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Digital transition for contemporary space

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sommario

Table of contents/*Sommario*

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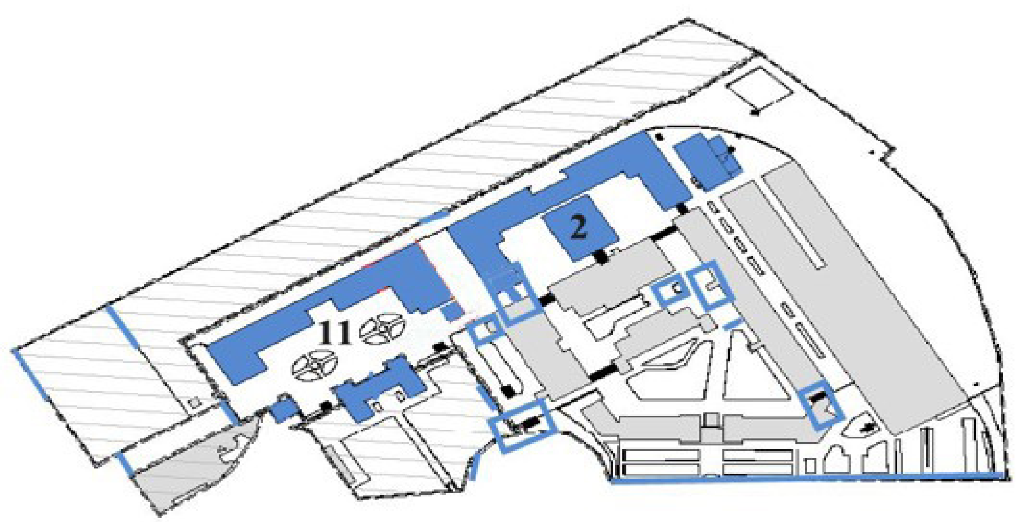
Testing programme of pre-characterization for c&d waste: an innovative approach developed on the disused factory “Manifattura Tabacchi”, a case study in South of Italy

Mariateresa Giammetti

Abstract

The article presents the first result of the research agreement signed by Federico II University and CDP Immobiliare concerning reusing and recycling construction waste in the urban regeneration project. The research introduces a new approach focused on the criteria for picking the material samples in order to undergo chemical-physical analysis aimed at verifying the possible contaminants that affects the construction materials, and the effective possibilities of recycling and reusing them in situ.

The methodological process aims at defining a protocol for brownfield sites that holds together the potential value of newly freed soils (empty spaces that can be returned



to the city) and the request for new specific uses to allocate the future life cycles of the brownfields. The paper will describe the results of the research work focused on an investigation about the scientific background concerning the urban regeneration topic based on the convergence of three thematic areas, interpreted as paradigms of the contemporary urban project: the care of the drosscape, the circular economy and the concept of urban mining. These paradigms could be guidelines useful to develop a transition aimed to re-define urban recovery strategies in the short and long term.

Keywords:

urban regeneration project, C&D waste, brownfields, drosscape, ex-ante evaluation, testing and sampling programme, innovation

Programma di sperimentazione di precaratterizzazione per rifiuti c&d: un approccio innovativo sviluppato nello stabilimento dismesso "Manifattura Tabacchi", un caso studio nel Sud Italia

L'articolo presenta i primi esiti dell'accordo di ricerca firmato dall'Università Federico II e da CDP Immobiliare sul riutilizzo e il riciclo dei rifiuti edili nel progetto di riqualificazione urbana. La ricerca introduce un nuovo approccio incentrato sul criterio di prelevare dei campioni di materiale da sottoporre ad analisi chimico-fisiche volte a verificare i possibili contaminanti che influiscono sui materiali da costruzione, e le effettive possibilità di riciclo e riutilizzo degli stessi in situ.

Il processo metodologico mira a definire un protocollo per i siti dismessi che tenga insieme il valore potenziale dei suoli appena liberati (spazi vuoti che possono essere restituiti alla città) e la richiesta di nuovi usi specifici per gestire i futuri cicli di vita dei brownfields. Il contributo descriverà i risultati del lavoro di ricerca incentrato su un'indagine del background scientifico riguardante il tema della rigenerazione urbana basato sulla convergenza di tre aree tematiche, interpretate come paradigmi del progetto urbano contemporaneo: la cura del drosscape, l'economia circolare e il concetto di estrazione mineraria urbana. Questi paradigmi potrebbero divenire linee guida utili per sviluppare una transizione finalizzata a ridefinire le strategie di recupero urbano nel breve e nel lungo periodo.

Parole Chiave:

progetto di rigenerazione urbana, C&D waste, brownfields, drosscape, valutazione ex-ante, programma di test e campionatura, innovazione

Testing programme of pre-characterization for c&d waste: an innovative approach developed on the disused factory "Manifattura Tabacchi", a case study in South of Italy

Mariateresa Giammetti

1. Premise

The research is framed in the thematic area of recovery, reuse, and recycling of demolition waste and identifies the selective demolition as one of the key steps to reducing the amount of waste to be disposed of in landfills. In particular, the research is aimed at defining a methodological process useful to develop an ex-ante evaluation in order to: a) manage the C&D waste flows; b) support the decision-making process underlying the recovery urban project; c) enhance the waste itself.

The cultural background of the research refers to an extended idea of Urban Mining (Cossu R., 2012), understood as an advanced operational context applied to urban recovery projects focused on the abandoned/disused real estate assets. This approach to *Urban Mining* concept aims at extending the useful life of the disused buildings which materials could be recovered at the end of their cycle of life (Ghosh S. K. 2020).

Operating on the abandoned/disused real estate assets may be an opportunity to extract Secondary Raw Material (SRM) from the so called drosscapes, particularly from disused structures (buildings, infrastructures, industrial complexes, etc.). Following a virtuous approach, inspired by the «systematic management of the anthropogenic resources (products and buildings) and waste, it could be possible to pursue some long-term environmental protection objectives, the protection of renewable resources and economic advantage» (Cossu et al. 2012, pp. 13).

The research is oriented to combine the extended Urban Mining principle with a non-extractive approach concerning the architectural field that is increasingly affirming itself as one of the cultural guideline of the international design avant-gardes that is aimed at exploring the possibilities of building spaces with zero environmental impact (Wigley, 2021). From this point of view, the disused real estate asset could be an effective mineral reserve useful to respond to the new needs of sustainability and circularity expressed by contemporary society.

Under-using products that are recovered from activities of demolition and/or revitalization of abandoned buildings is a trend that defines a central aspect as regards the research lines of the aggregate recovery process. The underuse demonstrates that the challenge of circularity is played not only on the quantities but above all on the performance that the C&D waste potentially expresses. Reducing the extraction of natural resources is a challenge that could be issued if C&D waste is fully returned to its original production cycle.

Applying the principles of the urban mining and circular economy to the construction market of and non-extractive architecture asses through a new season of design and construction products: MPS could be used as components of innovative building materials, they could improve both new construction solutions and the use of digital fabrication processes.

2. Introduction

The research focuses on the knowledge and classification stage of the buildings to be demolished in order to define an inventory phase aimed at: a) defining a methodology for an ex-ante evaluation of C&D waste flows; b) standardising the inventory phase to design a set of analytical information relating to the quantification of waste flows classified by type of material.

The methodology is organized as a cognitive technical protocol for structuring the inventory phase and supporting the demolition process. Specifically, the protocol is aimed at: a) providing data and estimating on the quantity and type of waste to be disposed of, reused, or recycled; b) pre-cataloguing C&D waste according to the EWC codes; c) modelling the data according to alternative design scenarios; d) defining strategies and time schedule useful for deconstructing and demolishing; e) developing an integrated design of the demolition and construction site, capable of optimizing the use of waste within it.

The protocol is structured by a BIM-based filing of the building system aimed at investigating quantity, material consistency, and state of conservation of the elements to be demolished. The protocol has been tested in several case studies. In particular, this paper is focused on the disused factory called Manifattura Tabacchi, a case study located in Naples, a city in southern Italy. The inventory phase provides for the interpolation of two cognitive moments: a) a desk phase, mainly aimed at the ex-ante analysis of the building; b) an on-field phase aimed at developing a testing programme of the demolition waste, a material sampling and physical-chemical analysis of the samples.

In order to convey the complexity of the research carried out, this paper is divided as follows: a) description of the objectives of the research; b) description of the research methodology; c) application of the research methodology to the case study; c) discussion of the results and conclusions.

3. Specific research objectives and methodology

The research aims at: a) defining a methodological process for the ex-ante evaluation and management of the waste flows derived from the demolition actions; b) distinguish and preliminary estimating the quantities of waste that can be used for recycling/reusing on-site, for being disposed of in landfills and being directed towards the production of technical elements to be reintroduced in the construction sector chains. This differentiation is directly derived from the different characteristics of the buildings to be demolished (by construction type, time of construction, intended use). The process for the ex-ante evaluation is as a protocol aims to verify the compliance of the waste produced with the legislation in force and the performance requirements that allow its return to the construction industry. The ex-ante evaluation methodology is designed for medium-large urban revitalization project, where the volumes to be demolished are such as to produce a great economic and environmental impact that justifies alternative procedures for the on-site recovery and recycling of C&D waste. The research looks at the urban regeneration project as a privileged field of experimentation as it includes a heterogeneous set of activities that make it possible to test the compatibility of the protocol on different types of buildings and to hypothesize a direct re-entry of the waste into the building cycle on the same site. The selective recovery of large building volumes is the necessary condition to experience the benefits of an ex-ante analytical knowledge process that aims to create an in situ supply chain for urban revitalization projects. It ranges from building rehabilitation to new construction and reconfiguration of open spaces, including soil modelling, green space creation and new traffic infrastructure. It is a broad set of activities that directs waste flows towards the production of a new repertoire of technical elements. In addition, the protocol is an important tool to support the sampling plan that establishes the samples to be subjected to chemical-physical analysis in order to certify their non-hazardousness and to verify their mechanical resistance performance.

The ex-ante evaluation is aimed at a) providing data and estimates on the quantity and type of waste to be disposed of, reused or recycled; b) organizing the C&D waste flows according to the codes of the EWC European Waste Catalogue; c) defining the guiding criteria of the sampling plan; d) defining ways and times schedule to organize the deconstruction and demolition activities; e) developing an integrated design of the demolition and construction site, capable of optimizing the use of waste within it.

The proposed methodology is also original concerning the European EU protocol for selective demolition (EU, 2016 and 2018), as the information deriving from the ex-ante evaluation allows to specifically finalize the design choices for organizing the demolition site.

The protocol is also designed in a BIM environment in order to provide the technical-administrative documentation necessary to authorize the demolition activities and then proceed with the tender.

Using BIM software represents an implementation of digital tools useful for combining compliance with regulatory constraints, the needs of the construction market and the use of advances procedures that the digital culture makes available. The BIM-based approach allows to manage the whole knowledge and classification stage from an informative point of view and monitor the building system in all its parts. This approach integrates data over time to fit the purposes and tasks of the recovery project, it develops ad hoc information fields that are representative of the project's specificity. It is possible to upload a lot if information into the BIM environment, they are functional to represent (and control) the whole decision-making process that underlies the design process of adapting to the regulatory framework (which is constantly evolving), the circular economy criteria and the economic and environmental balance underlying project implementation. The digital tool plays a strategic role in the research structure primarily to provide a reasoned inventory of building systems to be demolished and an analysis of building materials and their physicochemical characteristics in order to direct their flow towards disposal, or rather recycling/reuse chains.

The research methodology is structured in three phases: a) background knowledge: a/1 documentary survey (construction documents and history of building use); a/2) BIM-Based archiving of the building system (inventory of building elements organized by type, quantity, material consistency, state of preservation); b) data modelling and simulation of alternative intervention scenarios; c) construction site layout design.

3.1. Background knowledge

The knowledge phase was developed according to the EU protocol guidelines for the selective demolition. This phase, organized in desk-study mode, is essential to support the decisions on the technical-economic feasibility of the project. The knowledge phase has been structured in two interconnected moments, on the one hand on the material-constructive and usage aspects and on the other hand on the organization of the information collected in a BIM logic.

3.2. Documentary survey

The documentary survey was set up as a system of data sheets aimed to develop an inventory of the buildings to be demolished. The sheets have been designed according to the definition of building system provided by UNI 10838, or as "a set of elements intended to modify the environment in which human being lives to meet part of his basic needs". The data sheets are aimed at analyzing: a) the construction technologies; b) the construction materials; c) the chronology of the building's uses that took place during its life cycle. The filing is organized into 3 survey documents aimed at: a) producing a preliminary survey aimed at investigating the typology and morphology of the building, the current and past uses, and the volumetric consistencies; b) discretizing the classes of technological units of the buildings; c) producing the photographic and planimetric survey; d) classifying the information related to what kind of demolition will be carried out; e) collecting the references to the schedule and the demolition phases to which the building will be subjected according to the guidelines of the EU proto-

Fig. 1 - Aerial photograph of the disused factory called Manifattura Tabacchi in Naples.

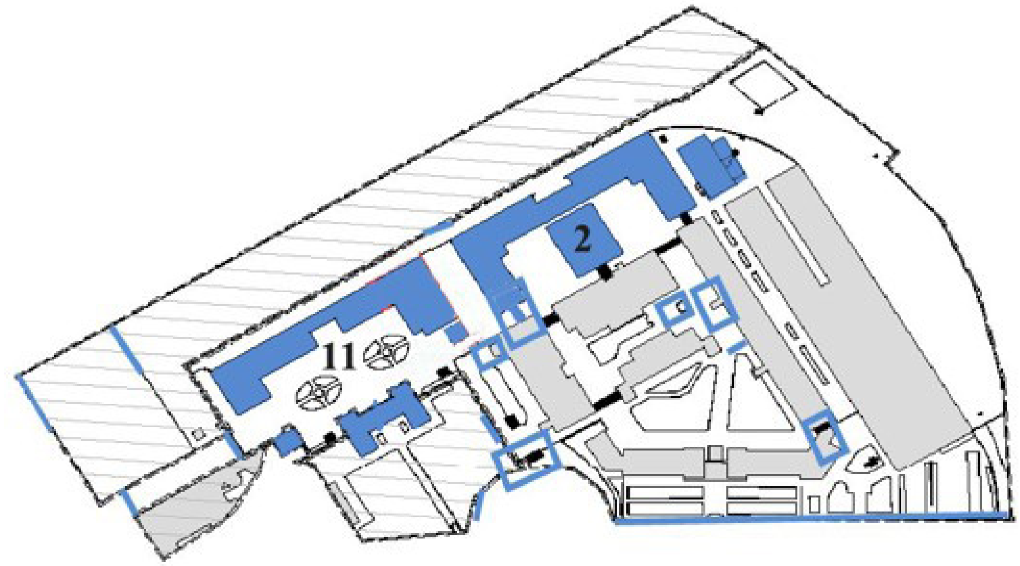


Fig. 2 - Graph with general indication of the buildings to be demolished.

col on the management of construction and demolition waste. The register system also includes fields of analysis concerning the demolition and safe handling of hazardous substances.

3.3. BIM-based data sheet

In order to understand the dimensional, material and technological characteristics of the waste that will be generated by the demolition, the buildings to be demolished is modelled in a BIM environment. Specifically, the modelling is implemented by subdividing the building system into classes of technological units, individual technological units and classes of technical elements that make up the buildings. The data introduced in the BIM model are further implemented with the Dynamo application in order to link the technical elements to the indications provided by the sampling plan; in addition, special filters ar applied for the management of the C&D waste flows. The correct management of the flows makes it possible to obtain a questionable model. By varying the information provided with the EWC codes and the degree of contamination present in the technical elements that make up the model, it is possible to manage the quantities of waste flows that will have to be disposed of or that can be reused or recycled. The speed and fluidity with which waste flows can be managed allow to hypothesize and evaluate different scenarios for the recycling and reusing C&D waste. Subsequently, the data are extrapolated into spreadsheets and the results are managed and implemented in information sheets to be used to support the correct management of the hypothesized scenarios and the subsequent construction of the processes for recycling or reusing C&D waste.

3.4. Allocation of EWC codes

The research designs a BIM modelling process capable of managing the EWC codes from future waste flows and the data useful to detect the possible presence of contaminants in future demolition waste. The implementation of the BIM model makes it possible to produce a pre-demolition evaluation sheet to support the demolition project and the integration of future recycled materials into the supply chains of additional cycles.

4. Testing programme for pre-characterization of c&d waste

Starting from this paragraph, the article describes an innovative approach concerning the testing and sampling program for the characterization of the C&D waste. The research introduce a new methodology focused on the criteria for picking the material samples in order to undergo chemical-physical analysis aimed at verifying the possible contaminants that affects the construction materials, and the effective possibilities of recycling and reusing them in situ. The pre-characterization activities are framed in a testing program divided into the following procedural steps:

- Developing analysis and studies preliminary to future management of the waste obtained from the demolition activities. They are aimed at evaluating a cost-benefit ratio concerning the opportunity of disposing or recycling on site.
- Defining a waste sampling criterion that, although it does not focus on the heaps of waste, but on the still intact buildings, provides a sufficiently representative projection of the chemical and physical characteristics regarding the construction materials that make up each building to be demolished.
- Fixing the analytes to be considered and analysing the samples in order to discover their chemical-physical characteristics and verify whether or not the values set by current legislation concerning the presence of ecotoxic substances in demolition waste are exceeded.
- Studying the results of the analyses in order to determine the percentage of material to be landfilled or that can be recycled.
- Evaluating possible treatment processes in order to bring the samples back into the regulatory range.
- Verifying the cost-benefit ratio concerning the opportunity of developing treatment processes or disposing in relationship to:
    - the costs of demolition and disposal;
    - the type and quantity of ecotoxic substances present;
    - the possible recovery treatments and their costs;
    - the effective quantities of waste to be treated;
    - the timing of the administrative procedures necessary to authorise demolition and recycling activities for reuse on site.

If the economic and environmental sustainability of the recovery operations is verified, administrative procedures will be initiated in order to speed up the entire demolition process.

5. Sampling objectives and indication of analytes

The sampling plan has the following main objectives:
Verifying the chemical-physical characteristics of a set of composite samples, obtained from increments of the same material in order to determine whether their chemical-physical characteristics are such as to allow their recycling or reuse on site, in line with the regulations of the D.lgs.152/2006 and ss. mm. ii., D.M. 27/2010 and ss. mm. ii. and D.M. 5/1998 and ss. mm. ii. When this phase is completed, optionally, one may also choose to test heterogeneous composite samples, obtained by the mixture of increments of different materials. The homogeneous and heterogeneous composite samples simulate two different demolition techniques:

1) the *homogeneous composite samples* simulate a selective demolition, including the stripping of the plant systems, windows, doors, sheathing, plaster and flooring, as well as a rigorous selection of materials to separate the materials of the non-bearing walls (made of brick and tuff) from the reinforced concrete structures, which will be deferred;
2) the *heterogeneous composite samples* simulate a controlled demolition, which includes the stripping of the plant systems, windows and doors, sheathing, plaster and flooring. It does not provide for the separation of the non-bearing walls from the concrete structure. The waste is stored in the same heaps, even if the concrete is deferrifiedThe two types of demolition differ not only in their execution techniques, but also in their costs. Demolition costs are a variable that can have a significant impact on the overall balance of waste management strategies and on the success of the recovery process on the one hand, and on the reduction of execution costs on the other. The sampling objectives conditioned the choices regarding the sampling strategy and techniques, and the type of analytical characterisation required. The block diagram below summarises the main analytes chosen according to the sampling objectives and in compliance with sector regulations.

The block diagram also includes analyses to verify compliance with the values established in Column A of Table 1 of Annex 5 to Part IV, Title V of D.Lgs. 152/06. From this point of view, it should be noted that the waste to be obtained from the demolition of the Manifattura Tabacchi di Napoli could be used to obtain a recycled aggregate to be used for the remodeling of soil morphology planned in the area's urban regeneration project. The recycled aggregate is not a natural matrix (a soil), but it is a building product, therefore it should not be subjected to the conformity verification according to Annex 5. In order to verify the recyclability characteristics of the materials, the plan stipulates that the samples meet the requirements set out in Annex 3 of Ministerial Decree No. 186 of 5 April 2006, as required by Italian legislation.

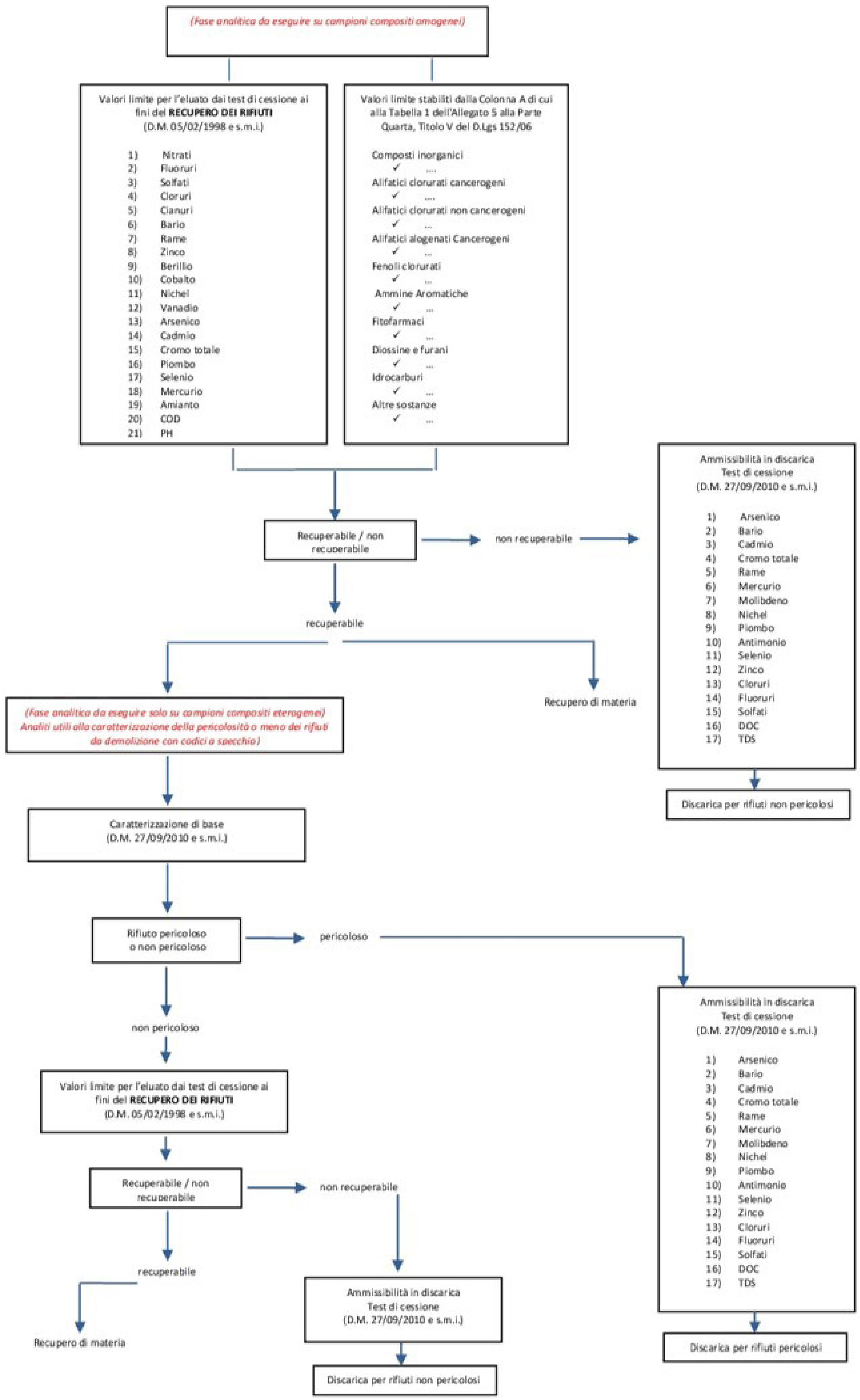


Fig. 3 - Block diagram summarising the main analytes chosen.

6. Sampling procedures: identification of lots and criteria for locating sampling points

Sampling is an extremely complex and delicate phase that conditions the results of all subsequent operations and consequently significantly affects the final outcome of the analytical results. The study has the task of simulating the chemical-physical characterisation of the demolition waste that will be obtained from the future demolition of the Manifattura buildings. To achieve this goal, it provides for the construction of representative samples through the composition of increments taken not from the waste heaps produced by actual demolition activities. Instead, the increments are extracted as specimens, obtained by coring the still existing structures. Since the sampling does not take place on *real waste heaps*, it was necessary to devise a model simulating *virtual heaps* for each building. They were devised to be as close as possible to the real ones in terms of material type and volume, although geometrically they do not have the shape of the real heaps but appear as the actual structures. In order to simulate the volumetry of the virtual heaps, each building was divided into Lots (*Homogeneous Areas_AO*), corresponding to the parts of the structure divided by structural joints. In order to simulate the type of material that makes up the virtual heaps, it was necessary to take into account the demolition techniques that may be used to demolish the buildings. In order to simulate the type of material that makes up the virtual heaps, it was necessary to take into account the demolition techniques that may be used to demolish the buildings. In the case of *controlled and selective demolition*, the heaps will consist of only one type of material (*homogeneous sample*); in the case of controlled and non-selective demolition, the heaps will consist of a mixture of different materials (*heterogeneous sample*). Once the lots were fixed, the volumes were calculated, both in total and for each material. The following tables show the volumes for each building:

Tab. 1 - Calculation of the volume of each material, divided for each Homogeneous Area.

building 2	tot mc
	15018
AO_1	937,7
AO_2	1222,5
AO_3	942,2
AO_5	1780,8
AO_6	2743,2
AO_7	2253,7
AO_8	5137,9

building 2	tot mc
	15018
Concrete	7729,4
Brick	5347,1
Concrete slabs	1113,4
Cement screed	477,8
Plaster	350,2

building 11	tot mc
tot	**3885**
AO_1	2096,2
AO_2	1788,7

building 11	tot mc
	3885
Concrete	1261.9
tuff	1427,40
Brick	96,53
Concrete slabs	654,8
Cement screed	349,20
Plaster	95,16

mc total	tot mc
building 2	**15018**
building 11	**3885**
	18903

Once the Homogeneous Areas were identified, the criteria for locating the sampling points were established. Since the buildings are very degraded, a systematic sampling procedure using a regular geometric grid could not be adopted for safety. Therefore, a

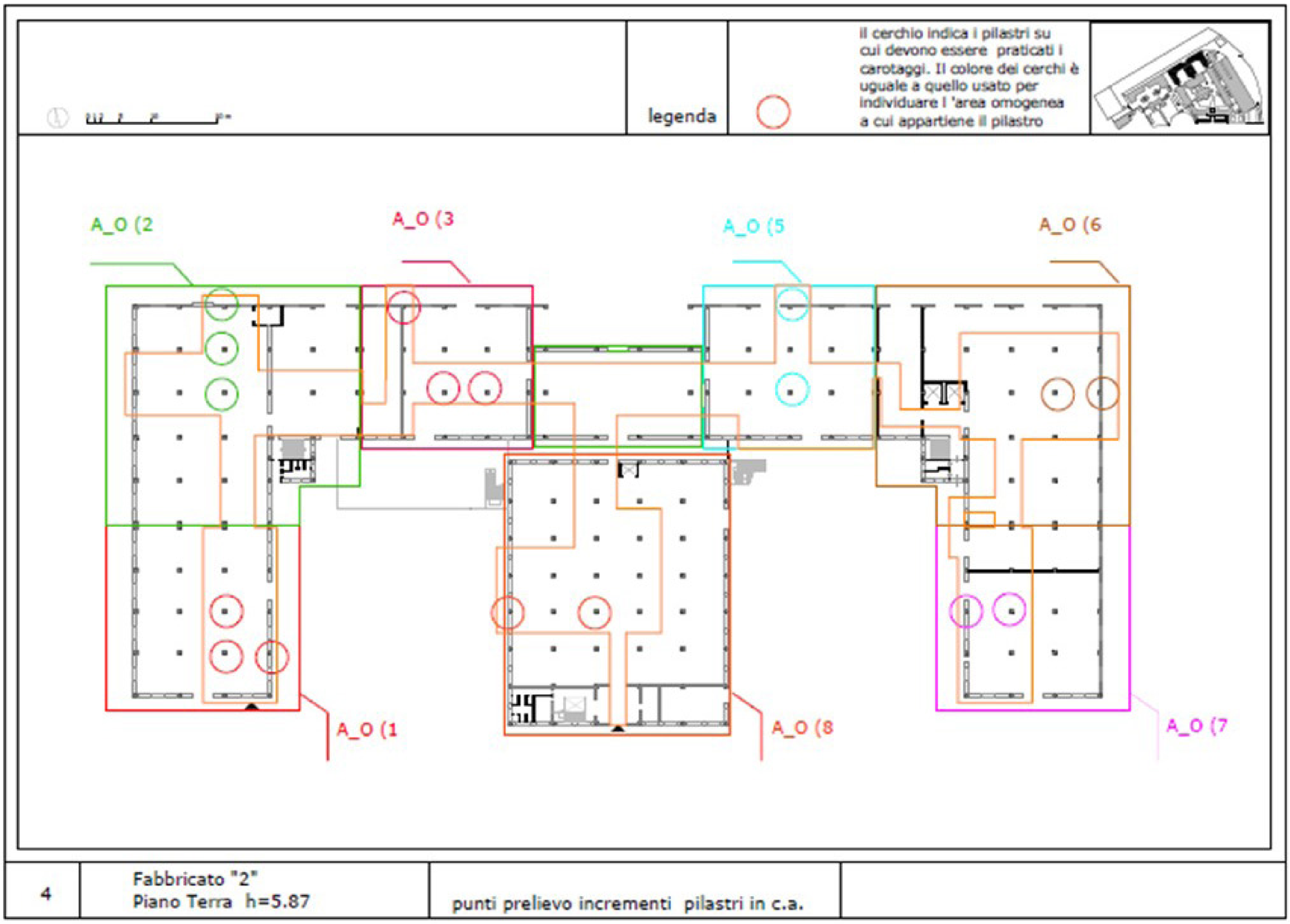


Fig. 4 - Building n.11: homogeneous Areas and sampling point.

random sampling procedure guided by the following criteria was chosen:

- distinguish increments according to materials;
- in building 2, which is multi-storey, repeating increment sampling at each level;
- alternating sampling points located in the innermost parts (more exposed to the action of pollutants derived from industrial activities) with sampling points located in the perimeter areas (more exposed to external agents). In this way, a composite sample is obtained that combines the chemical-physical characteristics of the building envelope with those of the internal part.

7. Number and characteristics of increments and formation of composite samples to be tested for leaching test

Table 1 highlights that the volume of materials is less than 2000 m^3 in both buildings that have a total volume that is more than 2000 m^3. The minimum number of increments is given by the following table:

Tab. 2 - Calculation of the number of increments.

Volume (m^3)	Increments
Up to 2000	20
From 2000 to 3000	25
From 3000 to 4000	30

From each lot, excluding plasters and floors, 20 increments will be taken. For very small lots, a proportionality criterion was applied, reducing the number of increments to 5.

The sampling procedure will produce homogeneous composite samples, a simulation of a waste with an absolute ERC code (cement, brick, natural stone, etc.). Table 3 shows the number of samples and increments for each building.

Tab. 3 - Increments and separate composite samples of each building.

Building	Increment (n°)	Composite sample (n°)
11	120	6
2	360	21
tot	**480**	**27**

Once the number of increments was fixed, the minimum mass was calculated. The minimum mass mi of the increments is calculated using the following formula:

$$m_i = 2{,}7 \text{ x } 10\text{-}5 \text{ rd}3$$

d is the material size (millimetres);
r is the density (tonnes/cubic metre).

Table 4 shows the minimum mass of the increments for each material:

Tab. 4 - Minimum mass of increments divided by material.

Material	m^i (kg)	r (kg/mc)	d (mm)
Concrete	1,750	2400	30
Tuff	1,094	1500	30
Brick	1,166	1600	30
Concrete slabs	1,312	1800	30

Starting from the results of the minimum mass calculation, the sampling plan provides for the extraction of cylindrical increments of material with a diameter and height of 10 cm (see table n. 5 for specimen characteristics). After coring, the increments will be set aside, so as to distinguish them by lot and material. Subsequently, the increments so divided will be crushed and mixed. After mixing, they will be sifted to obtain dust-free granular sections between 4 and 1 cm in size (samples for leaching tests). The fine fraction will be discarded and analysed separately. During crushing, the percentage incidence of the fine fraction obtained from each material will be measured. The study of the results of the chemical-physical analyses on the homogeneous samples will suggest whether or not it is necessary to proceed with the study of the heterogeneous composite samples.

After the crushing and sieving operations, increments of the same material from each Homogeneous Area will be mixed to obtain a composite primary sample. Composite samples weighing more than 10 kg will not be reduced by the quartering method in order to obtain *secondary samples*. It is important to check that the total mass of the secondary samples is always equal to or greater than a certain minimum mass value, called minimum raw sample mass, using the following formula:

$$M_{sam} = \frac{1}{6}\pi \times (D_{95})^3 \times \rho \times g \times \frac{(1-p)}{CV^2 \times p}$$

Below are tables of the characteristics and number of increments and samples.

Material	m^i (kg)	Weight increment (kg)	Volume increment (cm^3)	Dimension increment (cm)	Minimum sample mass M_{sam} (Kg)
Calcestruzzo	1,750	1,885	785,40	Provino Ø10 cm _ L 10 cm	5,09
Tufo	1,094	1,178	785,40	Provino Ø10 cm _ L 10 cm	3,18
Laterizio	1,166	1,257	785,40	Peso corrispondente ad un mattone a 6 fori (11X6,8X23)	3,39
Massi	1,312	1,414	785,40	Provino Ø10 cm _ L 10 cm	3,82

Tab. 5 - Weight and volume of increments and minimum mass of samples of different materials.

Building	Volume tot (mc)	Lot	Volume lot (mc)	Increment (n°)	Volume increment min. (cm^3)	Wheight increment min. (Kg)	Wheight increment (Kg)	Composit sample (Camp. Com.)	Wheigh comp. Primary sample (kg)	Primary composite sample weight after sieving (kg)	Secondary composite sample weight(kg)	Minimum sample mass (kg)
11	3885	AO_1 (11) Cls	651,31	20	785,40	1,750	1,885	CO_1 (11) Cls	37,699	28,27	7,07	5,09
11		AO_1 (11) Tufo	787,8	20	785,40	1,094	1,178	CO_1 (11) Tufo	23,562	17,67	8,83	3,18
11		AO_1 (11) Masso pt	367,2	20	785,40	1,312	1,414	CO_1 (11) Massi	28,274	21,21	5,30	3,82
11		AO_2 (11) Cls	610,57	20	785,40	1,750	1,885	CO_2 (11) Cls	37,699	28,27	7,07	5,09
11		AO_2 (11) Tufo	639,6	20	785,40	1,094	1,178	CO_2 (11) Tufo	23,562	17,67	8,83	3,18
11		AO_2 (11) Masso pt	287,6	20	785,40	1,312	1,414	CO_2 (11) Massi	28,274	21,21	5,30	3,82
2	15018	AO_1 (2) Cls	383.1	20	785,40	1,750	1,885	CO_1 (2) Cls	37,699	28,27	7,07	5,09
2		AO_1 (2)Laterizio	390,6	20	785,40	1,166	1,257	CO_1 (2)Later.	25,133	18,85	9,47	3,39
2		AO_1 (2) Masso pt	90,0	5	785,40	1,312	1,414	CO_1 (2) Massi	7,069	5,30		3,82
2		AO_2 (2) Cls	574,7	20	785,40	1,750	1885	CO_2(2) Cls	37,699	28,27	7,07	5,09
2		AO_2 (2)Laterizio	483,8	20	785,40	1,166	1,257	CO_2(2)Later.	25,133	18,85	9,47	3,39
2		AO_2 (2) Masso pt	90,0	5	785,40	1,312	1,414	CO_2 (2) Massi	7,069	5,30		3,82
2		AO_3 (2) Cls	395	20	785,40	1,750	1,885	CO_3(2) Cls	37,699	28,27	7,07	5,09
2		AO_3 (2)Laterizio	385,8	20	785,40	1,166	1,257	CO_3(2)Later.	25,133	18,85	9,47	3,39
2		AO_3 (2) Masso pt	88,5	5	785,40	1,312	1,414	CO_3 (2) Massi	7,069	5,30		3,82
2		AO_5 (2) Cls	806,4	20	785,40	1,750	1,885	CO_5 (2) Cls	37,699	28,27	7,07	5,09
2		AO_5(2)Laterizio	786,3	20	785,40	1,166	1,257	CO_5 (2)Later.	25,133	18,85	9,47	3,39
2		AO_5 (2) Masso pt	88,5	5	785,40	1,312	1,414	CO_5 (2) Massi	7,069	5,30		3,82
2		AO_6 (2) Cls	1512,7	20	785,40	1,750	1,885	CO_6 (2) Cls	37,699	28,27	7,07	5,09
2		AO_6(2)Laterizio	922,6	20	785,40	1,166	1,257	CO_6 (2)Later.	25,133	18,85	9,47	3,39
2		AO_6 (2) Masso pt	160,7	20	785,40	1,312	1,414	CO_6 (2) Massi	28,274	21,21	5,30	3,82
2		AO_7 (2) Cls	1159,8	20	785,40	1,750	1,885	CO_7 (2) Cls	37,699	28,27	7,07	5,09
2		AO_7(2)Laterizio	794,5	20	785,40	1,166	1,257	CO_7 (2)Later.	25,133	18,85	9,47	3,39
2		AO_7 (2) Masso pt	160,7	20	785,40	1,312	1,414	CO_7 (2) Massi	28,274	21,21	5,30	3,82
2		AO_8 (2) Cls	2897,7	20	785,40	1,750	1,885	CO_8 (2) Cls	37,699	28,27	7,07	5,09
2		AO_8(2)Laterizio	1583,6	20	785,40	1,166	1,257	CO_8 (2)Later.	25,133	18,85	9,47	3,39
2		AO_8 (2) Masso pt	435,0	20	785,40	1,312	1,414	CO_8 (2) Massi	28,274	21,21	5,30	3,82

Tab. 6 - description of the characteristics of increments and homogeneous composite sample.

8. Number and characteristics of increments and formation of composite samples for environmental characterisation (Column A of Table 1 of Annex 5 to Part Four, Title V of Legislative Decree 152/06)

The references for the environmental characterisation are the criteria described by DPR. 120/2017 (Regulation on simplified rules for the management of excavated earth and rocks, art. 8 D.Lgs.n.133/2014, converted into L. n. 164/2014), as described in the following table:

Tab. 7 - Calculation of increments.

Size of area	Sampling points
Less than 2.500 square meters	3
From 2.500 to10.000 square meters	3 + 1 each 2.500 square meters
Over 10.000 square meters	7 + 1 each 5.000 square meters

Table 8 shows the total surface area of the concrete structural elements of each of the two buildings and the number of samples.

Tab. 8 - Projection of surfaces corresponding to concrete structural elements.

Building	Structural concrete elements area (mq)	N points of sampling (DPR 120/2017)
11	10.130	8
2	11.614	8
tot	**21.734**	

Table 9 shows the characteristics of the increments and of the secondary homogenous composite samples by manufacturer, lot and material.

Tab. 9 - Characteristics of the increments and of the secondary homogenous composite samples.

Building	Structural concrete elements area (mq)	Weight increment in concrete (kg)	Lot	Weight reaaining materials from leaching test sample (kg)	Weight Secondary sample after quartering (kg)	Number of increments corresponding to the weight of the secondary sample after quartering	Weight Secondary samples (kg)	Weight of residual material (kg)
11	10.130	1,885	AO_1 (11) Cls	21,21		11,25	21,21	0
			AO_2 (11) Cls	21,21		11,25	21,21	0
2	11.614		AO_1/ AO_2/ AO_3 (2) Cls	63,63	15,90	8,44	15,90	47,71
			AO_5/ AO_6 (2) Cls	42.42	21,21	11,25	21,21	21,21
			AO_7/ AO_8 (2) Cls	42,42	21,21	11,25	21,21	21,21

9. Conclusions

The ex-ante evaluation is part of a perspective that aims at valorising demolition waste and proposes an innovative process compared to the state of the art. The ex-ante evaluation takes place upstream of the demolition phase, unlike current practices that characterise waste after demolition activities. The ex-ante evaluation proposes a first step of in-depth knowledge of the building to be demolished and pre-characterisation of the waste. The proposed methodology is aimed at objectifying the decision-making process for material recovery/recycling.

The ex-ante evaluation is structured through a protocol for the management of demolition waste streams set in a BIM environment. The protocol will allow estimating the quantity and quality of the waste before demolishing, as it will be able to provide specific knowledge of each building that will be demolished.

The methodology is complying with the European guidelines concerning the methods and techniques of execution of the demolition. The information deriving from the ex-ante evaluation will allow to specifically finalize the design choices regarding the organization of the demolition site. It will be precisely identified techniques and tools to be used, and also site layouts most suitable for managing the storage, handling, and recycling of waste materials.

The BIM technology will allow to know in advance a) the waste to be classified as hazardous/non-hazardous, the EWC code and the recycling techniques; b) the quantity of material referred to the single typologies; c) the inventory of the components of the building system to be reused; d) the composition of the waste; e) the exact location of the potentially hazardous waste in order to maximise the safety of the demolition activities; f) the recovery/re-use of the demolition waste defined on the basis of the pre-characterisation carried out and of the forecasts of the urban regeneration project.

A further implementation of the BIM application could be useful to automatically produce pre-demolition evaluation sheets to support the demolition project and the inclusion of future recycled materials in the supply chains of the additional cycles.

However, compared to the results obtained an expected, some procedural criticalities were highlighted that could hinder/slow down the full application of the protocol and the consequent inclusion of recycled products in the additional supply chains:

- according to Italian legislation, the recovery and treatment of C&D waste can only be carried out based on authorizations issued by public institutions. This bureaucratic process results in greater complexity of the authorization due the restrictive nature of the Italian environmental regulations. The bureaucratic process lengths of timing and rises the construction costs simultaneously.
- the end of waste declaration does not take into account the intended use of future recycled waste. The secondary raw materials are flattened into a generic definition. They are not calibrated on actual future uses and do not have a very high-performance requirement.

The critical issues emerged can be considered as starting points useful to organize institutional technical meetings aimed at optimizing procedures and criteria that could promote an effective circular dimension in the construction sector. The experimental results obtained by the research group can be considered a valid tool to support the formation of institutional technical tables.

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