decades ago.
2. The progressive evolution of criteria and regulatory framework regarding C&DW management in the EU can be currently recognized through local legislation, particularly in Spain.
3. Despite some delay, the requirements of the Directives are being introduced in different countries in two ways: legislation or mandatory regulation and promotion or incentives
4. The challenge now is to address the barriers in the single market for reused construction products and contribute to the European Green Deal and the Circular Economy action plans.
5. The role of public administration is essential to promote shared objectives and develop new sources: guidelines, best practices, software, etc. to support the different agents involved.
6. Considering how the new changes affect the building sector is crucial, particularly for new construction or rehabilitation projects, where construction systems and materials selection need to be taken into consideration.
7. All these new trends should change the perspective towards a future architecture that involves sustainability goals. This must be considered in upcoming projects from the very beginning.

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